115 年度中華農業氣象學會會員大會
暨因應氣候變遷之農業保險與生產調適策略研討會



遙測大數據與 AI 技術在農業極端氣候風險監測與韌性調適之應用

劉說安 講座教授

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National Central University, Taoyuan, Taiwan
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Google Scholar

ResearchGate





學歷:國立中山大學電機工程學士、美國密西根大學安娜堡校區電機工程碩士學位、大氣太空科學碩士學位與電機工程暨大氣海洋太空科學雙博士學位

現職:國立中央大學太空及遙測研究中心講座教授

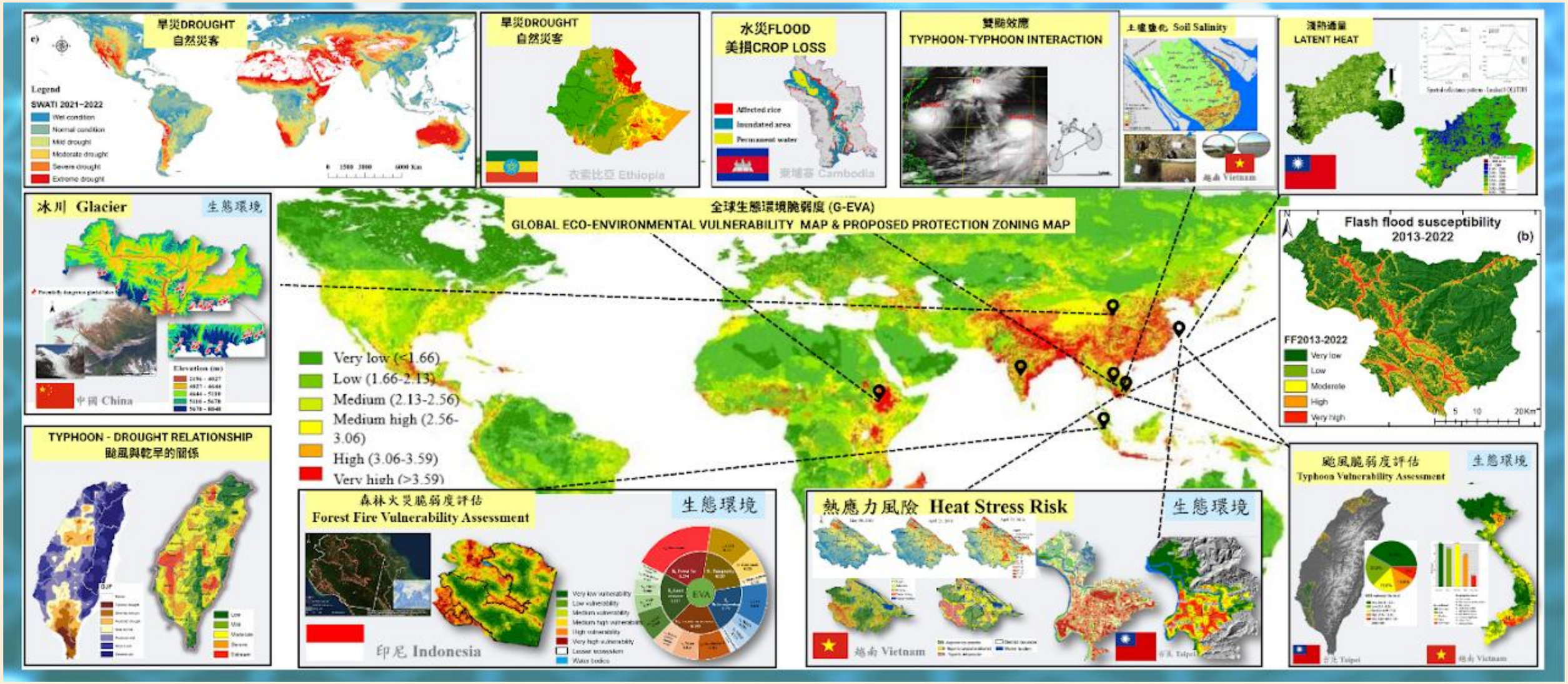
榮譽:國立中山大學傑出校友獎、**韓國**遙測學會榮譽終身會員、**俄羅斯**聯邦工程科學院及(UN/**法國**)國際宇宙航行科學院院士、**越南**國家科學與工程翰林院水晶傑出貢獻獎章、科技部傑出研究獎、**全世界**前2%領航科學家、駐臺北**越南**經濟文化辦事處傑出貢獻獎。

專長:遙測，推展遙測科技發展、應用遙測資料於防救災、精進GNSS掩星觀測理論、提昇衛星氣象研究與預報、推動國際學術交流與合作、科技人文整合及科普教育等工作逾30年，透過學術著作提出創新遙測理論及技術。

[研究興趣：極端天氣與氣候變遷、環境監測與永續發展、城市綠地與生態服務]



研究主軸



研究方法：物理指標、GIS 空間分析、機器學習與跨資料驗證。

多平台觀測：Landsat、MODIS、Sentinel、SAR 與地面資料。

研究議題：乾旱、颱風、暴洪、都市熱島與生態環境脆弱度。



TODAY'S TOPICS

01 緒論

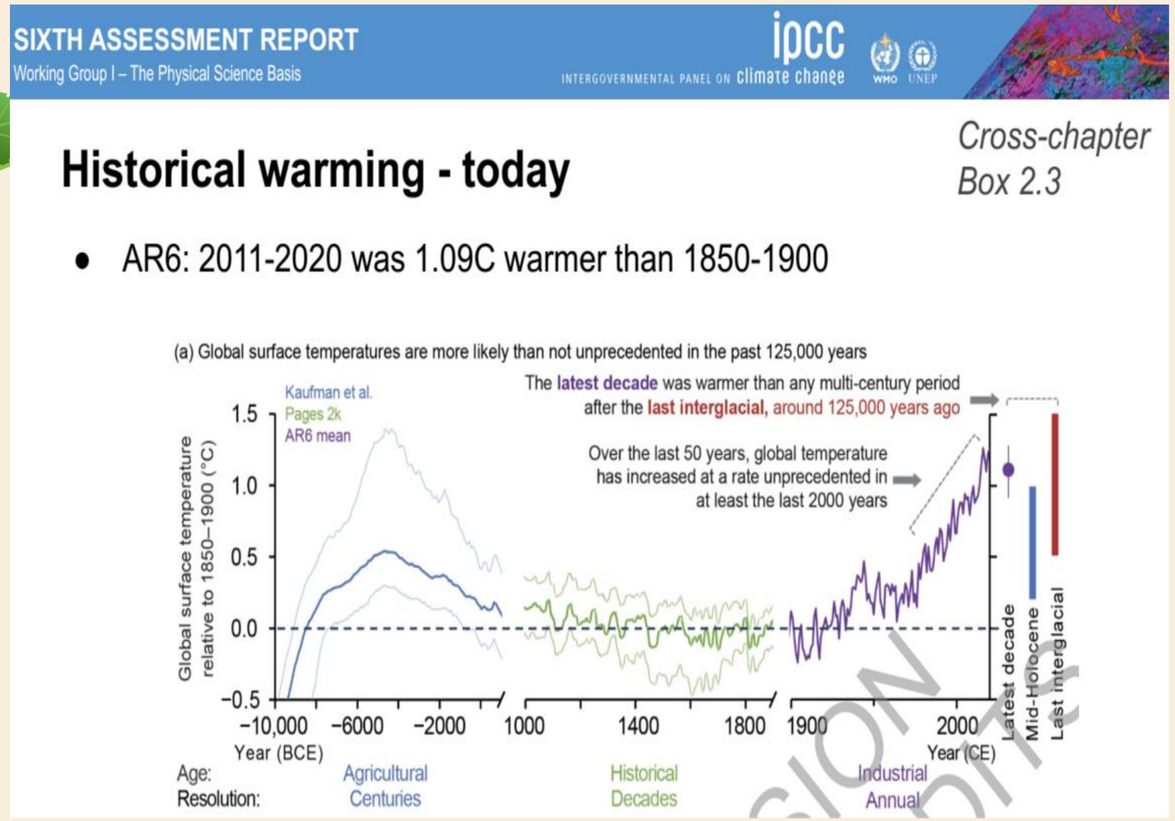
02 觀測基礎與水分指標
NDLI、TMDI、SWATI、RSETI 的方法與驗證

03 極端氣候與 AI 研究
乾旱、颱風降雨、暴洪與地表熱環境

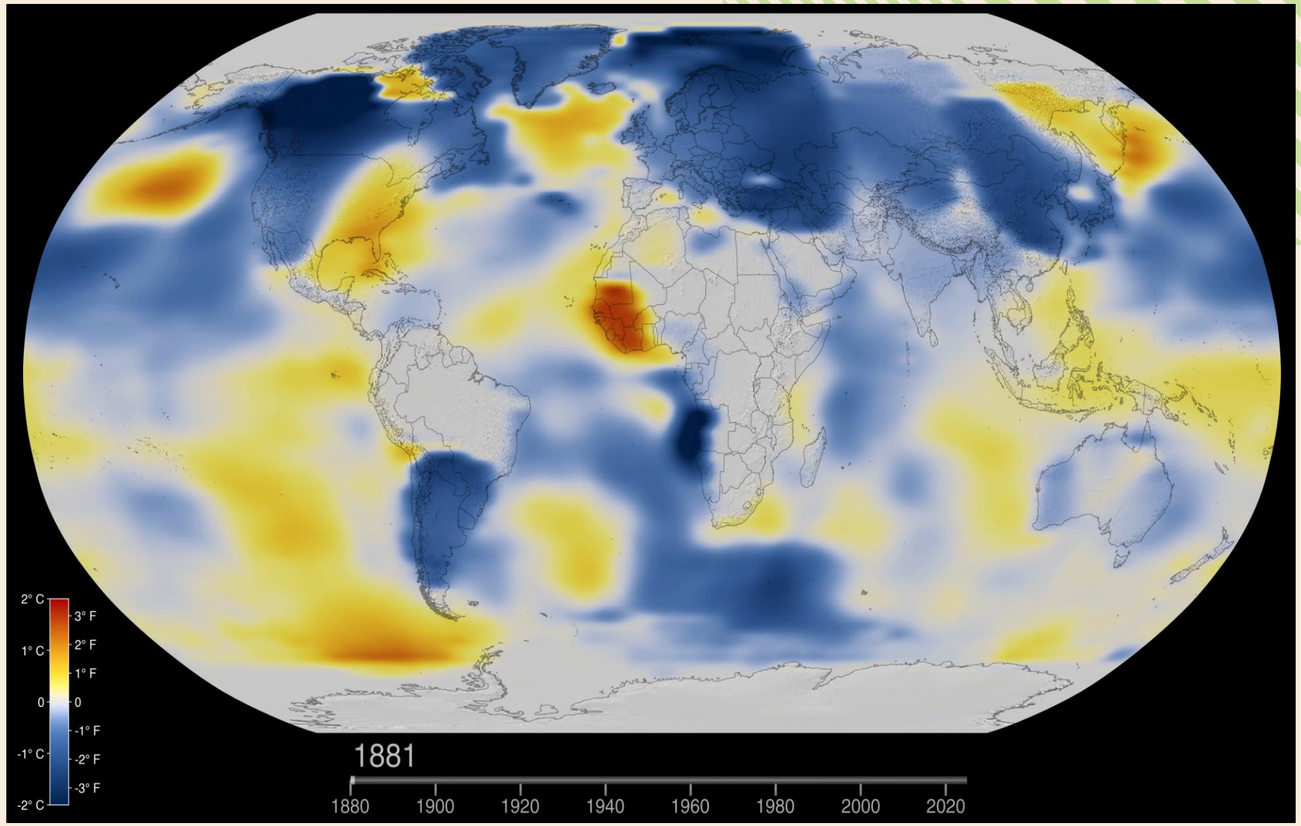
04 生態環境脆弱度
多因子整合、空間比較與研究限制

05 結論

緒論(1/5)－氣候變遷



Credit: IPCC / AR6 Synthesis Report Climate Change 2023
https://www.ipcc.ch/report/ar6/syr/

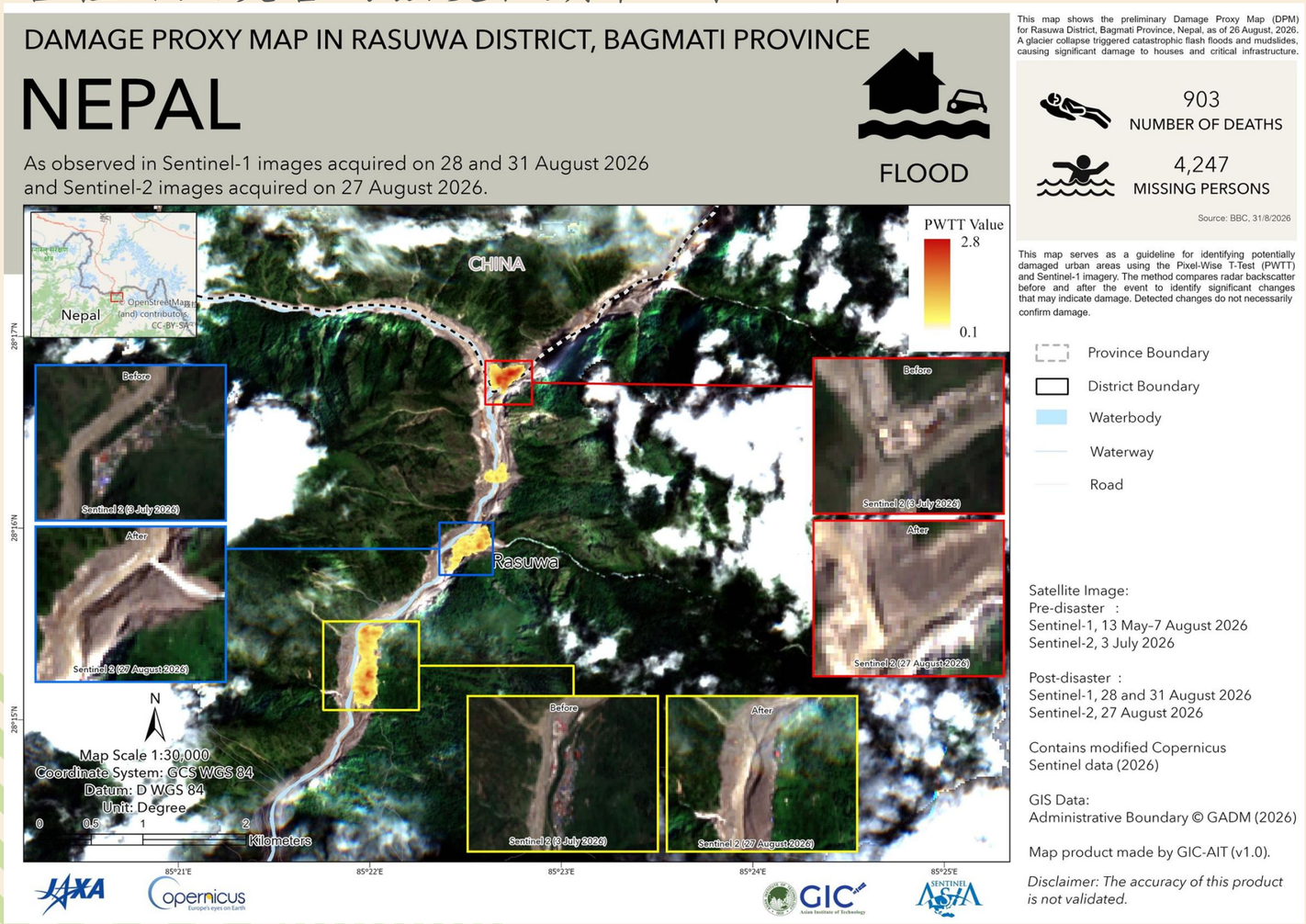


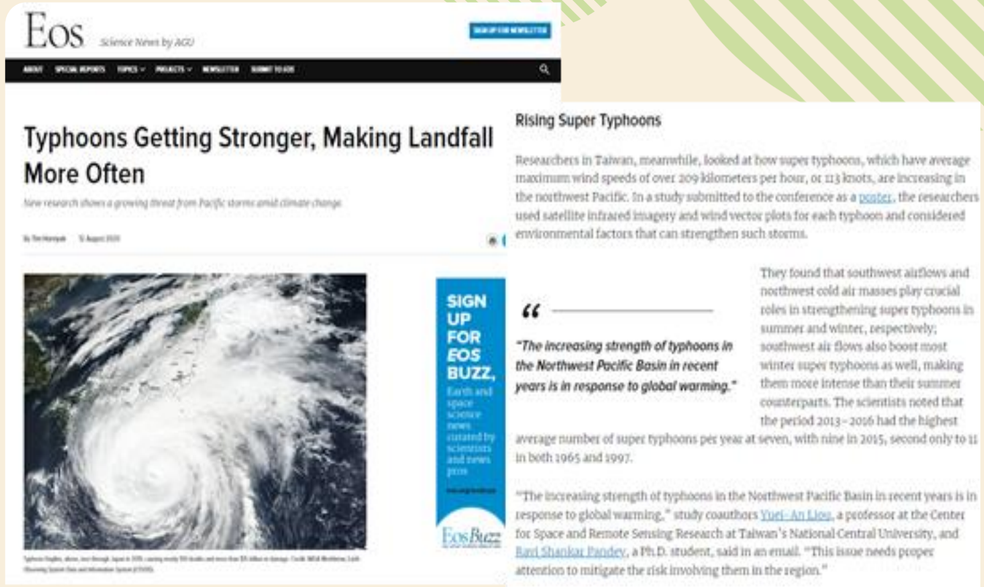
由NASA公布1880年至2024年全球各地區的氣溫變化。正常溫度以白色表示，高於正常的溫度以紅色和橙色顯示，低於正常的溫度則以藍色顯示。非常清楚地顯示全球溫度異常的變化趨勢。

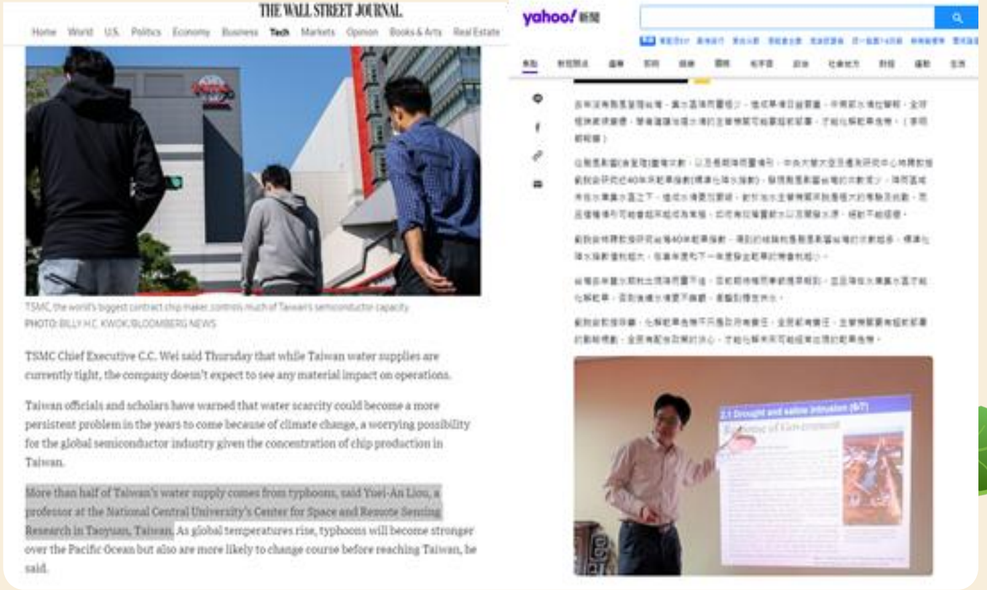
Visualization Studio:
https://svs.gsfc.nasa.gov/vis/a000000/a005400/a005450/2024GISTEMP_Map4K.mp4
Credit: NASA's Scientific Visualization Studio

緒論(2/5)－氣候變遷

近年來，氣候變化影響無處不在，其威脅日益嚴重，地球生態系統深受其害。在世界各地，我們可以輕易觀察到降雨分佈不均、乾旱、洪水、氣旋/颱風/颶風及森林火災等各種自然災害的強度和頻率正在上升。



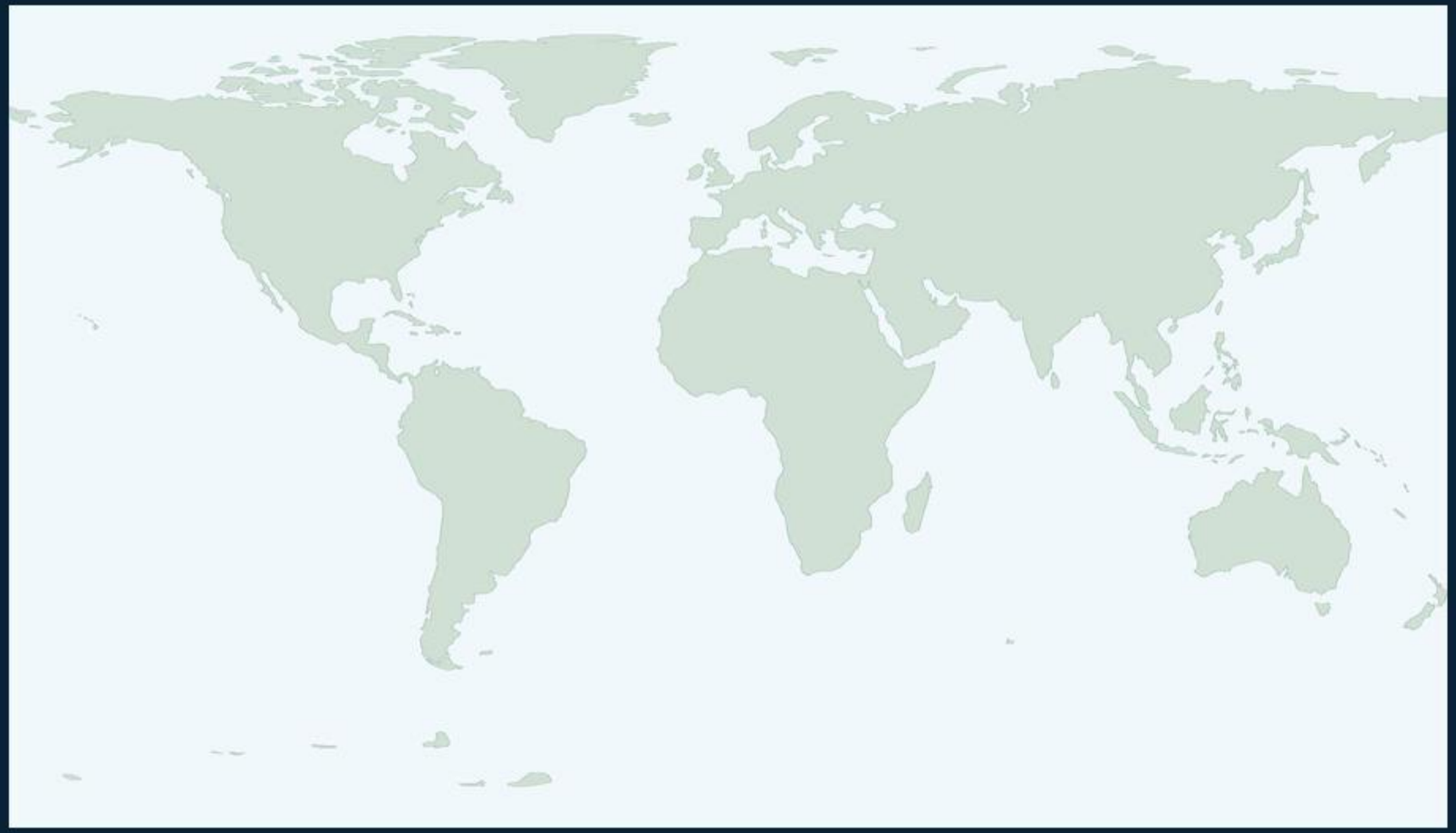




緒論(3/5)－氣候變遷

2026 世界各地的真實災害

先看位置與類型，再看衛星與現場影像

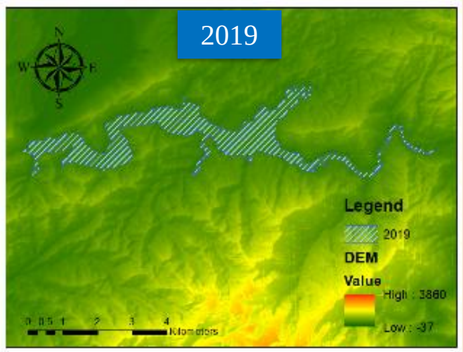


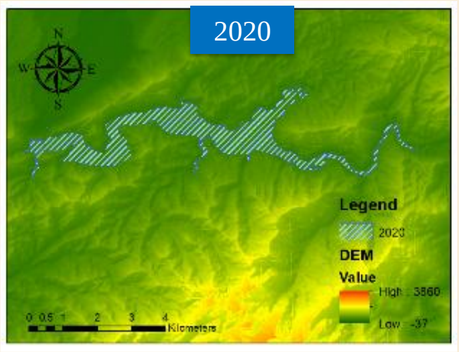
災害位置 / 類型

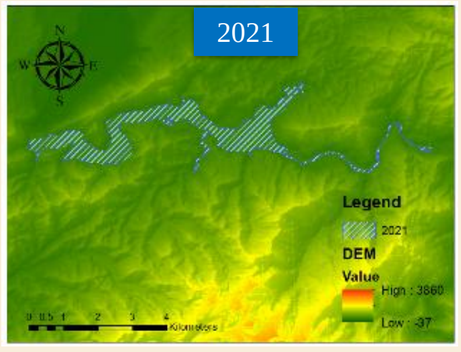
1. **加拿大安大略省**
   野火煙霧
2. **美國鮑威爾湖**
   乾旱低水位
3. **波多黎各**
   大範圍乾旱
4. **西歐**
   夏季熱浪
5. **尼泊爾北部**
   冰岩崩落．洪水
6. **莫三比克南部**
   洪水
7. **印尼婆羅洲**
   泥炭地火災
8. **關島與北馬里亞納**
   Bavi 颱風

緒論(4/5)-臺灣極端天氣

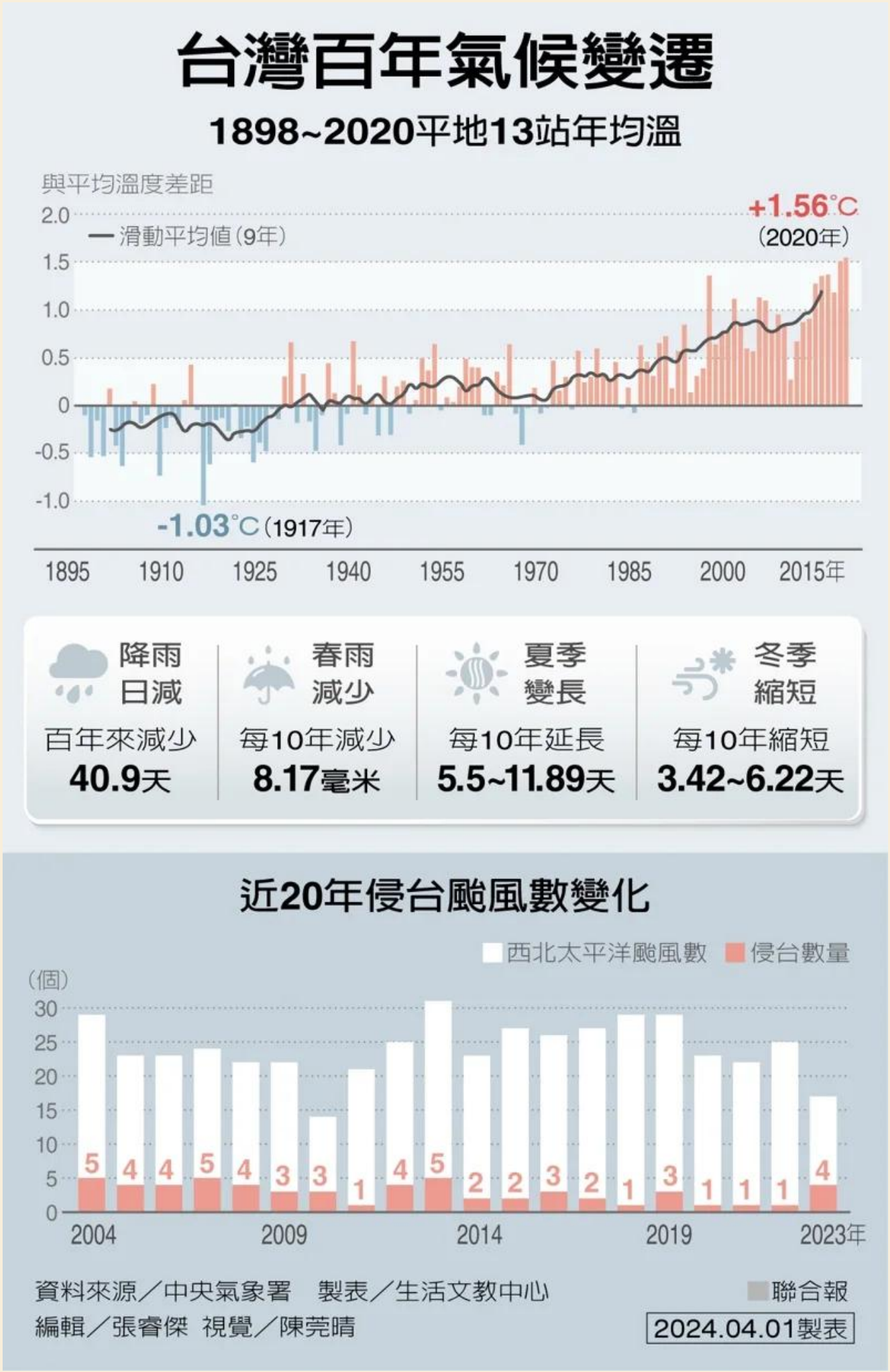
交通部「極端氣候災防預警暨汛期防汛準備辦理情形」報告中指出，台灣近百年在溫度上升約攝氏一點五度，未來天候整體趨勢，推估**冬季變短、夏季變長、春雨減少、梅雨強降雨增加**，極端**降雨頻率、強度也增加**，即便侵台颱風個數減少，但颱風強度、降雨都會增強。







石門水庫2019年-2021年水庫面積變化



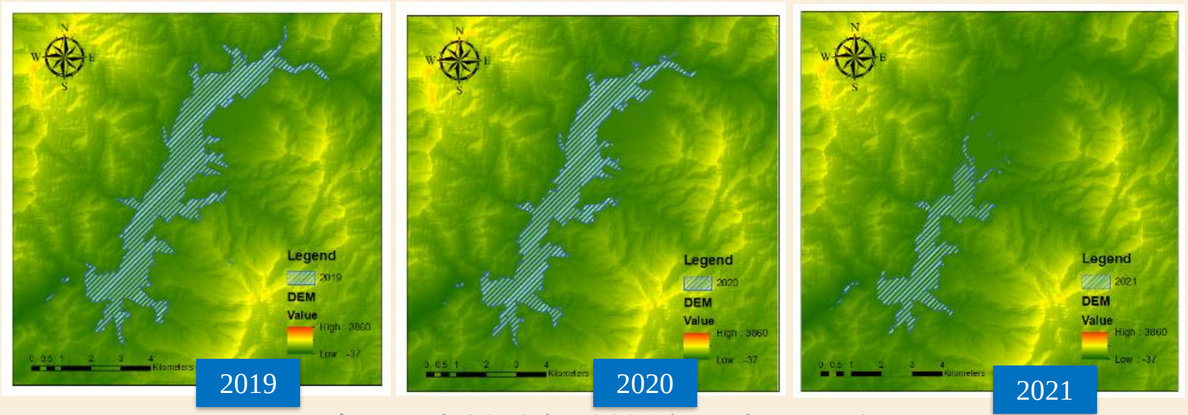
緒論(5/5)-臺灣極端天氣

從颱風影響(含登陸)臺灣次數，以及長期降雨量情形，研究近40年來乾旱指數(標準化降水指數)，發現颱風影響台灣的次數減少，降雨區域未在水庫集水區之下，造成水情更加嚴峻，對於治水主管機關來說是極大的考驗及挑戰，而且**這種情形可能會越來越成為常態**，如何有效落實節水以及開發水源、絕對不能迴避。



https://today.line.me/tw/v2/article/7LPoOr?utm_source=amp

中廣新聞網2021年3月12日



曾文水庫2019年-2021年水庫面積變化



2020/04/13



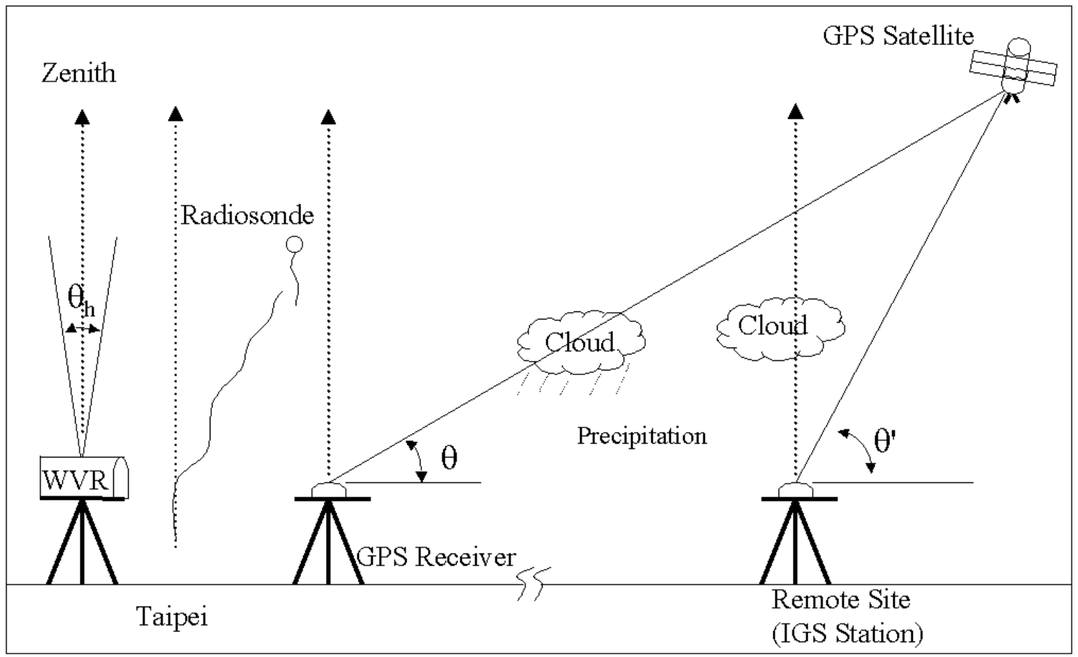
2021/04/06





日月潭風景區

星地觀測提供互補資訊



GPS、微波輻射計與探空觀測比較素材



GNSS

利用訊號遲延與掩星資料觀測大氣水汽及剖面。

地表衛星

光學、熱紅外與雷達描述植被、水分與地表變化。

地面資料

氣象站與量測資料提供交叉檢驗依據。

四種水分指標

NDLI
以光譜反射率描述潛熱與地表水分相關訊息。

TMDI
以 NDLI 與地表溫度的乾、濕邊界估計相對乾燥度。

SWATI
以水分、植被、溫度的三維距離表徵乾濕狀態。

RSETI
以 NDLI 的參考範圍描述相對蒸散發狀態。







Liou et al. (2019)；Le & Liou (2022)；Thai & Liou (2025)；Liou & Thai (2025)

NDLI

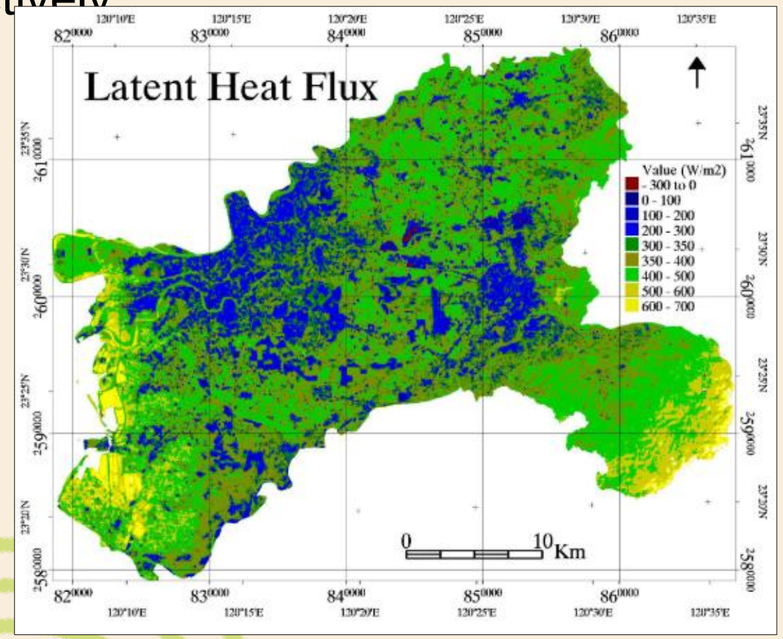
IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 57, NO. 3, MARCH 2019 1423

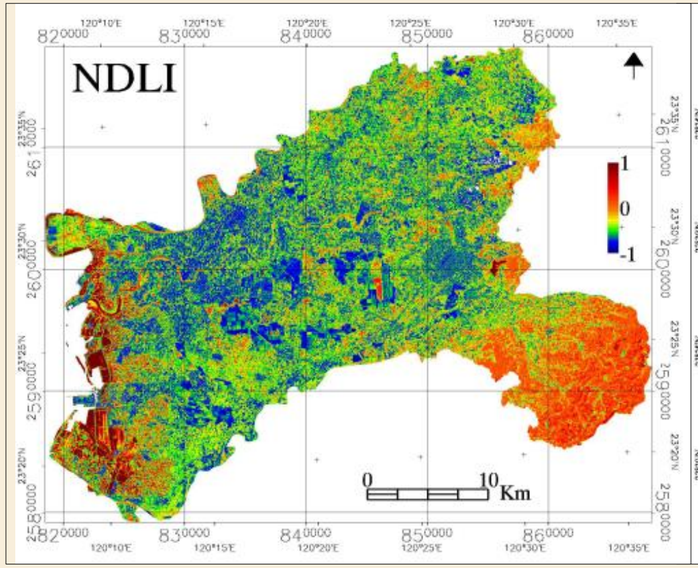
Normalized Difference Latent Heat Index for Remote Sensing of Land Surface Energy Fluxes

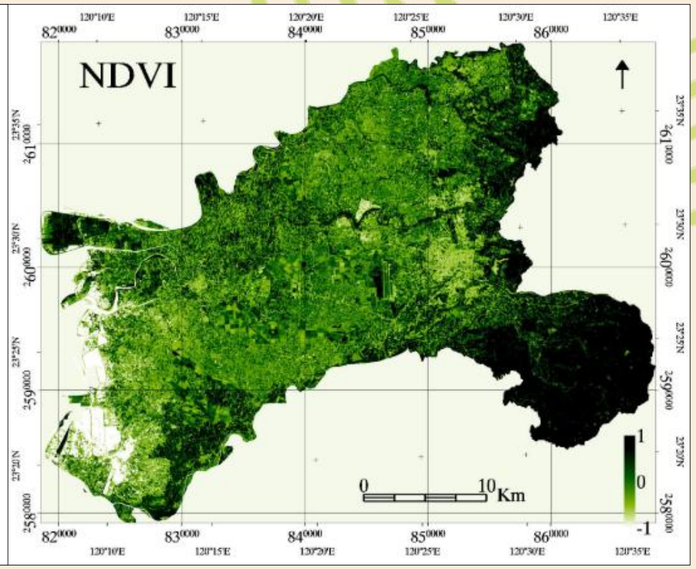
Yuei-An Liou, *Senior Member, IEEE*, Mai Son Le, and Hwa Chien

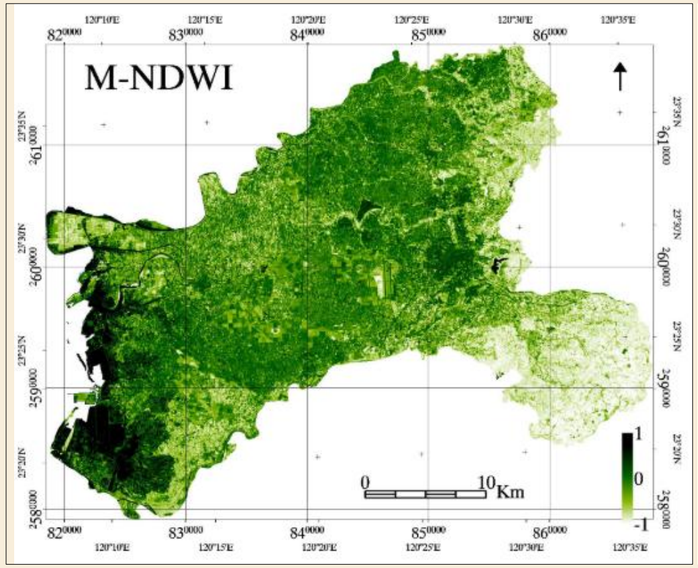
$$NDLI = \frac{\rho_{Green} - \rho_{Red}}{\rho_{Green} + \rho_{Red} + \rho_{SWIR1}}$$

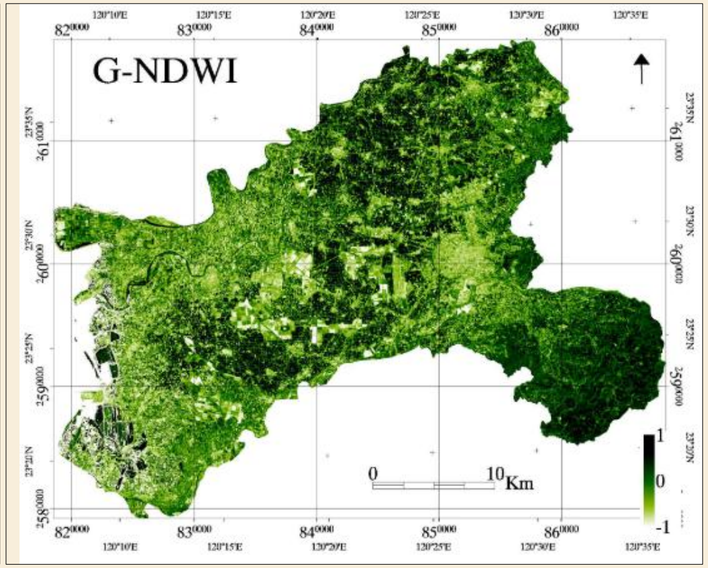
where ρ_{Green}, ρ_{Red}, and ρ_{SWIR1} represent reflectance in the green, red, and SWIR1 bands, respectively.





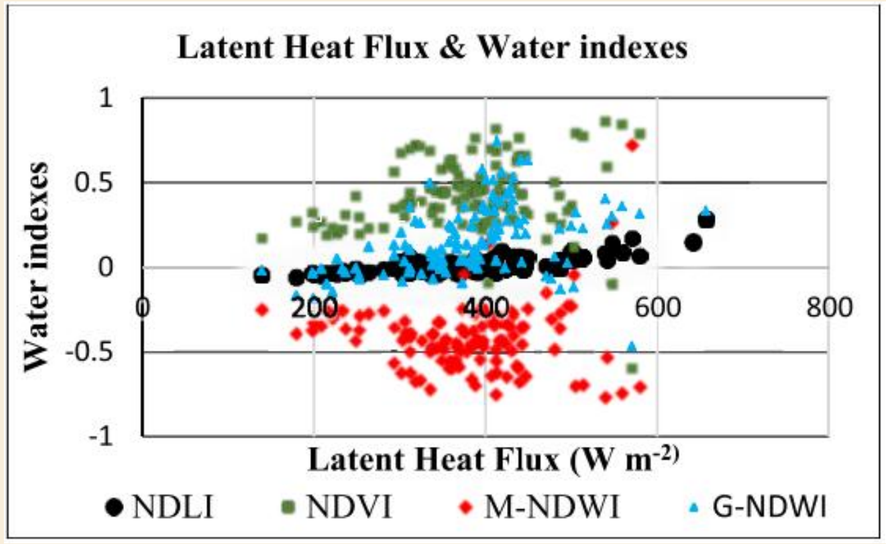




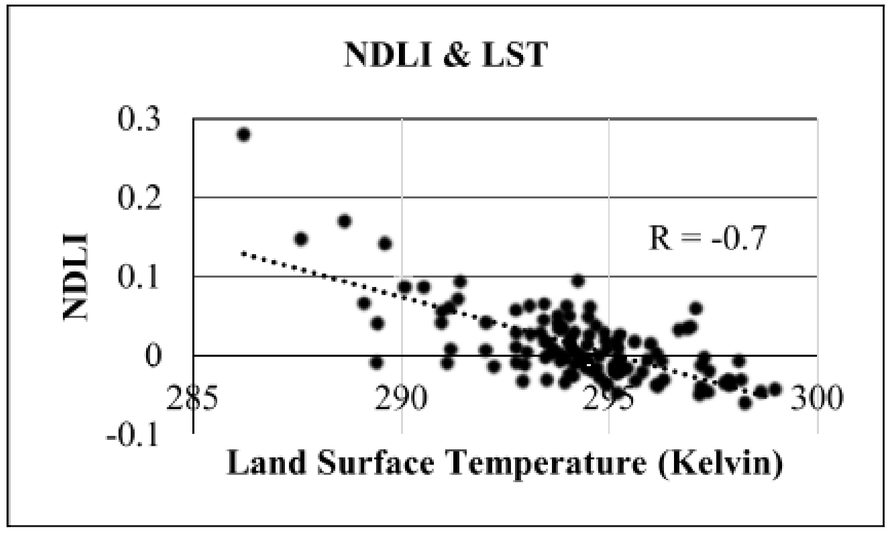


NDLI (a), NDVI (b), (c) M-NDWI and (d) G-NDWI generated from Landsat-8/OLI data over Chiayi, Taiwan, on February 21,

Results



Scatterplot of Latent heat flux versus water indices.



Scatterplot of NDLI and LST.

Correlation of Latent heat flux and water-related indices for different LULC types

Land cover types	Correlation of Latent heat flux and water indexes			
	NDLI	NDVI	MNDWI	GNDWI
Whole sample pixels	0.75	-0.14	0.3	0.16
Water	0.84	-0.76	0.79	-0.43
Agriculture	0.54	0.057	0.17	0.57
Vegetation	0.65	0.34	-0.23	0.43
Build-up	0.78	0.69	-0.52	0.2

Correlation of Latent heat flux and water-related indices for different vegetation features

Characteristic NDVI Signatures	Correlation of Latent heat flux and water indexes			
	NDLI	NDVI	M-NDWI	G-NDWI
(NDVI) 0-0.3	0.82	-0.004	0.46	0.39
(NDVI) 0.3-0.6	0.62	0.15	0.22	0.52
(NDVI) > 0.6	0.62	0.59	-0.44	0.16

Leveraging the NDLI for Water Scarcity Monitoring

IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received 15 May 2023, accepted 31 May 2023, date of publication 5 June 2023, date of current version 9 June 2023.

Digital Object Identifier 10.1109/ACCESS.2023.3283033

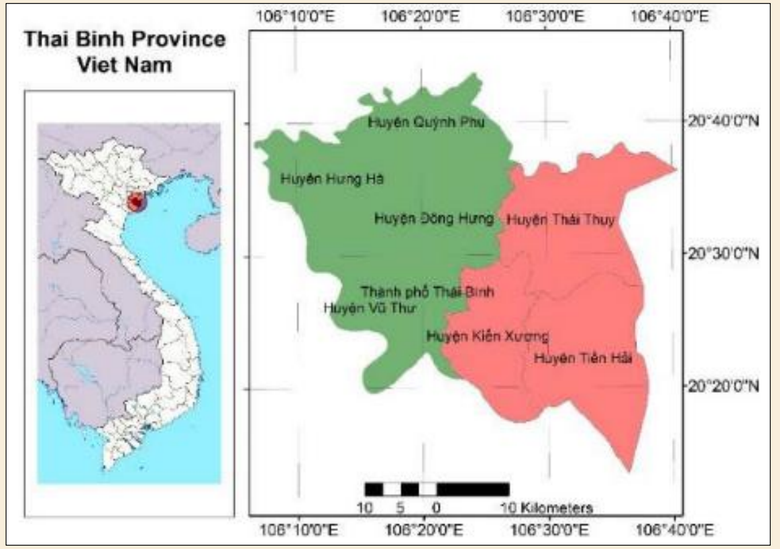
RESEARCH ARTICLE

Crop Response to Disease and Water Scarcity Quantified by Normalized Difference Latent Heat Index

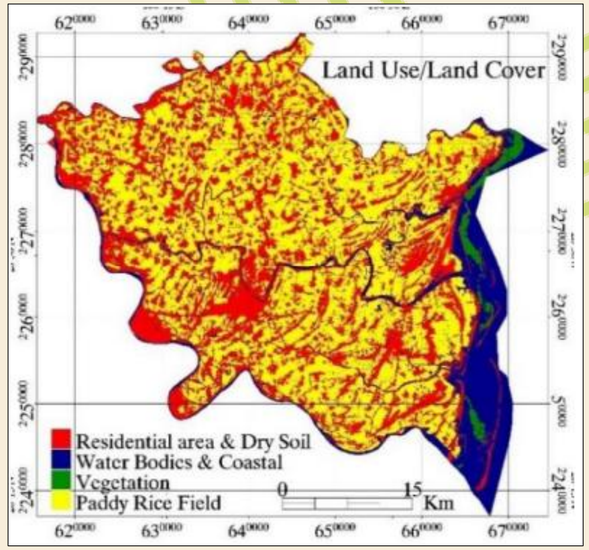
MAI SON LE[1], YUEI-AN LIOU[2], (Senior Member, IEEE), AND MINH TUAN PHAM[1]

[1]Space Technology Institute, Vietnam Academy of Science and Technology, Cau Giay, Hanoi 10000, Vietnam
[2]Hydrology Remote Sensing Laboratory, Center for Space and Remote Sensing Research, National Central University (NCU), Zhongli, Taoyuan 320317, Taiwan

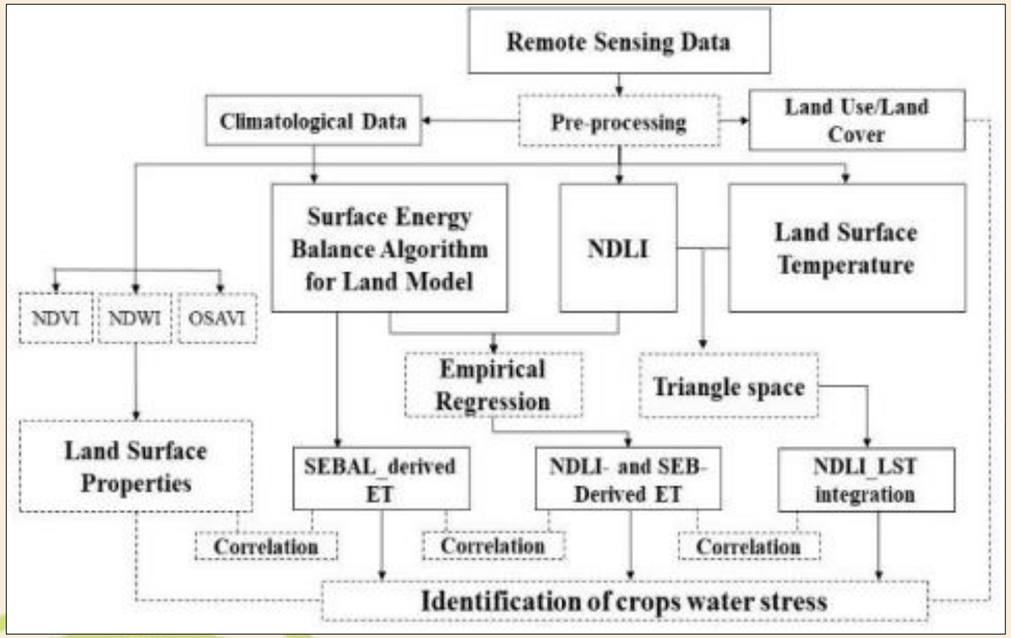
Corresponding author: Yuei-An Liou (yueian@csrsr.ncu.edu.tw)



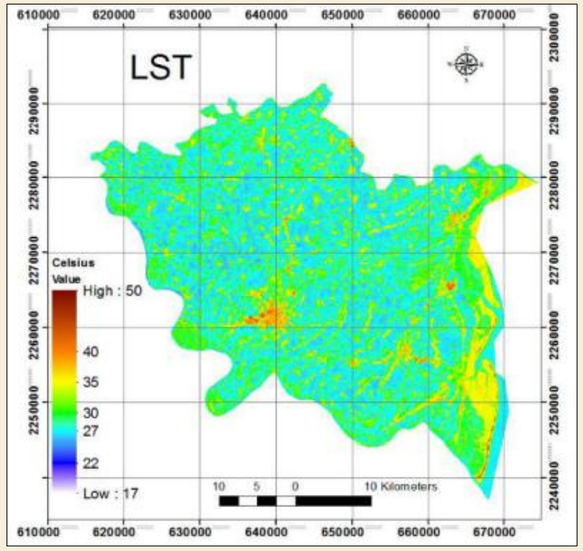
Study area, Thai Binh Province, Vietnam.

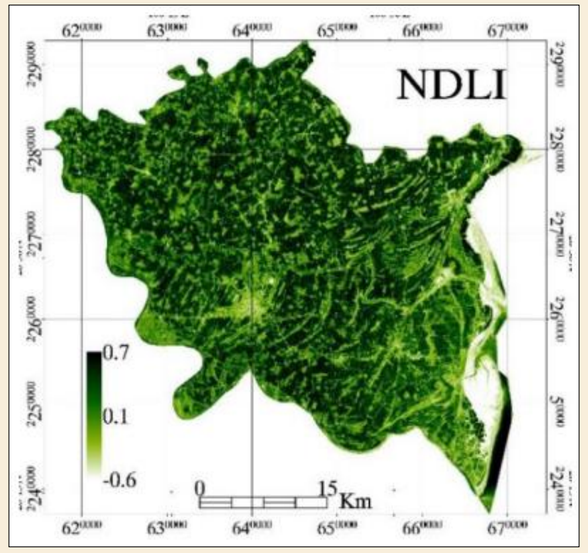


LULC types of study area.



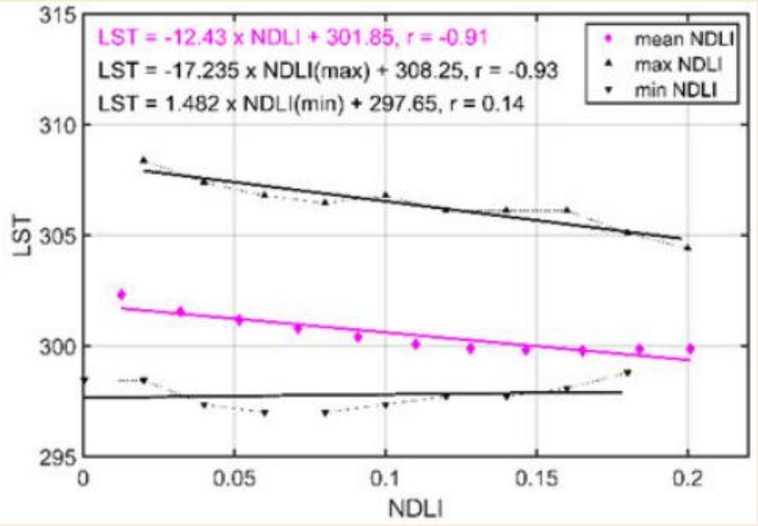
Flowchart of study tasks used in this study.

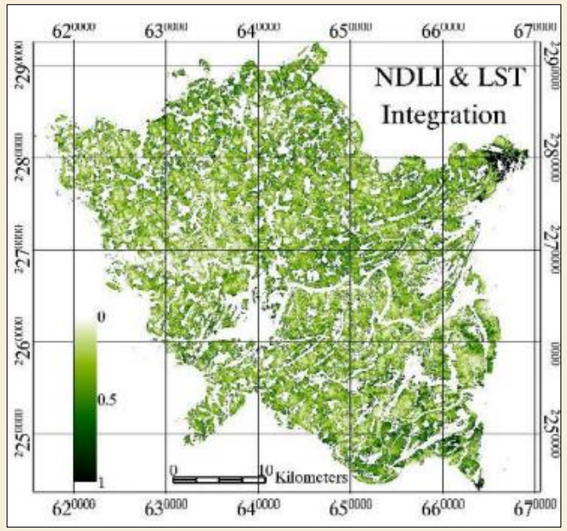




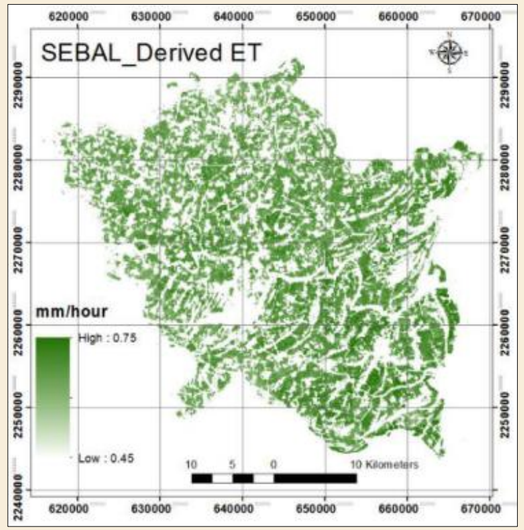
(a) NDLI and (b) LST generated from Landsat 7 over study area, on April 13, 2015.

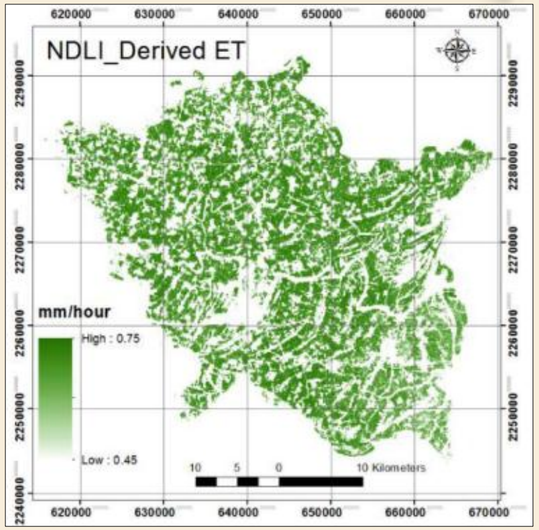
Leveraging the NDLI for Water Scarcity Monitoring



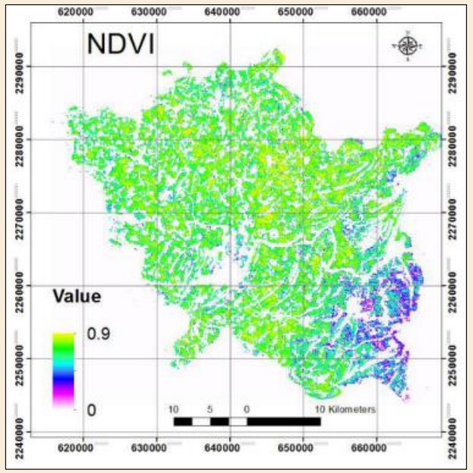


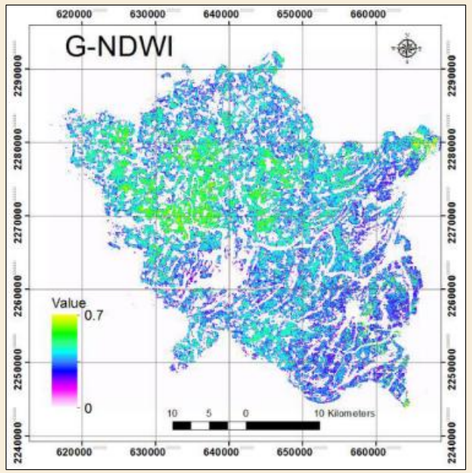
(a) NDLI-LST space and (b) NDLI & LST integration map.

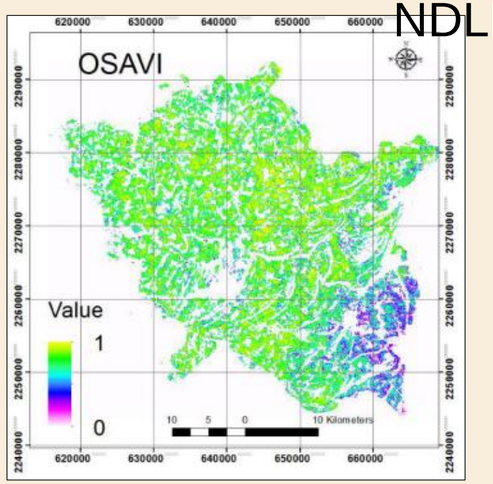




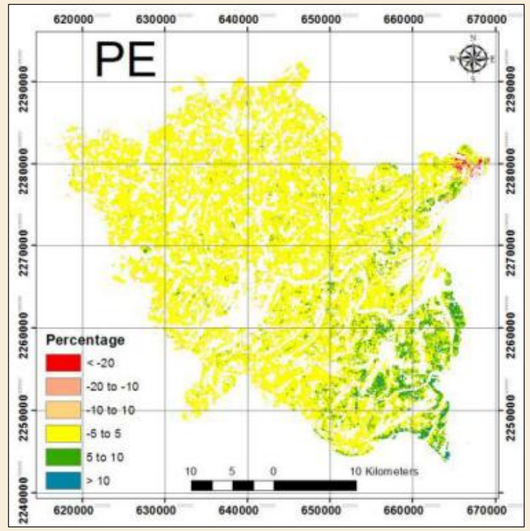
ET estimations based on (a) SEBAL and (b) NDLI.







(a) NDVI, (b) NDWI, and (c) OSAVI.
Note: The r values between NDVI, NDWI, and OSAVI with NDLI-derived ET are 0.84, 0.55, and 0.84, respectively.



Percentage error between NDLI- and SEBAL-derived ET.

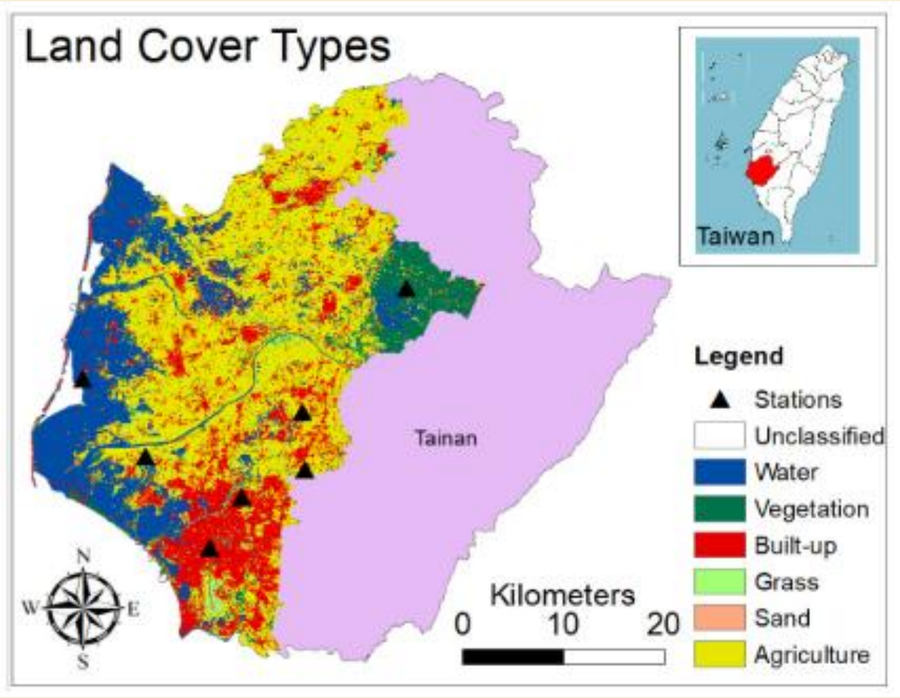
Temperature-Soil Moisture Dryness Index (TMDI)

IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, VOL. 19, 2022 3003805

Temperature-Soil Moisture Dryness Index for Remote Sensing of Surface Soil Moisture Assessment

Mai Son Le and Yuei-An Liou, *Senior Member, IEEE*

- Tainan is located in the southwestern part of Taiwan, with a long history of development. Land surface is of complex composition with low homogeneity.
- The annual precipitation is approximately 1,680 mm and concentrated in the rainy season (May–October) which corresponds to 84% of the annual total rainfall. The average temperature is 24.6 ◦C, with a consistent warm weather throughout the year.

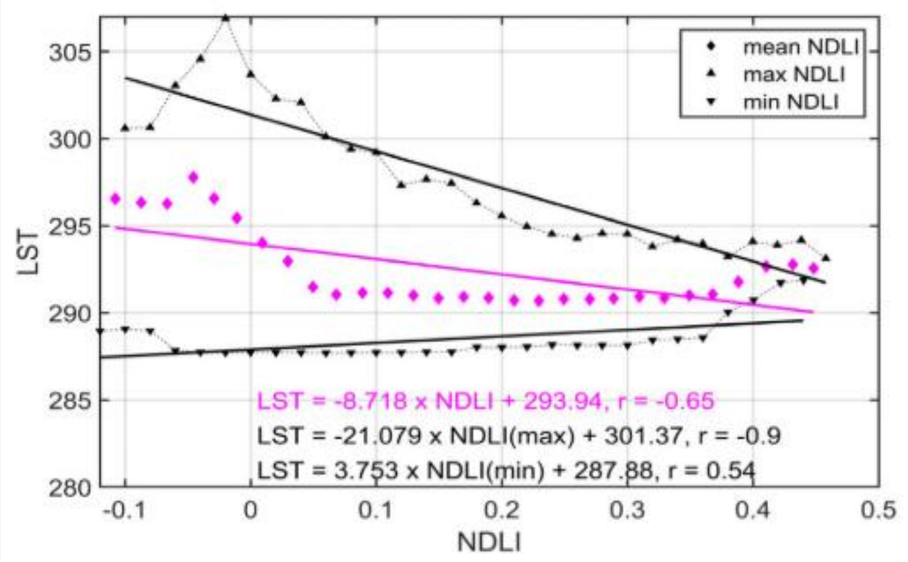


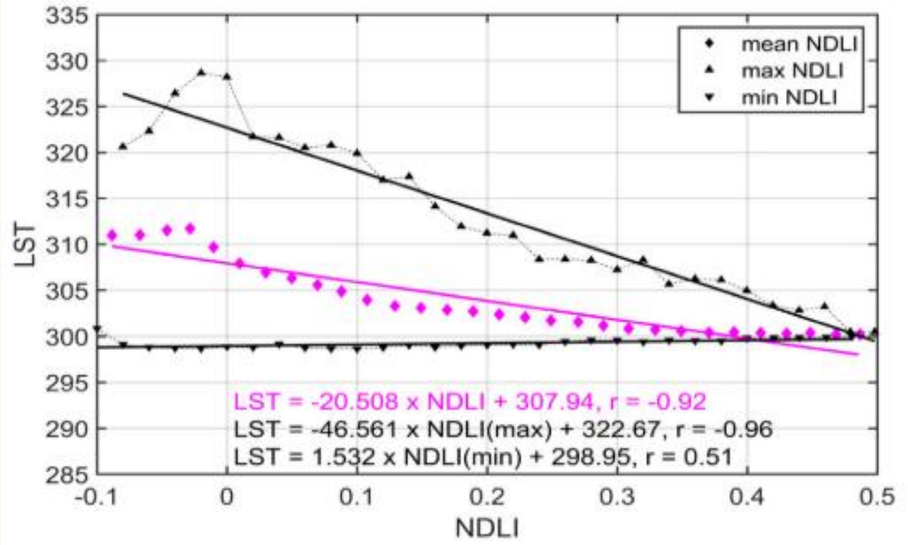
Geographical location and LULC of the study area generated from Landsat 8 OLI data.

Dataset used in the study

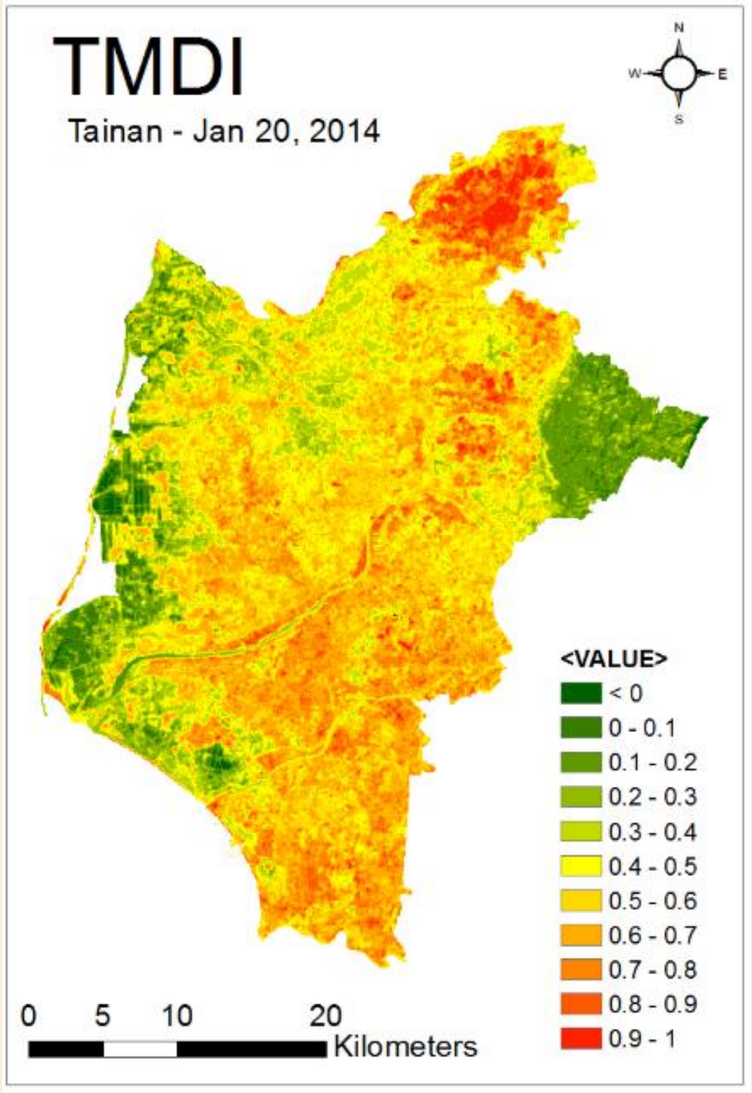
Data	Resolution/Unit	Time	Description
Landsat 8 OLI/TIRS	30 m/16 day	2014-01-20 2014-10-19	(1) Processing the SEBAL model for estimating the ET (2) Calculating the TVDI and TMDI (3) Classifying LULC types
Air temperature	mm		Evaluating the satellite drought indices
Humidity	%		

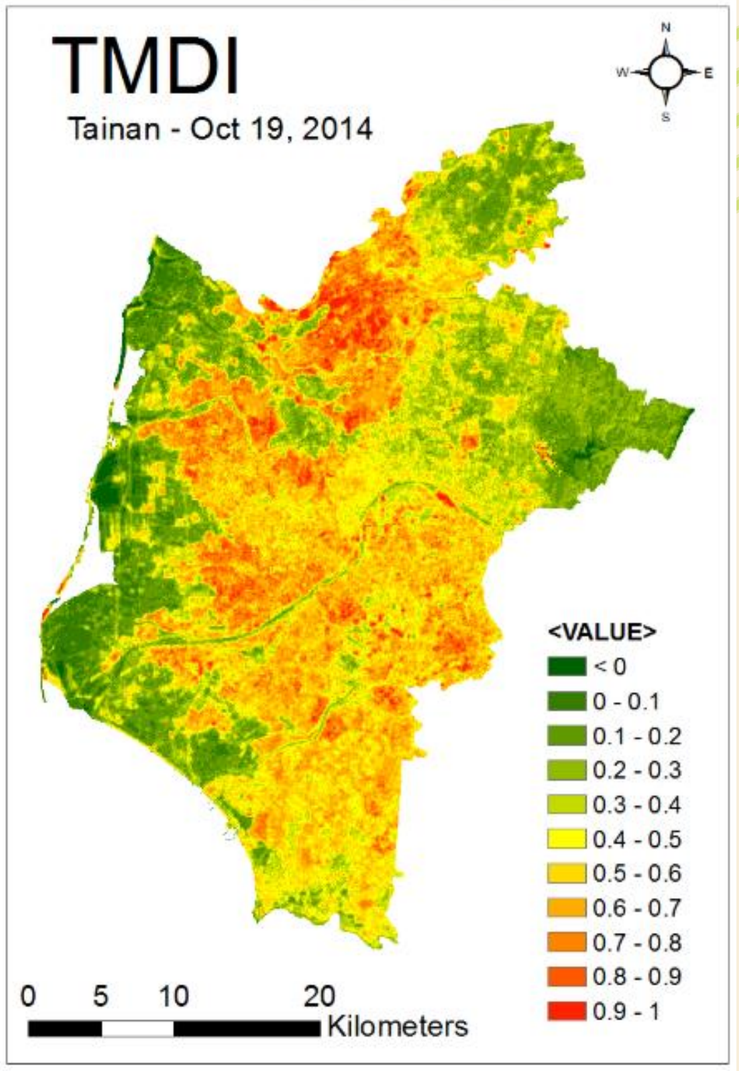
Results and discussion





Scatter plots of dry and wet edges in NDLI-LST space on (a) October 19 and (b) October 19, 2014 over Tainan, Taiwan.





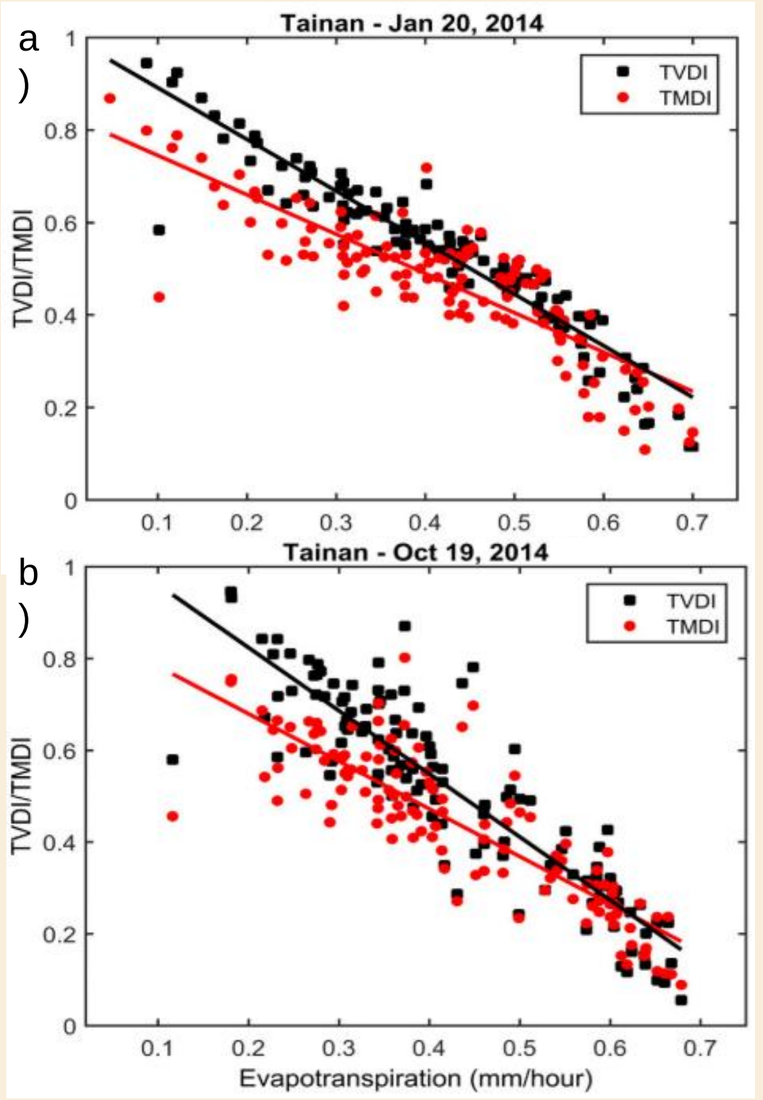
TMDI over Tainan, Taiwan, on (a) January 20 and (b) October 19, 2014.

Results and discussion

Correlation between TMDI/TVDI and ET for different LULC types

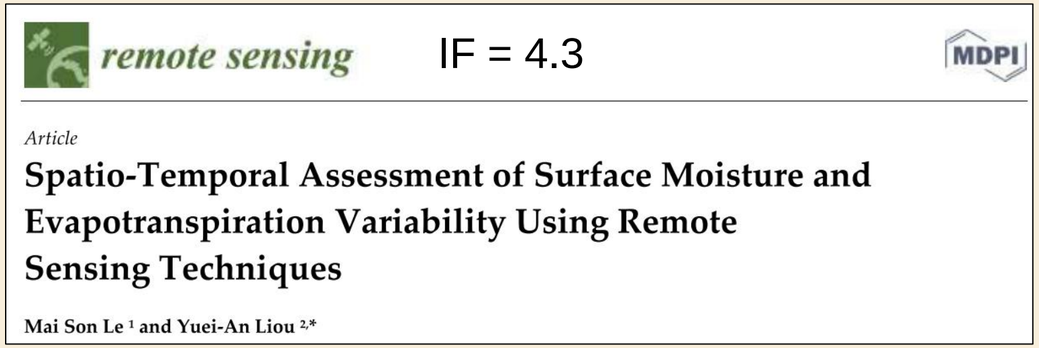
Land cover types		January 20, 2014		October 19, 2014	
		TVDI	**TMDI**	**TVDI**	**TMDI**
All land covers	ET	**-0.85**	**-0.95**	**-0.87**	**-0.9**
Built-up & bare soil		-0.634	-0.82	-0.678	-0.762
Vegetation		-0.98	-0.975	-0.953	-0.956
Agriculture		-0.88	-0.98	-0.84	-0.895

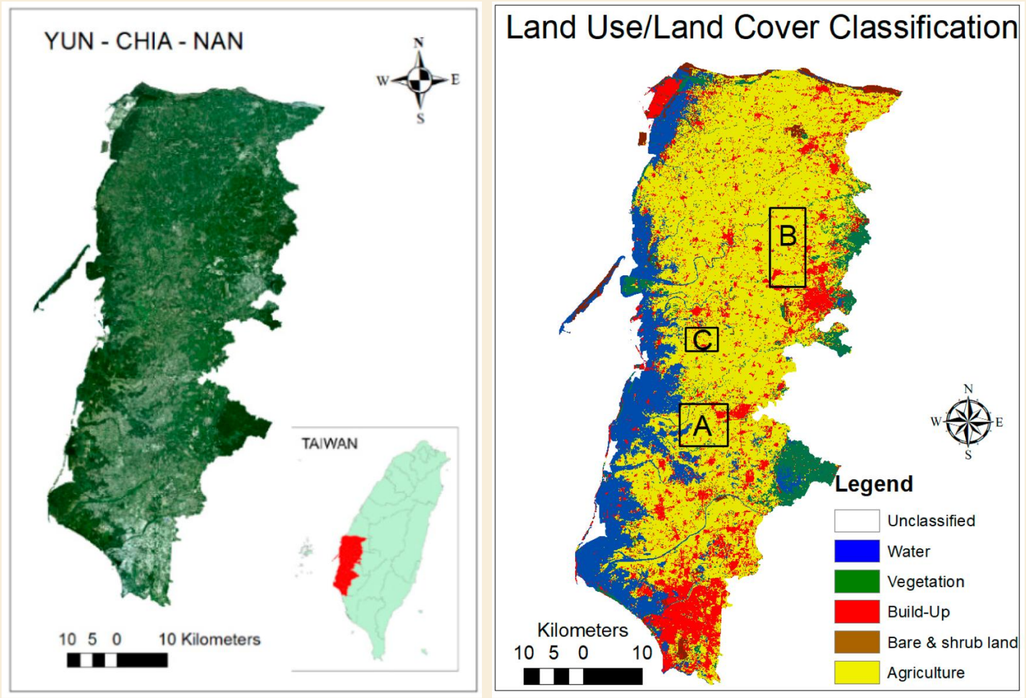
- The correlation coefficients of T_{air} with TMDI, TVDI, and SEBAL-derived ET are 0.94, 0.89, and −0.86 for January 20 and 0.78, 0.74, and −0.62 for October 19, respectively.
- The moderately negative correlation between TMDI and RH has also been presented with correlation coefficient of −0.66 and −0.41 for January 20 and October 19, respectively.



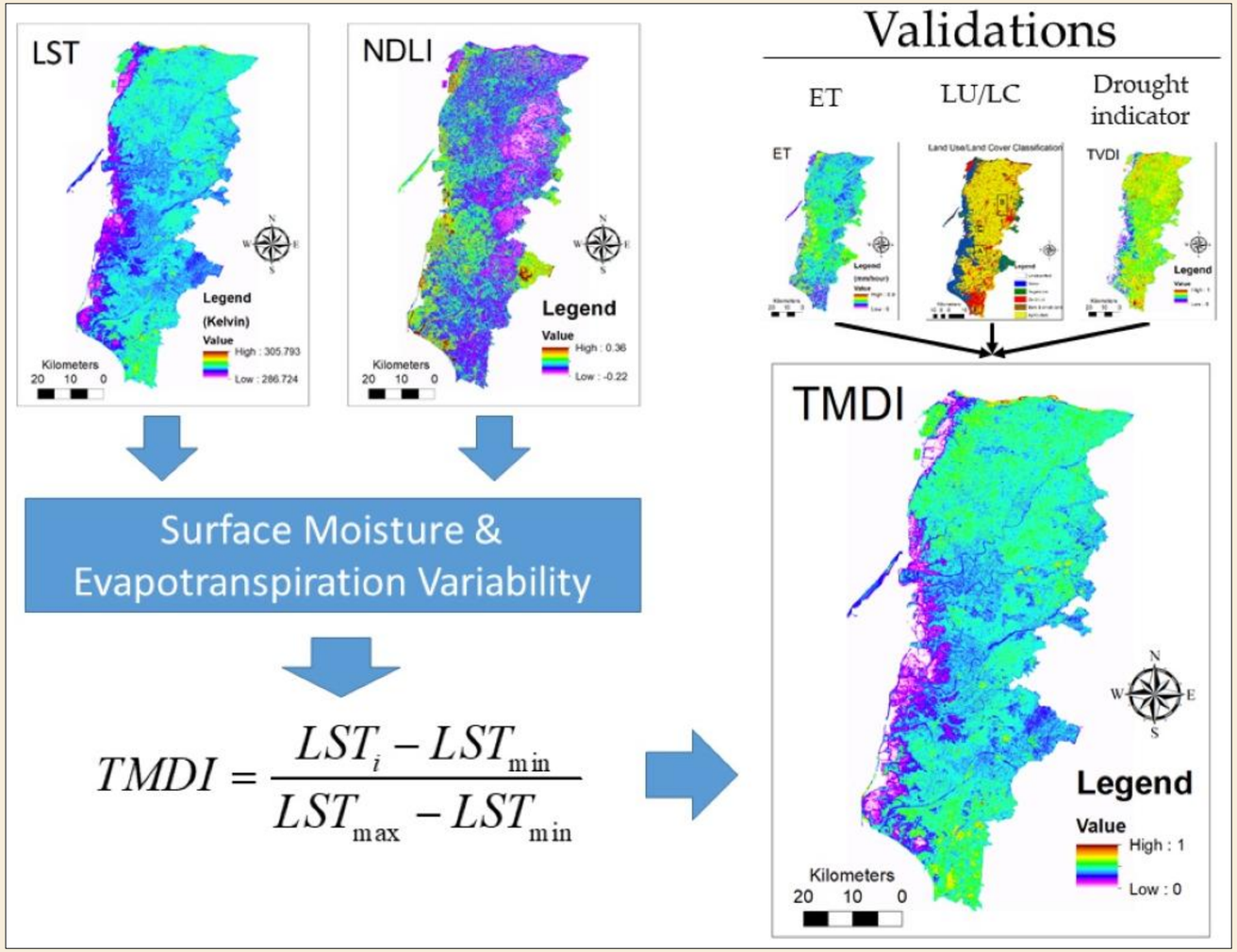
Correlation between TMDI/TVDI and ET on (a) January 20 and (b) October 19, 2014.

Applicability of TMDI



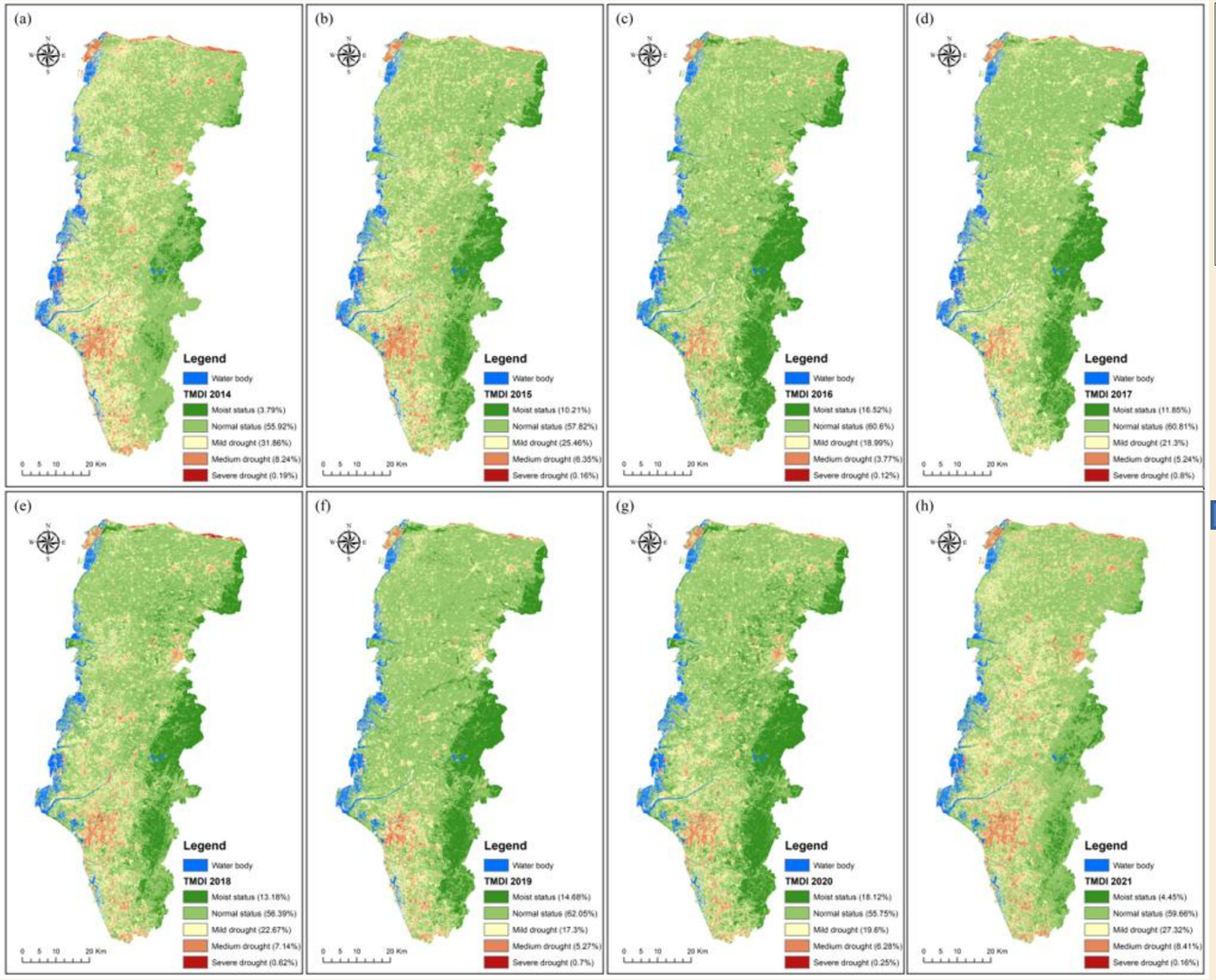


Geographical location and LULC of the study area.



Flowchart depicting the tasks involved in this study.

Advancements in the TMDI

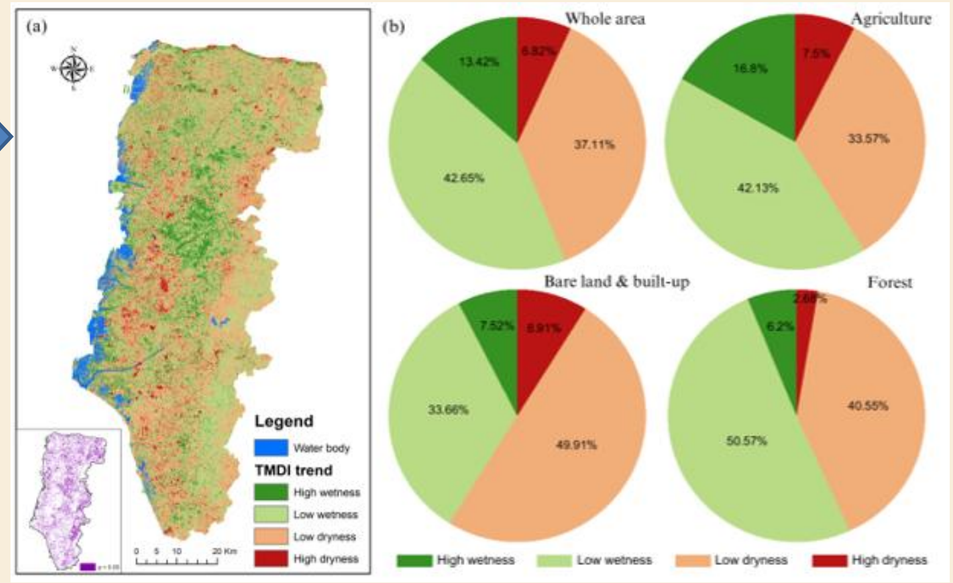


The TMDI maps during 2014–2021 in the YCNK Plain.

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 62, 2024 4405415

Advancements in the Temperature-Soil Moisture Dryness Index (TMDI) for Drought Monitoring in Southwestern Taiwan

Minh-Tin Thai, *Member, IEEE*, and Yuei-An Liou, *Senior Member, IEEE*



The TMDI-based trends for showing (a) the distribution and (b) area statistics.

Surface Water Availability-Temperature Index (SWATI)

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 61, 2023 4507312

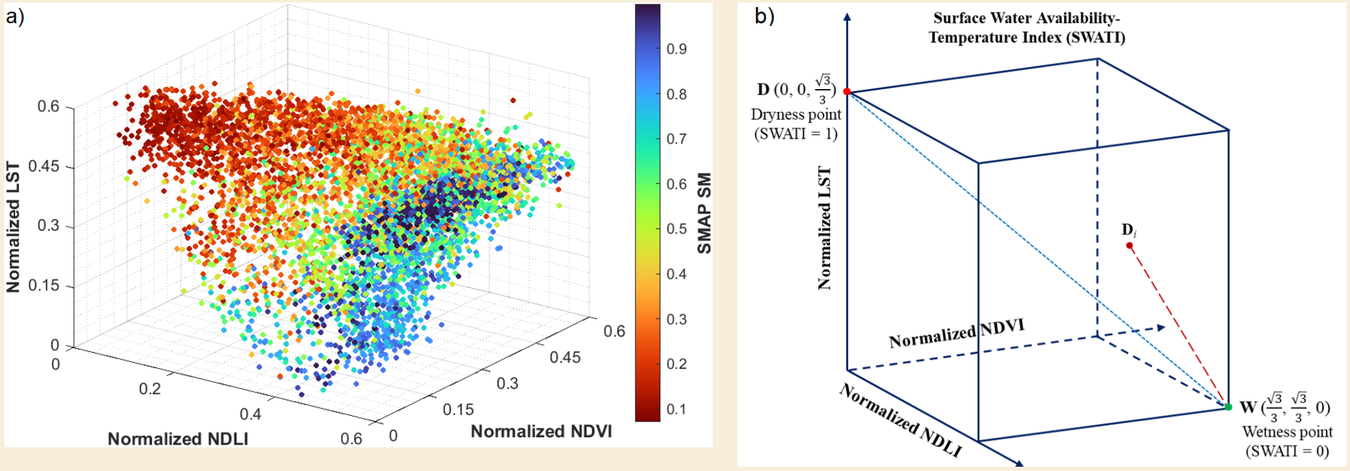
Surface Water Availability and Temperature (SWAT): An Innovative Index for Remote Sensing of Drought Observation

Yuei-An Liou, *Senior Member, IEEE*, and Minh-Tin Thai, *Member, IEEE*

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 63, 2025 4403714

Surface Water Availability-Temperature Index (SWATI) for Global Drought Monitoring

Minh-Tin Thai, *Member, IEEE*, and Yuei-An Liou, *Senior Member, IEEE*



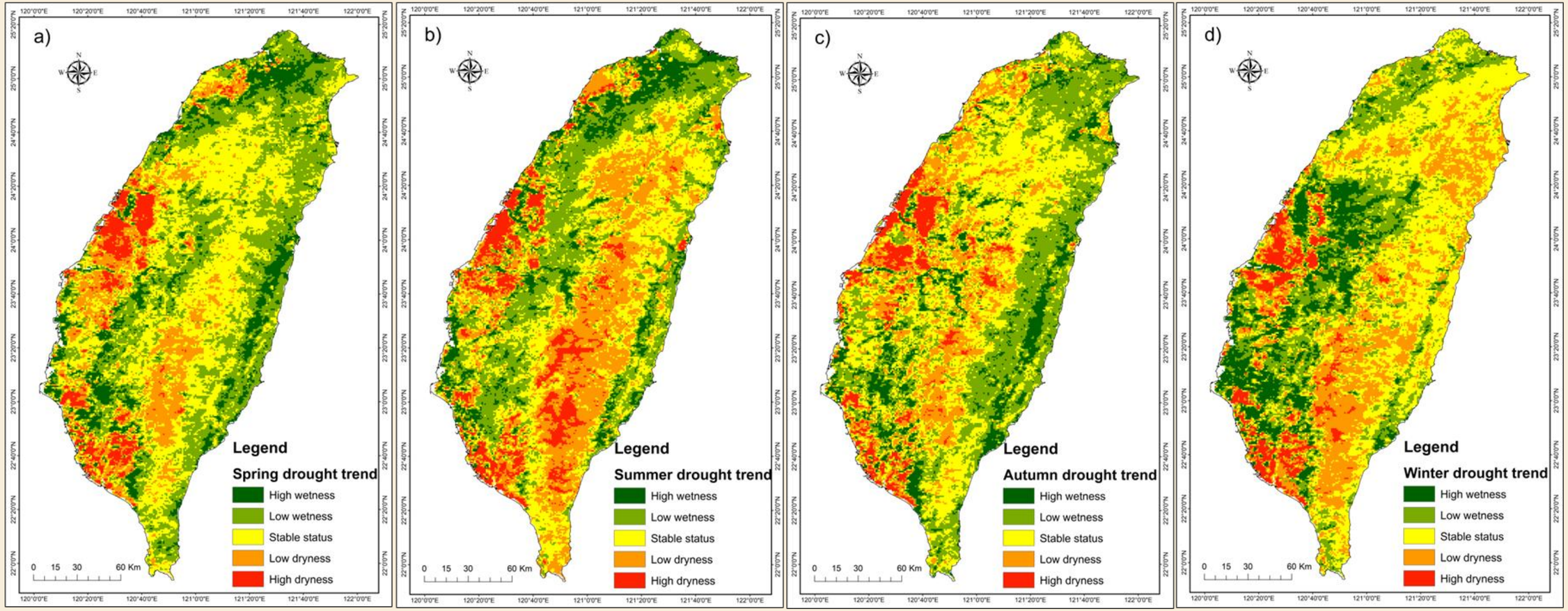
(a) The NDLI-NDVI-LST 3D scatterplot and (b) the sketch of the SWATI.

SM-related factors, such as water availability, vegetation state, and temperature, can be inferred by the NDLI, NDVI, and LST, respectively. An interrelation exists between these three factors (i.e., the NDLI, NDVI, and LST), so that if any of them changes, the other variables will undoubtedly be varied. A few limitations are inevitably found in using the single and coupled factors. Hence, a new index (i.e., the SWATI) could be developed based on these three variables. The SWATI is defined using the 3D scatterplots of the NDLI, NDVI, and LST with the Euclidean distance method.

$$\mathrm{SWATI} = \sqrt{\left(\frac{\sqrt{3}}{3} - \mathrm{NDLI}\right)^2 + \left(\frac{\sqrt{3}}{3} - \mathrm{NDVI}\right)^2 + \mathrm{LST}^2}$$

The NDLI, NDVI, and LST are all normalized to be between 0 and $\frac{\sqrt{3}}{3}$. The SWATI ranges from 0 to 1, representing wet and dry conditions, respectively.

SWATI 顯示台灣乾濕趨勢的季節差異



2001－2023 年的春、夏、秋、冬趨勢分布並不相同。

同一季節仍存在區域差異，需避免用全台平均掩蓋局部變化。

趨勢圖提供長期背景，當期狀態仍需搭配近期觀測。

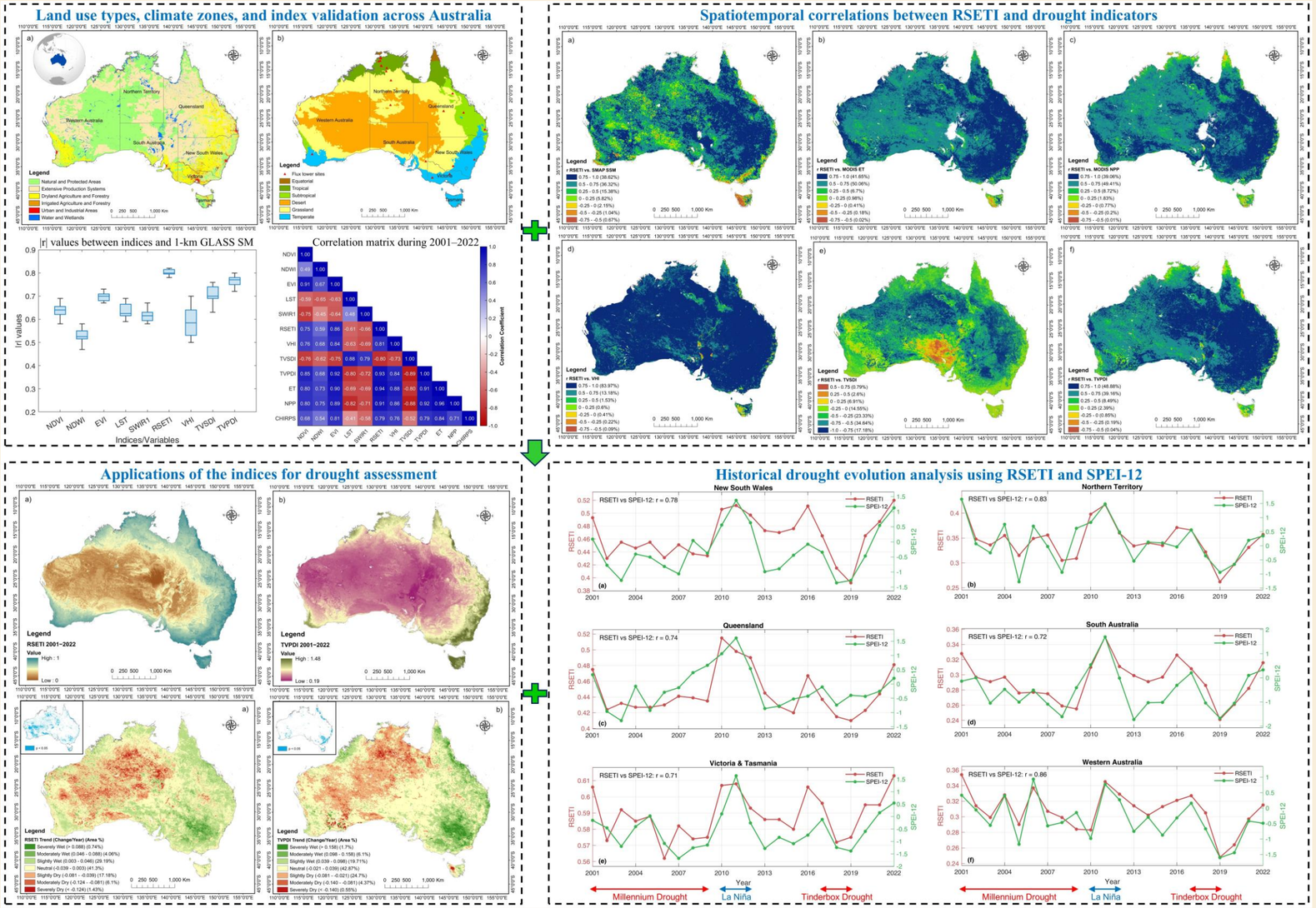
Relative Surface Evapotranspiration Index (RSETI)

Assuming an approximately normal distribution of NDLI values over the study period, outliers were defined as those falling outside three standard deviations (SD) from the mean (μ). This approach is based on the empirical rule, which states that values smaller than μ − 3SD or greater than μ + 3SD in a normal distribution are considered outliers and were removed.

$$\mathrm{RSETI} = \frac{\mathrm{NDLI} - \mathrm{NDLI}_{\min}}{\mathrm{NDLI}_{\max} - \mathrm{NDLI}_{\min}}$$

where $\mathrm{NDLI}_{\min}$ and NDLI_{max} are the minimum and maximum values of NDLI, respectively.

(Liou and Thai, 2025)
Remote Sensing of Environment
(SCI, IF = 12.3)



Drought assessment using satellite indices

Precipitation

Soil moisture

ET

Runoff

Precipitation deficit

1 Meteorological drought

Soil water deficit

2 Agricultural drought

Surface and Ground water deficit

3 Hydrological drought

Water shortage

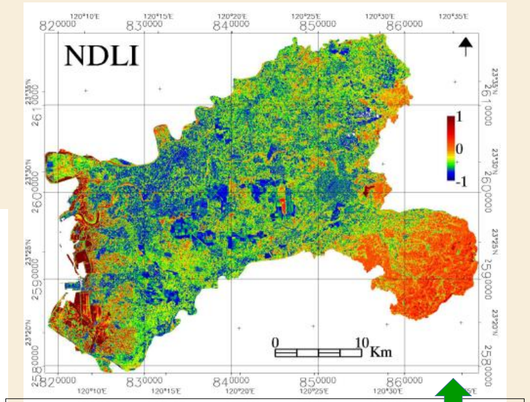
4 Social-economical drought

Forecasting the **Standardized Precipitation Evapotranspiration Index (SPEI)** Using **Artificial Neural Networks (ANN)**

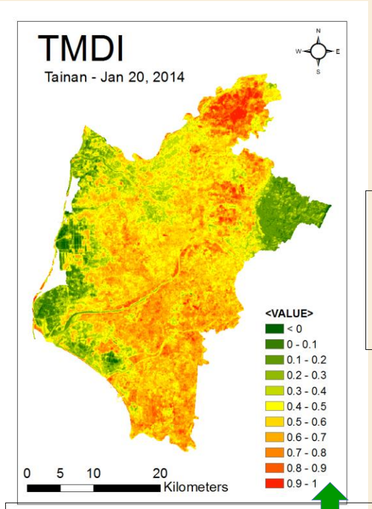
Estimating Surface Energy Fluxes and Evapotranspiration (ET) Using **Normalized Difference Latent Heat Index (NDLI)** and **Relative Surface ET Index (RSETI)**

Assessing Crop Water Stress Status Using **Temperature-Soil Moisture Dryness Index (TMDI)**

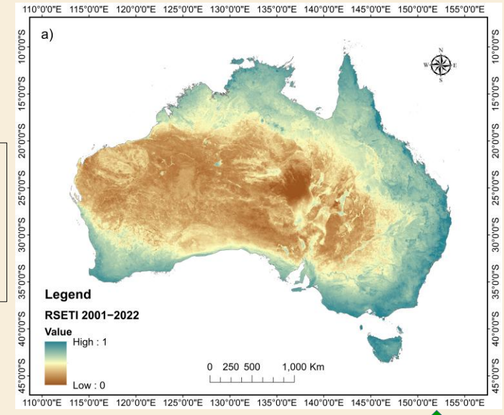
Assessing Global Drought Status Using **Surface Water Availability–Temperature Index (SWATI)**



(Liou et al, 2019)
IEEE Transactions on Geoscience and Remote Sensing (TGRS)
(SCI, IF = 9.4)

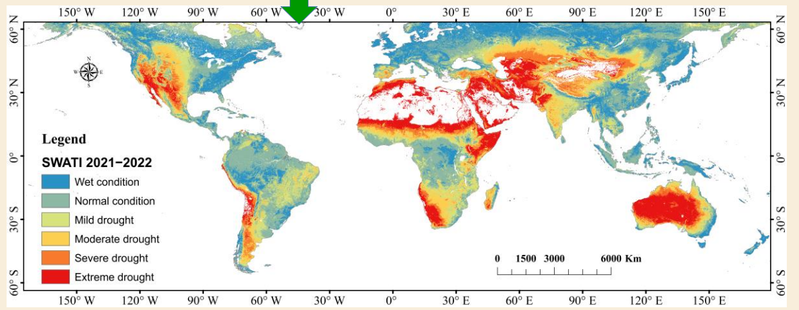


(Le and Liou, 2021)
IEEE Geoscience and Remote Sensing Letters
(SCI, IF = 4.8)



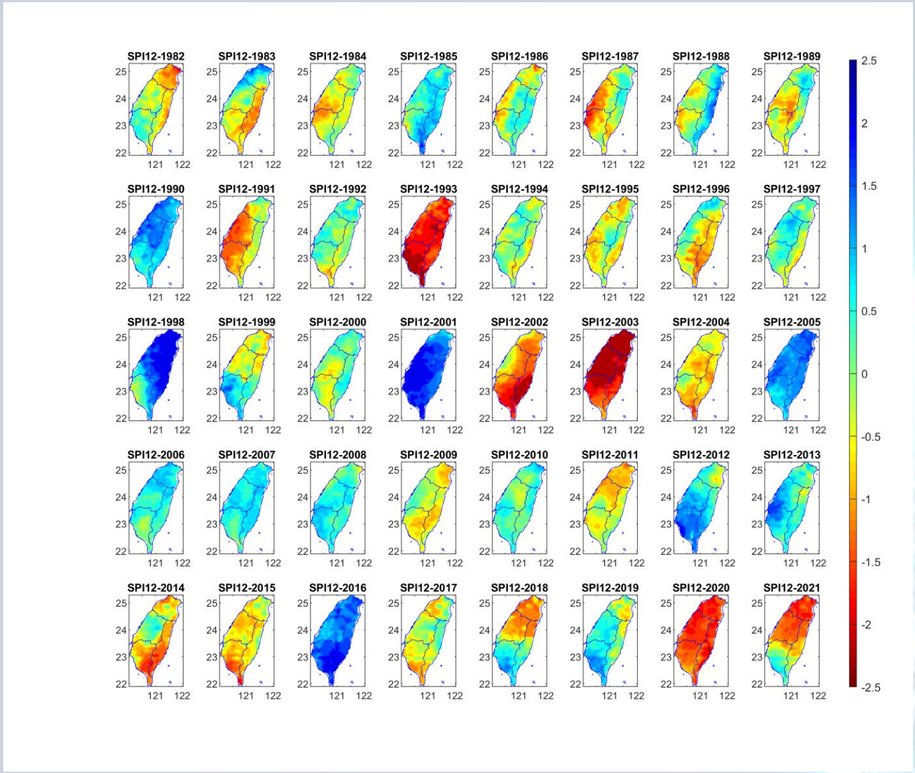
(Thai and Liou, 2025)
IEEE TGRS
(SCI, IF = 9.4)

(Liou and Thai, 2025)
Remote Sensing of Environment
(SCI, IF = 12.3)



乾旱研究與決策應用

降水缺乏、地表水分與經濟風險



臺灣 SPI12 年際分佈（1982–2021）

氣象與地表觀測

SPI 描述降水異常，遙測補充地表水分與溫度資訊

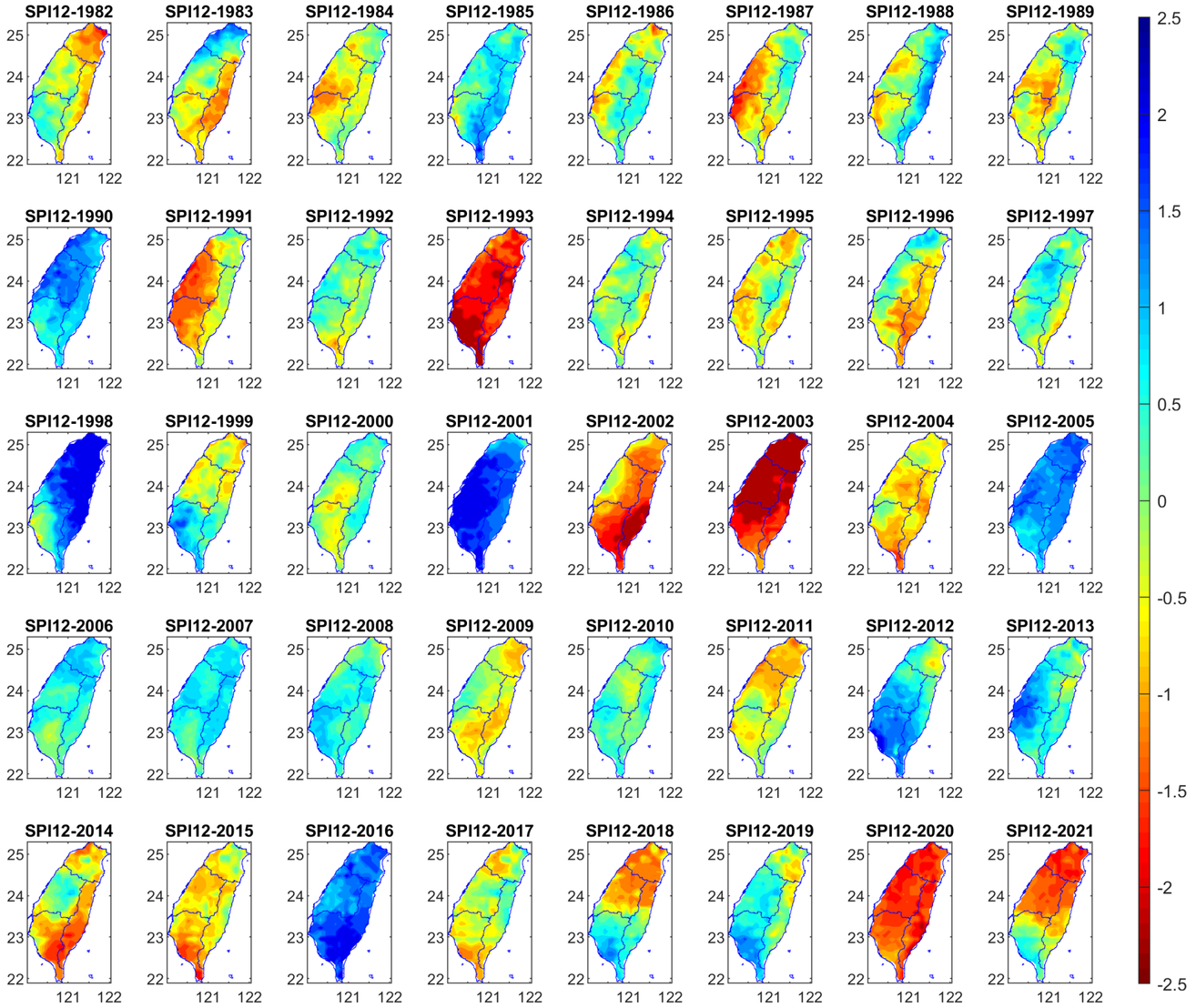
多層次風險

結合危害、暴露與環境條件，識別乾旱風險分佈

跨領域研究

探索乾旱風險與食品業權益成本的統計關聯

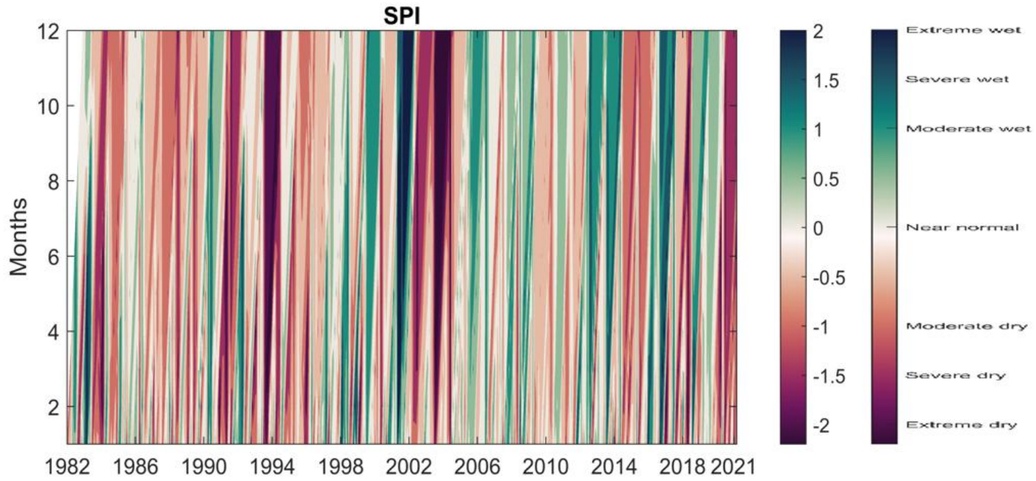
Drought in Taiwan



This study presents a comprehensive spatio-temporal assessment of drought in Taiwan from **1982 to 2021** using the **Standardized Precipitation Index (SPI)**.

The SPI is a widely used drought index that provides valuable insights into the severity and duration of drought events.

The results reveal **significant variations in drought occurrence and severity** across different regions and time periods in Taiwan.



(Vo and Liou, 2024)
Journal of Hydrology: Regional Studies (IF = 5.6)

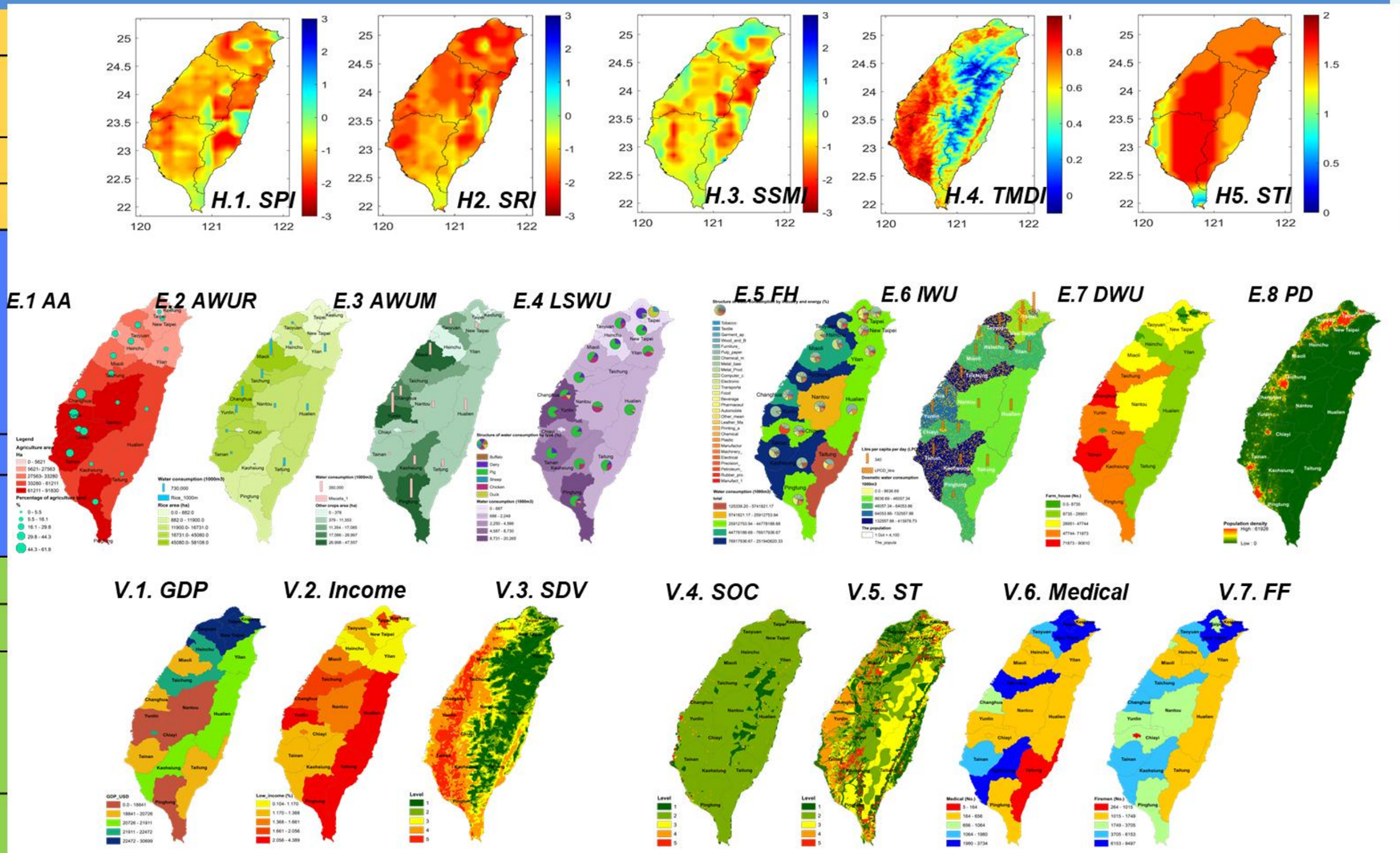
Drought in Taiwan (2021)

	Sectors
1	Meteorological drought
2	Agricultural drought
3	Hydrological drought
4	Climate change
5	Agriculture sector
6	Energy and industry sector
7	Drinking/domestic water supply sector
8	Economic vulnerability
9	Social vulnerability
10	Environmental susceptibility
11	Coping capacity

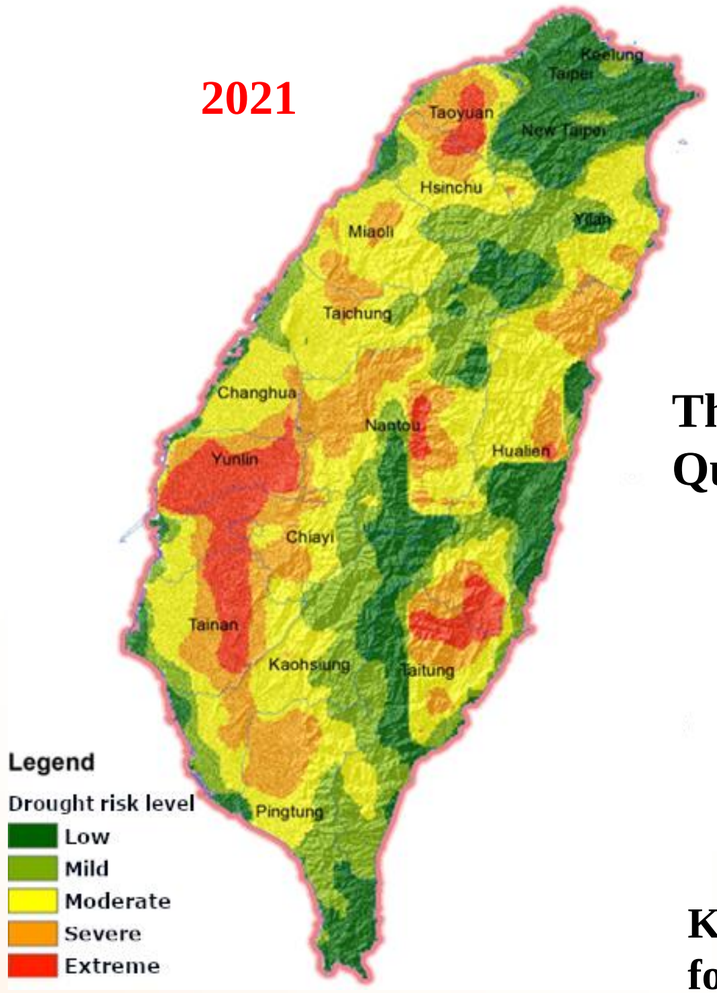
HAZARDS

EXPOSURE

VULNERABILITY



Drought in Taiwan (2021)



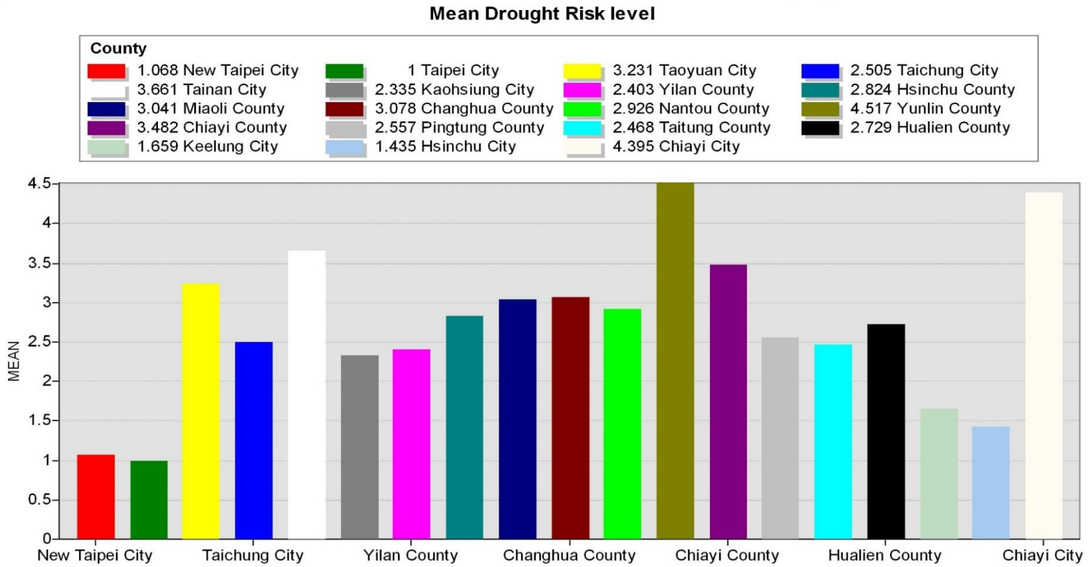
The Output: A Predictive Business Risk Map

The final map identifies high-risk regions for agriculture and supply chains, including Yunlin, Chiayi, and Tainan counties.

This is not a weather forecast; it's a strategic planning tool for proactive resource allocation and risk mitigation.

The Financial Connection: Quantifying Market Impact

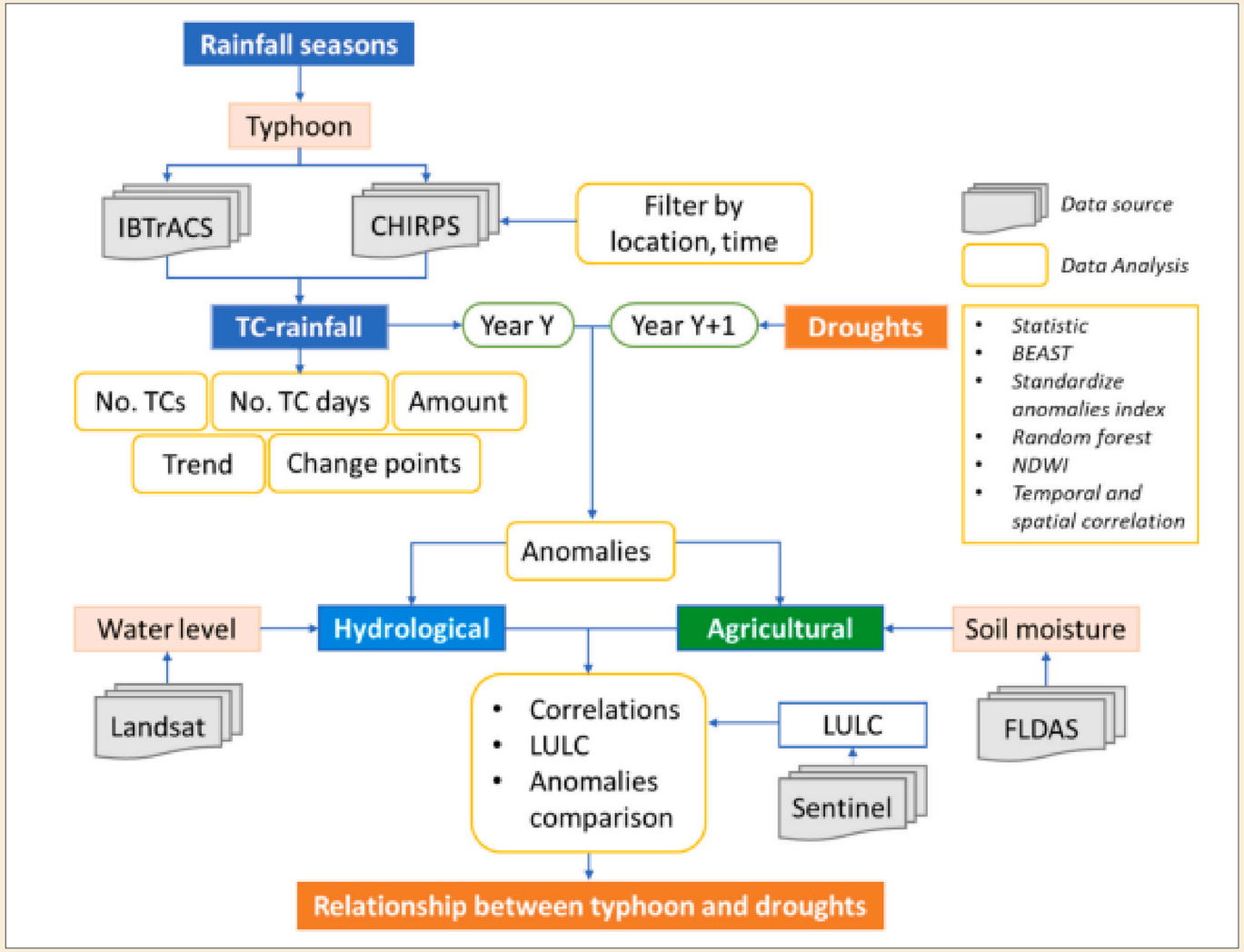
The study examines statistical associations between drought risk and corporate financial measures.

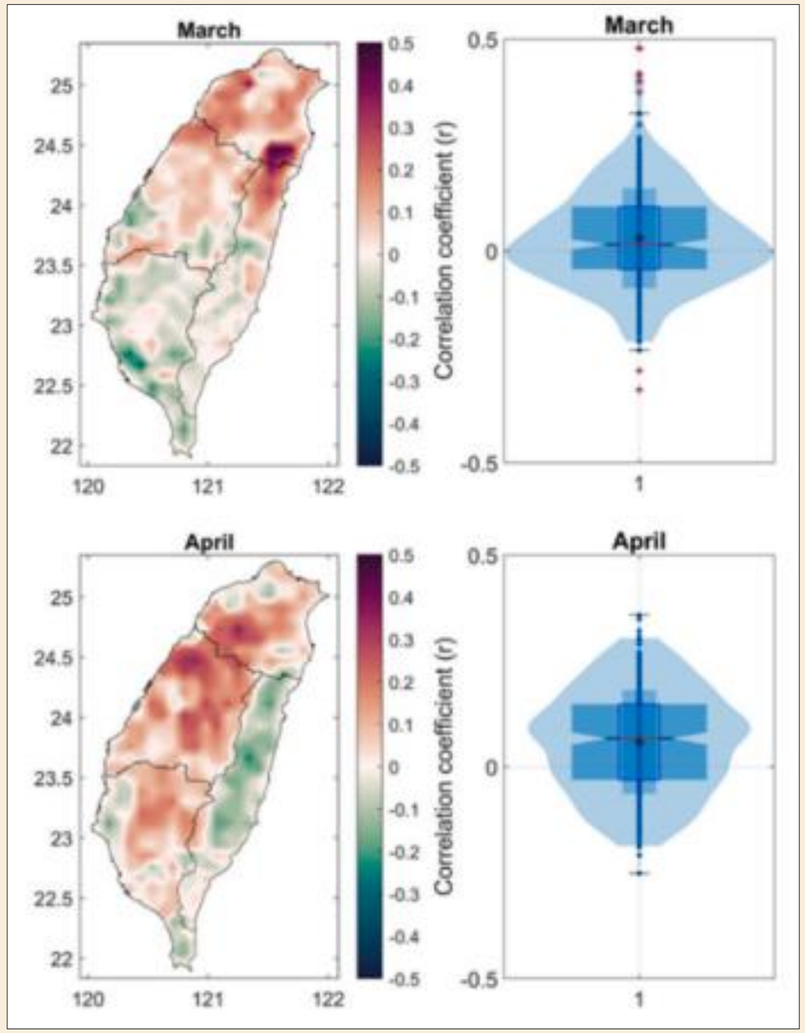


Key Finding: Exceptional drought risk was associated with **a higher cost of equity for the food industry**, providing a quantifiable link between climate risk and financial performance.

(Liou et al, 2024)
Science of The Total Environment

TC-induced rainfall vs. Drought in Taiwan





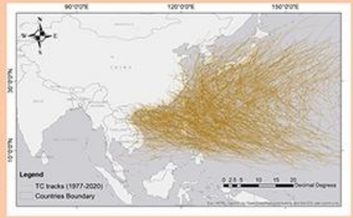
Relationships between TC-Rain (STCI) and soil moisture (SSMI).

(Vo and Liou, 2024)
Atmospheric Research (IF = 4.5)

Clustered insights into typhoon behaviors

TCs best-track data

IBTrACS



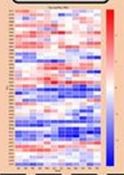
IBTrACS

ENSO&PDO Dataset

MEI v2

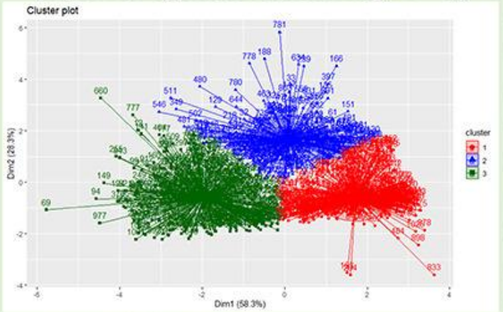


PDO

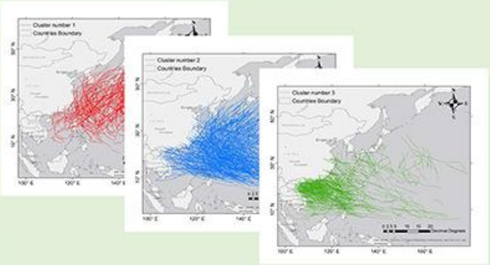


K-means clustering

(Optimal typhoon clustering, k = 3)

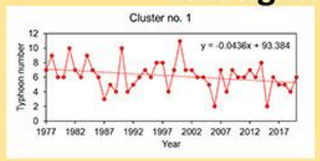


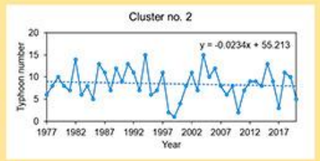
Spatial distribution and Regional Vulnerabilities

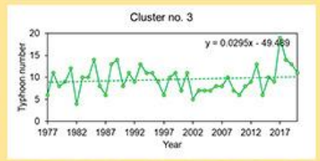


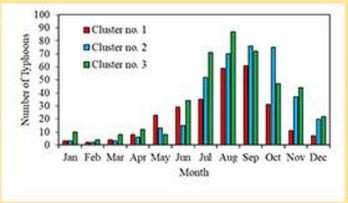
Cluster No. 1: moderate lifetimes, average track lengths, intermediate intensities, and high curviness.
Cluster No. 2: prolonged lifetimes, extensive tracks, high intensity, and medium curviness.
Cluster No. 3: shorter lifespans, limited tracks, lower intensity, and low curviness.

Temporal trends & seasonal variation among three clusters

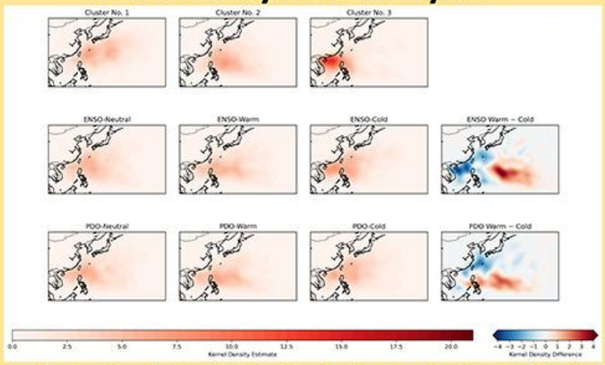






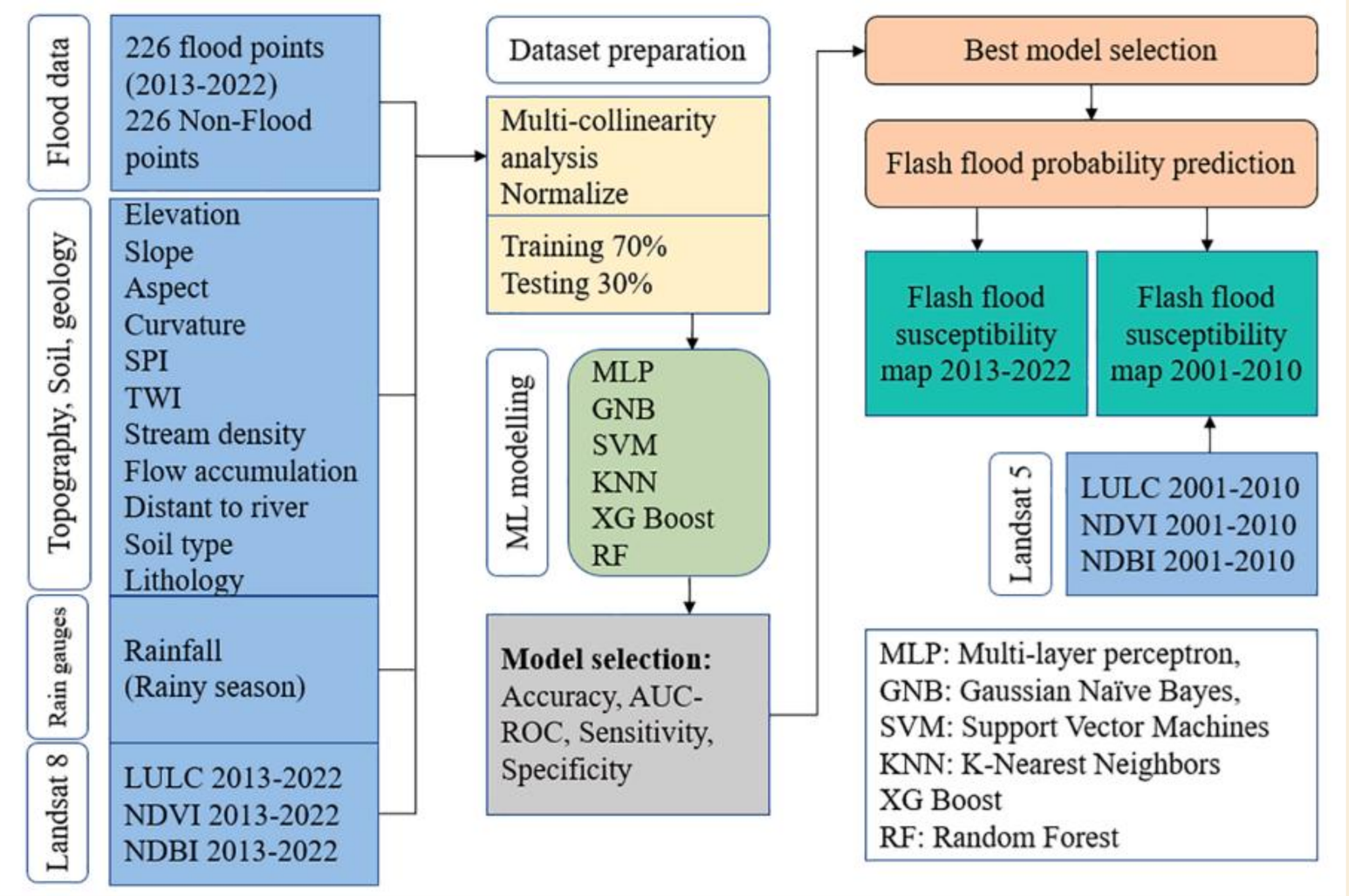


Clusters, ENSO, and PDO patterns as revealed by KDE analysis



(Le and Liou, 2026)
Global and Planetary Change (IF = 4.7)

AI 暴洪潛勢：資料、訓練與驗證



樣本：226 個暴洪點與 226 個非暴洪點。

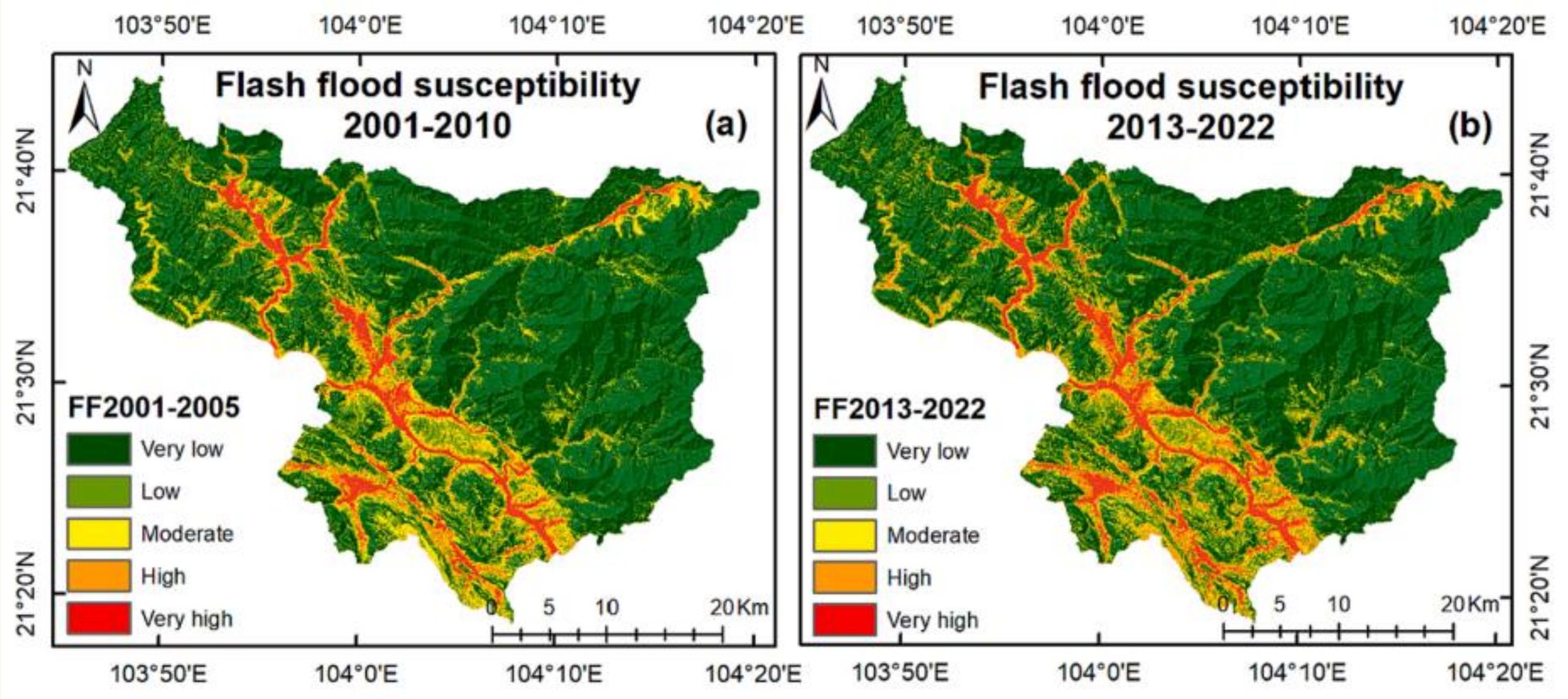
輸入：地形、地質、雨季降雨、土地覆蓋、NDVI 與 NDBI。

共線性檢查與正規化。
訓練 70%，測試 30%。

比較：MLP、GNB、SVM KNN、XGBoost、RF。

Hoang & Liou (2024), Ecological Indicators 158, 111417

暴洪潛勢的跨時期比較

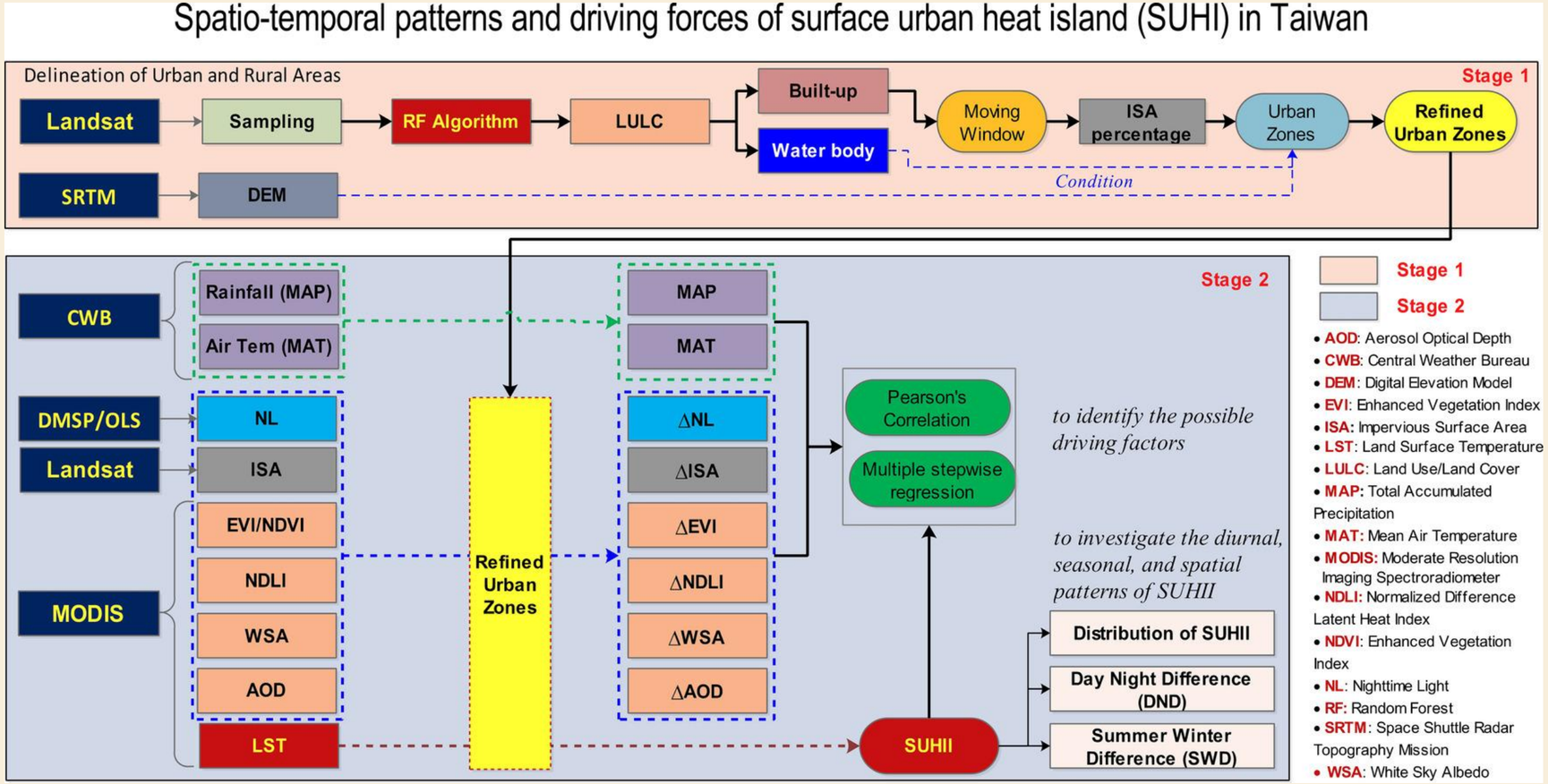


比較圖面主標所示的 2001－2010 與 2013－2022。

研究以土地覆蓋與環境因子變化，分析高潛勢區的空間差異。

潛勢圖可指出優先調查區域，仍須與實際事件紀錄對照。

台灣地表熱島：研究流程



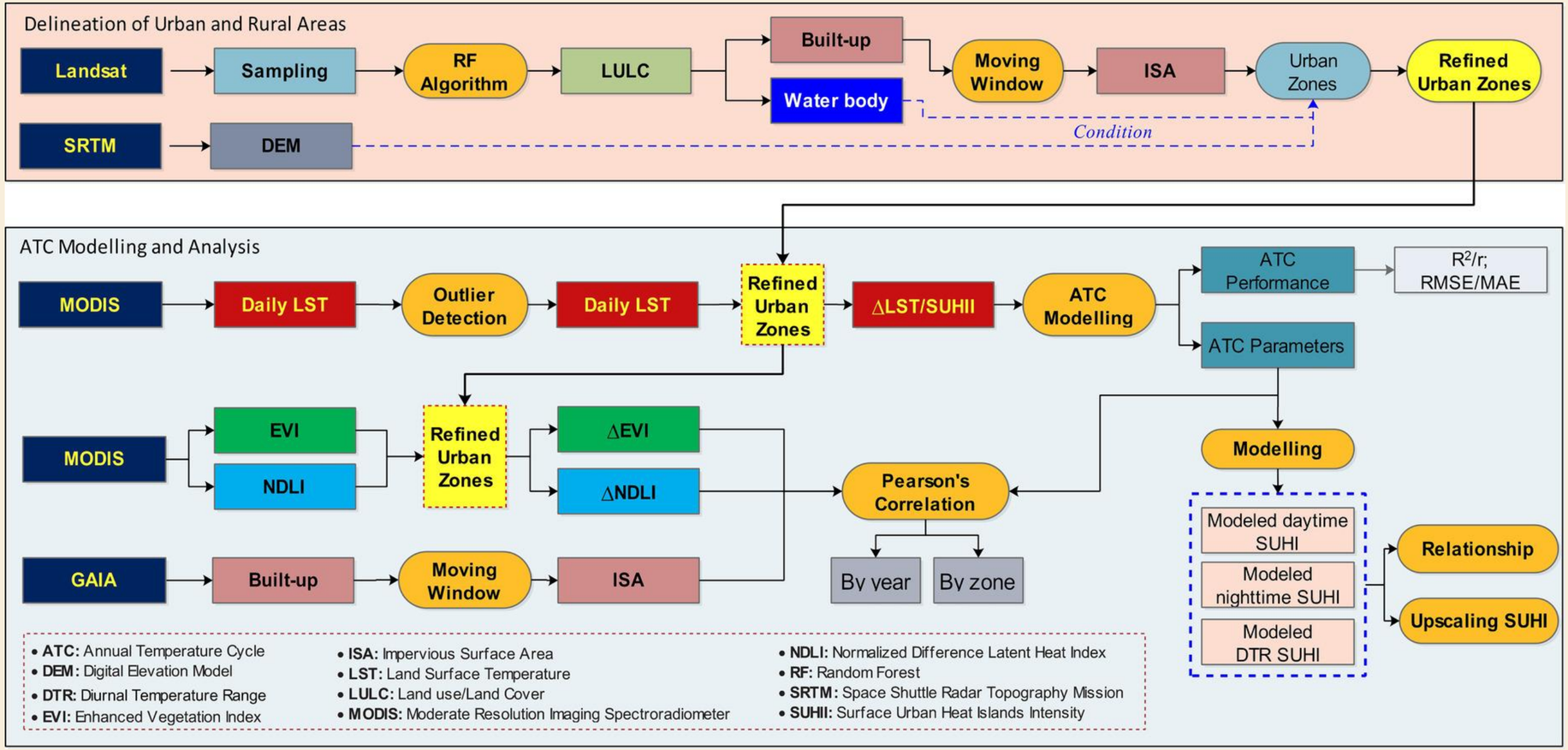
先以 Landsat 與 RF 分類土地覆蓋，界定都市與鄉村範圍。

再整合 MODIS 地表溫度、植被與水分指標，計算熱島差異。

分析不同區域、季節與地表條件對熱環境的影響。

Liou, Tran & Nguyen (2024), Urban Climate 53, 101806

雲遮造成的熱島觀測缺口

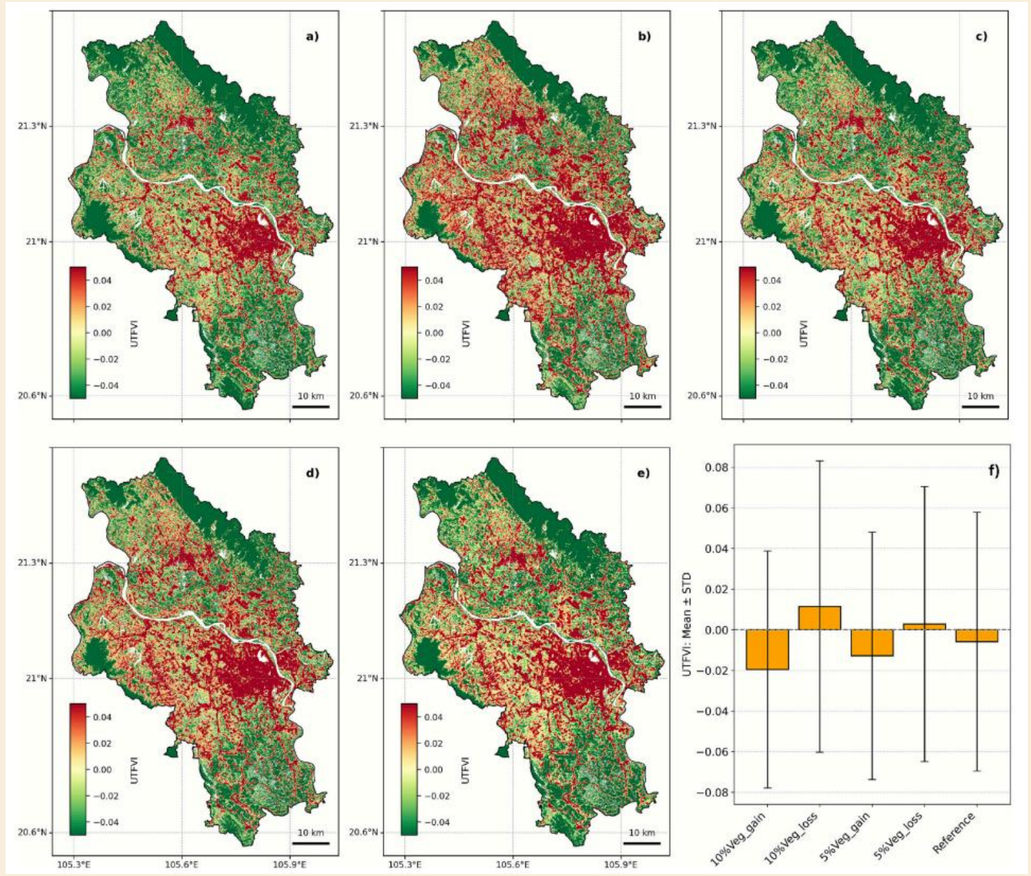


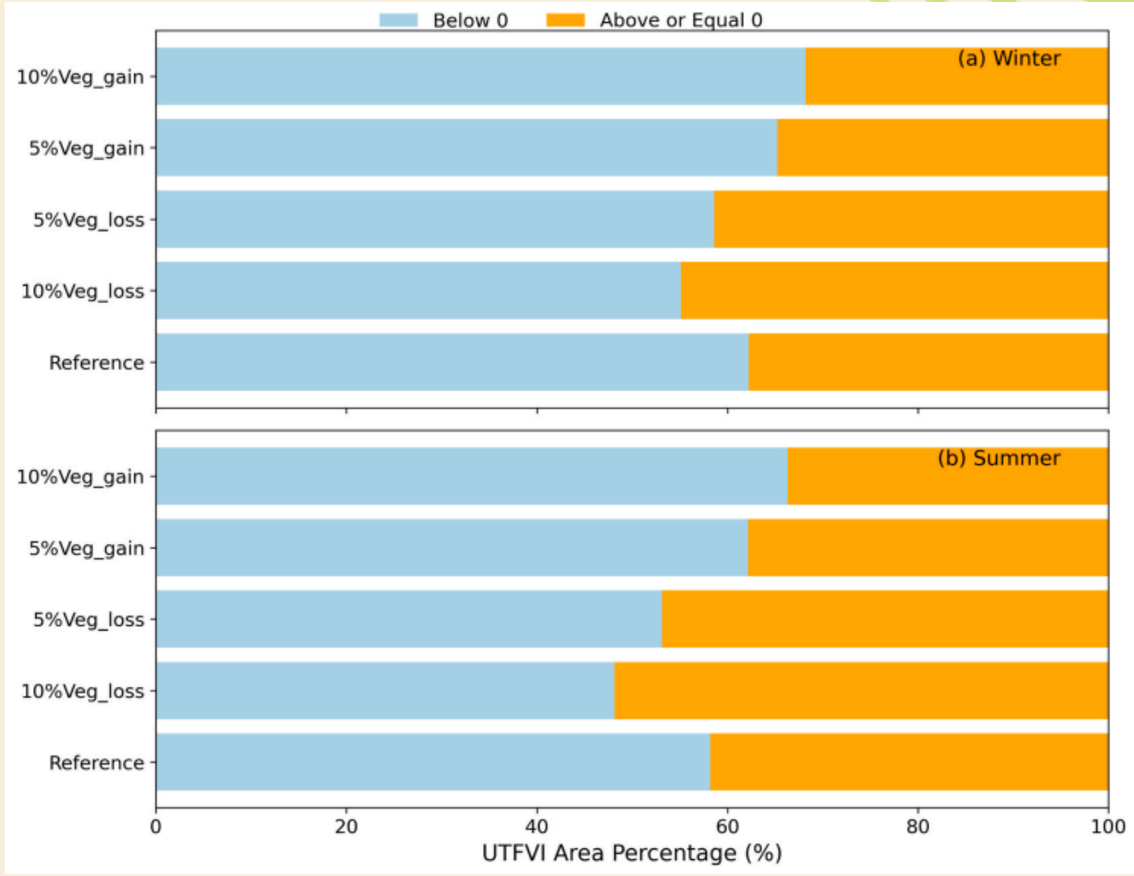
以 MODIS 每日 LST 序列與離群值處理，建立可用觀測。

採用年溫度週期模型（ATC），描述日間與夜間熱島變化。

以 R^2／r、RMSE、MAE 評估模型，並分析植被與不透水面關係。

都市綠地與地表降溫的情境研究





場址：越南河內都會區。

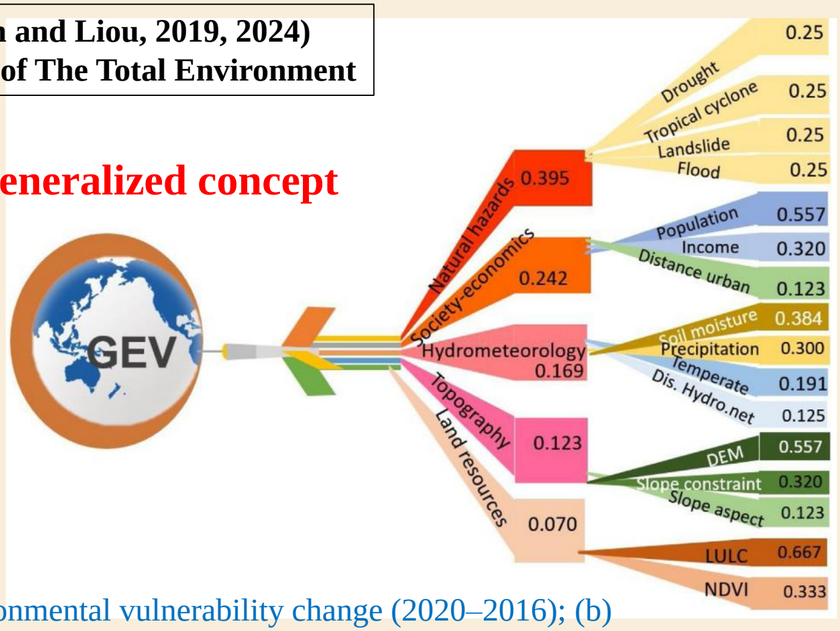
方法：以機器學習模擬植被增加／減少 5% 與 10% 的 LST。

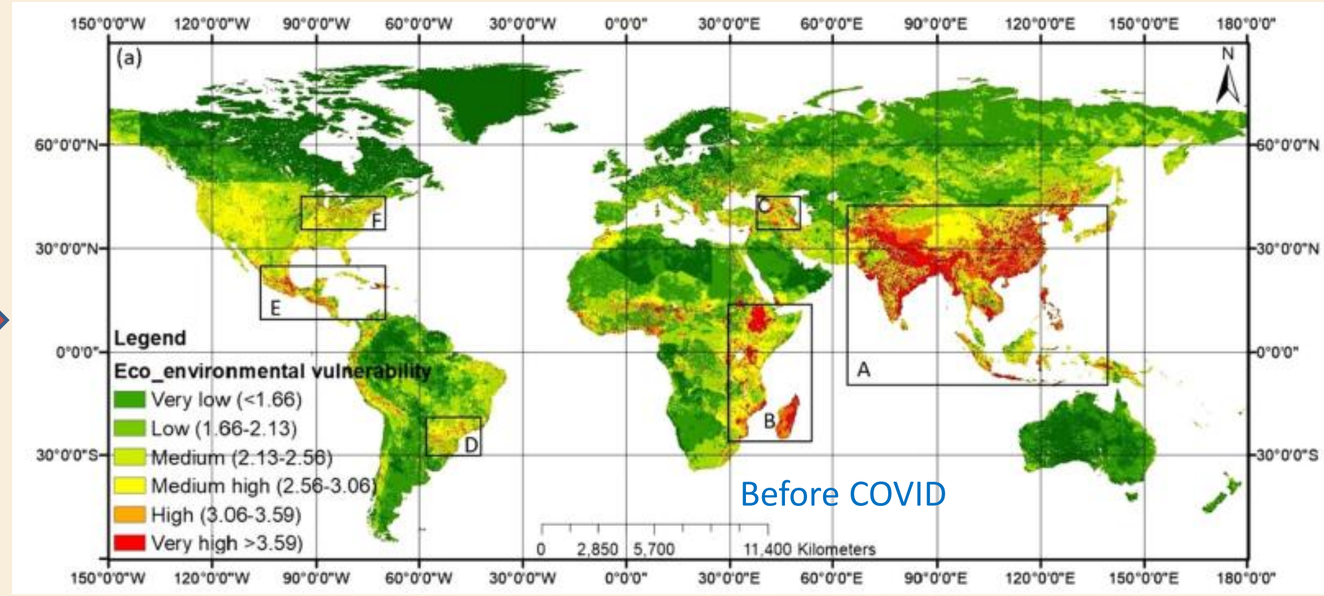
比較：冬、夏季的都市熱場變異指標 UTFVI 與各類別面積。

Eco-environmental Vulnerability Assessment (EVA)

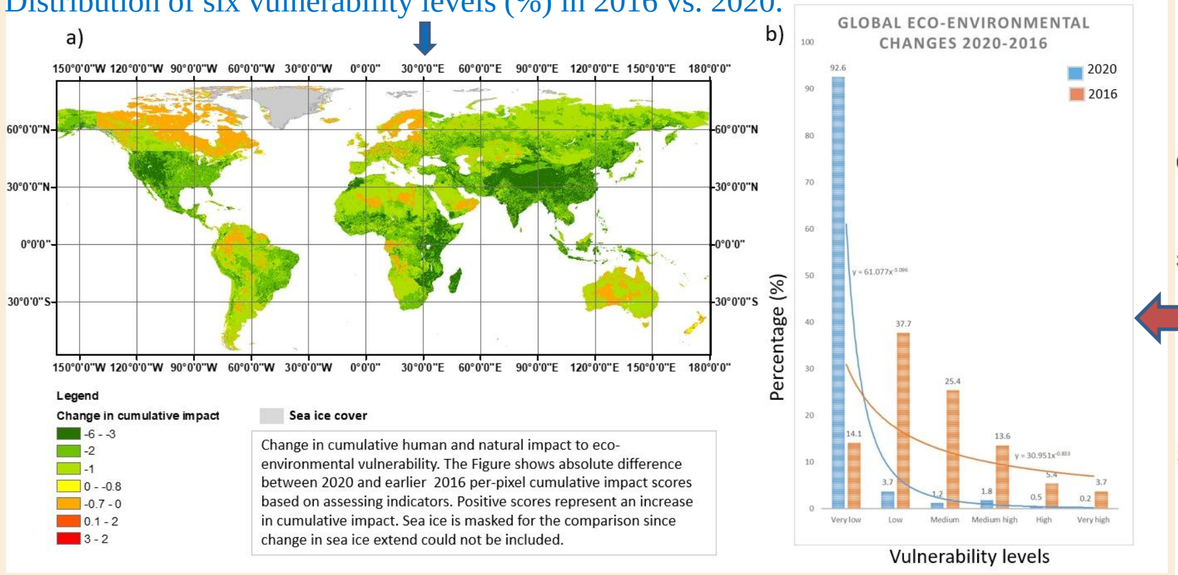
(Nguyen and Liou, 2019, 2024)
Science of The Total Environment

EVA generalized concept

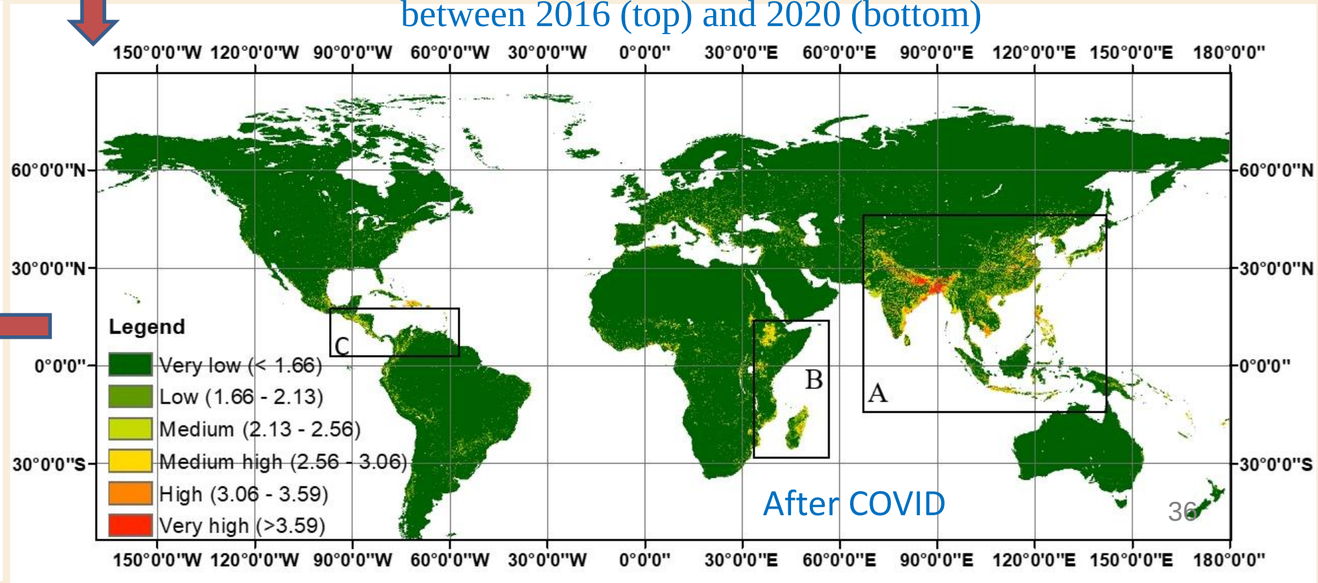




(a) Eco-environmental vulnerability change (2020–2016); (b) Distribution of six vulnerability levels (%) in 2016 vs. 2020.



Comparison of eco-environmental vulnerability hotspots (A, B, C) between 2016 (top) and 2020 (bottom)



颱風脆弱度：危害與承受能力的整合

越南案例把危害、暴露與敏感度、調適能力分開建構。

整合颱風、地形、土地利用、人口、設施與社會條件。

以 AHP 與 GIS 加權疊合，呈現區域脆弱度差異。

不同研究方法的證據與限制

物理與光譜指標：先確認變數的物理意義，再比較模式或觀測。

機器學習：交代樣本、分割方式與評估指標，檢查遷移到新場址的能力。

情境與脆弱度：說明參考條件、權重與不確定性。

跨研究整合：對齊時間尺度、空間解析度與驗證對象。

結論

水分指標的發展，補充了地表能量、水分與乾濕變化的觀測。

AI 與時間序列方法，拓展暴洪、颱風型態與都市熱環境的分析。

生態環境脆弱度整合多種自然與人為條件，呈現區域差異。

持續研究重點是資料連續性、跨尺度比較與獨立驗證。

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歡迎交流與討論

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2026 年 10 月 28 日

參考文獻

[1] IPCC. (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Chapter 5, Food, fibre and other ecosystem products. https://www.ipcc.ch/report/ar6/wg2/chapter/chapter-5/

[2] Liou, Y.-A., Teng, Y.-T., Van Hove, T., & Liljegren, J. C. (2001). Comparison of precipitable water observations in the near tropics by GPS, microwave radiometer, and radiosondes. Journal of Applied Meteorology, 40(1), 5–15. https://doi.org/10.1175/1520-0450(2001)040%3C0005:COPWOI%3E2.0.CO;2

[3] Liou, Y.-A., & Kar, S. K. (2014). Evapotranspiration estimation with remote sensing and various surface energy balance algorithms—A review. Energies, 7(5), 2821–2849. https://doi.org/10.3390/en7052821

[4] Liou, Y.-A., Le, M. S., & Chien, H. (2019). Normalized difference latent heat index for remote sensing of land surface energy fluxes. IEEE Transactions on Geoscience and Remote Sensing, 57(3), 1423–1433. https://doi.org/10.1109/TGRS.2018.2866555

參考文獻

[5] Le, M. S., & Liou, Y.-A. (2021). Spatio-temporal assessment of surface moisture and evapotranspiration variability using remote sensing techniques. Remote Sensing, 13(9), 1667. https://doi.org/10.3390/rs13091667

[6] Le, M. S., & Liou, Y.-A. (2022). Temperature-soil moisture dryness index for remote sensing of surface soil moisture assessment. IEEE Geoscience and Remote Sensing Letters, 19, 1–5. https://doi.org/10.1109/LGRS.2021.3095170

[7] Le, M. S., Liou, Y.-A., & Pham, M. T. (2023). Crop response to disease and water scarcity quantified by normalized difference latent heat index. IEEE Access, 11, 55938–55946. https://doi.org/10.1109/ACCESS.2023.3283033

[8] Thai, M.-T., & Liou, Y.-A. (2024). Advancements in the temperature-soil moisture dryness index (TMDI) for drought monitoring in southwestern Taiwan. IEEE Transactions on Geoscience and Remote Sensing, 62, 1–15. https://doi.org/10.1109/TGRS.2024.3381696

參考文獻

[9] Liou, Y.-A., & Thai, M.-T. (2023). Surface water availability and temperature (SWAT): An innovative index for remote sensing of drought observation. IEEE Transactions on Geoscience and Remote Sensing, 61, 4507312. https://doi.org/10.1109/TGRS.2023.3321910

[10] Thai, M.-T., & Liou, Y.-A. (2025). Surface water availability-temperature index (SWATI) for global drought monitoring. IEEE Transactions on Geoscience and Remote Sensing, 63, 4403714. https://doi.org/10.1109/TGRS.2025.3541287

[11] Liou, Y.-A., & Thai, M.-T. (2025). Relative surface evapotranspiration index (RSETI): A novel approach for drought characterization in Australia. Remote Sensing of Environment, 329, 114948. https://doi.org/10.1016/j.rse.2025.114948

[12] Vo, T.-H., & Liou, Y.-A. (2024). Four-decade spring droughts in Taiwan. Journal of Hydrology: Regional Studies, 54, 101849. https://doi.org/10.1016/j.ejrh.2024.101849

參考文獻

[13] Le, T.-V., Liou, Y.-A., & Nguyen, K.-A. (2024). Revealing the intricate relationship: Droughts and typhoons in Taiwan using the Standardized Precipitation Index (SPI). Journal of Hydrology: Regional Studies, 55, 101917. https://doi.org/10.1016/j.ejrh.2024.101917

[14] Vo, T.-H., & Liou, Y.-A. (2024). Tropical cyclone-induced rainfall variability and its implications for drought in Taiwan: Insights from 1981 to 2022. Atmospheric Research, 312, 107771. https://doi.org/10.1016/j.atmosres.2024.107771

[15] Talukdar, S., Singha, P., Mahato, S., Shahfahad, Pal, S., Liou, Y.-A., & Rahman, A. (2020). Land-use land-cover classification by machine learning classifiers for satellite observations—A review. Remote Sensing, 12(7), 1135. https://doi.org/10.3390/rs12071135

[16] Hoang, D.-V., & Liou, Y.-A. (2024). Assessing the influence of human activities on flash flood susceptibility in mountainous regions of Vietnam. Ecological Indicators, 158, 111417. https://doi.org/10.1016/j.ecolind.2023.111417

參考文獻

[17] Wang, L.-C., Hoang, D. V., & Liou, Y.-A. (2022). Quantifying the impacts of the 2020 flood on crop production and food security in the middle reaches of the Yangtze River, China. Remote Sensing, 14(13), 3140. https://doi.org/10.3390/rs14133140

[18] Liou, Y.-A., Tran, D.-P., & Nguyen, K.-A. (2024). Spatio-temporal patterns and driving forces of surface urban heat island in Taiwan. Urban Climate, 53, 101806. https://doi.org/10.1016/j.uclim.2024.101806

[19] Nguyen, K.-A., & Liou, Y.-A. (2019). Global mapping of eco-environmental vulnerability from human and nature disturbances. Science of the Total Environment, 664, 995–1004. https://doi.org/10.1016/j.scitotenv.2019.01.407

[20] Liou, Y.-A., Vo, T.-H., Tran, D.-P., & Bui, H.-A. (2024). Comprehensive drought risk assessment and mapping in Taiwan: An ANP-ANN ensemble approach. Science of the Total Environment, 952, 175835. https://doi.org/10.1016/j.scitotenv.2024.175835

參考文獻

[21] World Bank. (2013). Agricultural data and insurance: Innovations in agricultural data development for insurance. https://documents1.worldbank.org/curated/en/823271468321541794/pdf/949890BRI0Box30Data030Oct20130Final.pdf

[22] Jensen, N. D., & Barrett, C. B. (2017). Agricultural index insurance for development. Applied Economic Perspectives and Policy, 39(2), 199–219. https://doi.org/10.1093/aepp/ppw022