Archaeological Remote Sensing Risk Monitoring and Cultural Heritage Management: Historical Cairo in Egypt (A case study)

Contents :


Abstract

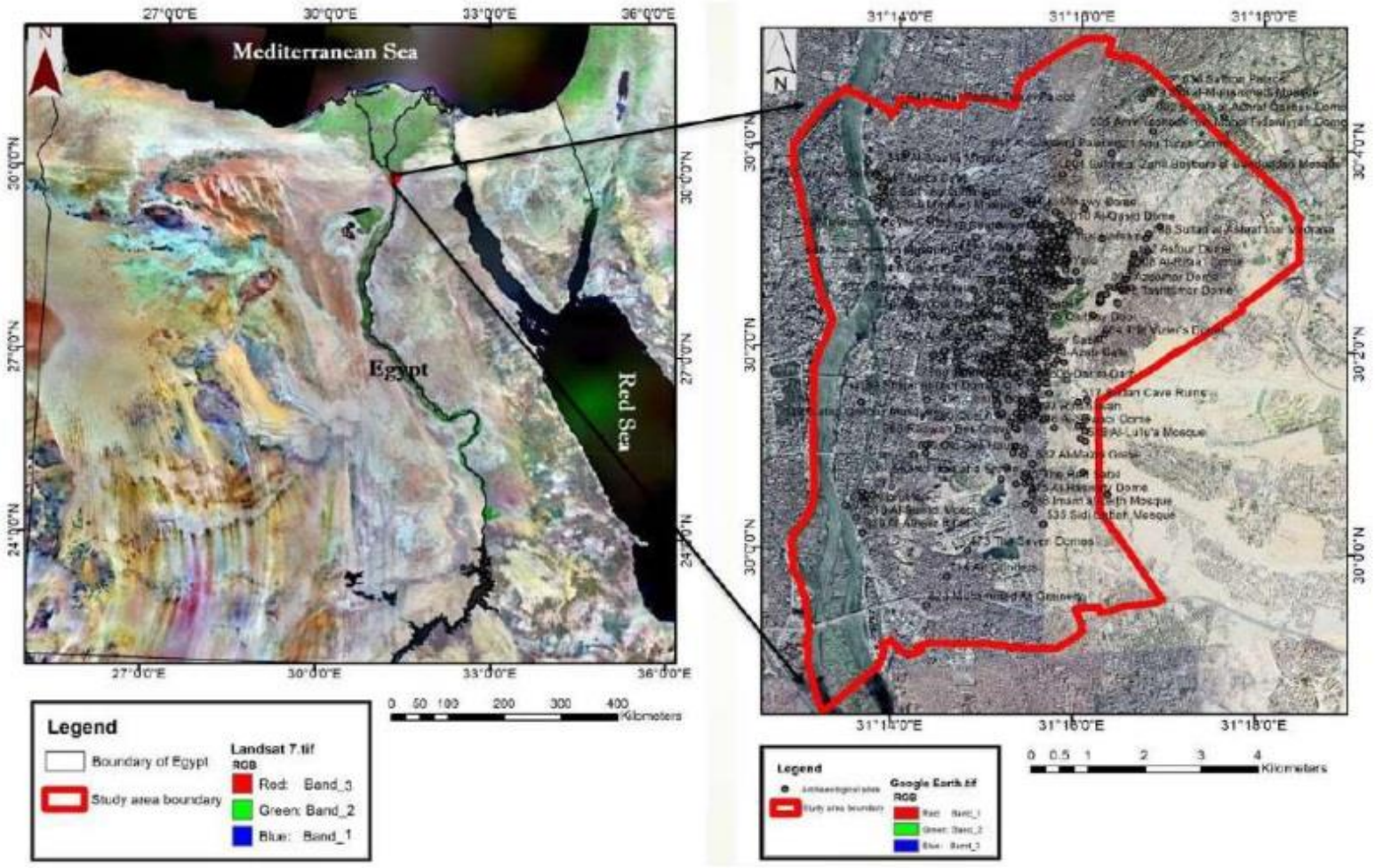
1) Abstract :

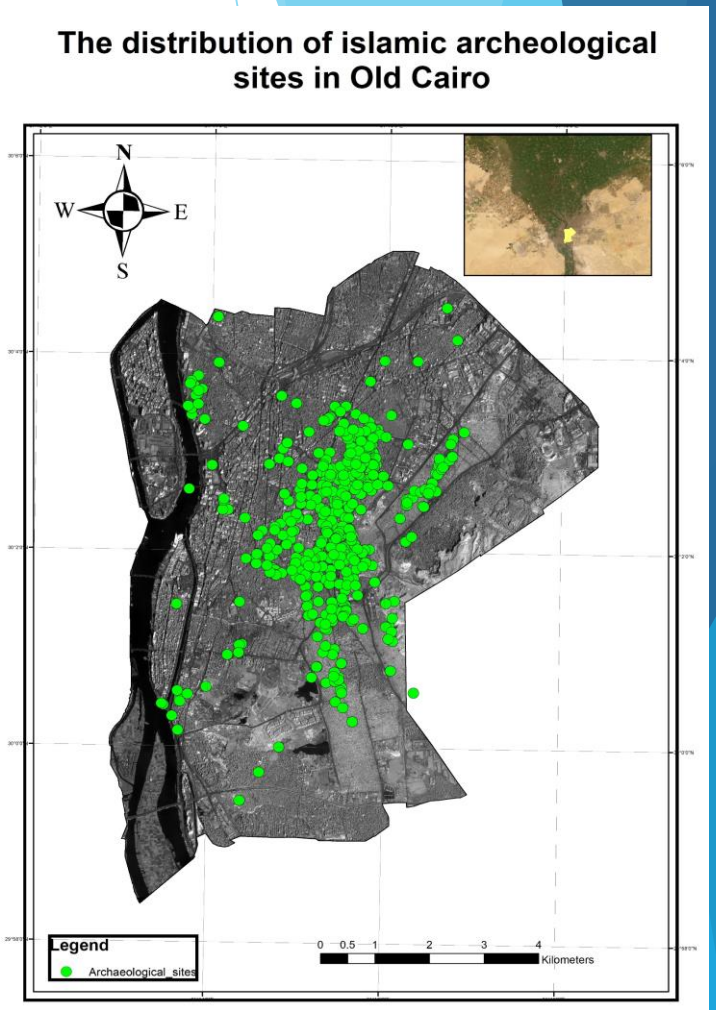
- First of all …our research is concerned with one of our national treasures

Both cultural and economic treasures ….

Let’s take a one minute tour …

Our study area



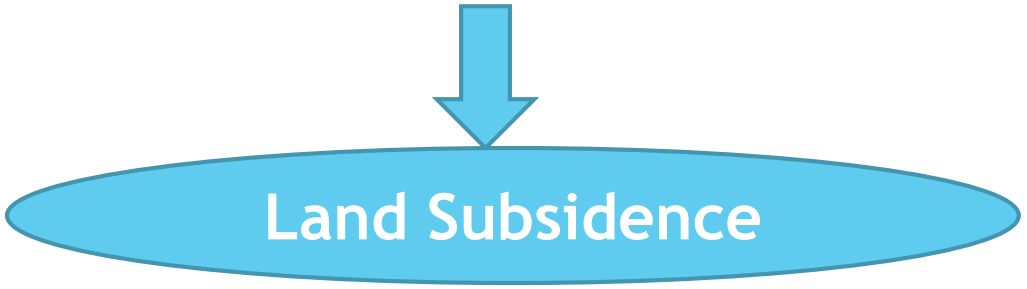


Under umbrella of cultural heritage management

We used remote sensing & GIS techniques to study the effects of anthropogenic & natural factors

On the Islamic monuments in old Cairo

Anthropogenic factors	Natural factors
1- Urban sprawl 2- Hot spot analysis	1-Urban Heat Islands 2-Flooding of heavy rains 3-Ground Water



The sole Aim :

- To make data analysis to reply to questions of study :

Is there a spatial relation between (anthropogenic and natural factors) and cracks , land subsidence that threaten the Islamic monuments ?

If the answer is yes ..we have to provide the decision maker with recommendations to protect our monuments .


Introduction

2)Introduction

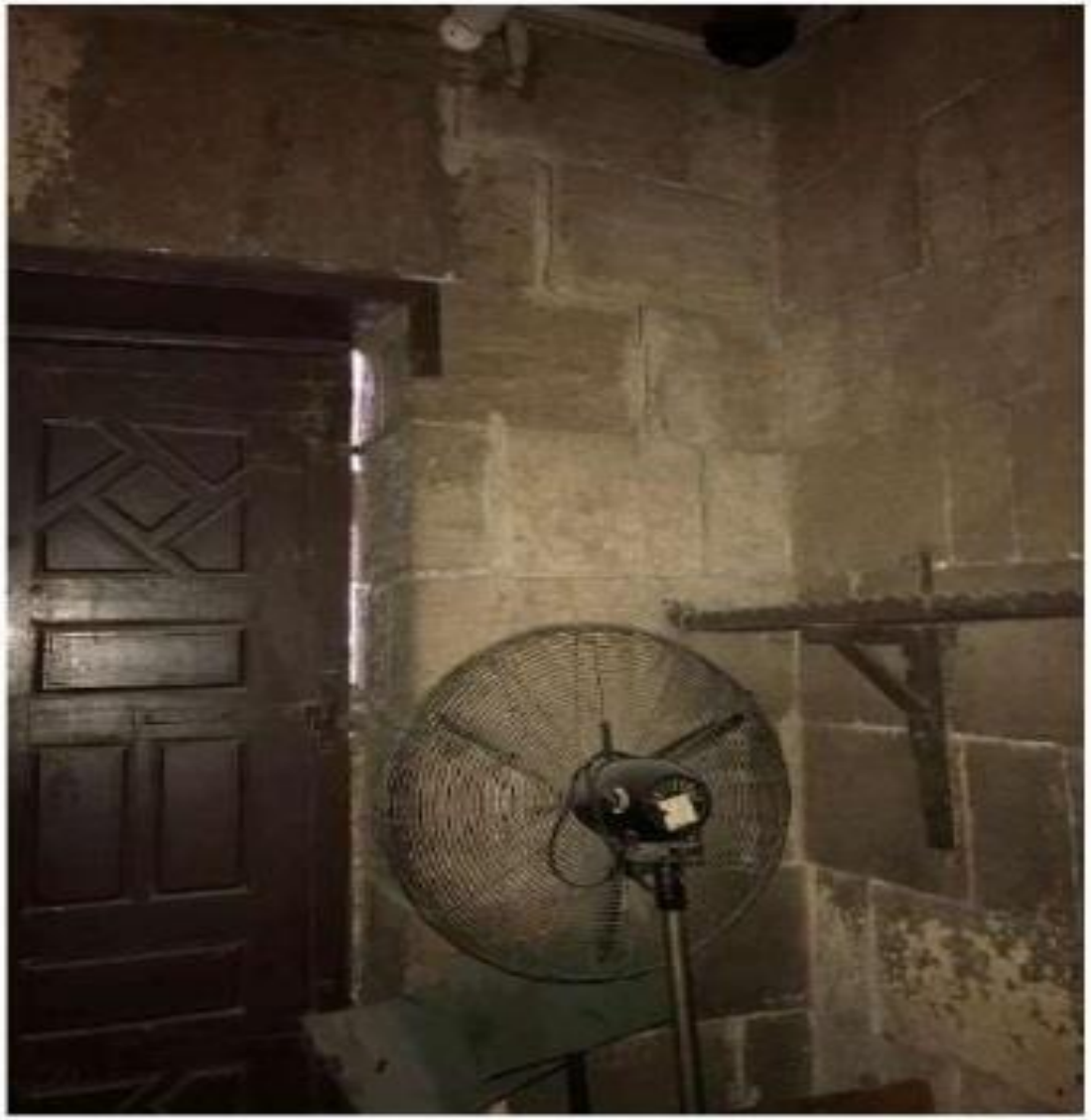
- According to Unesco : The historic old Cairo contain about 600 monuments either Islamic , Christian or Greek-Roman

-It is found that monuments in old Cairo suffer from cracks , damage and subsidence

Fig. 3 the effects of the subsidence phenomena on the groundwater level (After, Galloway et al., 1998).

(a)

(b)



(c)

(d)

(e)

Fig. 4 archaeological buildings deteriorations as results of high elevations of groundwater and land subsidence phenomena in (a) ElSaleh negmeldin Dome, (b) ElNaseh Mohamed Ibn Qlaun Mosque, (c) Zoelfakar bek mosque, (d) Sidi Temraz Elahmadi mausoleum, (e) Qanibay ElRammah Mosque

- So we have to answer the questions ..

- What are causes of these cracks and damage ?
- How to treat that in future …?


Data


METHODS

3)Data and Methods

Really we carried out eight tasks :

1)Digitizing of satellite images on area of interest at dates 1965 , 2004 , 2015

2)Change detection of urban sprawl from 1965 to 2004 and from 2004 to 2015

3)hot spot analysis of urban area at 1965 , 2004 , 2015

4)Land surface temperature LST or urban heat islands at 2004 , 2015

5)land subsidence of area of interest by radar data

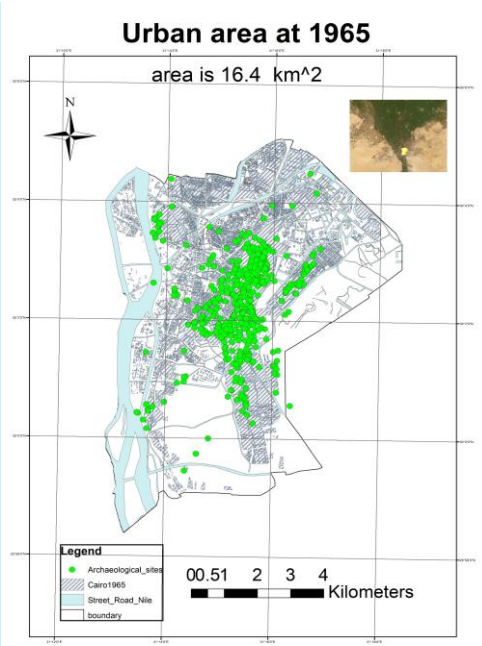
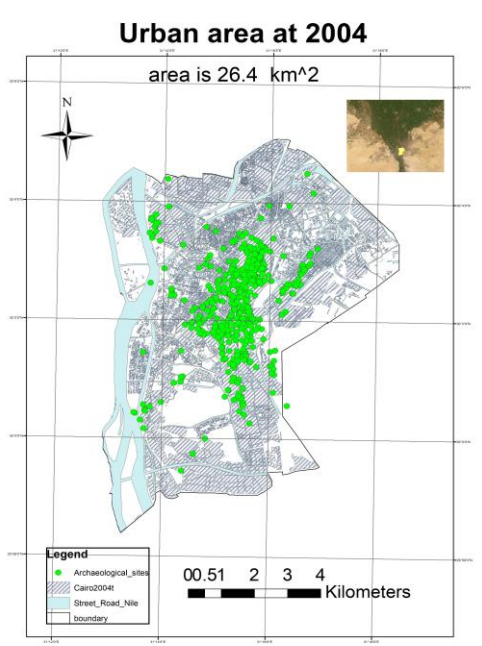
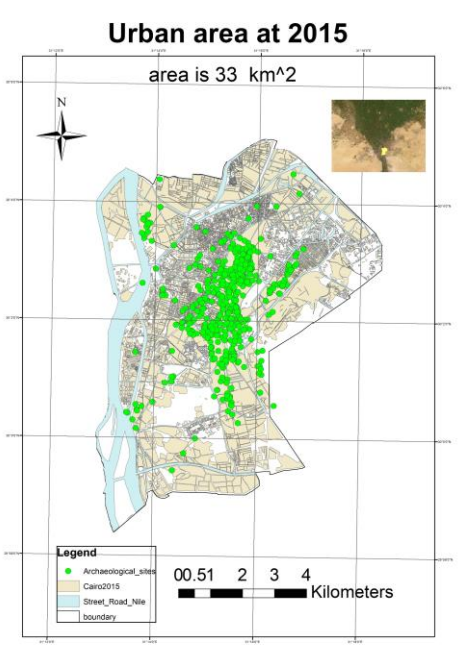
6)determination of flooding of heavy rains at area of interest

7)determination of valleys and sub valleys at area of interest

8)determination of underground water at points in area of interest.

Task 1 :Digitizing of satellite images on area of interest at dates 1965 , 2004 , 2015

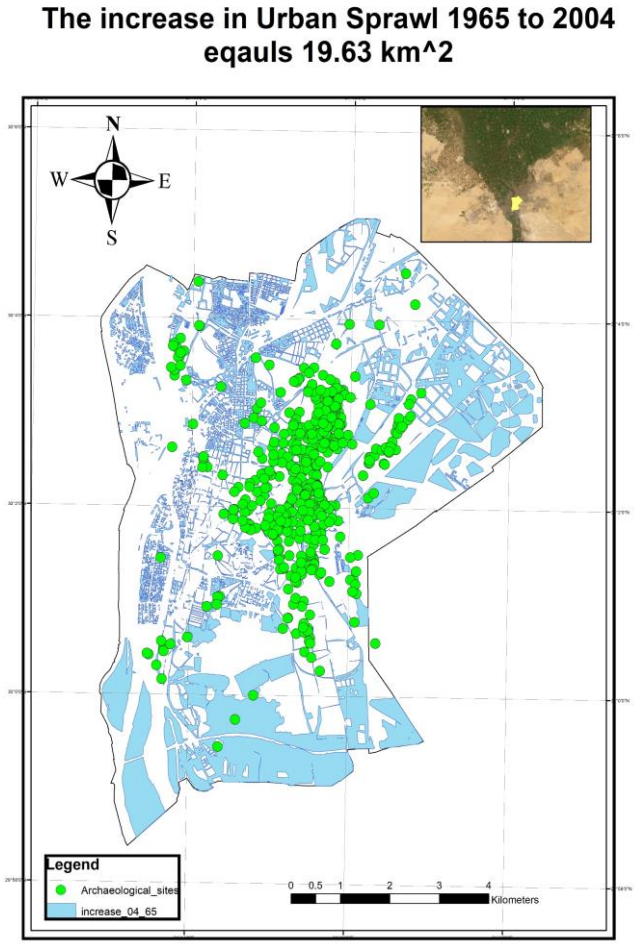
Data :

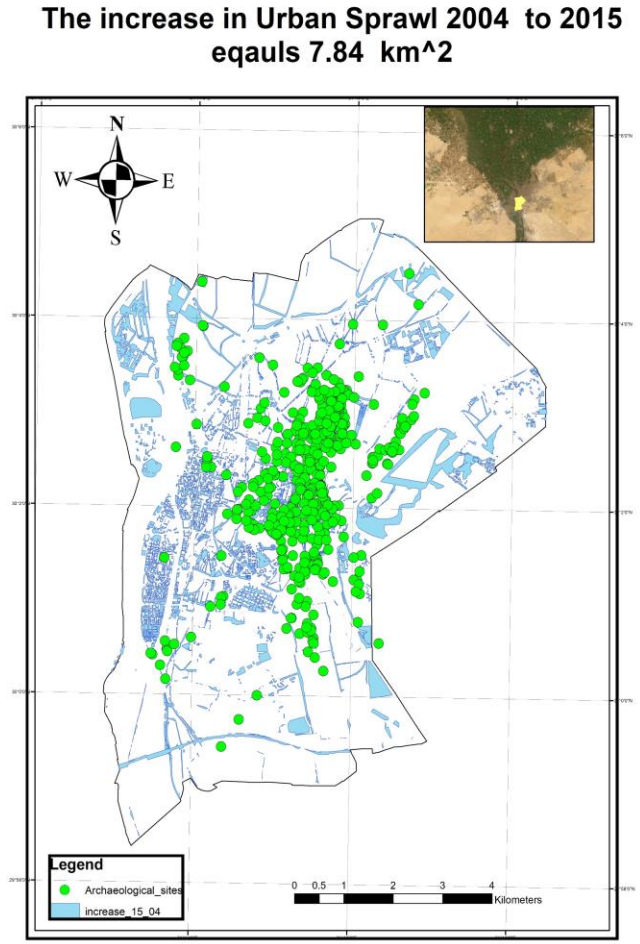
Corona satellite 1965	Orbview satellite 2004	Google earth 2015
		

Methods : editing tools in ArcGIS software

2) Task 2 : Change detection of urban sprawl from 1965 to 2004 and from 2004 to 2015

- **Data : out put of task 1**

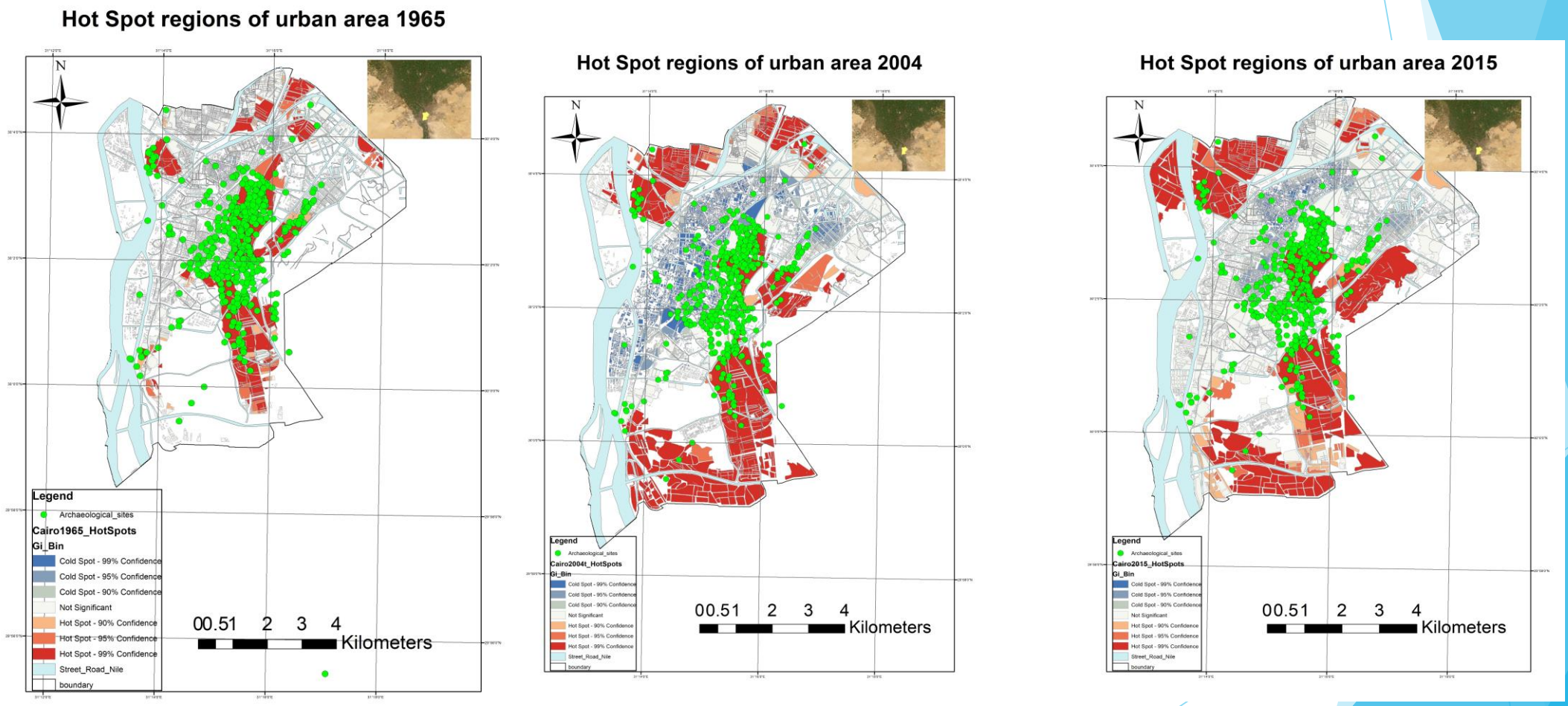




- **Method : erase tool to detect changes in vector layers in ArcGIS**

3) Task 3 : hot spot analysis of urban area at 1965 , 2004 , 2015

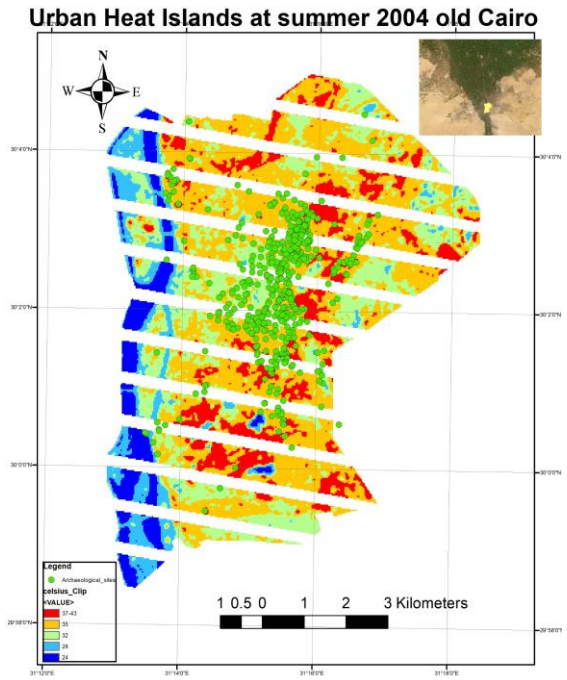
- Data : out put of task 1

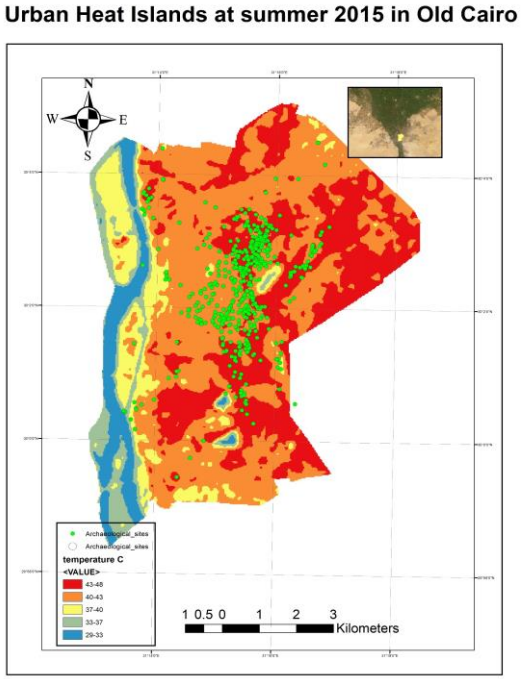


- Methods : Hot spot analysis tool in ArcGIS

4)Task 4 : Land surface temperature LST or urban heat islands at 2004 , 2015

Data : Landsat 7 satellite image at 17-7-2004 , Landsat 8 satellite image at 24-7-2015



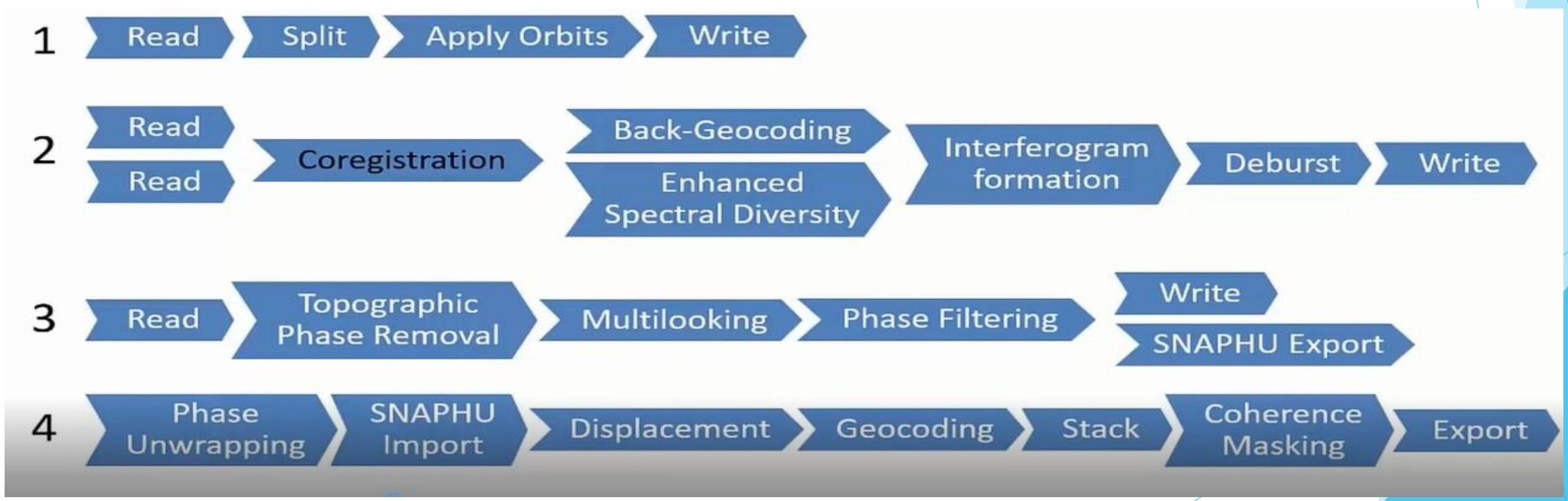


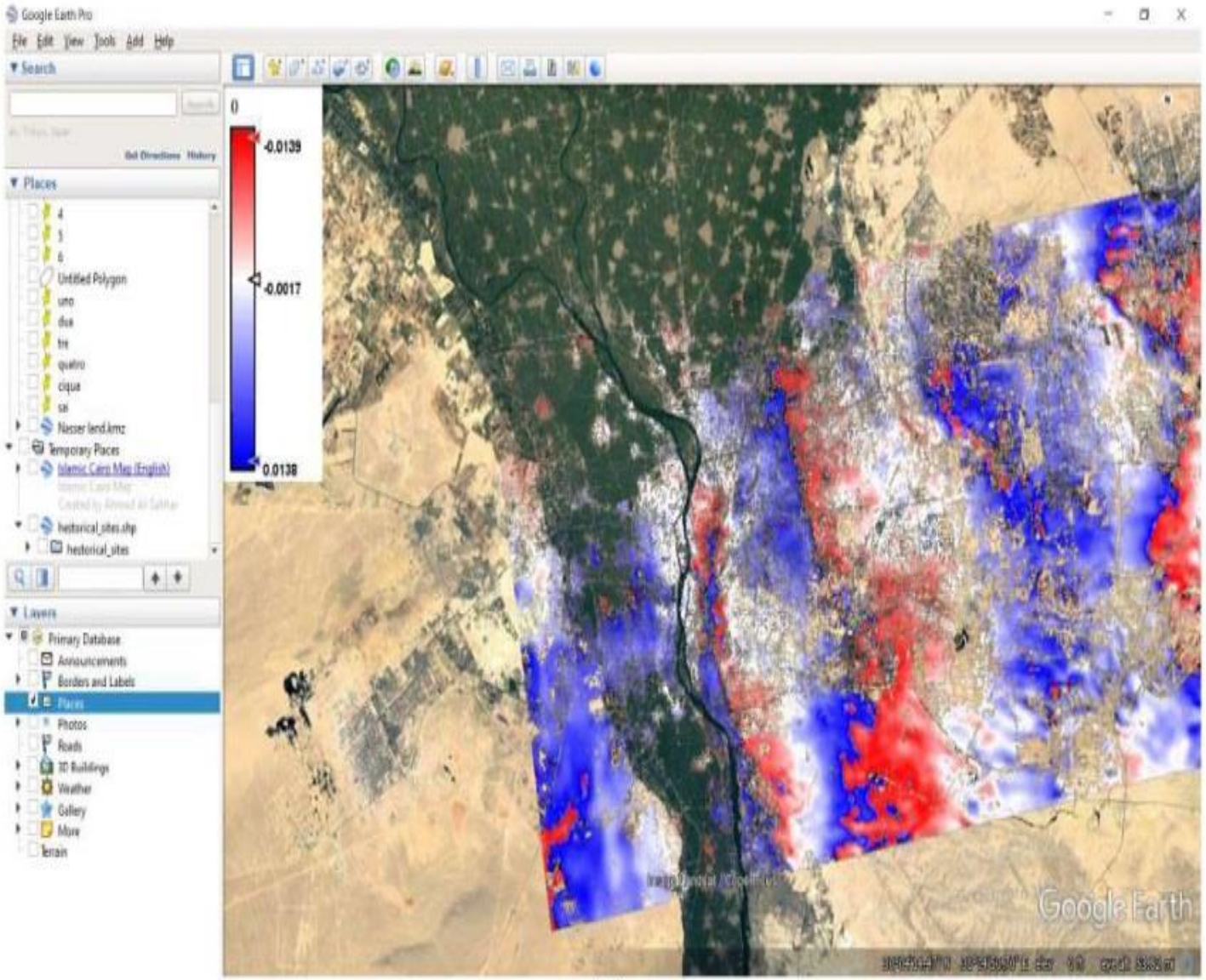
Methods : integration between Envi & ArcGIS

5) Task 5 : land subsidence of area of interest by radar data

Data : Two Radar Images of Sentinel-1 at 7-2017 and 12-2017

Mefhods : Preprocessing & Processing on SNAP software

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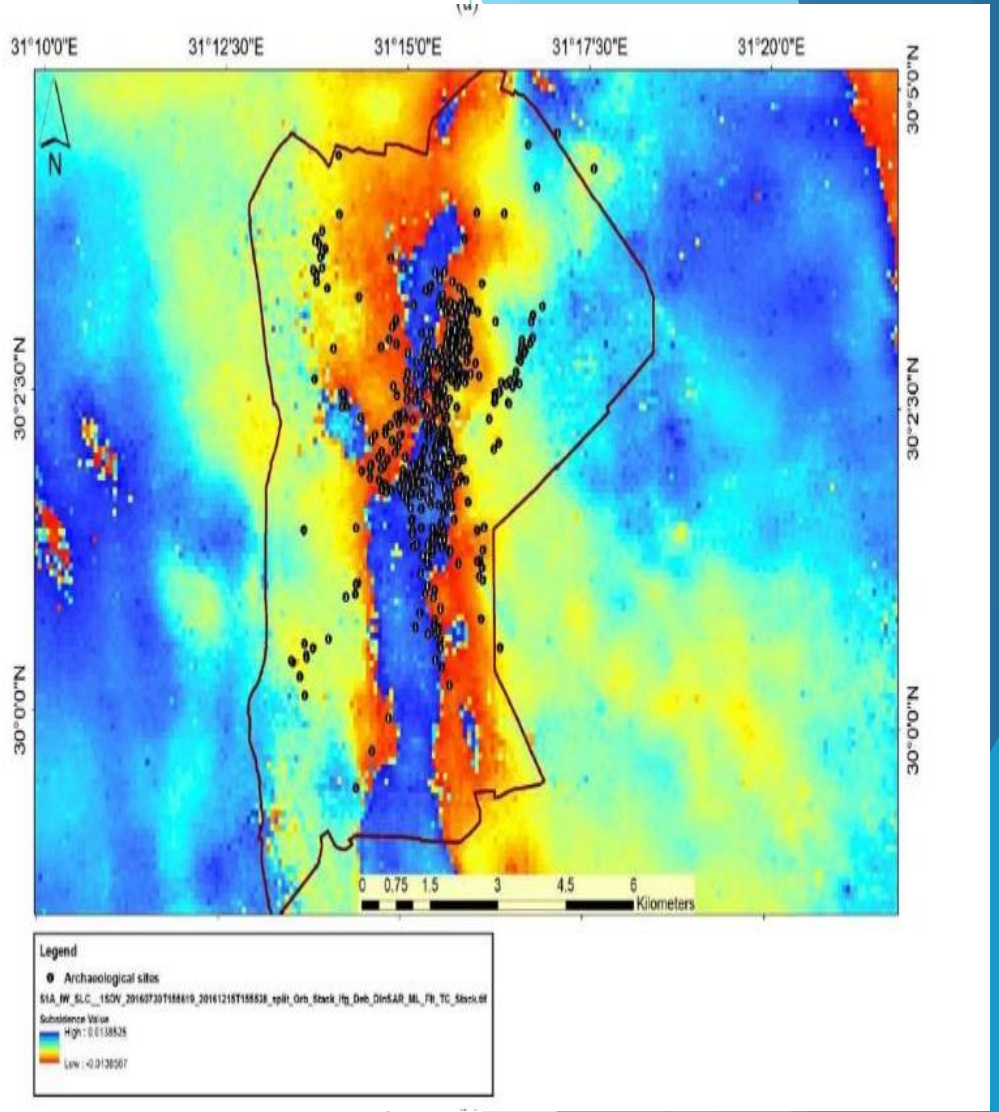
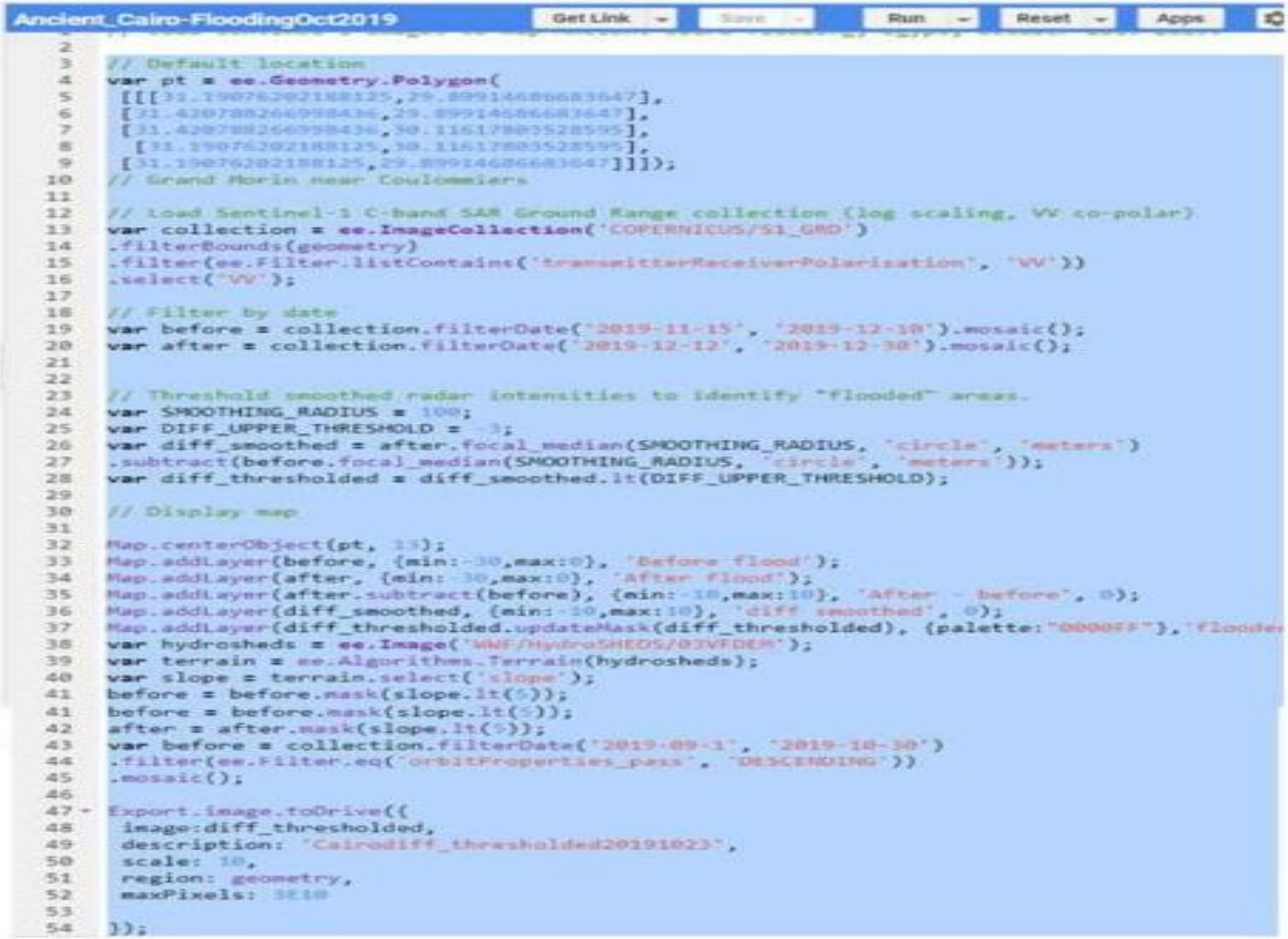
(a)


31°10'0"E
31°12'30"E
31°15'0"E
31°17'30"E
31°20'0"E
30°5'0"N
30°2'30"N
30°0'0"N
N
0 0.75 1.5 3 4.5 6
Kilometers
Legend
Archaeological sites

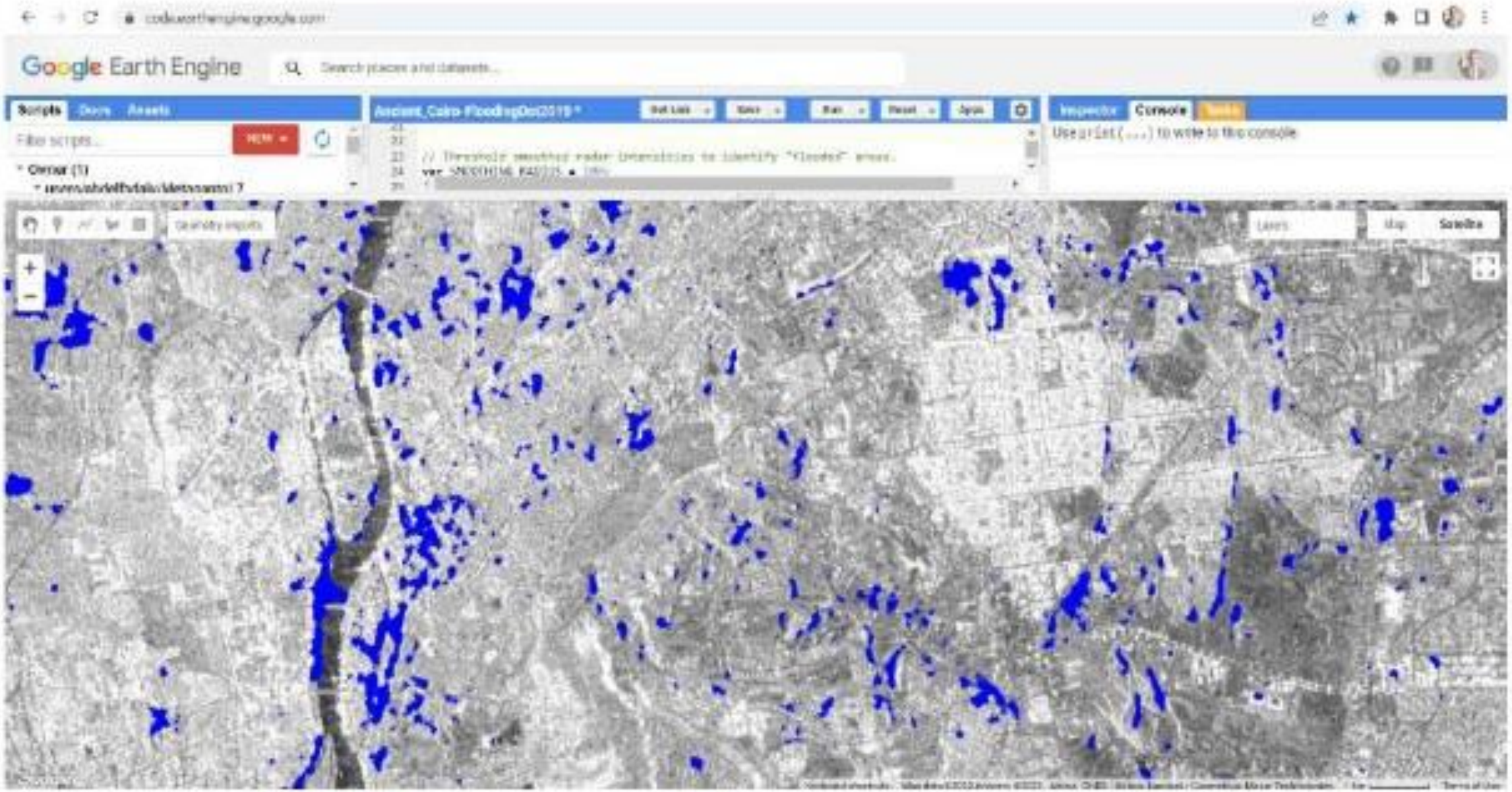
6)Task 6 : determination of flooding of heavy rains at area of interest

Data :
Radar image :Sentinel 1 data of flood occurred at 10 -2019

Methods :
Application of cloud computing and analysis on google earth engine by Scripting the following code by Java Script Language :




```
// Default location
var pt = ee.Geometry.Polygon(
 [[[31.190762021888125,29.899146866833647],
 [31.420788266998436,29.899146866833647],
 [31.420788266998436,30.116178035285595],
  [31.190762021888125,30.116178035285595],
 [31.190762021888125,29.899146866833647]]]);
// Grand Morin near Coulommiers

// Load Sentinel-1 C-band SAR Ground Range collection (log scaling, VV co-polar)
var collection = ee.ImageCollection('COPERNICUS/S1_GRD')
.filterBounds(geometry)
.filter(ee.Filter.listContains('transmitterReceiverPolarisation', 'VV'))
.select('VV');

// Filter by date
var before = collection.filterDate('2019-11-15', '2019-12-10').mosaic();
var after = collection.filterDate('2019-12-12', '2019-12-30').mosaic();


// Threshold smoothed radar intensities to identify "flooded" areas.
var SMOOTHING_RADIUS = 100;
var DIFF_UPPER_THRESHOLD = -3;
var diff_smoothed = after.focal_median(SMOOTHING_RADIUS, 'circle', 'meters')
.subtract(before.focal_median(SMOOTHING_RADIUS, 'circle', 'meters'));
var diff_thresholded = diff_smoothed.lt(DIFF_UPPER_THRESHOLD);

// Display map

Map.centerObject(pt, 13);
Map.addLayer(before, {min:-30,max:0}, 'Before flood');
Map.addLayer(after, {min: -30,max:0}, 'After flood');
Map.addLayer(after.subtract(before), {min:-10,max:10}, 'After - before', 0);
Map.addLayer(diff_smoothed, {min: -10,max:10}, 'diff smoothed', 0);
Map.addLayer(diff_thresholded.updateMask(diff_thresholded), {palette:"0000FF"},'flooded
var hydrosheds = ee.Image('WWF/HydroSHEDS/03VFDEM');
var terrain = ee.Algorithms.Terrain(hydrosheds);
var slope = terrain.select('slope');
before = before.mask(slope.lt(5));
before = before.mask(slope.lt(5));
after = after.mask(slope.lt(5));
var before = collection.filterDate('2019-09-1', '2019-10-30')
.filter(ee.Filter.eq('orbitProperties_pass', 'DESCENDING'))
.mosaic();

Export.image.toDrive({
 image:diff_thresholded,
 description: 'Cairodiff_thresholded20191023',
 scale: 10,
 region: geometry,
 maxPixels: 3E10

});
```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Scripts
Docs
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Console
Use print(...) to write to this console
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Map
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(a)

7)Task 7 : determination of valleys and sub valleys at area of interest

Data :
DEM image from SRTM data at 2014

Methods:
SWAT analysis

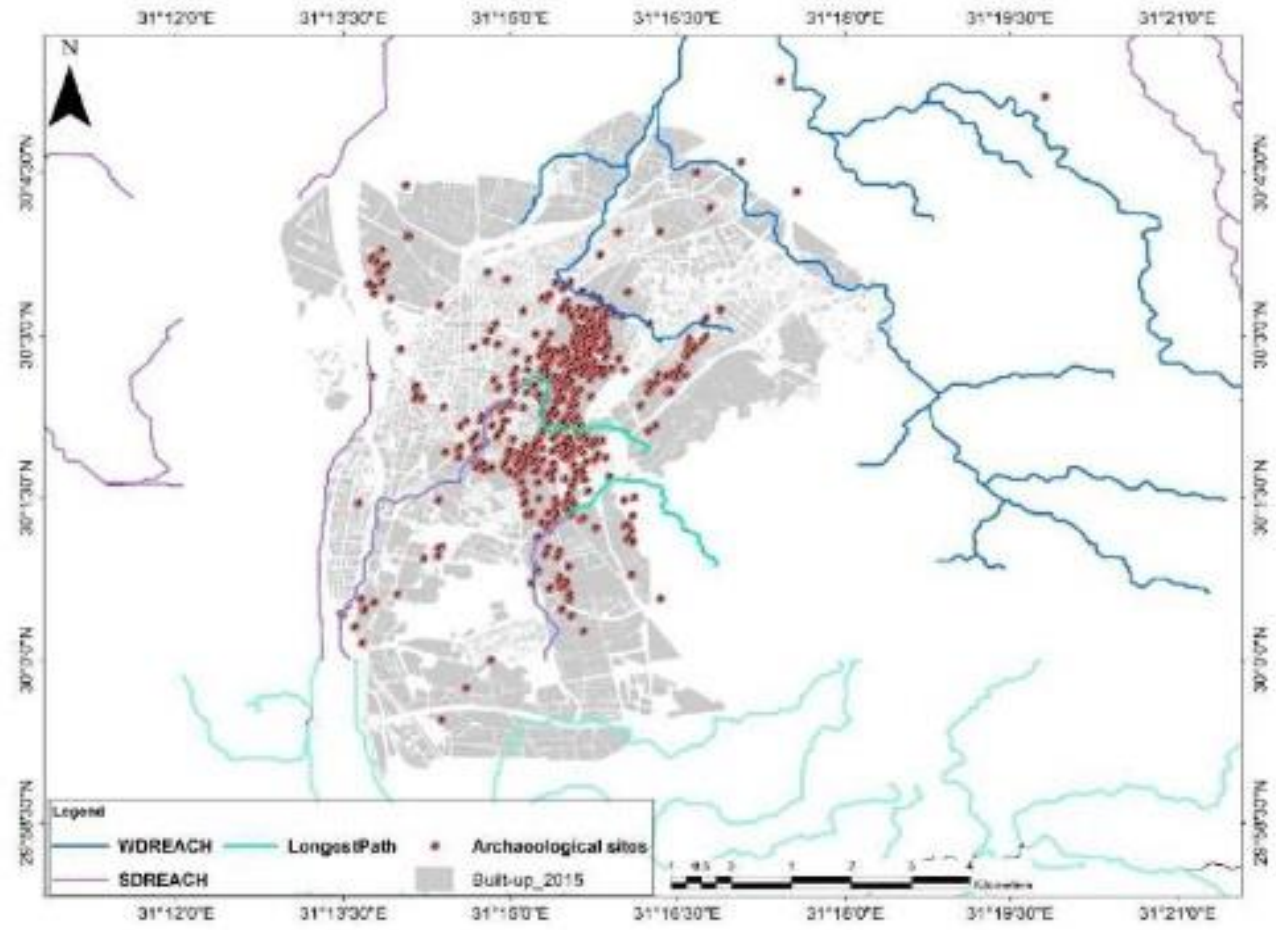


Fig. 14 the wadies net of the study area obtained from the SRTM radar data

8)Task 8 : determination of underground water at points in area of interest (Geophysics)

Data :
in site experimental measurement of underground water in two areas

Methods :
By Syscal Pro instrument .


RESULTS

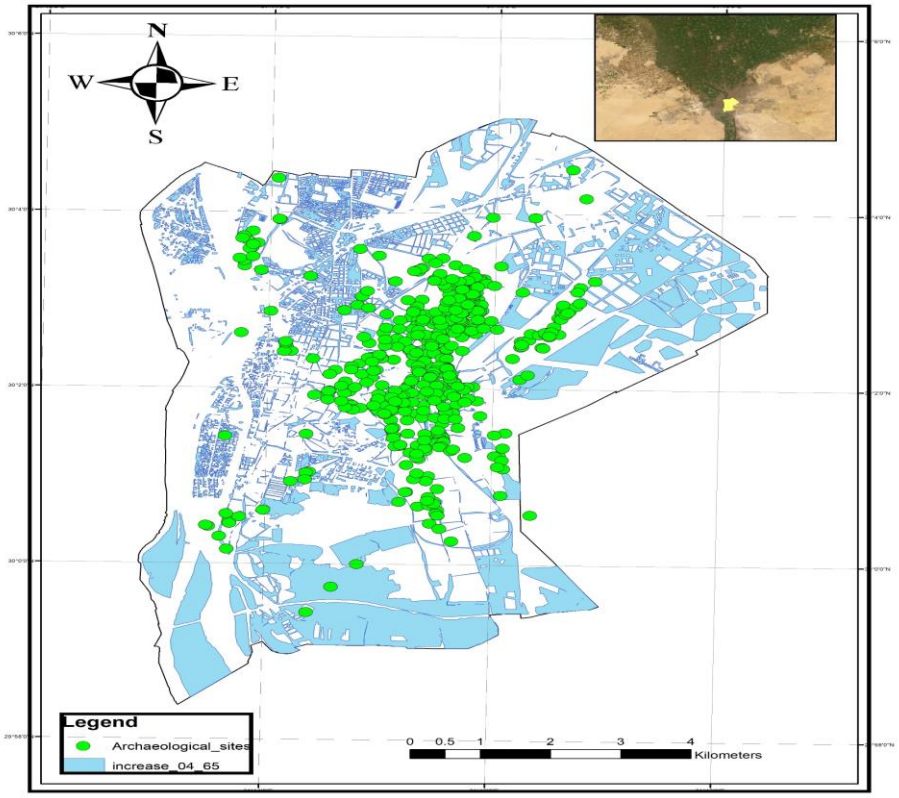

DISCUSSION

Task 1&2 : Change detection of urban sprawl from 1965 to 2004 and from 2004 to 2015

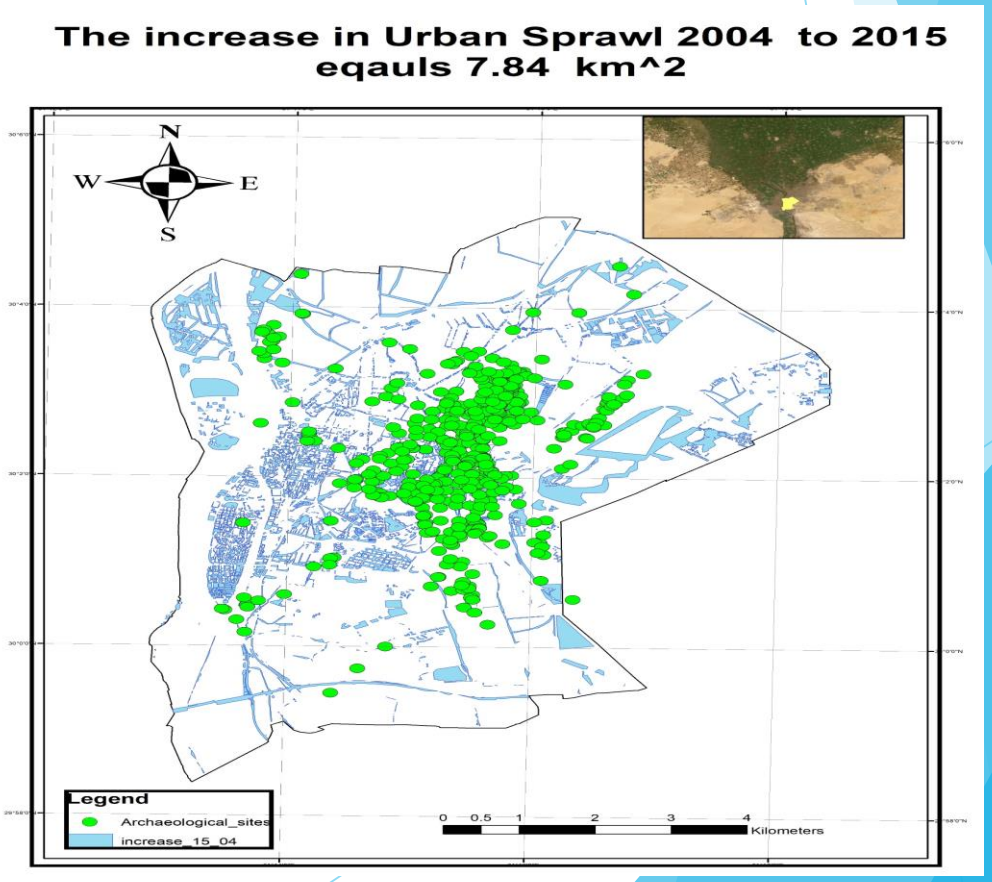
-Results : increase in urban sprawl 1965 to 2004 : 19.6 km^2

increase in urban sprawl 2004 to 2015 : 7.84 km^2

The increase in Urban Sprawl 1965 to 2004 eqauls 19.63 km^2



The increase in Urban Sprawl 2004 to 2015 eqauls 7.84 km^2



- Discussion :
- Increase in urban sprawl 2004 to 2015 > 1965 to 2004

Because in 39 years the increase was 19.6 km^

So the rate is 19.6/ 39 = approximately 0.5 km^ per year

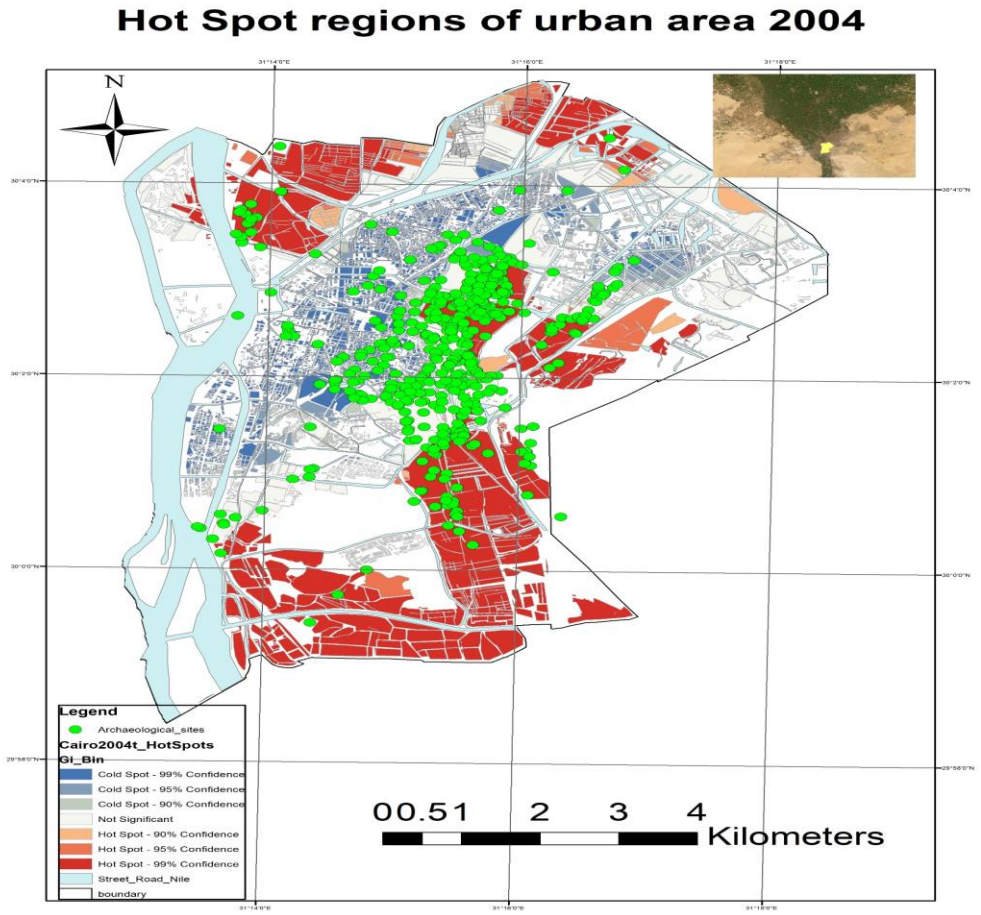
While in 9 years the increase was 7.84 km^2

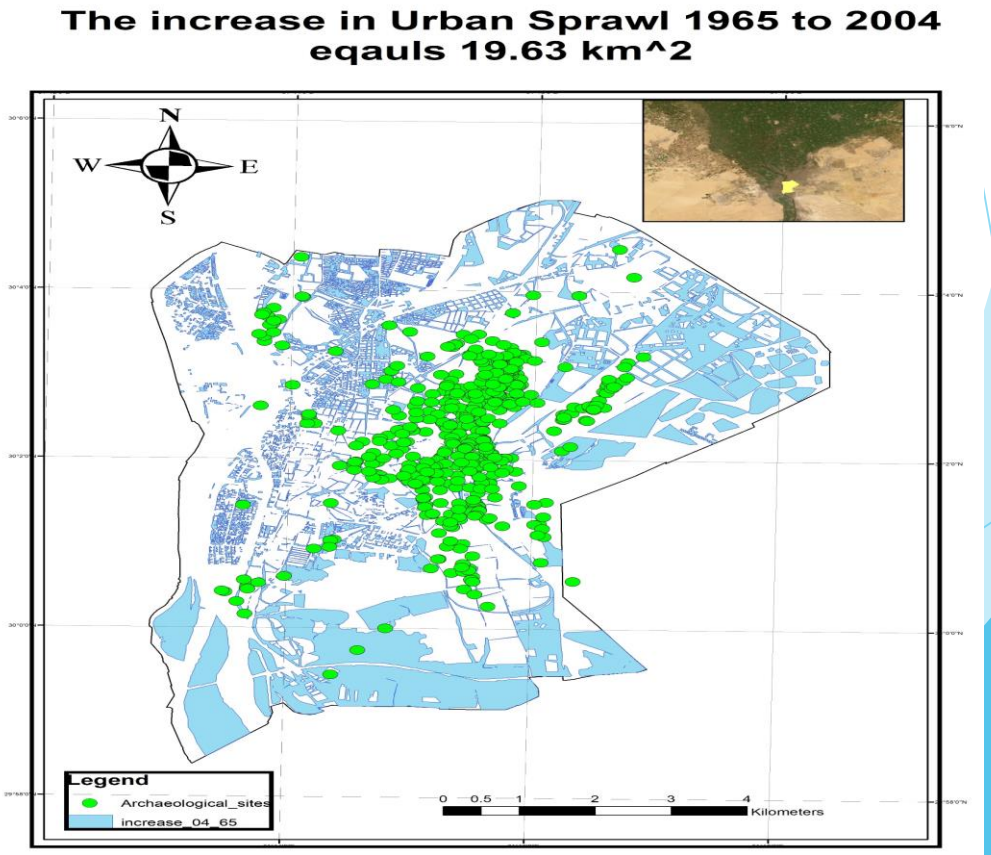
So the rate 7.84/9 = approximately 0.9 km^2

Which indicates the increasing unplanned urban sprawl.

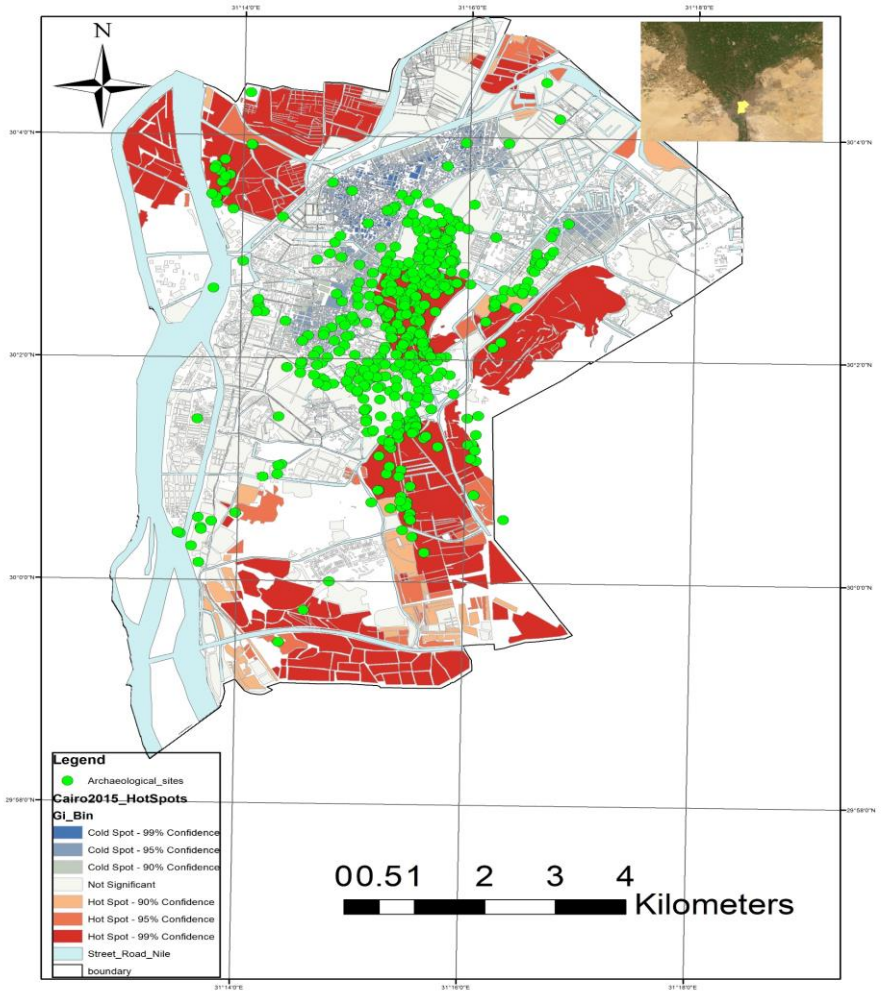
3) Task 3 : hot spot analysis of urban area at 1965 , 2004 , 2015

Results :there is spatial relation between areas with hot spot and increased urban sprawl areas

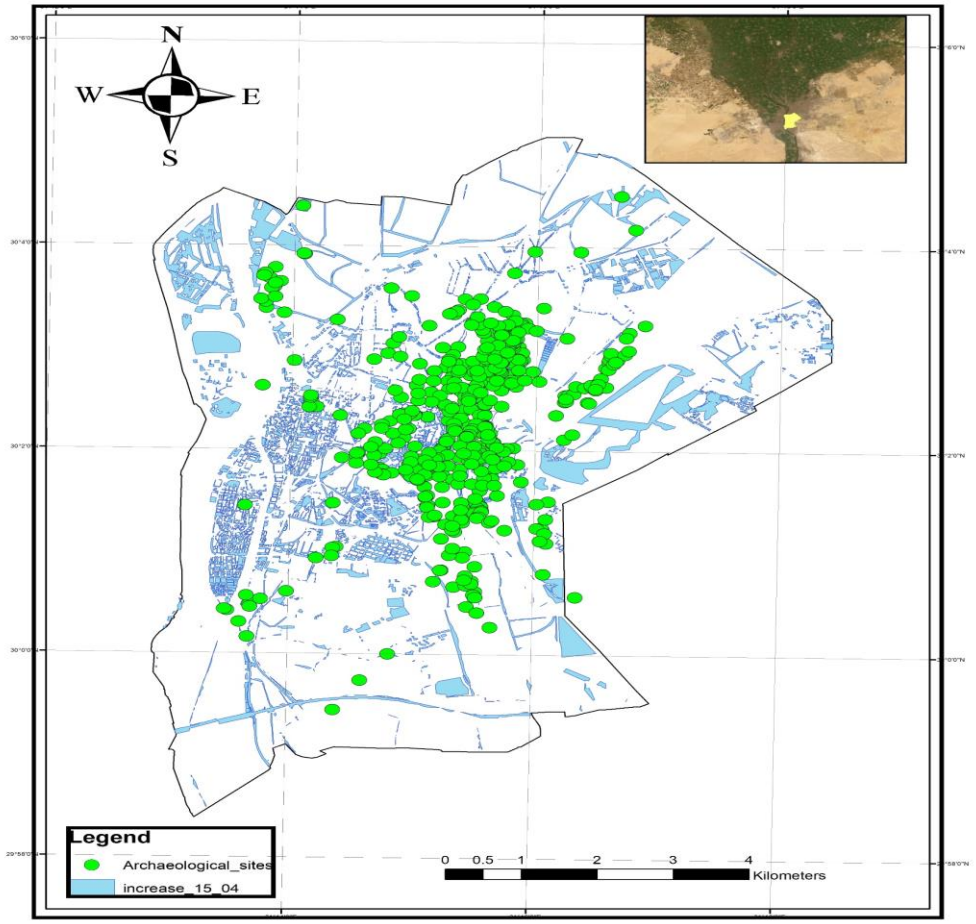




Hot Spot regions of urban area 2015



The increase in Urban Sprawl 2004 to 2015 eqauls 7.84 km^2



- Discussion :

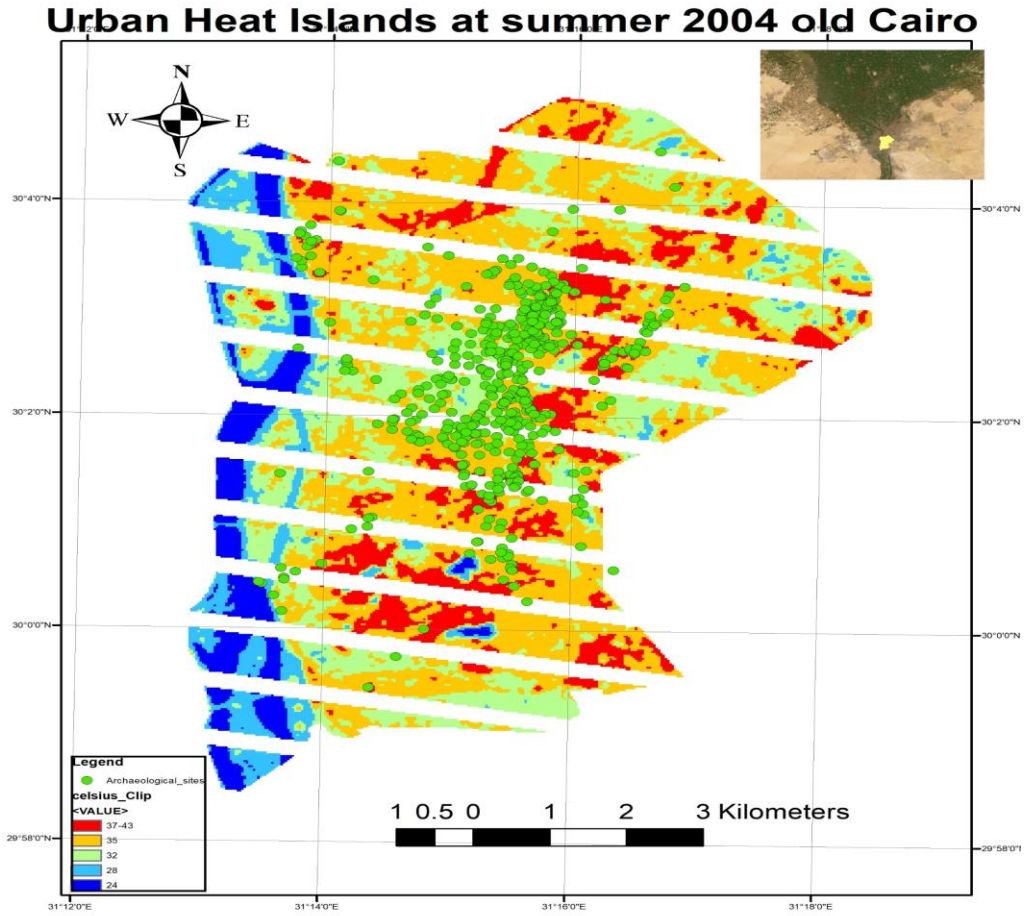
1) This indicate that the increased urban sprawl was condensed , random and unplanned .

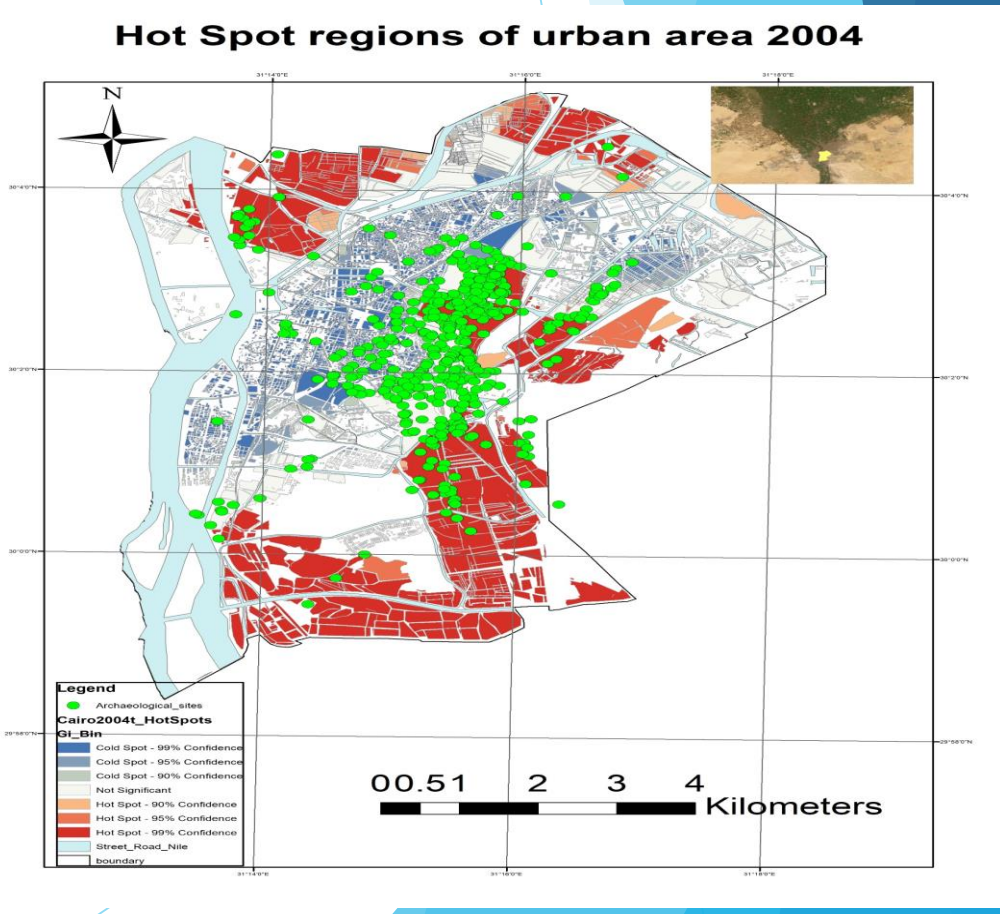
2)There will be spatial relation between these hot spot areas and urban heat islands …and all of these will lead to land subsidence as we will see

.

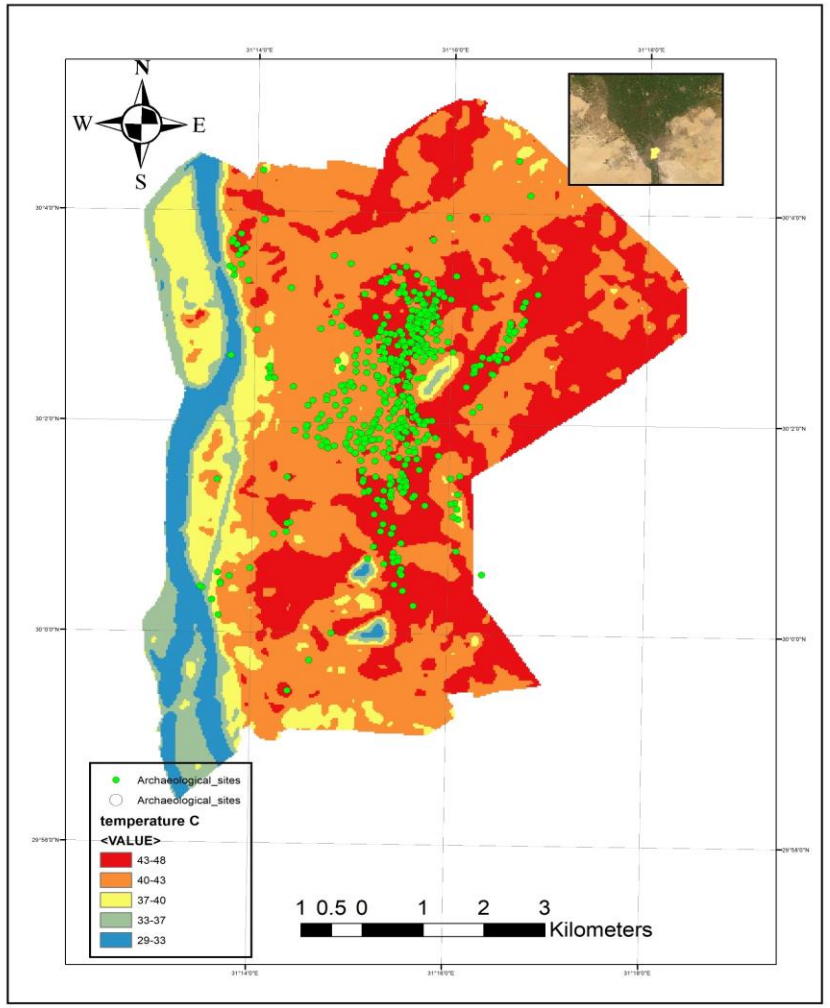
4)Task 4 : Land surface temperature LST or urban heat islands at 2004 , 2015

- Results : there is a spatial relation between LST or urban heat islands and hot spot areas and increased urban sprawl

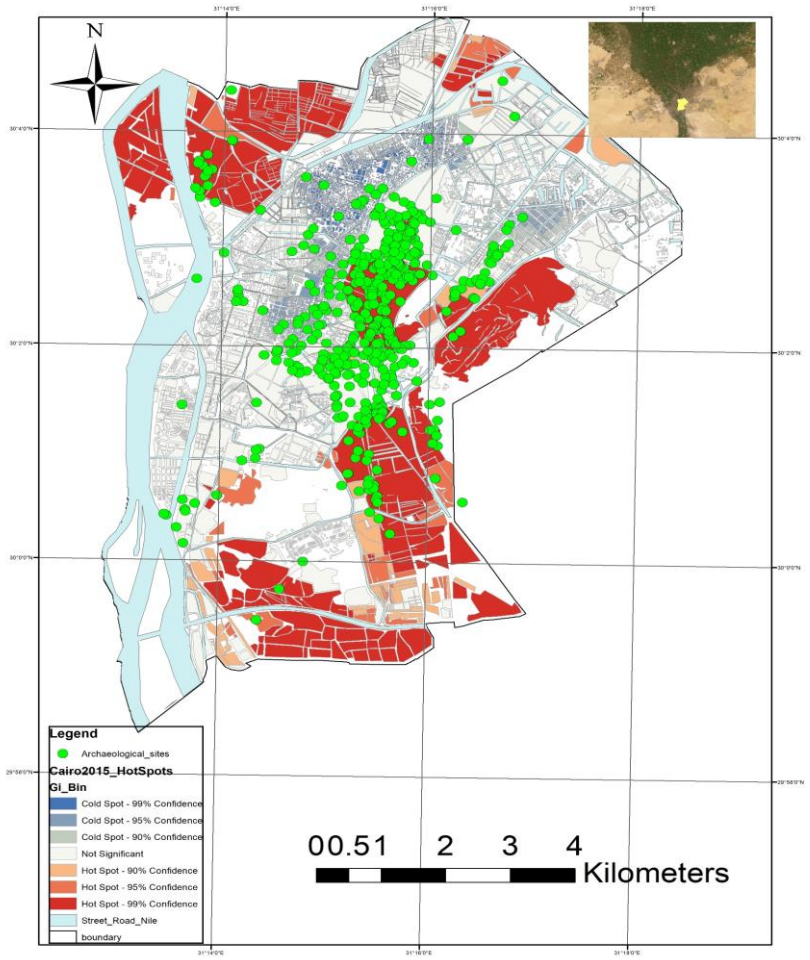




Urban Heat Islands at summer 2015 in Old Cairo



Hot Spot regions of urban area 2015

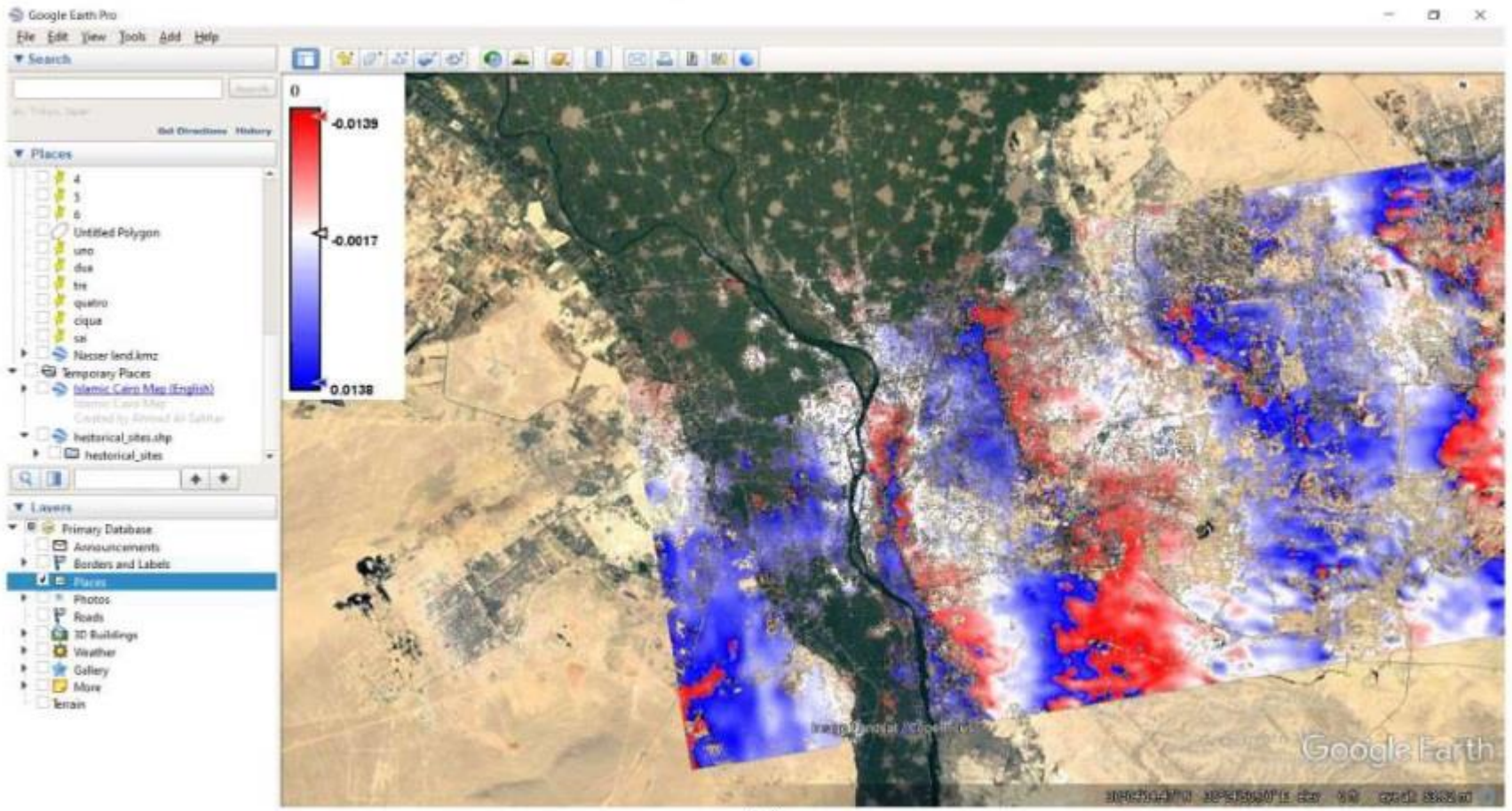


- **Discussion :**

The increased urban sprawl lead to hot spots that lead to urban heat islands which all will have a negative impact on Islamic archeological sites in old Cairo

5) Task 5 : land subsidence of area of interest by radar data

- **Results : there is approximately 1 mm subsidence in period studied (5 months 7/2017 to 12/2017)**

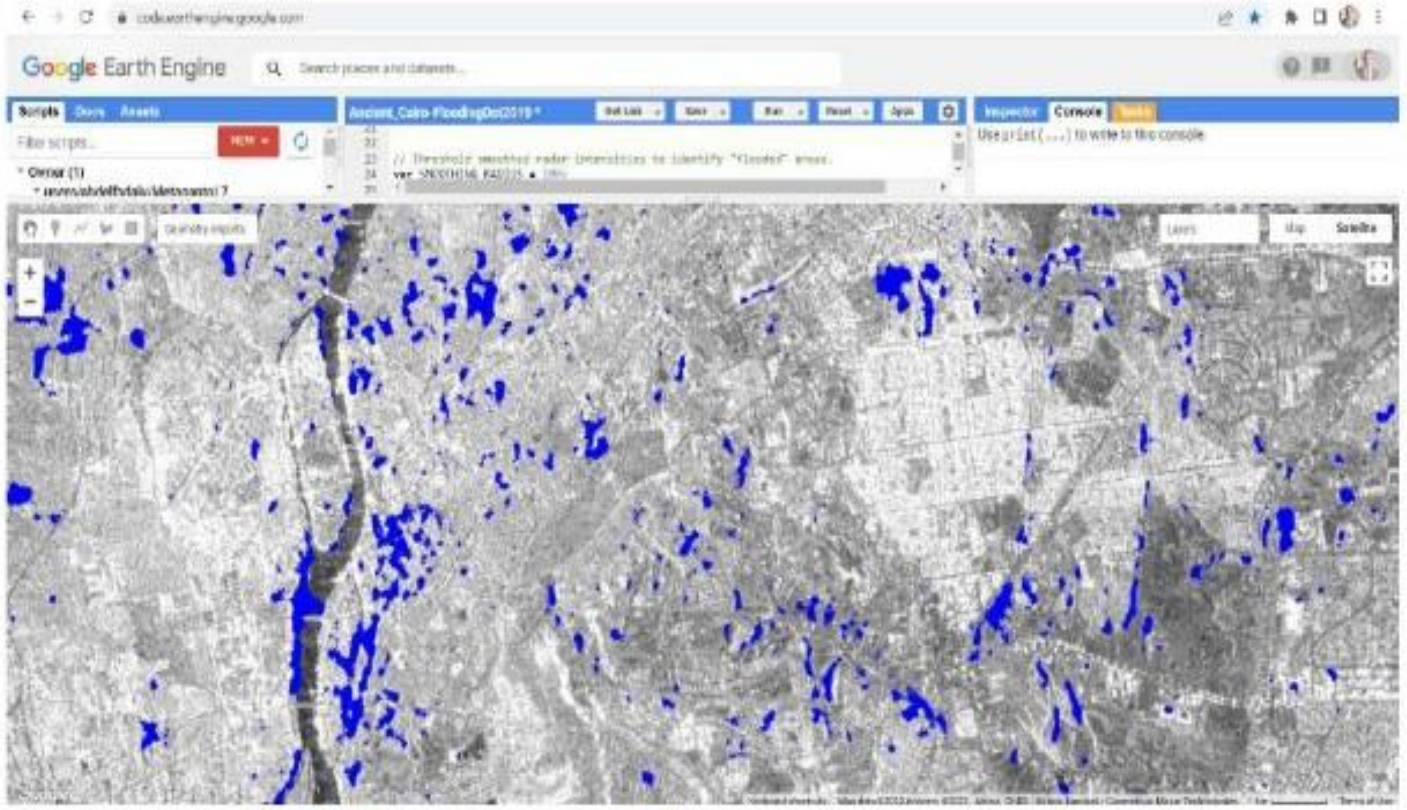


(a)

- Discussion : if we extend this subsidence rate for 1000 years …we find that there is about 3 meters subsidence happened to the Islamic monuments under high risk.

6)Task 6 : determination of flooding of heavy rains at area of interest

Results : we could map the areas of flooding happened in 10/2019



(a)

By merging result of task 6 with result of task 7 : determination of valleys and sub valleys at area of interest

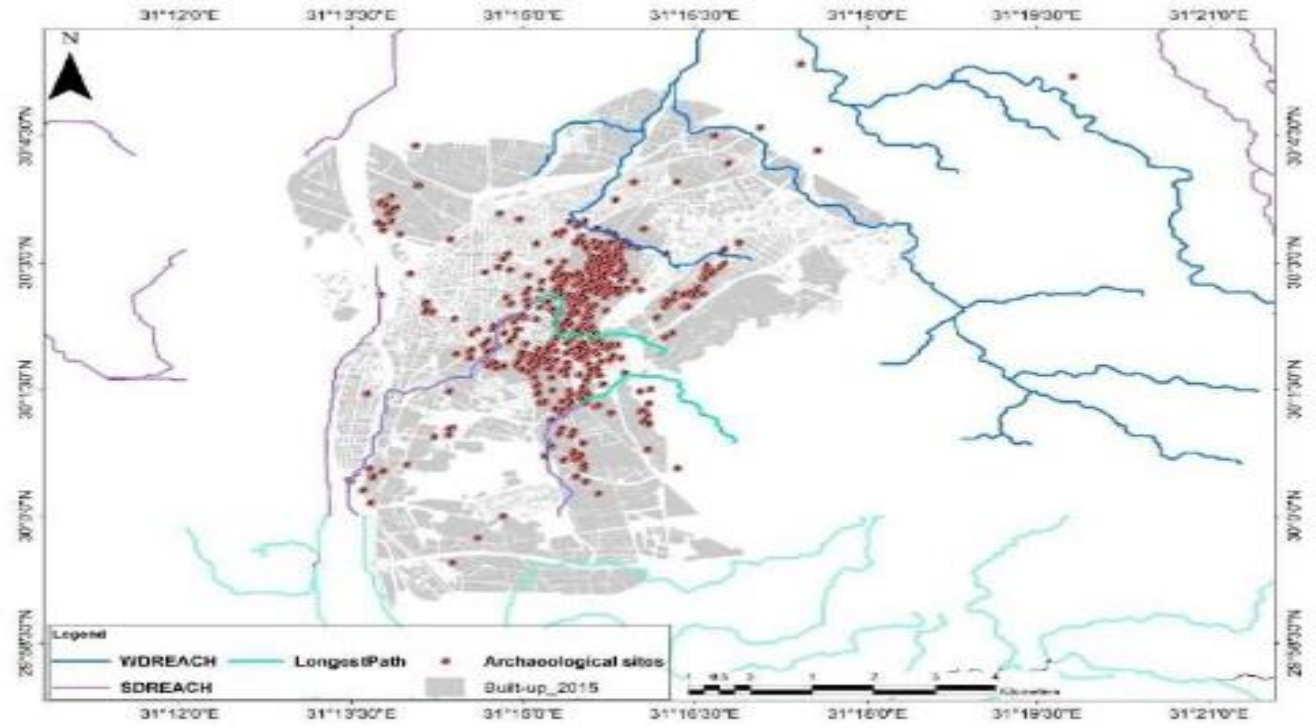


Fig. 14 the wadies net of the study area obtained from the SRTM radar data

We could reach to pathways of floods in our areas of interest

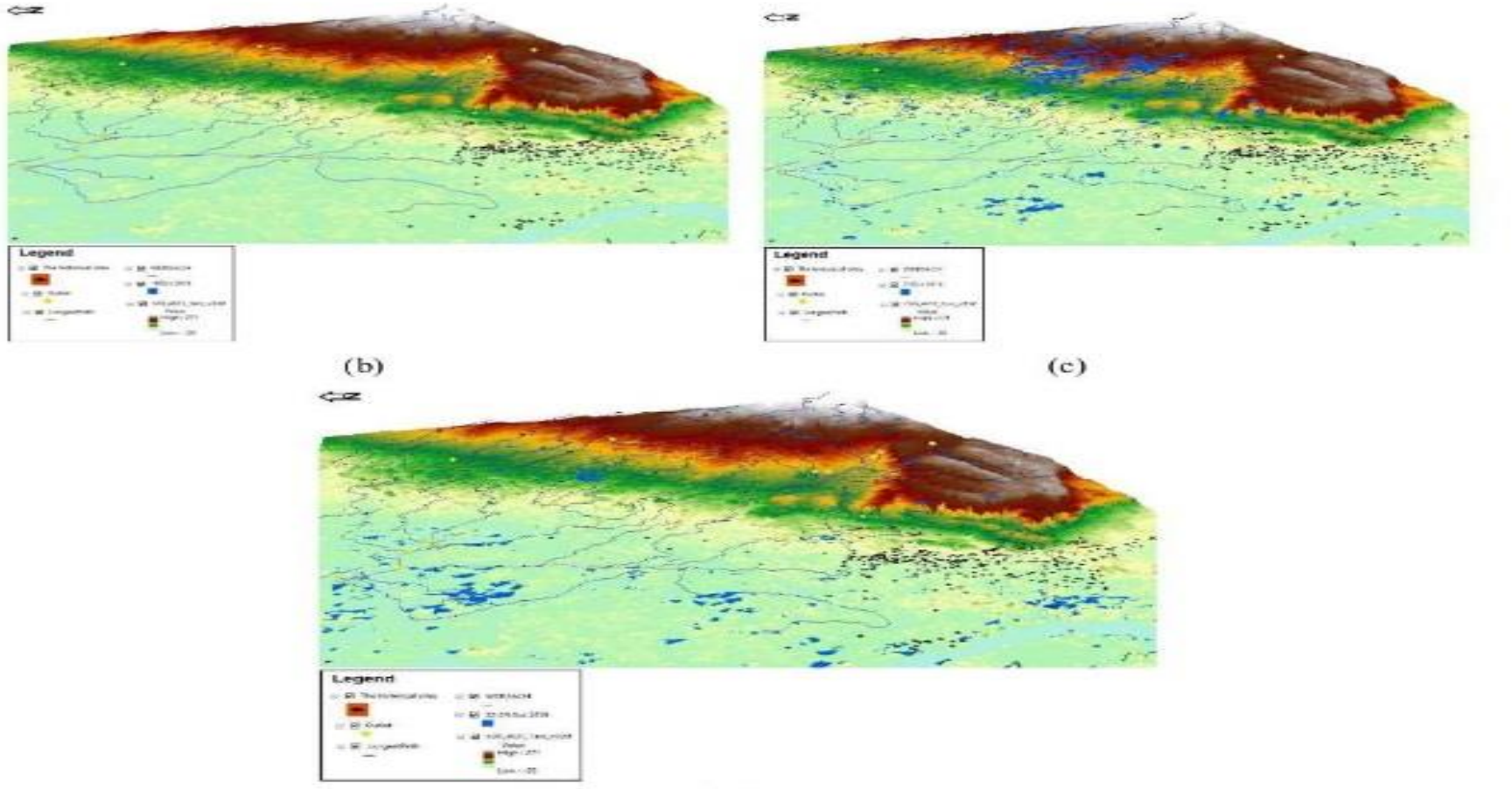


Fig. 15 the flooding events over the study area in Oct2019: (a) the flooding event showed by the GEE, (b) the study area before the heavy rain, (c) the study area during the heavy rain, (d) the study area after the heavy rain events

Discussion : by obtaining the map of pathways of flood

We are able to predict the high risk monuments in case of heavy rains so we can take protective actions as we will see in conclusion.

8)Task 8 : determination of underground water at points in area of interest (Geophysics task)

(a)

(b)

we used Syscal pro instrument to determine ground water at two Islamic archeological sites

1st high risk :El Hakim Mosque

2nd low risk : area close to Citadel Salah el din

The mechanism of action : electric resistivity measurement

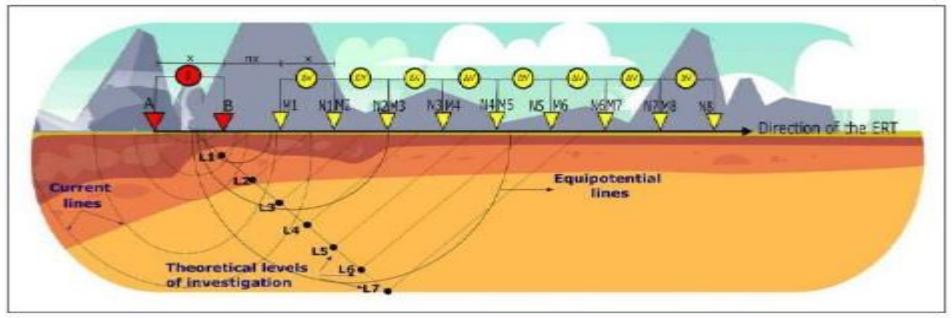


Fig.9 Setup for 2D resistivity measurements: building a pseudo-section. Circles identify the location assignment for the two measurement configurations shown. Each survey level corresponds to different electrode spacing.

Results : there is ground water at depth 6 meter in first site

there is no ground water until depth of 13 meter in second site

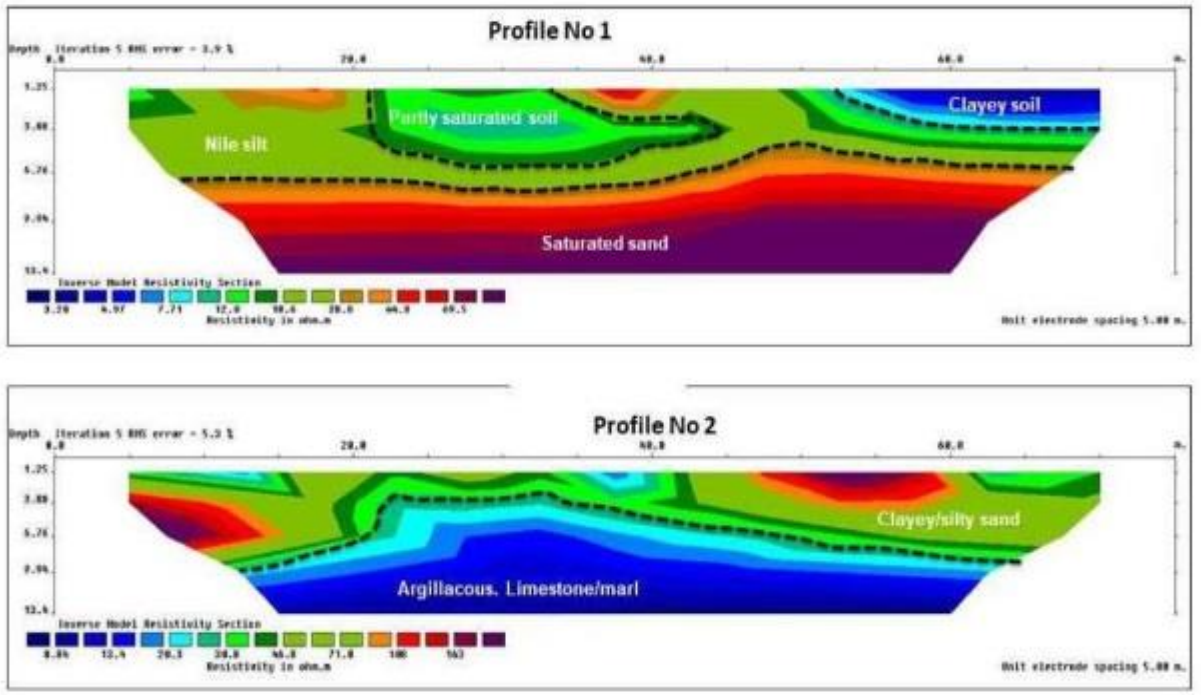
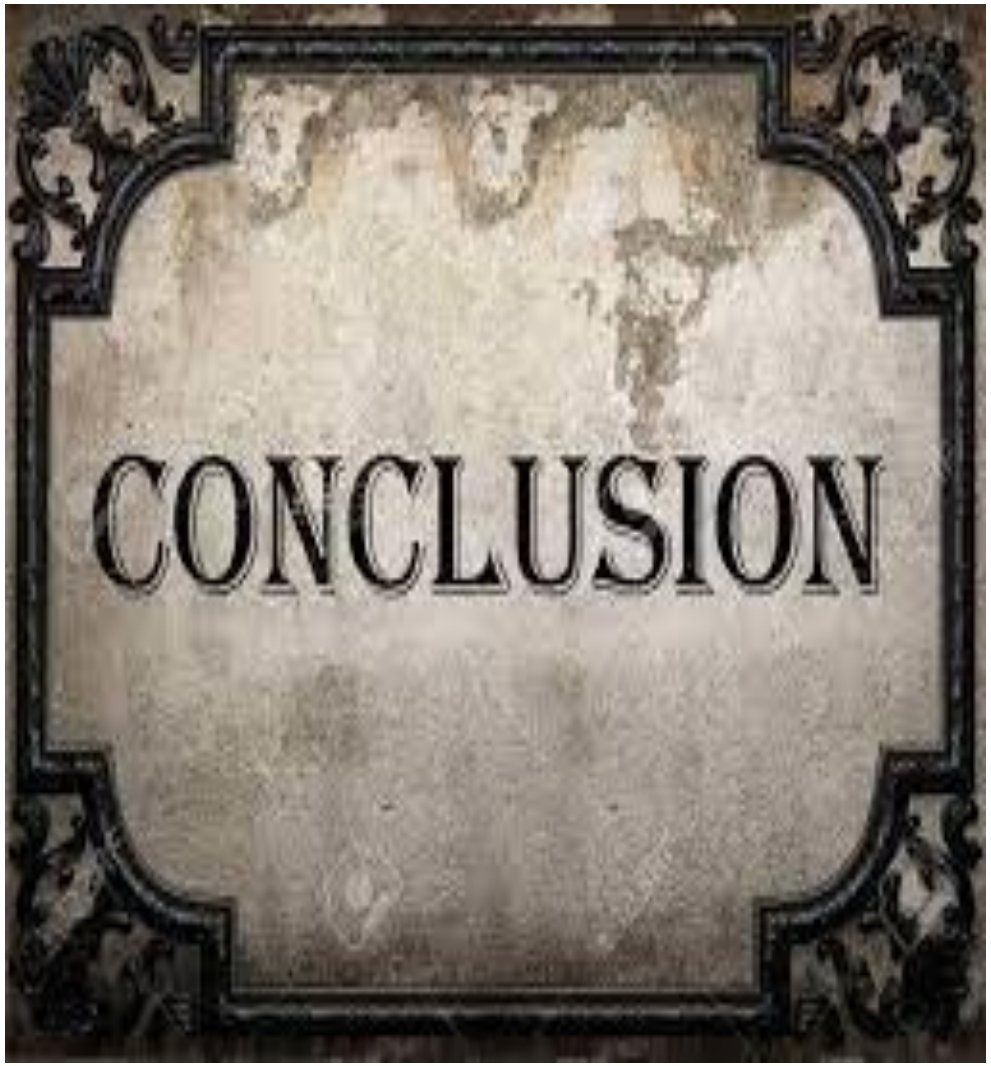


Fig. 17 the 2D interpretation sections of the 2D profiles P1 and P2 obtained from the inversion of Wenner beta data sets: profile no 1 represents the area close El Hakim mosque, profile no 2 represents the area close to Citadel of Salah Eldin

Discussion : practical results match the theoretical expectations

As high risk site 1 : has ground water

Low risk site 2 : has no gound water.


CONCLUSION


Recommendations

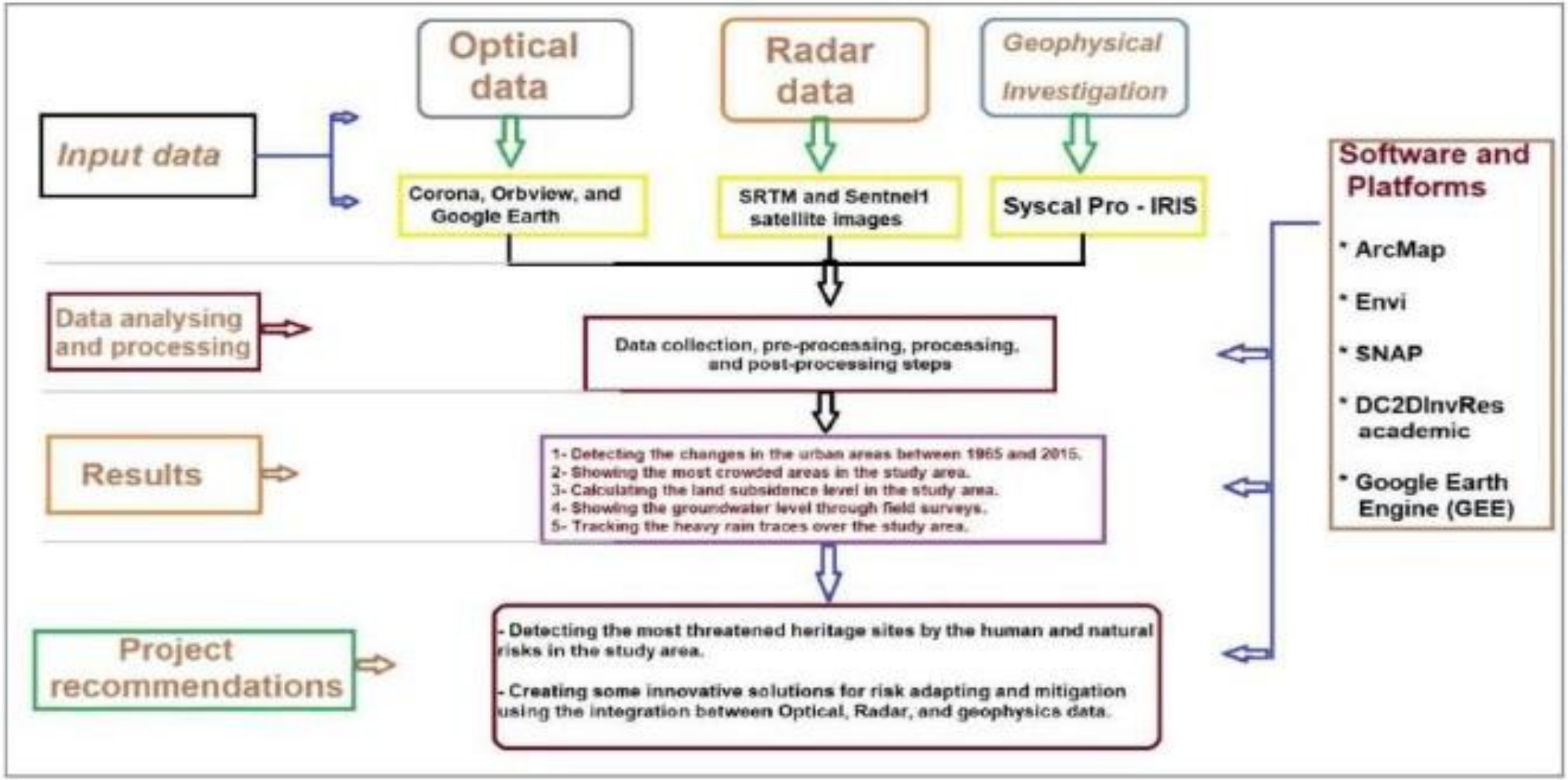


Fig. 11 Flowchart of the study includes the data, methods, results, and recommendations

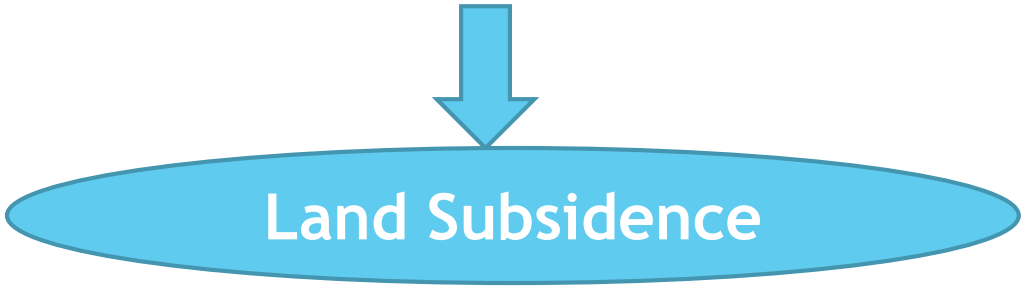
Remote sensing & GIS techniques proved that

there is negative effects and big risk of

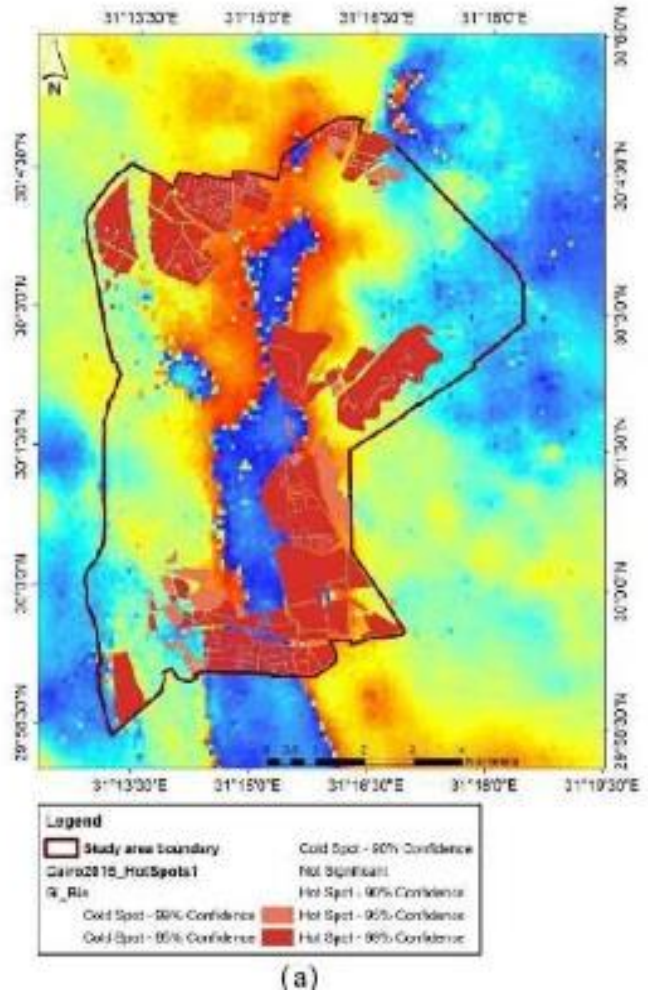
anthropogenic & natural factors

On the Islamic monuments in old Cairo

Anthropogenic factors	Natural factors
1- Urban sprawl 2- Hot spot analysis	1-Urban Heat Islands 2-Flooding of heavy rains 3-Ground Water

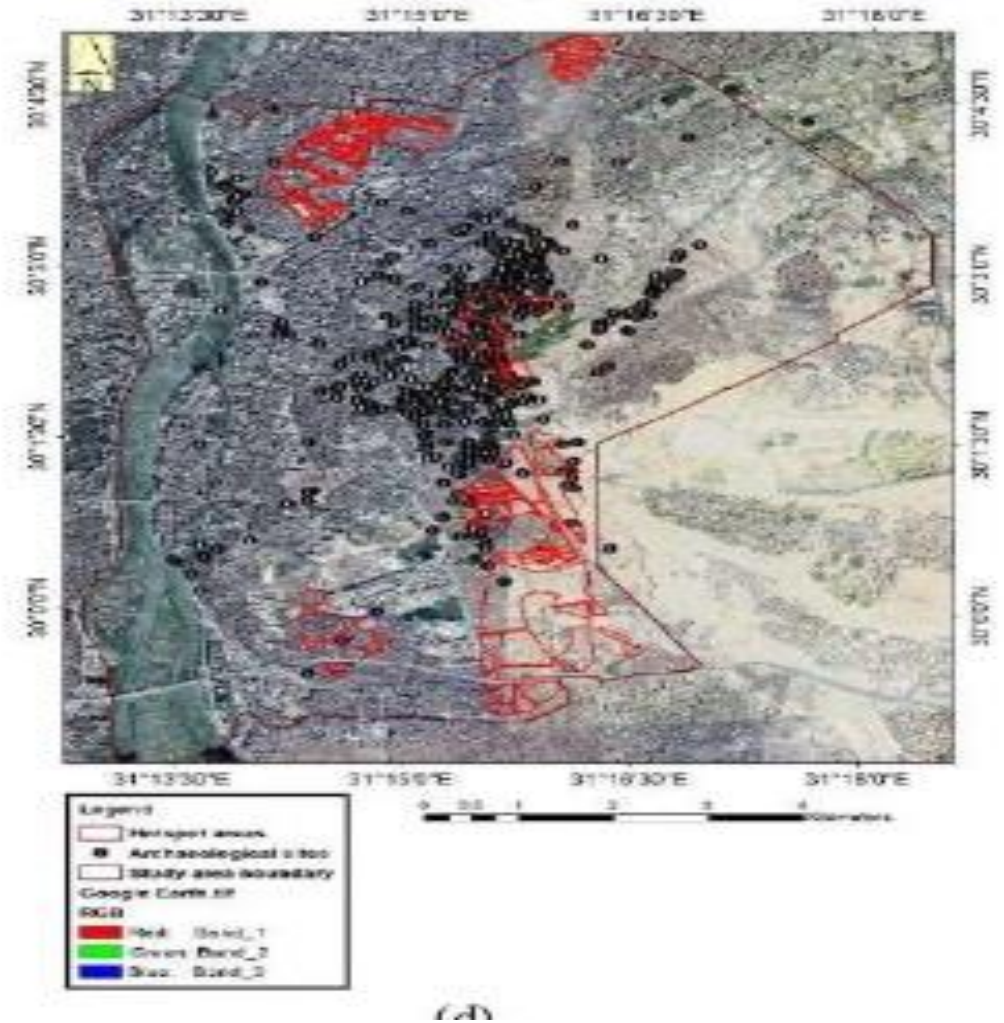


Merging land subsidence with hot spot regions



(a)

We discover that : there is much Islamic archeological sites are at high risk



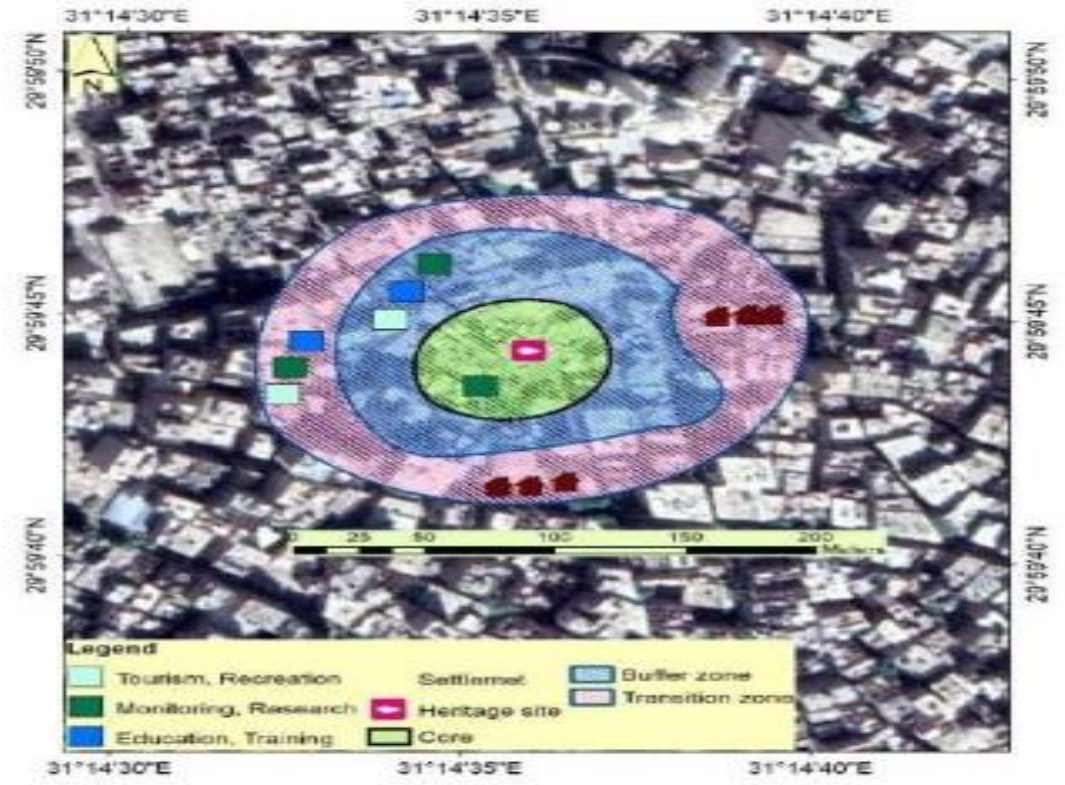
This list includes the archaeological sites threatened with high risk due to subsidence phenomena and Building overcrowding

1. Sidi Uqbah Mosque
2. Al-Muzni Grave
3. Imam al-Shafi'i Dome
4. Abu Ja'far al-Tahawi Dome
5. Abdullah al-Dakrory Dome
6. Yusuf's Brothers' Shrine

7. Suleiman Agha al-Hanafi Sabil and Grave
8. Mamluky Dome and Iwan
9. Tinkizbugha Dome
10. Tinkizbugha Bahari Dome
11. Amir Yunus al-Dawadar Dome
12. Ardabaz Dome
13. [illegible] al-Yusufi Mosque
14. Amir Tarabay al-Sharifi Portal and Dome
15. Sandal al-Manjaki Dome
16. Ibrahim Agha Mustahfizan (Aqsunqur) Mosque
17. Umm al-Sultan Sha'ban Mosque
18. Qaitbay Door
19. [illegible]
20. The Bunduqdari Judge's Dome
21. Ahmad Katkhuda al-Razzaz Residence and Hall
22. Zawiya al-Hunud Minaret
23. Ibrahim Agha Mustahfizan Sabil
24. Muhammad Darghan Zawiya
25. Qutlubugha al-Thahabi Madrasa
26. Alin Aq al-Husami Palace
27. Ibrahim Khalifah Gawdan Grave
28. Ibrahim Agha Mustahfizan House
29. Ibrahim Agha Mosque
30. Muhammad Bek Abu al-Dahab Sabil
31. Sultan al-Ghuri Caravanserai
32. Sultan al-Ghuri House
33. Sultan al-Ghuri Dome
34. Zayn al-Abidin Sabil
35. Suleiman Bek al-Kharbutly Sabil
36. Jamal al-Din al-Dhahabi House
37. Al-Azhar Mosque
38. Muhammad Bek Abu al-Dahab Mosque
39. Al-Fakahany Mosque
40. Al-Salih Tala'i' Mosque
41. Al-Kurdi Mosque
42. Inal al-Yusufi Madrasa
43. Jani Bek al-Ashrafi Mosque
44. Al-Tinbugha al-Maridany Mosque
45. Sultan al-Ghuri Mosque
46. Sultan al-Mu'ayyad Mosque
47. Baybars al-Khayyat Dome
48. Zuwaila Gate (Bab Zuwaila)
49. Radwan Bek Residence
50. Abdelrahman Katkhuda Zawiya Façade
51. Al-Wafa'iyyah Sabil
52. Al-Sukkariyah Hammam
53. Al-Shibshiri House
54. Al-Sharaybi House
55. Sultan Qaitbey House
56. Yusuf Agha al-Habashi Mausoleum
57. Nafisa al-Baydha Sabil
58. [illegible] Old House
59. Radwan Bek Zawiyat
60. Al-Shaykh wa al-Qazzaz House
61. Nafisah al-Baydha Caravanserai Façade
62. Muhammad Ali Sabil (1)
63. Radwan Bek House
64. Old House Façades
65. Sultan al-Mu'ayyad Hammam
66. Al-Ashraf Mosque Façade and al-Mahrouqy House
67. Al-Sharaybi Caravanserai Façade
68. [illegible] Building

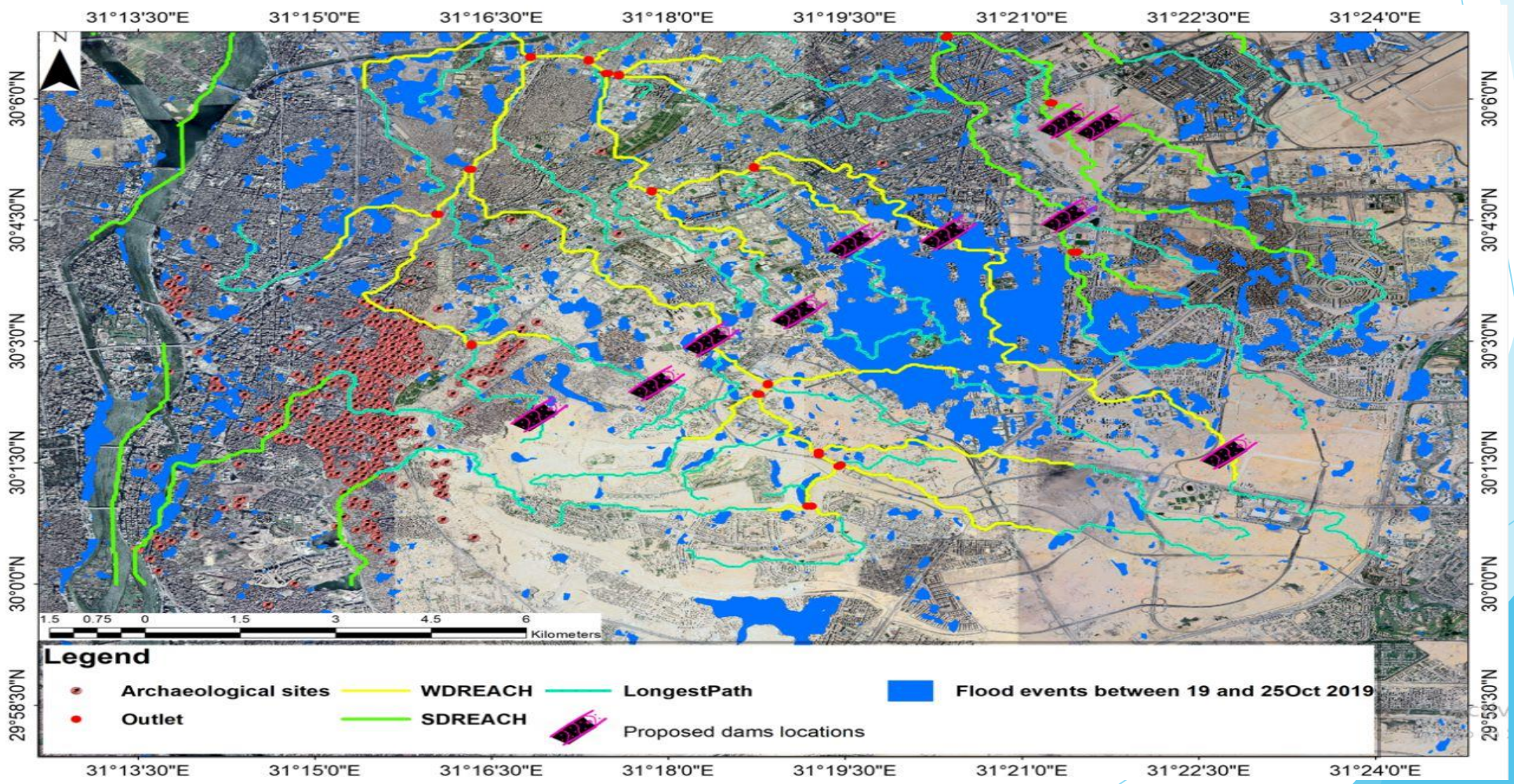
Recommendations :

1) **Applying the Unesco buffer zone for archeological sites and prevention of urban sprawl …even removal of random urbans**



- 2) cultivating green built in old Cairo to absorb the urban heat islands

3) Building Dams in the pathways of flooding and heavy rains




Thank
you!