Expansion or Contraction

Analysis of Urban Built-Up Area Change in China

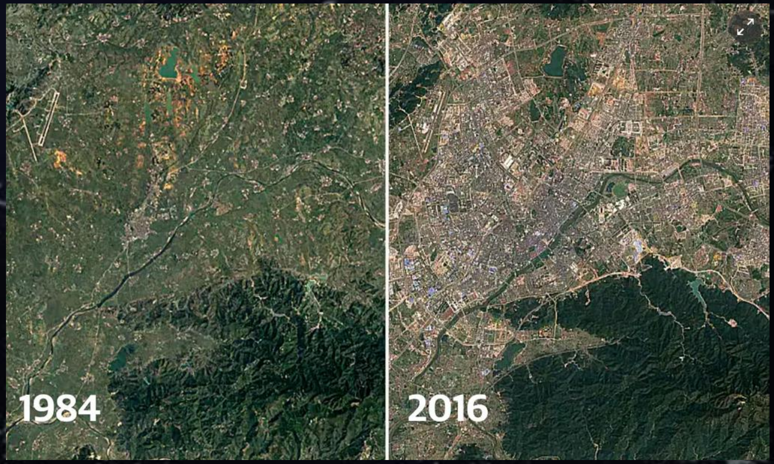
Ziqun Li
CPLN 670 Geospatial Software Design
Final Project
Instructor: Dr. Dana Tomlin

BACKGROUND

As one of the most prosperous urbanized countries in the world, China has witnessed an unprecedented active stage of urban expansion. However, **the global financial crisis** triggered by the decline of the export processing industry and the arrival of **the lewis turning point** of domestic labor force for the past few years have changed the conditions for urban growth in China *(Ying Long, 2016)*.

Although the urban population and built-up environment of some Chinese cities continue to grow, quite a few cities are also facing the situation of urban shrinkage. Nevertheless, this phenomenon of contraction has always been ignored by the mainstream of growth. Both decision makers and city planners in China are still accustomed to the urban growth, and there are few breakthroughs in the shackle concept of population growth in planning practice. More work is needed to understand those expanding & shrinking areas.

In this project, we focus on the **expansion and contraction** of urban built-up area based on the nighttime light data. Besides, we tried to explore the **changing characteristics of urban built-up areas in China , as well as the reasons behind them.**



Growth Planning (Yiwu, Zhejiang Province)

Shrinking Cities in China
(Yingcheng, Shandong Province， 2016)

METHODOLOGY

PART 1

Overview of Chinese built-up area (2003-2013)

↓

Calculation of built-up area increase by province

↓

Analysis of Centre-of-Gravity Change for built-up area

PART 2

Visualize the expansion & contraction of built-up area during different urbanization stages (*1992-1995, 1996-2010, 2010-2013*)

↓

Identify provinces with the largest positive & negative growth rate during the 3rd urbanization stages

PART 3

Compare the provinces with largest positive & negative growth rate from several dimensions

↓

Demographic
Landcover type
Climate
Construction suitability
Development Center change
....

The scale of built-up area is an important parameter of urbanization, which can be extracted from night light data. In this project, I try to use the nightlight data to explore the changes of urban built-up area in China. As a future urban planner, I focus not only on how to identify those changing areas, but also on the internal characteristic of urban contraction and urban expansion areas. Thus, this project will be divided into 3 parts:

The first part focus on giving an overview of urban built-up area changes in China (2003-2013).

The second part focus on the identification of the provinces with the most shrinking and expansion area (2010-2013).

The third part focus on the characteristics and differences between the selected two provinces, which might provide a basis for us to predict the future urban development.

DATA

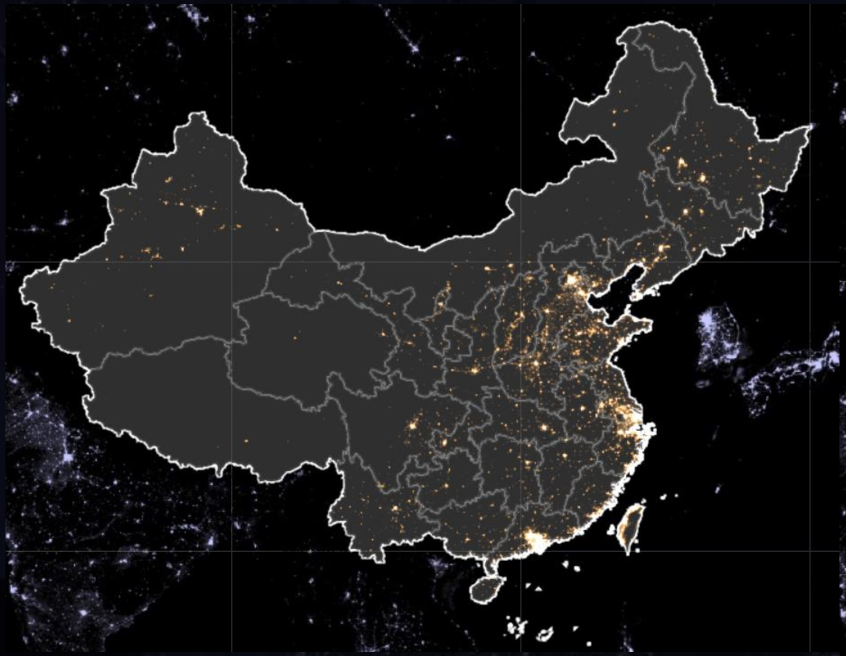
DMSP OLS: Nighttime Lights Time Series Version 4 (1992-2014) source from NOAA
2004 Chinese Province Boundary Shapefile source from CAUPD
GPWv411: Population Density World Version 4.11 source from CIESIN
MOD11A1.006 Terra Land Surface Temperature 2000-Present sourced from NASA LP DAAC
Climate Hazards Group InfraRed Precipitation with Station Data sourced from UCSB/CHG
Global Multi-resolution Terrain Elevation Data 2010 source from USGS
MCD12Q1.006 MODIS Land Cover Type source from NASA

TOOLS

GOOGLE EARTH ENGINE is the major tool for this project.
Besides, the analysis of center-of-gravity change in urban built-up area would be conducted by **ARCPY**.

PART 1. AN OVERVIEW OF URBAN BUILT-UP AREA CHANGES IN CHINA

1.1 Overview of the nighttime light change from 2003-2013



Nighttime light 2003

Nighttime light 2008

Nighttime light 2013

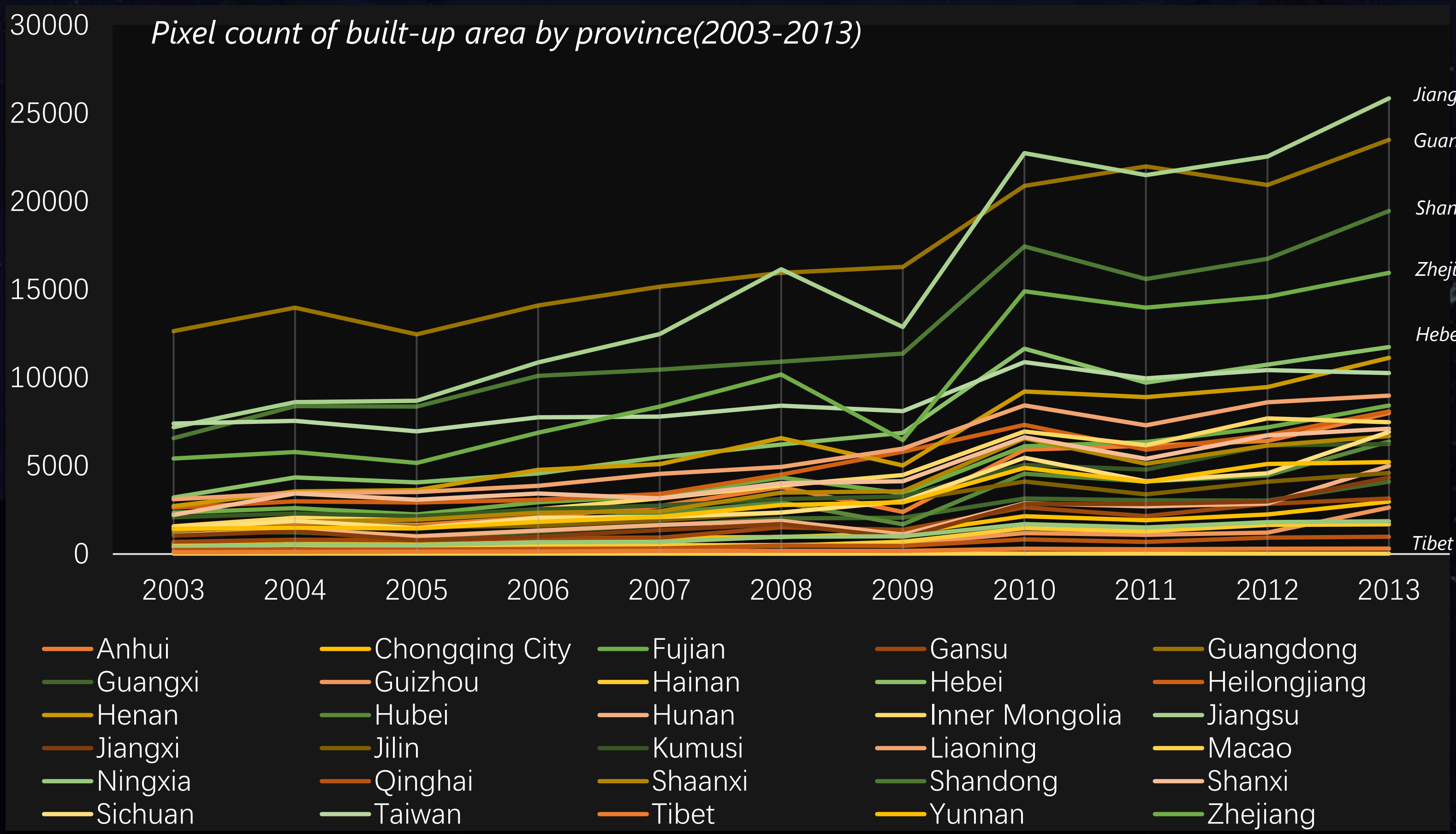
In the very first beginning, we visualized the nighttime light in China from 2003-2013. Generally, the area of urban built-up areas in China has been expanding for the past decade, and the brighter areas are mainly concentrated in the Yangtze river delta and the Beijing-Tianjin-Hebei region. .

```
//Load province boundary of China
var China=ee.FeatureCollection('users/lzqhust/province_China');
Map.addLayer(China,{color:'FFFFFF'},'China_Province');
Map.centerObject(China,4);
//Load country boundary of China
var boundary_geo=China.geometry();
var boundary = ee.Feature(boundary_geo);
```

```
//Load the nightlight of 2003. 2008 and 2013
var light_2003 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F152003').select('stable_lights').clip(boundary);
Map.addLayer(light_2003,{min: 3.0,max: 60.0,palette:['000000','FF9933','ffffff'],opacity:0.8},'Lights_2003');
var light_2008 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F162008').select('stable_lights').clip(boundary);
Map.addLayer(light_2008,{min: 3.0,max: 60.0,palette:['000000','FF9933','ffffff'],opacity:0.8},'Lights_2008');
var light_2013 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182013').select('stable_lights').clip(boundary);
Map.addLayer(light_2013,{min: 3.0,max: 60.0,palette:['000000','FF9933','ffffff'],opacity:0.8},'Lights_2013');
```

PART 1. AN OVERVIEW OF URBAN BUILT-UP AREA CHANGES IN CHINA

1.2 Stable nighttime light area change by province from 2003-2013

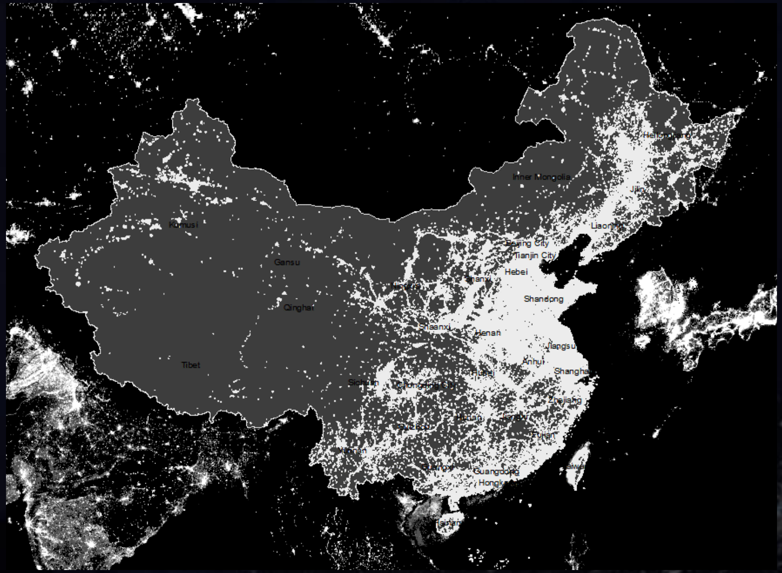


In order to have a Intuitive understanding for the expansion of urban built-up areas, we identified areas with a digital number larger than 31 (63 is the maximum DN) as lit area, and compared the increase of urban built-up area by province .

```
// Increased nightlight by province
var light_dataset =
ee.ImageCollection('NOAA/DMSP-
OLS/NIGHTTIME_LIGHTS').filter(ee.Filter.date('2003
-01-01', '2013-12-31'));
var blank = ee.Image(0);
function AreaLit(i){
  var thold=blank.where(i.gt(31),1);
  var alit = thold.mask(thold);
  alit = ee.Image.pixelArea().mask(alit);
  alit=alit.divide(1000000);
  alit=alit.set('index',i.get('system:index'));
  return alit;
}
function tabulate(i){
  return China.map(function (f){
    var r=i.reduceRegion({
      reducer:ee.Reducer.sum(),
      geometry:f.geometry(),
      scale:500,
      bestEffort:true,
      maxPixels:1e9});
    return ee.Feature(null,{
      name:f.get('province'),
      area:r.get('area'),
      index:i.get('index')});});}

var arelit=light_dataset.map(AreaLit);
var arelit_table=arelit.map(tabulate).flatten();
Export.table.toDrive(arelit_table,'DMSP_results','D
MSP results','results','csv');
```

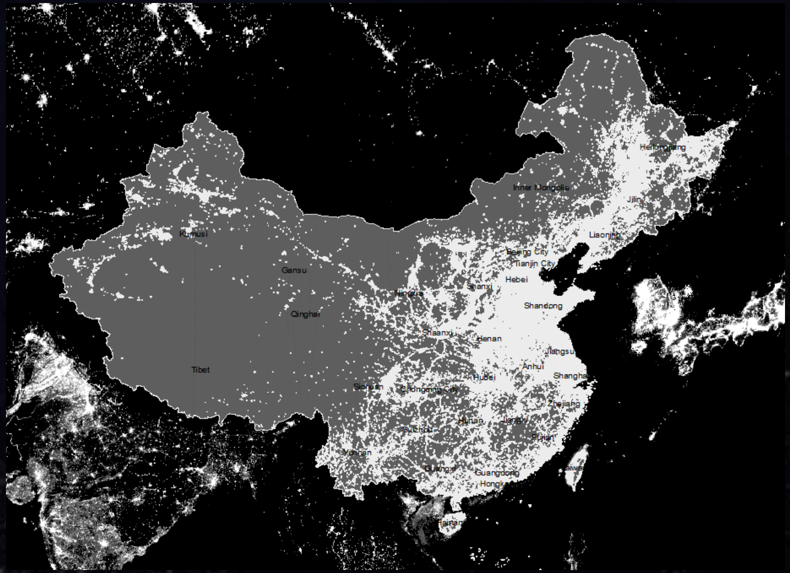
PART 1. AN OVERVIEW OF URBAN BUILT-UP AREA CHANGES IN CHINA

1.3 Analysis of center-of-gravity change for urban built-up area (ARCPY PART)



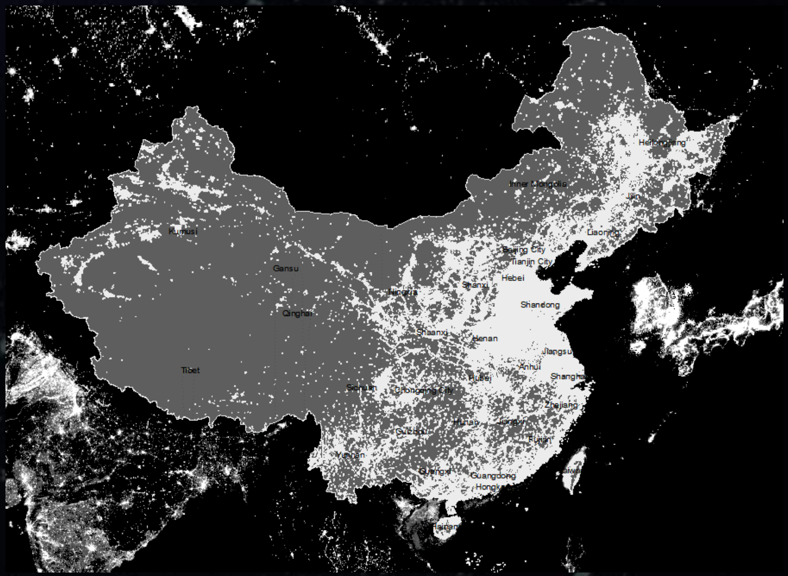
2003 nighttime light polygon

FID	Shape *	ID	GRIDCODE
0	Polygon	1	4
1	Polygon	2	5
2	Polygon	3	6
3	Polygon	4	4



2008 nighttime light polygon

FID	Shape *	ID	GRIDCODE
0	Polygon	1	4
1	Polygon	2	5
2	Polygon	3	6
3	Polygon	4	4



2013 nighttime light polygon

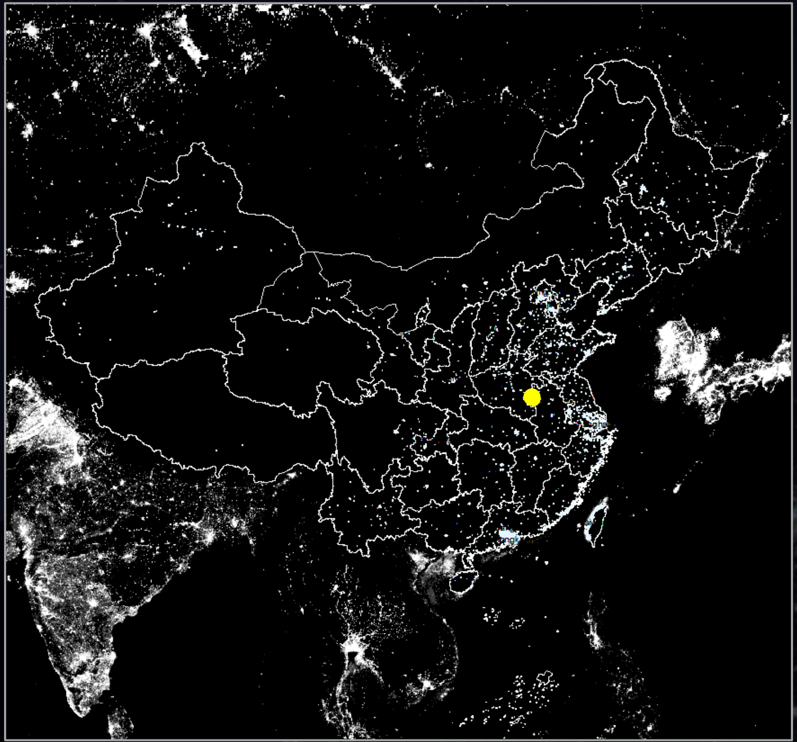
FID	Shape *	ID	GRIDCODE
0	Polygon	1	6
1	Polygon	2	7
2	Polygon	3	6
3	Polygon	4	8

To further explore the spatial characteristics of urban-built area change, we decided to explore the center-of-gravity change of urban built-up area from 2003-2013.

To be more specific , we downloaded the nightlight raster data from RESDC (http://www.resdc.cn/data.aspx?DATAID=213) , and created an Arcpy script to clip the study area (Chinese boundary) ,convert the raster nighttime light data into polygons.

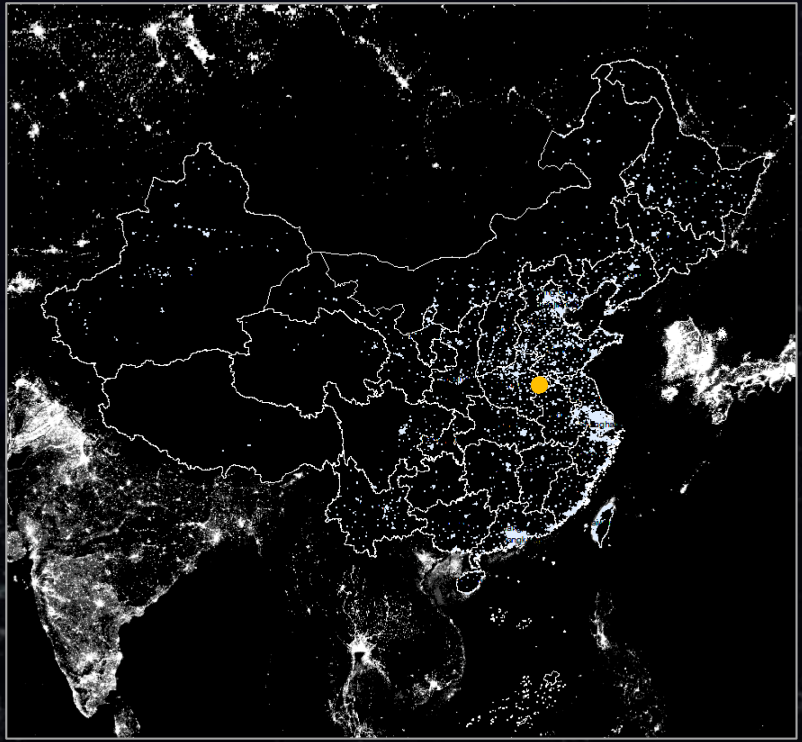
PART 1. AN OVERVIEW OF URBAN BUILT-UP AREA CHANGES IN CHINA

1.3 Analysis of center-of-gravity change for urban built-up area (ARCPY PART)



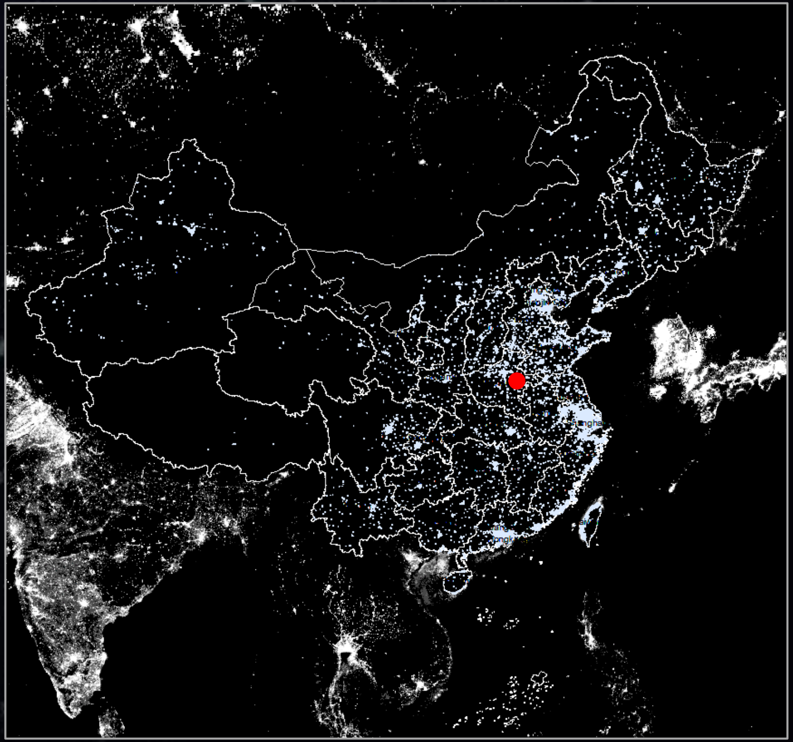
Gravity center of built-up area in 2003

FID	Shape *	Id	XCoord	YCoord
0	Point	0	12891831.1305	3890748.01106



Gravity center of built-up area in 2008

FID	Shape *	Id	XCoord	YCoord
0	Point	0	12873654.4682	4007622.73154



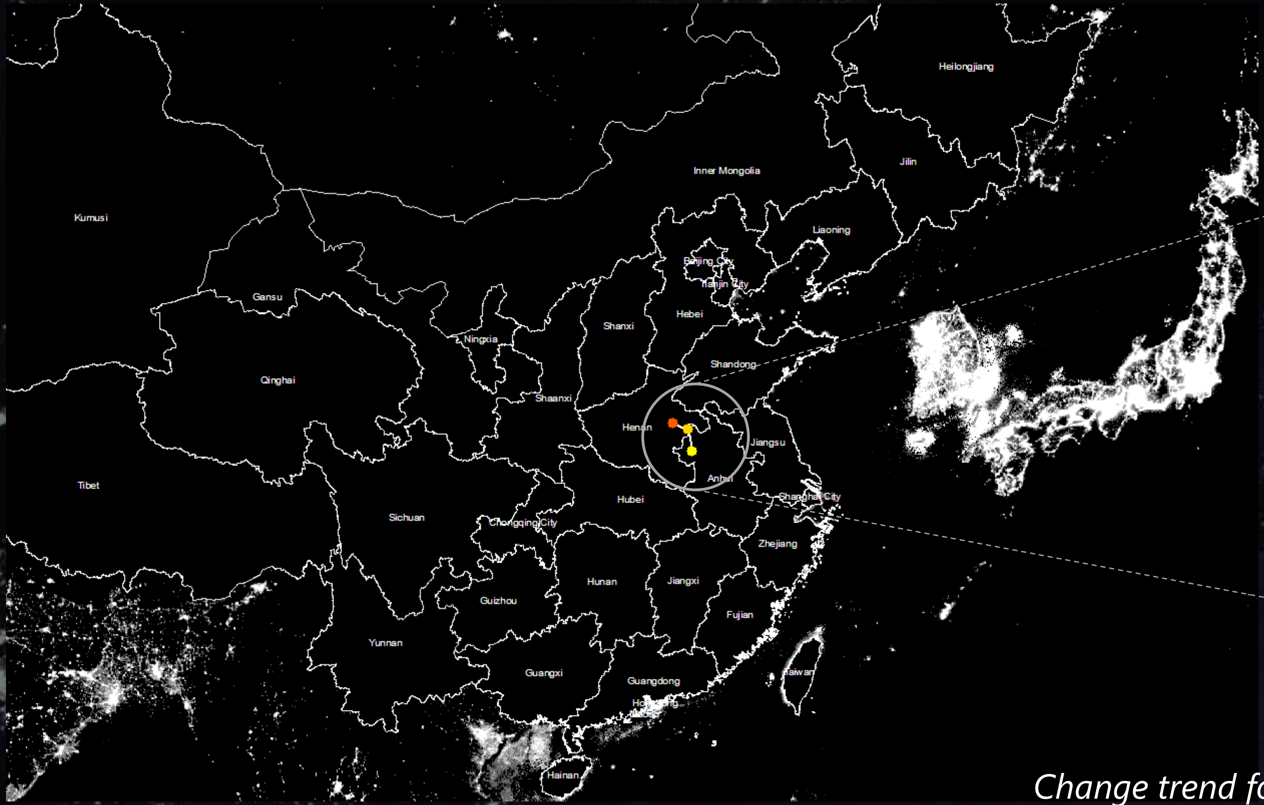
Gravity center of built-up area in 2013

FID	Shape *	Id	XCoord	YCoord
0	Point	0	12790752.633	4041036.76514

Then, we identified the polygons that have a GRIDCODE value (light value) large than 31 as built-up area, and calculated the gravity center locations for 2003,2008 and 2013. The results are showed above.

PART 1. AN OVERVIEW OF URBAN BUILT-UP AREA CHANGES IN CHINA

1.3 Analysis of center-of-gravity change for urban built-up area (ARCPY PART)



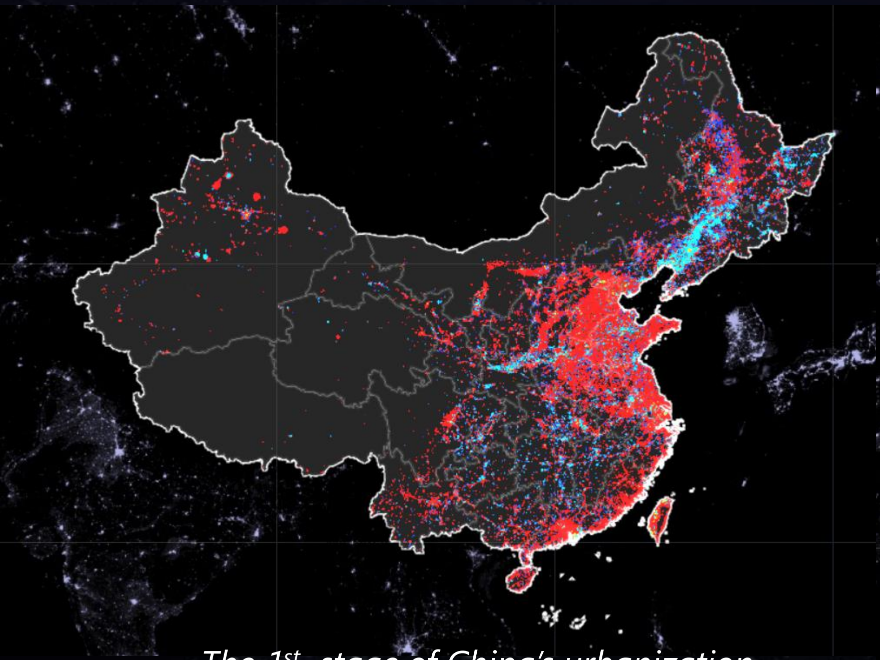
Change trend for gravity center of built-up area in China from 2003-2013

OID *	Shape *	From_ID	To_ID	Start_Time	End_Time	Distance_FT_Year	Duration_SEC_Year	Speed_MPH_Year	Course_DEG_Year	Shape_Length
1	Polyline	0	1	1/1/2003	1/1/2008	388056.036598	157766400	0.001677	351.160028	118279.716515
2	Polyline	1	2	1/1/2008	1/1/2013	293248.729665	157852800	0.001267	291.952166	89382.391567

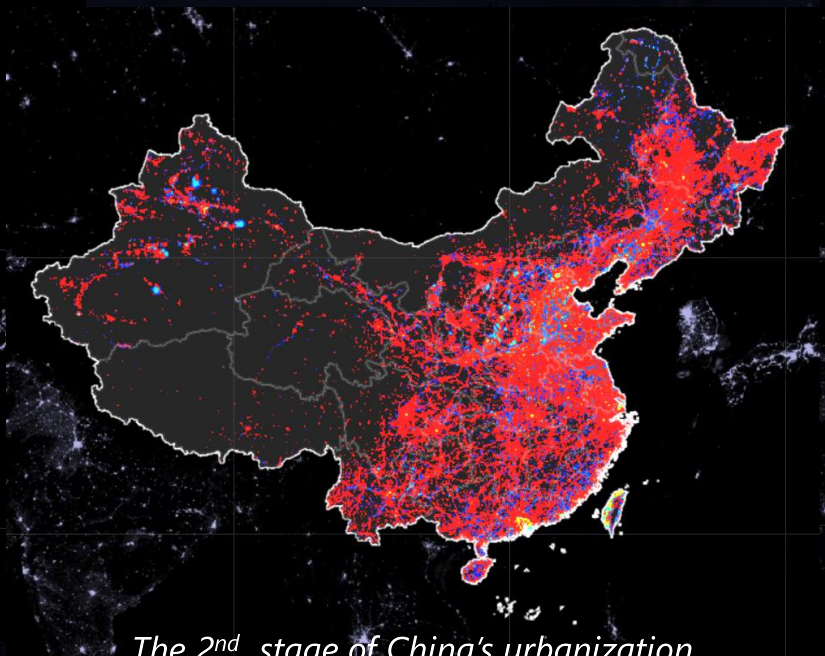
After that , we created another scripts to help visualizing the location change track during 2003-2013. As can be seen from the above map, China's urban center was moving north from 2003-2008. Since 2008, the center began to shift west, and this change might be related with the planning strategy of "Rise of Central China", which proposed by Chinese government according to the need of the region balanced development.

PART 2. THE POSITIVE/NEGATIVE GROWTH OF URBAN BUILT-UP AREAS

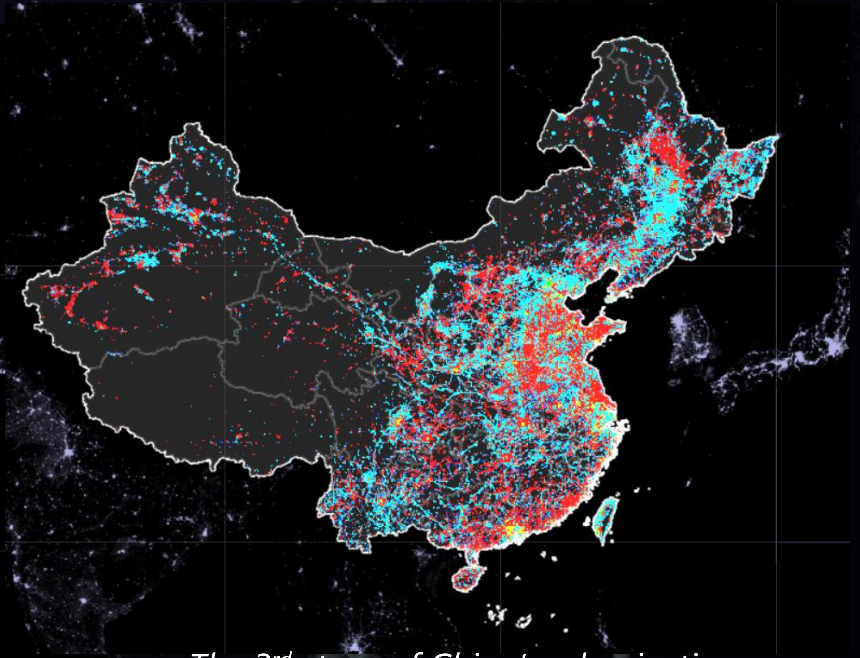
2.1 The change trend of urban built-up areas in China during different urbanization stages



The 1st stage of China's urbanization (1992-1995)



The 2nd stage of China's urbanization (1996-2010)



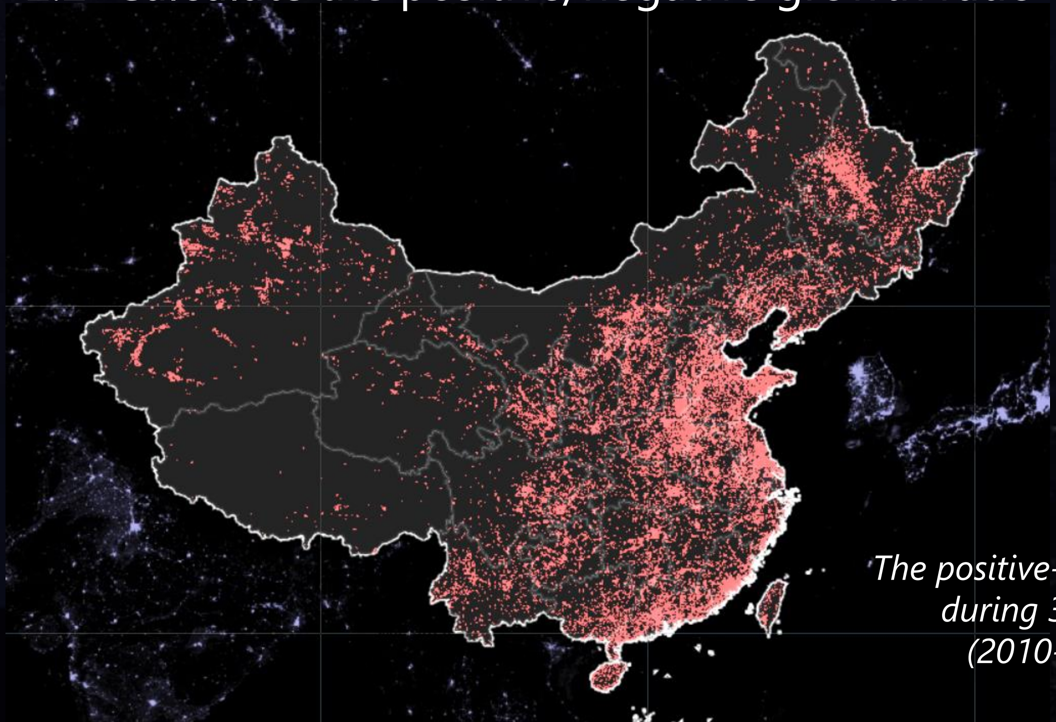
The 3rd stage of China's urbanization (2010-2013)

In this part, we focus on the identification of shrinking and expansion area. According to the CASS (Chinese Academy of Social Sciences) report , China's urbanization has gone through **three stages** since reform and opening up: **The first stage** was the early stage of rapid urbanization growth from 1978 to 1995; **The second stage** is the middle stage of accelerated urbanization growth from 1996 to 2010; **In the third phase** (after 2010) , China's urbanization has entered the middle and late stage, and the focus of planning gradually shifted from incremental planning to stock planning.

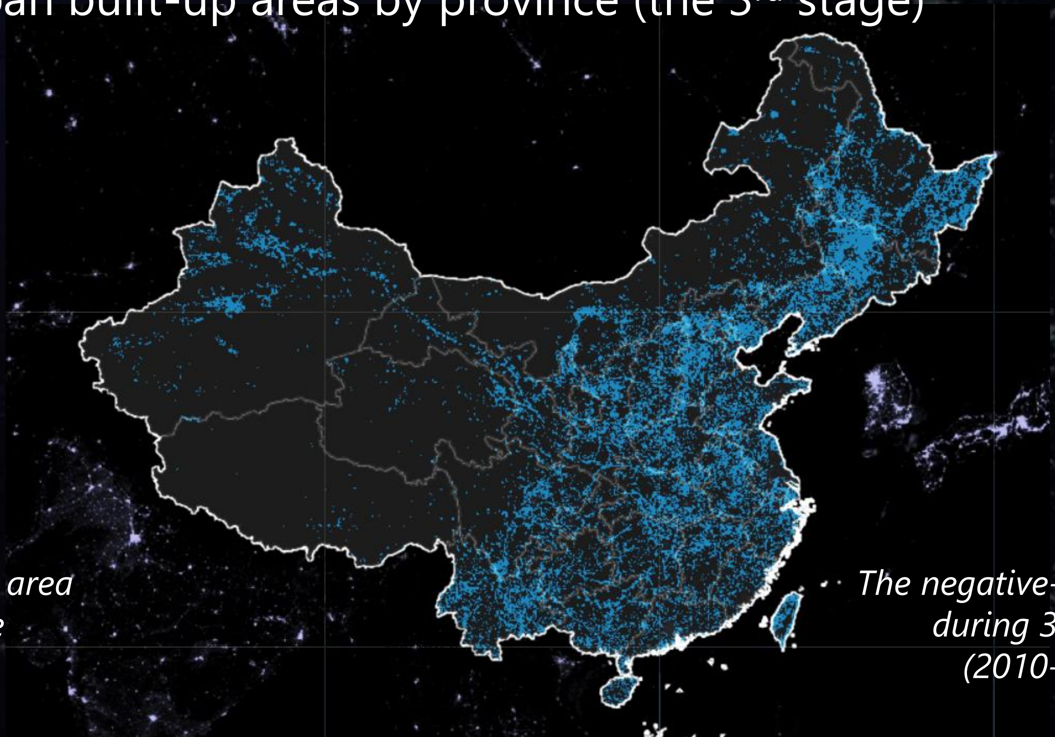
Here, a linear regression model was built to visualize the built-up area change trend: the trend has been displayed in **Red (positive growth), Blue (negative growth), and Green (stable brightness).** As can be seen from the above maps, China has indeed entered the mid to late stage of urbanization: The built-up area began to shrink inward instead of expanding outward.

PART 2. THE POSITIVE/NEGATIVE GROWTH OF URBAN BUILT-UP AREAS

2.2 Calculate the positive/negative growth ratio of urban built-up areas by province (the 3rd stage)



The positive-growth area during 3rd stage (2010-2013)



The negative-growth area during 3rd stage (2010-2013)

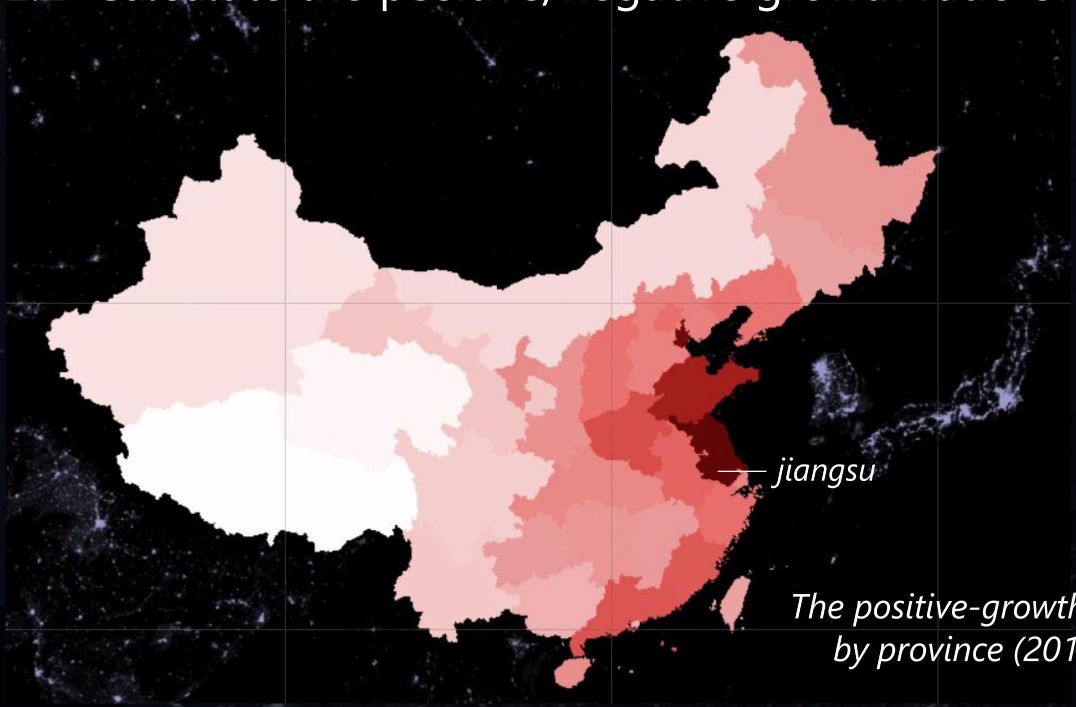
We were really interested in the change of urban built-up area during the third stage of urbanization (2010-2013). Thus, based on the regression results during 2010-2013, we extracted the area with positive growth and negative growth respectively.

```
var getyear=function(year){
  return ee.Date.fromYMD({
    day:1,month:1,year:year});};
var linear_fit=function(y1,y2){
  var startyear = getyear(y1);
  var endyear = getyear(y2);
  var timeband=light_dataset.filterDate(startyear,endyear).map(createTimeBand);
  var linearfit=timeband.select(['system:time_start','stable_lights'])
                    .reduce(ee.Reducer.linearFit()).clip(boundary);
  return linearfit;};
var fit_china_10_14=linear_fit(2010,2014);
```

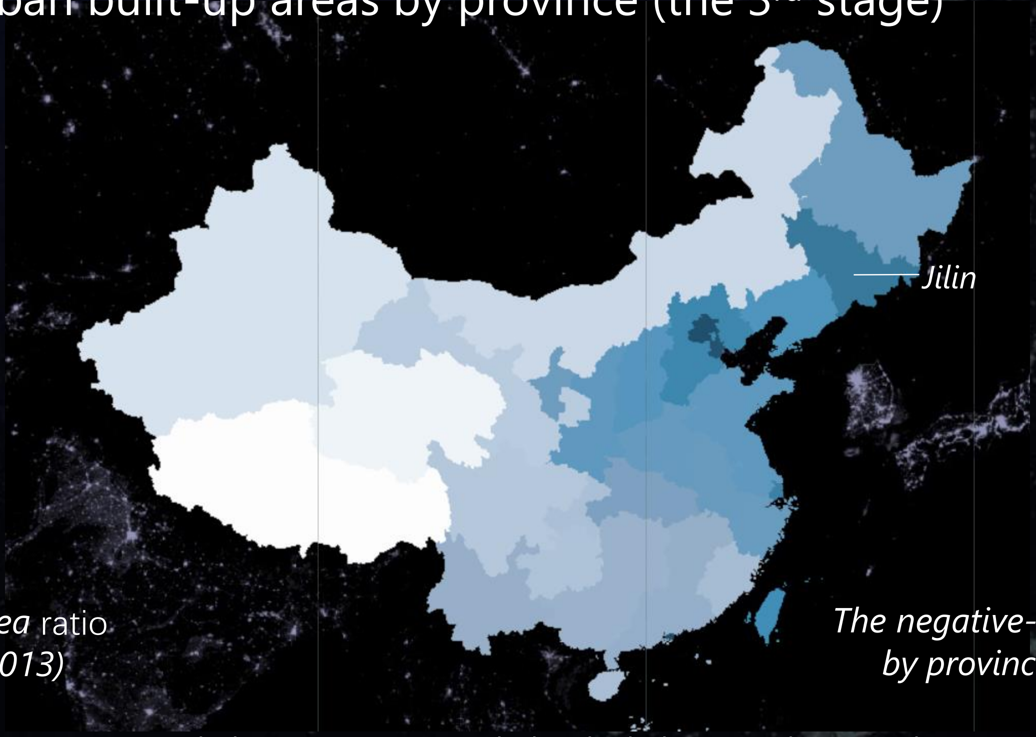
```
var positive_growth=function(img){
        var img_scale=img.select("scale");
        var positive=img_scale.multiply(img_scale.gt(0));
        return positive;};
var negative_growth=function(img){
        var img_scale=img.select("scale");
        var negative=img_scale.multiply(img_scale.lt(0).multiply(-1));
        return negative;};
var positive_10_14=positive_growth(fit_china_10_14);
var negative_10_14=negative_growth(fit_china_10_14);
```

PART 2. THE POSITIVE/NEGATIVE GROWTH OF URBAN BUILT-UP AREAS

2.2 Calculate the positive/negative growth ratio of urban built-up areas by province (the 3rd stage)



The positive-growth area ratio *by province (2010-2013)*



The negative-growth area ratio *by province (2010-2013)*

We also counted the number of pixels with positive growth and negative growth by province, and divided the number to the province area . The above maps indicate that both of positive-growth ratio value and negative-growth ratio value for China's coastal regions are higher than inland regions, which means the direction of urban expansion for those areas may change considerably during the past several years.

```
function density(Chi){
  var Area=ee.Number(Chi.area());
  var ratio=ee.Number(Chi.get('LitArea')).divide(Area);
  var Chi_copy=Chi;
  return Chi_copy.set({"ratio":ratio});
}
//calculate the ratio of positive_growth area to the provincial area
var ratio_positive=area_positive.map(density);
//calculate the ratio of negative_growth area to the provincial area
var ratio_negative=area_negative.map(density);
```

```
// plot the choropleth map of ratio by province
var choropleth=function(fc){
  var img=fc.reduceToImage(["ratio"],ee.Reducer.first());
  return img; };
var img_positive=choropleth(ratio_positive);
Map.addLayer(img_positive,{max:130,min:0,palette:["FFFFFF","E99C9A","E96D6A","C02A26","5D0606"],
opacity:1},"positive growth area/total area");
var img_negative=choropleth(ratio_negative);
Map.addLayer(img_negative,{max:130,min:0,palette:["FFFFFF","8FB2D1","679FD1","20517C","092C4C"],
opacity:1},"negative growth area/total area");
```

PART 2. THE POSITIVE/NEGATIVE GROWTH OF URBAN BUILT-UP AREAS

2.3 Identify provinces with the largest urban expansion rate and contraction rate

Table 1. Top 10 provinces (municipalities) with highest positive-growth ratio

Index	Name	Ratio_Positive
1	Jiangsu	128.82
2	Tianjin City	124.13
3	Shandong	107.34
4	Henan	80.35
5	Guangdong	76.01
6	Fujian	74.41
7	Anhui	69.13
8	Zhejiang	63.45
9	Beijing City	63.35
10	Shanxi	61.43

Table 2. Top 10 provinces (municipalities) with highest negative-growth ratio

Index	Name	Ratio_Negative
1	Hongkong	113.37
2	Beijing City	111.57
3	Tianjin City	107.57
4	Jilin	80.45
5	Shanghai City	75
6	Hebei	71.13
7	Macao	69.74
8	Taiwan	67.17
9	Liaoning	59.61
10	Shanxi	57.64

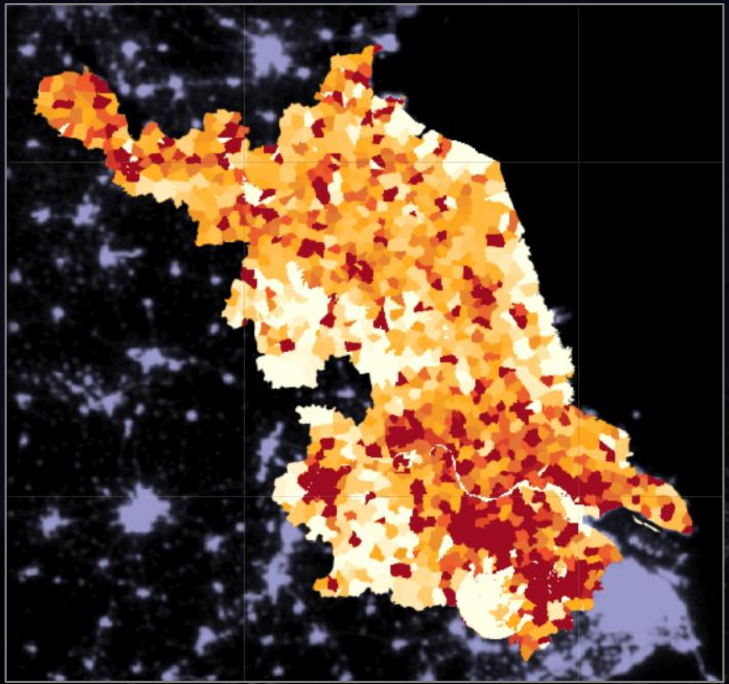
```
var
top_positive=ratio_positive.limit(10,"ratio",false);
print(top_positive);
var
top_negative=ratio_negative.limit(10,"ratio",false);
print(top_negative);
//export the result table
Export.table.toDrive({
  collection:top_positive,
  description: "top_positive",
  fileNamePrefix: "top_positive",
  fileFormat: "KML",
  selectors: ["Province","ratio"]
});

Export.table.toDrive({
  collection:top_negative,
  description: "top_negative",
  fileNamePrefix: "top_negative",
  fileFormat: "KML",
  selectors: ["Province","ratio"]
});
```

Besides, the top 10 provinces *(including several municipalities)* with highest positive-growth ratio and negative-growth ratio were listed. After deleting the information of municipalities, we identified the province with the highest proportion of positive-growth area, **Jiangsu**; as well as the province with the highest proportion of negative-growth area, **Jilin**.

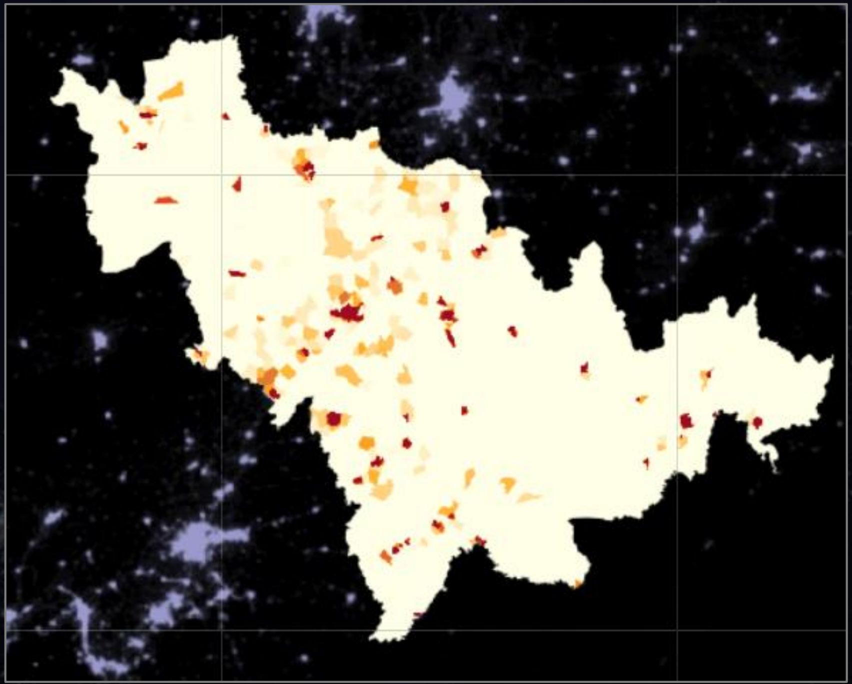
In the next part, we will focus on comparing the characteristics of these two provinces, trying to find the reasons behind the urban expansion & urban contraction.

PART 3. DIFFERENCE BETWEEN URBAN CONTRACTION & EXPANSION PROVINCE

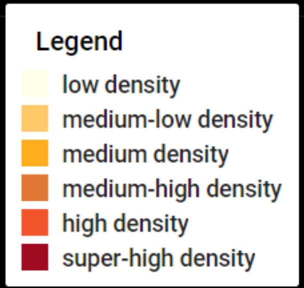
3.1 Demographic Characteristic



Population Density, Jiangsu, 2013



Population Density, Jilin, 2013



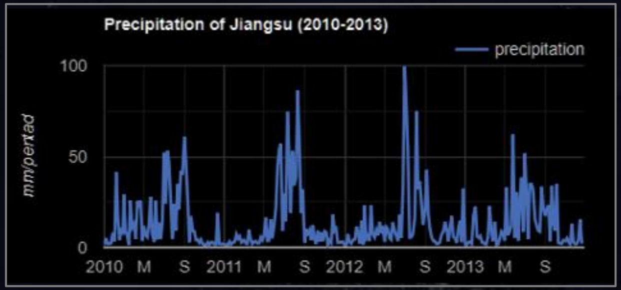
To begin with, we explored the population density of Jiangsu and Jilin in 2013, the result above shows that the population of Jiangsu is much higher than that of Jilin, which means the urban expansion might be related to population density. Urban expansion might be accompanied with population inflow, and urban contraction may be accompanied with population loss.

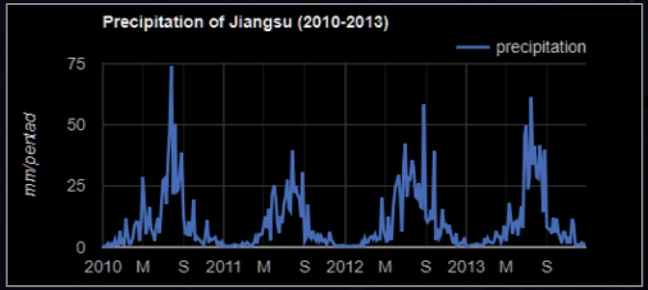
```
var dataset =
ee.ImageCollection("CIESIN/GPWv411/GPW_Populati
on_Density").first();
var raster =
dataset.select('population_density').clip(boundary);
Map.setCenter(79.1, 19.81, 3);
Map.addLayer(raster, raster_vis, 'population_density');

//add the legend
function addLegend(palette, names) {
var legend = ui.Panel({style: {position: 'bottom-
right',padding: '5px 10px'}});
var title = ui.Label({value: 'Legend',style: {
    fontWeight: 'bold',
    color: "black",
    fontSize: '16px'} });legend.add(title);
var addLegendLabel = function(color, name) {
var showColor = ui.Label({style: {backgroundColor:
    '#' + color,padding: '8px',margin: '0 0 4px 0'}});
var desc = ui.Label(
     {value: name,style: {margin: '0 0 4px 8px'}});
return ui.Panel(
{widgets: [showColor, desc],layout:
ui.Panel.Layout.Flow('horizontal')});};
for (var i = 0; i < palette.length; i++) {
var label = addLegendLabel(palette[i], names[i]);
  legend.add(label);}
  Map.add(legend);}
var palette = ['ffffe7','FFc869', 'ffac1d',
'e17735','f2552c','9f0c21'];
var names = ["low density","medium-low
density","medium density","medium-high
density","high density","super-high density"];
addLegend(palette, names);
```

PART 3. DIFFERENCE BETWEEN URBAN CONTRACTION & EXPANSION PROVINCE

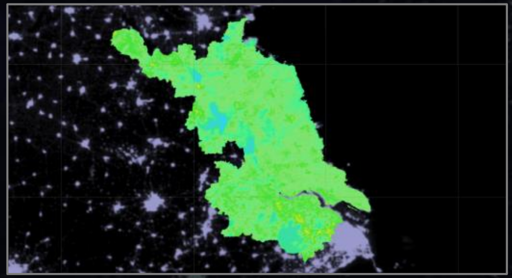
3.2 Climate Characteristic

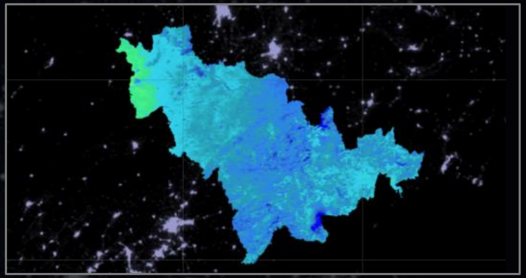
Line Chart of Precipitation (2010-2013)



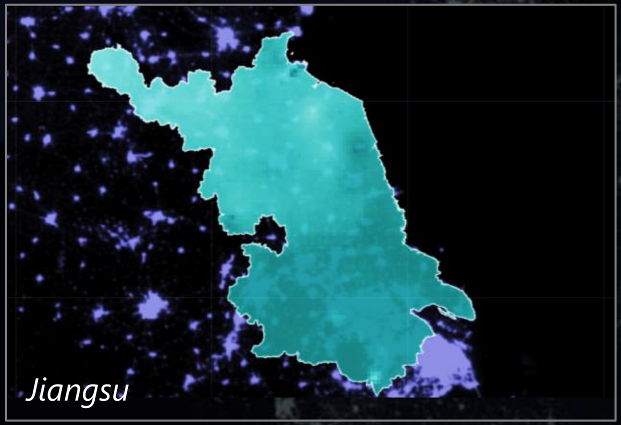


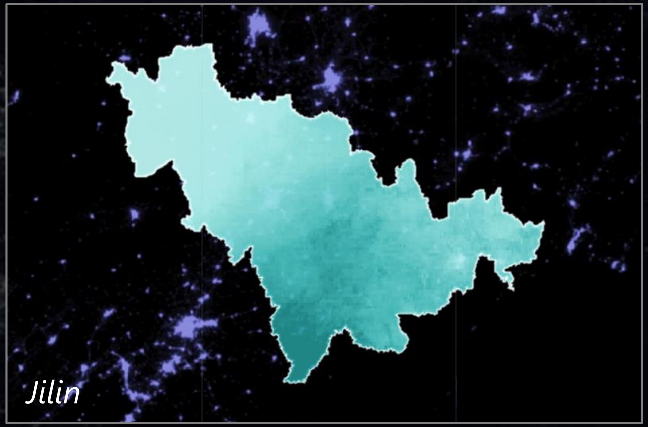
Original Temperature Map (2013)



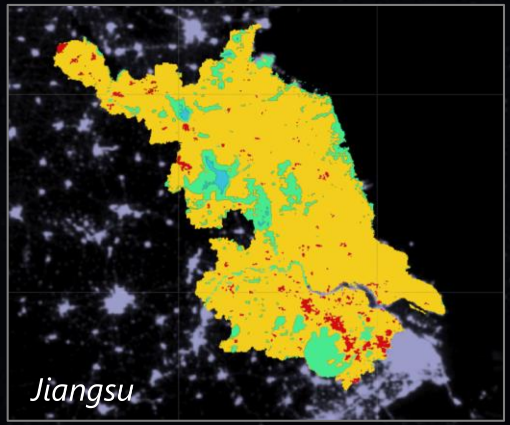


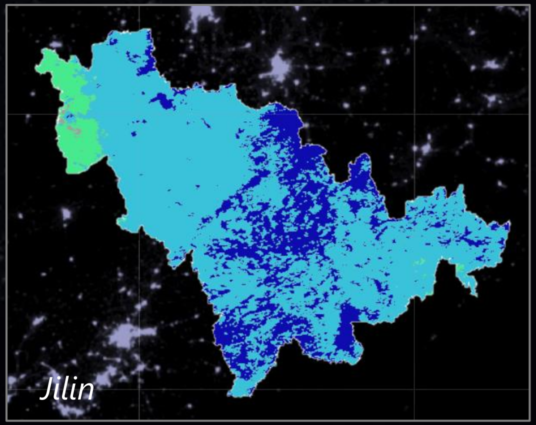
Precipitation Map





Evaluation of Temperature Suitability

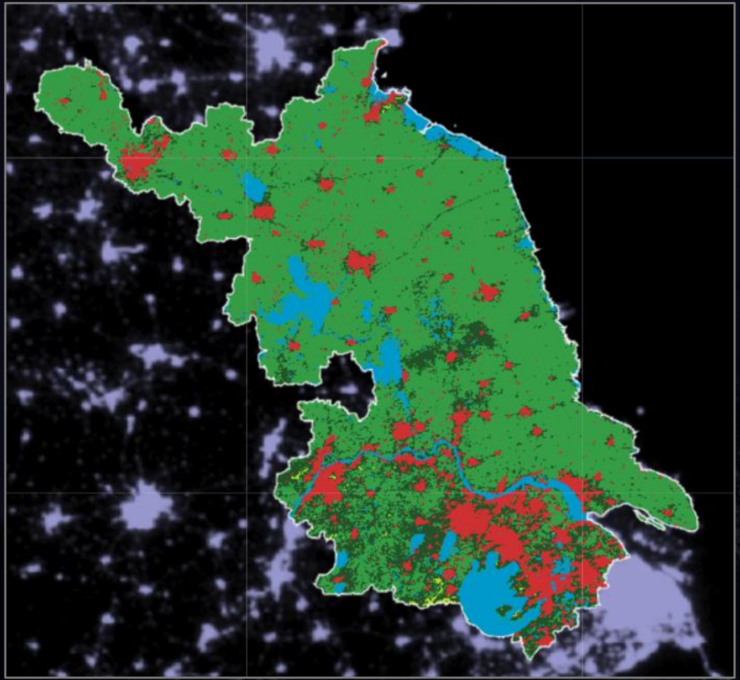




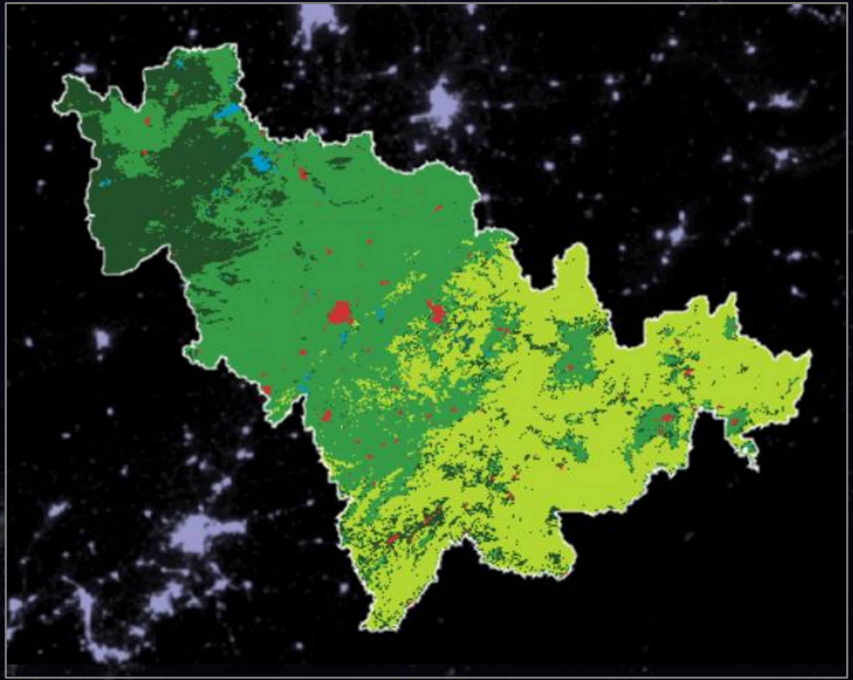
Is there any difference in climate between these two provinces? In terms of precipitation, we could learn from the line charts that the difference of average precipitation between those two provinces is relatively small . Then, we explored the average temperature of both province in 2013. To be more specific, we classify the yearly average temperature into 5 degrees: frosty (<8℃), cold (8-15℃), cool (15-20℃), warm （20-25 ℃ ） and hot （>25℃） . The maps above indicate that urban expansion is more likely to occur in temperate climates(15-25 ℃) .

PART 3. DIFFERENCE BETWEEN URBAN CONTRACTION & EXPANSION PROVINCE

3.3 Landcover Type

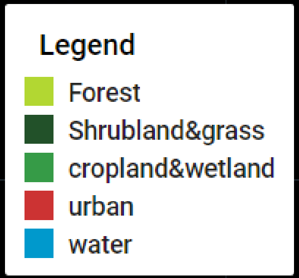


Classified land cover, Jiangsu, 2013



Classified land cover, Jilin, 2013

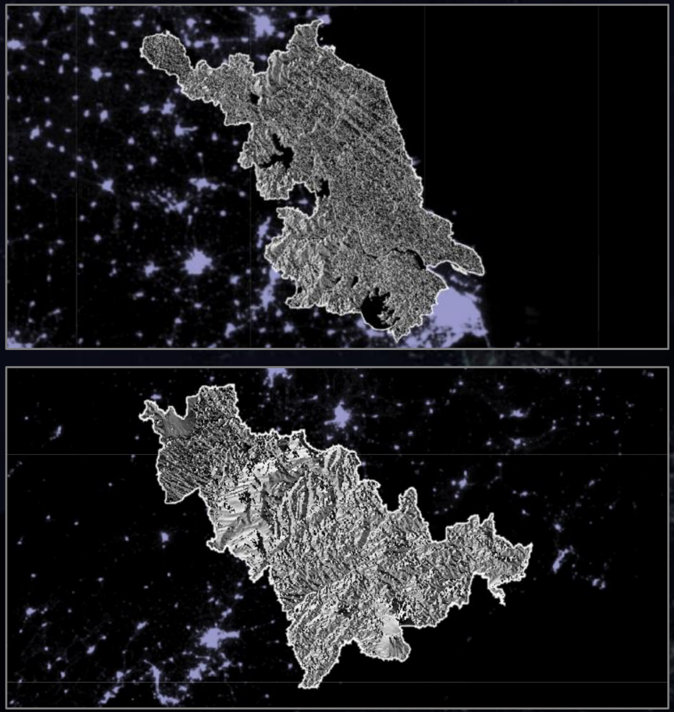
```
//Load and Reclassify the landcover data
var landcover=
ee.Image('MODIS/006/MCD12Q1/2014_01_01').select
('LC_Type1');

var landcover_classify
=landcover.remap([1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,
16,17], [1,1,1,1,1,2,2,2,2,2,3,3,4,3,2,2,5], 0, 'LC_Type1');

var ColorsForMODIS  = [
   'B2D732', // 01 = Forest
   '225129', // 02 = Shrubland&grass
   '369b47', // 03 = cropland&wetland
   'CC3333', // 04 = urban
   '0099CC', // 05 = water
   ].join(',');

var DisplaySETTINGS = { min:1, max:5, opacity:0.6,
palette:ColorsForMODIS };

var
landcover_classify=landcover_classify.clip(boundary);

Map.addLayer(landcover_classify,DisplaySETTINGS,
'Land Cover Classes' );

print(landcover_classify);
```



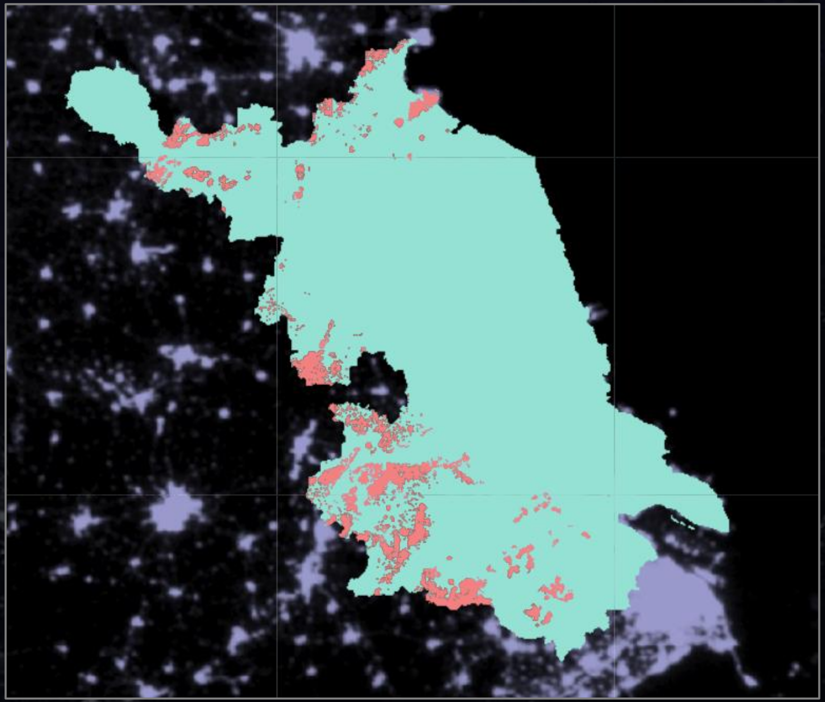
What about the landcover type in those regions? We loaded the Landcover data and reclassified it into five categories: forest, shrubland & grass, cropland & wetland, urban area and water. An interesting finding is that the landcover type of Jilin is more diverse than Jiangsu. However, Jiangsu has more cropland & wetland and water area than Jilin, which indicates the cropland & wetland area and water source might be a potential geography factor for urban expansion.

PART 3. DIFFERENCE BETWEEN URBAN CONTRACTION & EXPANSION PROVINCE

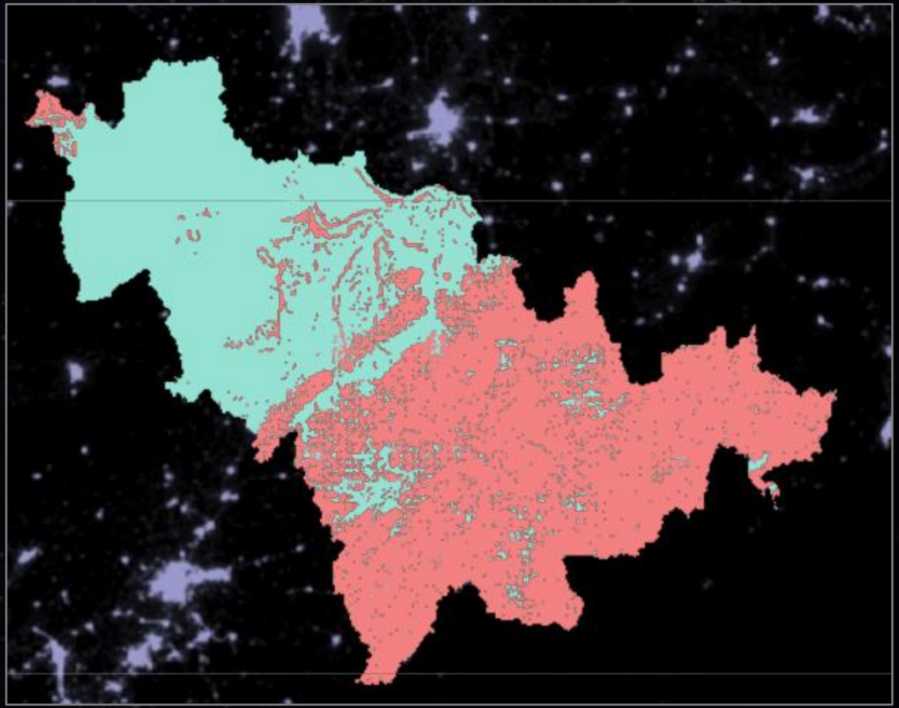
3.4 Topographic Characteristic



Original Slope Map



Evaluation of construction suitability, Jiangsu Province



Evaluation of construction suitability, Jilin Province

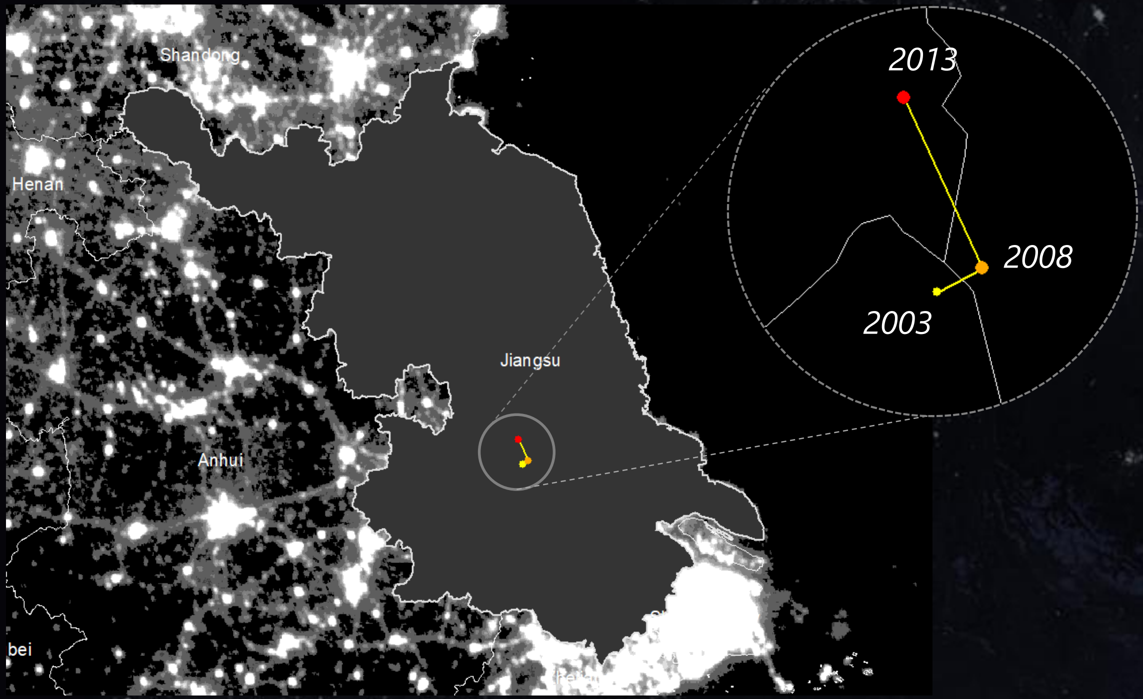
Legend

- Suitable for construction(Slope less than 0.5)
- unsuitable for construction(Slope greater than 0.5)

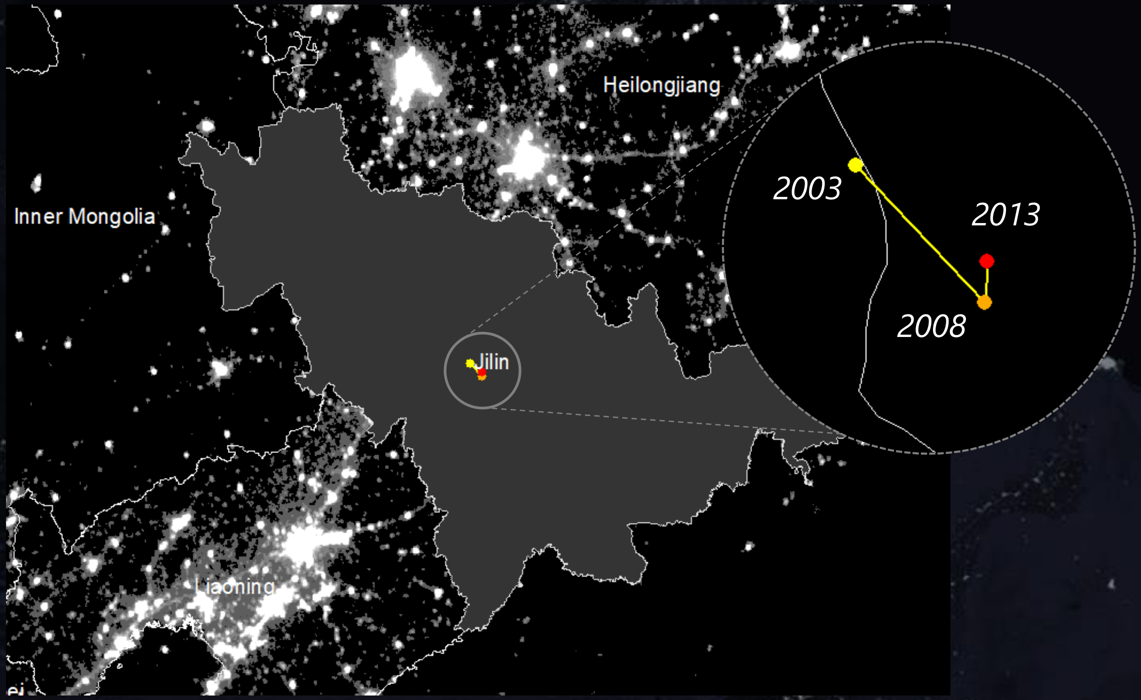
Topographic characteristic might also be a potential factor that influence the urban built-up area.We loaded the elevation data for both Jiangsu and Jilin Province, calculated their slope, and evaluated the construction suitability: the areas that have a slope less than 0.5 is regarded as suitable construction area, and the areas that have a slope more than 0.5 is regard as unsuitable construction area. As can be seen from the above maps, Jiangsu has much more areas that are suitable for construction than Jilin.

PART 3. DIFFERENCE BETWEEN URBAN CONTRACTION & EXPANSION PROVINCE

3.5 Change of Gravity Center for Urban Built-up Area (ARCPY PART)



Change of Gravity Center for Built-up area,
Jiangsu Province (2003-2013)



Change of Gravity Center for Built-up area,
Jilin Province (2003-2013)

Finally, we analyzed the change of gravity center for built-up area in both provinces. Obviously, Jiangsu's urban development speed is much faster than Jilin's. At the same time, we also noticed that direction of urban development for Jiangsu is shifting north, however, the gravity center of built-up area for Jilin is moving to the southeast. Recalling that there exists a lot of forest resource in the southeast area, it is necessary for the government to reconsider the direction of urban development, in order to avoid destroying the local ecological sensitivity.

CONCLUSION

Conclusion 1

In the first part, we visualized the urban built-up area in China during 2003-2013, finding that the overall increase of the total built-up area in China is significant, especially in Jiangsu, Guangdong and Shandong province. Besides, the gravity center of urban built-up area is moving from coastal regions to inland regions， which indicates the planning strategy of "Rise of Central China" that proposed by Chinese government according to the need of the region balanced development have been gradually implemented.

Conclusion 2

In the second part , we explored the change trend of urban built-up areas in China. The result indicates that although urban built-up areas were still expanding, Chinese urbanization process had already stepped into a slowdown stage since 2010. Then, we identified the Top 10 provinces with largest positive growth ratio and negative growth ratio from 2010-2013, which might serve as a reference to help understanding those shrinking areas during future urban planning process.

Conclusion 3

In the third part , we focus on the comparation of characteristics between the province with the most shrinking area (Jiangsu) and the province with most expansion area (Jilin) from 2010-2013. The following results might provide a basis for planners to predict the future urban development :

- Urban expansion might be accompanied with population inflow, and urban contraction may be accompanied with population loss.
- Urban expansion is more likely to occur in areas which have temperate climates(15-25 ℃) .
- The areas with high ecological sensitivity (more cropland & wetland and water source) and low-suitability construction might be potential areas for urban contraction.
- When it comes to the direction of urban development, the planner need to take multiple factors into consideration, in order to avoid destroying the local ecological sensitivity, as well as reduce the construction costs.

FULL CODE (GEE)

Code Link: https://code.earthengine.google.com/2e69d87c96556d633f96e9460e2ca730

```
// DATA PREPARATION
//Load the nightlight data
var light_dataset = ee.ImageCollection('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS').select('stable_lights');
Map.addLayer(light_dataset,{min: 3.0,max: 60.0,palette:['000000','9999CC']},'nighttimeLights');
//Load province boundary of China
var China = China;
Map.addLayer(China,{color:'FFFFFF'},'China_Province');
Map.centerObject(China,4);
print(China);
//Load country boundary of China
var boundary_geo=China.geometry();
var boundary = ee.Feature(boundary_geo);

// Part.1 AN OVERVIEW OF URBAN BUILT-UP AREA CHANGES IN CHINA
//Load the nightlight from 2003-2013
var light_2003 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F152003').select('stable_lights').clip(boundary);
Map.addLayer(light_2003,{min: 3.0,max: 60.0,palette:['000000','FF9933','ffffff'],opacity:0.8},'Lights_2003');
var light_2008 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F162008').select('stable_lights').clip(boundary);
Map.addLayer(light_2008,{min: 3.0,max: 60.0,palette:['000000','FF9933','ffffff'],opacity:0.8},'Lights_2008');
var light_2013 = ee.Image('NOAA/DMSP-OLS/NIGHTTIME_LIGHTS/F182013').select('stable_lights').clip(boundary);
Map.addLayer(light_2013,{min: 3.0,max: 60.0,palette:['000000','FF9933','ffffff'],opacity:0.8},'Lights_2013');

// find the place that are considered "lit"
var blank = ee.Image(0);
function AreaLit(i){
  var threhold=blank.where(i.gt(31),1);
  var alit = threhold.mask(threhold);
  alit=alit.divide(1000000);
```

FULL CODE (GEE)

Code Link: https://code.earthengine.google.com/2e69d87c96556d633f96e9460e2ca730

```
  alit = ee.Image.pixelArea().mask(alit);
  alit=alit.set('index',i.get('system:index'));
  return alit; }
// stable nighttime light area change (by province) from 2003-2013
function tabulate(i){
  return China.map(function(f){
    var r=i.reduceRegion({
      reducer:ee.Reducer.sum(),
      geometry:f.geometry(),
      scale:500,
      bestEffort:true,
      maxPixels:1e9});
    return ee.Feature(null,{
      name:f.get('Province'),
      area:r.get('area'),
      index:i.get('index')});});}
var arelit=light_dataset.map(AreaLit);
var arelit_table=arelit.map(tabulate).flatten();
Export.table.toDrive(arelit_table,'DMSP_results','DMSP results','results','csv');

// Part.2 CALCULATE THE POSITIVE/NEGATIVE GROWTH OF URBAN BUILT-UP AREAS
// Add a band containing image data as years
function createTimeBand(img){
  return img.addBands(img.metadata('system:time_start').divide(1e18));}
//fit a linear trend to the nighttime lights collection
var getyear=function(year){
  return ee.Date.fromYMD({
    day:1,month:1,year:year});};
```

FULL CODE (GEE)

Code Link: https://code.earthengine.google.com/2e69d87c96556d633f96e9460e2ca730

```
var linear_fit=function(y1,y2){
  var startyear = getyear(y1);
  var endyear = getyear(y2);
  var timeband=light_dataset.filterDate(startyear,endyear).map(createTimeBand);
  var linearfit=timeband.select(['system:time_start','stable_lights']).reduce(ee.Reducer.linearFit()).clip(boundary);
  return linearfit;
};
var fit_china_92_95=linear_fit(1992,1995);
var fit_china_96_10=linear_fit(1996,2010);
var fit_china_10_14=linear_fit(2010,2014);
// Display Trend in Red(positive growth),Blue(negative growth), and green(stable brightness)
var visParams={min:0,max:[0.18,20,-0.18],bands:['scale','offset','scale'],opacity:0.8};
Map.addLayer(fit_china_92_95,visParams,"linear_fit_92_95");
Map.addLayer(fit_china_96_10,visParams,"linear_fit_96_10");
Map.addLayer(fit_china_10_14,visParams,"linear_fit_10_14");

// Visualize the rate of urban sprawl and shrinkage by province
// extract the pixels with positive growth (The slope of linear regression is positive) and negative growth (The slope of linear regression is negative)
var positive_growth=function(img){
  var img_scale=img.select("scale");
  var positive=img_scale.multiply(img_scale.gt(0));
  return positive;   };
var negative_growth=function(img){
  var img_scale=img.select("scale");
  var negative=img_scale.multiply(img_scale.lt(0).multiply(-1));
  return negative;   };
var positive_10_14=positive_growth(fit_china_10_14);
var negative_10_14=negative_growth(fit_china_10_14);
```

```
Map.addLayer(positive_10_14,{min: 3.0,max: 60.0,palette:['000000','FF6666'],opacity:0.8},"positive_10_14");
Map.addLayer(negative_10_14,{min: 3.0,max: 60.0,palette:['000000','006699'],opacity:0.8},"negative_10_14");

//count the pixel of positive_growth and negative_growth by province, respectively
function count_positive(Chi){
  var area =positive_10_14.reduceRegion({
    reducer:ee.Reducer.sum(),
    geometry:Chi.geometry(),
    scale:500,
    bestEffort:true,
    maxPixels:1e9});
  var Chi_copy=Chi;
  return Chi_copy.set({LitArea:area.get('scale')});  }
function count_negative(Chi){
  var area =negative_10_14.reduceRegion({
    reducer:ee.Reducer.sum(),
    geometry:Chi.geometry(),
    scale:500,
    bestEffort:true,
    maxPixels:1e9});
  var Chi_copy=Chi;
  return Chi_copy.set({LitArea:area.get('scale')});  }
var area_positive=China.map(count_positive);
var area_negative=China.map(count_negative);

//calculate the ratio of positive_growth/negative_growth area and total area
function density(Chi){
  var Area=ee.Number(Chi.area());
  var ratio=ee.Number(Chi.get('LitArea')).divide(Area);
```

FULL CODE (GEE)

Code Link: https://code.earthengine.google.com/2e69d87c96556d633f96e9460e2ca730

```
  var Chi_copy=Chi;
  return Chi_copy.set({"ratio":ratio});}
var ratio_positive=area_positive.map(density);
var ratio_negative=area_negative.map(density);
// plot the choropleth map of ratio by province
var choropleth=function(fc){
  var img=fc.reduceToImage(["ratio"],ee.Reducer.first());
  return img; };
var img_positive=choropleth(ratio_positive);
Map.addLayer(img_positive,{max:130,min:0,palette:["FFFFFF","E99C9A","E96D6A","C02A26","5D0606"],opacity:1},
                           "positive growth area/total area");
var img_negative=choropleth(ratio_negative);
Map.addLayer(img_negative,{max:130,min:0,palette:["FFFFFF","8FB2D1","679FD1","20517C","092C4C"],opacity:1},
                           "negative growth area/total area");
//identify provinces with the largest urban expansion rate and contraction rate
var top_positive=ratio_positive.limit(10,"ratio",false);
print(top_positive);
var top_negative=ratio_negative.limit(10,"ratio",false);
print(top_negative);
//export the result table
Export.table.toDrive({
  collection:top_positive,
  description: "top_positive",
  fileNamePrefix: "top_positive",
  fileFormat: "KML",
  selectors: ["Province","ratio"]  });
Export.table.toDrive({
  collection:top_negative,
  description: "top_negative",
```

FULL CODE (GEE)

Code Link: https://code.earthengine.google.com/2e69d87c96556d633f96e9460e2ca730

```
fileNamePrefix: "top_negative",
fileFormat: "KML",
selectors: ["Province","ratio"]  });

// Part.3 CHARACTERISTIC OF URBAN CONTRACTION & EXPANSION AREAS
//Load the selected two province
var selected = selected;
Map.addLayer(selected,{color:'FFFFFF'},'selected_province');
Map.centerObject(selected,4);
print(selected);
var selected_boundary_geo=selected.geometry();
var boundary_selected = ee.Feature(selected_boundary_geo);

//Load and Reclassify the landcover data
var landcover=  ee.Image('MODIS/006/MCD12Q1/2010_01_01').select('LC_Type1');
var landcover_classify =landcover.remap([1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17],
                                          [1,1,1,1,1,2,2,2,2,2,3,3,4,3,2,2,5], 0, 'LC_Type1');
var ColorsForMODIS  = [
    'B2D732', // 01 = Forest
    '225129', // 02 = Shrubland&grass
    '369b47', // 03 = cropland&wetland
    'CC3333', // 04 = urban
    '0099CC', // 05 = water
    ].join(',');
var DisplaySETTINGS = { min:1, max:5, opacity:1, palette:ColorsForMODIS };
var landcover_classify=landcover_classify.clip(boundary_selected);
Map.addLayer(landcover_classify,DisplaySETTINGS, 'Land Cover Classes' );
print(landcover_classify);
```

FULL CODE (GEE)

Code Link: https://code.earthengine.google.com/2e69d87c96556d633f96e9460e2ca730

```
//Load the population density data
var pop = ee.ImageCollection("CIESIN/GPWv411/GPW_Population_Density").first();
var raster_pop = pop.select('population_density').clip(boundary_selected);

var raster_vis = {
  "max": 1000.0,
  "palette": ["ffffe7", "FFc869","ffac1d","e17735","f2552c","9f0c21"],
  "min": 200.0
};
Map.addLayer(raster_pop, raster_vis, 'population_density');

//Load the elevation data
var elevation = ee.Image('USGS/GMTED2010').select('be75').clip(boundary_selected);
var terrain=ee.Terrain.aspect(elevation);
Map.addLayer(terrain, {opacity:1}, 'terrain');
var slope=ee.Terrain.slope(elevation);
var suitable=ee.Image(slope).lt(0.5);
var suitable_area=slope.mask(suitable);
Map.addLayer(suitable_area, {palette:"95e1d3"},'suitable');
var unsuitable=ee.Image(slope).gte(0.5);
var unsuitable_area=slope.mask(unsuitable);
Map.addLayer(unsuitable_area, {palette:"f38181"},'unsuitable');

//Load the climate data
var dataset = ee.ImageCollection('MODIS/006/MOD11A1')
                  .filter(ee.Filter.date('2013-01-01', '2013-12-31'));
var landSurfaceTemperature = dataset.select('LST_Day_1km').mean().clip(boundary_selected);
```

FULL CODE (GEE)

Code Link: https://code.earthengine.google.com/2e69d87c96556d633f96e9460e2ca730

```
var landSurfaceTemperatureVis = {
  min: 13000.0, max: 16500.0,
  palette: [
    '040274', '040281', '0502a3', '0502b8', '0502ce', '0502e6',
    '0602ff', '235cb1', '307ef3', '269db1', '30c8e2', '32d3ef',
    '3be285', '3ff38f', '86e26f', '3ae237', 'b5e22e', 'd6e21f',
    'fff705', 'ffd611', 'ffb613', 'ff8b13', 'ff6e08', 'ff500d',
    'ff0000', 'de0101', 'c21301', 'a71001', '911003’],
};
Map.addLayer(
    landSurfaceTemperature, landSurfaceTemperatureVis,
    'Land Surface Temperature');
var Temp = landSurfaceTemperature.multiply(0.02).subtract(273.15);
var temp_frosty=ee.Image(Temp).lte(8);
var frosty=Temp.mask(temp_frosty);
Map.addLayer(frosty,{palette:"0502b8"},"frosty");
var temp_cold=ee.Image(Temp).gt(8).and(Temp.lte(15));
var cold=Temp.mask(temp_cold);
Map.addLayer(cold,{palette:"30c8e2"},"cold");
var temp_cool=ee.Image(Temp).gt(15).and(Temp.lte(20));
var cool=Temp.mask(temp_cool);
Map.addLayer(cool,{palette:"3ff38f"},"cool");
var temp_warm=ee.Image(Temp).gt(20).and(Temp.lte(25));
var warm=Temp.mask(temp_warm);
Map.addLayer(warm,{palette:"ffd611"},"warm");
var temp_hot=ee.Image(Temp).gt(25);
var hot=Temp.mask(temp_hot);
Map.addLayer(hot,{palette:"de0101"},"hot");
```

FULL CODE (GEE)

Code Link: https://code.earthengine.google.com/2e69d87c96556d633f96e9460e2ca730

```
//Load the precipitation data
var CHIRPS= ee.ImageCollection('UCSB-CHG/CHIRPS/PENTAD’);
// Filter Date of the CHIRPS data
var jiangsu=jiangsu;
var jilin=jilin;
var rain = CHIRPS.filterDate('2010-01-01', '2013-12-31’);
// Visualize 2010-2013 precipitation time series in a chart
var per_js = Chart.image.series(rain, jiangsu, ee.Reducer.mean(),500,'system:time_start').
                                setOptions({ title: 'Precipitation of Jiangsu (2010-2013)', vAxis: {title: 'mm/pentad'}});
var per_jl = Chart.image.series(rain, jilin, ee.Reducer.mean(),500,'system:time_start').
                                setOptions({ title: 'Precipitation of Jiangsu (2010-2013)' ,
                                           vAxis: {title: 'mm/pentad'}});
print(per_js);
print(per_jl);
// Map out results
var Precip = rain.reduce(ee.Reducer.mean()).clip(selected);
Map.addLayer(Precip, {'min': 0, 'max': 15,opacity:0.7, 'palette':'E9F5F4,BAF5F3,006363'}, 'precipitation’) ;

// ADD THE LEGEND
function addLegend(palette, names) {
 //Panel
 var legend = ui.Panel({
   style: {
     position: 'bottom-right',
     padding: '5px 10px'
   }
 });
```

FULL CODE (GEE)

Code Link: https://code.earthengine.google.com/2e69d87c96556d633f96e9460e2ca730

```
//Label
var title = ui.Label({
  value: 'Legend',
  style: {
    fontWeight: 'bold',
    color: "black",
    fontSize: '16px'
  }
});
legend.add(title);
//add color and name
var addLegendLabel = function(color, name) {
      var showColor = ui.Label({
        style: {
          backgroundColor: '#' + color,
          padding: '8px',
          margin: '0 0 4px 0'
        }
      });
      var desc = ui.Label({
        value: name,
        style: {margin: '0 0 4px 8px'}
      });
      return ui.Panel({
        widgets: [showColor, desc],
        layout: ui.Panel.Layout.Flow('horizontal')
      });
};
for (var i = 0; i < palette.length; i++) {
  var label = addLegendLabel(palette[i], names[i]);
  legend.add(label);
}
Map.add(legend);
}
//define palette & names
var palette = ["95e1d3","f38181"];
var names = ["Suitable for construction(Slope less than 0.5)","unsuitable for construction(Slope greater than 0.5)"];
addLegend(palette, names);
```

```
//var palette = ['B2D732','225129', '369b47', 'CC3333','0099CC'];
//var names =
["Forest","Shrubland&grass","cropland&wetland","urban","water"];

//var palette = ["0502b8","30c8e2","3ff38f","ffd611","de0101"];
//var names =
["frosty","cold","cool(suitable)","warm(suitable)","hot"];

//var palette = ['ffffe7','FFc869', 'ffac1d',
'e17735','f2552c',"9f0c21"];
//var names = ["low density","medium-low density","medium
density","medium-high density","high density","super-high density"];
```

FULL CODE (ArcPy Script)

Script 1 FindGravityCenter

```
# Import external modules
import sys, os, string, math, arcpy, traceback, numpy
from arcpy.sa import *

# Allow output to overwite any existing grid of the same name
arcpy.env.overwriteOutput = True

# If Spatial Analyst license is available, check it out
if arcpy.CheckExtension("spatial") == "Available":
    arcpy.CheckOutExtension("spatial")

    try:
        # set local variables
        InputRaster= arcpy.GetParameterAsText(0)
        InputShapefile=arcpy.GetParameterAsText(1)
        arcpy.AddMessage('\n'+"The input raster name is "+ InputRaster)
        arcpy.AddMessage('\n'+"The input shapefile name is "+ InputShapefile)
        OutputShapefile=arcpy.GetParameterAsText(2)
        OutputShapefile_polygon=arcpy.GetParameterAsText(3)
        OutputShapefile_point=arcpy.GetParameterAsText(4)
        arcpy.AddMessage('\n'+"The output shapefile name is "+ OutputShapefile)
        arcpy.AddMessage('\n'+"output shapfile(selected polygon) is" +
                                  OutputShapefile_polygon +"\n")
        arcpy.AddMessage('\n'+"output shapefile(gravity center point)
                                 is" +  OutputShapefile_point +"\n" )
```

FULL CODE (ArcPy Script)

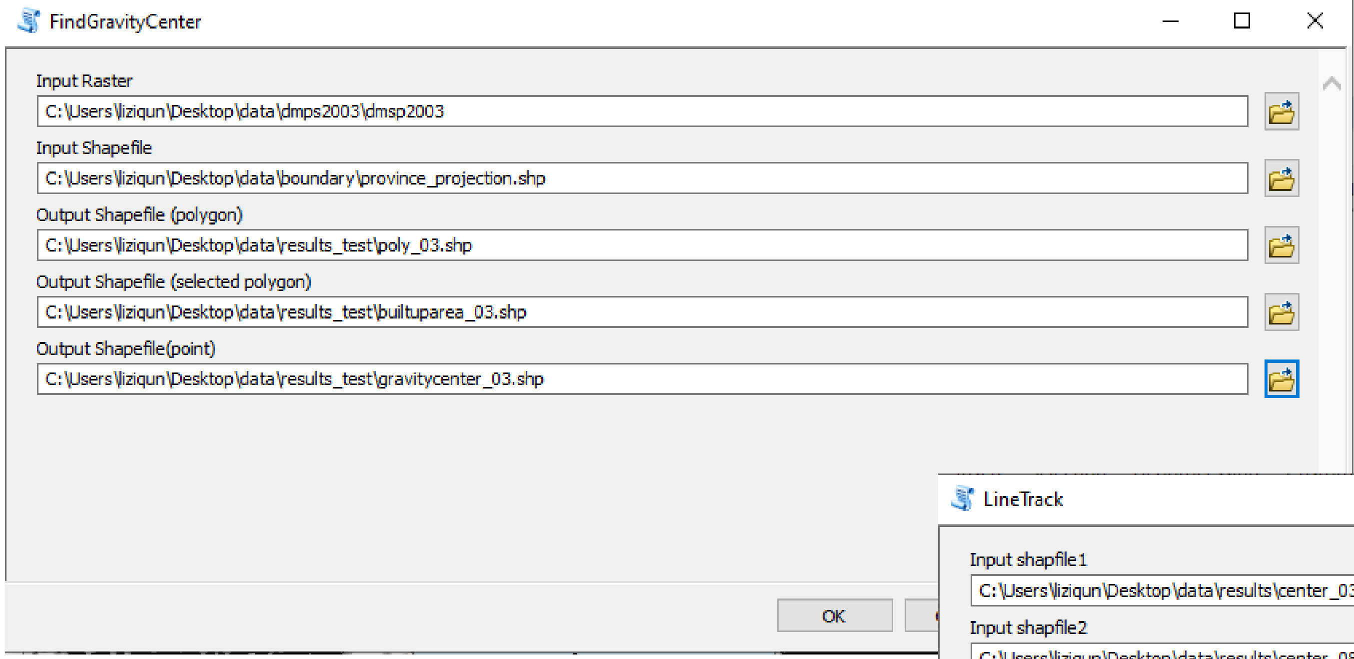
```
        # Execute ExtractByMask
        outExtractByMask = ExtractByMask(InputRaster, InputShapefile)
        # Execute RasterToPolygon
        arcpy.RasterToPolygon_conversion(outExtractByMask, OutputShapefile, "NO_SIMPLIFY", "value")

        # Make a layer from the input shapefile
        arcpy.MakeFeatureLayer_management(OutputShapefile, "polygon")
        # Selected only those polygons that have a value more than 31
        arcpy.SelectLayerByAttribute_management("polygon","NEW_SELECTION",'"gridcode" >= 31')
        # Write the selected features to a new featureclass
        arcpy.CopyFeatures_management("polygon", OutputShapefile_polygon)
        # Process: Mean Center
        arcpy.MeanCenter_stats("polygon", OutputShapefile_point, "gridcode", "#", "#")

        # Deactivate ArcGIS Spatial Analyst license
        arcpy.CheckInExtension("spatial")

    except Exception as e:
        # If unsuccessful, end gracefully by indicating why
        arcpy.AddError('\n' + "Script failed because: \t\t" + e.message )
        # ... and where
        exceptionreport = sys.exc_info()[2]
        fullermessage   = traceback.format_tb(exceptionreport)[0]
        arcpy.AddError("at this location: \n\n" + fullermessage + "\n")
    # Check in Spatial Analyst extension license
    arcpy.CheckInExtension("spatial")
else:
    print "Spatial Analyst license is " + arcpy.CheckExtension("spatial")
```

FULL CODE (ArcPy Script)

Script 2 TrackLine

```
# import external modules
import sys,string,os,arcpy,traceback,math,csv
# set environment
arcpy.env.overwriteOutput = True
try:
    # Receive parameters
    Inputshp_point_1=arcpy.GetParameterAsText(0)
    Inputshp_point_2=arcpy.GetParameterAsText(1)
    Inputshp_point_3=arcpy.GetParameterAsText(2)
    Outputshp_points=arcpy.GetParameterAsText(3)
    Outputshp_lines=arcpy.GetParameterAsText(4)

    # merge the shapefiles
    arcpy.Merge_management([Inputshp_point_1, Inputshp_point_2,Inputshp_point_3],
                           Outputshp_points, "")

    # Create the new polyline shapefile
    arcpy.PointsToLine_management(Outputshp_points,Outputshp_lines)

except Exception as e:
    # if unsuccessful, end gracefully by indicating why
    arcpy.AddError('\n'+"Script failed because:\t\t"+e.message)
    # and where
    exceptionreport = sys.exc_info()[2]
    fullermessage=traceback.format_tb(exceptionreport)[0]
    arcpy.AddError("at this location:\n\n"+fullermessage+"\n")
```

FULL CODE (ArcPy Script)



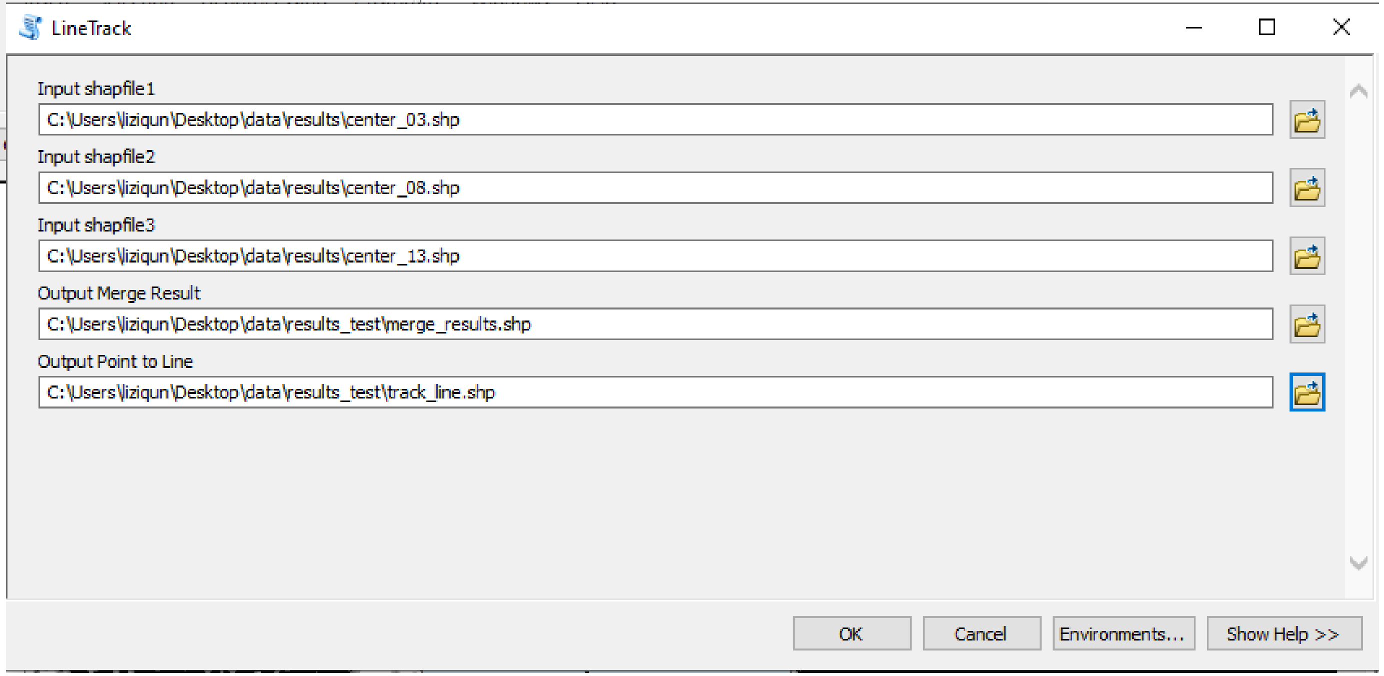
Dialog box of script 1

"""""

PARAMETERS OF SCRIPT 1:

Displayed Name	Data Type	VALUE
Input Raster	Raster Dataset	Input
Input Shapefile	Shapefile	Input
Output Shapefile(polygon)	Shapefile	Output
Output Shapefile(selected polygon)	Shapefile	Output
Output Shapefile(point)	Shapefile	Output

"""""



"""“

PARAMETERS OF SCRIPT 2 :

Displayed Name	Data Type	VALUE
Input shapefile1	Shapefile	Input
Input Shapefile2	Raster Dataset	Input
Input Shapefile3	Raster Dataset	Input
Output Merge Result	Shapefile	Output
Output Point to line	Shapefile	Output

"""""

Dialog box of script 2