

運用無人機系統評估林分特徵 之研究

鍾智昕



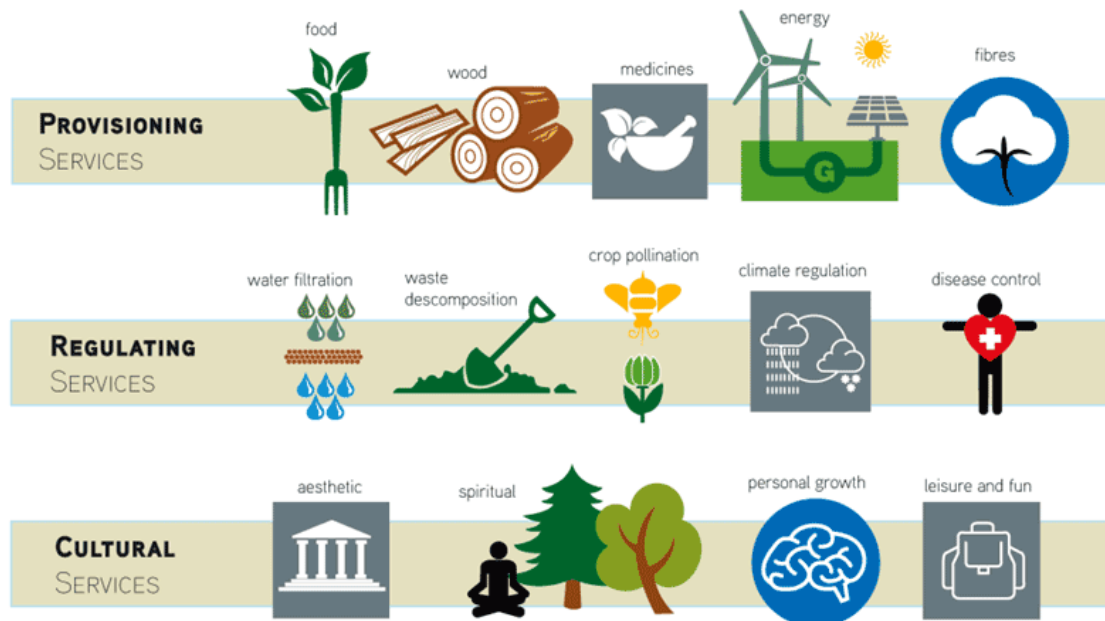
國立宜蘭大學
National Ilan University NIU



Forest multiple functions and services

- 森林永續經營(sustainable management) , 使森林可持續提供**多元的生態系統服務功能** , 因此需要掌握資源的現狀分布與**監測**後續發展(Balenovic et al., 2017) 。

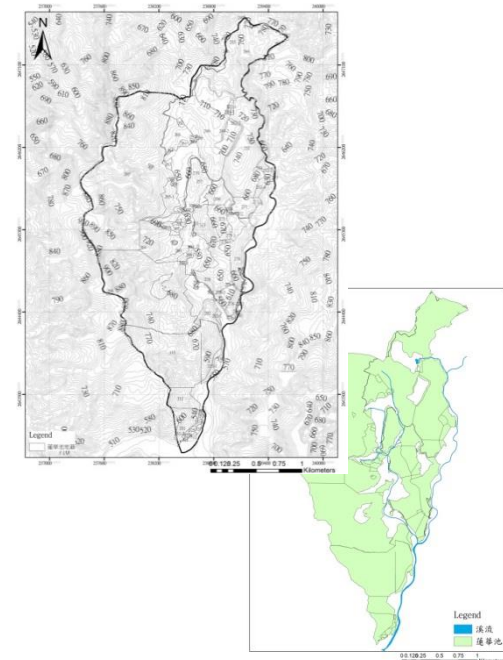
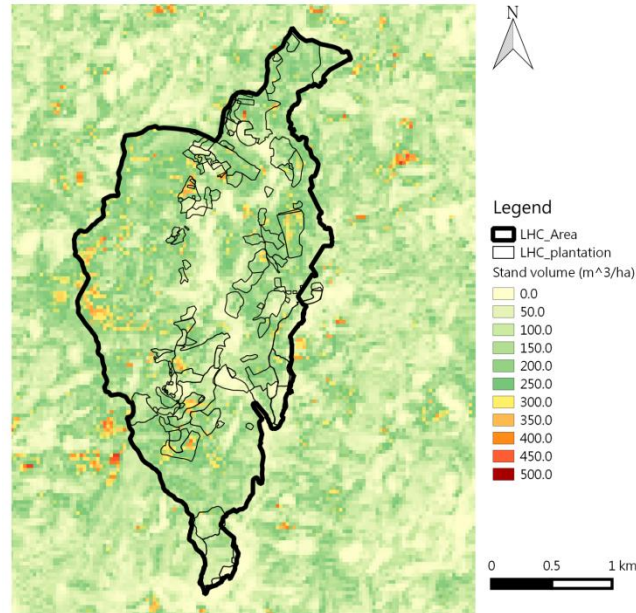
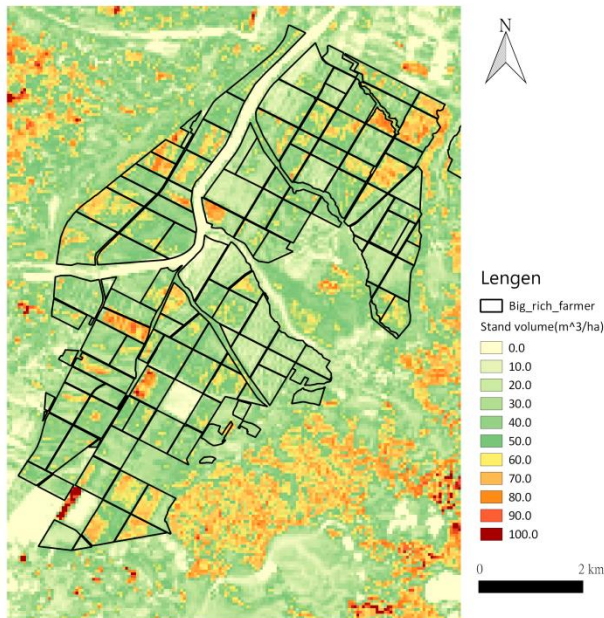
WHAT DO WE GET FROM **ECOSYSTEMS**?



<http://www.ehu.eus/cdsea/web/index.php/research/ecosystem-services-basque-country/results/definition-of-ecosystem-services-and-typology/?lang=en>

Map of forest management

- 對自然資源的經營及管理而言，**地圖**是相當重要的工具，依地圖主題類型而有多種不同地圖:例如地形圖、地籍圖、流域圖等，其中**森林蓄積量分布圖**(Kelsey and Neff, 2014)是描述林木資源現況與瞭解陸域碳資源分布的重要圖資。



Traditional forest inventory

- **森林具有一定範圍的空間尺度大小**
 - 森林的定義為面積在0.5公頃以上，林木高度至少5公尺，樹冠覆蓋率大於10%，或林木在原生地可到此標準的土地（FAO,2015）。
- **地面調查工作耗時耗力**
 - 時間冗長->資料時間不一致
 - 空間侷限->地形困難處缺乏資料
- **地面調查提供精確的地真資料(ground true data)**

林分特徵

- 林分類型

- 天人林, 人工林

- 林分結構

- 胸高直徑, 樹高(樹冠層高), 林分蓄積, 年齡, 地上部生物量, 胸高斷面積... etc.

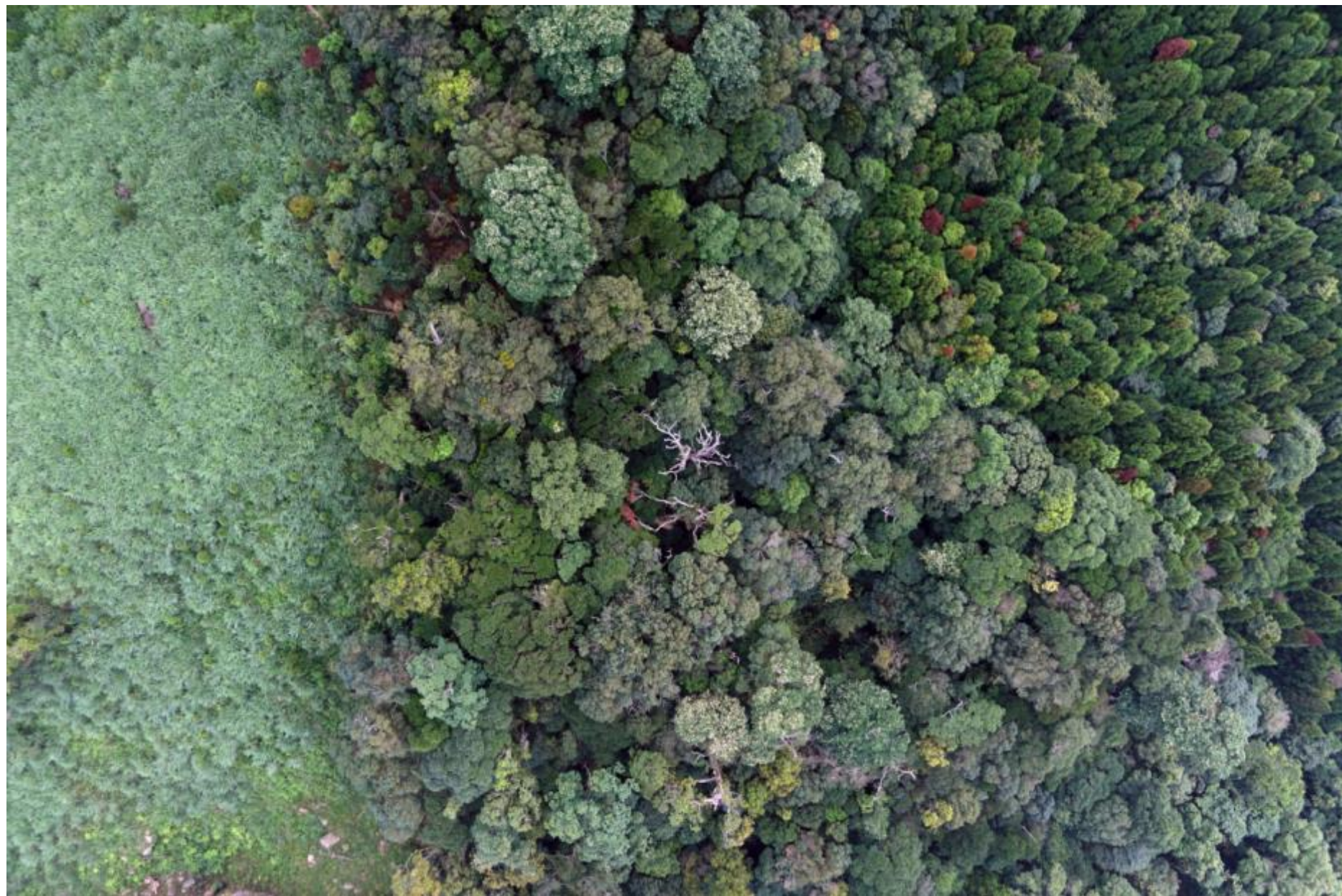
- 生物多樣性

- Abundance, Evenness, Richness(Shannon-Wiener index), Simpson's diversity Index... etc.



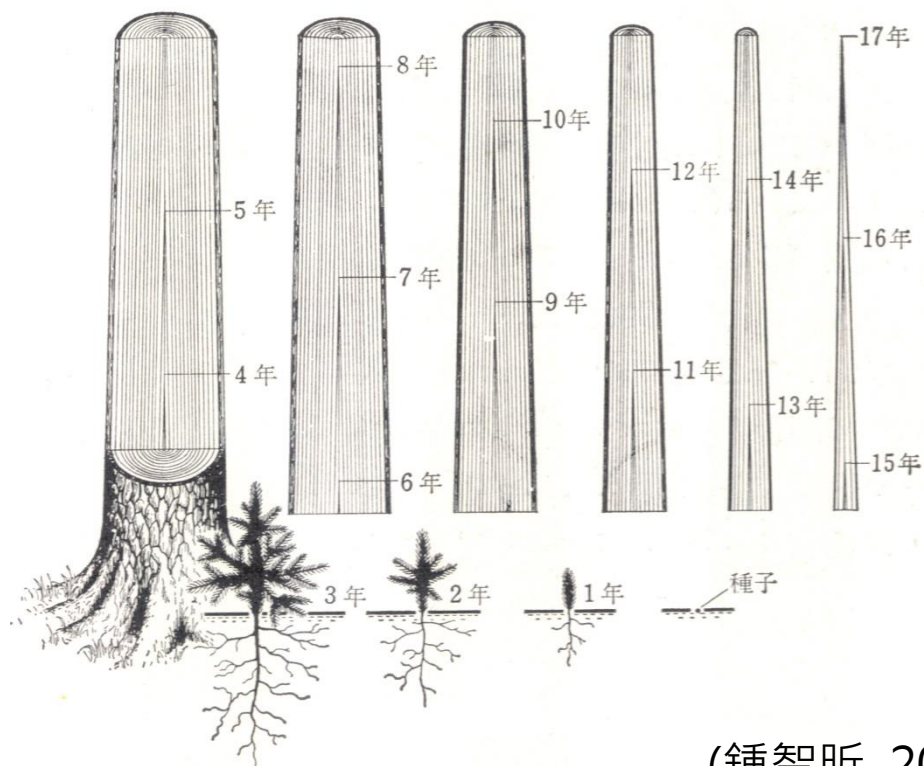
www.histoireforestiereoutaouais.ca



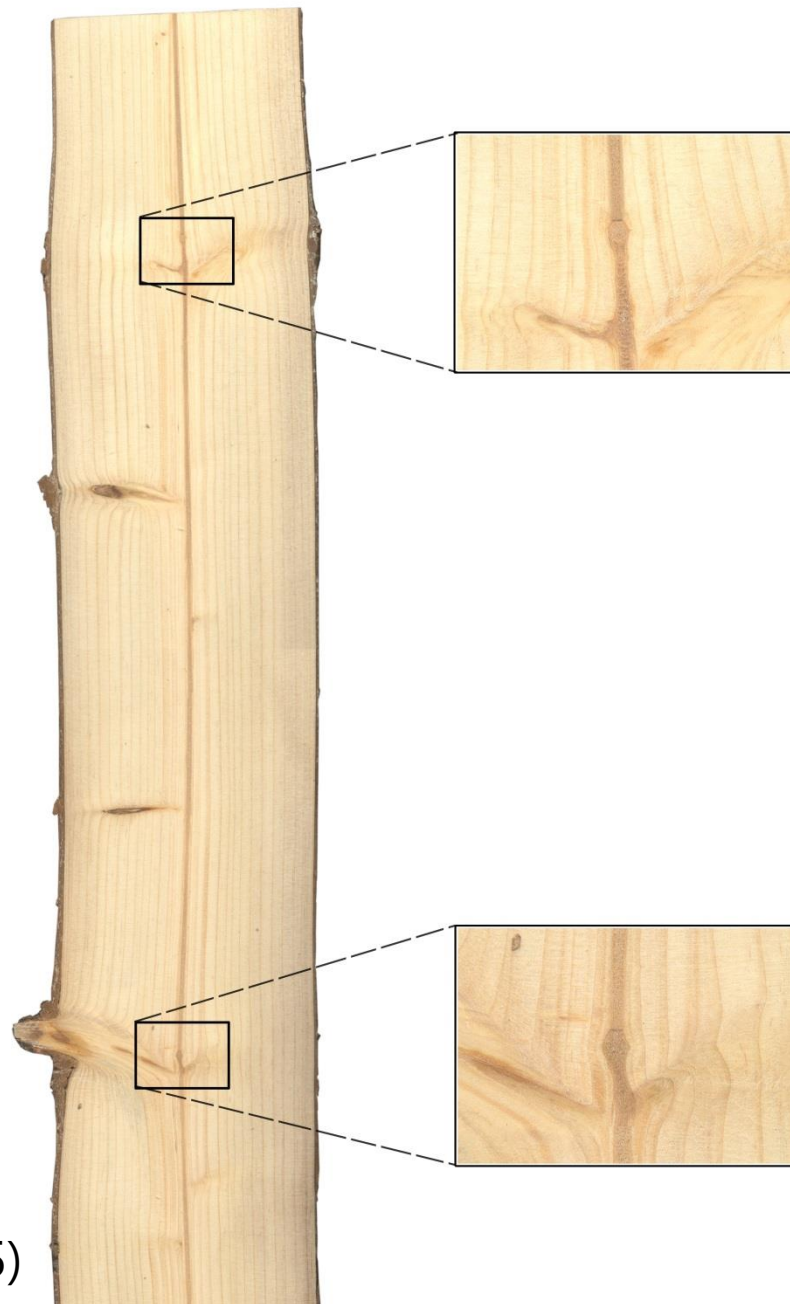


Measurement



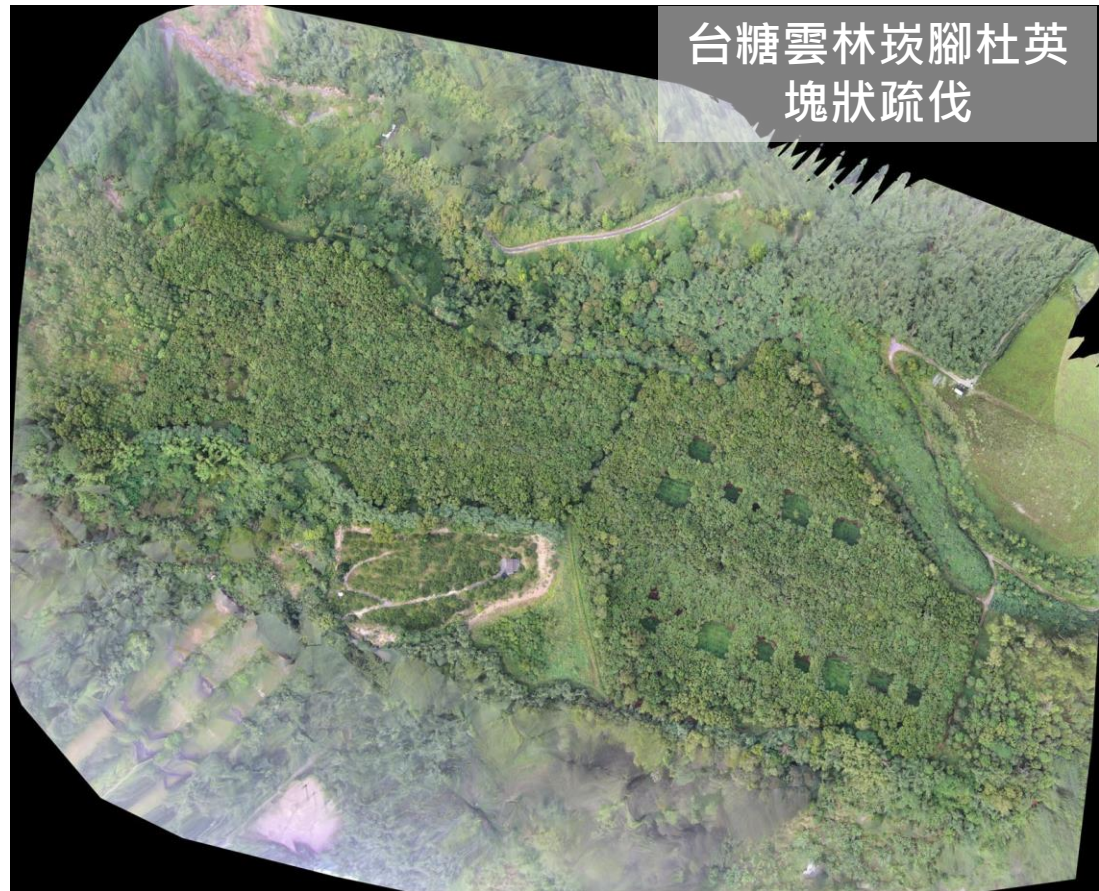


(鍾智昕, 2005)



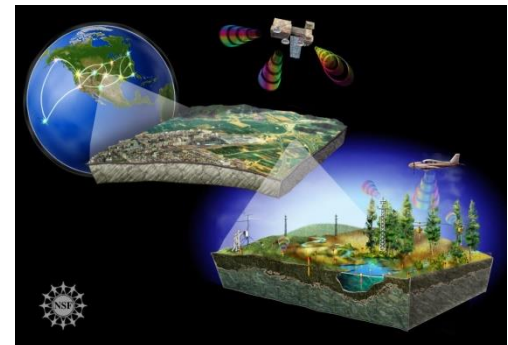
監測林分特徵

- 森林資源的調查或監測非常的耗費人力、金錢和時間。
- 需要有效率的遙測工具



遙測(Remote sensing)

- 衛星或航照所收集的遙測資料，是評估與研究大尺度空間範圍森林結構(Hyde et al., 2006)、生物多樣性(Cord et al., 2013)、樹冠高度 (Zhang et al., 2016)與炭儲存量 (Saatchi et al., 2011)的重要工具。



遙測製圖

主動式 光學遙測

LiDAR

- 樹種
- 樹高
- 冠幅
- 地形

被動式 光學遙測

無人機 電腦視覺

- 樹種
- 樹高
- 冠幅

航照 攝影測量

- 樹種
- 樹高
- 冠幅

衛星影像 光譜特徵

- 植生指標
- 光譜混合分析
- 光譜紋理

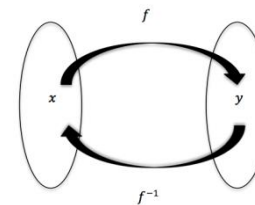
地面調查

森林特徵

- 樹種
- 胸高直徑
- 樹高
- 冠幅
- etc.

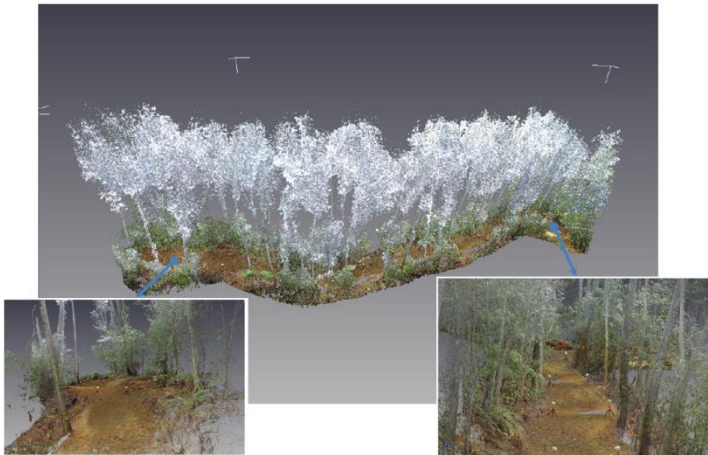
統計方法

- 直線迴歸
- 非線性迴歸
- 機器學習
- 人工智慧

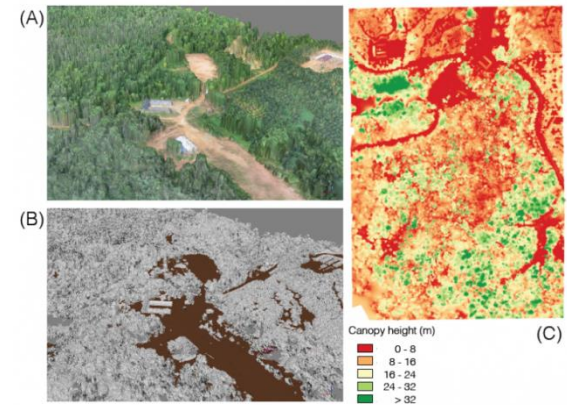


-地圖-

- 蓄積量
- 樹種分布
- 地形圖
- etc.



航遙測資料
無人機資料

[illegible]

<https://www.wildlabs.net/resources/case-studies/can-uavs-be-used-measure-forest-quality>

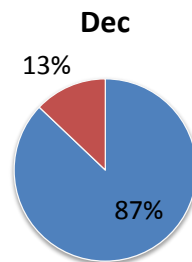
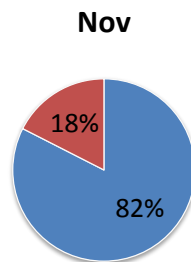
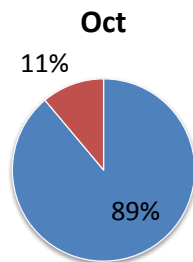
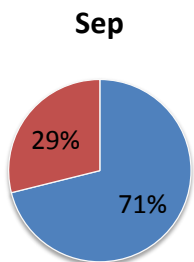
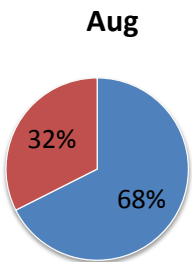
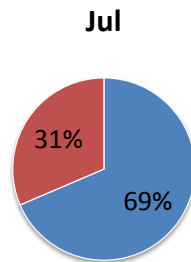
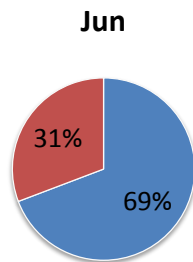
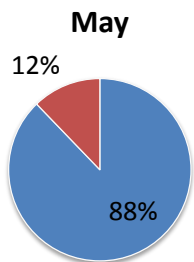
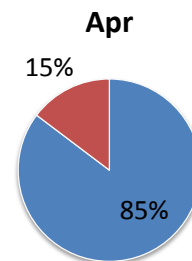
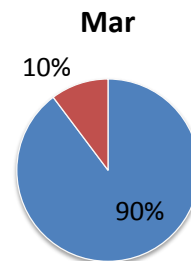
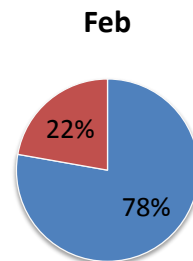
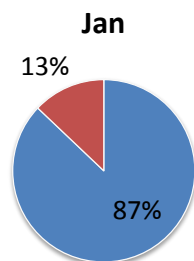
衛星與航照在實際應用時的缺點

- 較低的時間與空解析度
- 容易受雲遮蔽
- 成本高

無雲影像 11~32%



<https://www.nasa.gov/feature/goddard/2016/study-shows-cloud-patterns-reveal-species-habitat>



cloud
clear

Small unmanned aircraft system(UASs)

- 一個新的遙測平台
- 填補衛星與航測影像的不足
- 輕型、低成本、超高解析度



Forestry applications of UASs

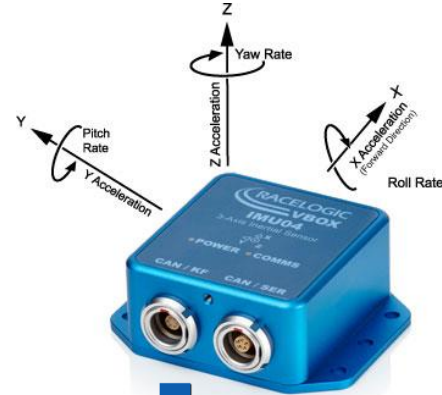
- Estimation of dendrometric parameters
- Tree species classification
- Quantification of spatial gaps in forests
- Wild fire monitoring
- Forest health monitoring and forest diseases mapping
- Forest harvest
- Soil displacement estimation

UASs構成

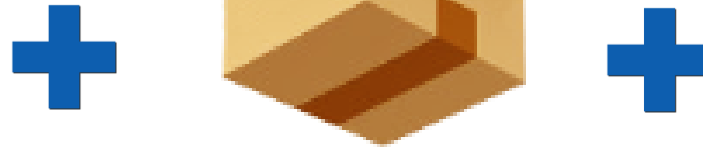
GPS



IMU



<https://www.vboxautomotive.co.uk/index.php/en/products/modules/inertial-measurement-unit>

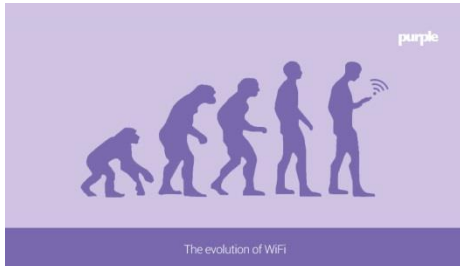


飛行器+載具

CPU



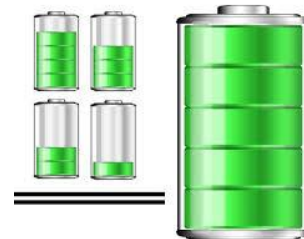
<https://www.pugetsystems.com/labs/articles/Revit-2017-2-CPU-Comparison-958/>



<https://purple.ai/history-wifi/>



無線通訊



電池

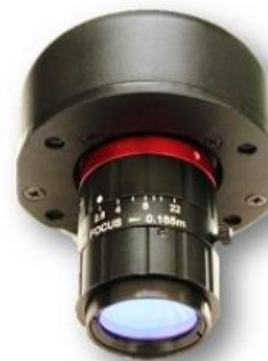
被動式感測器



(a)



(b)



(c)



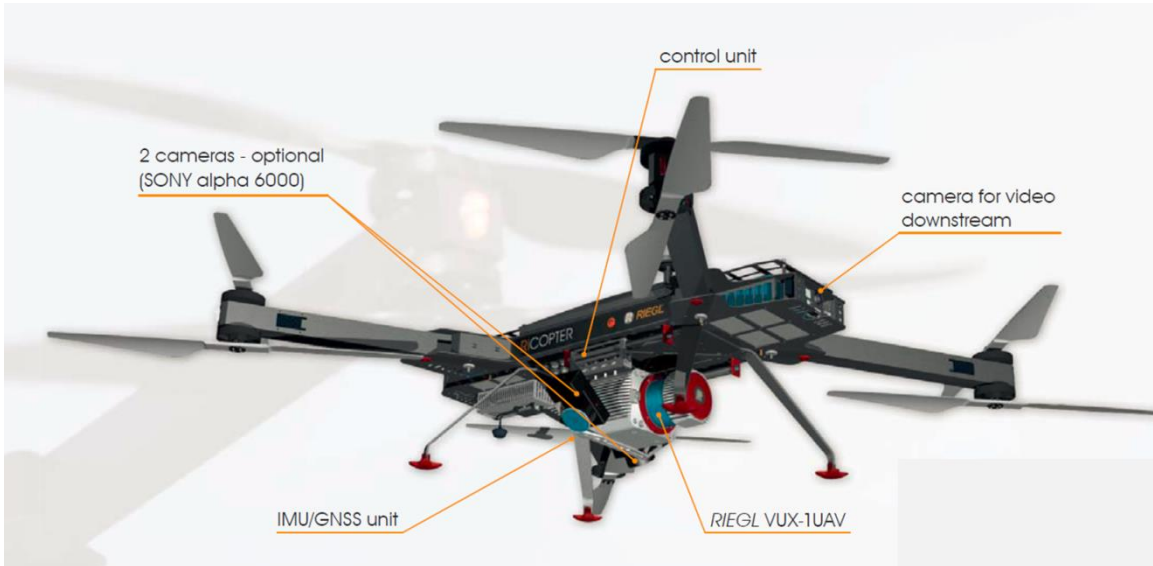
(d)

- (a) Airinov Agrosensor multispectral
- (b) Tau 640 thermal;
- (c) OCI-UAV-1000 pushbroom hyperspectral
- (d) Nikon D800E RGB with a Zeiss ZF2 lens.

(Cahalane et al, 2017)

主動式感測器

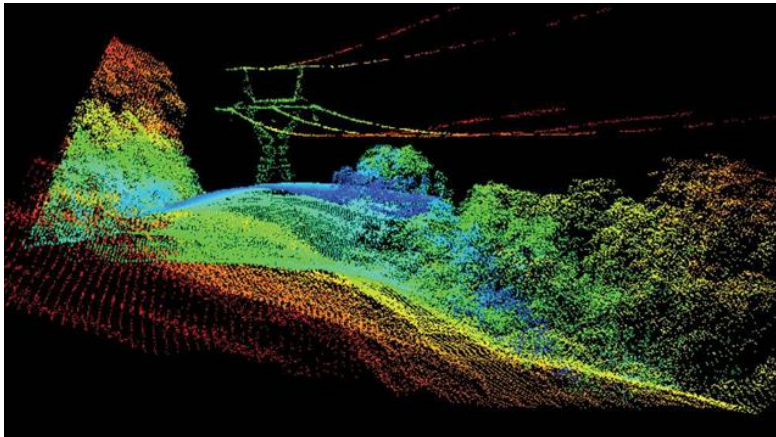
LiDAR 光達



<https://www.wur.nl/en/product/Unmanned-Aerial-Vehicle-for-Laser-Scanning-LiDAR-UAV.htm>



<http://www.lidar360.com/archives/4244.html>



<https://www.ausgrid.com.au/Common/About-us/Newsroom/News-gallery/Network-maintenance/Bushfire-safety-patrols.aspx>

無人機系統優勢

- 可以收集高重疊率的大量照片
- 高度操作彈性
- 可高頻度蒐集研究區資料(每年,每月,每天)
 - 林分冠層動態監測
 - 物候觀測
- 可低空飛行
 - 在雲下飛行
 - 觀測樹冠層



俯瞰 vs. 鳥瞰

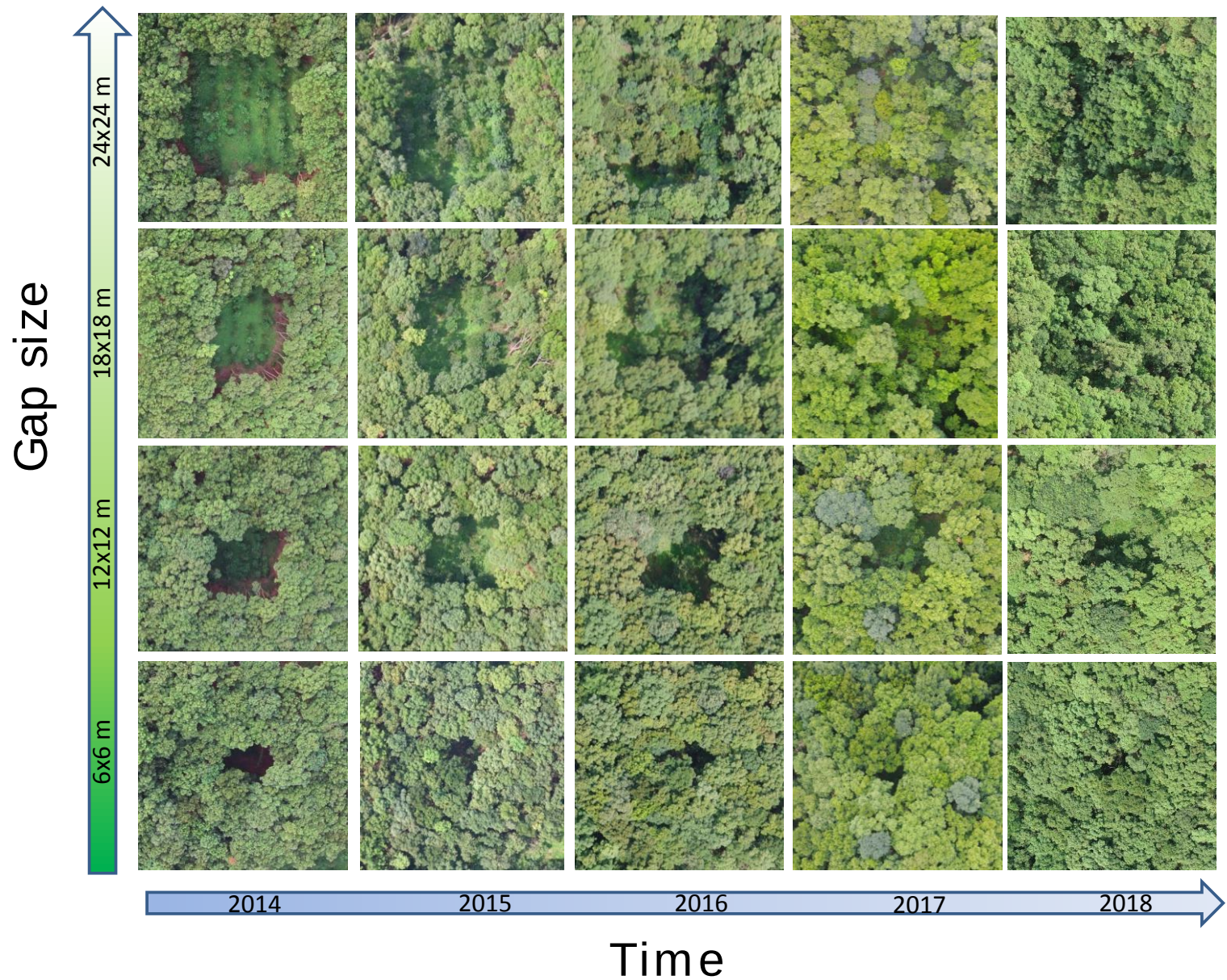


Camera
On the ground

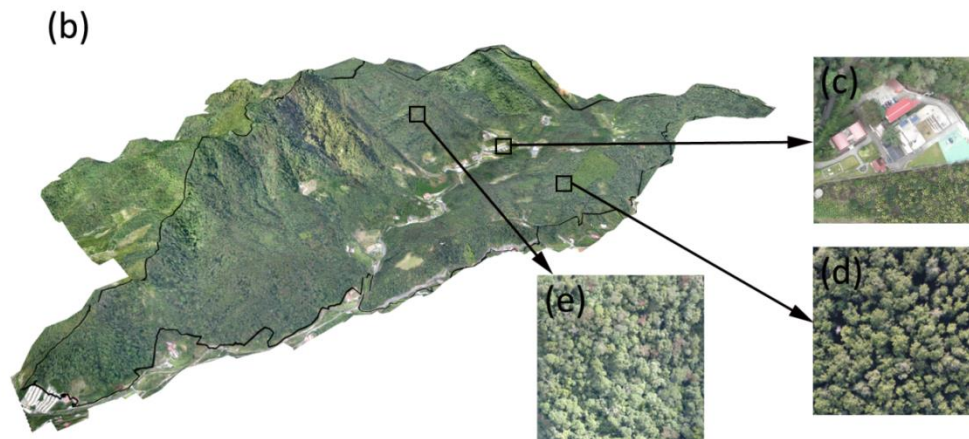
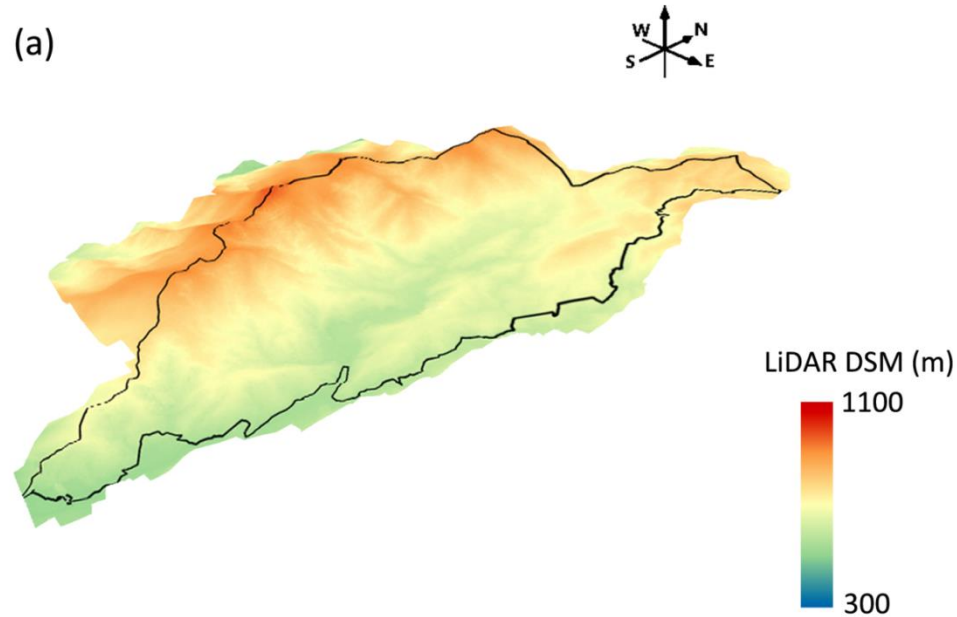


UAV
From the Air

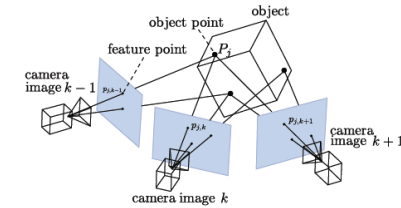
UASs imagery cube



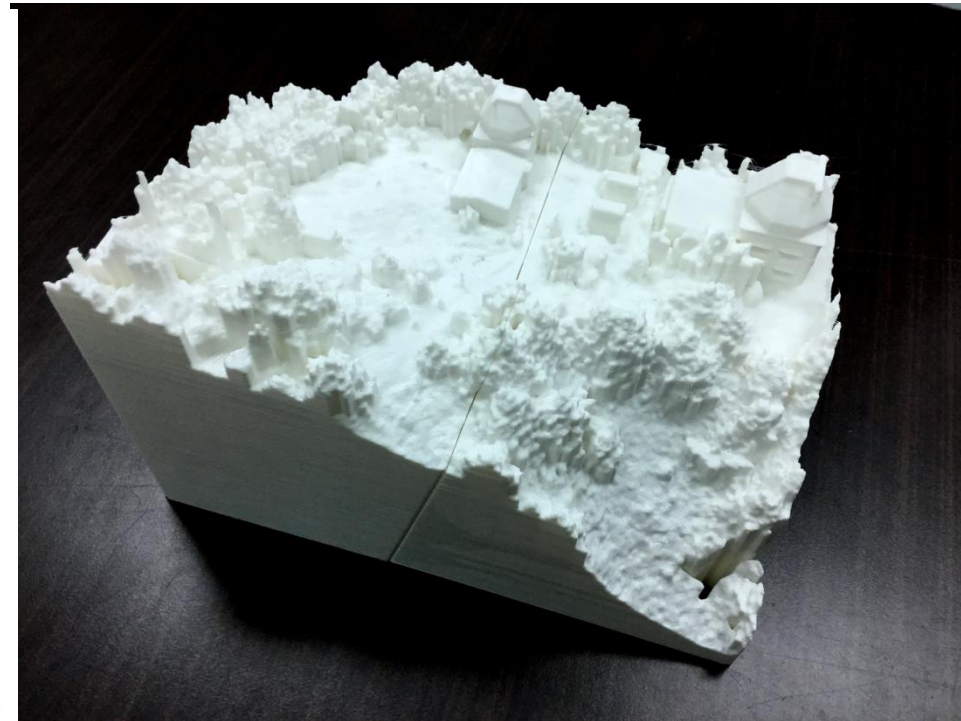
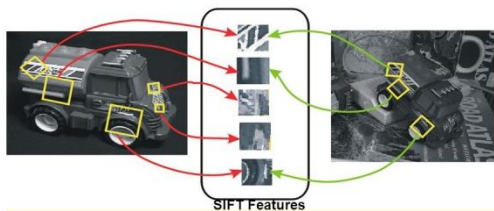
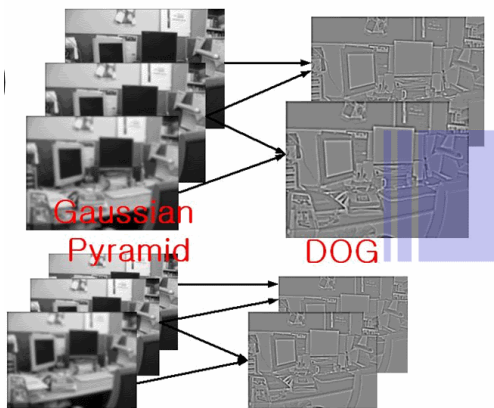
UASs provides 2D and 3D information



重建3D資訊



- UASs imagery can **reconstruct 3D model** and **dense points cloud** by using “photogrammetry” and “Structure from Motion” (SfM).



3D點雲資訊

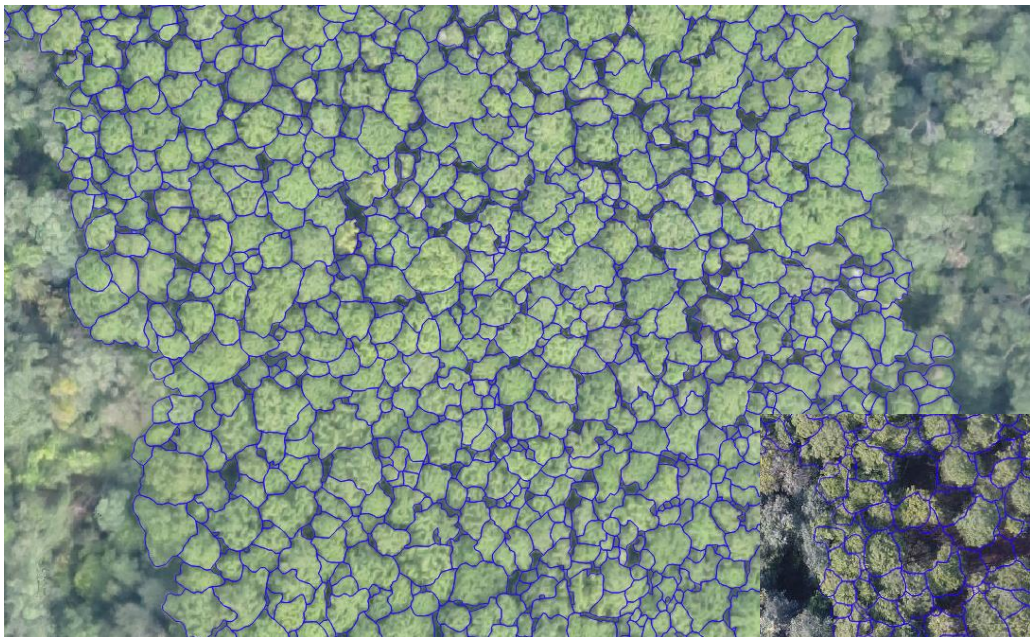


由空拍影像處理計算成3D的視覺模擬

UASs data compares with LiDAR

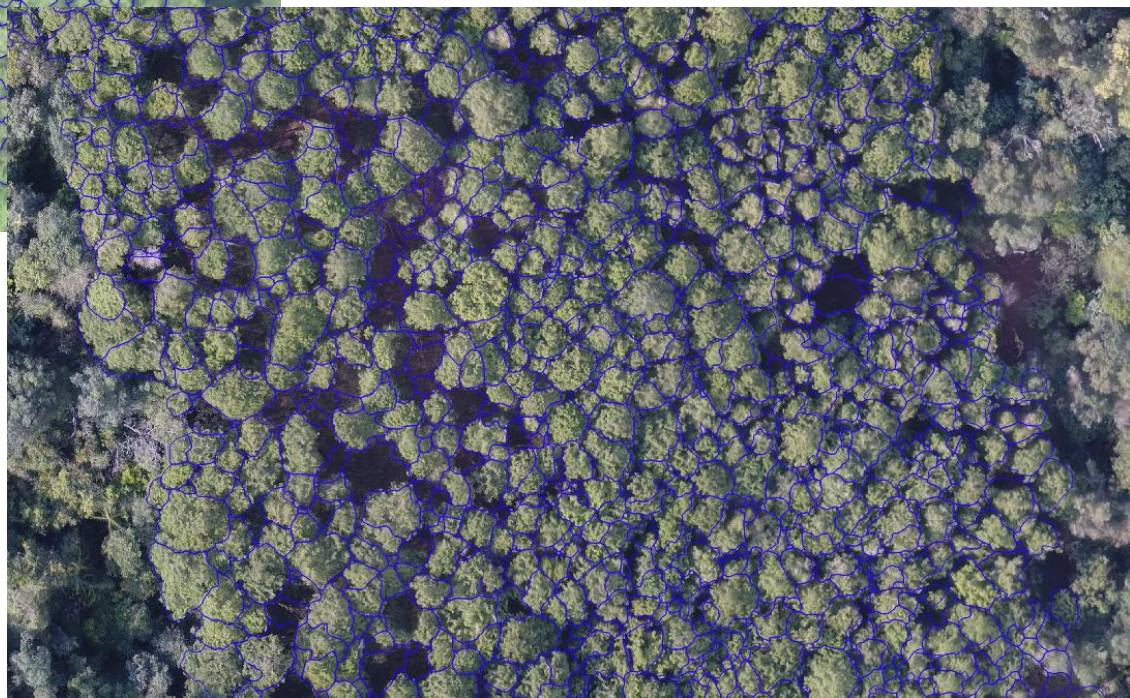
- UASs點雲具有與光達LiDAR點雲相似的精度
 - (Lisein et al., 2013; Wallace et al., 2016;Herrero-Huerta et al, 2016)
- 2種方法都可以提供研究森林結構特徵
 - (Wallace et al., 2016)
- 已經有許多的研究應用 UASs的樹冠高程模型
 - (canopy height model,CHM(Zaro-Tejada et al., 2014;Lisein et al., 2013;Zahawi et al., 2015; Ota et al., 2015;Wallace et al., 2016;Herrero-Huerta et al, 2016;Zhang et al., 2016)

疏伐前後冠層動態



<-疏伐前

疏伐後->



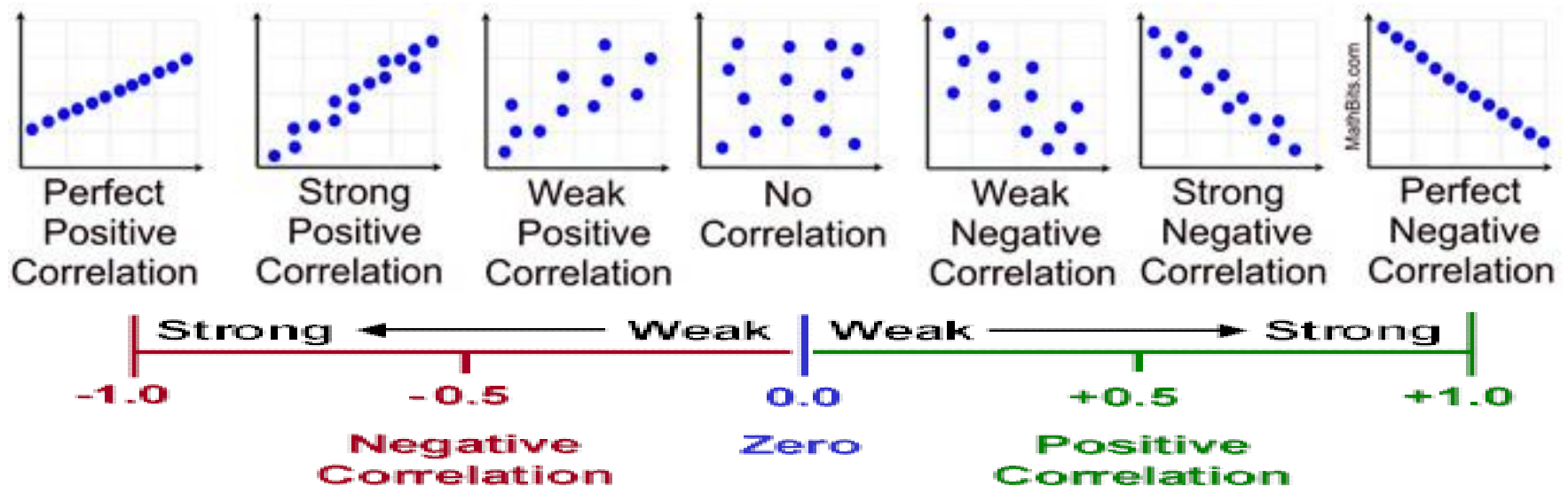
研究動機

- 目前台灣UASs的樹冠高程模型與林分特徵間的相關性的研究相對較少。
- 評估無人機系統所收集到的影像資料，可有效掌握那些林分的特徵。



研究目標

- 本研究著重於研究UASS' CHM and 林分特徵的相關性，以提升UASS在森林的應用。

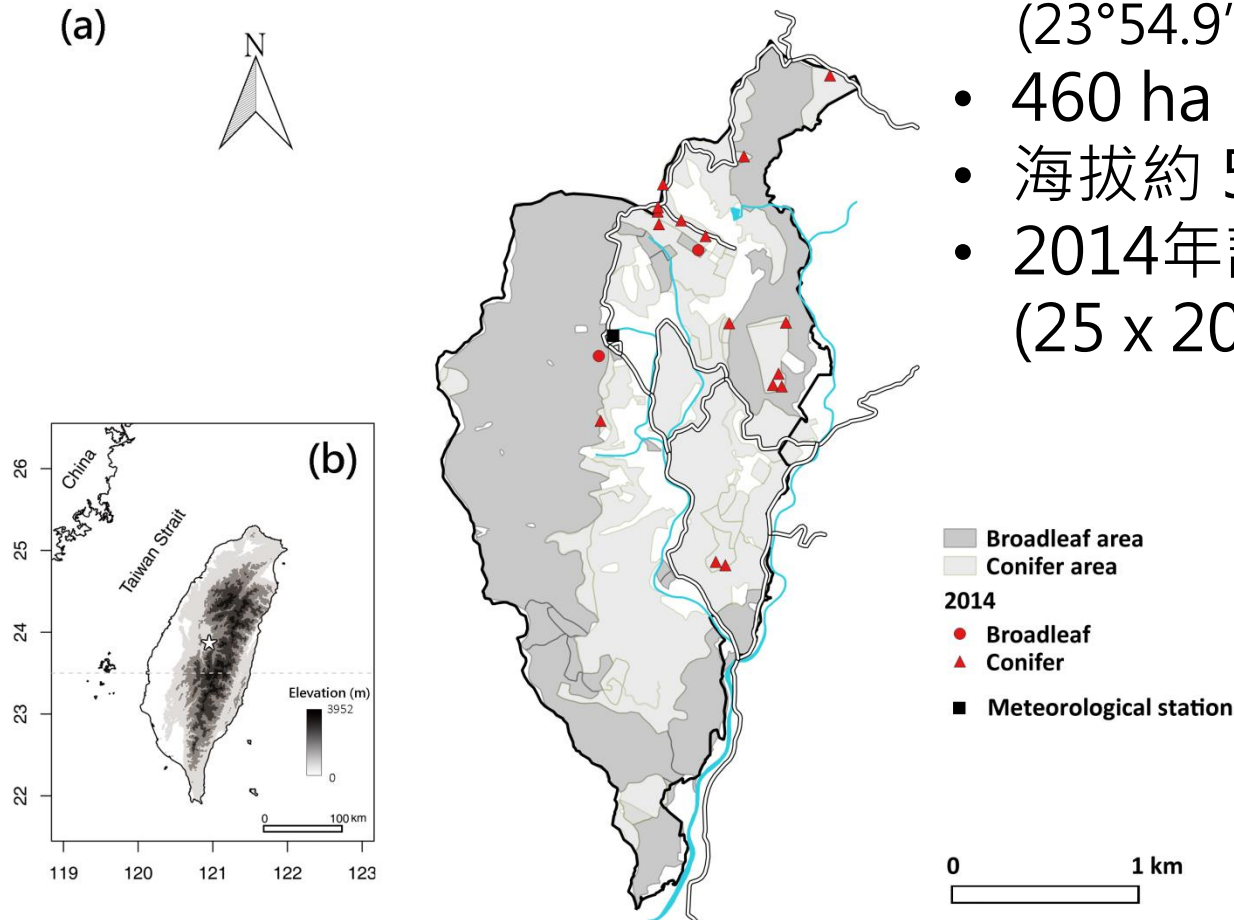


<https://mathbitsnotebook.com/Algebra1/StatisticsReg/ST2CorrelationCoefficients.html>
<https://psychlopedia.wikispaces.com/Correlation+Coefficient>

材料與方法

• A. 研究樣區

- 林業試驗所蓮華池研究中心
(23°54.9' N, 120°52.8' E)
- 460 ha
- 海拔約 576–925 m
- 2014年調查18個 0.05 ha
(25 x 20 m)



樣區調查

- 調查項目:

- 林木株數,
- 胸高直徑(DBH),
- 樹高,
- 樹冠幅,
- 樹種.

- 將調查資料計算:

- 林分密度
- 林分蓄積量
- Quadratic mean diameter (QMD)
- Species diversity indices : species richness, Shannon' s diversity, Simpson' s diversity.



$$H = - \sum_{i=1} p_i \ln p_i \quad (\text{Shannon \& Weaver 1949})$$

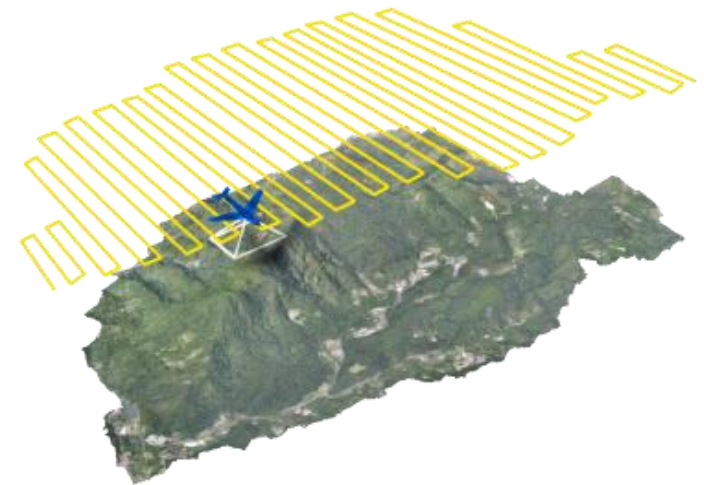
$$D = 1 - \sum_{i=1}^s p_i^2 \quad (\text{Simpson 1949})$$

UASs Photogrammetric survey

Charateristics	UASs
Flight cover area	590 ha
Altitude(above ground)	1110 m a.s.l
Image	1217 RGB images
Side overlap	80%
Flight speed	25 m/s
Acquisition date	2014/12/23
Instrument	Canon PowerShot S110
Ground sampling distance	0.13 m
Focal length	5 mm
Ground control point	9
Error X(RMSE)	-0.02 m (1.89)
Error Y(RMSE)	-0.03 m (1.78)
Error Z(RMSE)	-0.03 m (2.57)

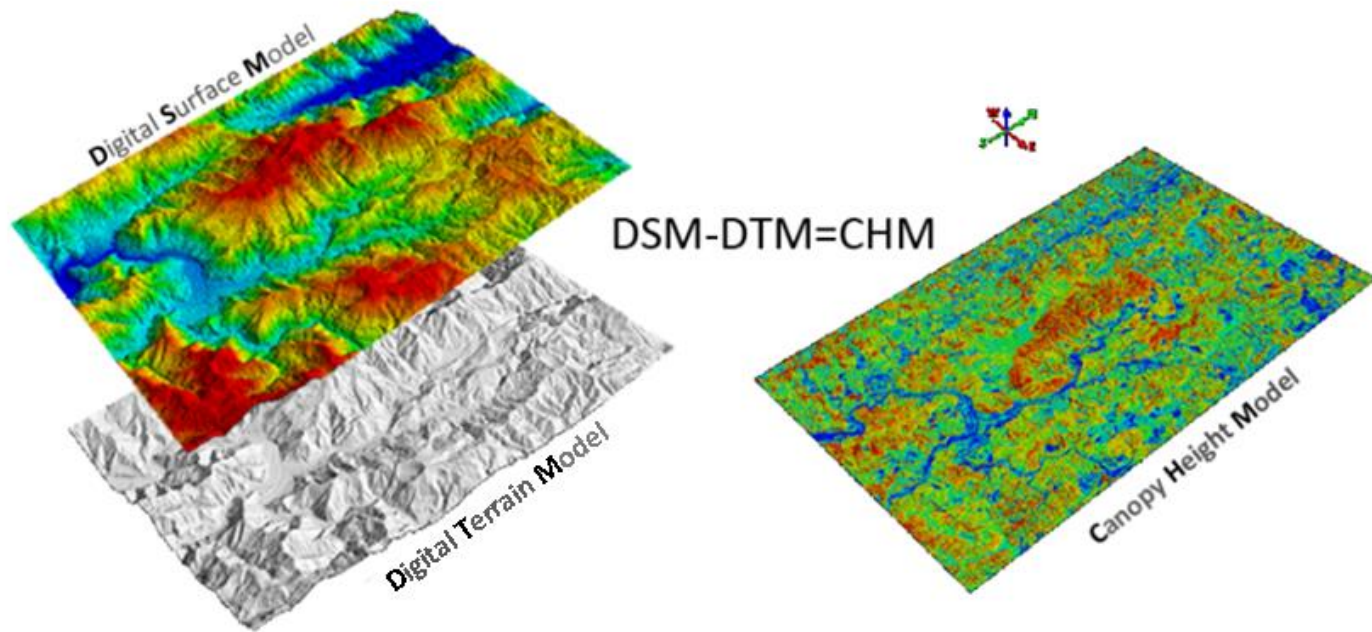


<https://www.youtube.com/watch?v=G4UAdyYOAUK>

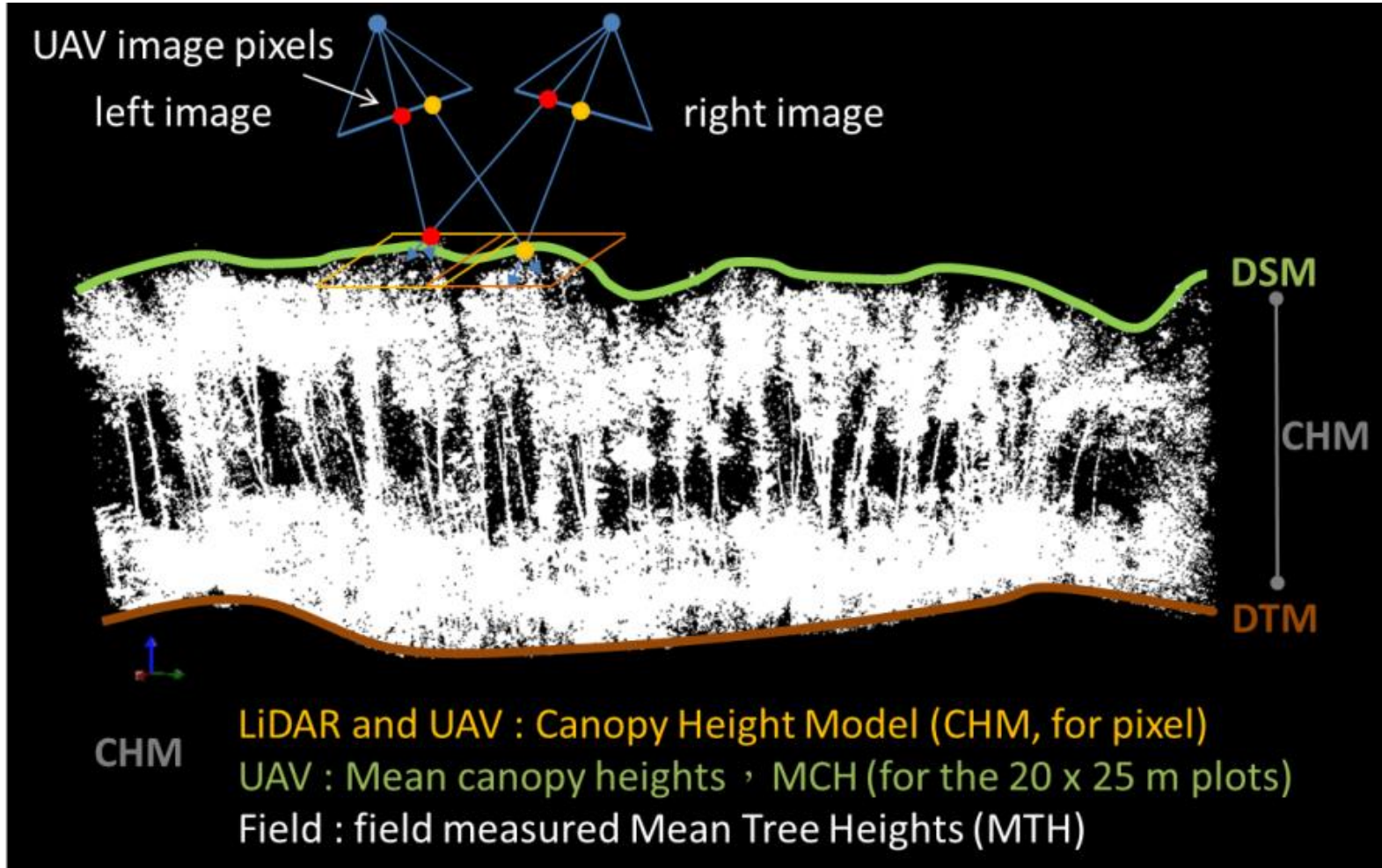


無人機影像資料處理與分析

- 軟體使用Pix4D(Pix4D SA, Lausanne, Switzerland)
- 13 cm 數值表面高程模型(Digital surface model, DSM)
- 樹冠高程模型(canopy height model, CHM)

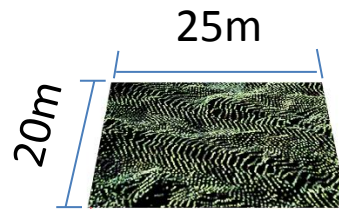


The point cloud data



無人機影像資料處理與分析

use  to extract

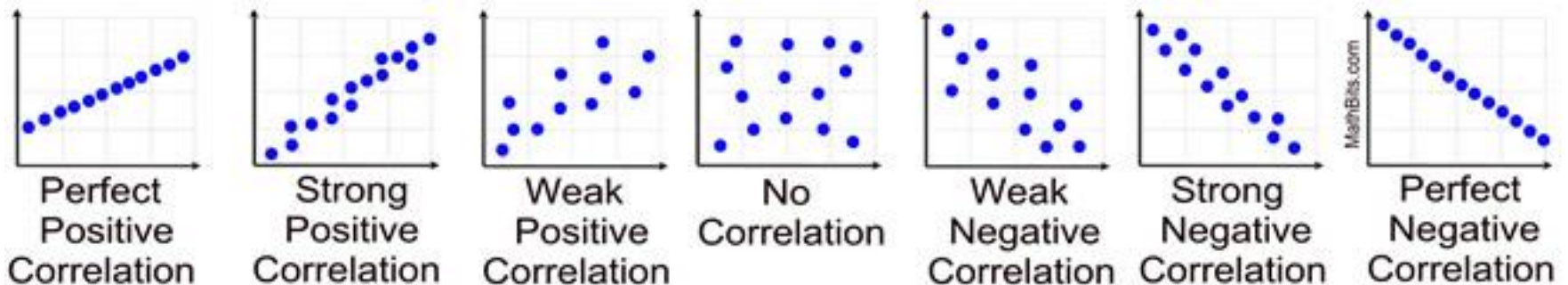


UASs CHM point cloud data
計算成 12 個樹冠高度參數:

- **Mean CHM**
- **minimum CHM**
- **Maximum CHM**
- **Standard deviation**
- **Covariance**
- **25th percentile**
- **50th percentile**
- **75th percentile**
- **Kurtosis**
- **skewness**
- **Weibull 2 parameters**

Pearson correlation

- 分析12 個 UASs樹冠高度參數與林分特徵值
- 相關性強度
 - $r < 0.3$ 相關性微弱或沒有相關;
 - $0.3 < r < 0.5$ 弱度相關;
 - $0.5 < r < 0.7$ 中度相關;
 - $r > 0.7$ 高度相關.



<https://mathbitsnotebook.com/Algebra1/StatisticsReg/ST2CorrelationCoefficients.html>

<https://psychlopedia.wikispaces.com/Correlation+Coefficient>

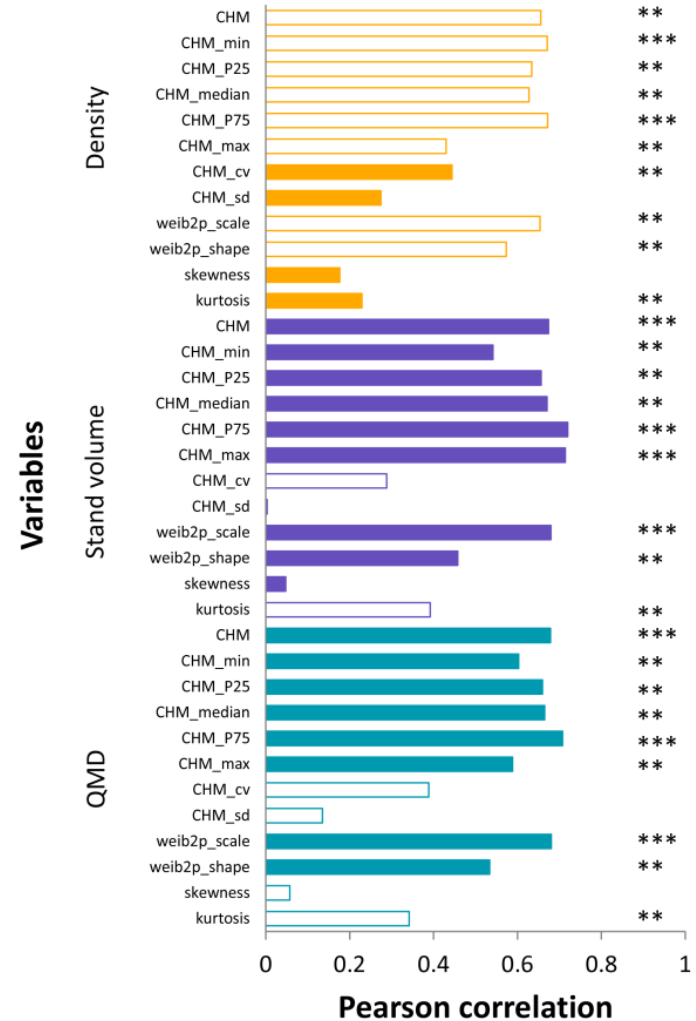
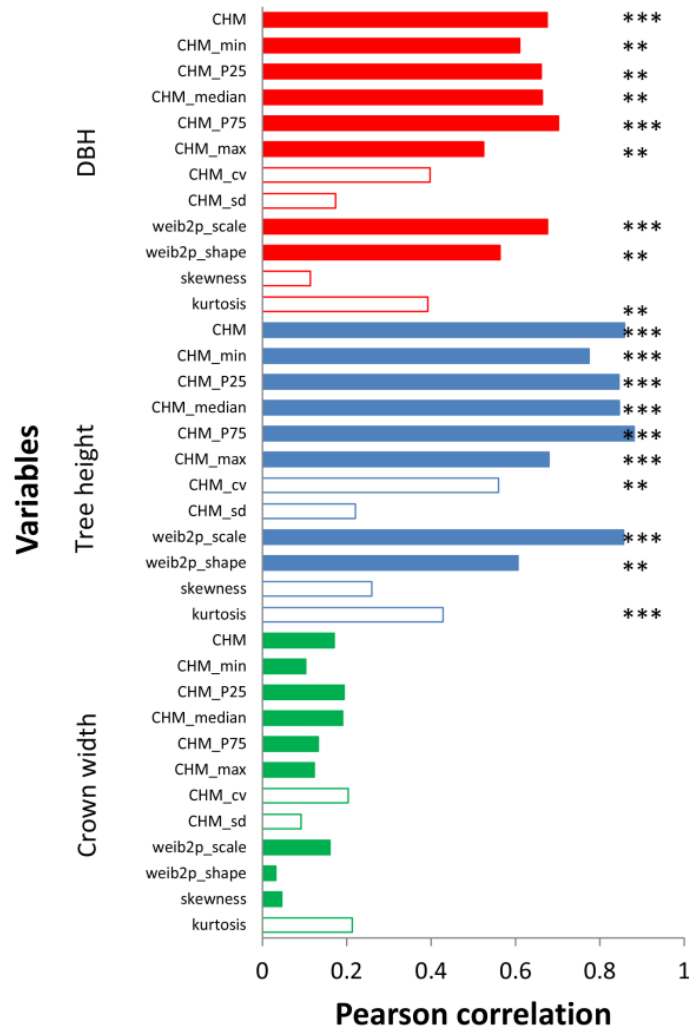
結果

- 樣區調查與 UASs CHM
- The 18 plots mean ($\pm$ standard deviation, sd)

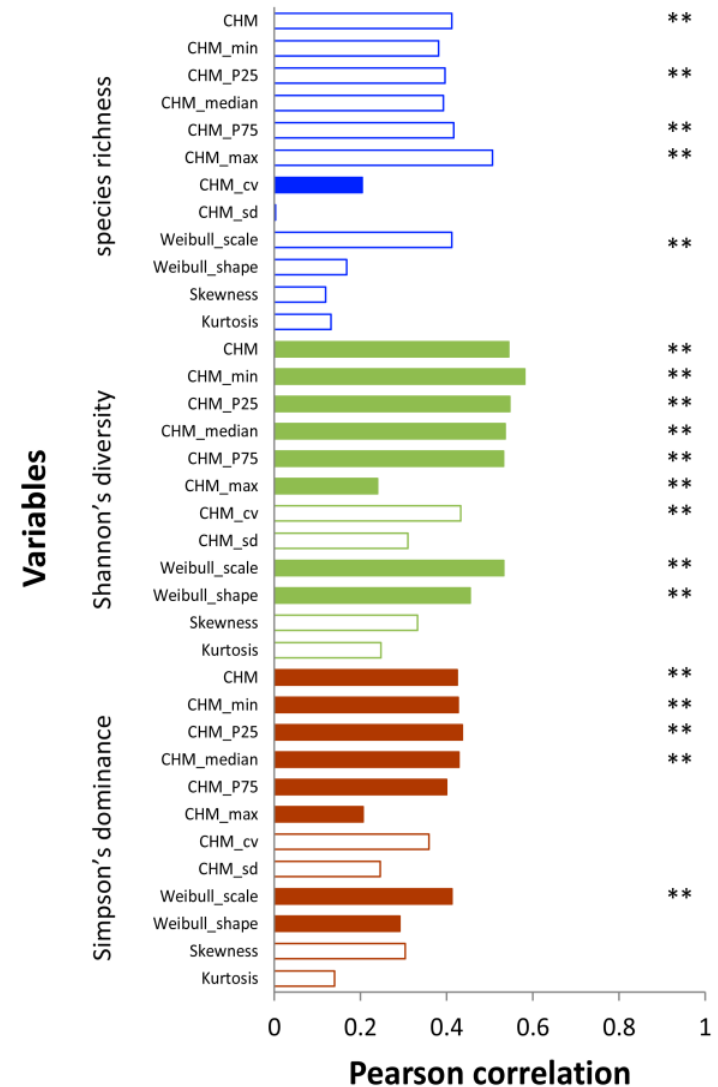
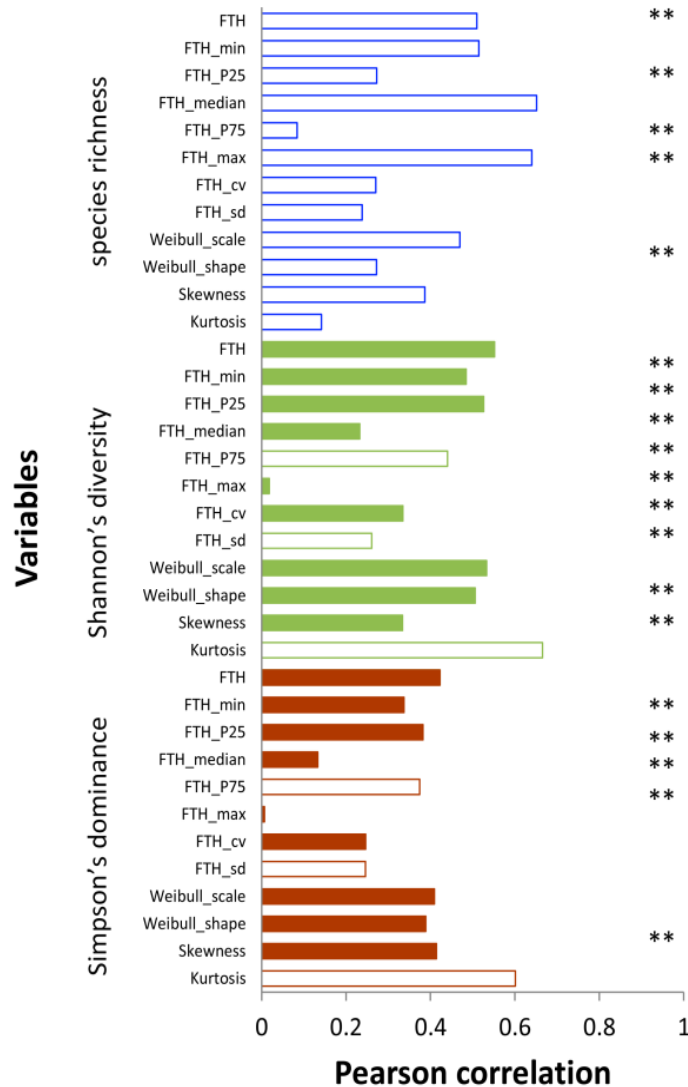
Items	Statistics
Density (n/ha)	1455 $\pm$ 635
DBH(cm)	16.2 $\pm$ 6.7
field tree height (FTH) (m)	12.1 $\pm$ 3.6
UAV CHM	17.5 $\pm$ 4.0

- The normality test results showed the data sets were normalized (Shapiro-Wilk normality test: $W = 0.97$, $p = 0.94$).

B. The relations between CHM and stand structural characteristics



C. The relations between CHM, FTH and species diversity



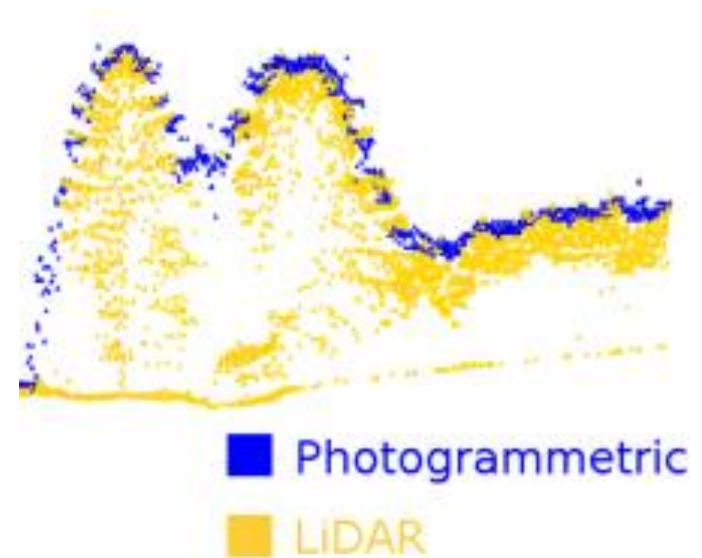
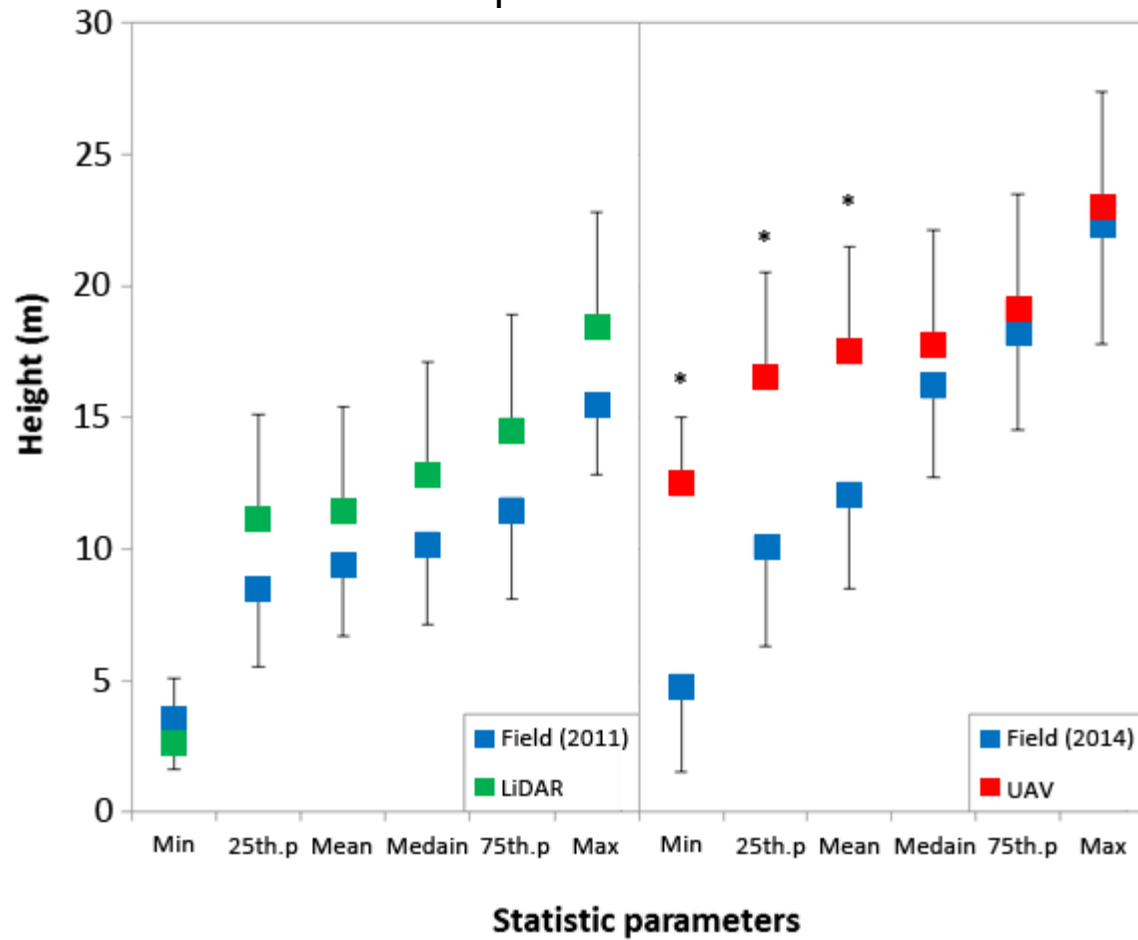
Summaries

Strength of Correlation	Stand characteristics	Highest statistics (UAV-CHM)	Range of r
Strong	Tree height	75 th percentile (r=0.88) ^{***}	-0.55-0.88
Moderate	DBH, Density, stand volume, QMD	75 th percentile (r=0.70) ^{***} 75 th percentile (r=-0.67) ^{***} 75 th percentile (r=0.72) ^{***} 75 th percentile (r=0.71) ^{***}	-0.39-0.70, -0.67-0.44, -0.39-0.72, -0.39-0.71
Weak	Crown width	Kurtosis(r=-0.21) ^{ns}	-0.21-0.19

Strength of Correlation	Species diversity	Highest statistics	Range of r
Moderate(UAV)	species richness, Shannon index, Simpson's dominance	CHM_max(r=-0.50) ^{***} CHM_min(r=0.58) ^{***} 75 th percentile (r=0.44) ^{***}	-0.50-0.20 -0.43-0.58 -0.36-0.44
Moderate(Field)	species richness, Shannon index, Simpson's dominance	FTH_max (r=-0.63) ^{**} FTH_mean(r=-0.55) ^{**} FTH_mean(r=0.53) ^{***}	-0.65-0.14 -0.66-0.55 -0.60-0.42

討論

LiDAR vs. UAV point cloud

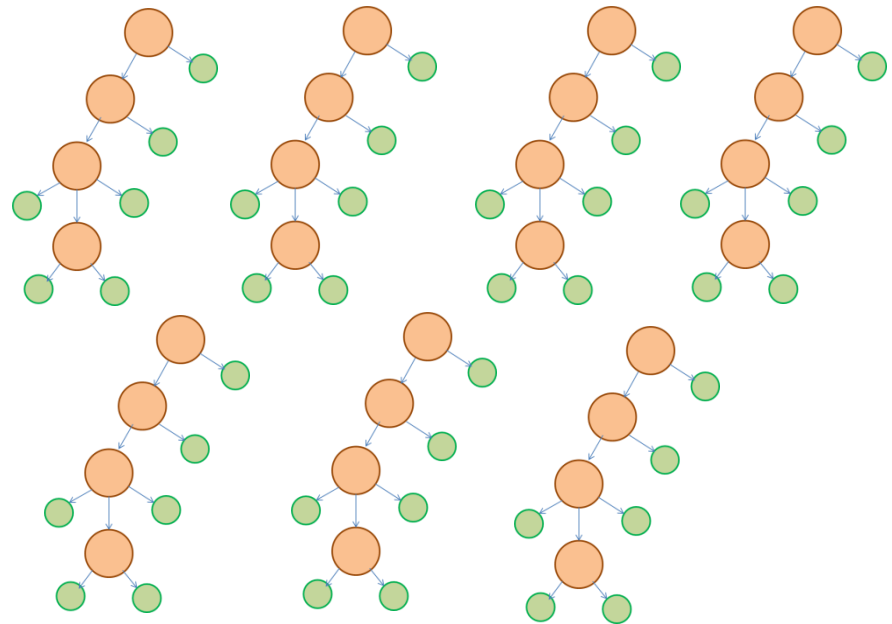
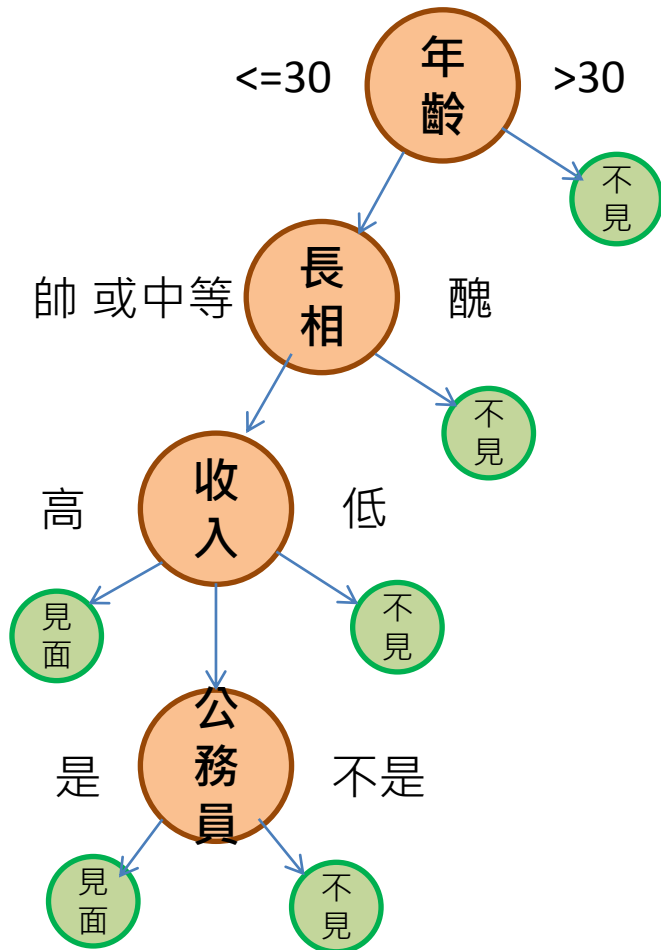


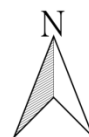
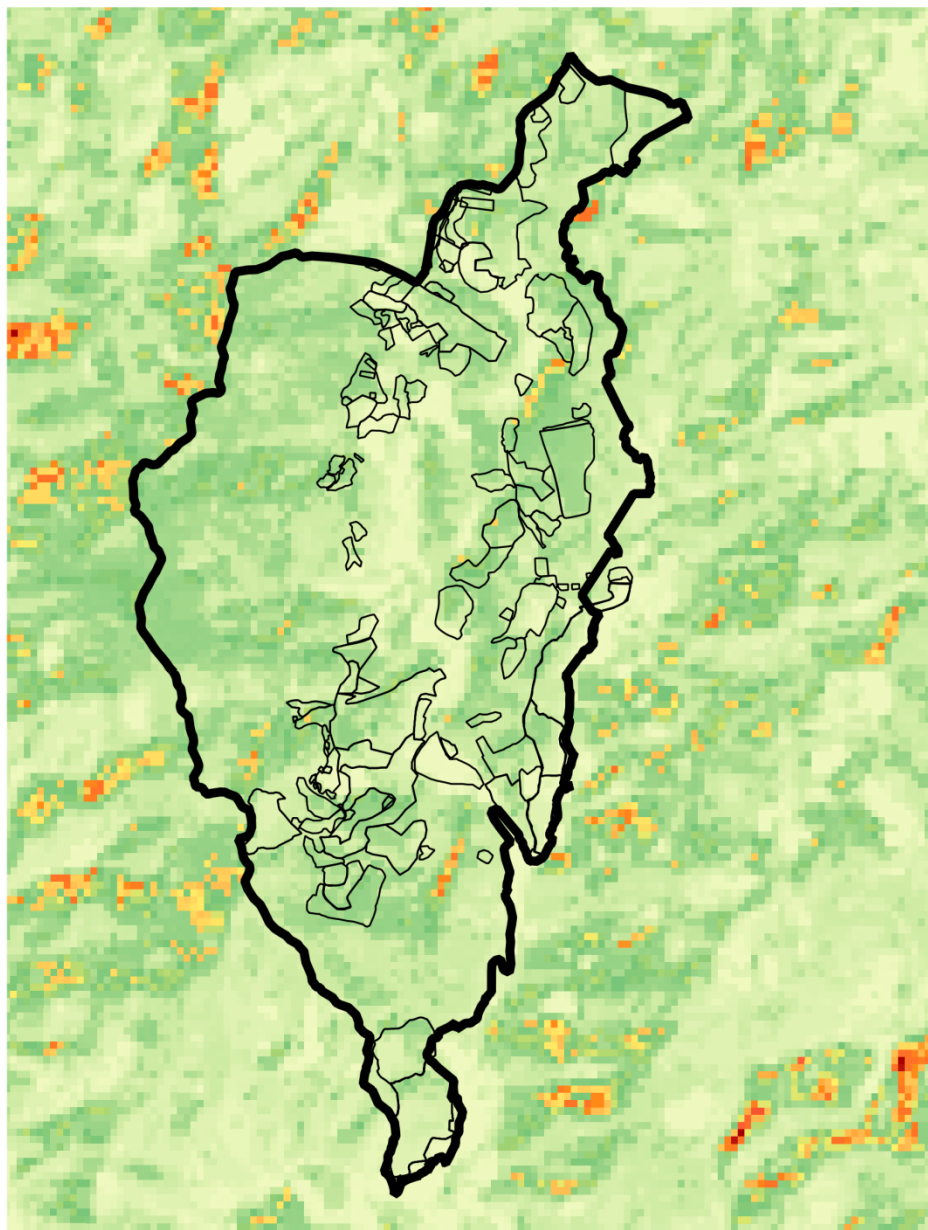
(Lisein et al., 2013)

機器學習-隨機森林

- 決策樹

1. 每一棵樹從訓練樣本中置還取樣
2. 每一棵樹隨機選取變數(少於總變數量)
3. 用每一個決策樹分類進行投票(機率)產生最終結果



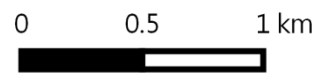
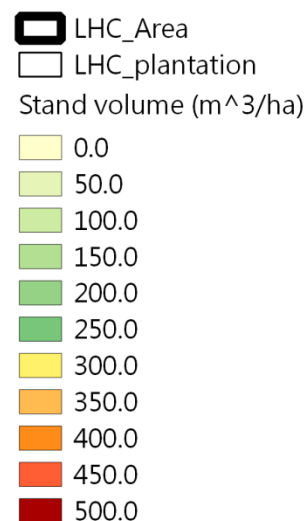


機器學習(Machine Learning)

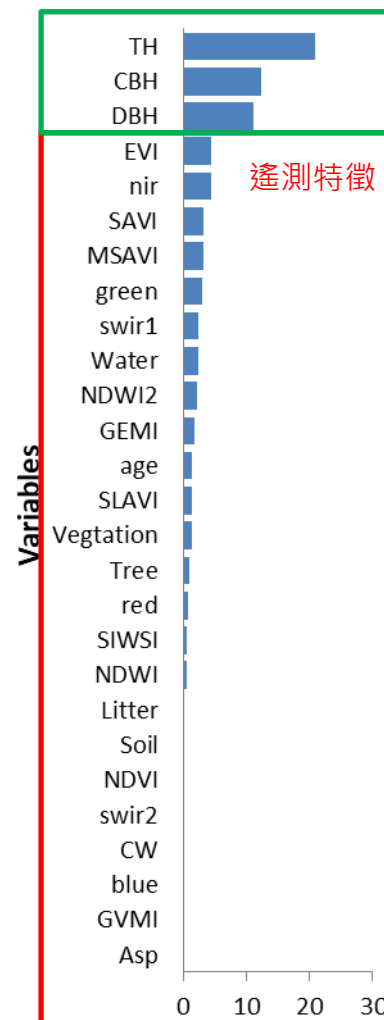
- Random forest

分類精度65.3%

Legend



地面調査特徴



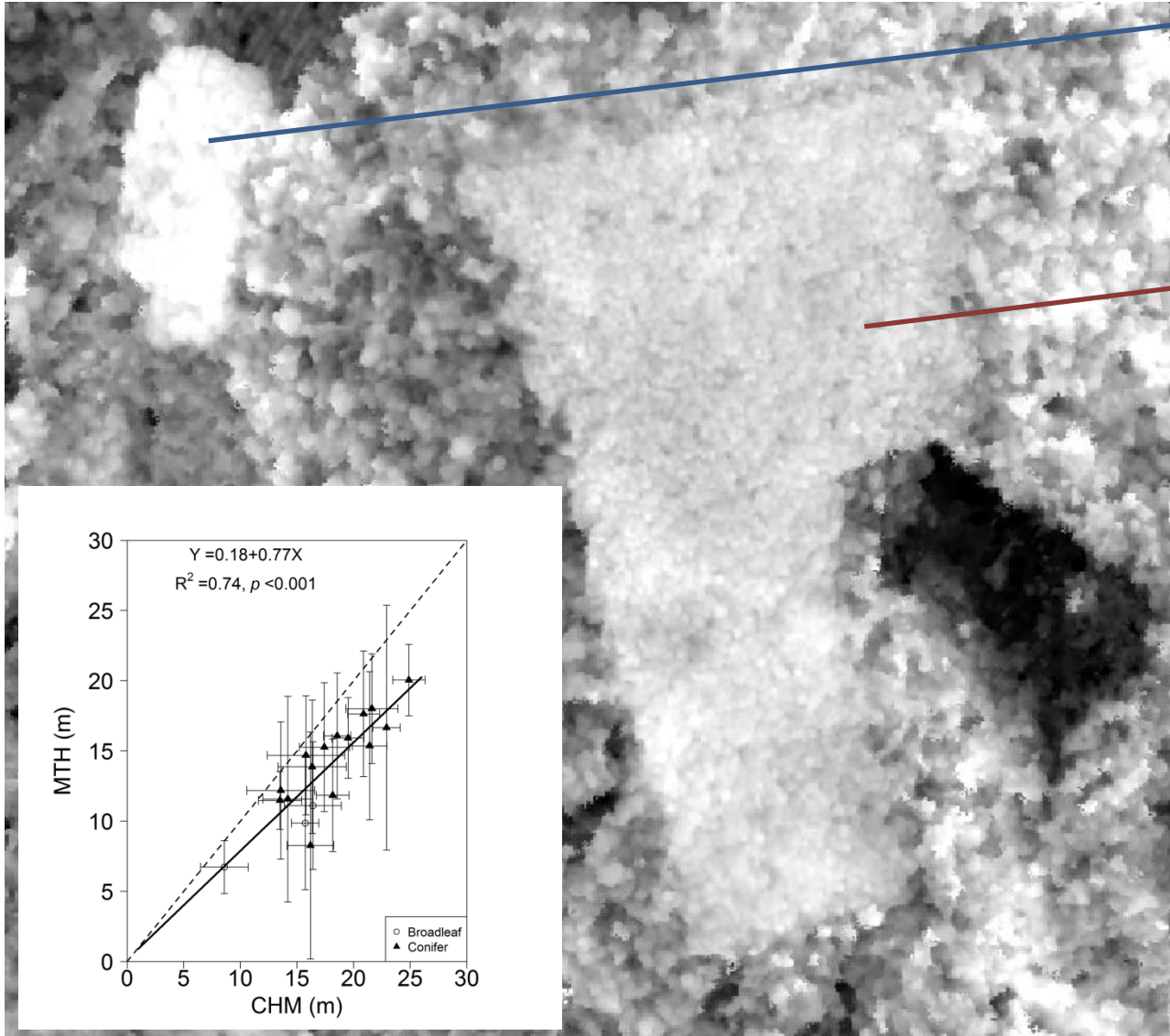
Relative Importance

Ref: Hakkenberg et al., 2016

- USDA FIA data(5-10 yr)
- 2428 plots

Statistics	Shannon (This study)	Hakkenberg et al., 2016	Shimpson (This study)	Hakkenberg et al., 2016
CHM_mean	0.54	0.30	0.42	0.29
CHM_cv	-0.43	0.42	-0.35	0.45
Weibull_shape	0.45	-0.47		-0.48
Weibull_scale	0.53	0.27	0.41	0.29
Skeness		0.21		0.21
kurtisis		0.30		0.24

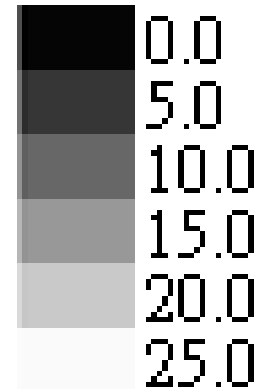
繪製樹高分布圖



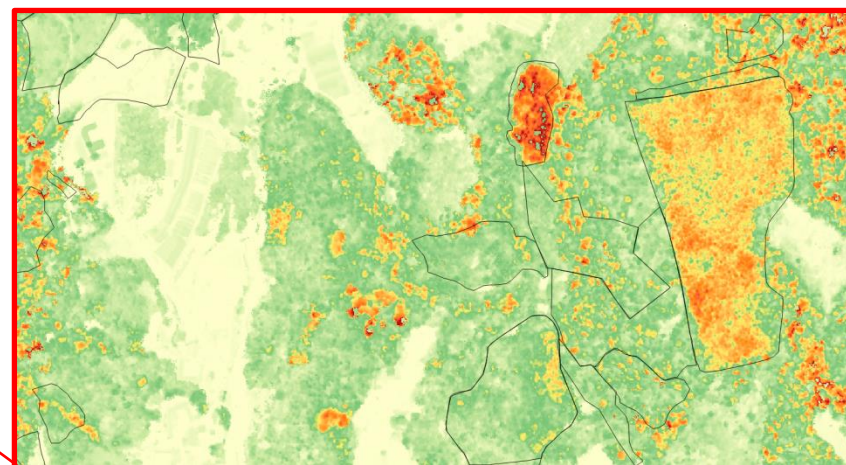
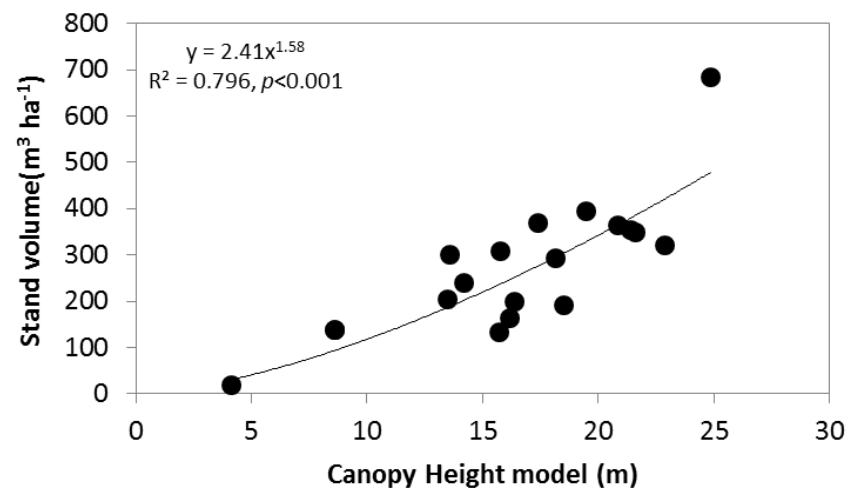
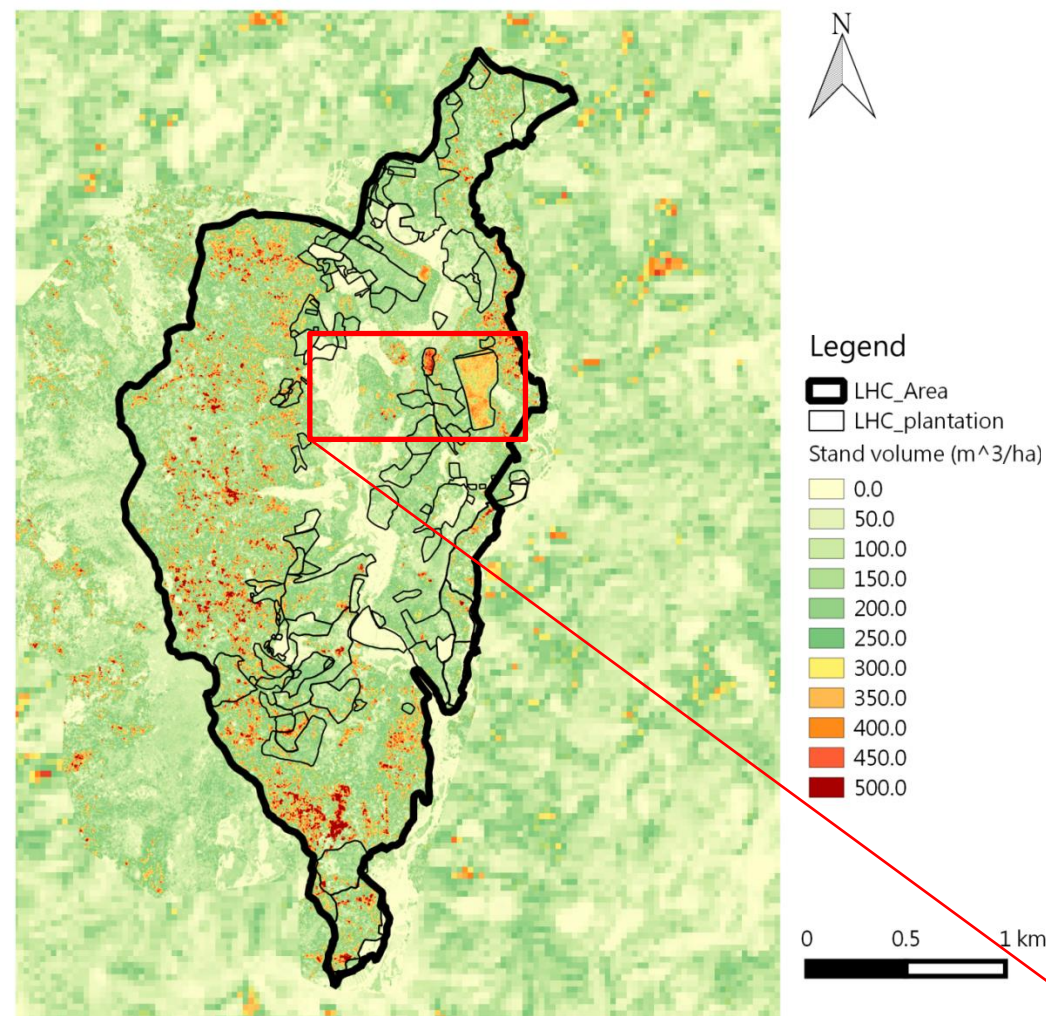
78 years old
stand

58 years old
stand

Canopy height (m)



UASs 繪製蓄積量分布圖



結論

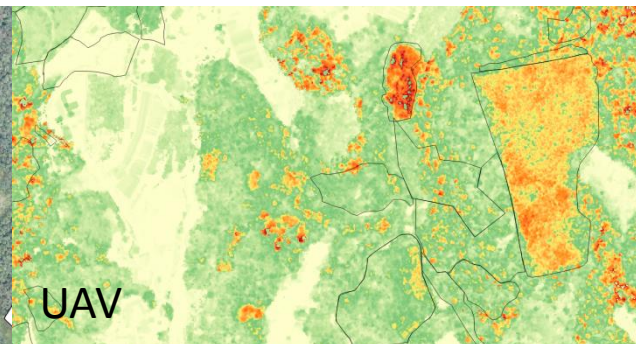
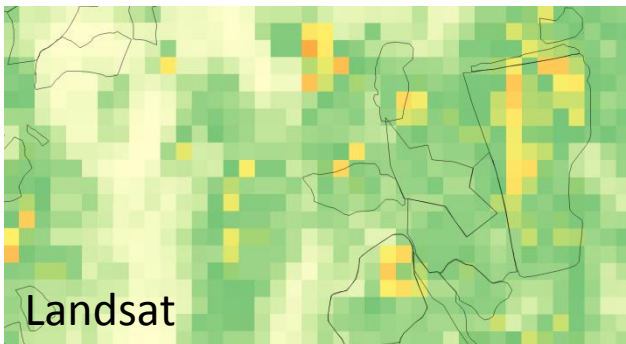
- **UASs 的調查方式提供一個有效率的新途徑**
 - UASs的樹冠高程模型可以精確的偵測樹冠的高度
 - UASs提供高度高度操作彈性，可以高頻率的監測與蒐集目標區域資料
- **UASs樹冠高程模型可用來評估胸徑,樹高與蓄積量**
 - 與林分結構特徵(DBH, tree height, stand volume stock and QMD) 成正相關
 - 與林分密度成負相關
- **與生物多樣性間有中度相關**
 - 與Shannon index, Simpson' s dominance成正相關
 - 與species richness負相關

活化無人機影像資料

- 無人機影像是描述土地變遷的重要紀錄
- 但大多數的無人機影像資料只用於特定研究與計畫(一次性)
- 應建立影像資料倉儲系統，讓無人機的影像提供更多的服務

致謝

- 感謝王豫煌博士與林朝欽博士提供蓮華池研究中心空拍影像。
 - 2014-> 1 Gb
 - 2015-> 200 Gb
 - 2016->1000 Gb
 - 2017->3000 Gb
 - 2018->6000 Gb



- THANKS
- Q & A

<https://tinyurl.com/uav3d2018>

