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# Measuring Regional Difference in Urban Growth of Taipei City (Taiwan, China) by Means of ENVI GIS and Remote Sensing Data

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# Measuring regional difference in urban growth of Taipei city (Taiwan, China) by means of ENVI GIS and remote sensing data

2013/05/02 13:26

# Structure of Presentation

Current presentation consists in 2 parts:

- 1) Overview of the **environmental** research problem, urbanization and characteristics of Taipei. Consequences of urban sprawl for the global cities, such as Taipei.
- 2) Detailed **technical** description of the GIS part: remote sensing data capture, pre-processing, algorithm processing, image classification and spatial analysis.

Part I

**Part I:**  
**Environmental Analysis**

# Summary

- Research area: Taipei urban landscapes, Taiwan R.O.C.
- Research aim: spatio-temporal analysis of urban dynamics in study area during 15 years (1990-2005)
- Research objective: application of geoinformatic tools, remote sensing data and application of methodology to spatial analysis for urban studies, a case study of Taipei
- Current work has been supported by the Taiwan Ministry of Education Short Term Research Award (STRA) for research stay at National Taiwan University (NTU), Department of Geography during April-May 2013.

# Introduction: study area

- **Study area** is located in Taiwan, Taipei city capital area.
- **Location:** Taipei is located on the north of the Taiwan island
- **Significance:** Taipei is the Taiwan's core urban political & economic center
- **Characteristics:** the fundamental features of the Taipei city include its favorable topographic location and climatic- geographic settings. This provided advantageous conditions for habitation here during centuries.

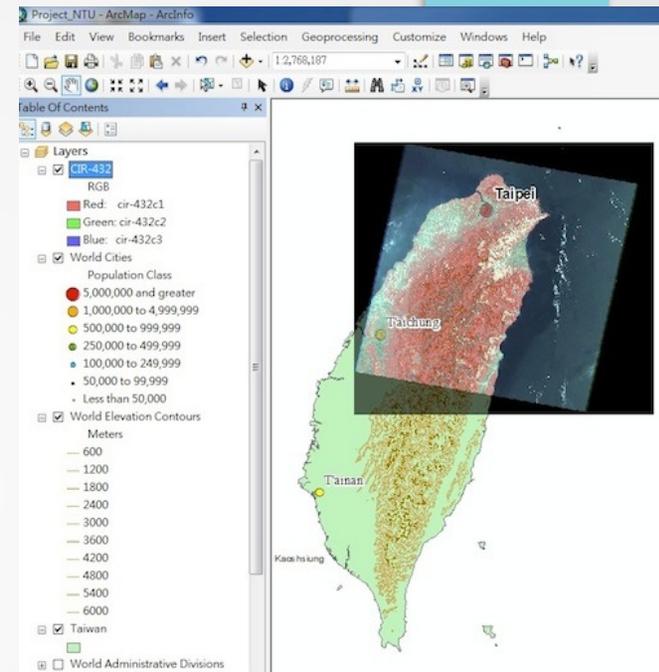


Fig.1. Study area: overlay of the Landsat TM image with vector map of Taiwan Island and elevation contours. ArcGIS visualization.

**Physical geography:** the geomorphology of Taipei is characterized by mostly flat relief within the city and several rivers of Tamsui basin with alluvial soils. Natural borders of the city are created by surrounding mountains and hills ([Tsou & Cheng, 2013](#)). Rich sediments from the upstream area maintain soils fertility, creating favorable resources for agricultural activities ([Huang et al., 2001](#)).

# How anthropogenic activities affect landscapes

Urban growth and city sprawl affects ecosystems.

Consequences of human impacts include:

- landscape degradation,
- changes in land cover and land use types,
- decrease in biodiversity richness within the city,
- deforestation, urbanization, and wetlands destruction ([Chen and Lin, 2013](#))
- decreased in species; losses of rare and extinct species

[\(McKinney, 2006; Shochat et al., 2004; Ramachandra et al., 2012\)](#)

In turn, modified land use types...

- affect hydrological components in the surrounding watersheds and
- cause changes of the land use **patterns**, namely, landscape **composition**, **configuration**, **connectivity**, **variety** and **abundance** of patch types within a landscape, which are the primary descriptors of the landscape patterns ([Lin et al., 2007](#)).

# “Land cover” vs “land use” types...

1. **Land cover** data documents **how much of a region is covered by** forests, wetlands, impervious surfaces, agriculture, and other land and water types. Water types include wetlands or open water.

while....

2. **Land use** shows just how **people** use the landscape – whether for development, conservation, or mixed uses. The different types of land cover can be managed or used quite differently.

**Land cover** can be determined by analyzing satellite and aerial imagery.

**Land use** cannot be determined from satellite imagery.

Land cover maps provide information to help best understand the current landscape.

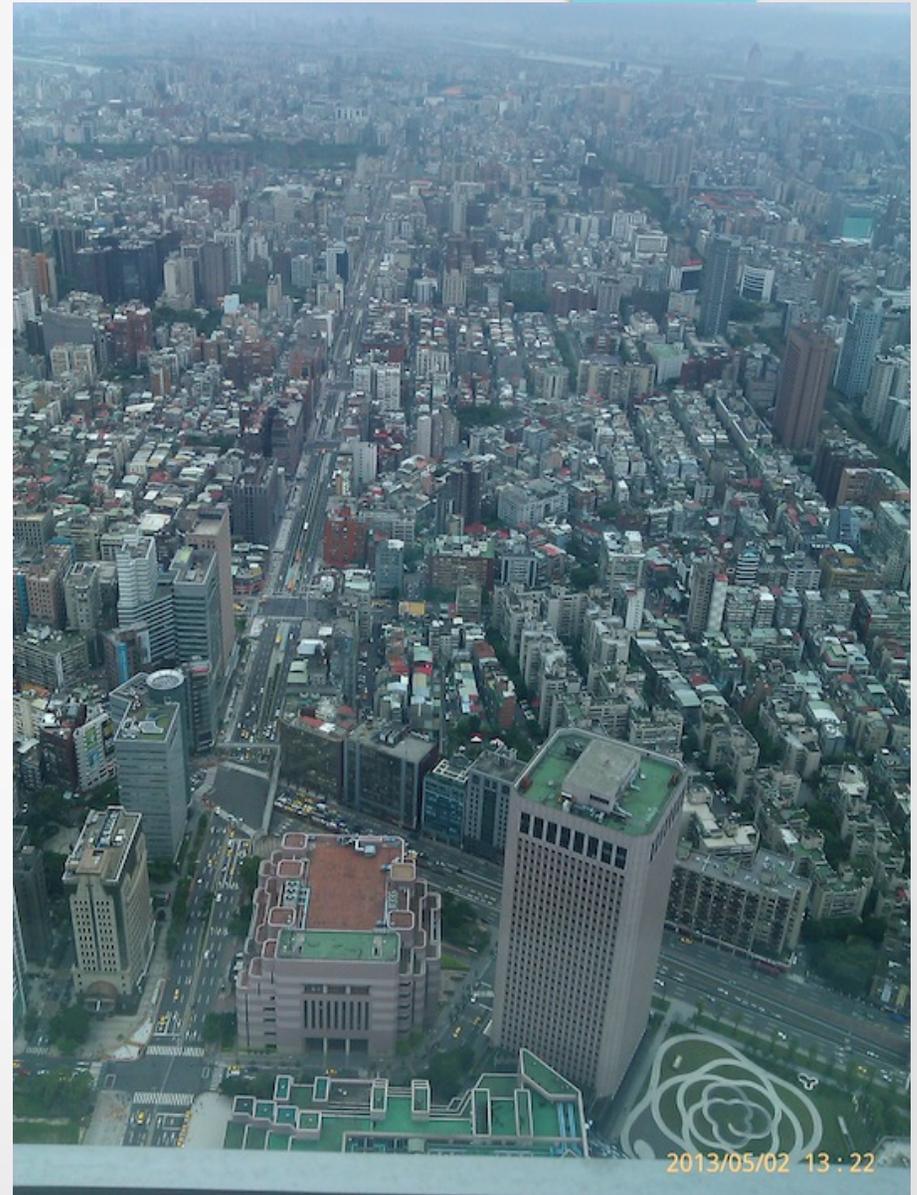
This research focused on study of **land cover types in Taipei** using GIS & RS.

To see changes in land cover types over time, images (RS data) for several different years are needed. With this information, I evaluated past situation as well as gained insight into the effects of urban sprawl in Taipei area.

# Taipei's urban area

A Taipei population living within an area of 271.8 square kilometers has a density of 9566 persons / square km, which is higher than the corresponding figures for most of Asia's other major cities ([Tsou & Cheng, 2013](#)).

Located on the north of the Taiwan Island, Taipei is the country's core urban political and economic center with population reaching over 2.6 M and continuing to expand within the metropolitan region.



# Urbanization of Taipei

Global cities, such as Taipei, have to face specific environmental problems, due to the **concentrated human density** and **environmental pressure** within the **limited geographic space and resources**.

Consequences of urbanization (selected, the most major ones):

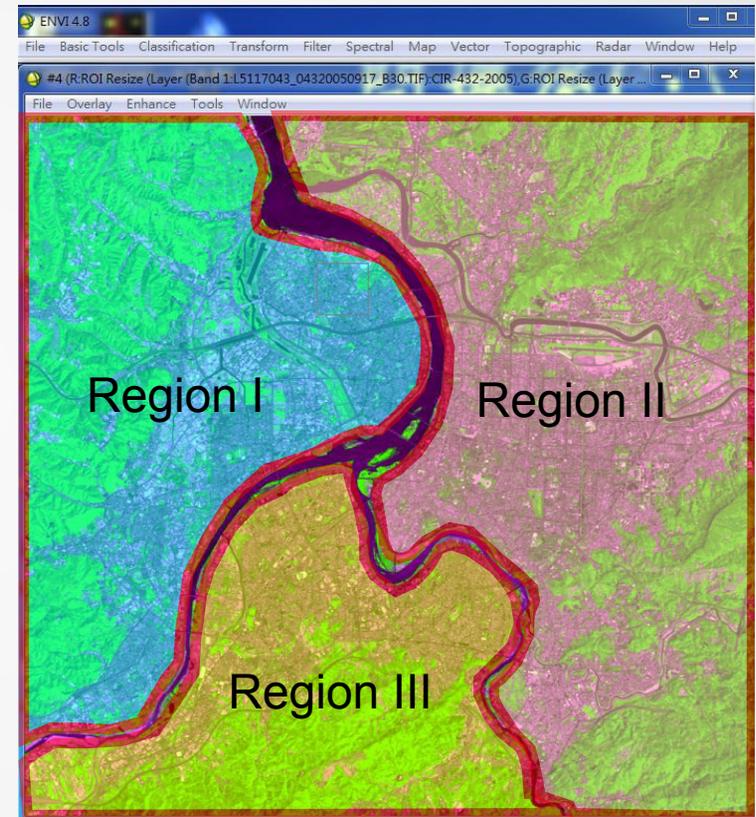
- 1) transformation in **structure of natural landscapes**: e.g. simplification of species, changes in landscape composition, disconnected and disrupted components within the hydrological systems, fragmentation of natural habitats.
- 2) changes in **land cover types**: e.g., from forests, river deltas, meadows, native grasslands, wetlands, etc towards anthropogenic affected **agricultural areas** or **built-up areas** which consist of large amounts of **impervious surfaces**, covered by concrete blocks, asphalt pavement, bricks, buildings...
- 3) significantly altered **aboveground net primary productivity**
- 4) serious changes in **soil respiration rates**, compared to natural ecosystems (Kaye et al., 2005),
- 5) **air pollution** and
- 6) decreased **water quality** ([Huang et al., 2001](#))

# Urban areas in Taipei: regional differences

Uncontrolled urbanization is gradual limitation of the land and water resources, which leads insufficient infrastructure within the city and consequently, contributes to the development of densely concentrated mixed types of land use.

According to [Tsou and Cheng \(2013\)](#), about 45% of the Taipei city is categorized as restricted with regard to availability and usage due to its topography. Only 14% (46.30 km<sup>2</sup>) is available for further development (residential and commercial).

Nowadays, new Taipei city face consists of built-up new apartments, buildings, office centers and residential areas, re-structured districts. This process is reinforced by the average structure age of the buildings and modernization ([Lin and Jhen, 2009](#)).



Regional differences in Taipei city: these areas have been undergone urbanization at different rates and in different years.

# Urban ecosystems: structure & functions

The urban ecosystems have highly complex composing structure and functioning. In the variety of Earth landscapes, urban landscapes have the highest level of ecosystems hierarchy.

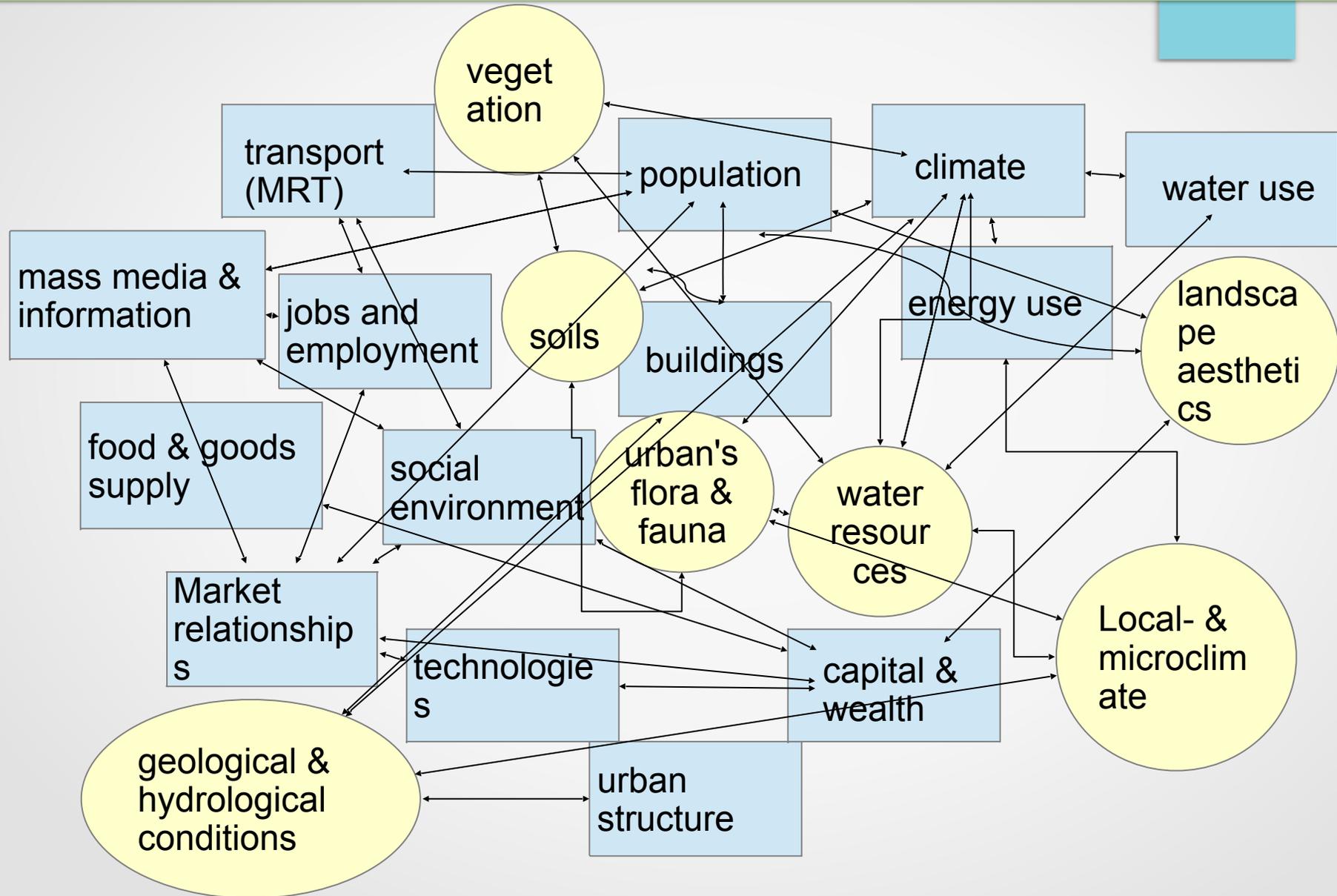
The energy flows and density reach the most intensity in the cities (comparing to natural and semi-natural ecosystems).

From the geographic point of view, city landscapes are composed of the green areas of various shape and size, water bodies, human built-up quarters and hilly mountainous areas.

Typical functions of urban ecosystem include: **cultural, supporting** and **regulating** services which indicate core criteria for the measurement of the environmental quality of urban areas ([Flores et al., 1998](#)).

[Bonaiuto et al. \(2003\)](#) developed the complexity of these functions and suggested four aspects of the urban landscapes: 1) **spatial** (architecture and planning space, 2) **organization** and access to green spaces within the city), 3) **human** (i.e. people and social interrelations), 4) **functional** (recreational, commercial, transport services and welfare) and 5) **contextual** aspects (life style and environmental health).

# Urban structure: a simplified flowchart



# Urbanization

In the past decades, the process of urbanization became more and more notable in the world. About half of the world's population will reside in urban areas and cities by 2000 ([Huang et al., 1998](#)).

World's global megapolises (e.g. New York, London, Tokyo, Taipei, Paris, Seoul, Hong Kong, Singapore, cites of Silicon Valley) are the key engines of the human development and global cooperation.

The importance of these cities cannot be underestimated: such cities are the drivers of these economies and play more important role than national and regional economy in their countries ([Scott, 2000](#); [Hsu, 2005](#); [Sassen, 2001](#)).

Capitals and megapolises:...

- **control resources and information**,
- attract major **material and economic forces**,
- trigger **human activities**,
- attract **financial investments** for further development
- involve **informational knowledge centers and strategies**, etc

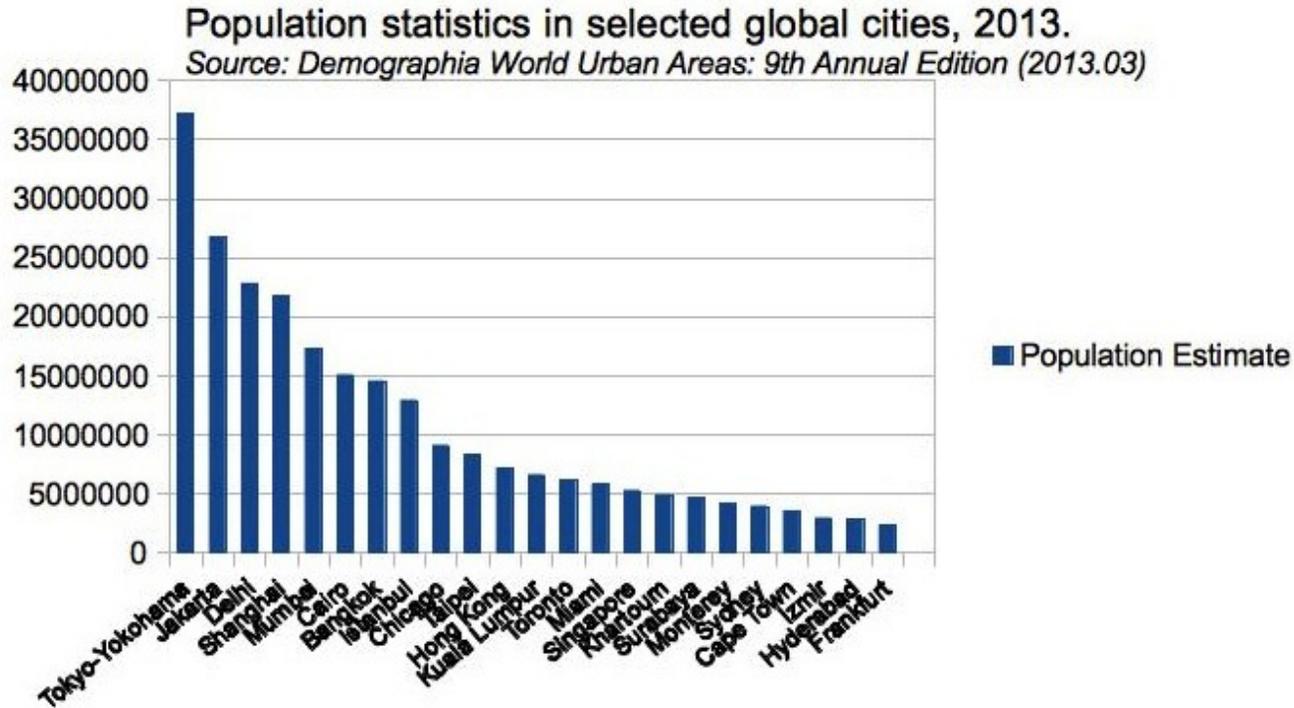
# Urbanization of Taipei

Global cities, such as Taipei, have to face specific environmental problems, due to the **concentrated human density** and **environmental pressure** within the **limited geographic space and resources**.

## Consequences of urbanization:

- 1) transformation in **structure of natural landscapes**: e.g. simplification of species, changes in landscape composition, disconnected and disrupted components within the hydrological systems, fragmentation of natural habitats.
- 2) changes in **land cover types**: e.g., from forests, river deltas, meadows, native grasslands, wetlands, or agricultural areas, towards anthropogenic affected **built-up areas** which consist of large amounts of **impervious surfaces**, covered by concrete blocks, asphalt pavement, bricks, buildings...
- 3) significantly altered **aboveground net primary productivity**
- 4) serious changes in **soil respiration rates**, compared to natural ecosystems (Kaye et al., 2005),
- 5) **air pollution** and decreased **water quality** ([Huang et al., 2001](#))

# Taipei comparing to largest urban areas in the world



Taipei's population = **2,618,772** people

Taipei metropolitan area (Taipei, New Taipei & Keelung)= **6,900,273** people

Taiwan' population (for the whole country) according to the last two censuses:  
year 1990: **20.393,628**; year 2000: **22.226,879.**; year 2012: **23,315,822.**

Source: "Number of Villages, Neighborhoods, Households and Resident Population". MOI Statistical Information Service. Retrieved 2 January 2013.

# Environmental problems of Taipei

Human-driven effects on the environment and landscapes of Taipei agglomeration consist in **high industrialization and urbanization**.

The spatiotemporal pattern of landscape diversity changed within Taipei metropolitan region between 1971 and 2005.

Rapid urbanization affects **interrelations between natural and urban ecosystems**, changes their **structure, size** and **shape**, which gradually became a serious environmental problem.

Thus, in Taipei, natural, typical land cover types are being gradually transformed into human-affected artificial surfaces ([Hung et al., 2010](#)).

Analysis of the landscape biogeographic characteristics of the urban forests shows that species diversity, composition and richness, spatial variability is done by [Jim and Chen, 2008](#). According to their findings, the **Taipei's urban the built-up areas with space limitations the poorest biodiversity richness**, while parks accommodate the highest one, as represented by native species.

Part II

**Part II:**  
**GIS - Processing**

# Techniques

- The research was performed using ENVI GIS software using Landsat TM images for years 1990 and 2005.
- The landscapes in study area at both Landsat TM images were classified using "K-means" algorithm into different land use types
- The area covered by each land cover class is compared and dynamics is analyzed for respecting years.
- The changes in selected land cover types were analyzed and the human impacts on natural landscapes detected.
- Finally, classified land cover types across study area were compared at both maps of land cover types for the years 1990 and 2005, respectively.

# Methods

Methods used in the current work include following steps:

*Data capture*

*Color composition from 3 bands*

*Defining Region of Interest (ROI)*

*Selection of 3 different regions within the city area*

*Image classification*

*Combining classes and re-classification*

*Post-processing*

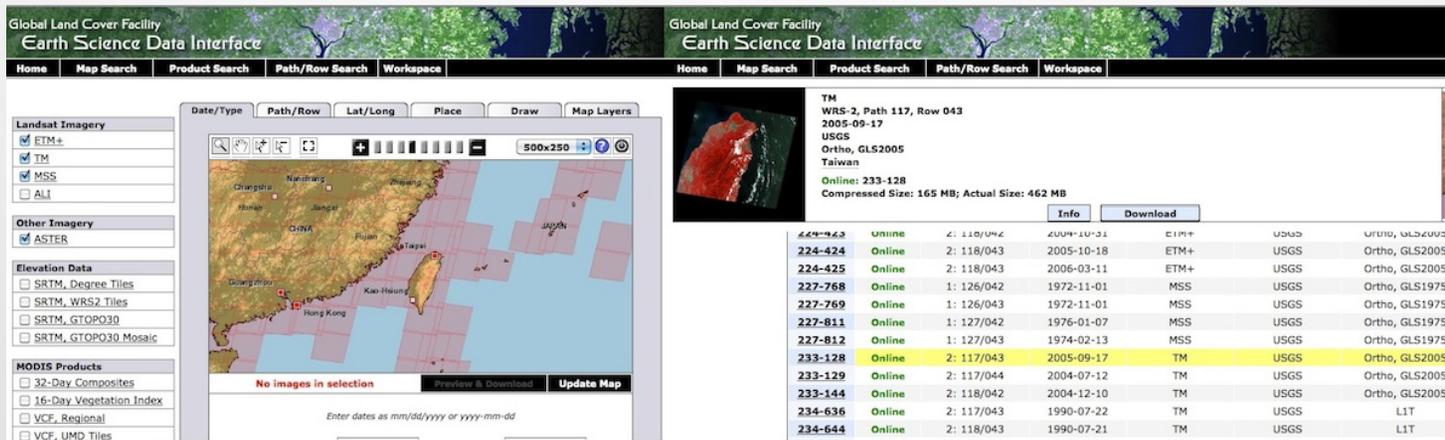
*Spatial analysis for 3 different areas of Taipei city*

# Data capture

The research data include Landsat TM imagery taken from the U.S.G.S. website covering world with satellite images.

The importance of the GIS and remote sensing (RS) data were successfully used for environmental monitoring since 1970s (rapid development of Earth observation satellite systems and launch of the Landsat TM program).

However, with regards to selected territory in Taipei, given study period (1999-2005), and focused on 3 different areas within Taipei, the effective application of the RS data, such as Landsat TM, have received scant attention. Therefore, current study applies Landsat TM imagery for geospatial analysis of the study area in the period of 1990-2005 with comparison of three districts of Taipei.

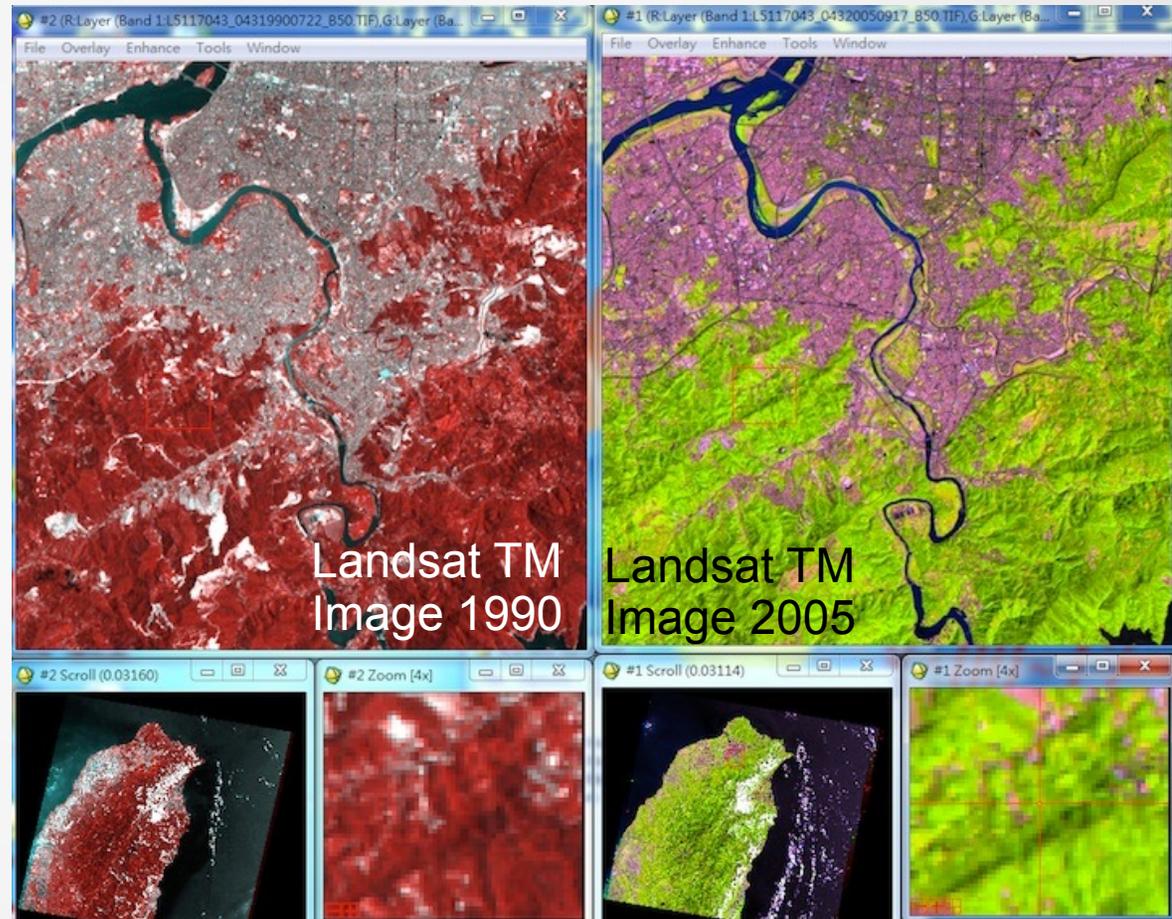


The screenshot displays the Global Land Cover Facility Earth Science Data Interface. The interface includes a navigation menu (Home, Map Search, Product Search, Path/Row Search, Workspace) and a search bar. The main area shows a map of Taiwan with a grid overlay. A sidebar on the left contains filters for Landsat Imagery (ETM+, TM, MSS, ALI), Other Imagery (ASTER), Elevation Data (SRTM, WRS2, TOPO30), and MODIS Products (32-Day Composites, 16-Day Vegetation Index, VCF\_Regional, VCF\_UMD Tiles). The right side of the interface shows a detailed view of a selected Landsat TM image (TM WRS-2, Path 117, Row 043, 2005-09-17) and a table of available imagery data.

Product ID	Availability	Path/Row	Date	Product	Agency	Tile ID
224-424	Online	2: 118/043	2005-10-18	ETM+	USGS	Ortho, GLS2005
224-425	Online	2: 118/043	2006-03-11	ETM+	USGS	Ortho, GLS2005
227-768	Online	1: 126/042	1972-11-01	MSS	USGS	Ortho, GLS1975
227-769	Online	1: 126/043	1972-11-01	MSS	USGS	Ortho, GLS1975
227-811	Online	1: 127/042	1976-01-07	MSS	USGS	Ortho, GLS1975
227-812	Online	1: 127/043	1974-02-13	MSS	USGS	Ortho, GLS1975
233-128	Online	2: 117/043	2005-09-17	TM	USGS	Ortho, GLS2005
233-129	Online	2: 117/044	2004-07-12	TM	USGS	Ortho, GLS2005
233-144	Online	2: 118/042	2004-12-10	TM	USGS	Ortho, GLS2005
234-636	Online	2: 117/043	1990-07-22	TM	USGS	LIT
234-644	Online	2: 118/043	1990-07-21	TM	USGS	LIT

# Data

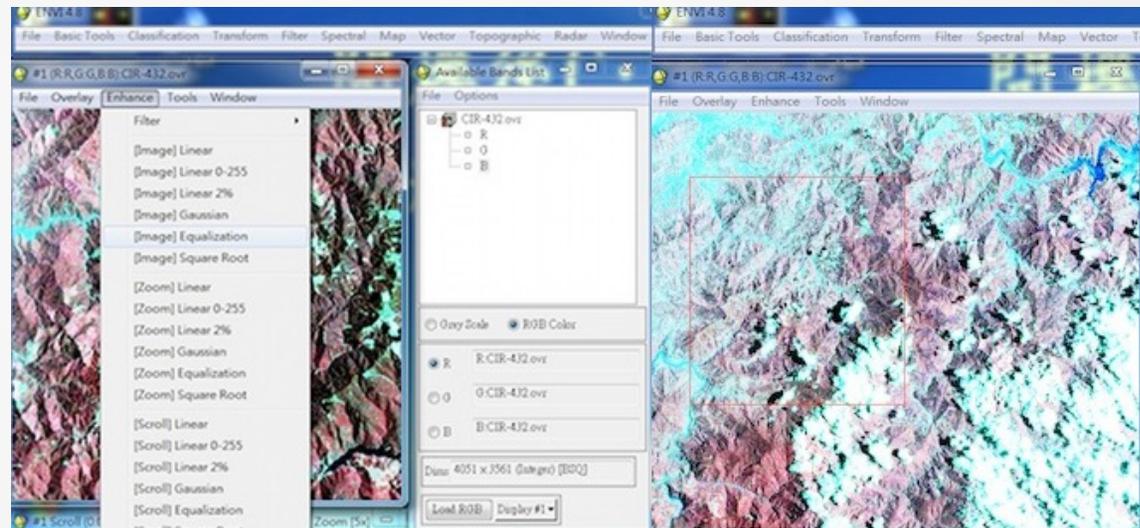
- Data used in the research include 2 Landsat TM images.
- Images cover the same area of southern surroundings of Taipei, Taiwan (along the Tamsui river).
- The data taken in summer periods, on 1990 and 2005.



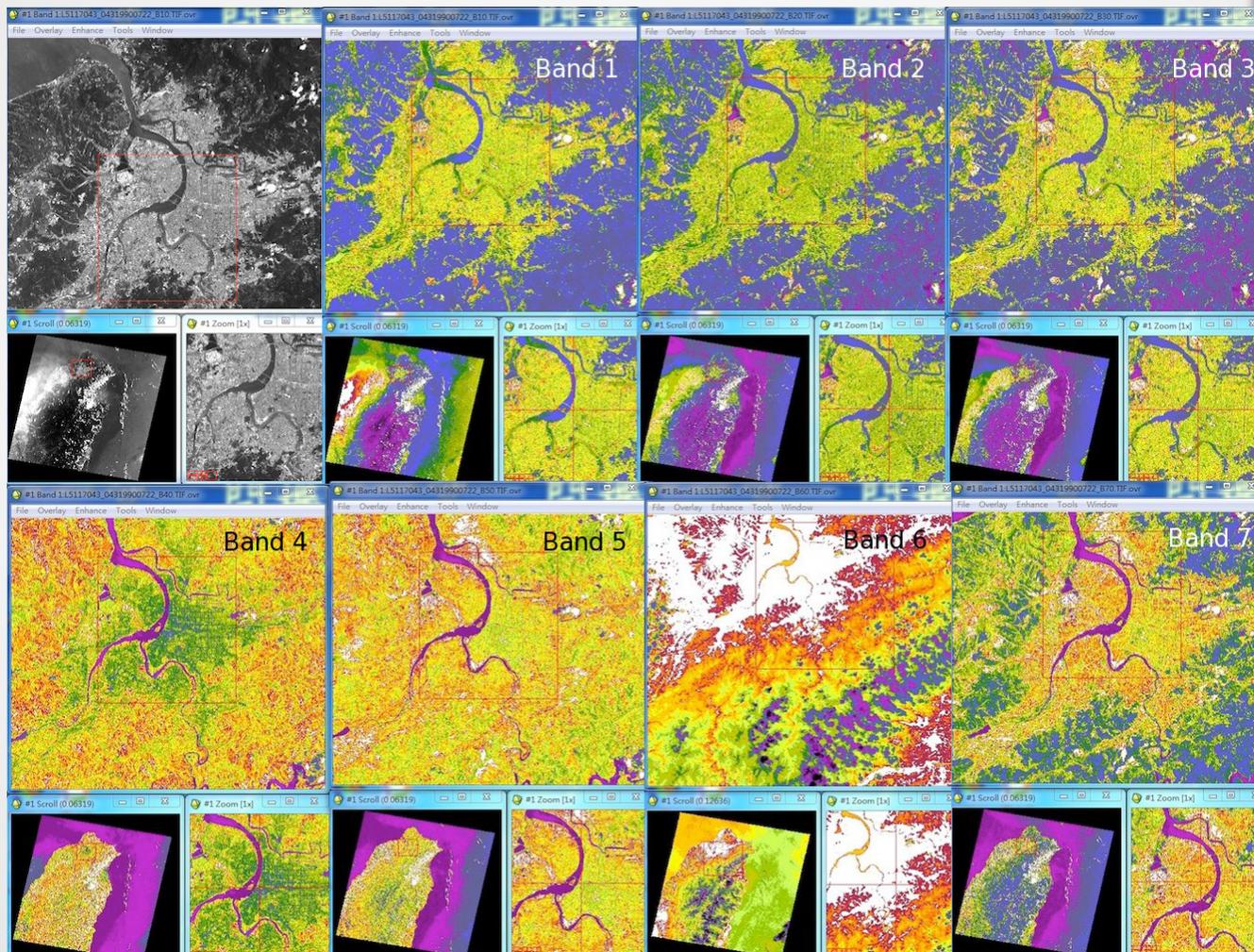
# Preliminary data processing.

The preliminary data processing includes image contrast stretching, which is useful as by default, ENVI displays images with a 2% linear contrast stretch.

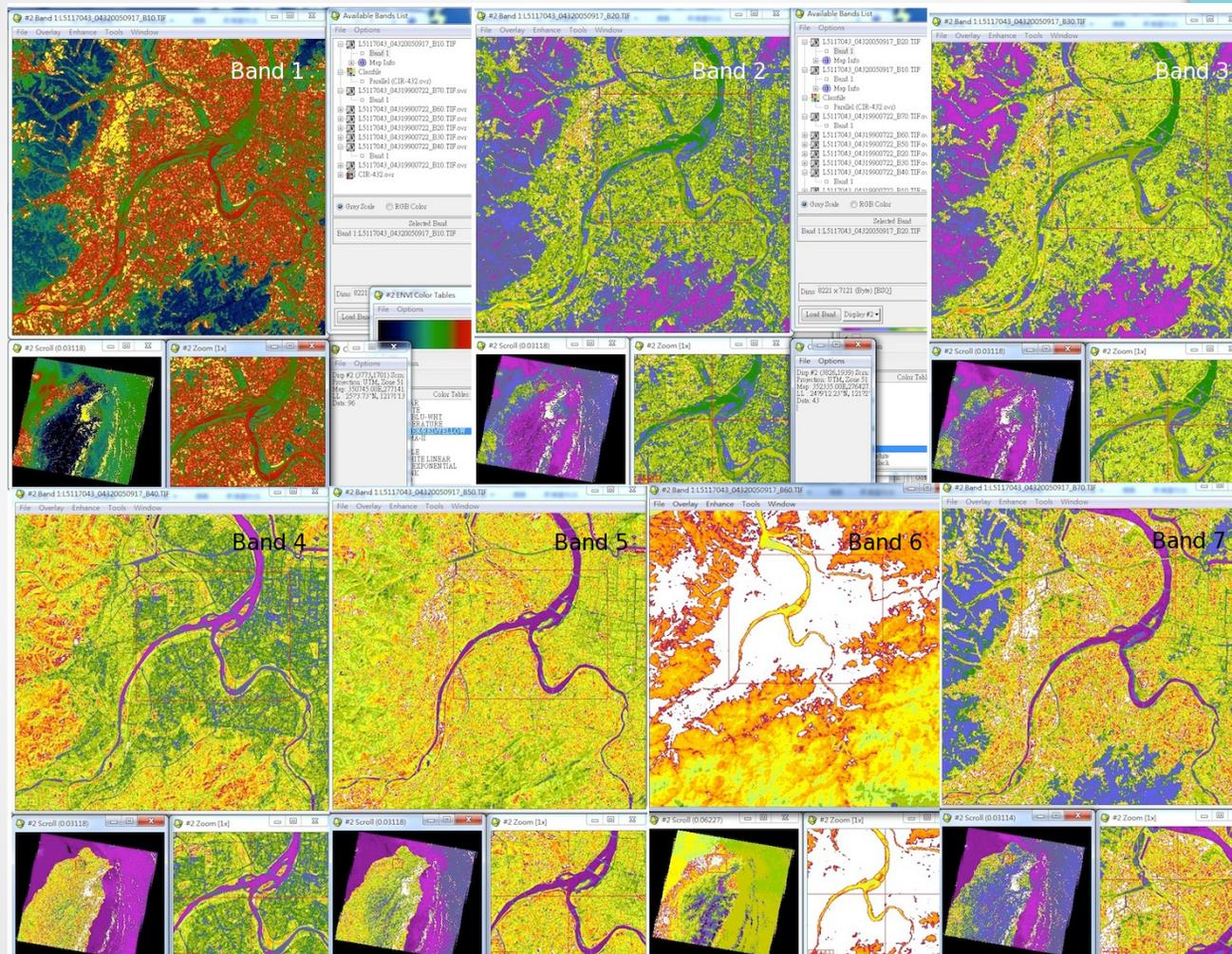
For better contrast the histogram equalization contrast stretch was applied to the image in order to enhance the visual quality



# Landsat TM image (1990). Bands 1-7 (fragment). Color composites (ENVI)



# Landsat TM image (2005). Bands 1-7 (fragment). Color composites (ENVI)



# *K-means* algorithm: a logical procedure

K-means algorithm procedure has 3 steps:

1) Choosing the initial centroids for defined number of land classes

*Looping between the other two major steps:*

2) Assignment of each pixel to the nearest centroid which represent certain land cover class

3) Creating new centroids by taking the mean value of all pixels assigned to each previous land cover class (i.e. centroid).

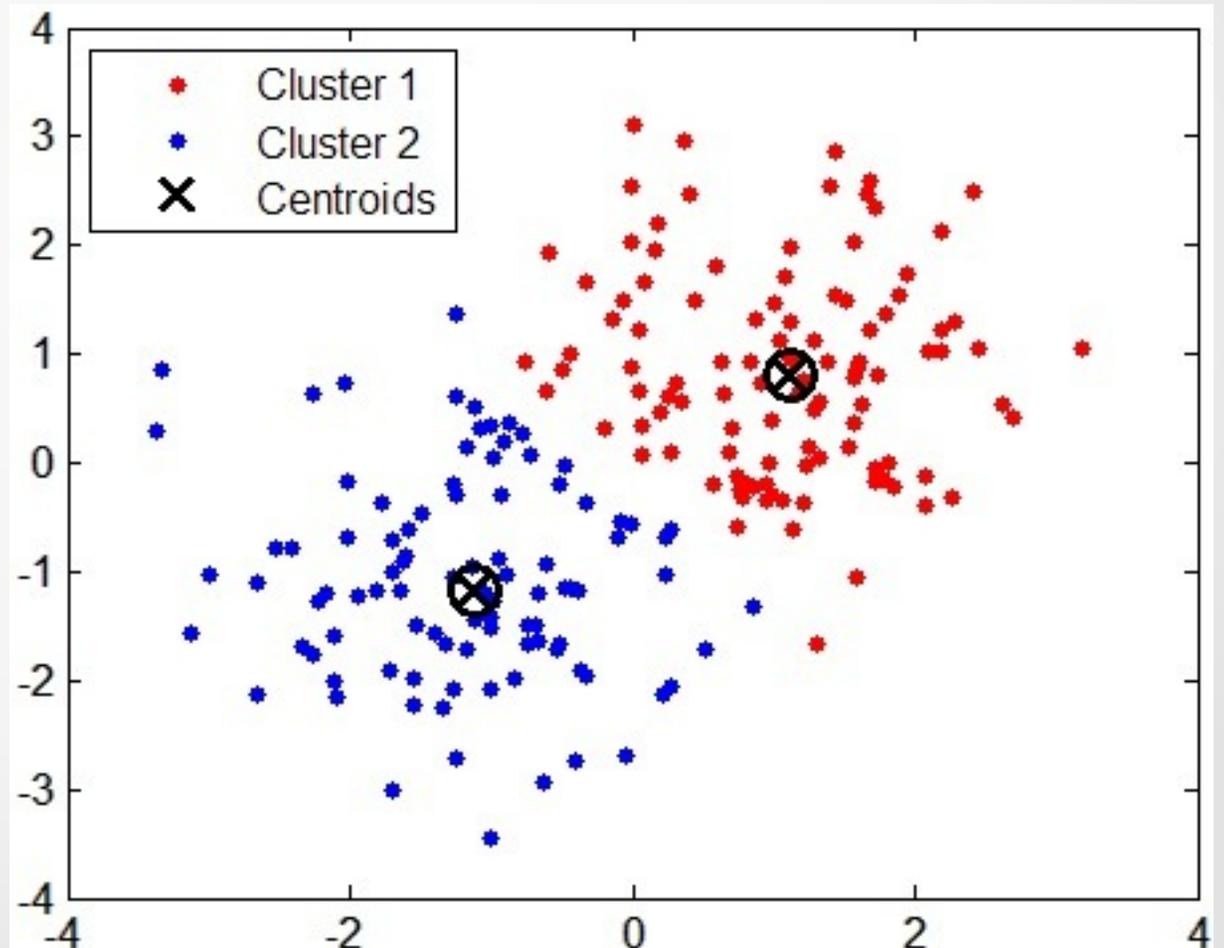
The difference between the old and the new centroids is the “*inertia*”. The algorithm repeats these last two steps until this value (the “*inertia*”) is less than a threshold.

In other words, it smoothes iteratively the allocation of pixels until the centroids do not move significantly.

## *K-Means* classification: a general idea.

K-means is a flat clustering algorithm which is often used in classification techniques.

The objective of K-means: to minimize the average squared Euclidean distance between the cluster centers (the means).



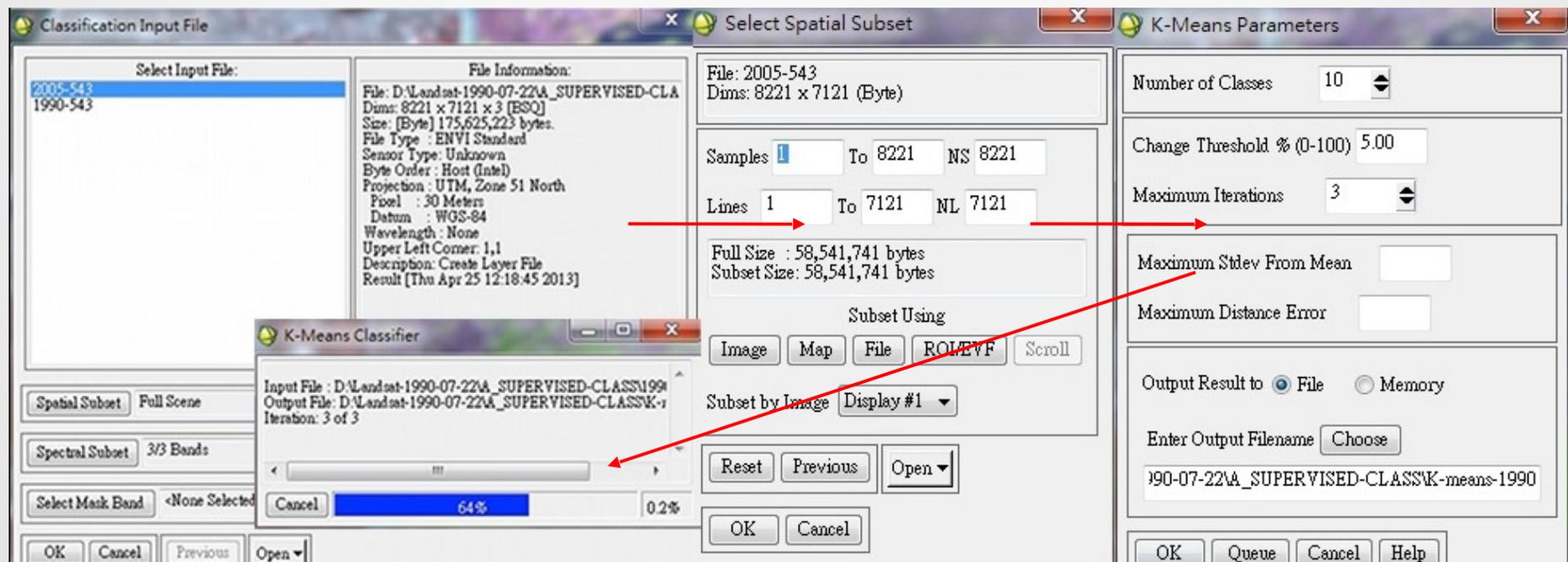
## *K-Means* clustering: a mathematical approach

The K-means analysis separates pixels into various clusters by defining the mathematical centroids of all clusters - groups of pixel with similar values of spectral reflectance, or digital number (*DNs*):

$$J(X, C) = \sum_{i=0}^n \min_{\mu_j \in C} (||x_j - \mu_i||^2)$$

The K-means separates raster pixels in ***n*** clusters (groups of equal variance) by minimizing the '*inertia*' criterion.

# Classification *K-means* by means of ENVI GIS.

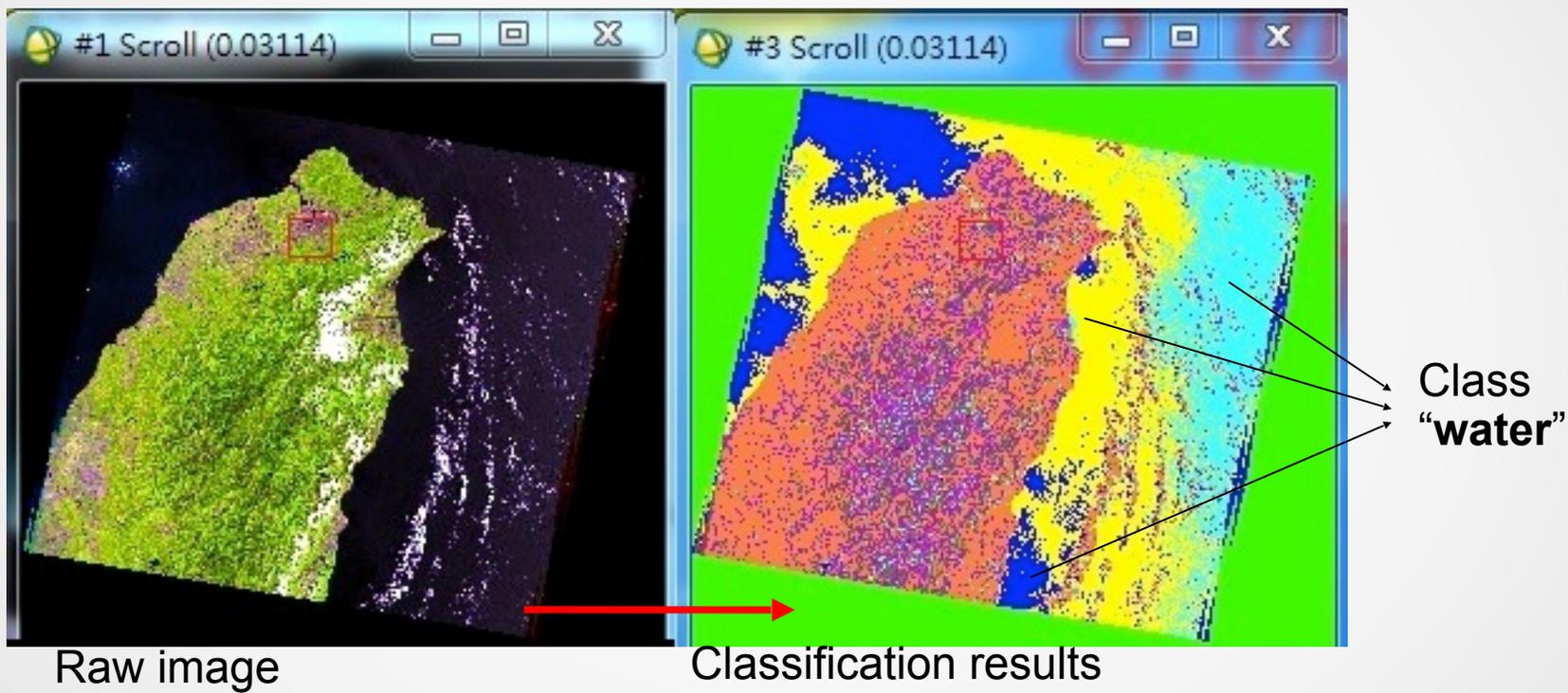


# Land cover types

[Yeh and Huang \(2009\)](#) developed classification of the land cover types in the city. Their studies were adopted and adjusted to the current studies suggesting following types:

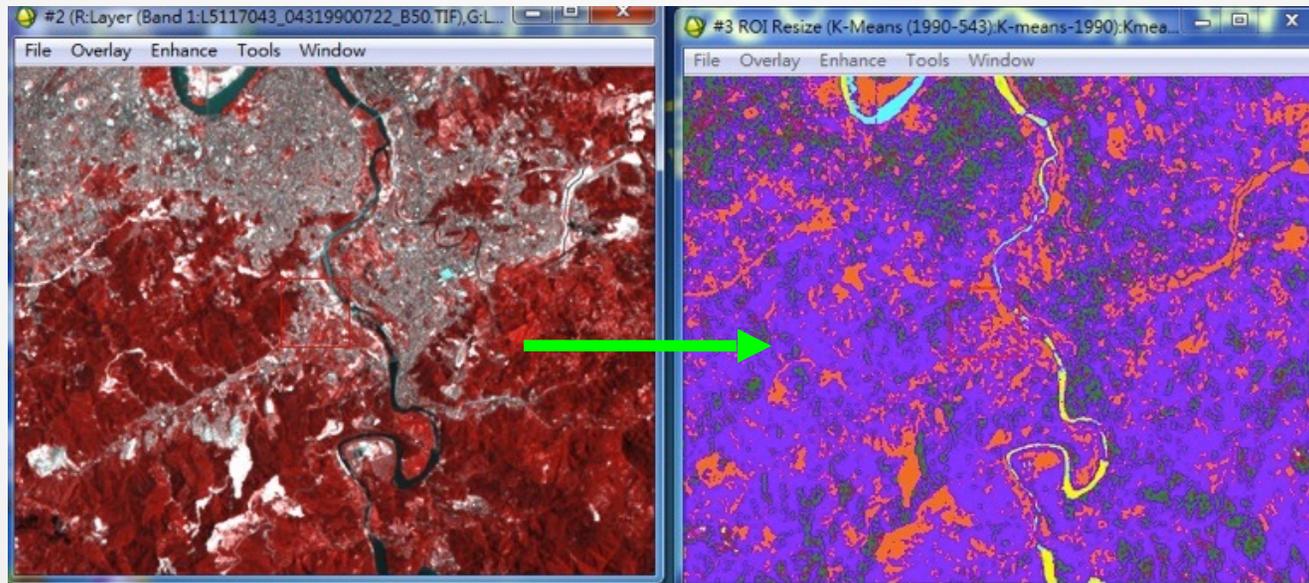
- 1 ) Forests;
- 2) Urban areas – 2 (roads);
- 3) Grasslands;
- 4) Open fields (little or no vegetation);
- 5) Water areas;
- 6) Urban vegetation – 1 (bushes);
- 7) Cultivated lands
- 8) Agricultural facilities;
- 9) Urban vegetation –2 (parks and squares);
- 10) Urban areas -2 (built-up surfaces).

# Re-classifying



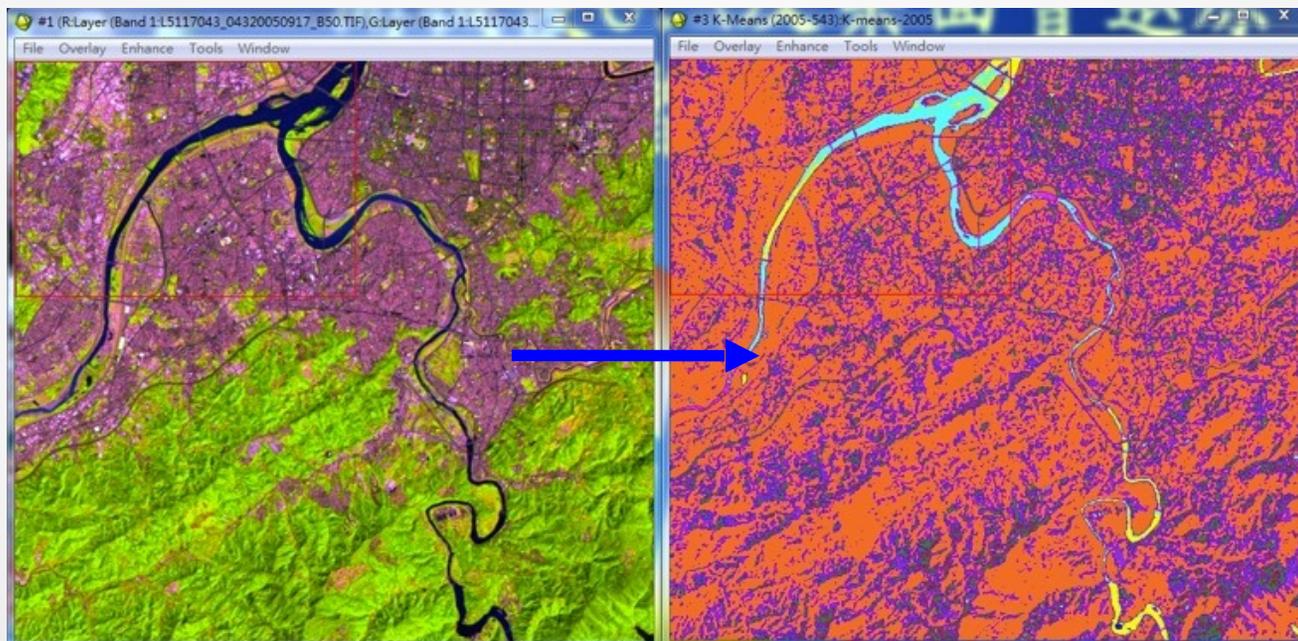
# Classification using *K-means* method (I)

1990 Landsat TM scene classification (fragment).  
Random color visualization



# Classification using *K-means* method (II)

2005 Landsat TM scene classification (fragment).  
Random color visualization



# Combining classes

The screenshot illustrates the 'Combine Classes' process in ENVI 4.8. The main window shows a classified map with a red box highlighting a specific area. The 'Classification' menu is open, and the 'Combine Classes' option is selected. The 'Combine Classes Parameters' dialog is open, showing the following configuration:

- Select Input Class:** Water-river, Class 6, Class 7, Class 8, Class 9
- Select Output Class:** Class 1, Class 2, Water-deep, Water-shallow, Water-river (selected)
- Input Class:** (Empty)
- Output Class:** Water-river
- Buttons:** Add Combination, OK, Cancel
- Combined Classes:** Water-deep -> Water-river, Water-shallow -> Water-river

The 'Combine Classes Output' dialog is also open, showing the following configuration:

- Remove Empty Classes?** Yes
- Output Result to:** File (selected), Memory
- Enter Output Filename:** Choose
- Filename:** 190-07-22\A\_SUPERVISED-CLASS\K-means-2005
- Buttons:** OK, Queue, Cancel

# Creating Region Of Interest (ROI)

The image illustrates the process of creating a Region of Interest (ROI) in a GIS application. The steps are as follows:

- Image Selection:** A satellite image is displayed with a red rectangular ROI overlaid on a specific area.
- ROI Properties:** The 'Available Bands List' window shows the ROI details: ROI Name: ROI-Taipei, Color: Red, Pixels: 101,582.
- File Naming:** The 'Enter ROI File Names' dialog shows the ROI being saved as 'ROI-Taipei.roi' in the 'Data (D:) \ Landsat-1990-07-22' directory.
- Saving to File:** The 'Save ROIs to File' dialog shows the ROI being saved to 'D:\Landsat-1990-07-22\ROI-Taipei.roi'.
- Subsetting Data:** The 'Select Input File to Subset via ROI' dialog shows the ROI being used to subset the input file 'D:\Landsat-1990-07-22\CIR-432.ovr'.

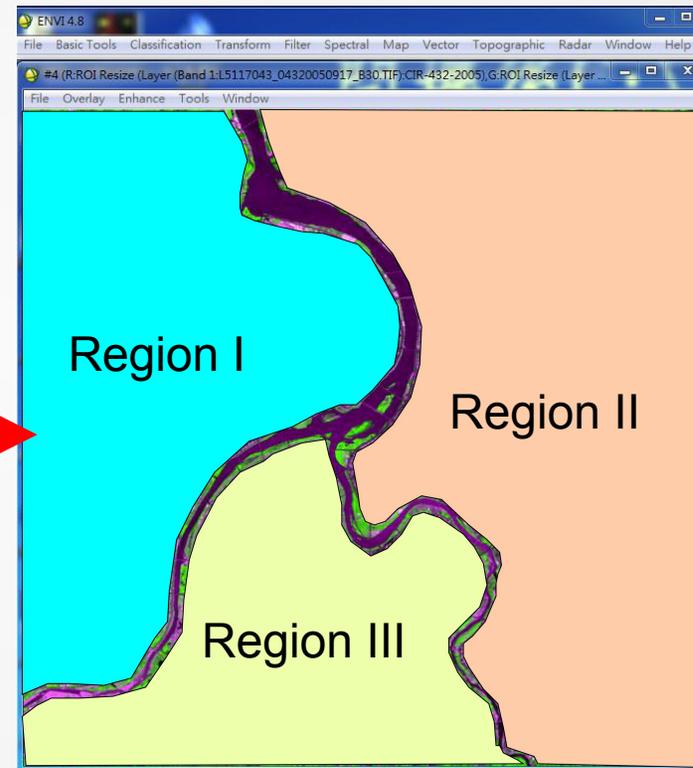
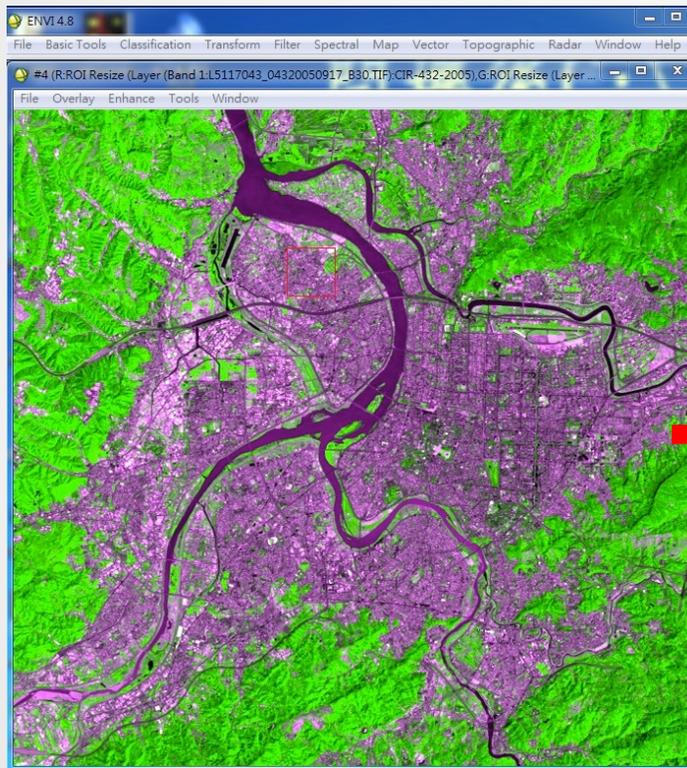
# Subset Data via ROI

The image displays a composite screenshot of the ENVI 4.8 software interface, illustrating the workflow for subset data using a Region of Interest (ROI). The interface is divided into several key windows:

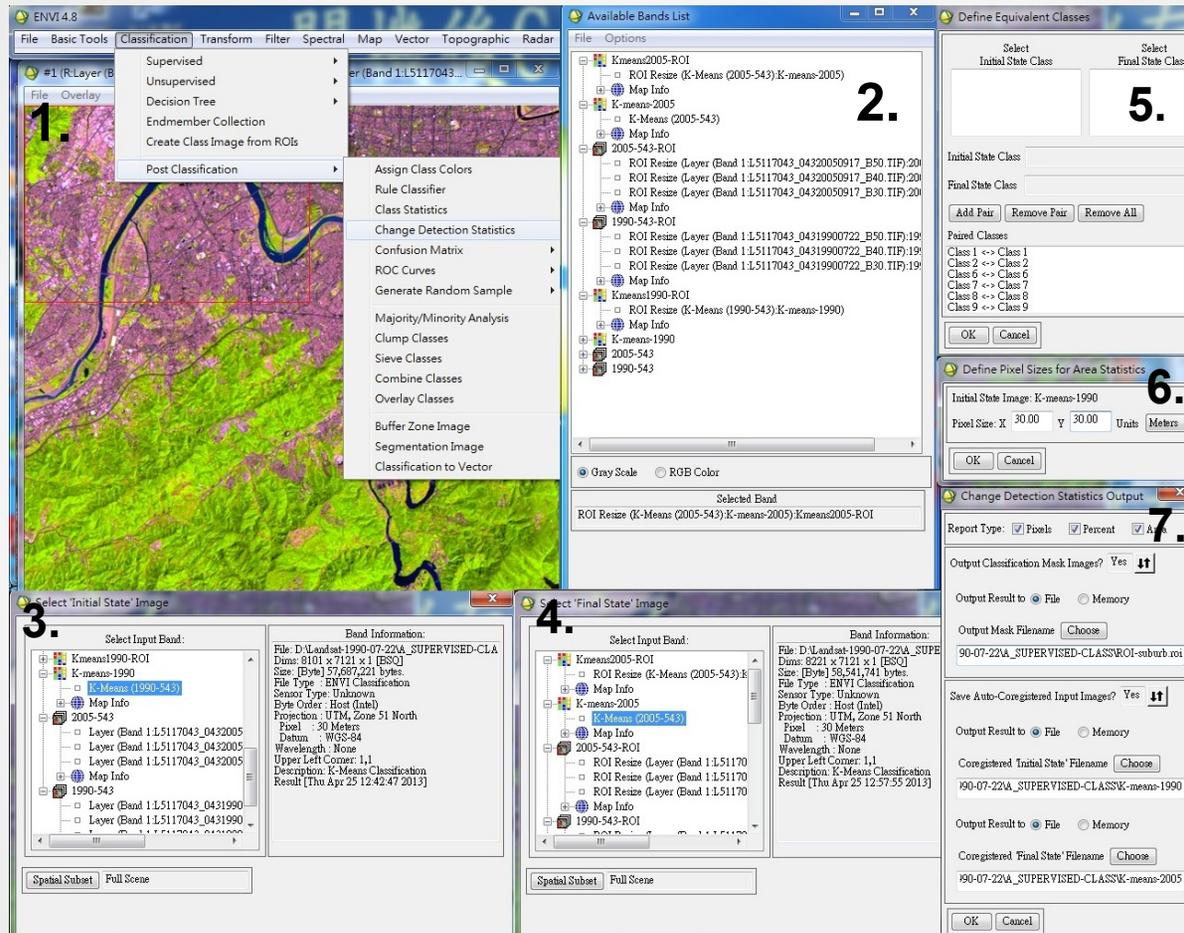
- Available Bands List:** Shows a tree view of data layers. A blue arrow points to the 'CIR-432.ovr' layer.
- Select Input File to Subset via ROI:** A dialog box where the user selects the input file. A blue arrow points to the 'CIR-432.ovr' file in the list.
- Enter ROI Filenames:** A file explorer window showing the selection of ROI files. A blue arrow points to the 'ROI-Taipei.roi' file.
- Spatial Subset via ROI Parameters:** A dialog box for configuring the subset operation. A blue arrow points to the 'Output Result to' section, where 'File' is selected.
- Main Display Area:** Shows the original data with a red ROI box. A blue arrow points from the ROI box to the 'Subset Data via ROIs' menu item in the top-left window.
- ROI Tool:** A panel on the right side of the interface used for managing ROIs.
- Available Bands List (Bottom Right):** Shows the resulting 'ROI Resize' files for the selected ROI.

Blue arrows throughout the interface indicate the flow of the process: from the ROI selection in the main display, through the 'Subset Data via ROIs' menu, to the selection of the input file, the ROI file, and the output destination.

# Regional division of Taipei city



# Change detection statistics: process



## Process workflow:

- 1). Change detection statistics (selection the tool from the menu)
- 2). Setting options of process
- 3). Choice of 'Initial Stage' image
- 4). Choice of 'Final Stage' image
- 5). Defining equivalent classes
- 6). Defining pixel size for area statistics
- 7). Change detection statistics output

# Post-classification data processing

The screenshot displays the ENVI 4.8 interface with the 'Local Spatial Statistics' workflow. The 'Local Spatial Statistics Input File' dialog is open, showing a list of input files. The 'Local Spatial Statistics Parameters' dialog is also open, showing various settings for the analysis.

**Local Spatial Statistics Input File**

Select Input File:

- 1990-local-statgetis\_ord\_gi
- 1990-local-statgeary\_c
- 1990-local-statmoran\_i
- Kmeans2005-ROI**
- 2005-543-ROI
- 1990-543-ROI
- Kmeans1990-ROI
- 2005-543
- 1990-543

Spatial Subset: Full Scene

Select Mask Band: <None Selected>

File Information:

File: D:\Landsat-1990-07-22\A\_SUPERVISED-CLA  
Dims: 703 x 670 x 1 [BSQ]  
Size: [Byte] 471,010 bytes  
File Type: ENVI Classification  
Sensor Type: Unknown  
Byte Order: Host (Intel)  
Projection: UTM, Zone 51 North  
Pixel: 30 Meters  
Datum: WGS-84  
Wavelength: None  
Upper Left Corner: 3332,1409  
Description: File Resize Result, x  
resize factor: 1.000000, y resize  
factor: 1.000000 [Thu Apr 25  
13:00:18 2013]

**Local Spatial Statistics Parameters**

Neighborhood Rule: Rook's Case

Calculate Statistics at Multiple Ranges

Select Maximum Lag (Pixels): 2

Include Intermediate Lags

Output Local Moran's I (Clustering)

Output Local Getis-Ord Gi (Hot Spots)

Output Local Geary's C (Variability)

Output Result to:  File  Memory

Enter Output Root Name: Choose

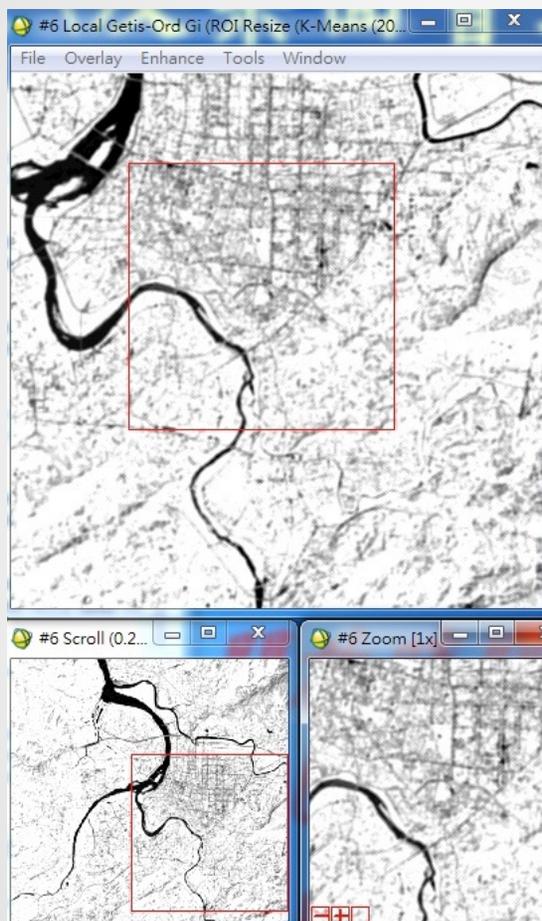
190-07-22\A\_SUPERVISED-CLASS\1990-local-stat

Unclassified	Max	Mean	Stdev
0	0	0.000000	0.000000

DN	Npts	Total	Percent	Acc Pct
0	0	0	-NaN	-NaN
1	0	0	-NaN	-NaN
2	0	0	-NaN	-NaN
3	0	0	-NaN	-NaN
4	0	0	-NaN	-NaN
5	0	0	-NaN	-NaN
6	0	0	-NaN	-NaN

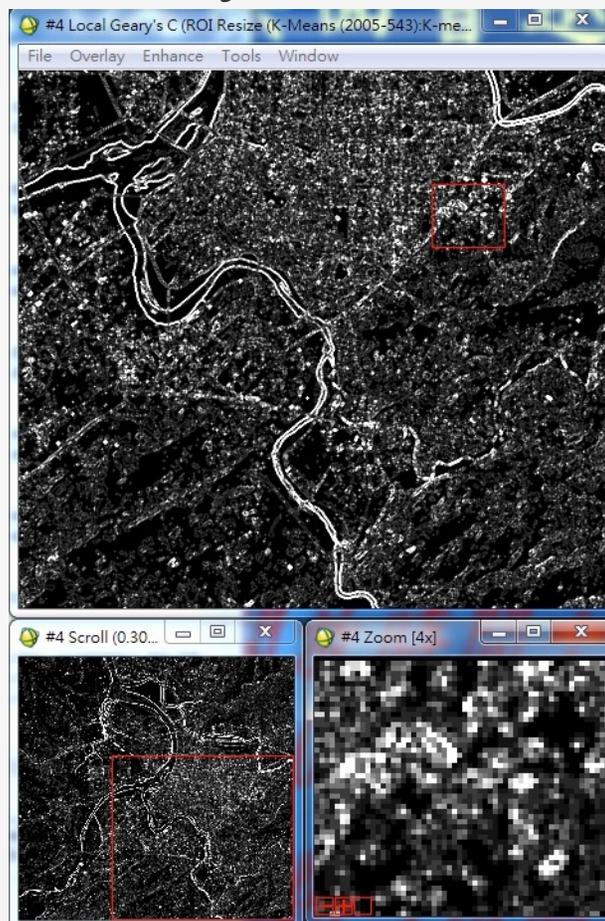
# Statistical processing

## Getis Ord G statistics



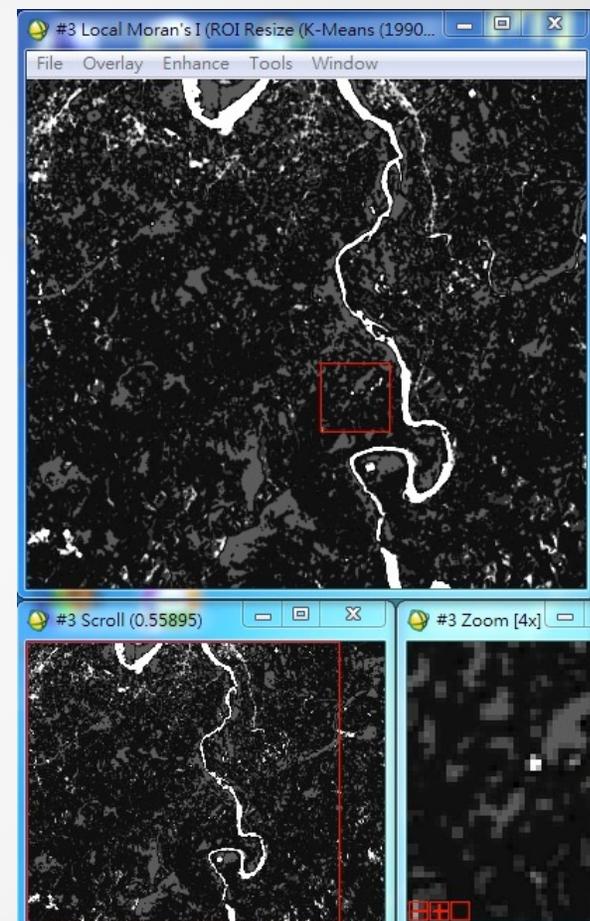
Measures the concentration of the emergency values (highest or lowest) for the land cover classes

## Geary statistics



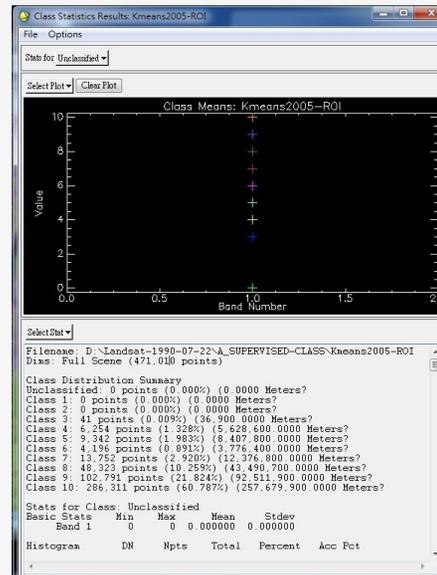
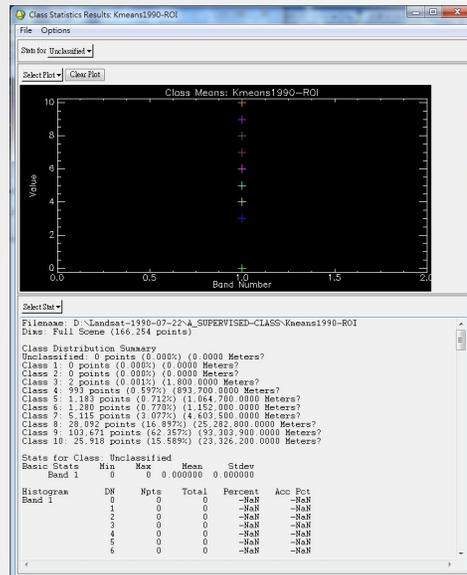
Measures spatial dependence and autocorrelation of pixels.

## Moran statistics



Measures spatial features similarity values based on pixels location and values

# Computed areas of land cover types



- According to results, the **whole study area** has changes in the selected land cover classes:
- 1) area of land cover class "urban areas" increased from 16.9% in 1990 to 21.8% in 2005
  - 2) area of land cover class "urban vegetation" decreased from 3.1% in 1990 to 2.9% in 2005
  - 3) area of land cover class "forests" decreased from 62.4% in 1990 to 60.8% in 2005
  - 4) area of land cover class "grasslands" decreased from 15.6% in 1990 to 10.3% in 2005

# Results: regions I, II and III.

However, three different regions of Taipei have these differences in the land cover types:

	1990, %	2005, %
Region I: "urban areas"	17,1	21,9
Region I: "urban vegetation"	5,7	4,1
Region I: "forests"	19,8	18,6
Region I: "grasslands"	21,4	18,3
Region II: "urban areas"	79,3	83,2
Region II: "urban vegetation"	4,3	5,2
Region II: "forests"	32,7	31,8
Region II: "grasslands"	15,9	14,7
Region III: "urban areas"	24,3	38,2
Region III: "urban vegetation"	3,7	4,3
Region III: "forests"	42,4	41,8
Region III: "grasslands"	13,8	12,1

# Conclusions (I)

To resume a table at the previous slide, following conclusion can be drawn.

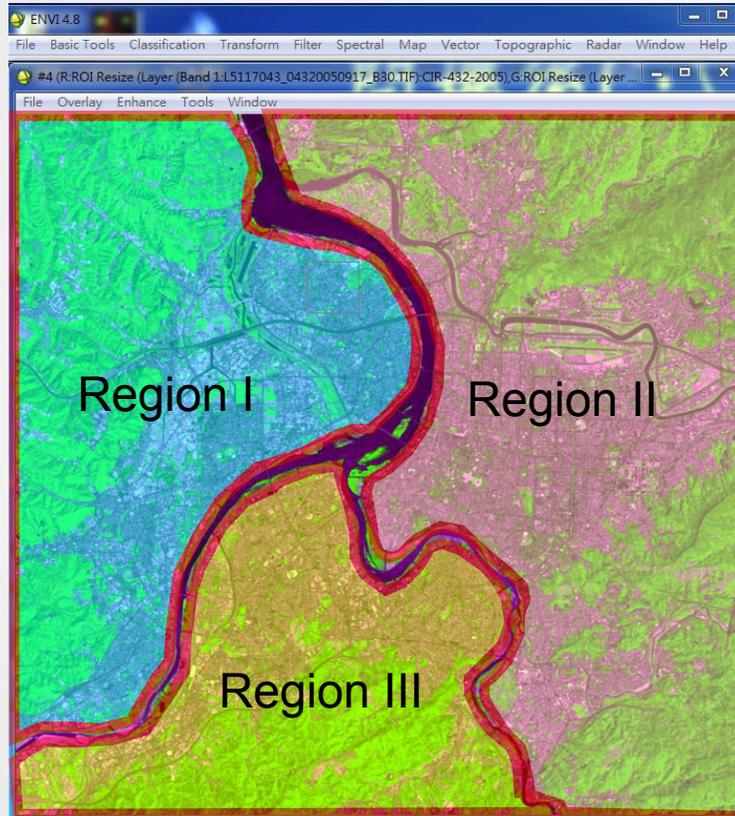
Comparing regions I, II and III, the conclusion is the following:

**Region I** has changes in the land cover types since 1990s. It has much more changes comparing to the core, old city area (region II)

**Region II** (the core city) is the most stable region. It has the least changes, because this area has been already industrialized for a long time.

**Region III**, has undergone notable changes. This is caused by the intensive relocation of the population to the Taipei area after 1980s. This is regions is dynamically developing within the Taipei since 1990s.

# Conclusions (II)



1) *Region I = located on the left bank of Tamsui river, “agricultural” area*

2) *Region II = the core, old city of Taipei*

3) *Region III = the region located southwards from the core city*

# Discussion

The spatial analysis performed by means of GIS ENVI enabled to use satellite images for social and urban studies. The spatio-temporal analysis was applied to Landsat TM images taken at 1990 and 2005. Built-in functions of the mathematical algorithms (*K-means*) enabled to process raster Landsat TM images and to derive information from them.

The classification of the images was used to analyze changes in the Taipei's landscapes that consist in different land cover types, including built-up areas and natural land cover types.

According to the results of image processing and spatial analysis, the structure, shape and configuration of urban landscapes in Taipei changed since 1990: the areas occupied by human activities increased, while natural landscapes undergone modifications.

Changes in urban landscapes of Taipei metropolis area are caused by the increased anthropogenic pressure, intensified urbanization and occupied lands for the urban needs.

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End of presentation

Thank you for your attention.

# Questions and discussions

Do you have any questions ?