



Environmental Impact from a Satellite perspective before the construction of the new International Airport in Mexico City

Fernando Mireles Arellano¹, Amayrani Martínez Mendoza²,
Amanda Oralia Gómez González²

¹ ESIA-Ticomán, National Polytechnic Institute, Mexico City

² Mexican Space Agency, Delegation Álvaro Obregón

Abstract: ¿The construction of the new International Airport in Mexico City (NAICDMX) will cause irreversible environmental impact?, ¿Dried in the Lake Nabor Carrillo to avoid the presence of migratory birds?, ¿What will happen with the vegetation that exists in that place?, ¿What consequences will have its construction?, Answers to questions like these give rise to the next article where will be displayed using satellite images for remote sensing the change that over four years of construction of the new International Airport in Mexico City has caused to the environment. For the study will be used Landsat imagery and Sentinel through a spatial-temporal analysis will show the change in temperature of the affected area, with the NDVI (Index of Natural Vegetation) will analyze the quality and quantity of vegetation along with a MNDWI (Index of water saturation) which will allow us to show the change in bodies of water ending with virtual combinations which will show important properties.

Keywords: Landsat, Mexico City, Remote Sensing, Satellite, Sentinel

INTRODUCTION

The idea of building a new International Airport in Mexico City (NAICDMX) becomes a work plan that will take about five years in its first stage, i.e. having the infrastructure sufficient to carry out its first operations. An architectural challenge which Mexico carried along its construction, once the project is part of the **largest airports in the world and sustainable** words that hundreds of people claimed. What seemed a monumental work little by little he would be becoming an area of endless work due to the great adversity with which hundreds of engineers of all kinds were found in his way.

The differential settlements and the degree of subsidence in the area didn't take long to be present, the constant visit of migratory birds that liked the nature that he perceived that environment did not stop and if the plant deterioration which would imply the replacement of large blocks of concrete by green bodies. Constant challenges and arduous work led to think more than one if the construction of the new airport would be a profitable project.

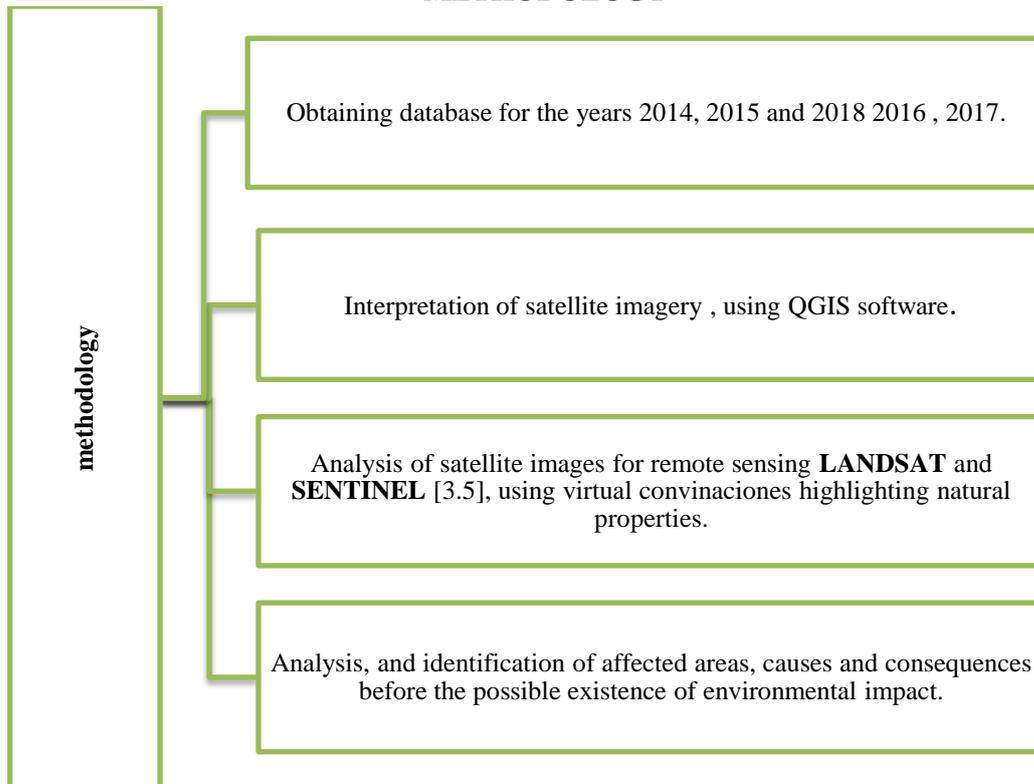
It didn't take long for these adversities be made public and will begin to perform an in-depth technical evaluation to try to mitigate risks and reduce what was already a start of environmental impact. Hundreds of technical opinions were conveyed showing their dissatisfaction through writings endorsed with tests where they were demonstrating errors produced in the works, and that in the future would make of this new airport somewhat unsafe.

Environmental engineers and researchers were present to perform technical analysis to determine the degree of environmental impact that the construction of the new airport was generating not only during construction, but also what the consequences would in the future. Many of these environmental studies retake subjects of migratory birds, desiccation of lakes around the construction zone, others more questioning on the vegetation present in the area; some others set objectives in the changes and modifications that the environment will react once the work is finished.

In order to contribute to environmental studies and to respond to the questions that the majority of people are wondering about this topic is made the following writing where through remote sensing satellite imagery (**LANDSAT AND SENTINEL** [3.5]) analyzes the environmental impact produced during four years of the construction of the new airport in Mexico City.



METHODOLOGY



Methodology implemented to carry out the analysis and determination of environmental impact before the construction of the new International Airport in Mexico City.

Table 1: Equations and parameters for the analysis of Landsat satellite images [3]

Equations	Parameter
1. $L_{\lambda} = M_L * Q_{cal} + A_L$ Spectral radiance	$M_L = \text{RADIANCE_MULT_BAND_X}$ $A_L = \text{RADIANCE_ADD_BAND_X}$ $M_L = \text{Previously translated to ND Band}$
2. $\rho_{\lambda} = \frac{M_p * Q_{cal} + A_p}{\sin \theta_{se}}$ Angular reflectance with correction	$M_p = \text{REFLECTANCE_MULT_BAND_X}$ $A_p = \text{REFLECTANCE_ADD_BAND_X}$ $Q_{cal} = \text{Previously translated to ND Band}$ $\theta_{se} = \text{SUN_ELEVATION}$
3. $T = \left[\frac{\left(\frac{k_2 [TIRS 1]}{K1 [TIRS 1]} \right) + \left(\frac{k_2 [TIRS 2]}{K1 [TIRS 2]} \right)}{\ln \frac{K1 [TIRS 1]}{L_{\lambda} [TIRS 1]} + 1} + \frac{\left(\frac{k_2 [TIRS 2]}{K1 [TIRS 2]} \right) + \left(\frac{k_2 [TIRS 1]}{K1 [TIRS 1]} \right)}{\ln \frac{K1 [TIRS 2]}{L_{\lambda} [TIRS 2]} + 1} \right] - 273,15$ Brightness Temperature	$k_1 = \text{K1_CONSTANT_BAND_X}$ $k_2 = \text{K2_CONSTANT_BAND_X}$ $L_{\lambda} = \text{Previously translated to Radiance Band}$
4. $NDVI = \frac{\left[\frac{(\text{Infrarrojo Cercano} - \text{Rojo})}{(\text{Infrarrojo Cercano} + \text{Rojo})} + 1 \right] * 10}{2}$ Standardized Indices of Vegetation Index (NDVI)	Near Infrared = Previously trucidida band Red Reflectance Red = Previously translated band reflectance



<p>5. $\text{MNDWI} = \frac{\left[\frac{(\text{Verde} - \text{InfrarrojoMedio})}{(\text{Verde} + \text{InfrarrojoMedio})} + 1 \right] * 10}{2}$</p> <p>Modification of Standardized Indices of Water (MNDWI)</p>	<p>green = previously Band Reflectance traducida Medium Infrared=Reflectance previously translated</p>
<p>6.- $\text{Vegetation Health} = \frac{\left[\frac{M_p * Q_{\text{cal}} + A_p}{\sin \theta_{\text{se}}} + 1 \right] * 10}{2}$</p> <p>Vegetation Health</p>	<p>M_p = REFLECTANCE_MULT_BAND_X A_p = REFLECTANCE_ADD_BAND_X Q_{cal} = Previously translated to ND Band θ_{se} = SUN_ELEVATION</p>

Table 2: Parameters for the analysis of satellite images Sentinel [5]

Equations.	Parameter
$\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})}$	<p>Normalized Difference Vegetation Index NIR= Near Infrared Red= Red Spectrum</p>
$\text{NDWI} = \frac{(\text{NIR} - \text{SWIR})}{(\text{NIR} + \text{SWIR})}$	<p>Modified Normalized Difference Water Index NIR= Near Infrared Spectrum SWIR= Short Wave spectrum</p>

AREA OF STUDY

The study area is located to the east of Mexico City in the land of what was once a Lake Texcoco.

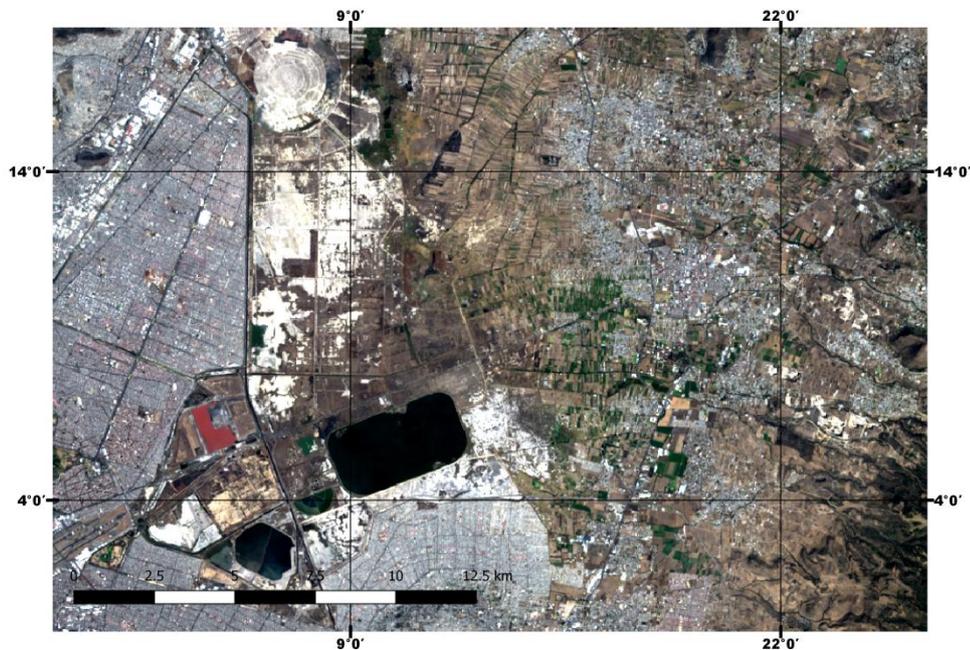


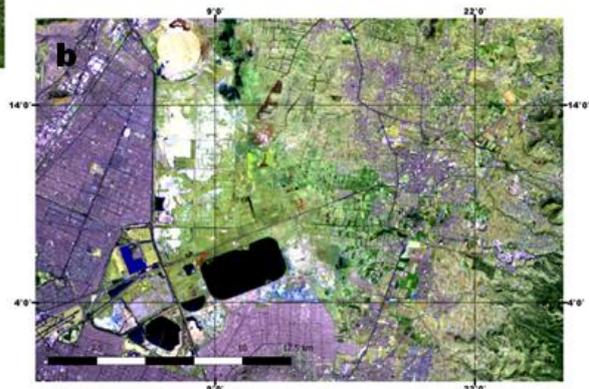
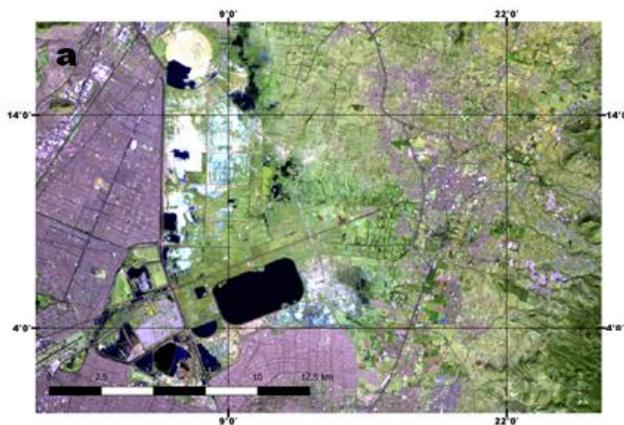
Figure 1: Location New Mexico City International Airport. (2016).



Figure 2: Prototype of the new airport in Mexico City (Source: <https://expansion.mx>)

RESULT

"In terms of national priorities, the atmosphere is always the latest, especially when it is **infrastructure**" phrase that we listen to repeat every that a new architectural work of global impact is created. The new International Airport in Mexico City is planned as a sustainable; however, the environmental destruction that this is leaving along its construction is more than evident. It is here where we wonder **¿What would it meaning in environmental terms the construction of a new airport in Texcoco?**



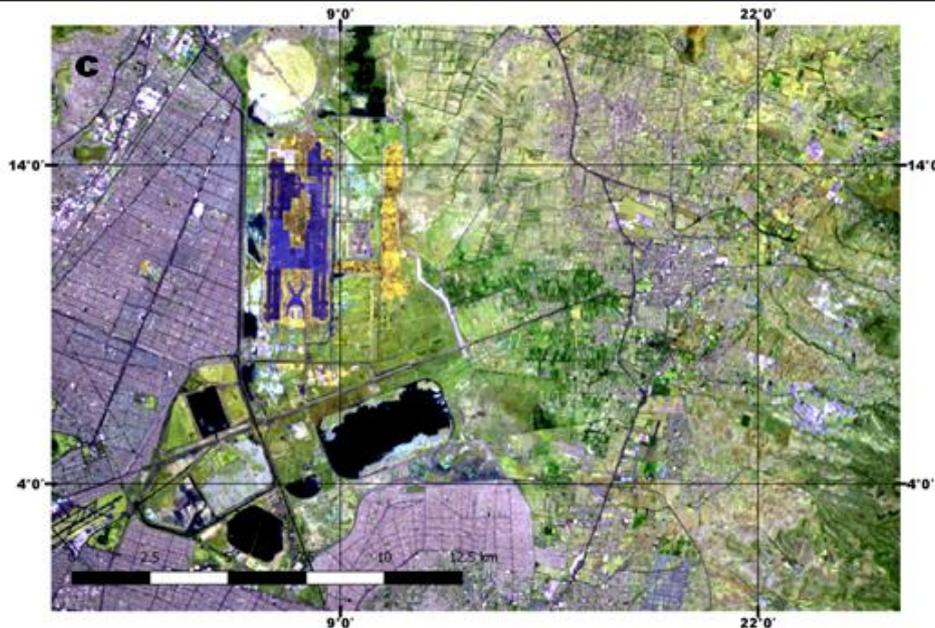
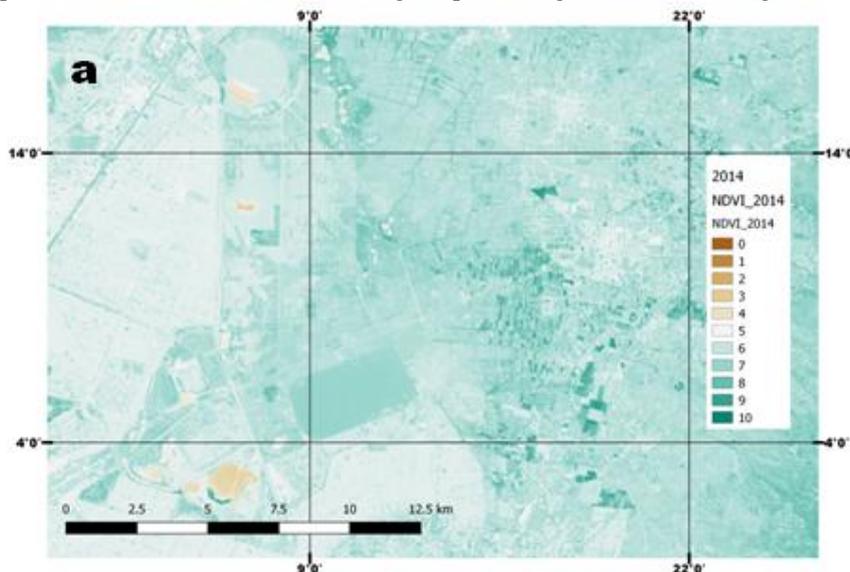


Figure 3: virtual combination of color to the year 2014 (a), 2016(b) and 2018(c)

Figure 3 shows a false-color combination for the years 2014, 2016 and 2018 respectively where we can highlight the general conditions that preserves the study area. One of the facilities offered by this combination is to highlight the contrast between urban and rural area, with this we can delimit the study area more accurately.

NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

Main function is to enhance the vegetation in function of its spectral response and mitigate the details of other elements such as the floor, lighting, water, among others. That is to say, these images are calculated on the basis of algebraic operations between different spectral bands. By applying the equation 4 in the table of mathematical equations of Landsat data [3] and doing the processing in the software Qgis is obtained as follows:



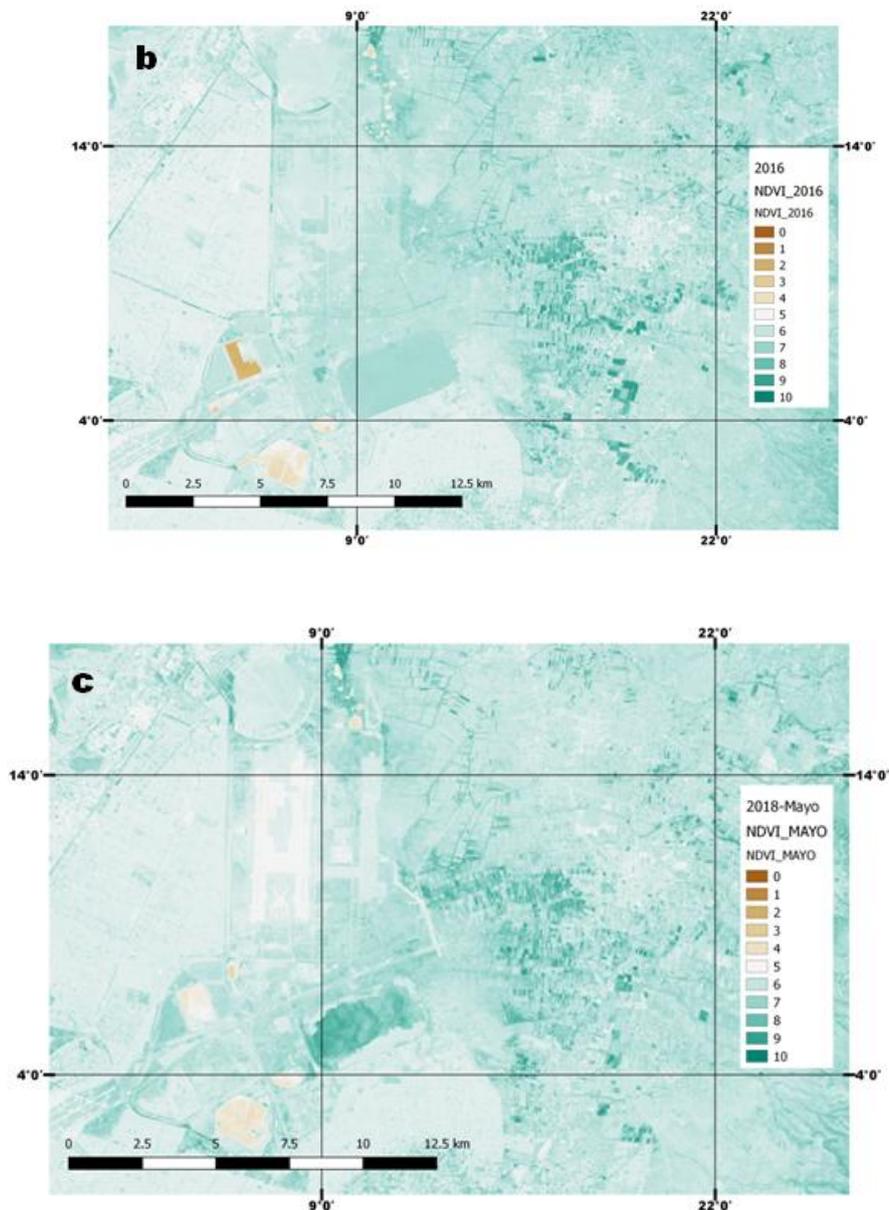


Figure 4: NDVI for the year 2014 (a), 2016(b) and 2018(c).

More than 57 thousand trees savory and cacti, as well as a thousand 600 specimens of wild life of 32 different species listed in some category of risk, have been rescued in the polygon in new International Airport in Mexico City (NAICDMX) and relocated three kilometers to the southeast, off-site. There identified 209 species of aquatic and terrestrial birds, whose habits are monitored by specialists. "Priority is given to the rescue of those species that are found in any category or conservation status. We talked about in the area we have at least 13 species of fauna that are in the Rule 059 of the Semarnat [6] and 19 species that are categorized in accordance with the Red List of the International Union for the Conservation of Nature (IUCN) with a lower status of conservation", Martin said Candela Tornes, responsible for the program to rescue Flora and Fauna of the NAICDMX. The company is responsible for the rescue Ragamex, endorsed by experts in the management of species of the National Polytechnic Institute, who identified in the estates of the NAICDMX 12 different species of mammals, 15 of reptiles and five of amphibians. There is dominated by the snake, the rabbit mexican deaf serrano and the lizard, tree species endemic to the region. "The 72 percent of the species that have been rescued correspond to reptiles, 12 percent to mammals and 2 percent to amphibians. In total we have rescued nearly a thousand 600 copies of these three groups". The Polygon was part of the habitat of mammals, such as the Gopher Mexican, long tailed weasel, rabbit serrano, hare black tail shrew, mexican meteor, common mouse,



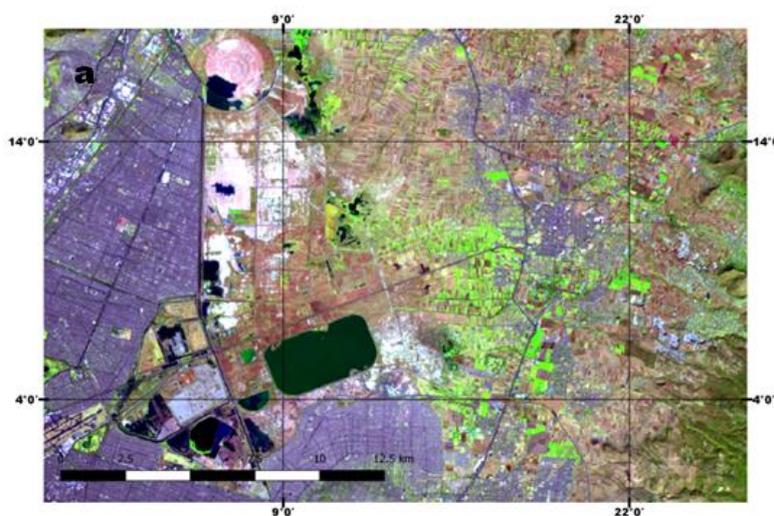
mouse common crop, mouse opossum norteño, American, Mexican and gopher coterie scratched, which are on the IUCN Red List classified as "least concern". Among the reptiles we identified eight species of snakes, such as the black water, mountain listonada listonada long tail, in southern Mexico and Mexican deaf, listed as threatened in the NOM 059; while the snake Baird parchada is under special protection. Meanwhile, the snake mountain listonada short tail, the narigona toluquense land and are found in the IUCN Red List as Least Concern. There were also three species of lizards: The tree is subject to special protection, while the thorny and scaly skin are staggered on the red list. The species was found neck lizard alicante rough, that is in danger of extinction and the Alicante of the Popocatépetl, subject to special protection. The area is also regional environmental sea turtle habitat broken chest of Mexico and the broken leg chest rough, endemic species of the glasses of water of the former Lake Texcoco, both listed in the category of special protection according to the NOM 059. In terms of amphibians, identified the frog of Moctezuma, subject to special protection, as well as the mountain tree frog, Tree Frog, Rana ladradora folded yellow and the toad in the plateau.

DISCARDED RISK

The person responsible for the program to rescue said that the construction of the **NAICDMX** does not represent a threat to the diversity of flora and fauna, as the program envisages its relocation "in 240 hectares that similar environmental characteristics or improved." In the areas that present the quality of the ideal habitat is the liberation and to each copy it places a monitoring chip with which we are going to record its evolution, its stability, growth". He explained that the rescue of animals is carried out prior to the intervention of the construction companies; "Will the technical team, performs the uprising, the zoning of areas of habitat of each specimen and makes the lifting of how many copies it is possible to rescue and relocate to areas of relocation". The rescue and relocation of the flora and fauna of the polygon where we build the new airport is one of the determining factors in the operative paragraph 20 of the Environmental Impact Statement (EIS) issued by the Secretariat of Environment and Natural Resources for the change in land use. The species are relocated on federal lands managed by the National Water Commission in the vicinity of the Lake Nabor Carrillo, right in front of one of the major points of access to the land on labor, on the other side of the rock-*Texcoco* (<https://www.milenio.com/estados/mudan-flora-y-fauna-del-poligono-del-naicm>).

Based on the above we can observe in figure 4(a) corresponding to the year 2014 the initial conditions where was still intact, the flora and fauna of this place, for when the news of the mobilization of the species (this in the year 2017), for the year 2018 Figure 4 subsection (c) of NDVI shows a decrease of vegetation in some points that coincide with what in the year 2017 was "removed". Locating the area where these species would be relocated, the image of NDVI we would have to show a shade close to the green color, however, is not displayed an increase in this tonality.

ANALYSIS OF THE VEGETATION AND HEALTHY VEGETATION VEGETATION



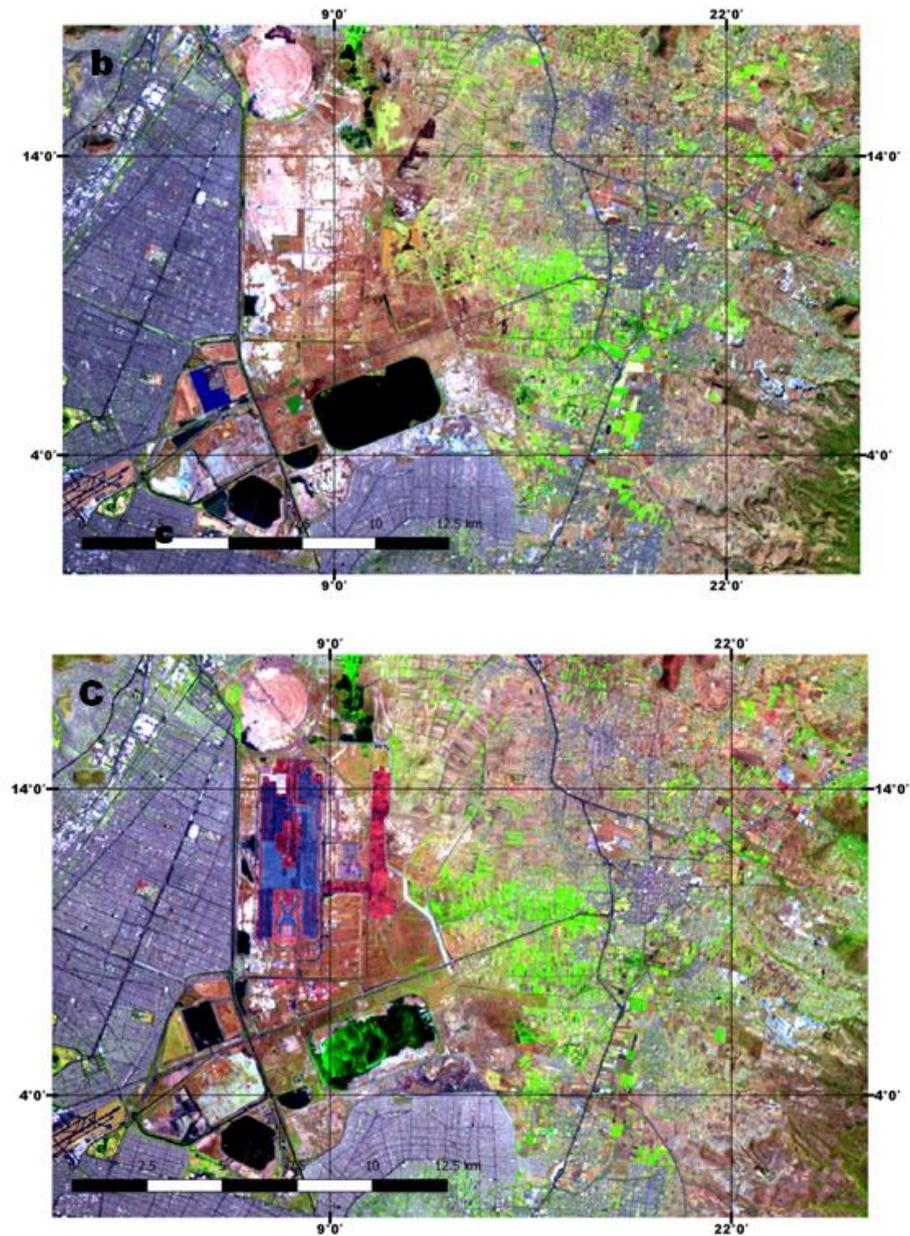
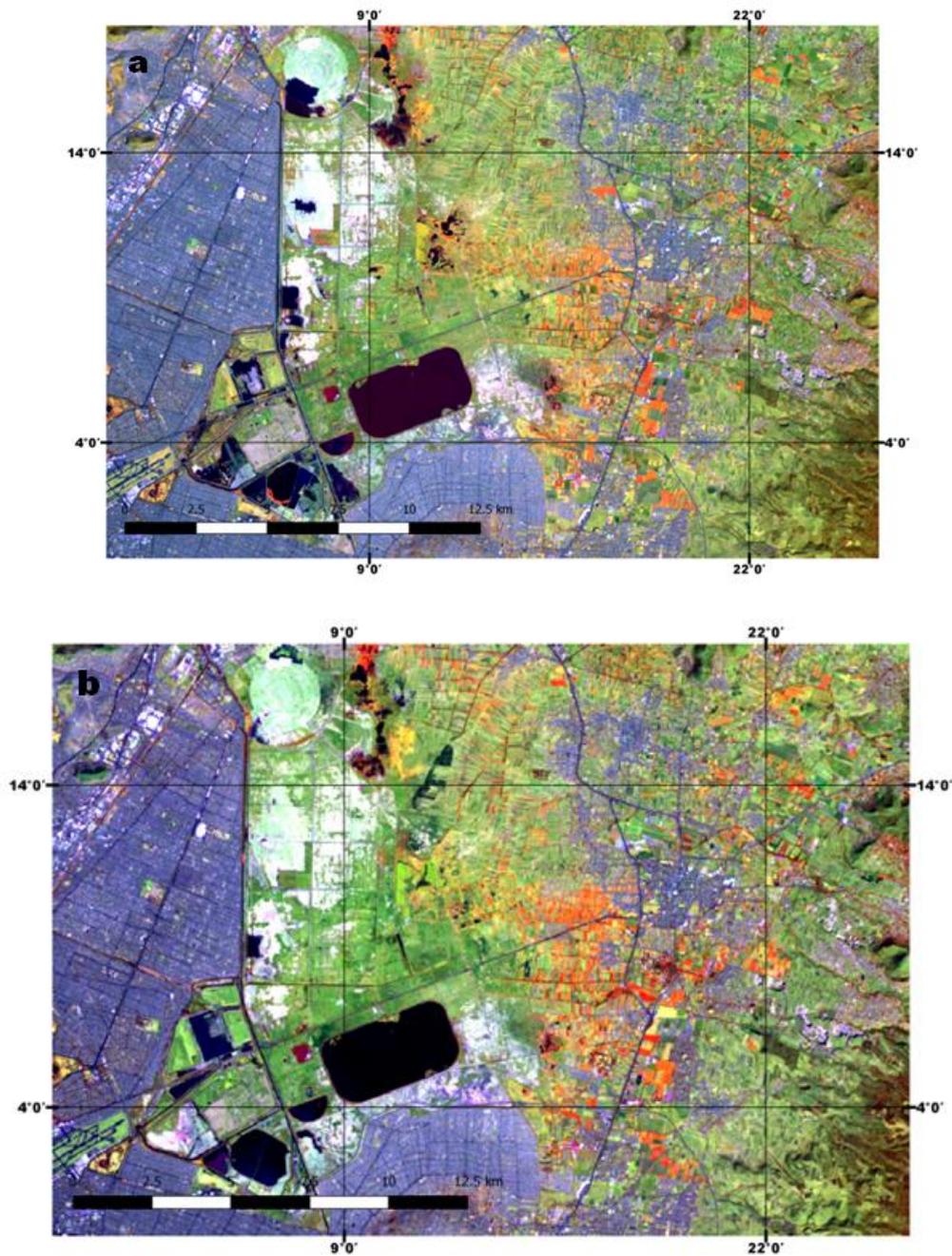


Figure 5: Analysis of the Vegetation for the year 2014 (a), 2016(b) and 2018(c).

According to the analysis carried out in figure 5 of the vegetation for the year 2014, 2016 and 2018 confirm that there was a decrease of water bodies and vegetation, showing the greatest deterioration in the area belonging to the NAICDMX. The construction of the same leads to deforestation in some aquatic and terrestrial species in just 4 years of its construction.

HEALTHY VEGETATION



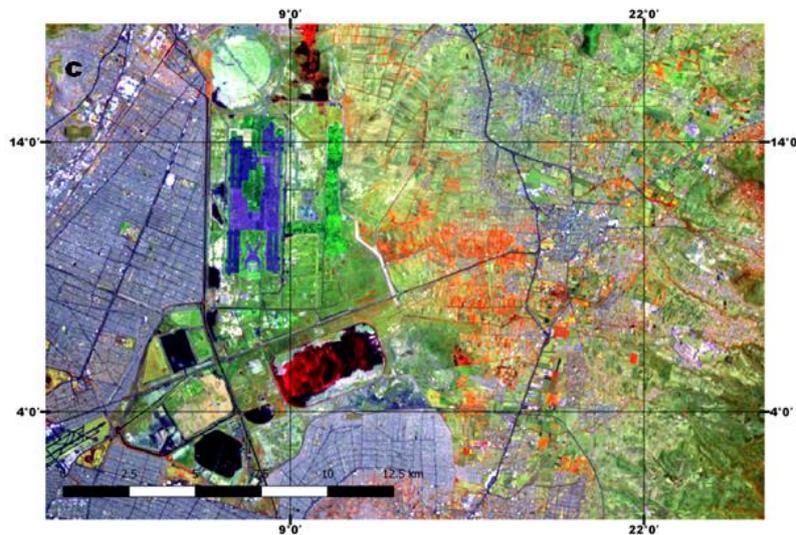
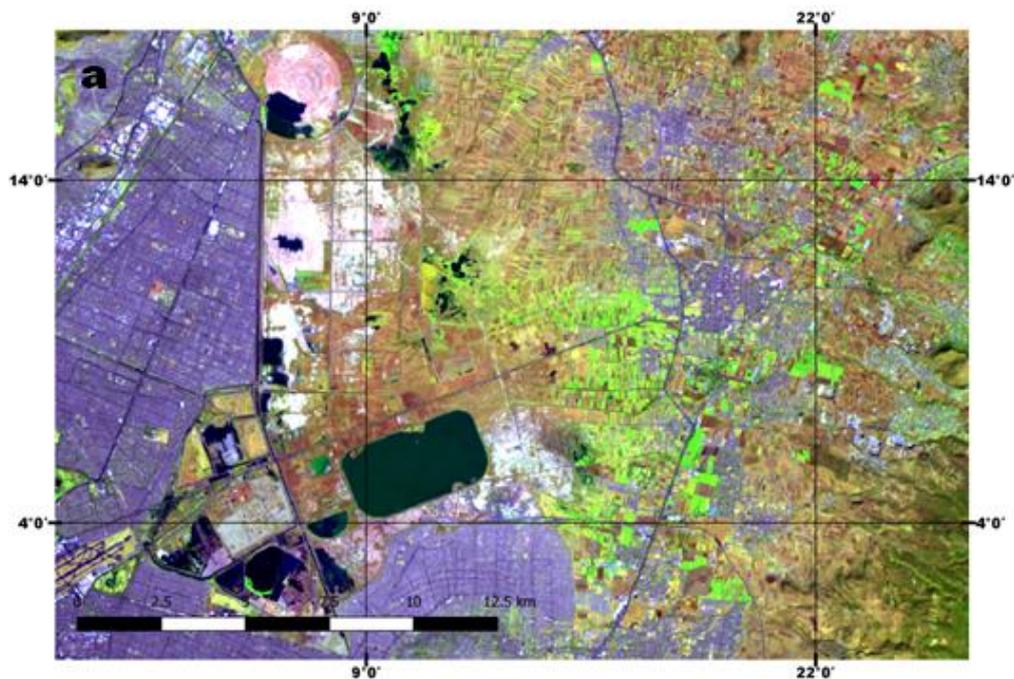


Figure 6: Healthy vegetation for the year 2014 (a), 2016(b) and 2018(c).

The analysis of healthy vegetation shown in figure 6 of the year 2014,2016 and 2018 shows drastic changes in the lake Nabor Carrillo for the year 2018 has not been ruled out the presence of pollutant concentration it is recommended that a chemical study of water. On the other hand, images of healthy vegetation do not show signs of existence of species relocated.

AGRICULTURE



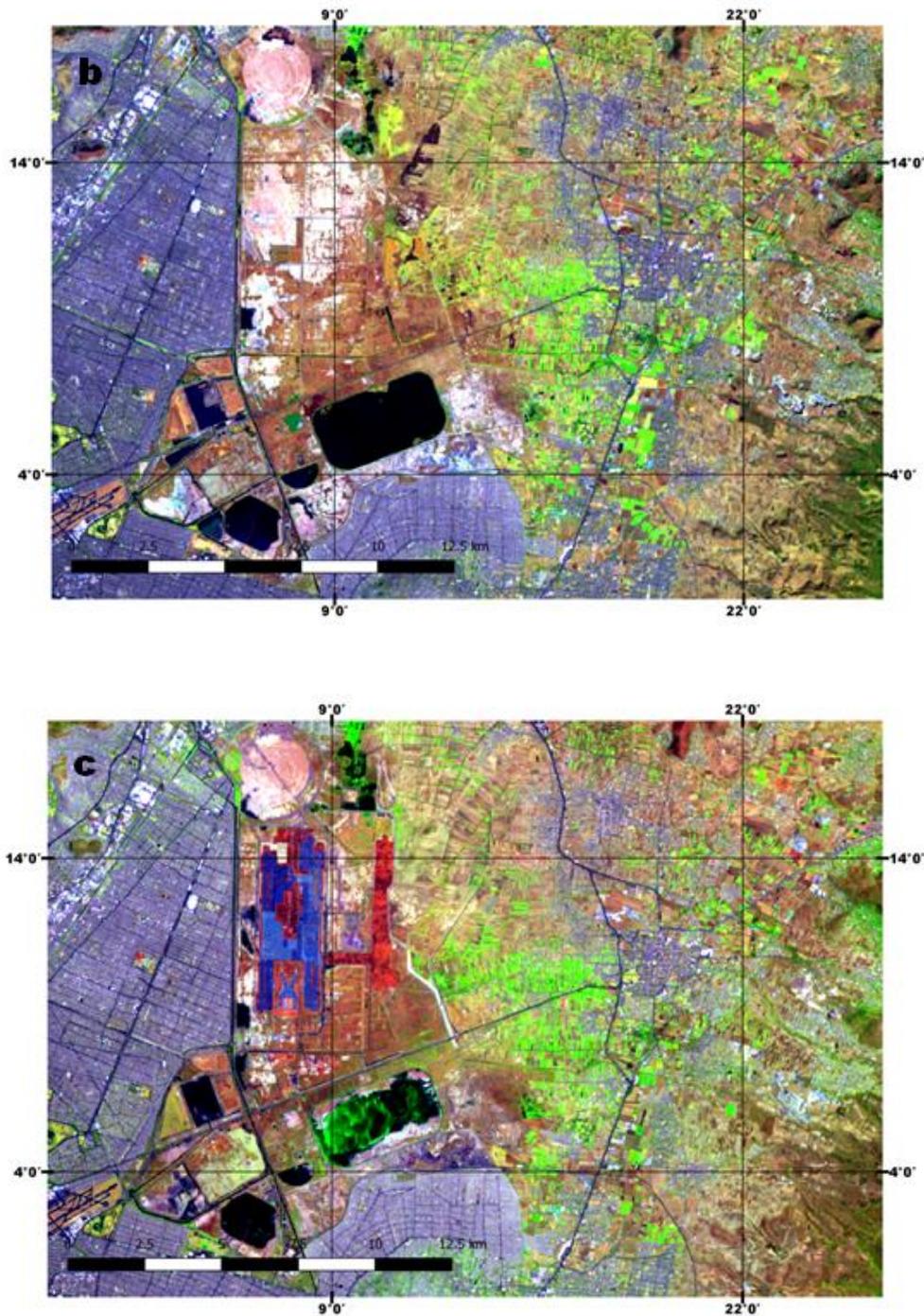


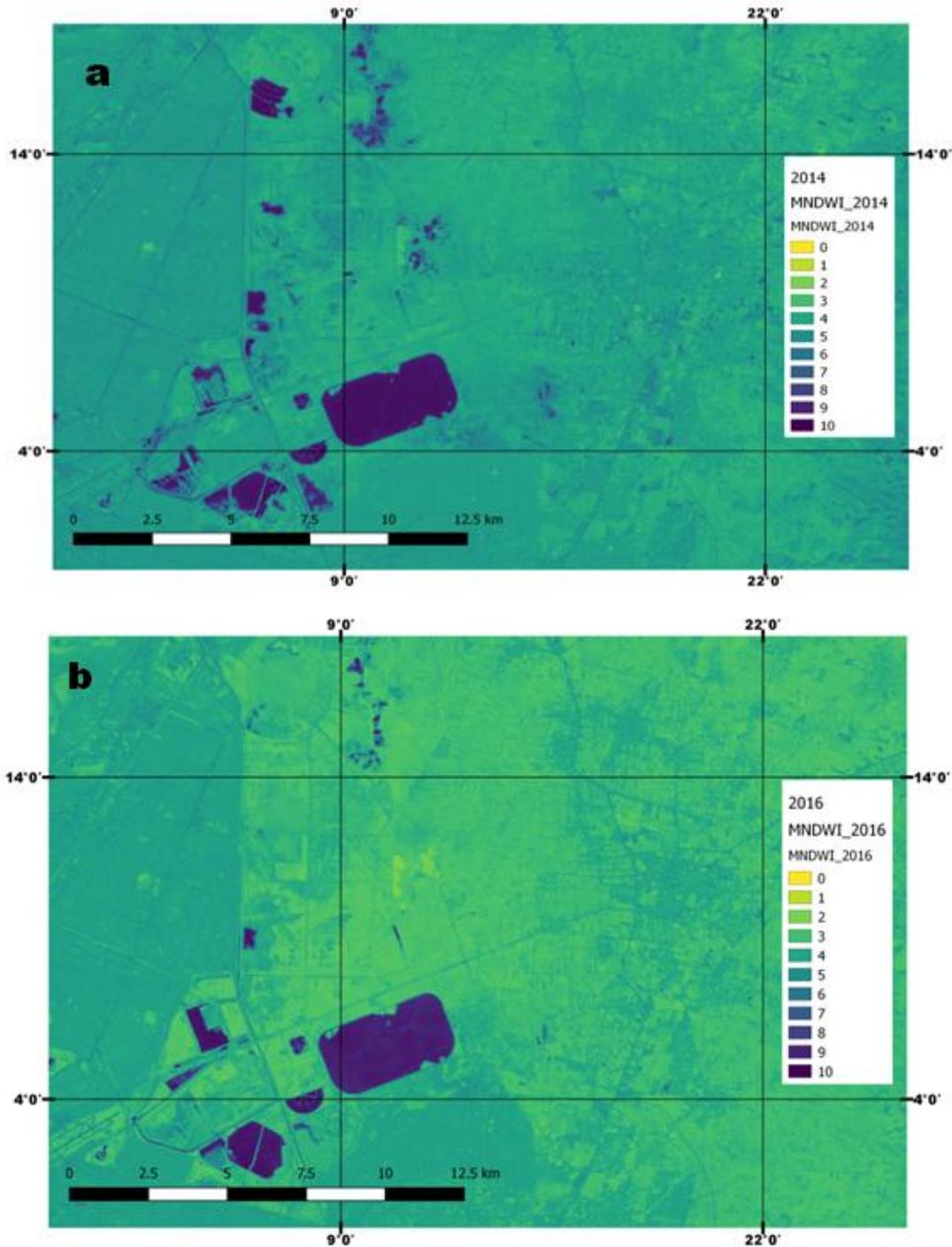
Figure 7: Agriculture for the year 2014 (a), 2016(b) and 2018(c).

In Figure 7 relating to agriculture can be noticed that the light green color corresponds to the fields of which according to the analysis have not been significant changes, however, this does not mean that they are not exposed to undergo changes in the future as a result of a local climate change.



MODIFIED NORMALIZED DIFFERENCE WATER INDEX (MNDWI)

Its main function is to highlight the territory covered by water that will help identify bodies of water, as well as the moisture is present that can persist in that moment. Making use of the equation 5 in the table of equations for Landsat images are obtained the following results:



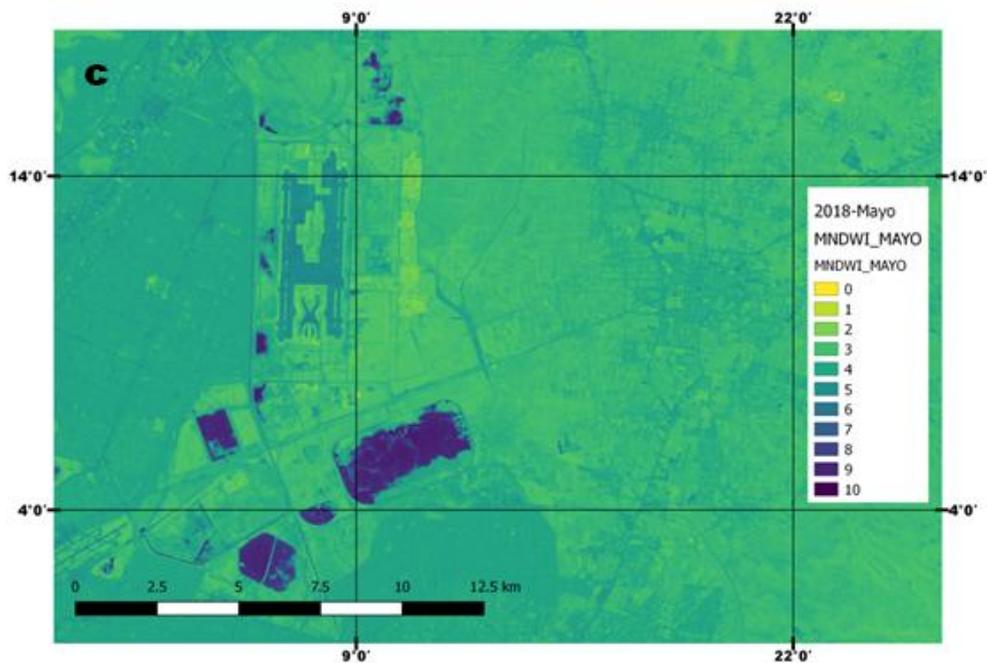


Figure 8: MNDWI for the year 2014 (a), 2016(b) and 2018(c).

The **CONABIO** (National Commission for the Knowledge and Use of Biodiversity) [4] provides that the lake Texcoco is considered, from 2007, a AICA because it represents an area of 1.700 hectares of permanent lakes and ponds 2.000 of seasonal shallow which gives shelter to populations of 100.000 or more birds during the winter, being the most important area of hibernation of aquatic birds of the valley of Mexico (CONABIO, 2016). It is currently made up of five permanent artificial lakes with contributions from water from rivers, Coacacoaco, Xalapango, Texcoco, San Bernardino, and Nevada, as well as by contributions of black waters coming from the drainage of the City of Mexico (CONABIO, 2004). Only in this area have recorded 250 species of birds, which are designated in various categories according to the Birdlife (2007) and the classification in Mexico of 1999, such as: endangered species at risk and that at the very least have the 1% of the biogeography population for an aquatic species congregator.

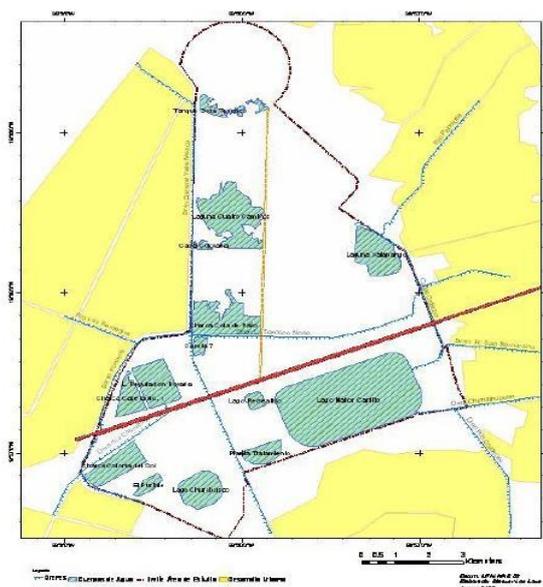


Figure 9: Bodies of water Lake Texcoco (Source:<http://www.dumac.org/dumac/habitat/esp/pdf/Informe-Final-Texcoco.pdf>)

According to the previous article where Figure 9 we can observe the distribution of the existing lakes in what will be the construction of the new airport, lakes that match the distribution obtained by figure 8 of the year 2014 MNDWI (a). With the passage of time and the construction of the new airport we can observe the disappearance of at least three bodies of water that had endured for a long time and that surely were the home of many species.

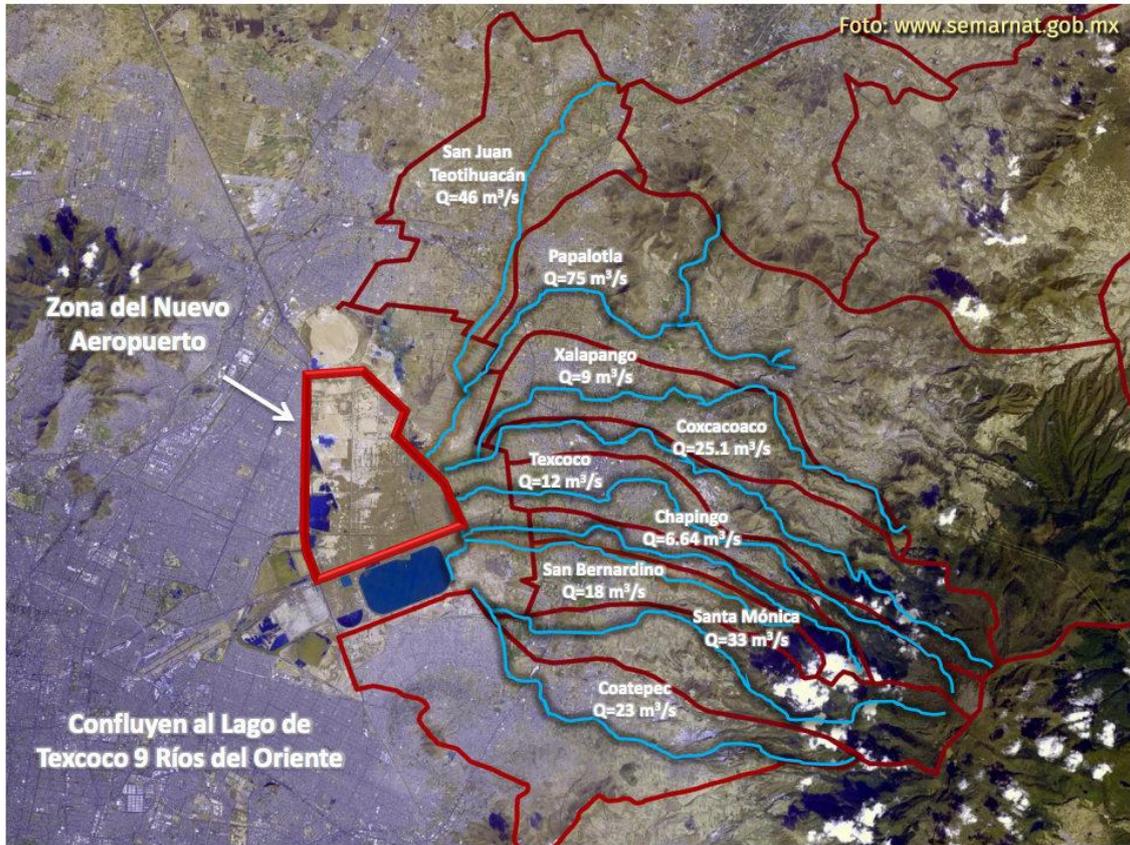
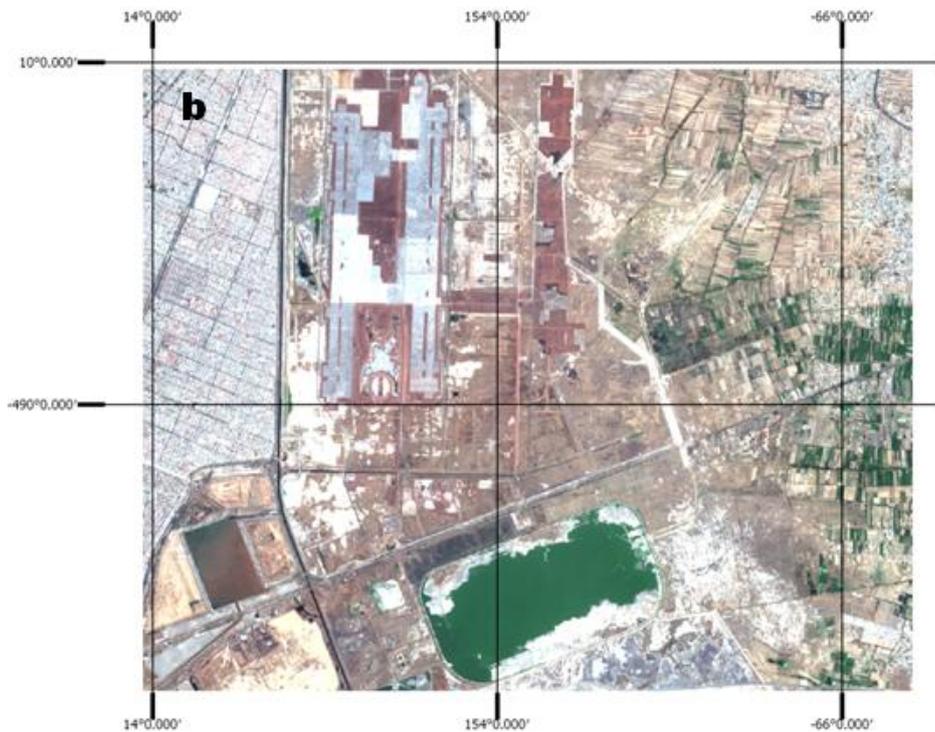
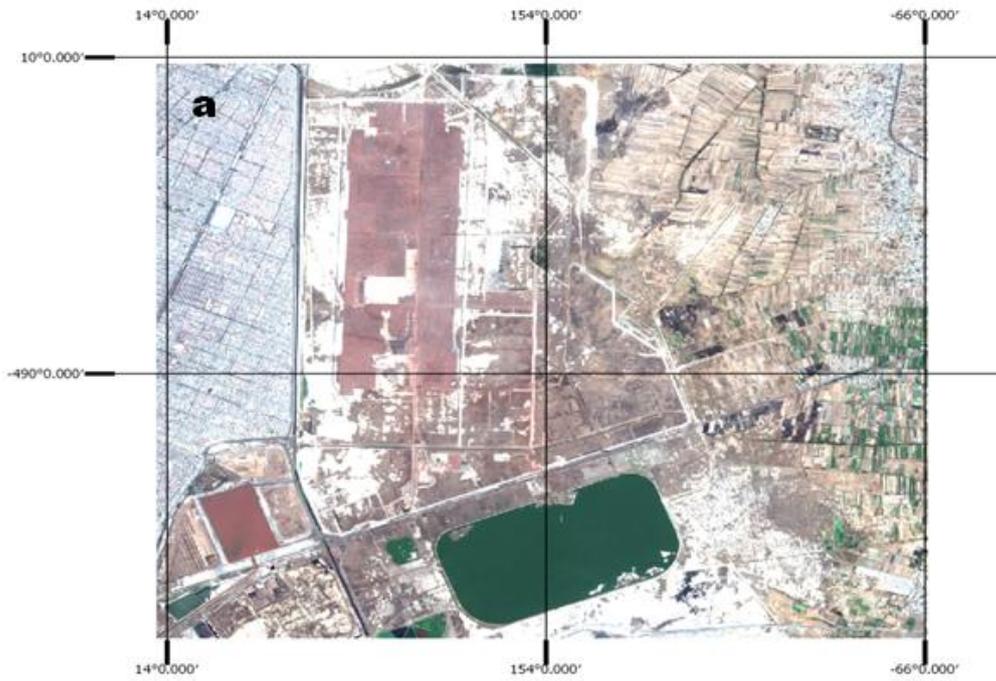


Figure 10: rivers flowing into the Lake Texcoco (Source: Semarnat [6]).

The question arises here; **¿It was a good idea to dry lakes in the area of the new airport?** ¿What will happen to the rivers that flow there? The previous image surely will give us an idea of the response we would like to listen to analyze the 9 rivers that meet at the lake of Texcoco. Surely it is time to perform a spatial analysis to see each and every one of the consequences that this would bring us to the future.



**SENTINEL PERSPECTIVE
FALSE COLOR**



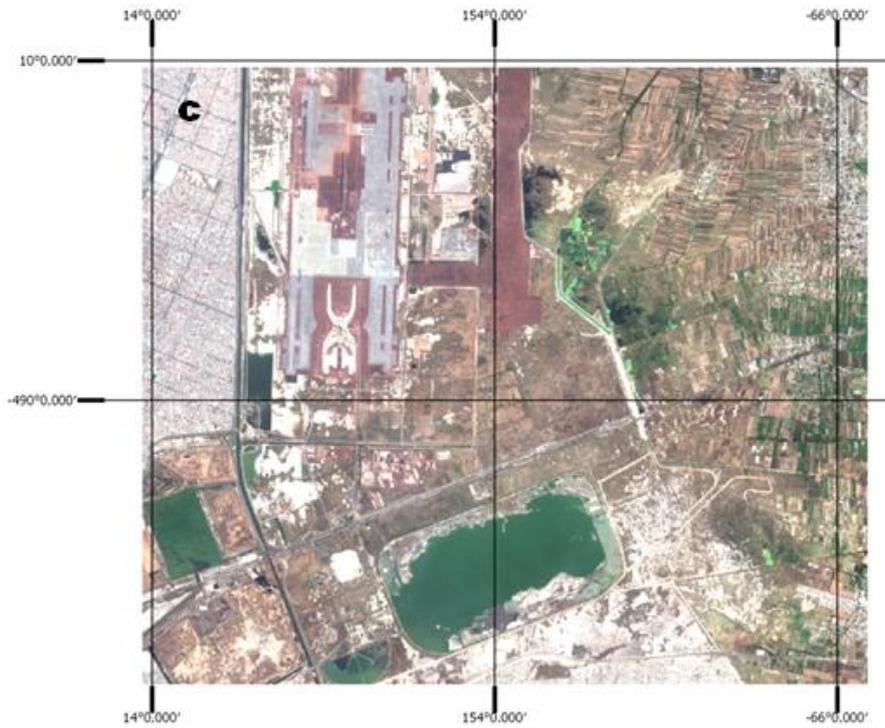
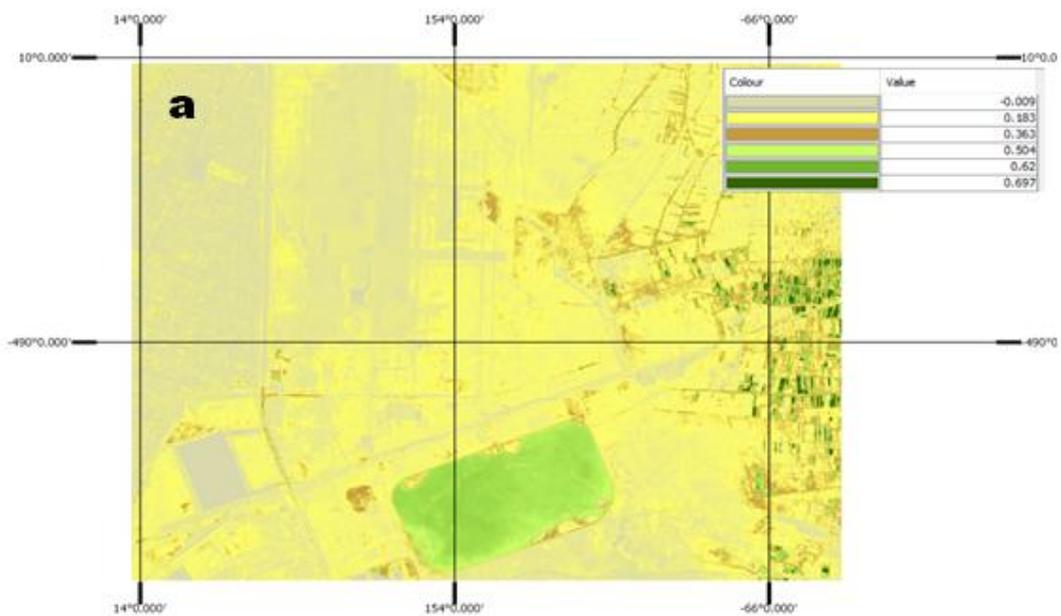


Figure 11: False Color for the year 2017 (a) and 2018(b, c).

The results obtained with the Satellite Sentinel show a better spatial resolution because these images are able to work at 10m resolution. Allowing a better perspective of the changes and events that happened in the study area.

NDVI



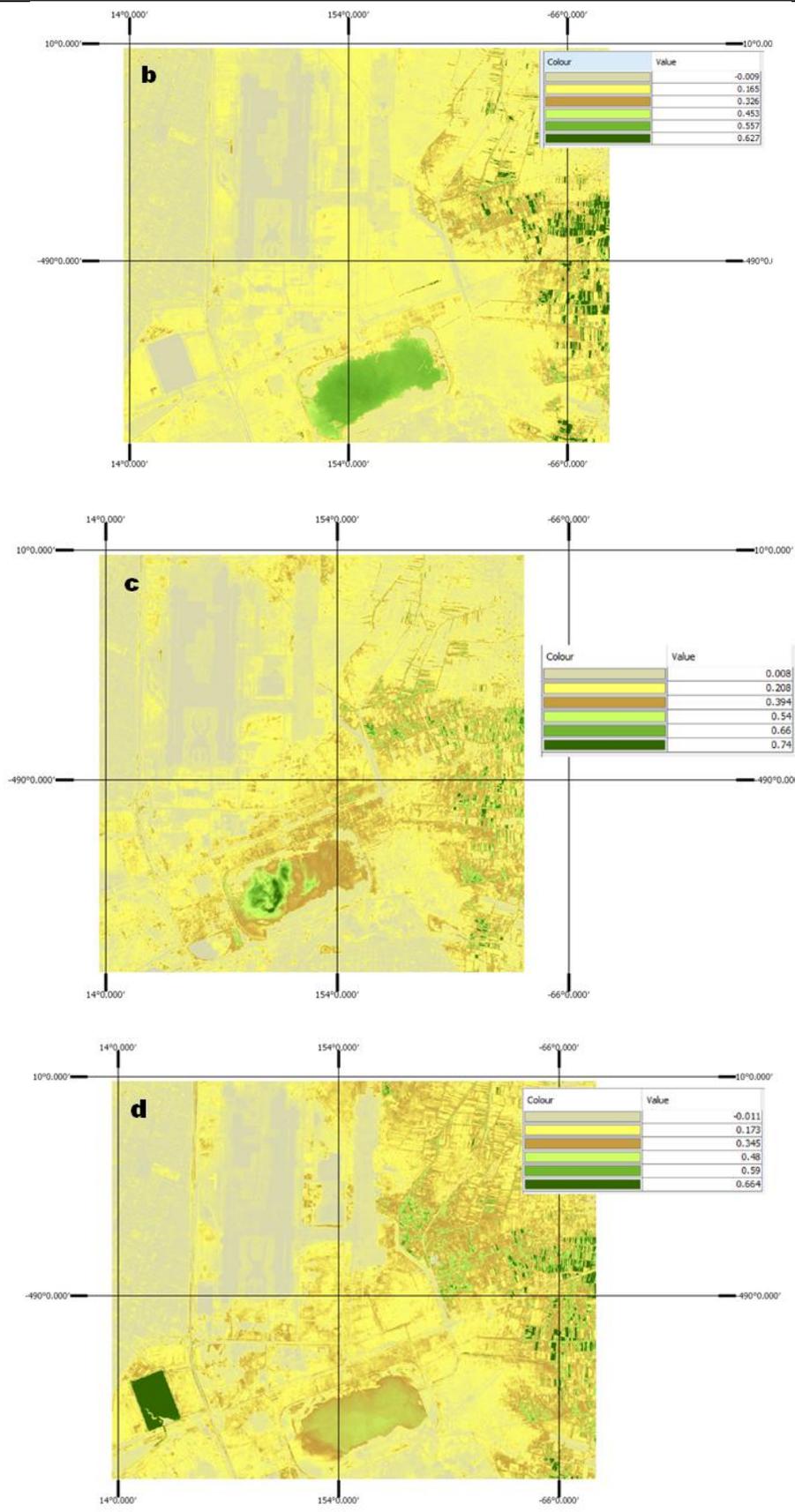
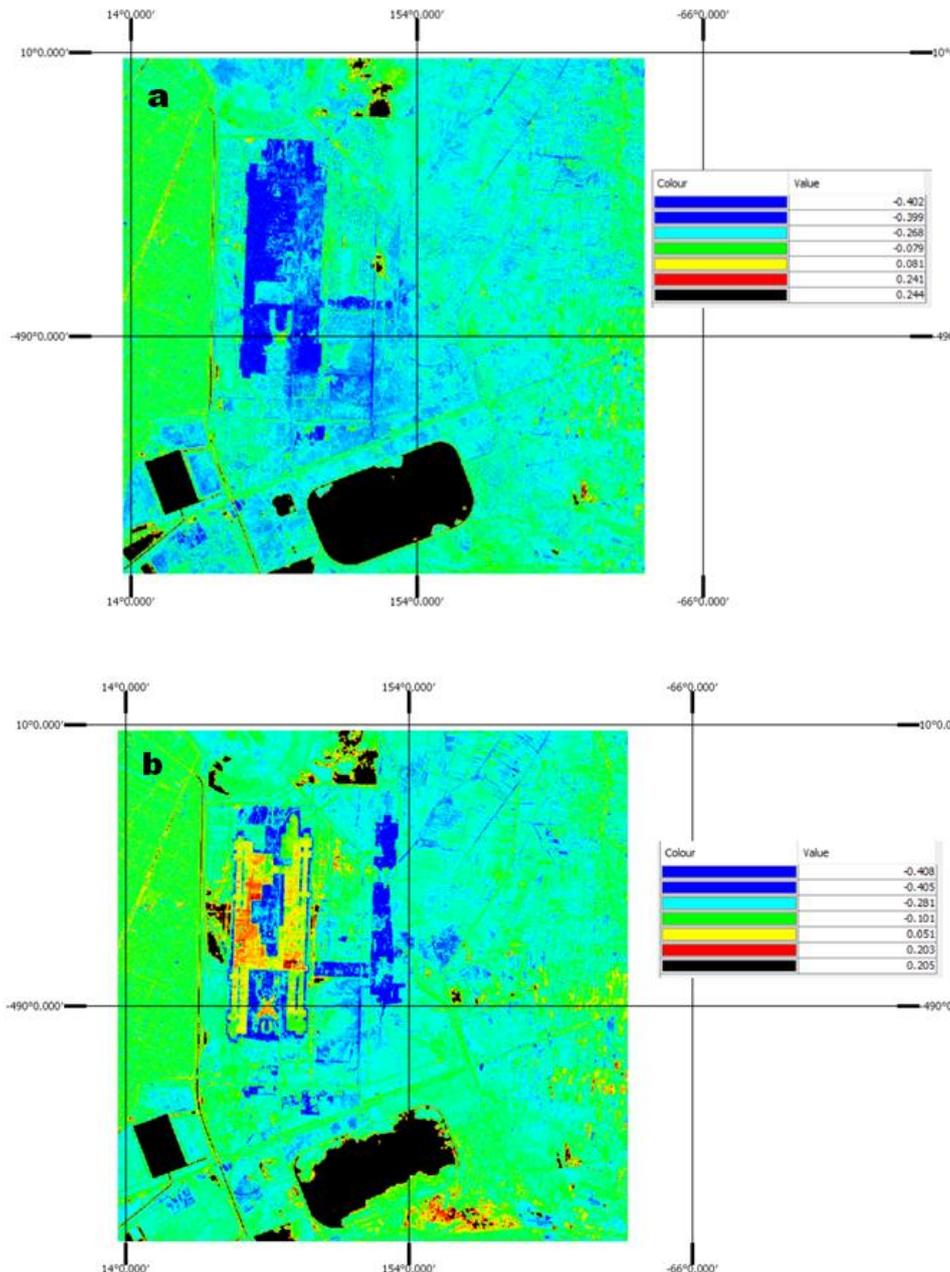


Figure 12: NDVI for the year 2017 (a) and 2018 (b,c,d).



The analysis of NDVI with Sentinel allows us to appreciate in more detail the contrasts of vegetation present in the study area. For the evaluation of the images we must consider that these are in a scale from -1 to 1 where -1 shows null values of vegetation while existing vegetation and abundant. The yellow color is predominant, who is to say that the vegetation is located very close to the 0 which means that the vegetation is damaged, this is due to the zone in which it is located, which does not allow the abundant growth of the same. The area is limited to certain species that can be adaptable. The area that shows strong green colors to the middle of figure 12, are linked to areas of cultivation while the south are linked to the existing vegetation in lakes (Nabor Carrillo L.R Horaria) that would correspond to aquatic plants, a product of the great concentration of organic matter. The NDVI for these years shows the deterioration that have led several bodies greens, **as can be seen in the lake Nabor Carrillo where in just 2 years aquatic vegetation has decreased significantly.**

MNDWI



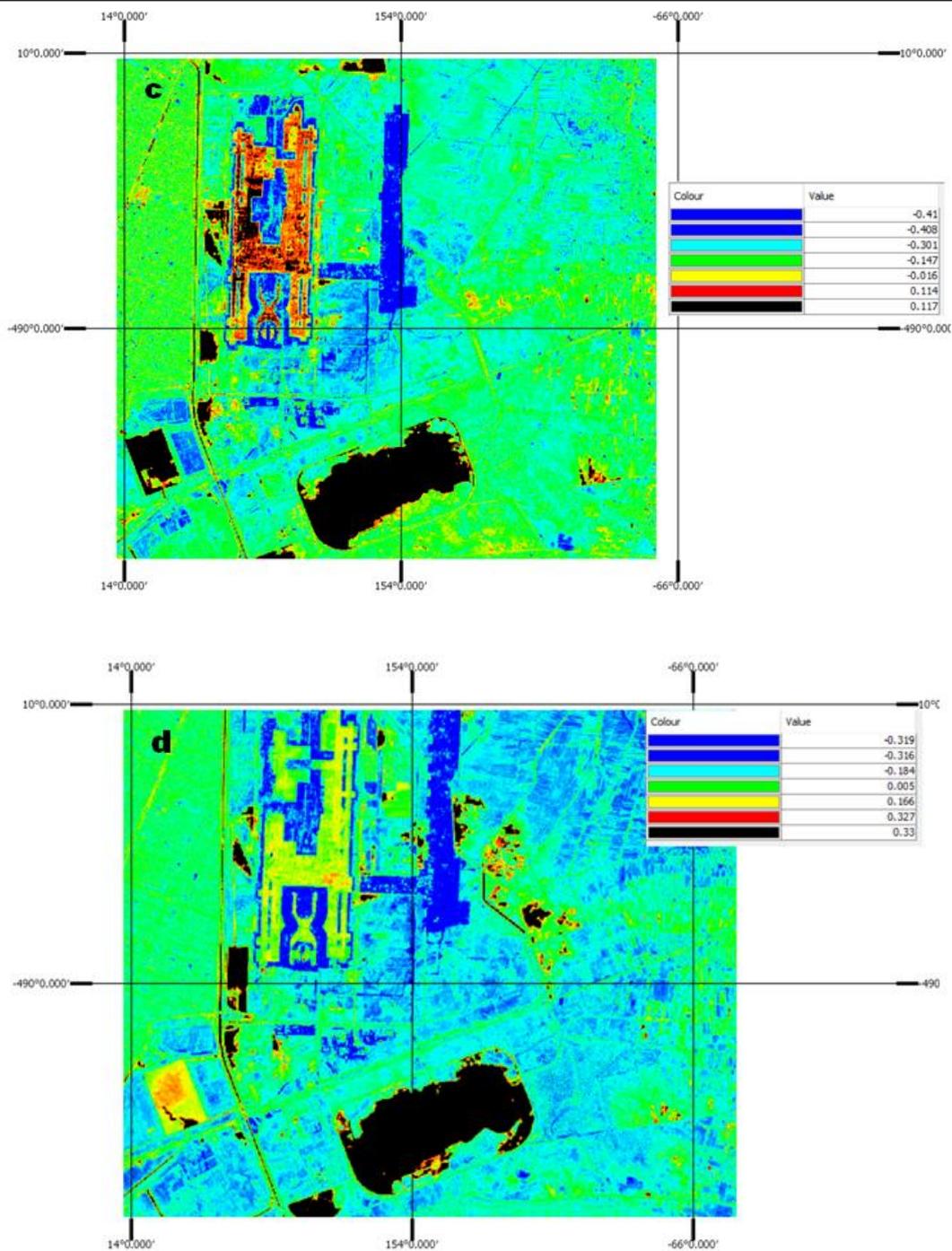


Figure 13: MNDWI for the year 2017 (a) and 2018 (b,c,d).

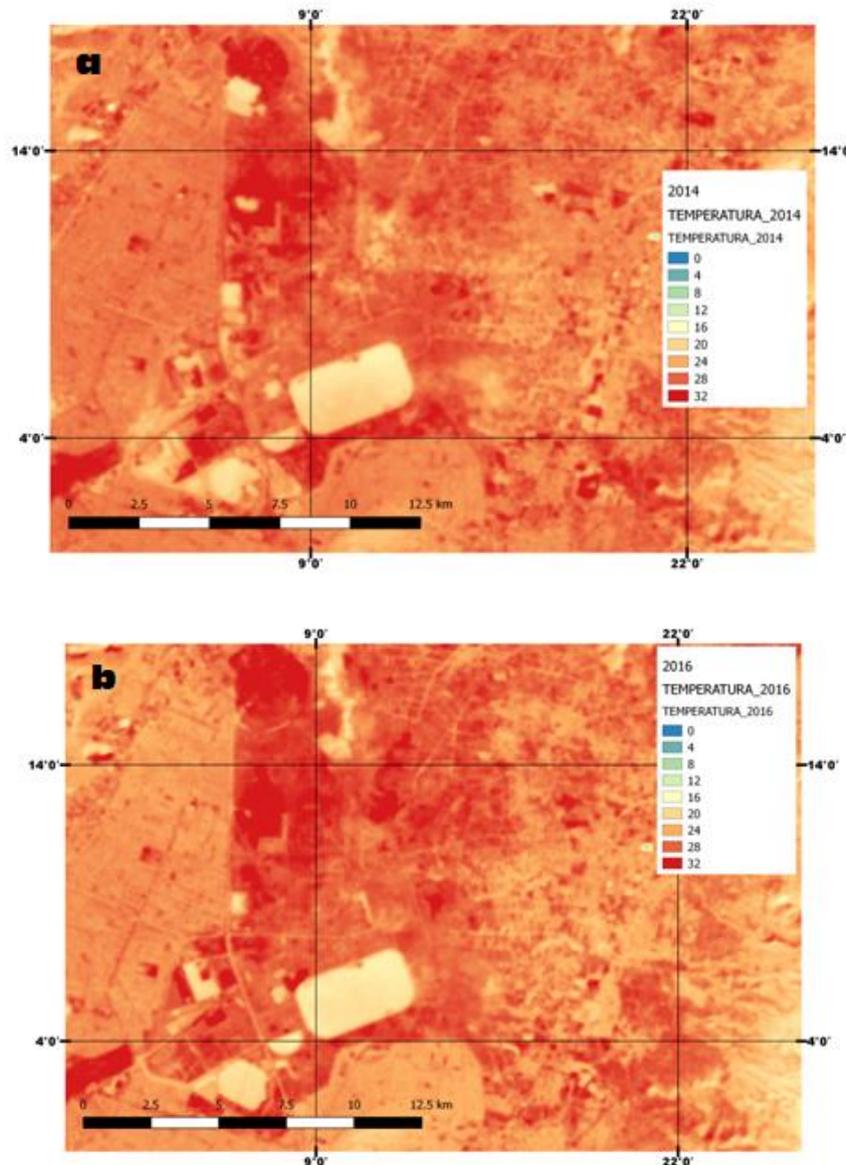
The images of Sentinel of MNDWI show the existence of bodies of water on a scale from -1 to 1 where -1 is body of water null and void 1 Existence of body of water. With regard to the figure 13 subsection (a) for the year 2017 shows mastery of color blue in the study area, however for the year 2018 subsection (b,c,d) shows shades of red and yellow this is due to the fact that the green areas that existed at the time were replaced by igneous rock (tezontle) which by its properties of porosity is able to retain the water until you reach a saturation point. According to the scale of color, black shows values near 1, i.e., the existence of a body of water. The image of the 2017 shows the lake Nabor Carrillo as a consolidated body of water in an almost perfect rectangle, however, by the end of the year 2018 this deformation representative which leads us to think in a desiccation that this presents. In addition, the image of the end of 2018 subsection (d) shows the existence of body's lagoon that lie to the north and west of our study area which according to the advertisements issued by companies



contracted for the construction of the new airport would remain as green area to preserve the life in the lake. Let us remember that these bodies perennial lagoon often result, that is to say, we can find them in its maximum splendor after the presence of rains.

HEAT ISLANDS

The term heat island [1] is an urban problem that is due to the build-up of heat due to the absorption of the construction materials. The increase in temperature of an urban area is directly associated with the change in atmospheric conditions. Currently, the ex-vessel of the Texcoco Lake and Lake Nabor Carrillo play an essential role in the regulation of temperature in the east zone. With the construction of the airport and the desiccation of the lake you can expect a dramatic rise in the temperature of the whole region. Following the methodology and applying the equation 3 of the table mathematical equations for Landsat satellites, we obtained the variability of temperature of brightness that presented the area in just 4 years of construction of the airport.



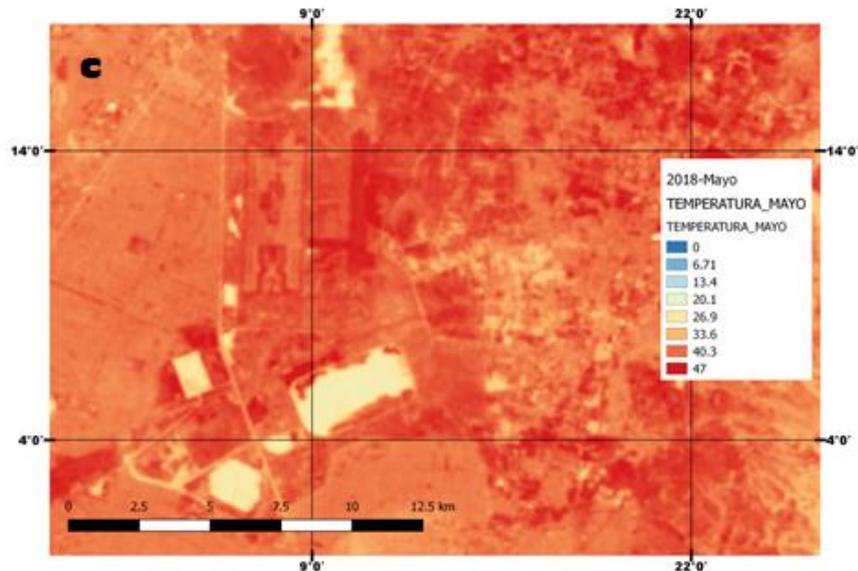


Figure 14: Temperature of brightness for the year 2014, 2016 (a) (b) and 2018(c).

The spatial analysis shows that the figure 14 corresponding to the year 2014 the contrast that existed between urban and rural areas by talking in terms of temperature. For the year 2018 (c) it can be seen that the tone in contrast of colors appeared to be the same, numerically speaking what for 2014 (a) it was a maximum of 32 in the study area for the 2018 (c) would be 47 degrees Celsius. We must think of the periodic resolution that have this type of images before giving a conclusion about the increase in temperature, but what is certain is that when you change the vegetation cover by concrete and rock that favors the absorption of energy (tezontle) what was previously a balance point will now be an area more than a contribution to high temperatures (heat islands). Although we have already spoken of the pan effect in Mexico City, causes and consequences, can we say that with the construction of the new airport through the effect of this phenomenon causing the equilibrium points for the hot air coming from the city are now more toward the east. Which in future will cause damage to vegetation or in the plantations than in the NDVI images we can observe. It must be to raise awareness if we really want to cause an irreversible impact.

CONCLUSION

Talk about environmental impact in the area of construction of the new International Airport in Mexico City is too soon, however think that this damage caused irreversible consequences in the future is a fact. Remote Perception allowed us to visualize a history of 4 years where we were able to observe the development of the project and where the images speak for themselves.

The plant presented with a decrease of NDVI analysis allowed us to see areas where there is no longer green bodies, on the other hand the MNDWI allowed us to analyze the bodies of water and its behavior. It was noted the change that led to the replacement of topsoil by concrete and igneous rock in large proportions of the study area, as well as the desiccation of water bodies. As in any study, it is always necessary to link information from different sources before giving a conclusion of what really happens. This work provides a satellite perspective analyzed from LANDSAT satellite imagery and SENTINEL [3.5], jobs previously analyzed, with the purpose of that can resolve many of the issues that have and will have in the future on the subject of environmental impact.

It is recommended that you deeply to complement the work with physical visits, tests of flora and fauna to analyze their development, inventory per season of migratory birds that visit the lakes, In addition to continue using this technique to have a broader spatial perspective because if environmental impact assessment this will little by little in the form of consequences and from an increase in temperature, modification of the wind currents, death of flora and fauna, among many others.

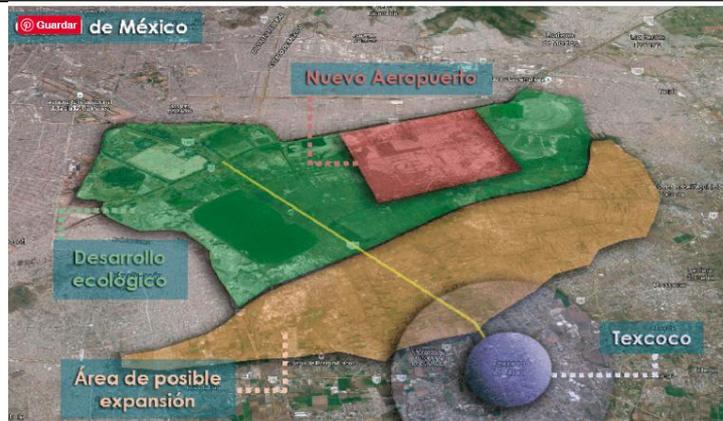


Figure 15: Construction Strategy (Source:<https://epireality.wordpress.com/2015/07/28/texcoconuevo-aeropuertosmart-city/>)

Taking as reference the previous image, the area of ecological development proposal sounds pretty good however is something that must really be working hand in hand with the structural development of the new airport because the remote sensing analysis above shows the opposite to what was planned.

REFERENCIAS

- [1]. Heat Islands in México City: A Perspective from Remote Sensing Satellite Images, Author: Fernando Mireles Arellano, Amanda Oralia Gómez González, Carlos Hernández López; International Journal of Latest Research in Engineering & Technology (IJLRET) (ISSN: 2454-5031).
- [2]. Amanda Oralia Gómez González, Fernando Amir Espinoza Acuña, Carolina Coronado Alderete and Frida Ximena Jimenez Law (2017). Qgis Manual focused on Tele-Epidemiologia. First Edition, Mexico City.
- [3]. The United States Geological Survey, USGS <https://earthexplorer.usgs.gov/>
- [4]. National Commission for the Knowledge and Use of Biodiversity <https://www.gob.mx/conabio>
- [5]. Copernicus European Space Agency <https://scihub.copernicus.eu/dhus/#/home>
- [6]. Secretariat of Environment and Natural Resources <https://www.gob.mx/semarnat>