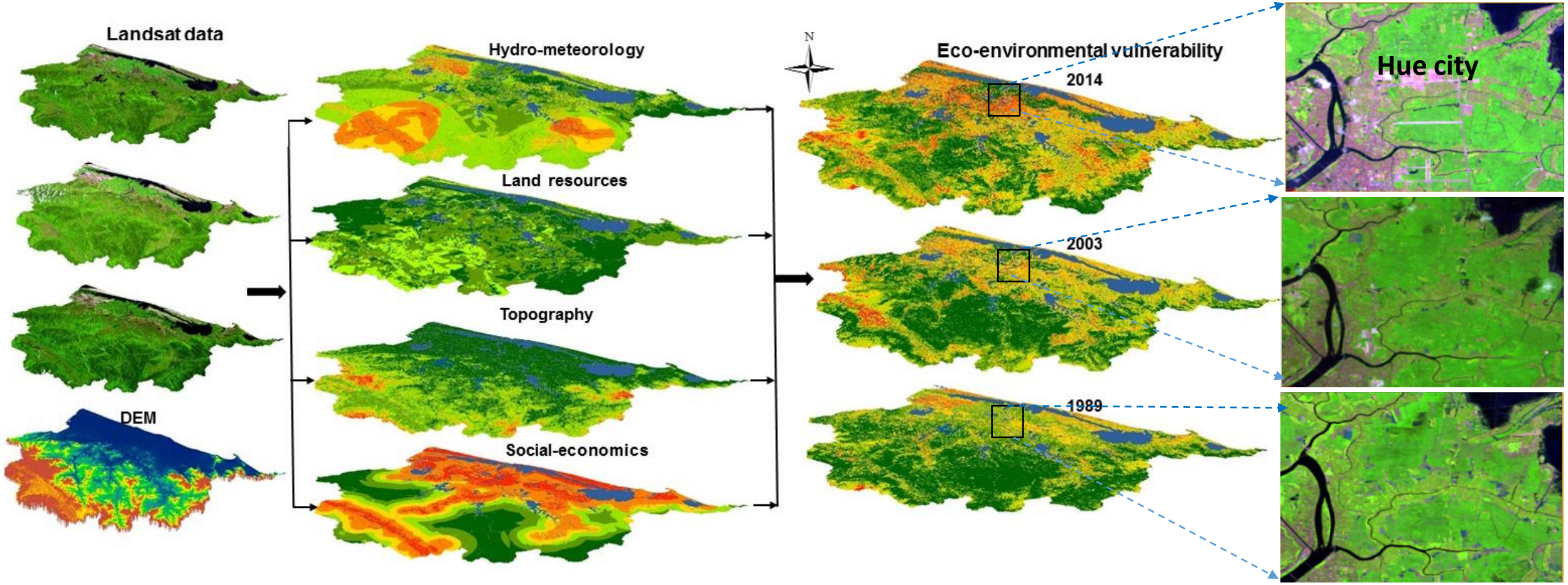
Assessing spatiotemporal eco-environmental vulnerability by Landsat data



Yuei-An Liou, Anh Kim Nguyen and Ming-Hsu Li

Introduction (1/3)

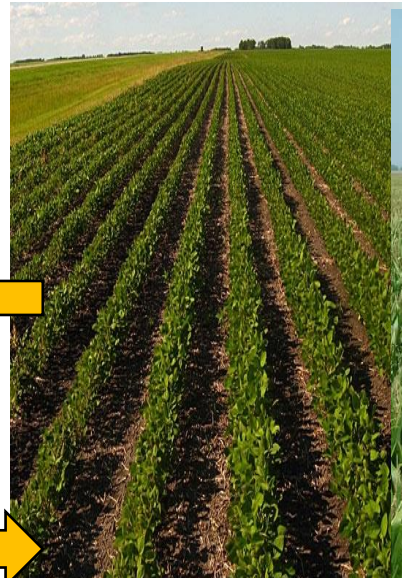
Water bodies

Built up areas

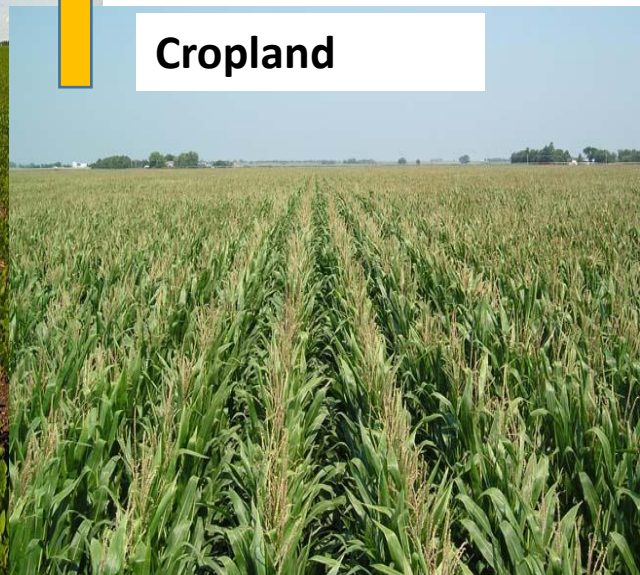
Changes in Land use

Forestry

Rural & urban recreation



Cropland



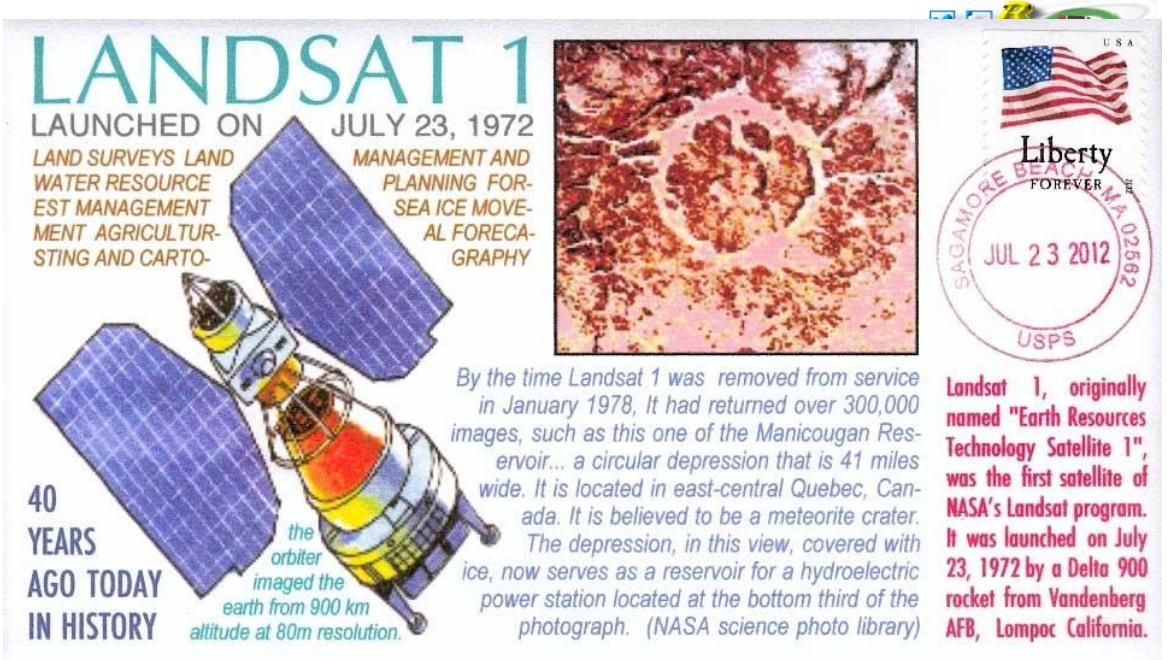
Introduction (2/3)

- ✓**Nguyen *et al*., 2016** proposed the framework to evaluate eco-environmental vulnerability. However, in view of long-term environmental monitoring across the region, it often becomes a barrier by using in situ measurements due to their limited spatiotemporal resolution, insufficient historical data, and infeasibility to capture both natural and man-made attributes within a given place and time.
- ✓There is a strong demand to improve the assessment framework to resolve the difficulties in obtaining long-term in situ eco-environmental measurements that are required in the previous framework.
- ✓In addition, the impacts and trends of LULC on environmental vulnerability for the past decades also need to consider in the analysis.

Introduction (3/3)

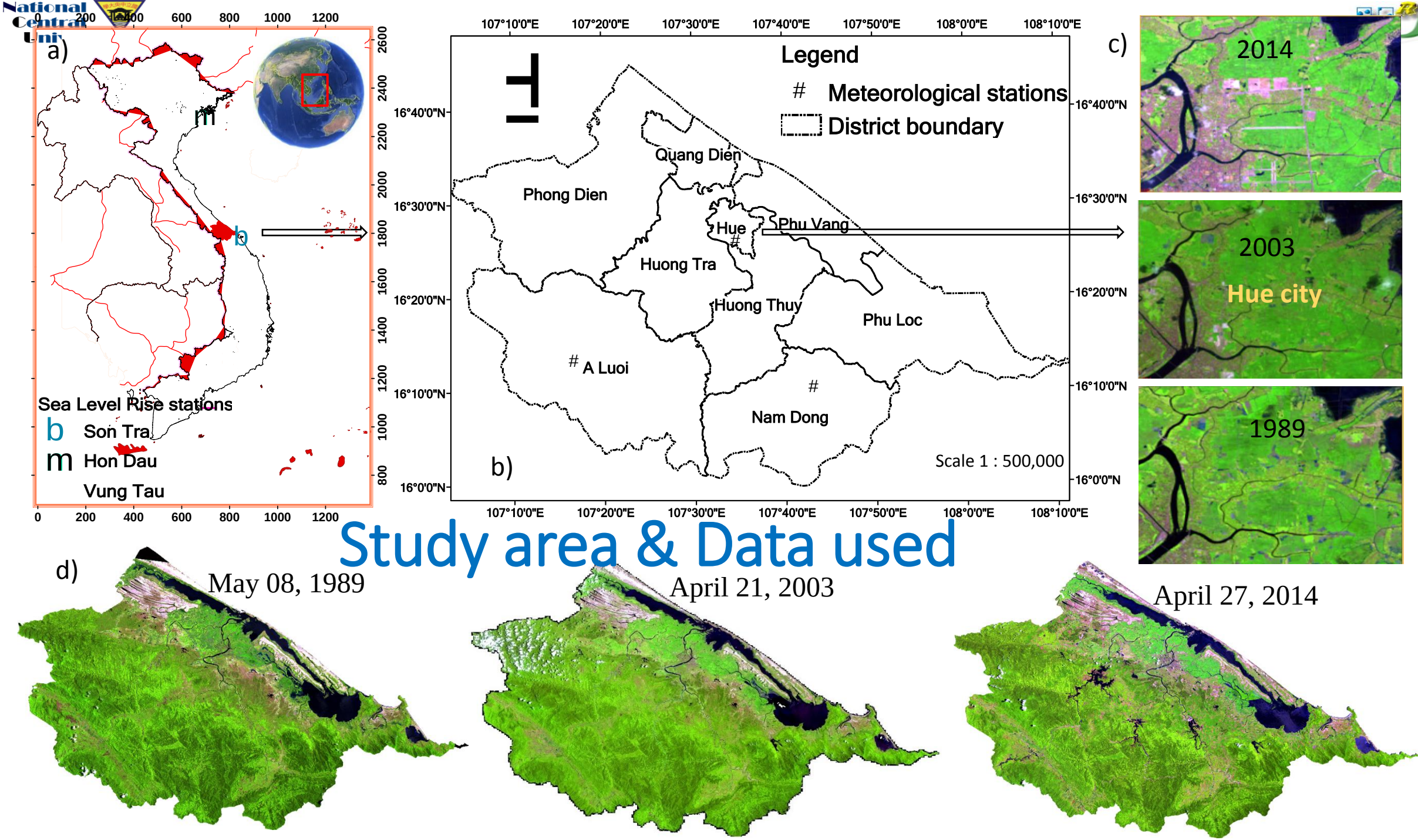
System	Launch (End of service)	I(s)	Resolution (meters)	Communications	Alt. Km	R Days	D Mbps
Landsat 1	7/23/72 (1/6/78)	RBV MSS	80 80	Direct downlink with recorders	917	18	15
Landsat 2	1/22/75 (2/25/82)	RBV MSS	80 80	Direct downlink with recorders	917	18	15
Landsat 3	3/5/78 (3/31/83)	RBV MSS	40 80	Direct downlink with recorders	917	18	15
Landsat 4*	7/16/82	MSS TM	80 30	Direct downlink TDRSS	705	16	85
Landsat 5	3/1/84	MSS TM	80 30	Direct downlink TDRSS**	705	16	85
Landsat 6	10/5/93 (10/5/93)	ETM	15 (pan) 30 (ms)	Direct downlink with recorders	705	16	85
Landsat 7	4/99	ETM+	15 (pan) 30 (ms)	Direct downlink with recorders	705	16	150
Landsat 8	02/11/2013	OLI TIRS	15 (pan) 30 (m)	(solid state) Direct Downlink with Solid State Recorders	705	16	384 Mbps on X-band frequency; 260.92 Mbps on S-band frequency

I(s) = Instrument(s)
R = Revisit interval
D = Data rate
*TM data transmission failed in August, 1993.
** Current data transmission by direct downlink only. No recording capability.



Source: http://landsathandbook.gsfc.nasa.gov/program/

Study area & Data used

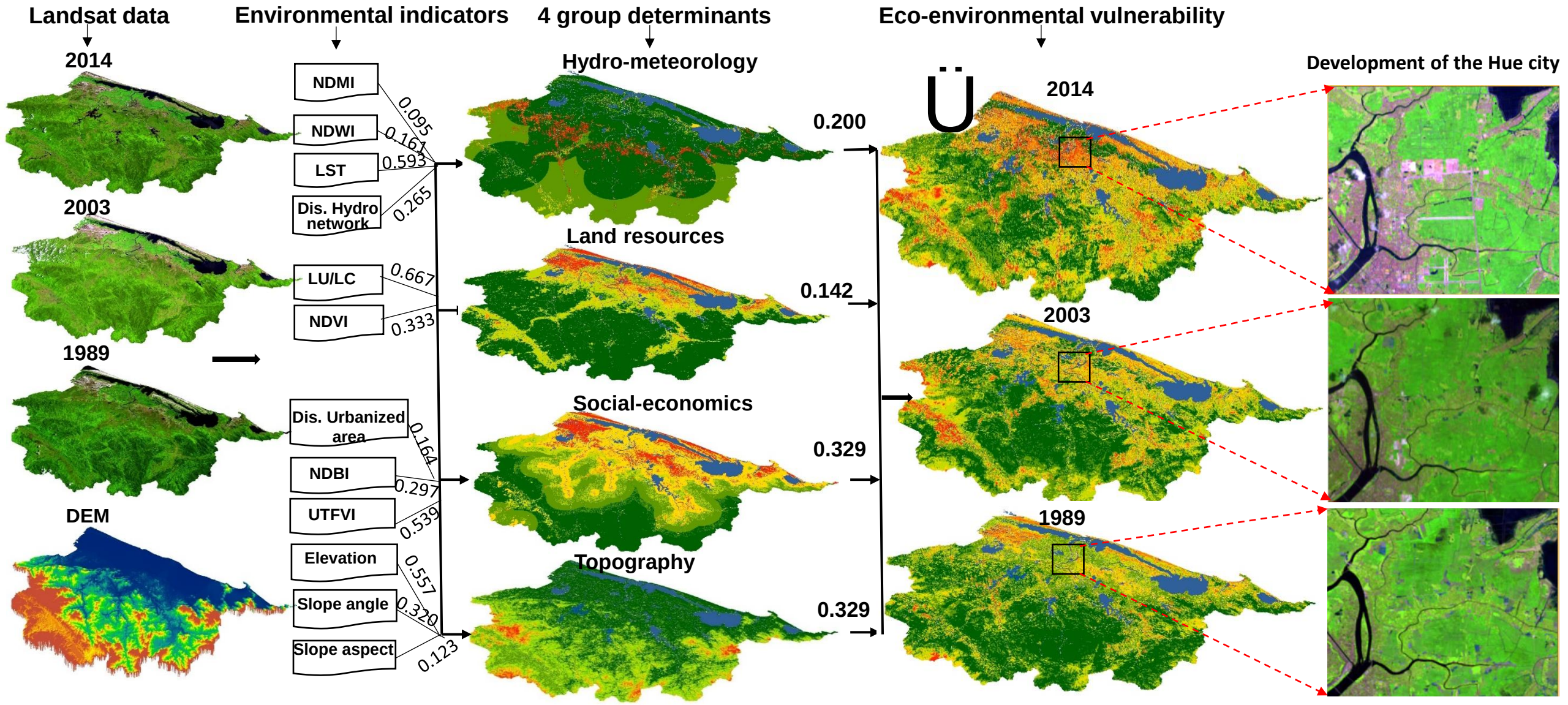


Objectives

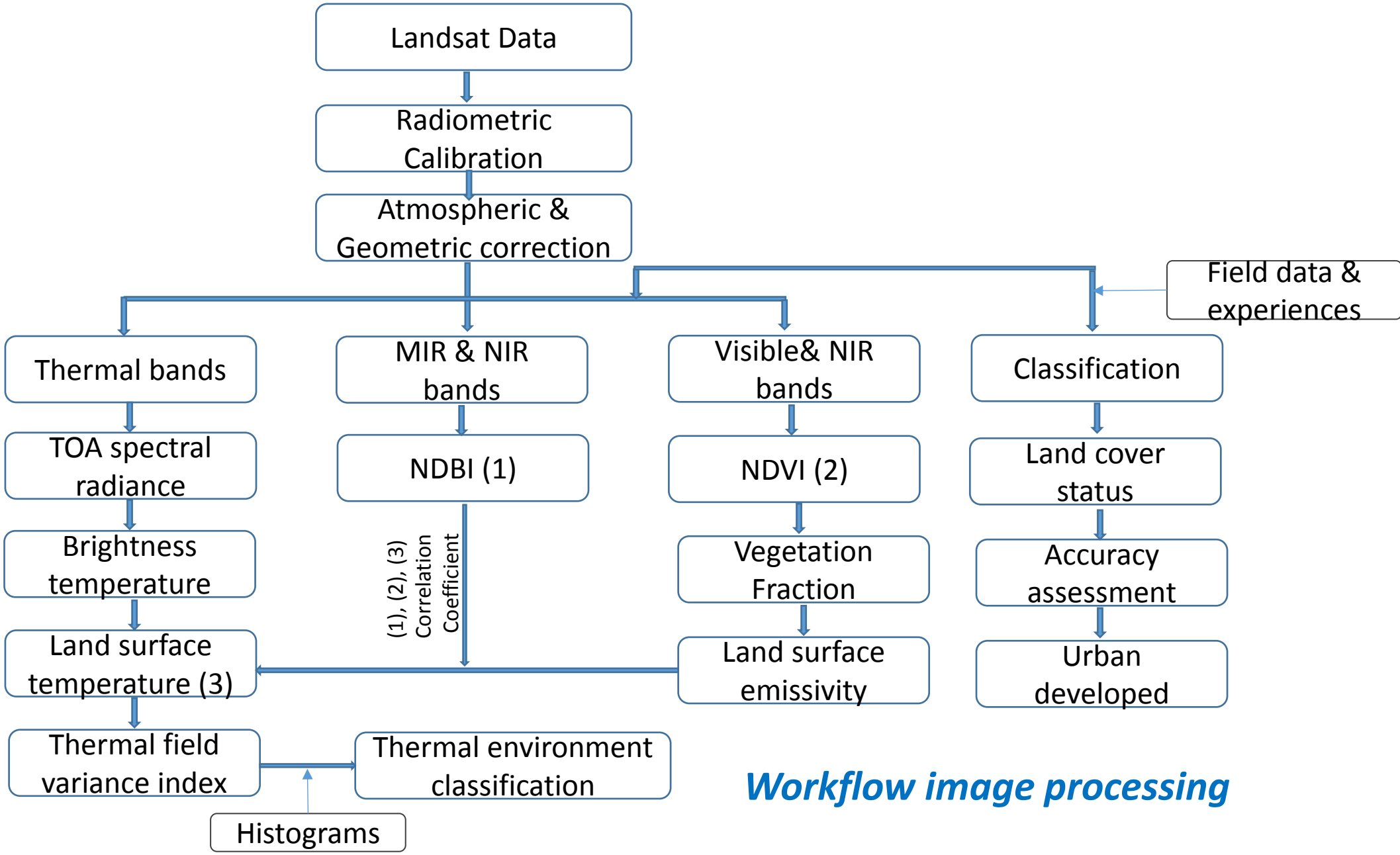
(1) Evaluate eco-environmental vulnerability changes based on indices retrieved from Landsat TM, ETM, and OLI & TIRS (Thematic Mapper, Enhanced Thematic Mapper, and Operational Land Imager & Thermal Infrared Sensor).

(2) Analyze the relationship between land use changes, thermal anomaly and eco-environmental vulnerability by computing correlation coefficient between LST and Normalized Difference Build-up Index (NDBI) over the past 20 years (1989–2003-2014).

Method(1/5)


Landsat data
Environmental indicators
4 group determinants
Eco-environmental vulnerability
2014
2003
1989
DEM
NDMI
NDWI
LST
Dis. Hydro network
LU/LC
NDVI
Dis. Urbanized area
NDBI
UTFVI
Elevation
Slope angle
Slope aspect
0.095
0.161
0.593
0.265
0.667
0.333
0.164
0.297
0.539
0.557
0.320
0.123
Hydro-meteorology
Land resources
Social-economics
Topography
0.200
0.142
0.329
0.329
Ü
2014
2003
1989
Development of the Hue city

Method (2/5)



Workflow image processing

Method (3/5)

Thermal Environment Evaluation

$$TFVI = \frac{T_s}{T_s - T_{mean}}$$

where TFVI is the thermal field variance index;
Ts is the LST of certain pixel in C degree;
Tmean is the mean LST of the whole study area in C degree.

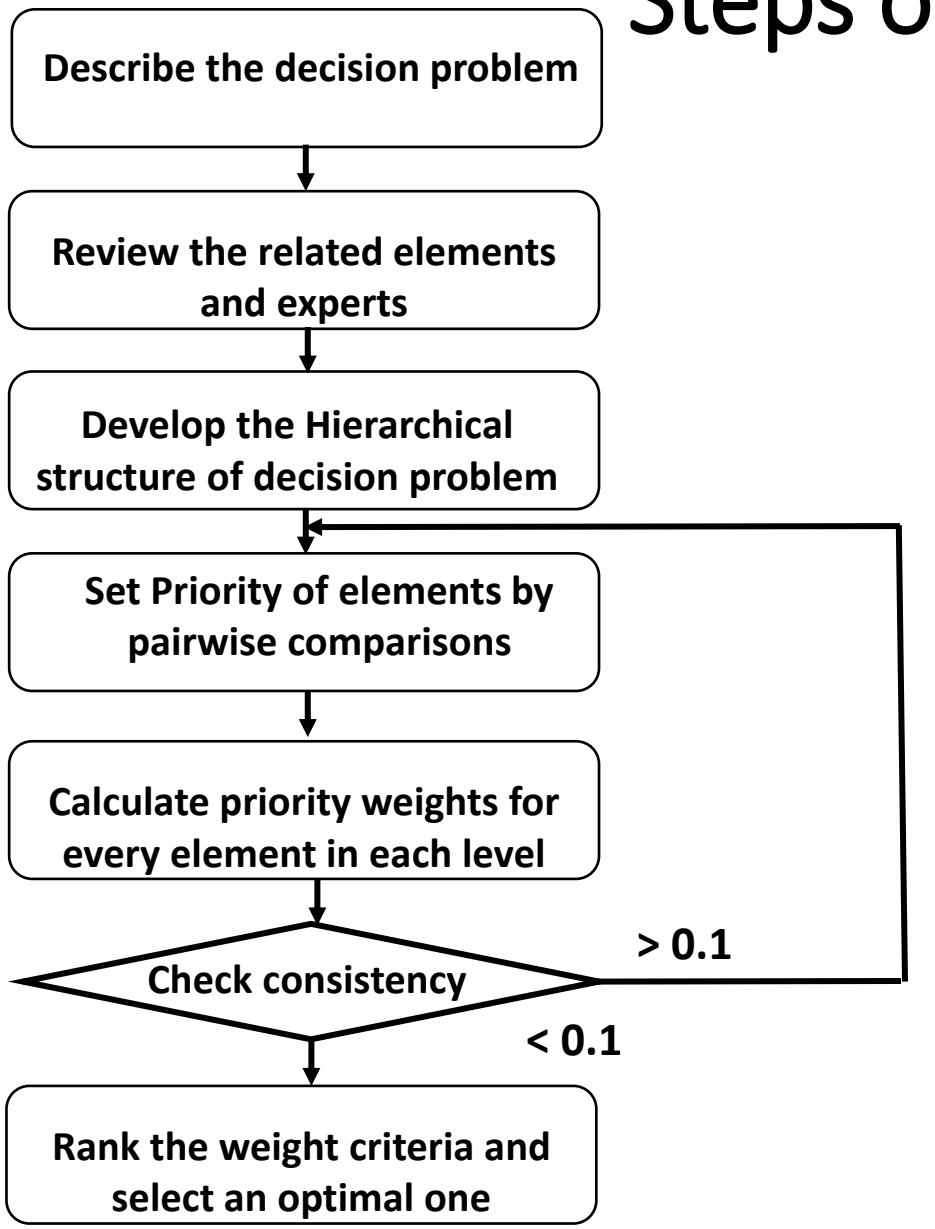
To classify thermal field variance index into different levels, histograms were used to reveal the statistical distribution of calculated thermal field variance values from grid cells

Methods (4/5)

Analytic Hierarchy Process (AHP)

The AHP technique is used to determine the weight for each variable and class. The overall scheme of the AHP can be simplified by six steps (Saaty, 1980; Saaty and Vargas, 2001; Bhushan and Rai, 2004).

Steps of AHP



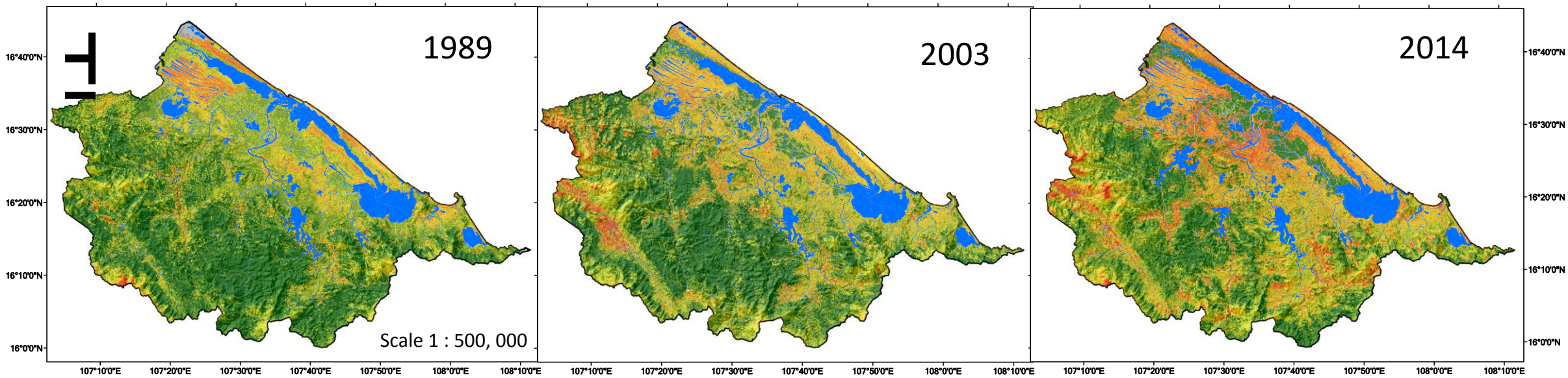
Method (5/5)

Table 1. Weightings of group variables and variables used for the calculation of eco-environmental vulnerability for the Thua Thien - Hue Province.

Group variables/Factors (B_i)	Global weight (W_i)	Variables/Factors (C_i)	Local weight (w_i)
B_1. Hydro-Meteorology	0.200	C_1 NDMI	0.095
		C_2 NDWI	0.161
		C_3 LST	0.593
		C_4 Distances from hydrological network	0.265
B_2. Society-economics	0.329	C_5 Distances from developed land	0.164
		C_6 NDBI	0.297
		C_7 UFTVI	0.539
B_3. Land recourse	0.142	C_8 Land use/ Land cover	0.667
		C_9 NDVI	0.333
B_4. Topography	0.329	C_{10} DEM	0.557
		C_{11} Slope angle	0.320
		C_{12} Slope aspect	0.123

Results and Discussions (1/7)

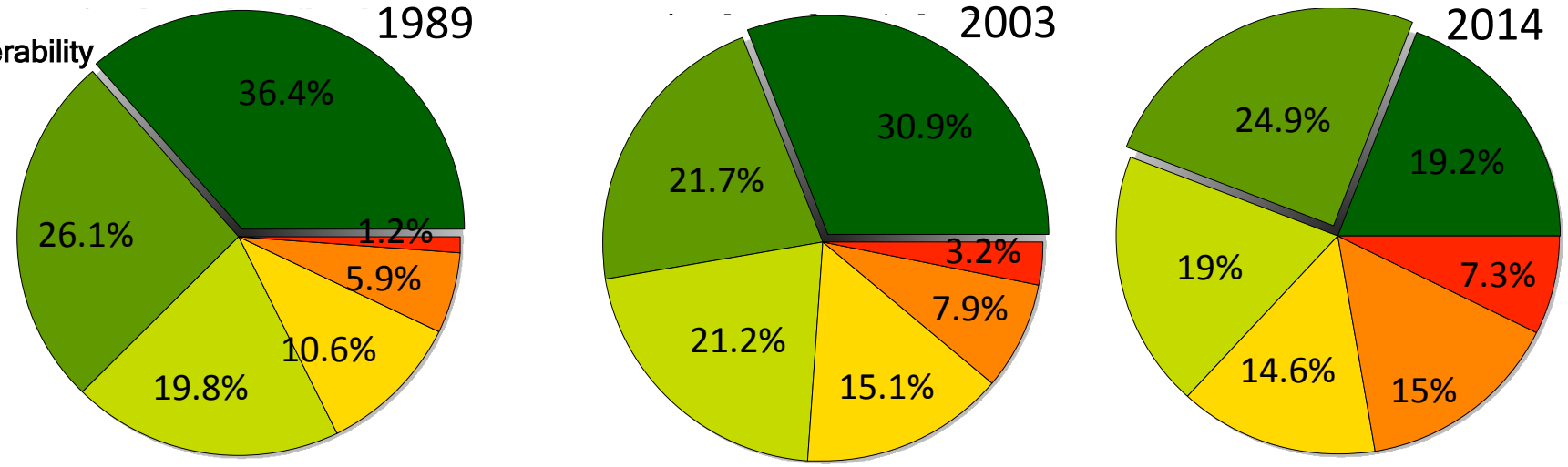
Eco-Environmental Vulnerability 1989-2003-2014



Legend

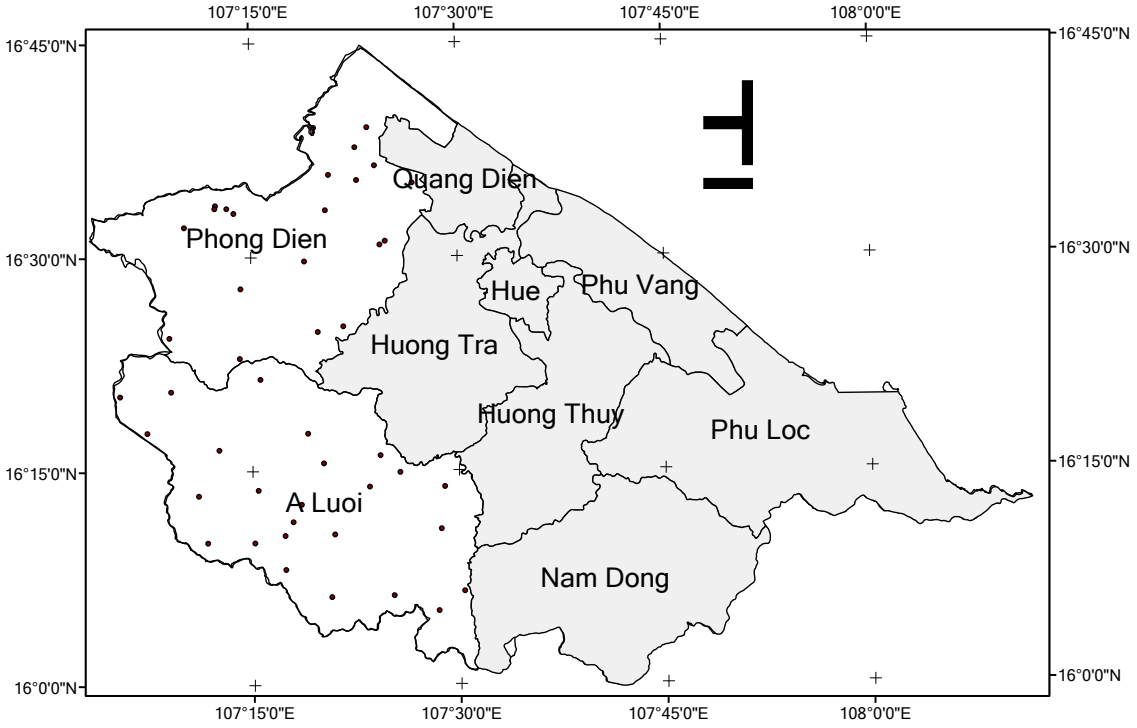
Eco_environmental vulnerability

- Potential
- Slight
- Light
- Medium
- Heavy
- Very heavy
- Water bodies



Results and Discussions (2/7)

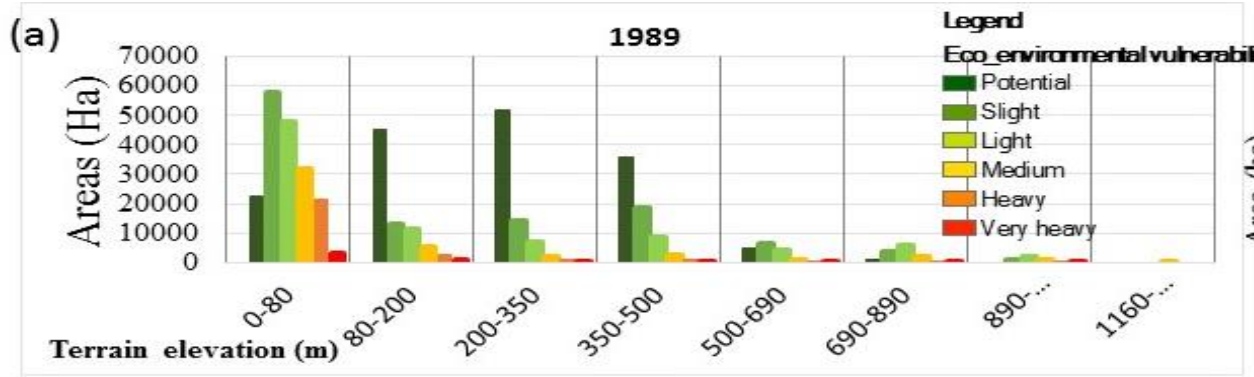
Correlation Coefficient of LST and NDBI and NDVI

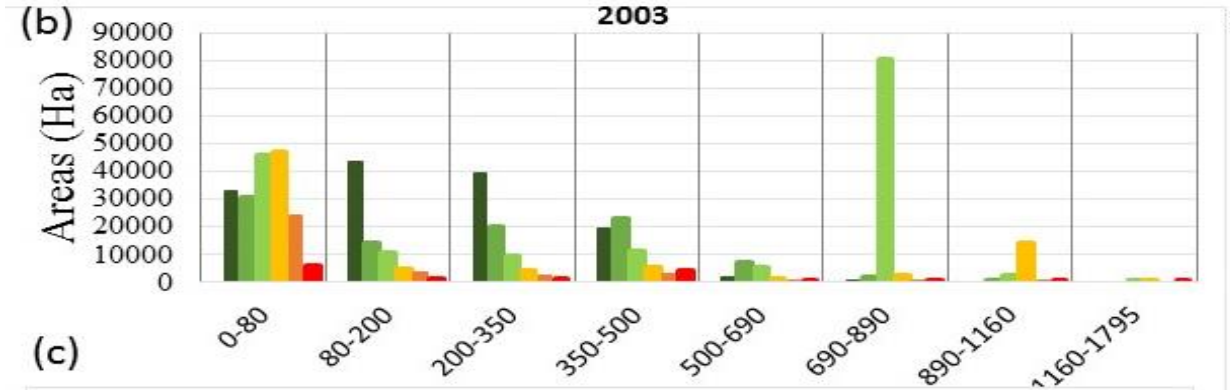


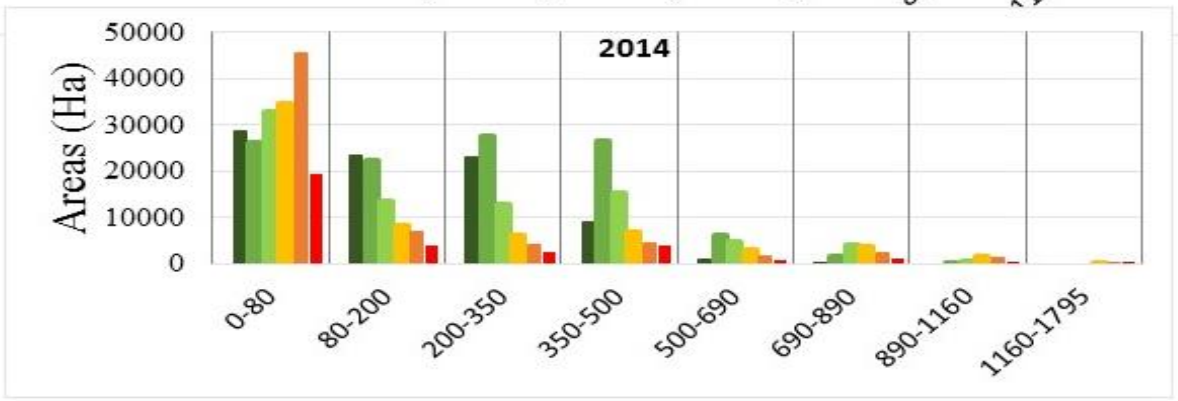
Random points distribution

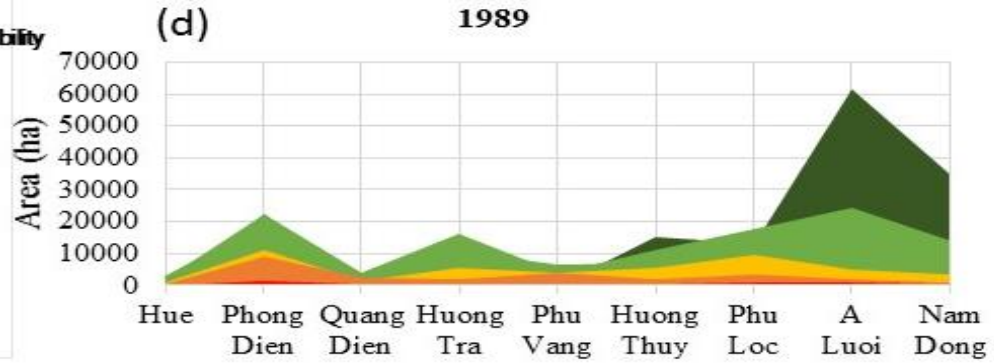
	1989	2003	2014
LST_NDBI	0.87	0.89	0.84
LST _NDVI	-0.81	-0.81	-0.76

Results and Discussions (3/7)

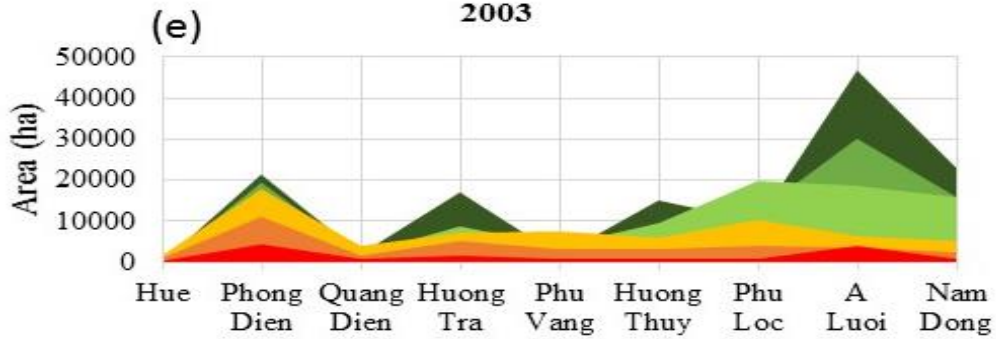


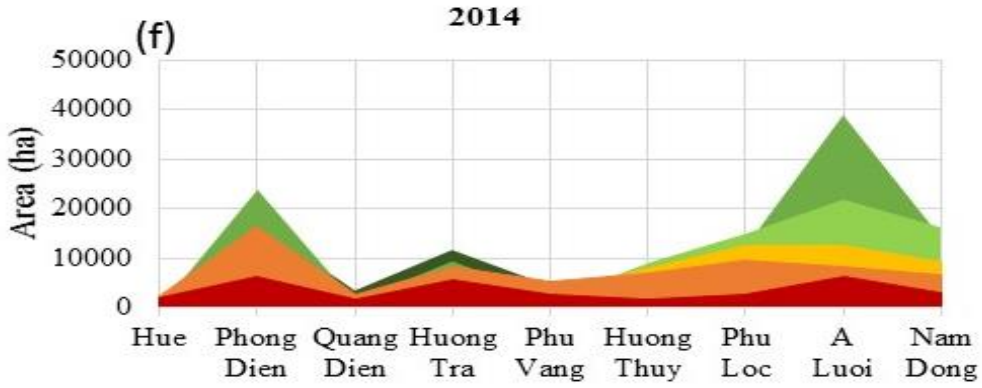




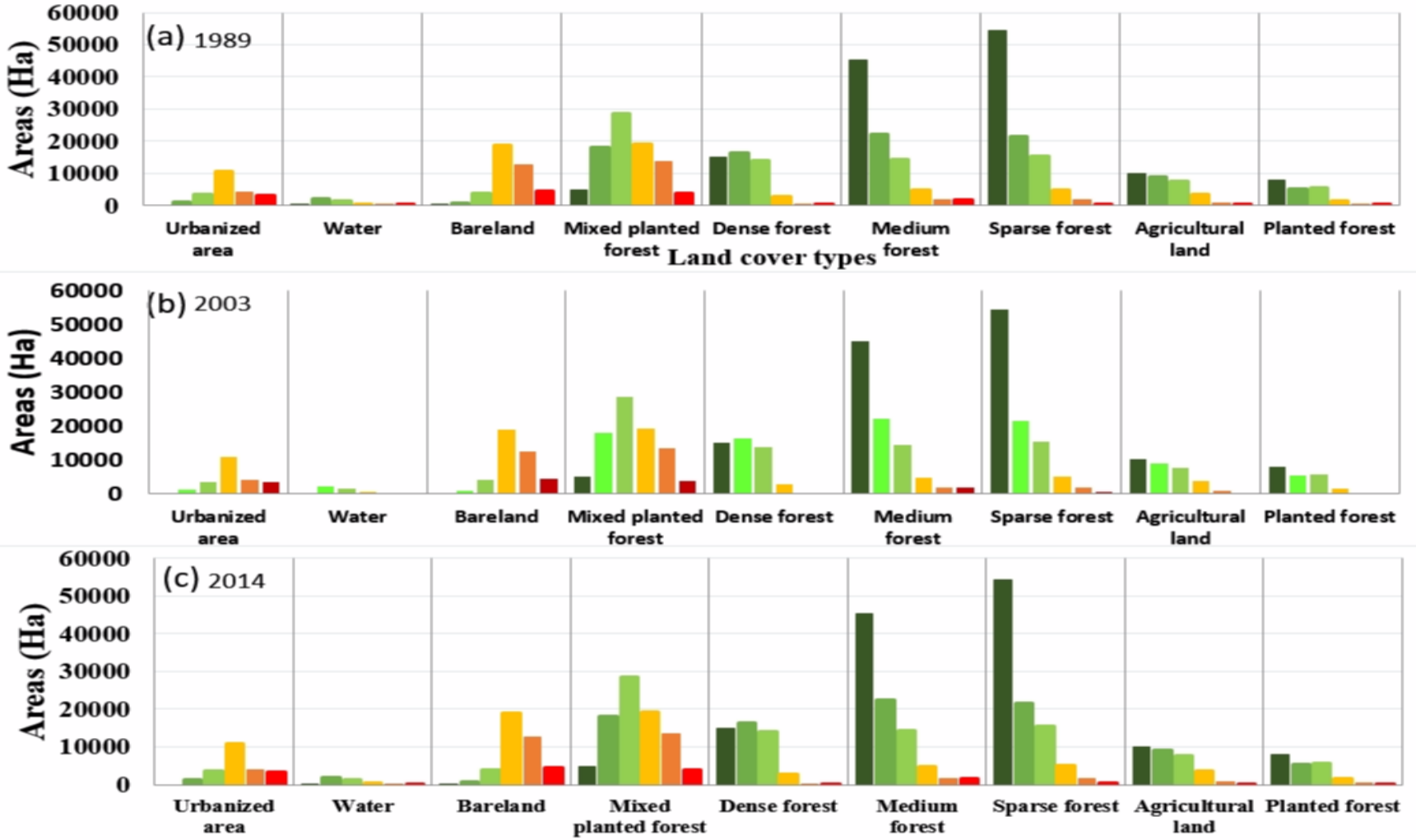


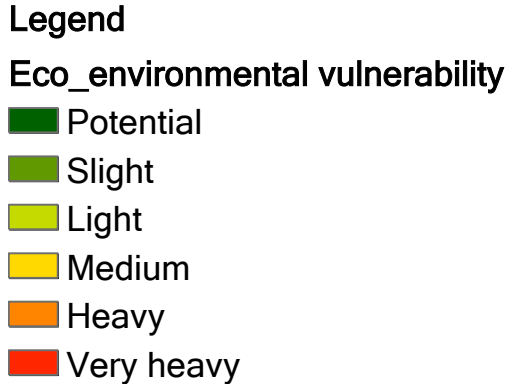
District names in the Thua Thien - Hue Province





Results and Discussions (4/7)





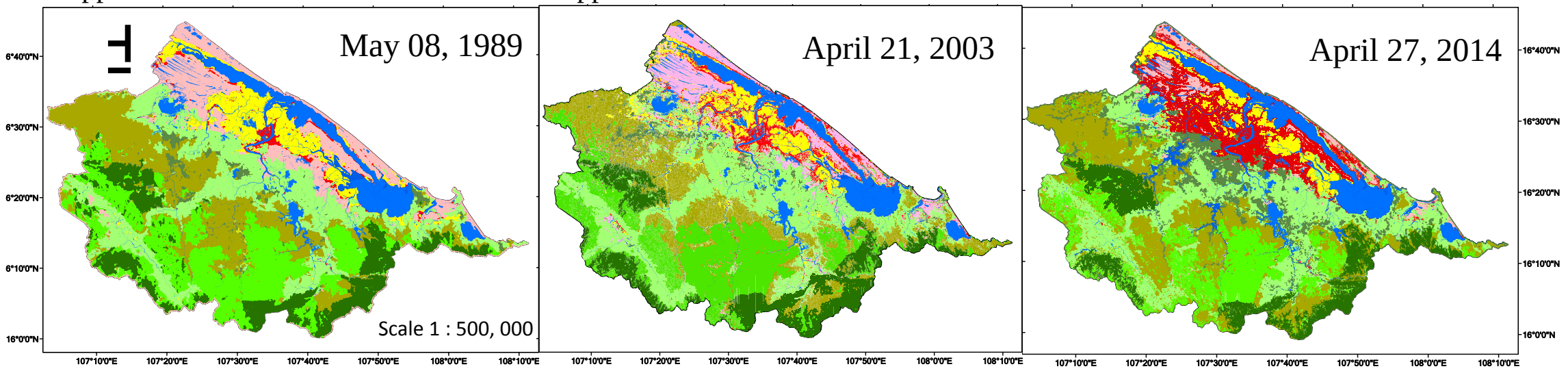
Results and Discussions (5/7)

Land cover changes in The Thua Thien- Hue Province

Overall classification accuracy: 85.7%
Kappa coefficient : 0.84

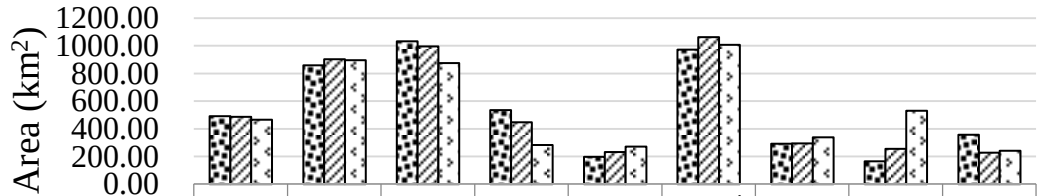
Overall classification accuracy: 90.9%
Kappa coefficient : 0.89

Overall classification accuracy: 89%
Kappa coefficient : 0.88



Legend

- Urbanized area
- Water
- Bare land
- Mixed planted forest
- Dense forest
- Medium forest
- Sparse forest
- Agriculatural land
- Planted forest



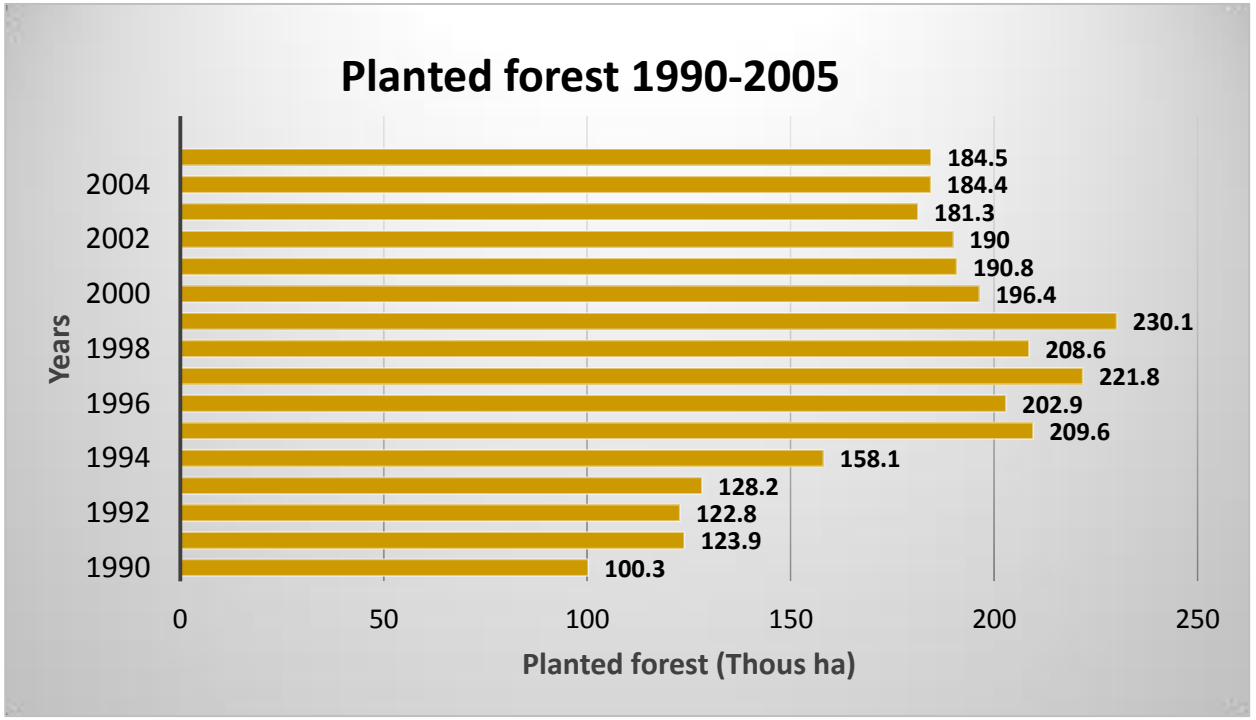
	Dense forest	Medium forest	Sparse forest	Bare land	Planted forest	Mixed planted forest	Water	Urbanized area	Agricultural land
1989	491.78	859.70	1034.5	535.76	198.21	974.10	293.28	166.12	357.25
2003	486.69	904.90	996.44	447.56	233.55	1062.6	293.86	256.64	228.94
2014	465.18	895.95	875.15	283.08	272.84	1008.1	339.07	530.93	240.88

Land cover types

Results and Discussions (6/7)

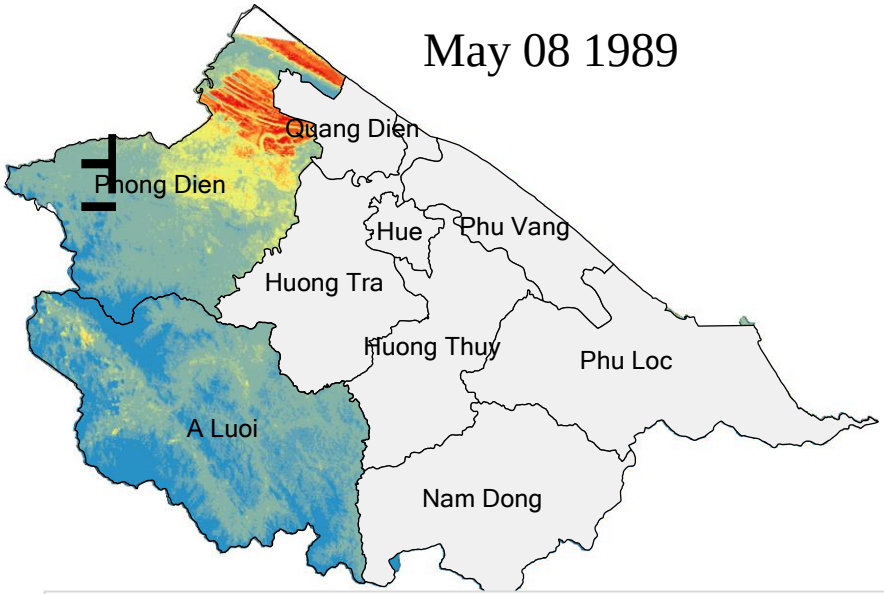
Influential factors: *Land cover changes in the Thua Thien - Hue Province*

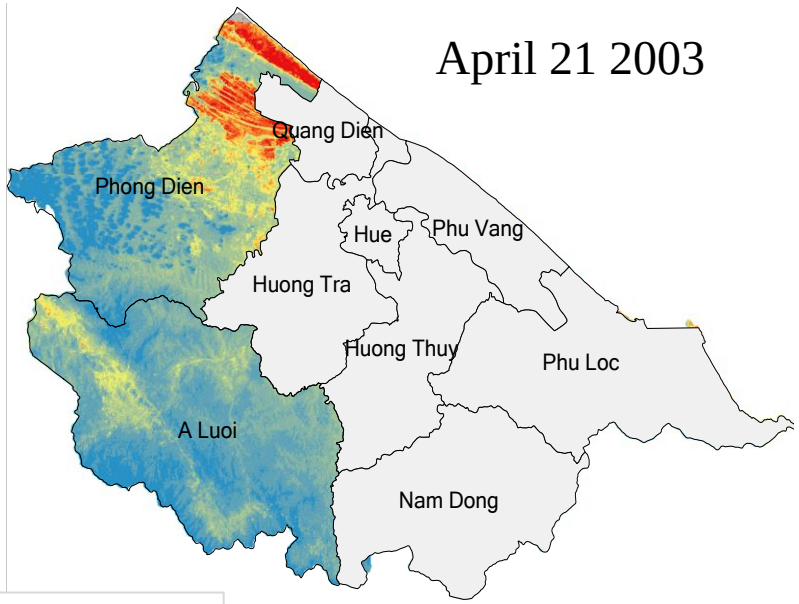
Forest inventory data

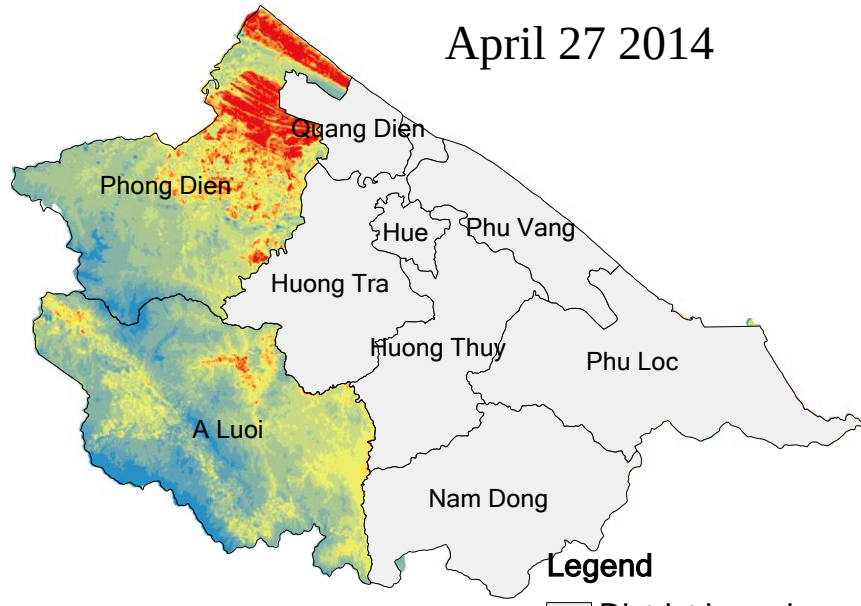


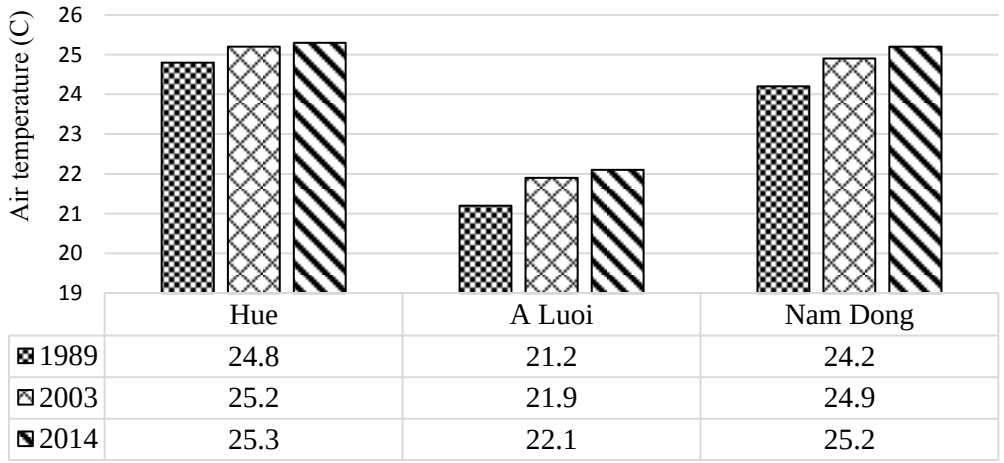
Results and Discussions (7/7)

Influential factors: *Land surface temperature in the Thua Thien - Hue Province*









	Hue	A Luoi	Nam Dong
1989	24.8	21.2	24.2
2003	25.2	21.9	24.9
2014	25.3	22.1	25.2

Annual measured air temperature at 3 stations (Hue, A Luoi, and Nam Dong).

Time (YY/MM/DD)	Mean LST (degree C)	Std
1989_05_08	23.9	2.1
2003_04_21	24.6	2.4
2014_04_27	26.1	2.7

Legend

- District boundary

LST degree (C)

- <22
- 22- 23
- 23 - 24
- 24 - 25
- 25 - 26
- 26- 27
- 27- 28
- 28- 29
- 29 - 30
- 30 - 31
- 31 - 32
- > 32

Conclusions (1/2)

- ✓ In general, time series maps of eco-environmental vulnerability in the Thua Thien–Hue Province in 1989, 2003, and 2014 show an evolving pattern of urban thermal anomalies highly associated with sprawl of urbanized area. Also, they are closely correlated with higher eco-environmental vulnerable levels, namely medium, heavy, and very heavy over the period of interest as the heavy vulnerability level raised from 5.9% in 1989, to 7.9% in 2003, and 15% in 2014; and the very heavy vulnerability level increased from 1.2% in 1989, to 3.2% in 2003, and 7.3% in 2014.

- ✓ Analysis of eco-environmental vulnerabilities associated with LULC changes in recent 25 years indicates that evolving distributions of heavy and very heavy vulnerability levels mainly occurred on urbanized area, bare land, semi bare land, agricultural land, and sparse forests. In contrast, there is a significant decline in potential vulnerability level (36.4% in 1989, 30.9% in 2003, and 19.2% in 2014). The remaining vulnerability levels slight, light, medium fluctuated slightly by increasing in 2003 and decreasing in 2014.

Conclusions (2/2)

- ✓ Supporting reasons for the observed changes are possibly due to: *(1)* deforestation, agriculture intensification, and construction of three hydro-electric projects during 2003-2014; and *(2)* significant expansion of urbanized area leading to differences in thermal signatures in urban areas as compared with rural areas. It is readily aware of that intensification and expansion of human activities from lowland to highland have amplified the vulnerability of eco-environment in the Thua Thien-Hue Province.

- ✓ The successful assessment framework proposed and practiced in this study can be applied to the other regions by adjusting factors relevant to the concerned variables required. Also, it is necessary to conduct eco-environmental vulnerability assessments for neighboring regions of the Thua Thien-Hue Province to further evaluate regional eco-environmental vulnerability in the central Vietnam associated with severe disaster and anthropogenic disturbances.

Future work

- ✓In this study, there is not much analysis between eco-environmental vulnerability and disaster events, which can become a crucial topic for future investigations. Besides, the study area only focuses on the Thua Thien-Hue Province so that there still exists a big gap for future exploitation to expand the study side and study eco-mechanism of eco-environmental vulnerability, not only based on LULC changes, but also considering climate changes and characteristic of disaster events in the region of concern.

- ✓Explore the association of vector bone diseases (public health) with eco-environmental dynamics.

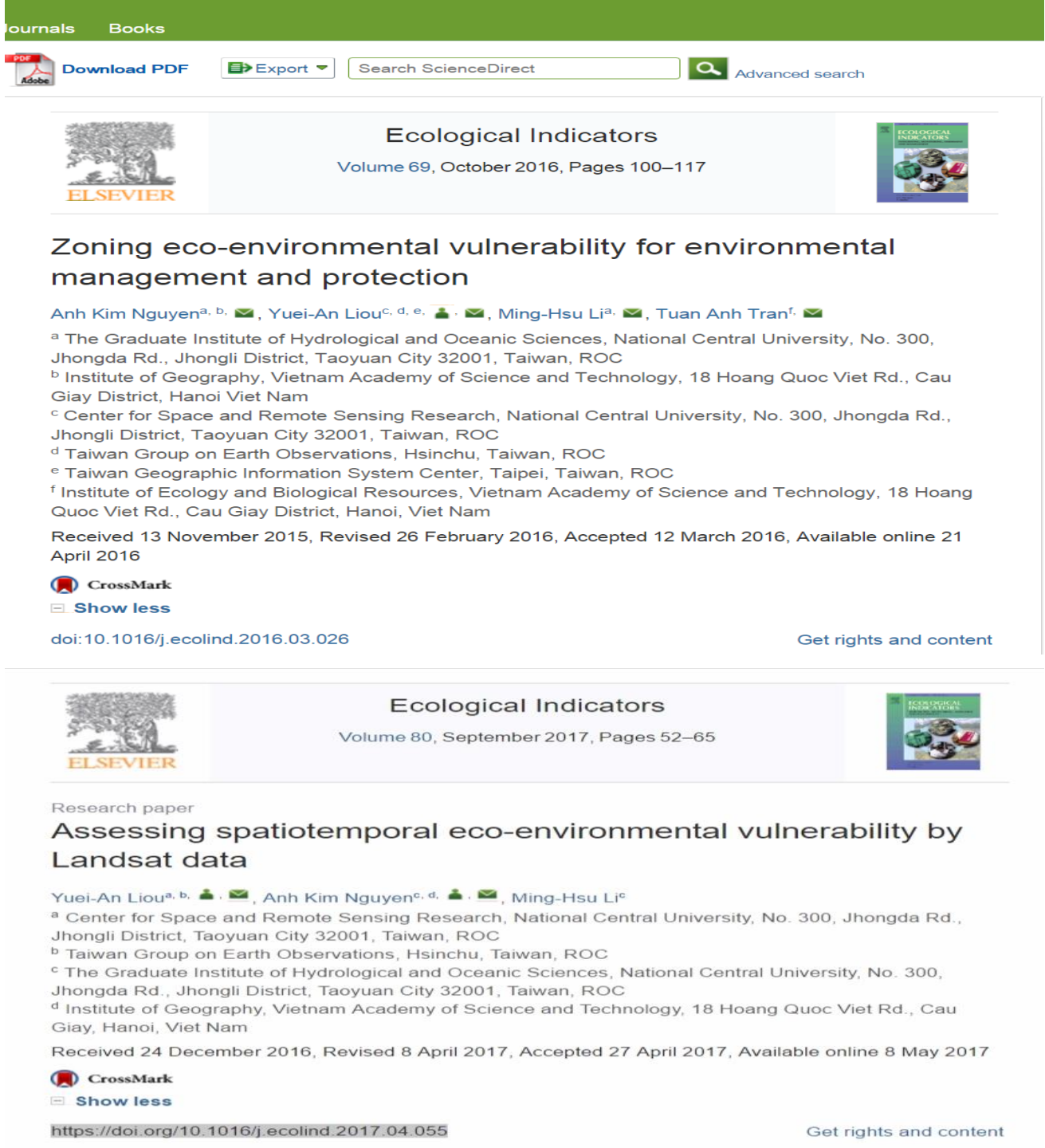
National Central University

Publications

Liou, Y.A., **Nguyen, A.K.,** Li, M.H., and Lin, C.Y. Landsat 8 operational land imager derived variables for environmental risk assessment in Taoyuan, *IGARSS*, 2015, July 26-31, Milan, Italy, *doi: 10.1109/IGARSS.2015.7325904.*

Nguyen, A.K., Y.A. Liou, M.H. Li, and T.A. Tran. Zoning eco-environmental vulnerability for environmental management and protection. *Ecological Indicators*, Vol 69, 2016, Pages 100–117. *doi:10.1016/j.ecolind.2016.03.026. (SCI, IF:* 3.898*).*

Liou, Y.A., Nguyen, A.K, and Li, M.H, 2017. Assessing spatiotemporal eco-environmental vulnerability by Landsat data. *Ecological Indicators*, Vol 80, 2017, Pages 52–65. *doi.org/10.1016/j.ecolind.2017.04.055*. *(SCI, IF:* 3.898*).*



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Ecological Indicators

Volume 69, October 2016, Pages 100–117

Zoning eco-environmental vulnerability for environmental management and protection

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Ecological Indicators

Volume 80, September 2017, Pages 52–65

Research paper

Assessing spatiotemporal eco-environmental vulnerability by Landsat data

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