Urban Climate Analysis on The Land Use and Land Cover Change (LULC) in Bandung-Indonesia with Remote Sensing and GIS

Laras Tursilowati & team

Centre for Application of Atmospheric Sciences & Climate
National Institute of Aeronautics & Space
LAPAN – Bandung, INDONESIA

UN/Austria/ESA Symposium on “Space Tools and Solutions for Monitoring the Atmosphere in support of Sustainable Development”

11-14 September 2007

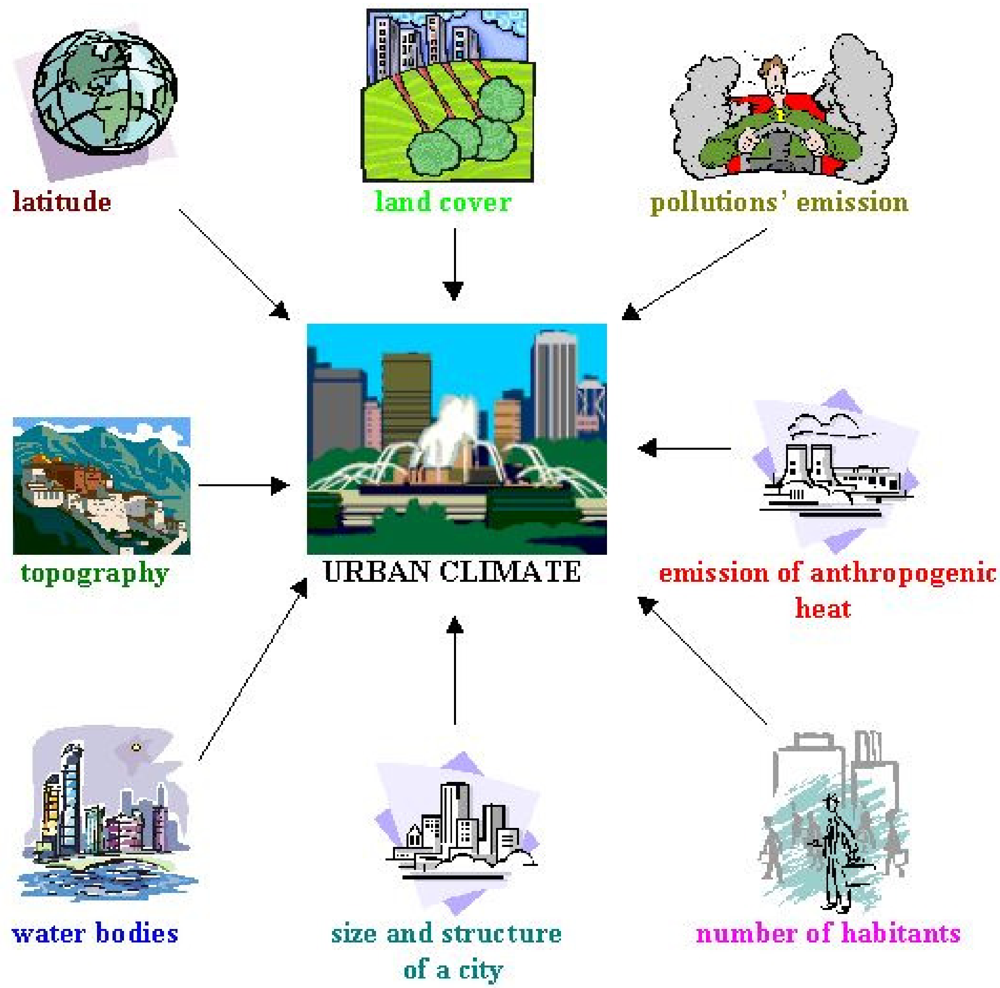
Graz, Austria

LAPAN

LEMBAGA PENERBANGAN DAN ANTARIKSA NASIONAL

Factors controlling urban climate

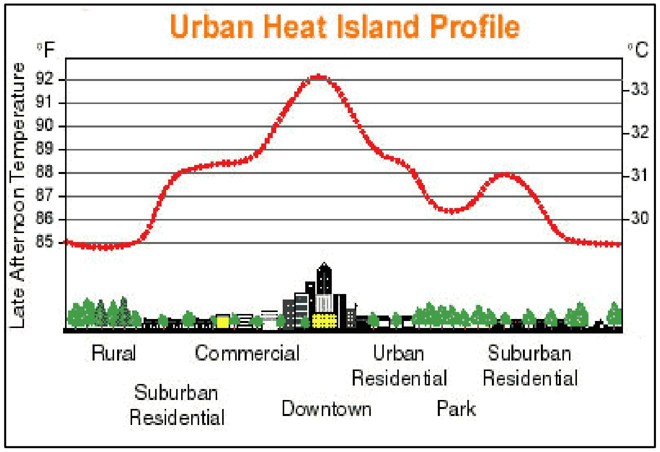
Source : //www.atmosphere.mpg.de.   Author : Sebastian Wypych

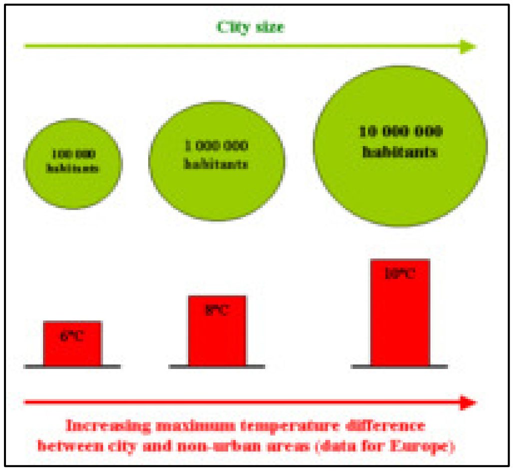


URBAN HEAT ISLAND

In many cities, air temperature is higher than in the surrounding non-urban areas by 0.5-0.8℃ on average, and in winter even 1.1-1.6℃.

Source : //www.atmosphere.mpg.de

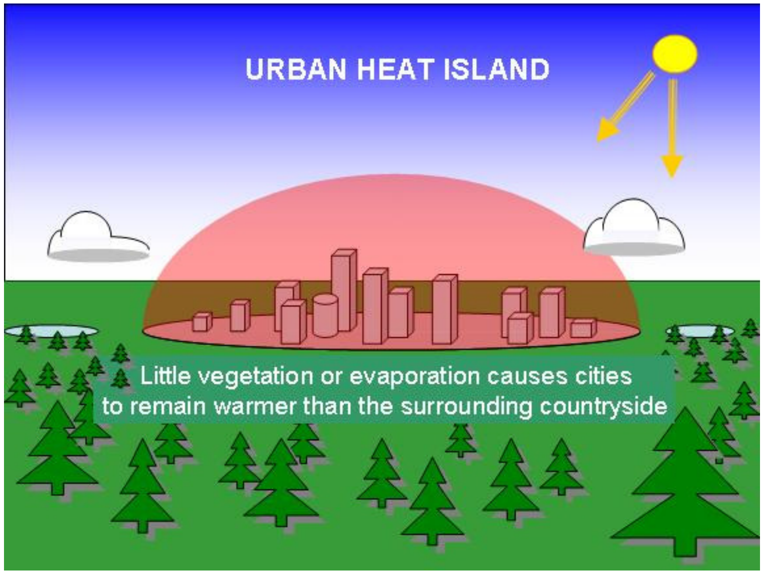




Dependence of maximum intensity of UHI on the number of habitants of a city

Emission of anthropogenic heat - cooling towers

Emission of anthropogenic heat - cars



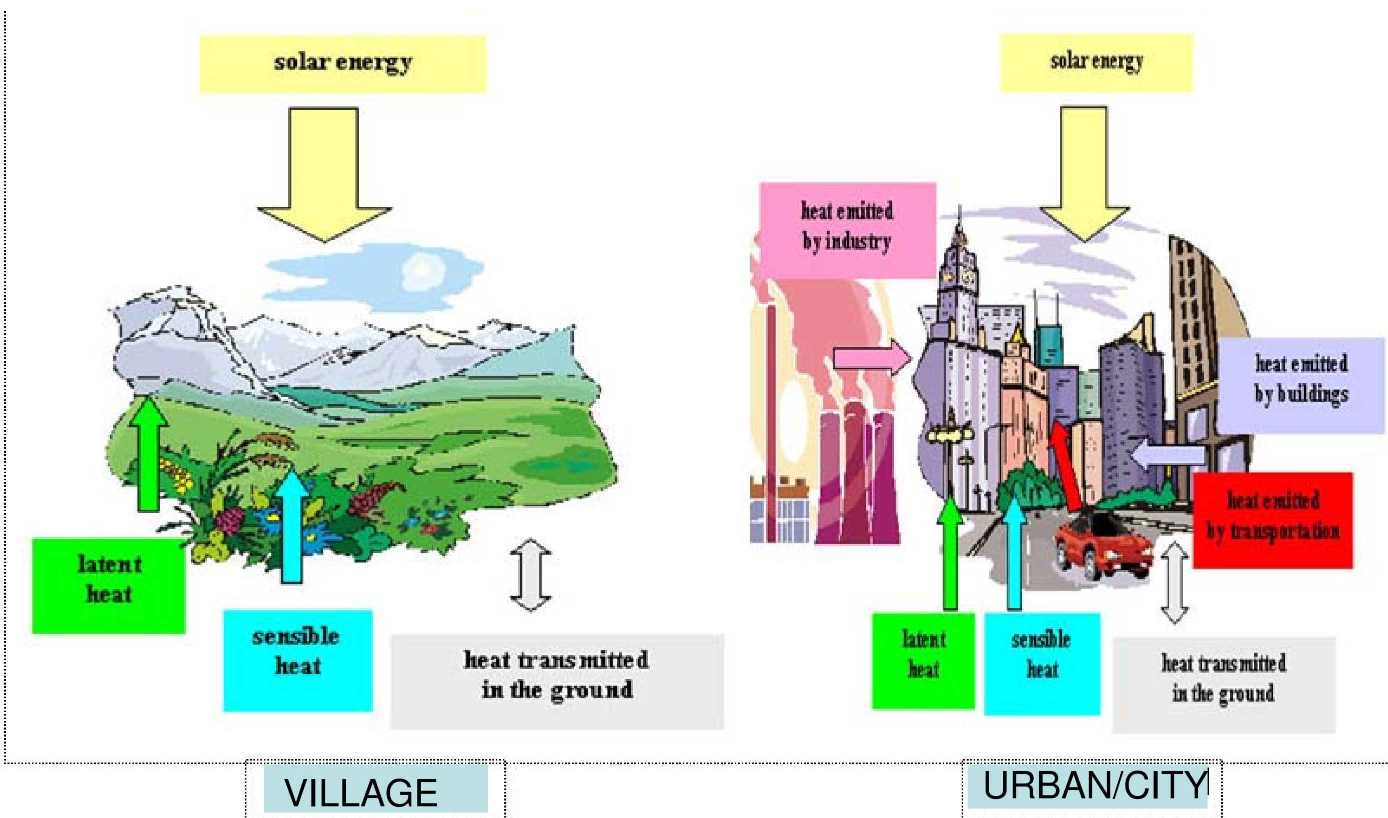
- UHI : the tendency for a city to remain warmer than its surroundings
- Caused mostly by the lack of vegetation and soil moisture
- Vegetation & soil moisture use much of the absorbed sunlight to evaporate water as part of photosynthesis ("evapotranspiration").
- The sunlight is absorbed by manmade structures: roads, parking lots, and buildings.
- No water to evaporate, the sunlight's energy goes into raising the temperature of those surfaces.
- After the sun sets, the city is so warm that it never cools down as much as the countryside around it, and so retains the heat island effect all night long

Major Causes of UHI Effect

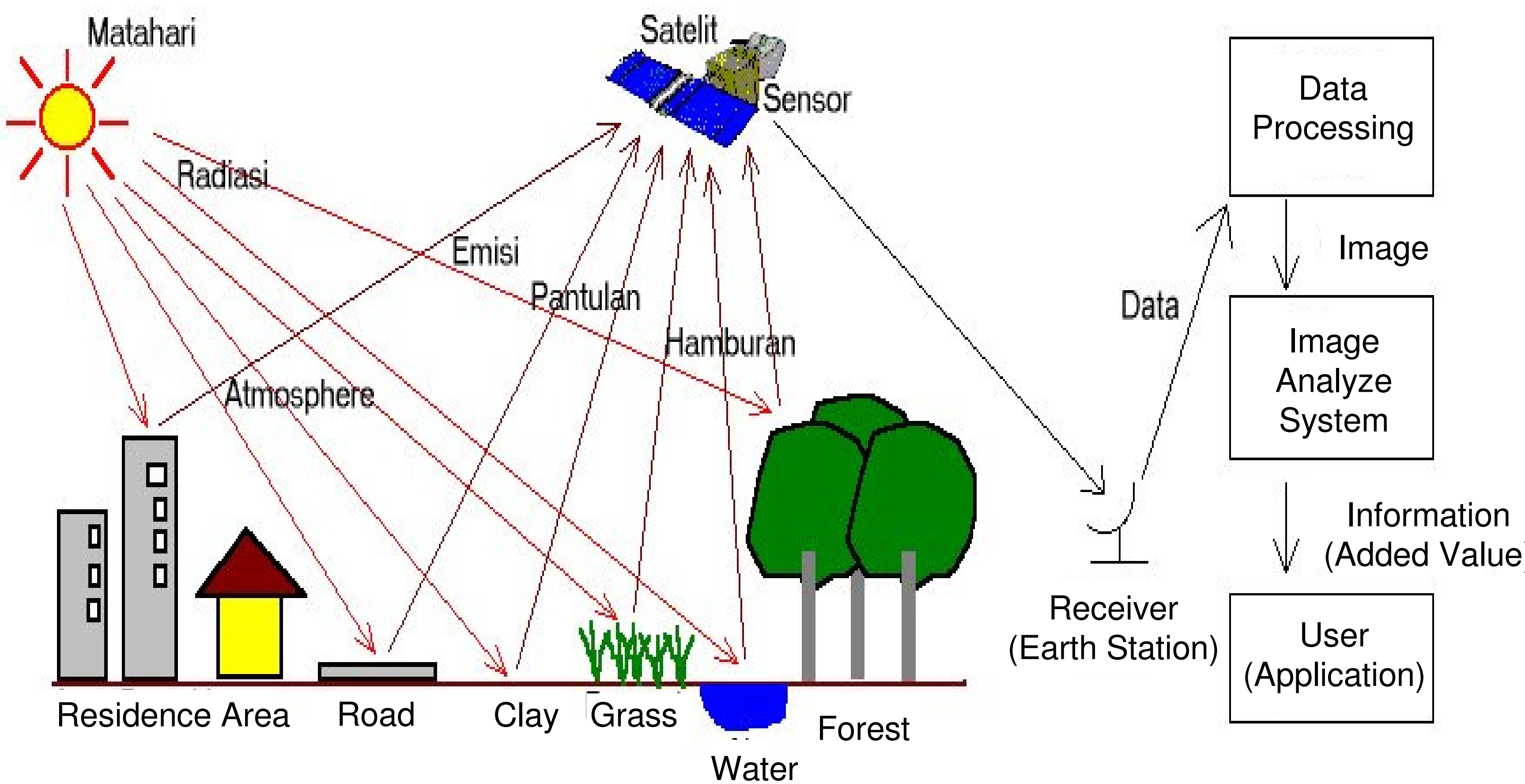
- Reduce of Evaporation by plants.
- Replacing the forest by buildings and roads.
- Tall buildings increase the surface roughness, thus reducing the ventilation of urban areas.
- Preferential heating of the city against the surrounding area increase convections over the city that trap the heat (as well as pollutants).
- Roads, parking lots, and driveways paved with dark, heat absorbing materials (e.g., asphalt)
- Large number of habitants and anthropogenic heat emission.

Effect of Land Cover Change and Urban Heat Island

- Increase of air temperature, surface run off, local turbulence, use of AC (Air Conditioning/GRK), pollution, uncomfortable in city. (Baumann, 2001)
- Increase of heat transfer (heat flux) in the city. (Wypych *et al*., 2003)



Basic Concept of Remote Sensing



Characteristic and General Application of LANDSAT TM/ETM+ BAND respectively

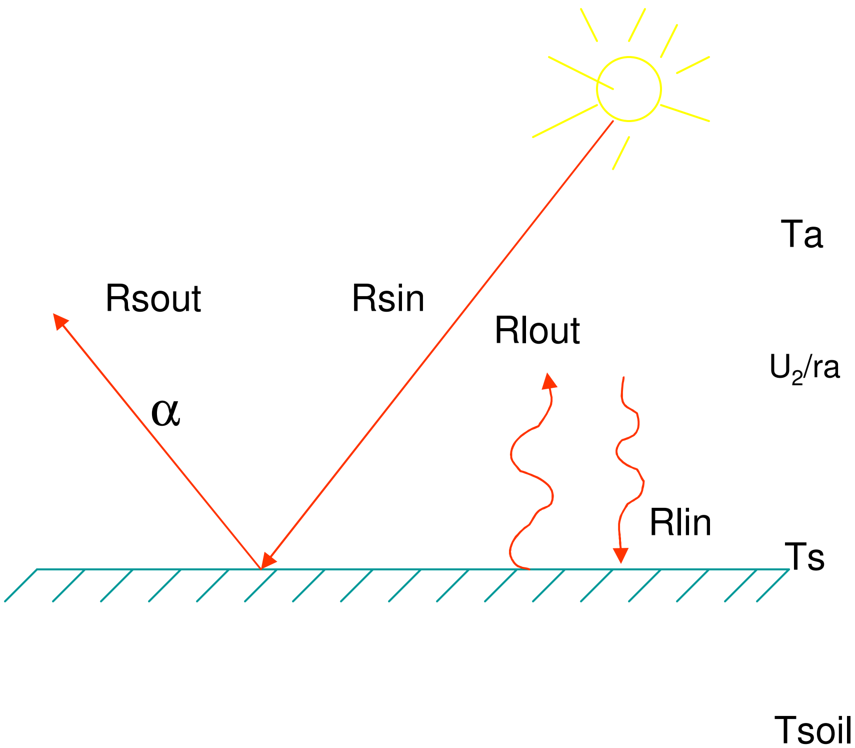
BAND	Longwave (µm)	EM Wave area	General Application
1	0.45 - 0.52	*Visible Blue*	Penetration to water, Coastal Mapping, Differentiating of soil/vegetation type, Forest type mapping, Culture archeological remains identification.
2	0.52 - 0.60	*Visible Green*	Measuring of top vegetation emitted in green spectrum that used for differentiating vegetation and thriving.
3	0.63 - 0.69	*Visible Red*	To investigate chlorophyll absorption area that used to differentiating plant species.
4	0.76 - 0.90	*Near Infrared*	Used in vegetation type identification, biomass content and strudy.
5	1.55 - 1.75	*Middle Infrared*	To identify the vegetation and soil humidity. To differentiate of Cloud and snow.
6	10.40- 12.50	*Thermal Infrared*	For soil humidity, high of vegetation, to detect the vegetation temperature. For to detect vegetation and plan stressing, heat intensity, Insecticide application, and geothermal activity placing.
7	2.08 - 2.35	*Far Infrared*	Used to differentiating rock type and mineral type, also sensitive to vegetation.
8	0.52 - 0.90 *(panchromatic)*	*Green, Visible Red, Near Infrared*	Mapping of wide region and for investigate urban region changes.

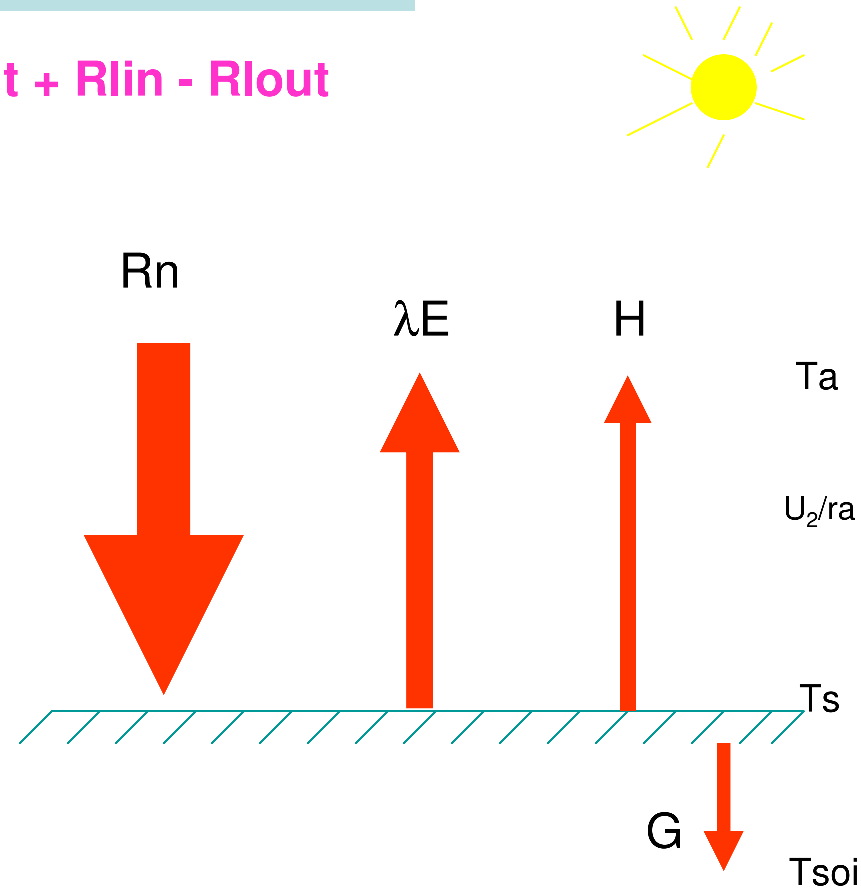
Source:www.gsfc.nasa.gov/

BASIC CONCEPT OF ENERGY BALANCE

$$Rn = H + G + \lambda E$$

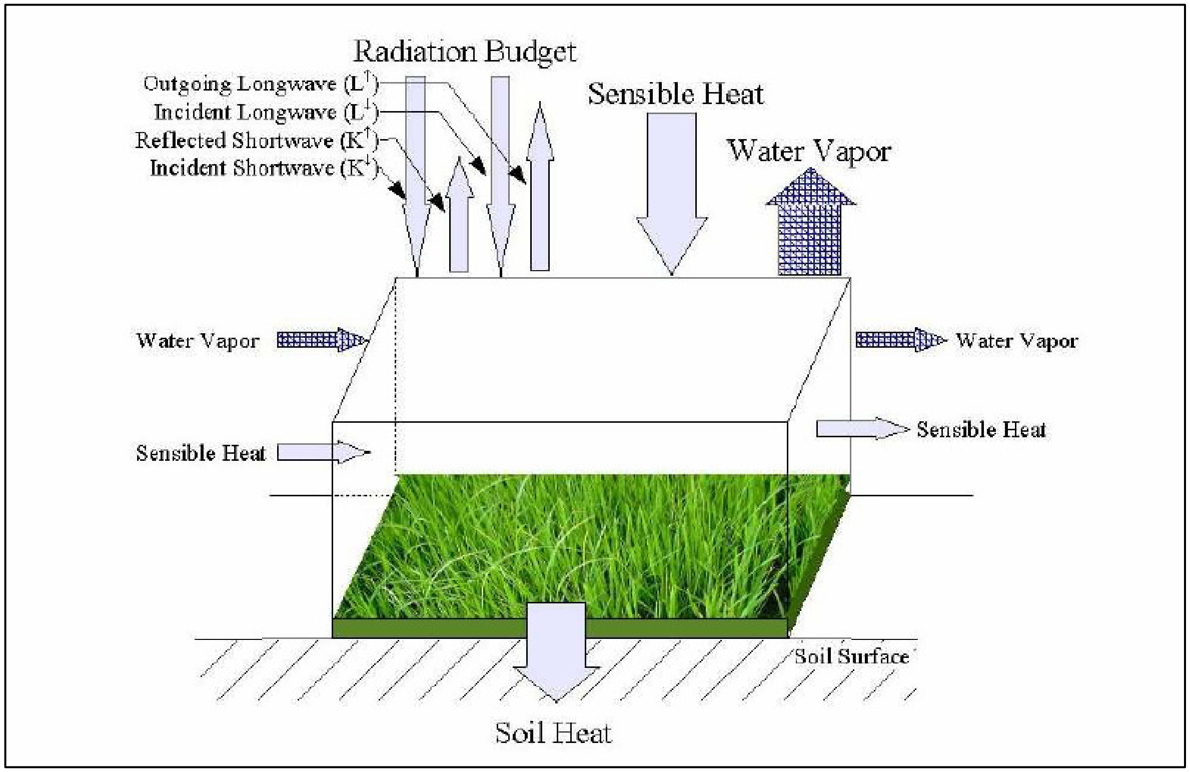
$Rn = Rsin - Rsout + Rlin - Rlout$

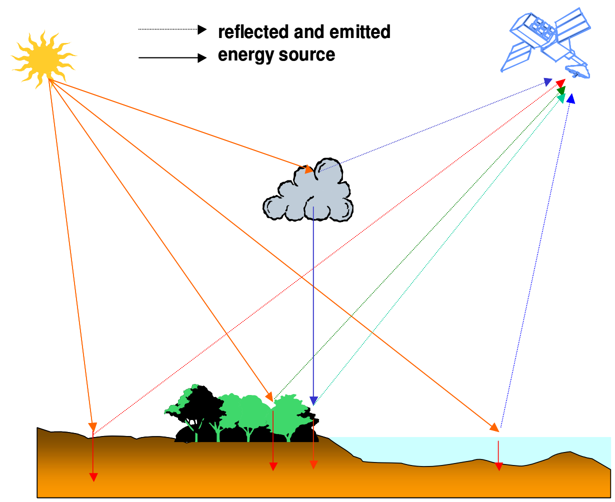




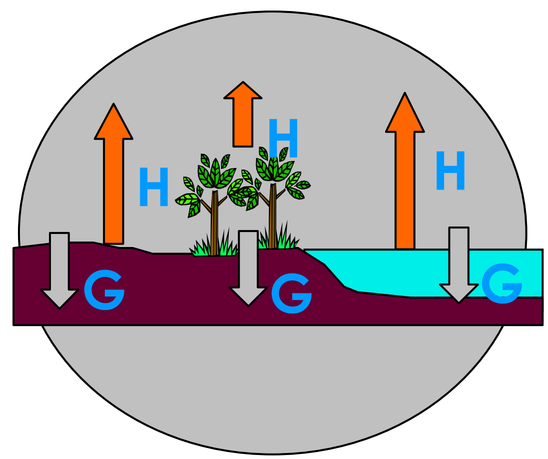
BASIC CONCEPT OF ENERGY BALANCE

$$Rn = G + H + \lambda E$$





www.Lawr.Ucdavis.Edu/Coopextn/Biometeorology/Index/Rad.Htm



f(H) → Surface Air Temperature

f(G) → Soil Temperature

f(λE) → Energy Potency for Evaporation

METODOLOGI

EQUATION OF ENERGY BALANCE

$$Rn - (H+G+\lambda E) = 0$$

Where:

Rn = Net Radiation ($W\ m^{-2}$)

H = Sensible Heat Flux ($W\ m^{-2}$)

G = Soil Heat Flux ($W\ m^{-2}$)

λE = Energy for Evaporation ($W\ m^{-2}$)

CALCULATION OF NET RADIATION

$$Rn = (Rsin + Rlin) – (Rsout + Rlout), \text{ or}$$

$$Rn = Rs\downarrow - Rs\uparrow + Rl\downarrow - Rl\uparrow$$

$$Rn = (1- \alpha)\, Rs + Rl - \varepsilon\sigma\, (Ts + 273.16)^4$$

where,

Rn	= Nett Radiation (W m^{-2})
Rs	= Incoming Shortwave Radiation (W m^{-2}) (FAO, 1998)
Rl	= Outgoing Longwave Radiation (W m^{-2}) (Swinbank, 1963)
α	= Surface Albedo (Chrysoulakis, N (2003))
Ts	= Surface Temperature (℃)
ε	= Surface Emisivity (Weng, 2002)
σ	= Stefan Bolztman Constants (5.67 x 10^{-6} W m^{-2})

CALCULATION OF SENSIBLE HEAT FLUX

$$H = (\rho_a . cp / ra)(Ts - Ta)$$

$$H = \gamma \frac{900}{Ta + 273} \lambda . U_2 (Ts - Ta)$$

where,

H = Sensible Heat Flux (W m-2)

γ = Psychometrics constants (kPa °C $^{-1}$)

$\gamma = 0.665 \times 10^{-3} P$

$P = 101.3 (293-0.0065z)/293)^{5.26}$

P= Atmospheric pressure (k Pa)

z= Altitude (m)

U2 = Wind velocity in 2 m (m s^{-1})

Ts = Surface Temperature (Derive from ASTER) (K)

Ta = Air Temperature (K) (empiric equation)

ρcp = Contants 1250 J m^{-3} K^{-1}

ra = Aerodinamic resistance which is different for water, vegetation, and soil domination of land cover (s/m)

CALCULATION OF SOIL HEAT FLUX

Base on Allen (2002)

$$\frac{G}{Rn} = \frac{T_s}{\alpha}\left(0.0038\alpha + 0.0074\alpha^2\right)\left(1 - 0.98NDVI^4\right)$$

CALCULATION OF EVAPOTRANSPIRATION

$$\lambda E = Rn - G - H$$

Where:

Rn = **nett radiation (W m^{-2})**
H = **sensible heat flux (W m^{-2})**
G = **soil heat flux (W m^{-2})**
λE = **energy for vaporation (W m^{-2})**

SURFACE TEMPERATURE ESTIMATION

- $L\lambda$ = Gain * QCAL + Offset

L_λ	=	*Spectral radiance* in band-*i* ($Wm^{-2}sr^{-1}\mu m^{-1}$)
QCAL	=	*Digital Number band- i*
$LMIN_i$	=	Minimum value of *spectral radiance* band-*i*
$LMAX_i$	=	Maximum value of *spectral radiance* band-*i*
QCALMIN	=	Minimum pixel value 1 (LPGS *Products*) 0 (NLAPS *Products*)
QCALMAX	=	Maximum *Pixel value* (255)

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)}$$

LANDSAT ETM : K1= 666.09 Wm-2sr-1µm-1, K2 = 1282.71K
LANDSAT TM : K1= 607,76 Wm-2sr-1µm-1, K2 = 1260.56K.

EQUATION OF SURFACE TEMPERATURE CORRECTED

$$T_s(koreksi) = \frac{T_s}{1 + \left(\frac{\lambda T_s}{\alpha}\right) Ln\,\varepsilon}$$

T_S	=	Surface Temperature Corrected (K)
λ	=	Longwave Emitted Radiation (11,5 µm (Markham and Barker 1985)
α	=	hc/K (1.438 x 10^{-2} mK)
h		Planck's constante (6.26x10^{-34} J sec)
c	=	Light velocity (2.998 x 10^{8} m.sec^{-1})
K	=	Stefan Bolzmans constante (1.38 x 10^{-23} JK^{-1})
ε	=	Emissivity of Object

EQUATION OF AIR TEMPERATURE ESTIMATION

$$T(0,t) = \overline{T} + A(0)\sin \omega t$$

$$T(z,t) = \overline{T} + A(0)\, e^{-z/D} \sin(\omega t - z/D)$$

<u>ASSUMPTION :</u>

Air Condition is no turbulence

z = appropriate with height of Air Temperature measurement in BMG Station.

Daily Maximum Surface Temperature on 12.00 WIB (West Indonesian Time).

DETERMINE OF WIND VELOCITY CONTANTE (U_2)

$$U_2 = \frac{H}{\left(\gamma \dfrac{900}{Ta + 273} \lambda (Ts - Ta)\right)}$$

Y

X

Narasimhan and Srinivasan (2002)

DIFFERENTIATION ON LAND USE WITH DOMINATION OF WATER, VEGETATION, AND URBAN AREA.

- Evaporative fraction (EF) dan Bowen Ratio (β):

  Vogt dan Niewmeyer (1999)

$$EF = \frac{\lambda.ET}{Rn - G}$$

$$\beta = \frac{H}{\lambda E}$$

  LOW EF OR HIGH β : DRY AREA,

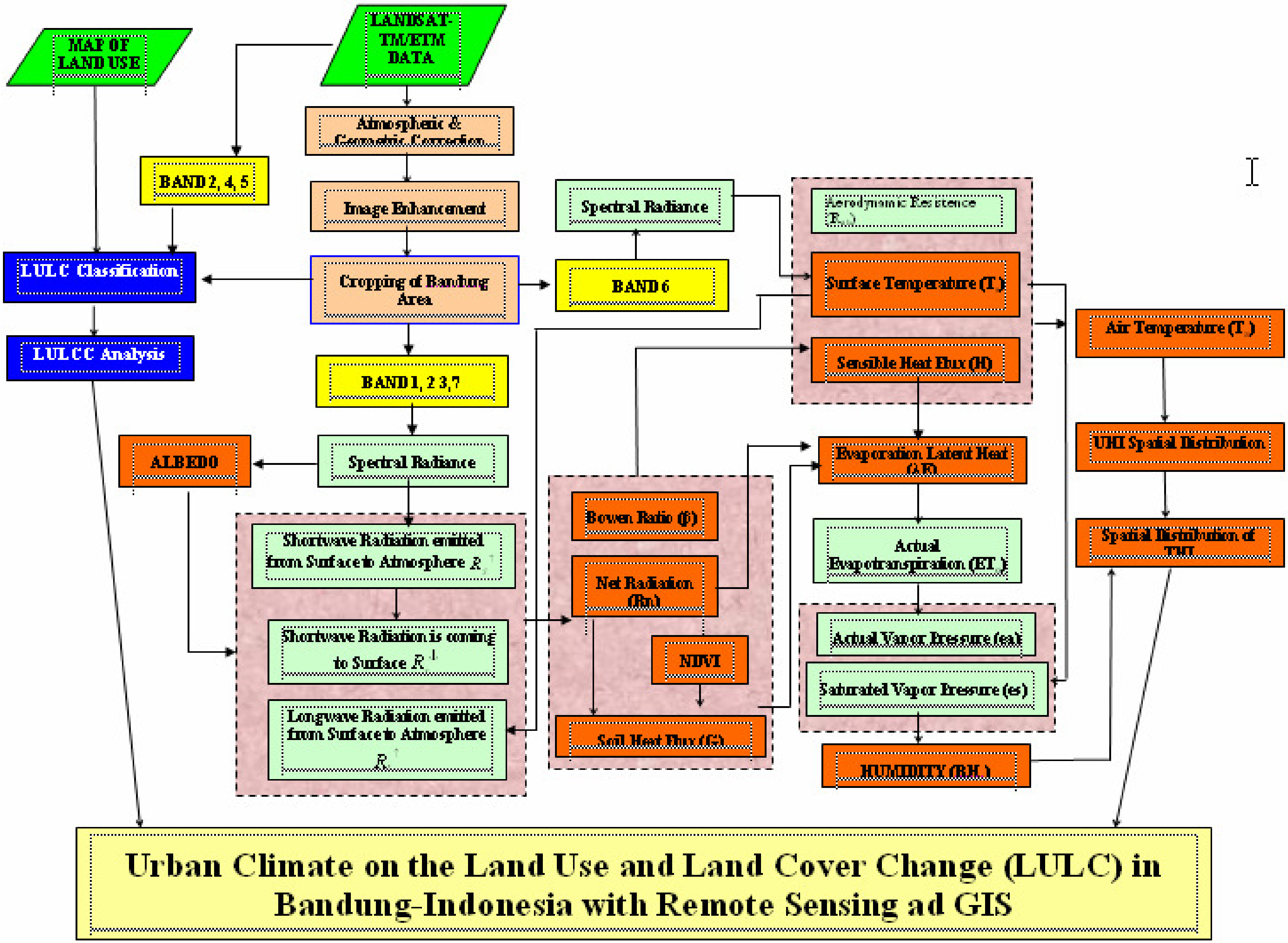
- Temperature Humidity Index (THI):

$$THI = 0.8Ta + \frac{(RHxTa)}{500}$$

- Classification of THI :

uncomfort (cold & wet)	(THI < 20),
comfort	(20 < THI < 26),
uncomfort (hot & dry)	(THI>26)

Flow chart


MAP OF LAND USE
LANDSAT-TM/ETM DATA
Atmospheric & Geometric Correction
BAND 2, 4, 5
Image Enhancement
Spectral Radiance
Aerodynamic Resistence
LULC Classification
Cropping of Bandung Area
BAND 6
Surface Temperature
Air Temperature
LULCC Analysis
BAND 1, 2 3,7
Sensible Heat Flux (H)
ALBEDO
Spectral Radiance
Evaporation Latent Heat
UHI Spatial Distribution
Bowen Ratio (β)
Shortwave Radiation emitted from Surface to Atmosphere
Actual Evapotranspiration
Spatial Distribution of
Net Radiation (Rn)
Actual Vapor Pressure (ea)
Shortwave Radiation is coming to Surface
NDVI
Saturated Vapor Pressure (es)
Longwave Radiation emitted from Surface to Atmosphere
Soil Heat Flux (G)
HUMIDITY
Urban Climate on the Land Use and Land Cover Change (LULC) in Bandung-Indonesia with Remote Sensing ad GIS

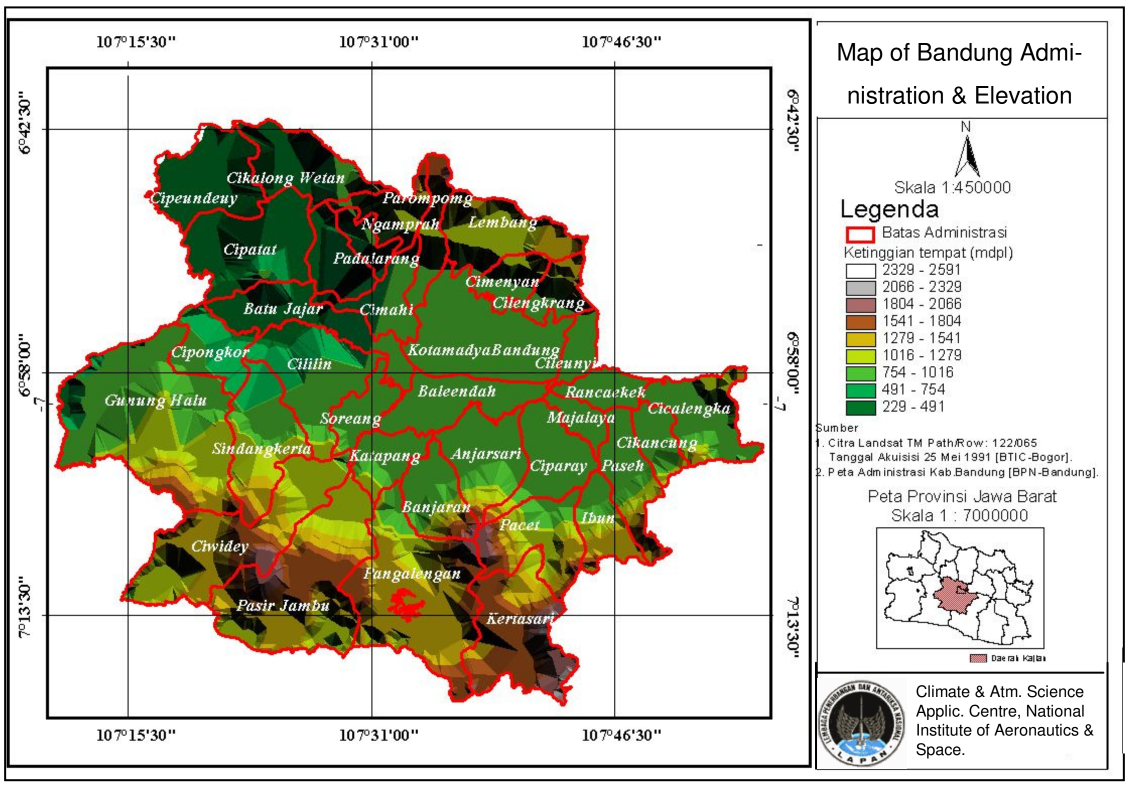
Data & Instrument

- LANDSAT Satellite data August 1994, September 2001.
- Climate Data (observation)
- Land Use data of Bandung.
- Map of Bandung 1 : 25.000.
- ER MAPPER Software for Image Processing of Satellite data.
- Arc View GIS
- Instrument : GPS (Geographic Positioning System), termokopel.
- Area Study : Bandung.

Study Area Location

Bandung (Capital of West Java, Indonesia) :
107 20’ 50” – 107 42’ 12” E,
06 43’ 55” – 070 06’ 51” S,
368.372 Ha

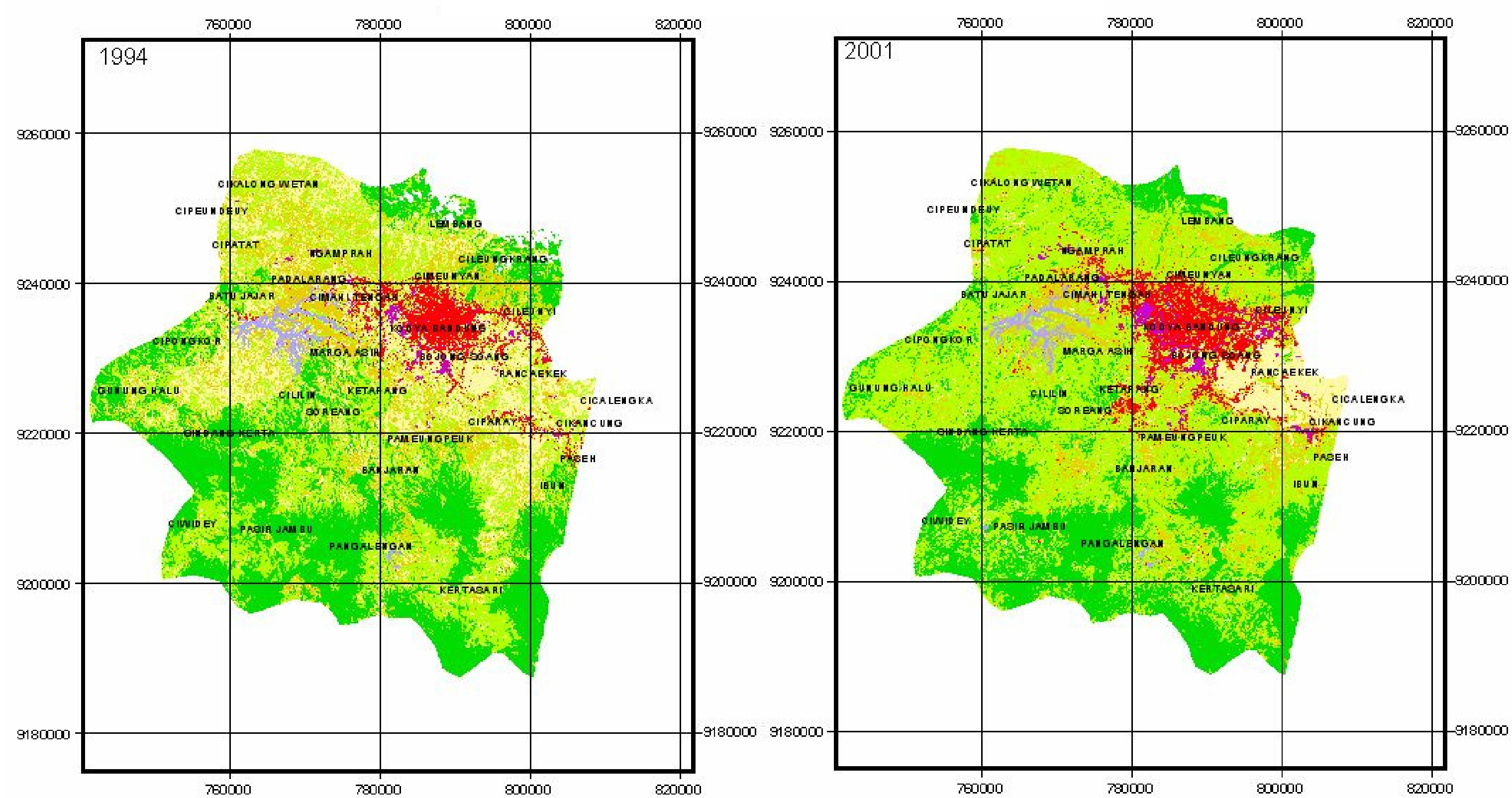
Other area that already investigated :
Medan, Jakarta, Balikpapan, Bogor, Semarang, Surabaya, Bali.



DESCRIPTION OF AREA STUDY

- Bandung city is Capital City of Province of West Java. It is located at 1070 36'E, 60 55"S.
- The location is not isolated and which is good communication will easy the institution of security advance to every corner.
- TOPOGRAPHIES : around 791 m MSL, the highest point area in the north is around 1.050 m and the lowland in the south which is around 675 m MSL. The land in South Bandung Municipality area until the line of grade crossing, the land is smooth relatively, whereas in the north of the land is mountainous that make the area have the beautiful panorama.
- GEOLOGICAL : is built at quarters period and have alluvial soil layer from Tangkuban Perahu Mount explosion. The kind of material in the north is andosol generally and in the part of south and east consist of kind of grey alluvial with clay sediment. In the part of central and west scattered kind of andosol.
- CLIMATE : is controlled by mountain climate which humid and cool. The general average temperature is 23,10 C, the average of rainfall is 204,11 mm and rainday is 18 day per mount (the condition of 2001).

a. LAND USE AND LAND COVER CHANGES IN BANDUNG (1994, 2001)



Forest	
Industry	
Open Land	
Residence	
Agriculture	
Paddy Field	
Water	

Map Projection : UTM

Data Source : 1. LANDSAT TM 1994

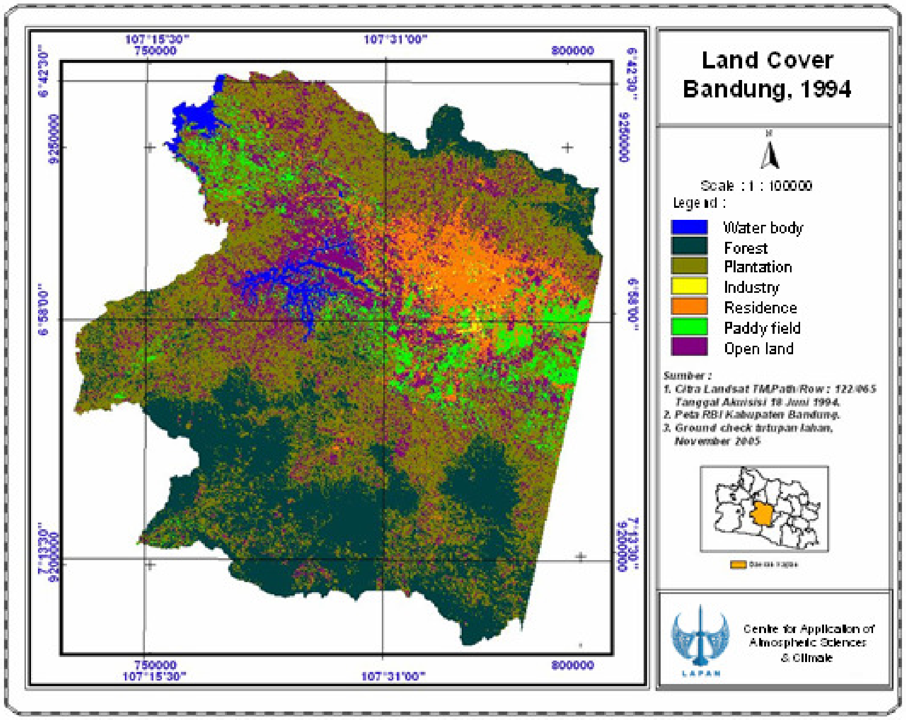
2. LANDSAT ETM 2001

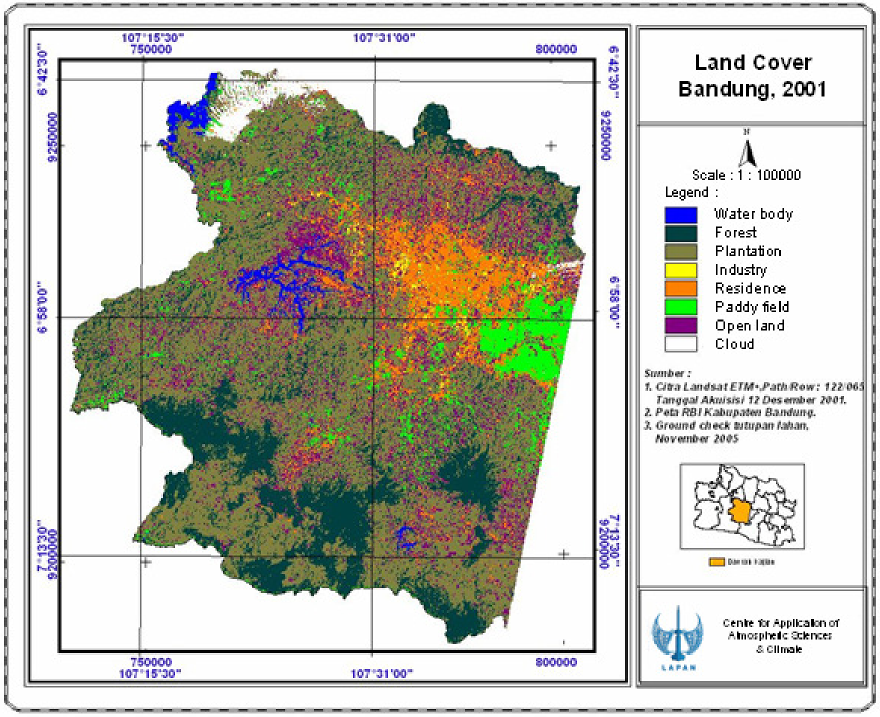
Spatial Resolution : 30 m x 30 m

Climate & Atmospheric Science Application Centre

National Institute of Aeronautics & Space.

LAND USE AND LAND COVER CHANGES IN BANDUNG (1994, 2001)

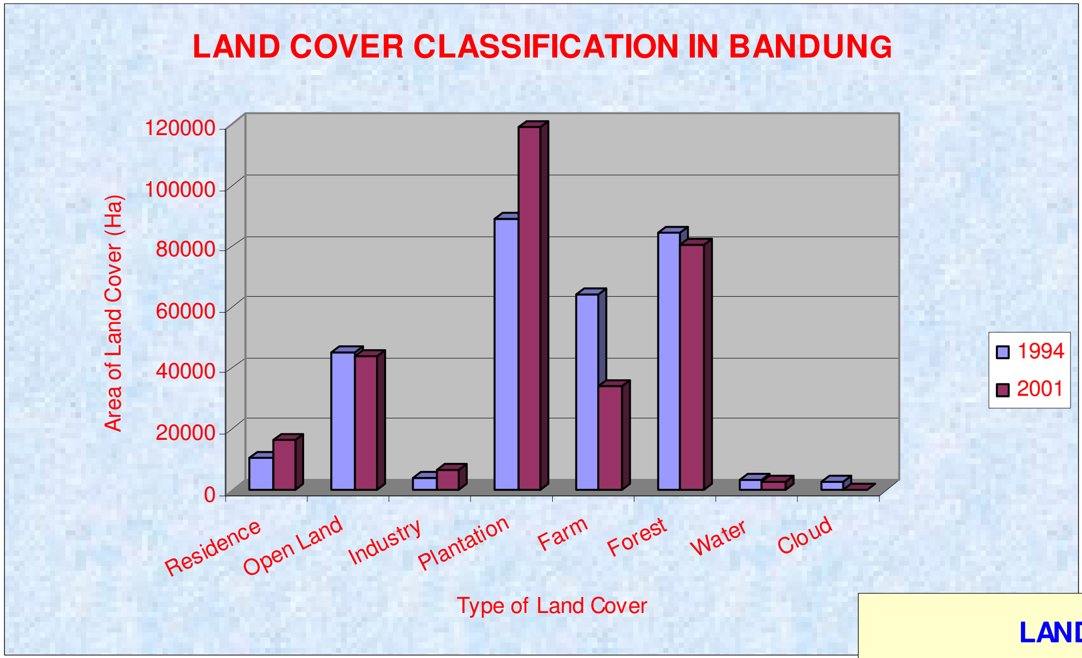


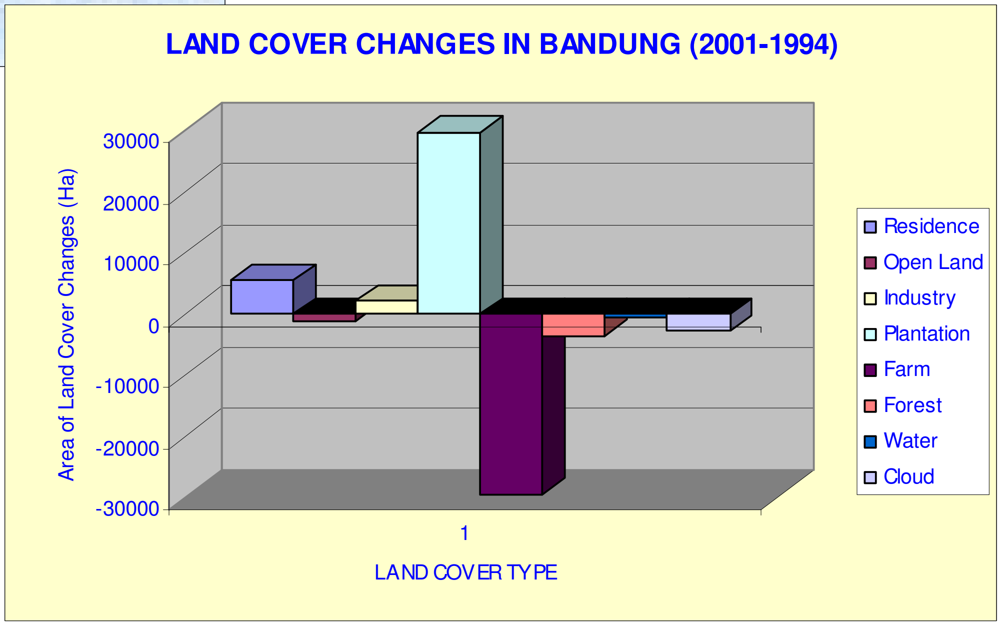


Statistic of BANDUNG Land Cover Change

No.	Land Cover Type	Land Cover Area (1994)		Land Cover Area (2001)		Land Cover Change Area	Land Cover Change Area
		(Ha)	(%)	(Ha)	(%)	(2001-94) in Ha	per year (Ha)
1	RESIDENCE	10858.14	3.58	16364.79	5.39	5506.65	786.66
2	OPEN LAND	45081.27	14.85	44071.47	14.51	-1009.8	-144.26
3	RESIDENCE	4264.47	1.40	6396.57	2.11	2132.1	304.59
4	AGRICULTURE	89139.69	29.36	118918.62	39.16	29778.93	4254.13
5	PADDY FIELD	63937.26	21.06	34456.59	11.35	-29480.67	-4211.52
6	FOREST	84520.53	27.83	80898.75	26.64	-3621.78	-517.40
7	WATER	3095.28	1.02	2558.34	0.84	-536.94	-76.71
8	CLOUD	2762.46	0.91	0	0.00	-2762.46	-394.64
	TOTAL	303659.1	100	303665.13	100		

Bandung Land Cover Changes in Graphics

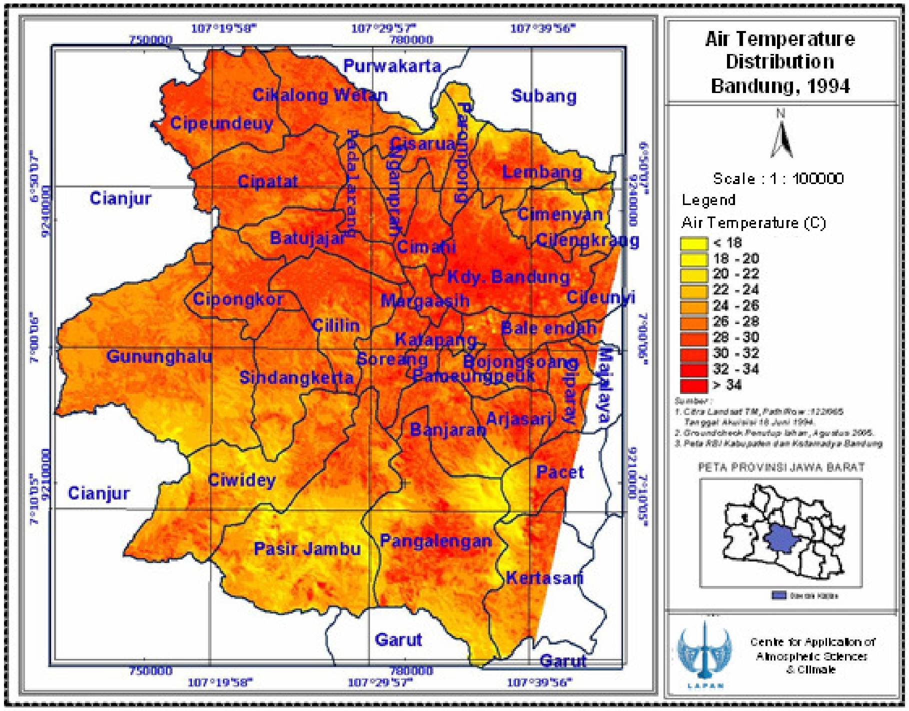


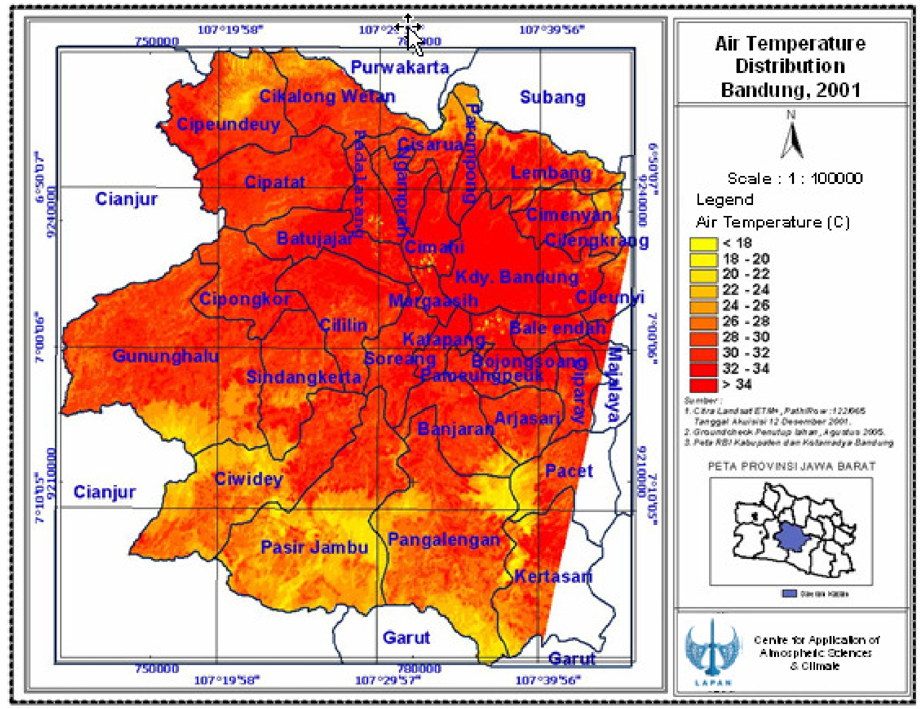


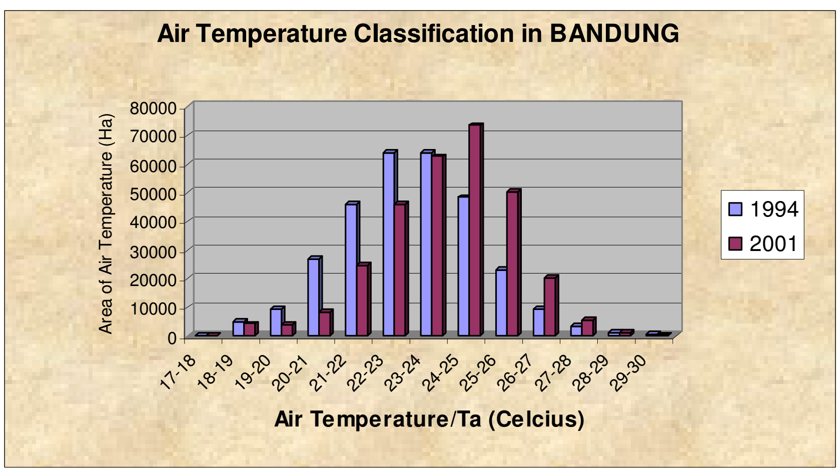
Land Cover Changes in Bandung with Matrix Overlay

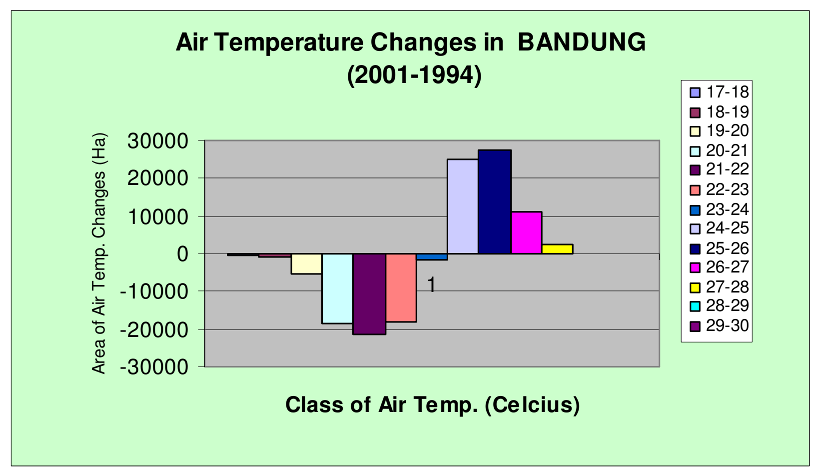
No.	Land Cover Changes	Area of Land Cover Changes	
		(Ha)	(%)
01.	Plantation to Farm	69171	24.52
02.	Forest to Plantation	32970	11.69
03.	Plantation to Residence	16323	5.79
04.	Plantation to Industry	12377	4.39
05.	Open Land to Residence	11798	4.18
06.	Farm to Plantation	7094	2.52
07.	Forest to Open Land	4189	1.49
08.	Farm to Open Land	2098	0.74
09.	Open Land to Industry	1948	0.69
10.	Farm to Residence	1465	0.52
11.	Forest to Residence	646	0.23
12.	Forest to Farm	243	0.09
13.	Plantation to Open Land	149	0.05
14.	Industry to Industry	138	0.05
15.	Farm to Industry	89	0.03

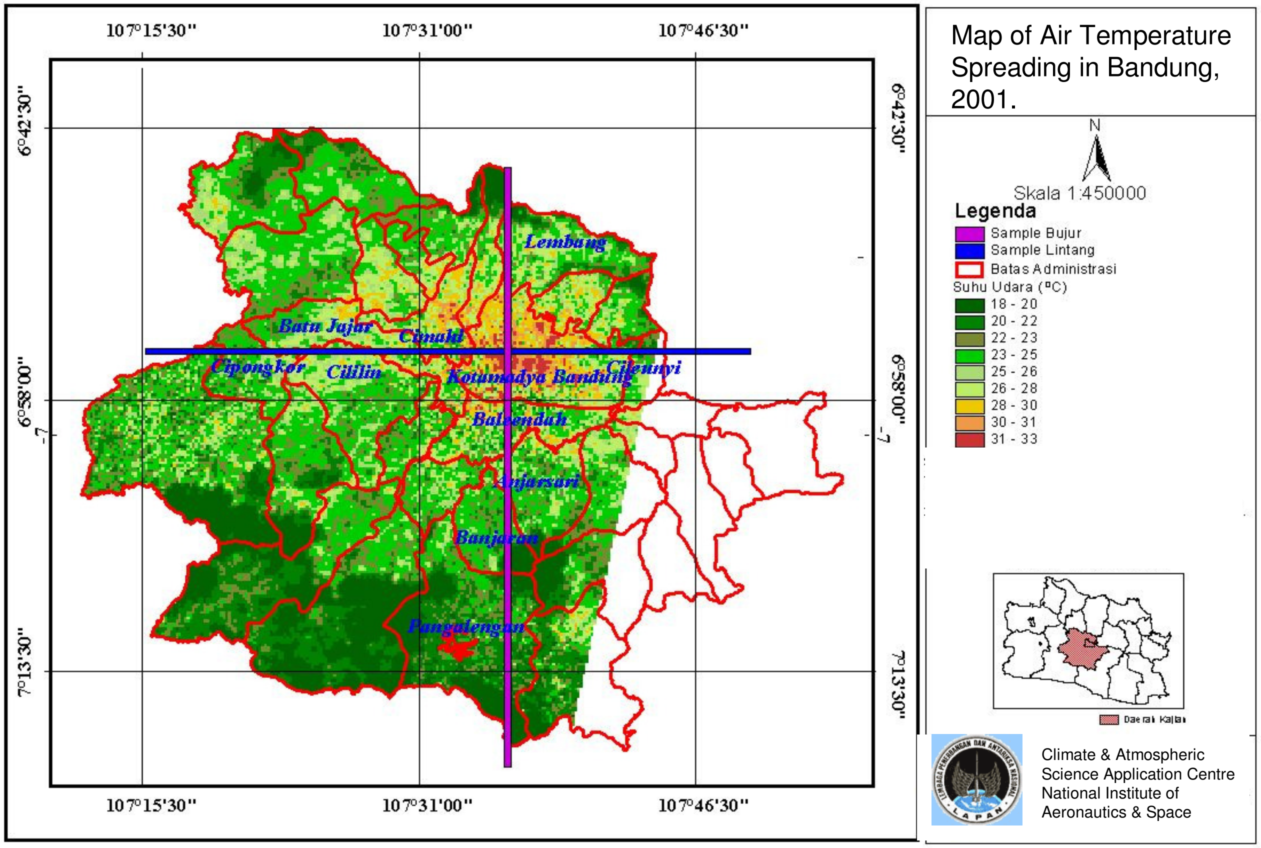
Air Temperature (UHI) spreading in Bandung

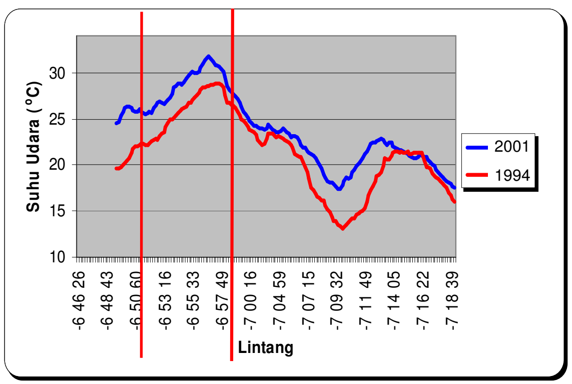




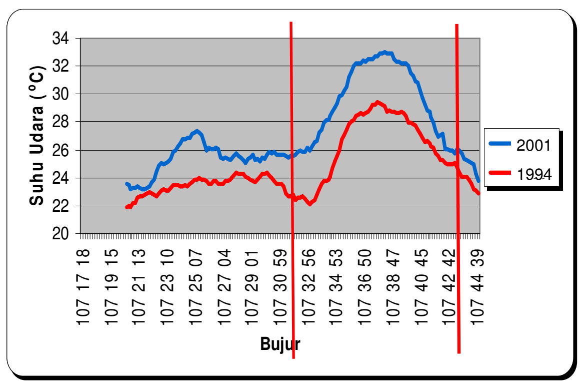




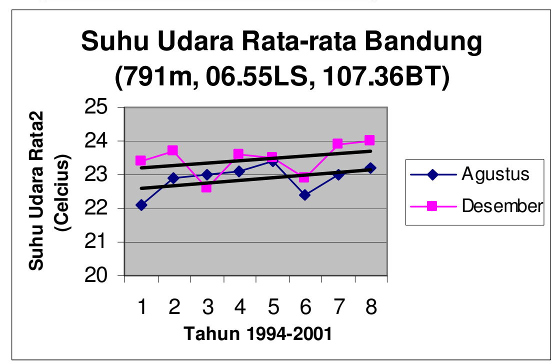




Air Temperature Profile in Longitude 107 36' 19" E



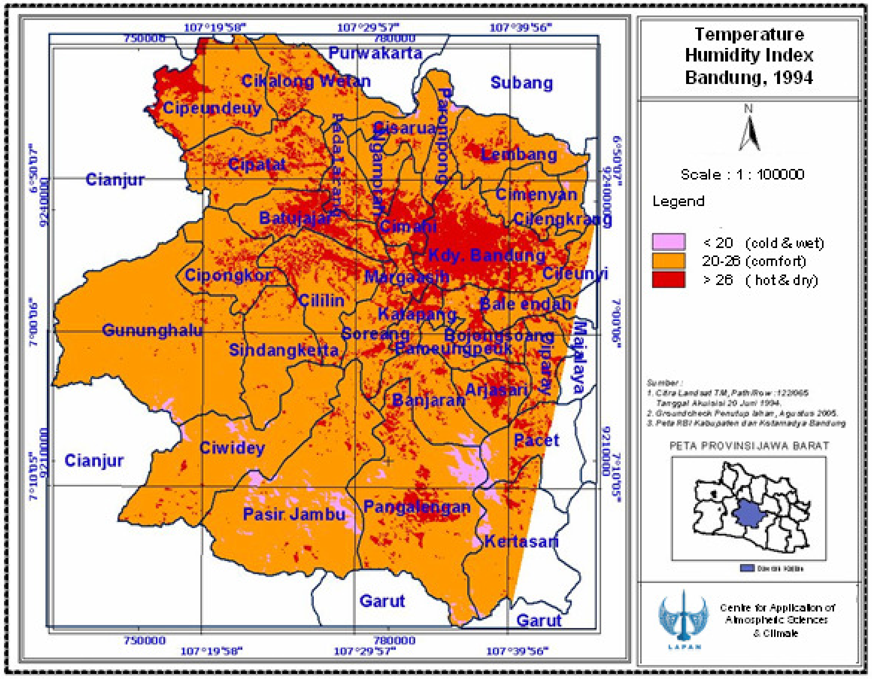
Air Temperature Profile on Latitude 60 54' 23" S

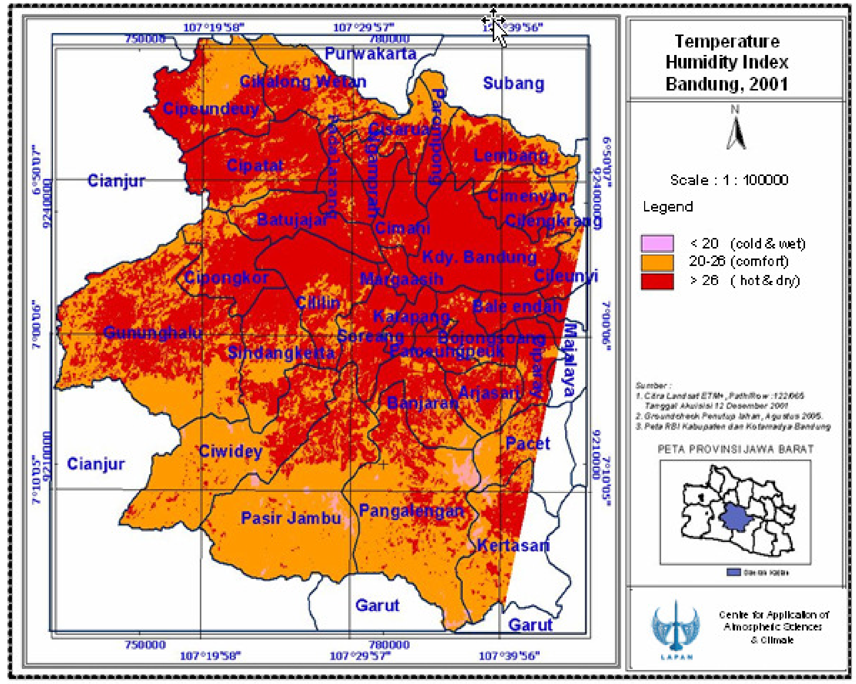


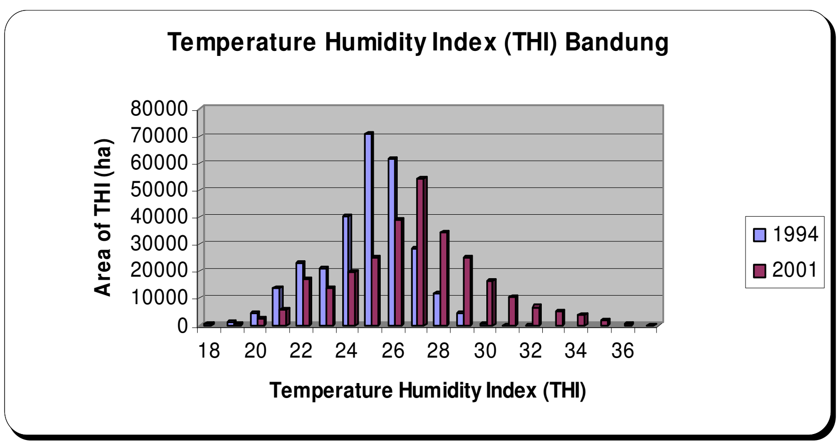
$Y_{Aug} = 0{,}0798\ X + 22{,}523$

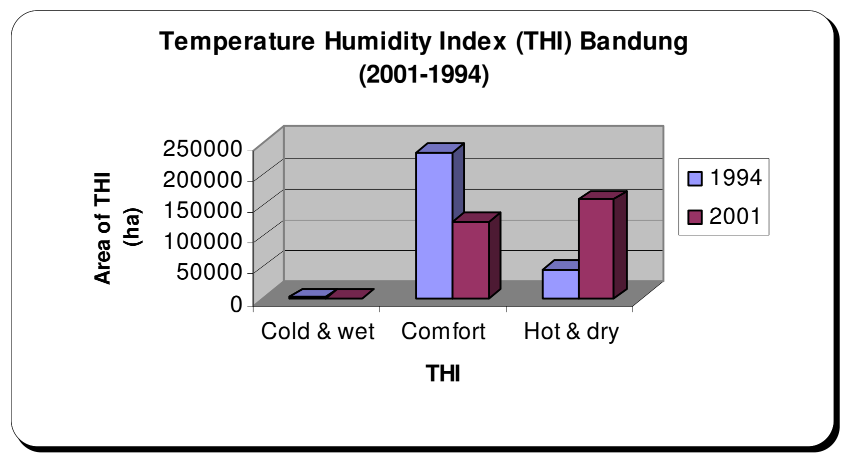
$Y_{Sept} = 0{,}0714\ X + 23{,}129\ 22{,}523$

Temperature Humidity Index (THI)

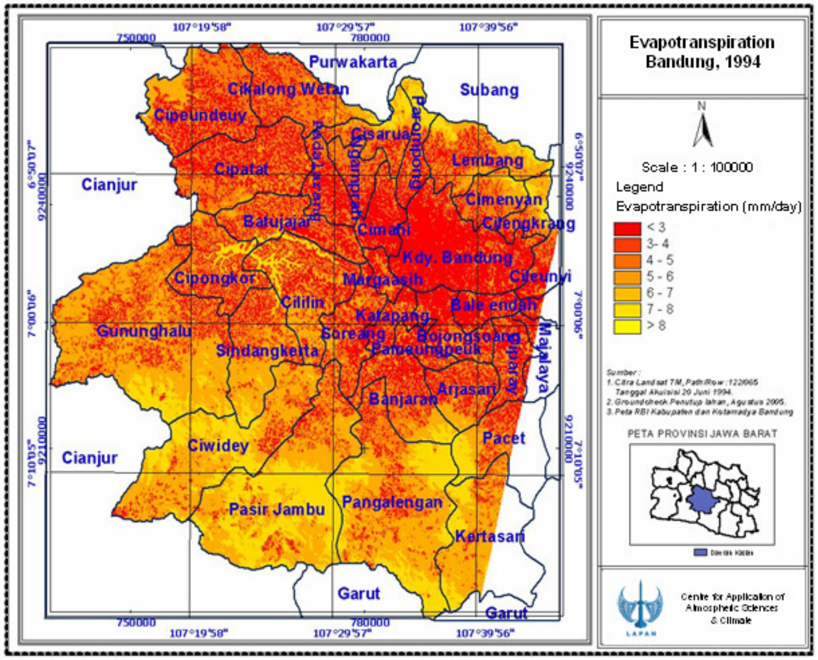


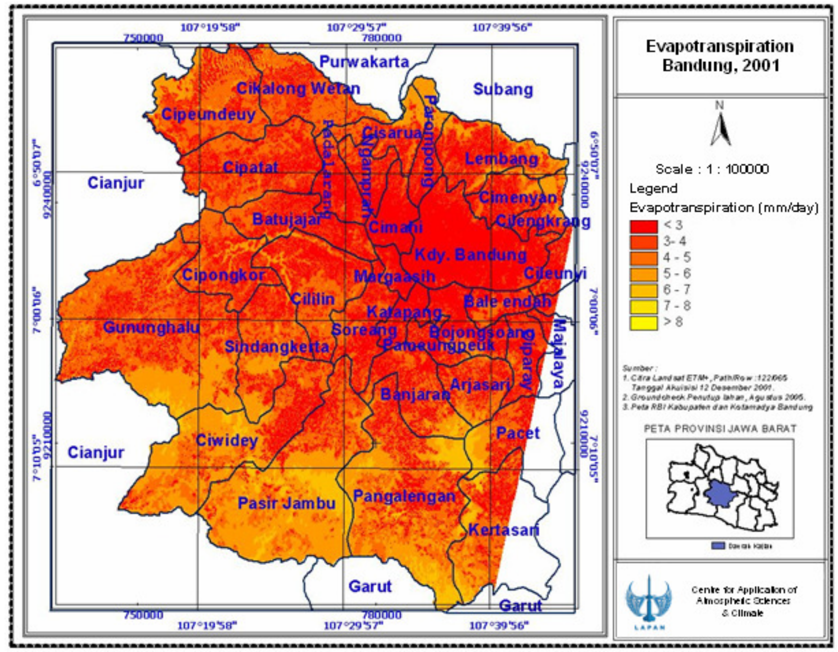


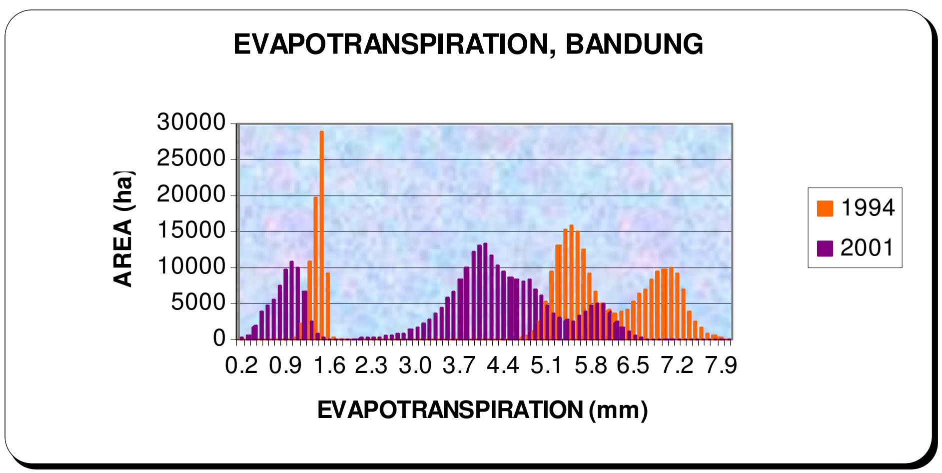




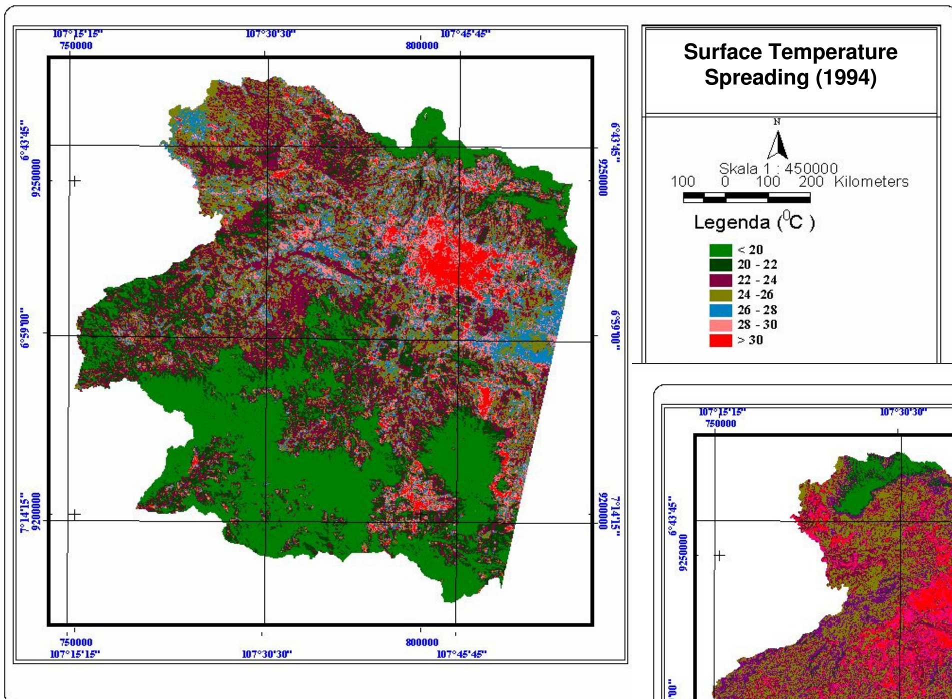
Evapotranspiration (ETP)

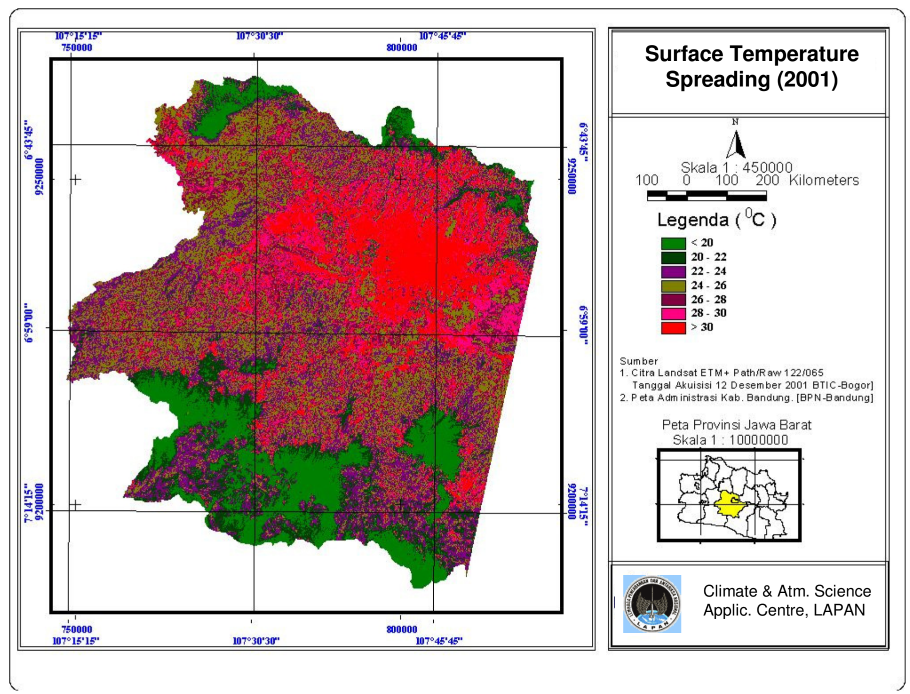




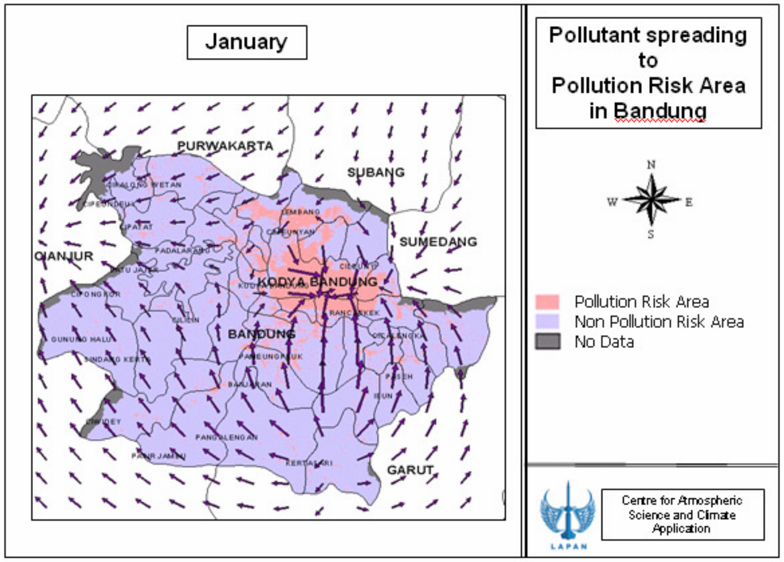


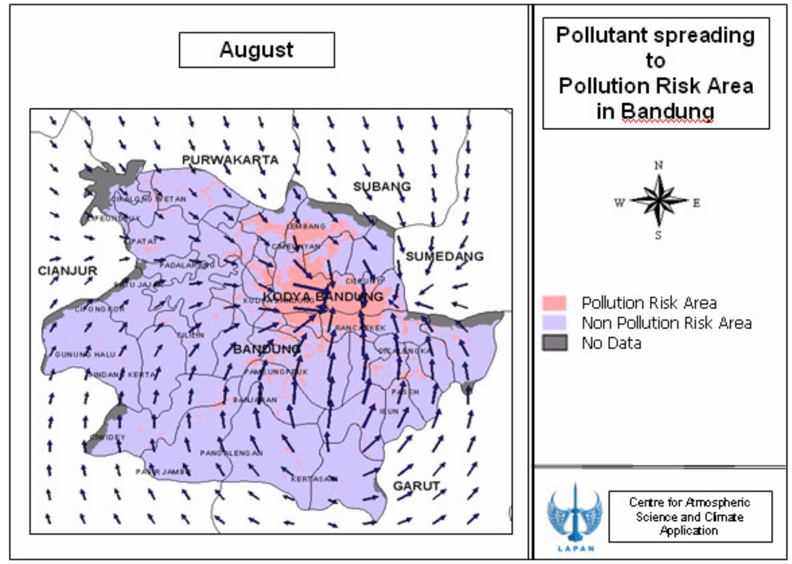
Different of Surface Temperature spreading in Bandung



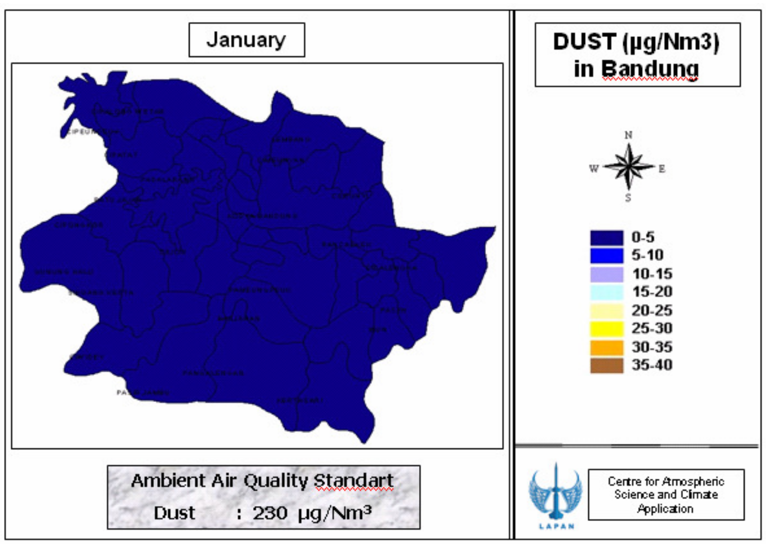


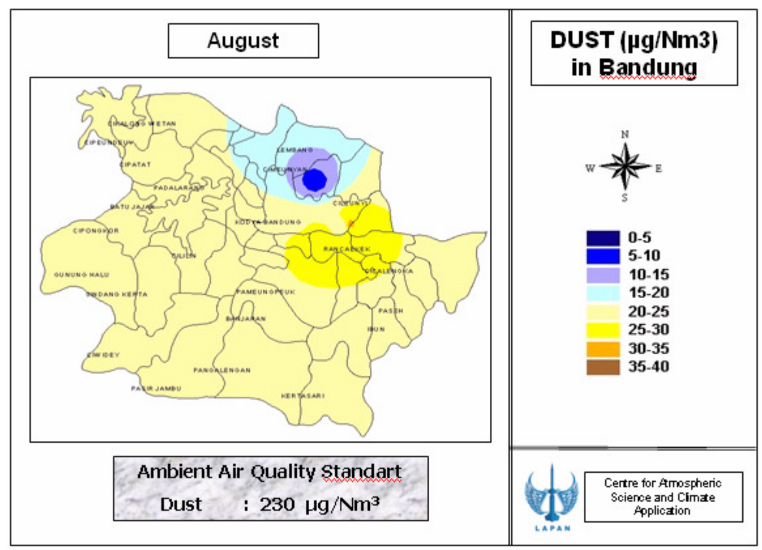
Pollutant spreading & Pollution Risk Area in Bandung



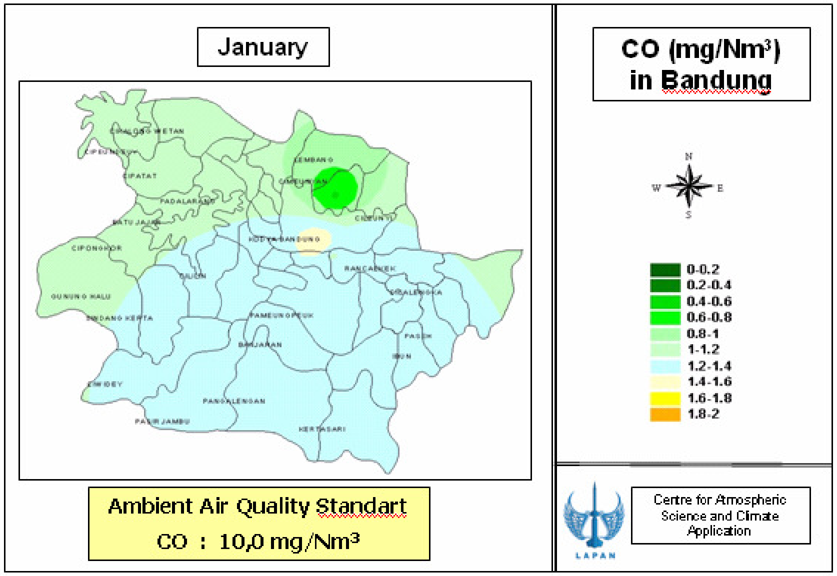


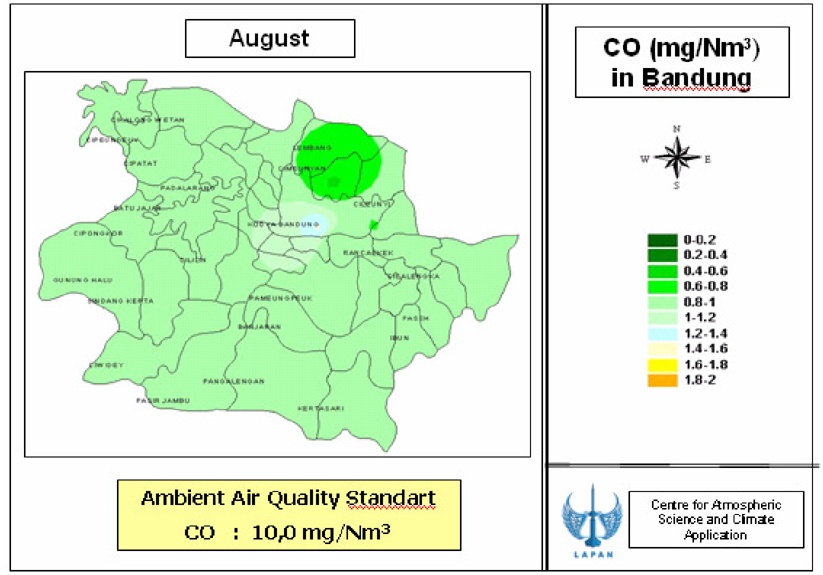
Dust in Bandung



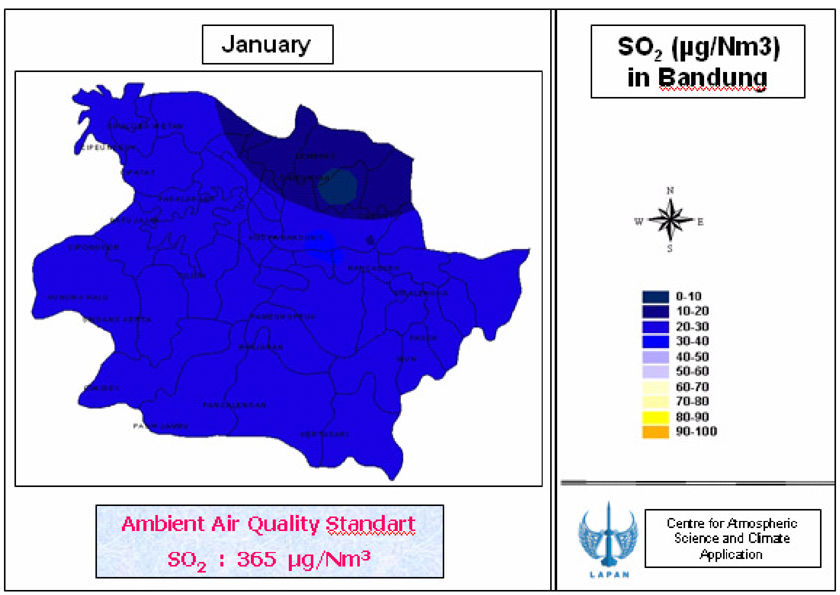


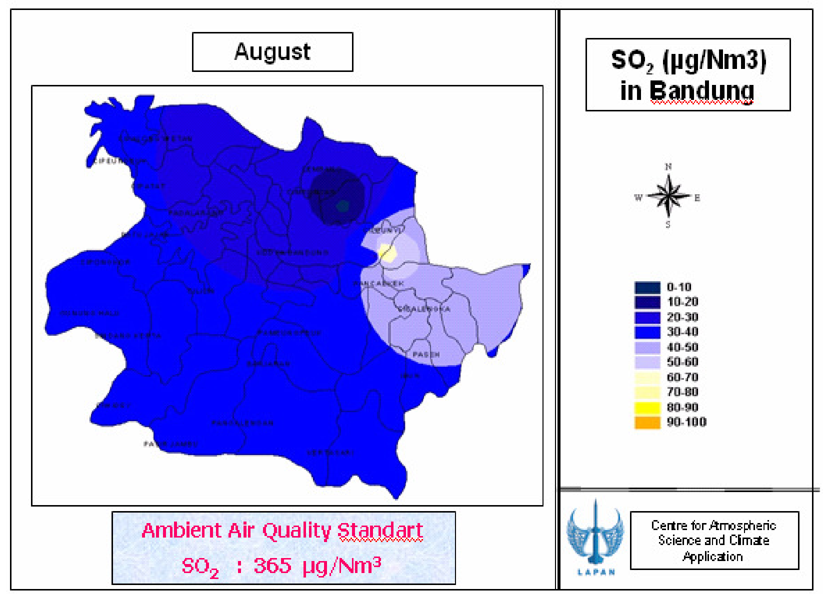
CO in Bandung





SO2 in Bandung





CONCLUSION

- There is evidence of widespread regional heat island effect over Bandung's central plain.
- The heat-island effect has significant impacts on the climate of Bandung, most apparent in air temperature and the surface temperature, and relative humidity.
- Increasing in THI would be make uncomfortable to the human life.
- Reduce of Evapotranspiration because of land cover change from vegetation area to non vegetation area, and reduce of water body.
- Global Warming issue will be influence the city planning, then the changes of increase in air temperature would be decrease comfortable.
- Air pollution (CO, SO_2, and dust) for Bandung area were centralized in the downtown. In the wet season the pollution was weak, and stronger in the dry season. Pollutant spreading for Bandung region still the range of security (under air quality standard),
- Pollutant spreading that come up from air temperature average. This pollutant spreading was evaluated to oblique elevation and land use to area of pollution risk.
- Bandung concave need guard because constitute convergence region then regency environment factor contribute. This is very important for city planning.
- Research still in progress : to definite the open green area. How many open green area that was needed for comfortable in the city. This is for Recommendation to government for the city planning.
- Research still in progress : The simulation of LULC impact to Urban Climate Changes with WRF.

Mitigation Long Term Strategies

- Planting shade tress reduces the amount of heat absorbed by buildings by directly shielding them from the sun’s rays. Tress, shrubs, and other plants help reduce ambient air temperatures (Urban Heat Island) through “evapotranspiration”. Trees absorb air pollution too.
- Installing reflective materials for roofs and pavements. When the sun beats down on building covered with dark colored roofing materials, most of the heat collected by the roof is transferred inside, increasing the demand for air conditioning. Installing highly reflective roofs will keep buildings cooler and reduce energy bills.
- Increasing the albedo of these surfaces (Roads, parking lots, and driveways) through the use of reflective paving materials will help to cool down the surrounding ambient air temperature.
- To manage the transportation that could be reduce of air pollution increase.
- Sustainable development need integration of city planning between government, citizen, industrialist and scientist.

THANK YOU

Terimakasih