模擬衛星遙測估算甘蔗生育期葉片色素之含量

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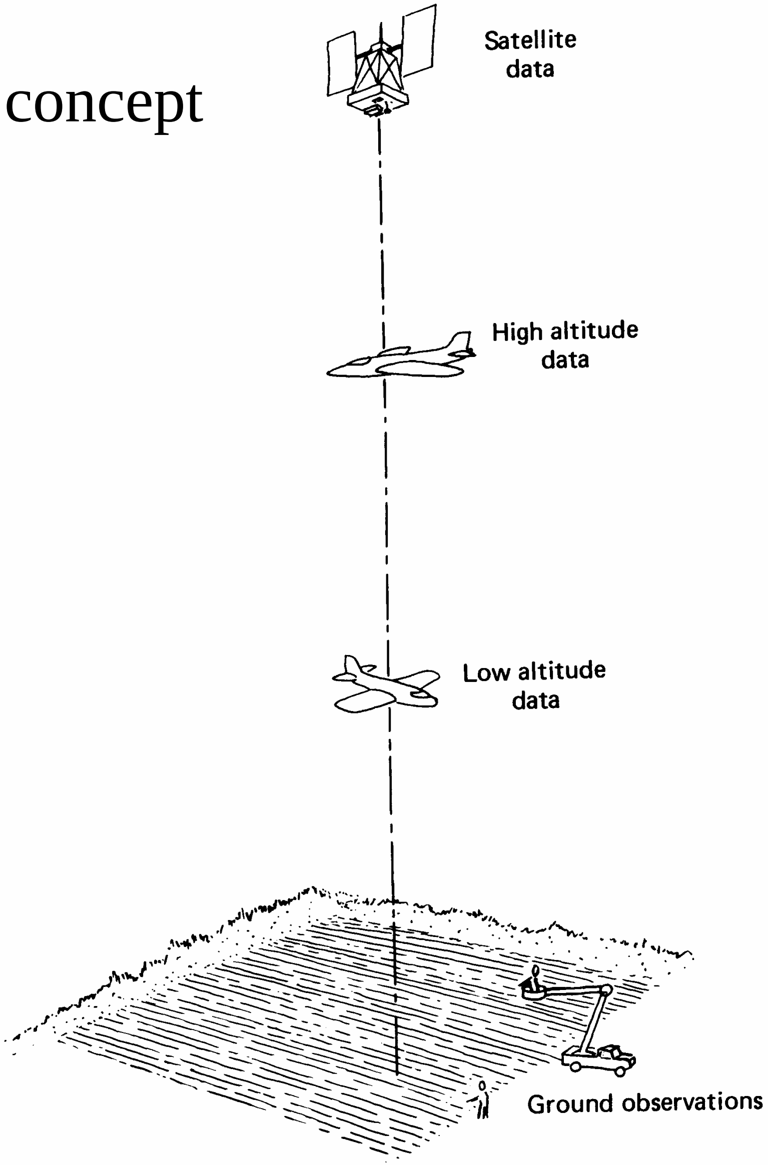
Multistage remote sensing concept

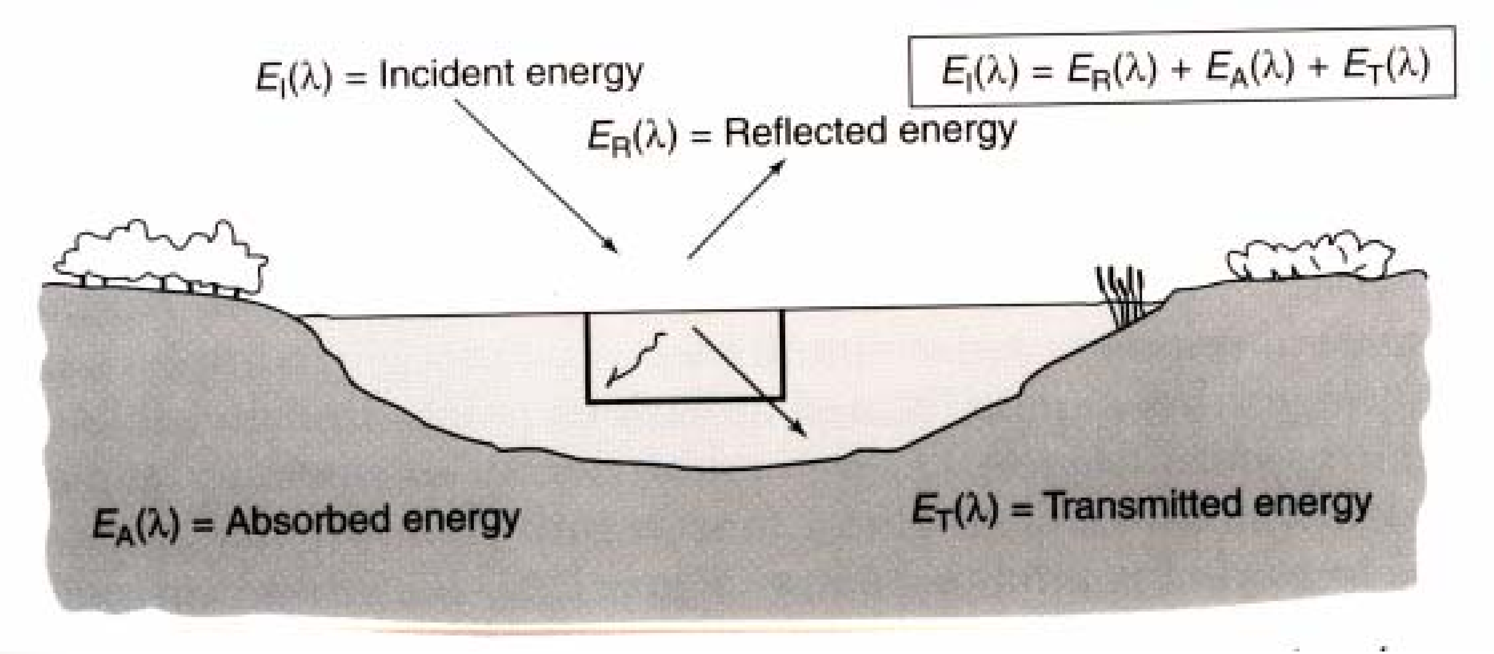


研究背景

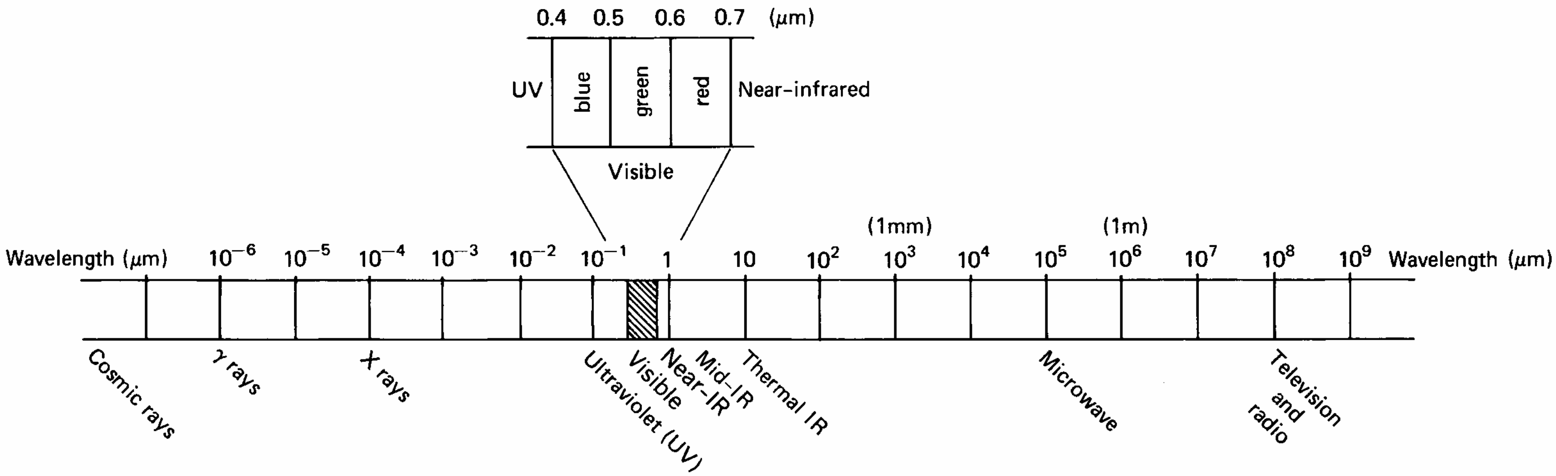
- 地面遙測是航測及太空遙測的基礎，其目的在於獲取地真資料(ground truth data)，作為其它平台遙測資料的參考基準。
- 農業遙測工作的主軸是在於反射光譜與作物狀態及農田狀態之關係，在作物地面遙測光譜資料庫建立之後，才能更精確的判讀及解析航測及太空遙測收取的影像光譜資料(數位或類比資料)，獲得準確與精確的量測。
- 葉片反射光譜及植物色素種類與含量彼此間有相關性，此相關性一旦在理論層次建立，將可建立重要農、林植物的特徵光譜資料庫的理論基礎與實務應用之參考資料。

- 光合色素含量之減少可作為葉片老化之指標，發展非破壞性方法測定葉片色素含量可監控作物生長狀況，在遭受逆境危害時可提供即時預警。
- 非破壞性測定葉片色素含量之技術中，較常用之方法為以葉片或植冠反射光譜來估算色素含量。
- 以不同波段反射比值所計算之各種植生指數(vegetation index)與作物的生理反應及生長狀況有密切關係。
- 常用於植物資源探測的植生指數，多使用紅光(R)與近紅外光(NIR)之反射比值或差值。

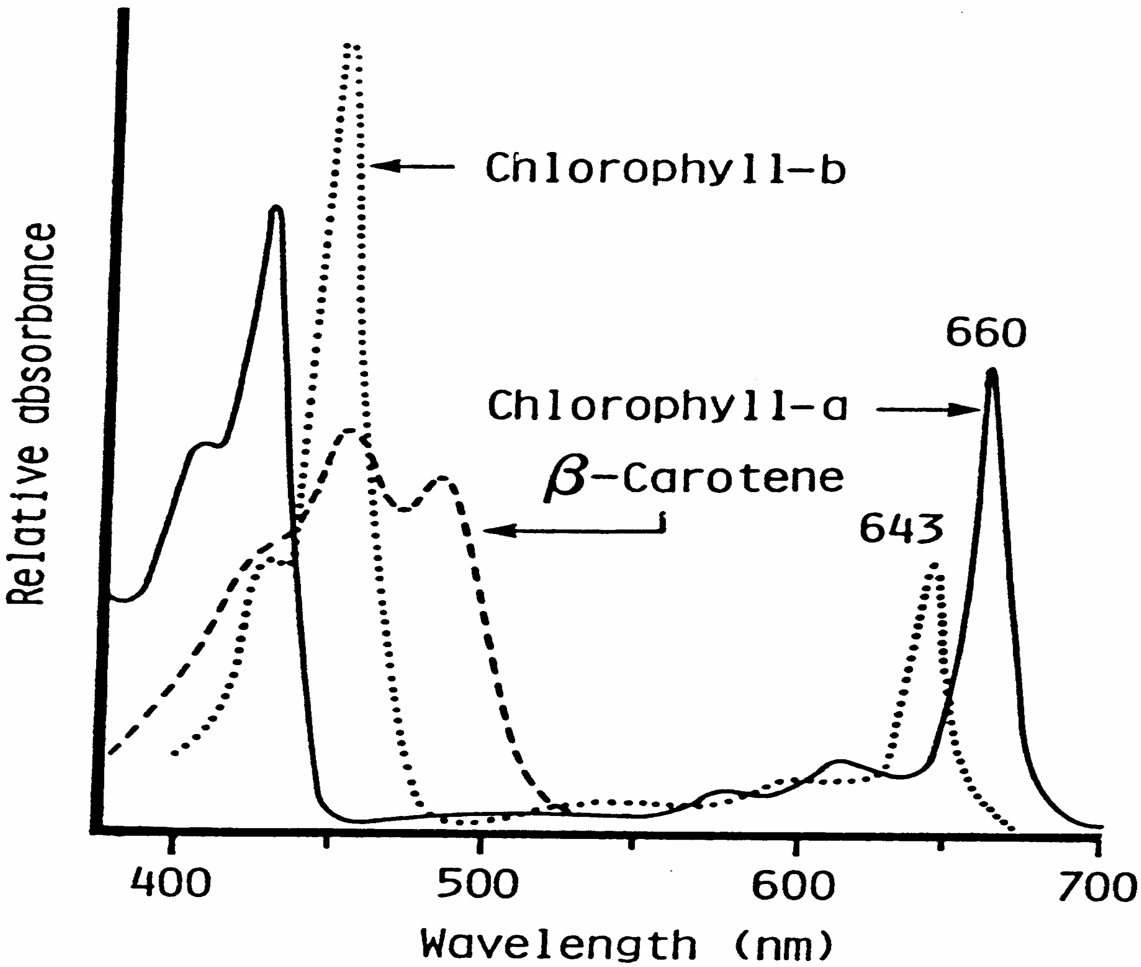
Electromagnetic energy interactions with surface features



The electromagnetic spectrum



Absorption spectra of Chl *a*, Chl *b* and Car



The reflectance, absorptance and transmittance of a green leaf

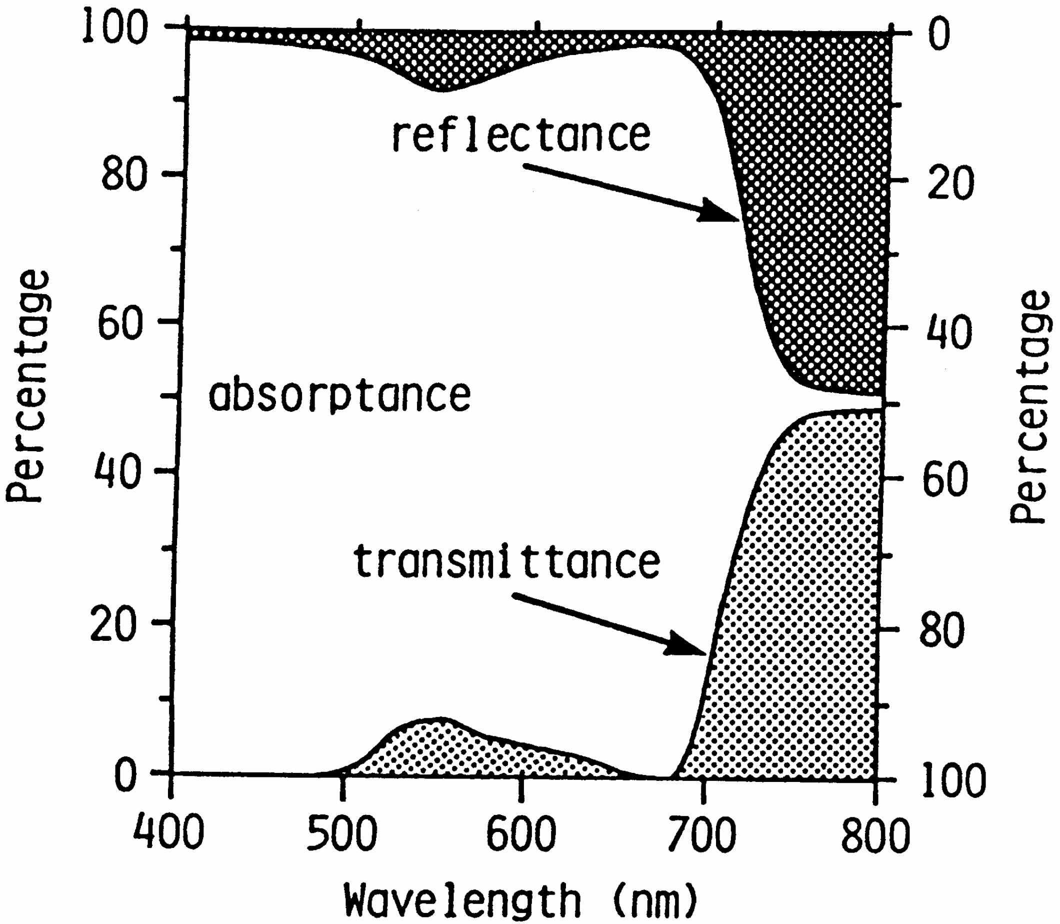


Table 1. Red and NIR vegetation index formulae†

Abbreviation	Name	Vegetation Index	Reference
NDVI	Normalized difference vegetation index	$NDVI = \frac{NIR - RED}{NIR + RED}$	Rouse *et al.* (1973)
SRVI	Simple ratio vegetation index	$SRVI = \frac{NIR}{RED}$	Jordan (1969)
SAVI	Soil adjusted vegetation index	$SAVI = \frac{NIR - RED}{NIR + RED + L}(1 + L)$	Huete (1988)
TSAVI	Transformed soil adjusted vegetation index	$TSAVI = \frac{a(NIR - aRED - b)}{RED + aNIR + ab}$	Baret *et al.* (1989)
$SAVI_2$	Soil adjusted ratio vegetation index	$SAVI_2 = \frac{NIR}{RED + b/a}$	Major *et al.* (1990)
PVI	Perpendicular vegetation index	$PVI = \frac{NIR - aRED - b}{\sqrt{1 + a^2}}$	Richardson and Wiegard (1977)
DVI	Difference vegetation index	$DVI = NIR - RED$	Tucker (1979b)
1DL_DGVI	First-order derivative green vegetation index derived using local baseline	$1DL\_DGVI = \sum_{\lambda 1}^{\lambda n} \left\| \rho'(\lambda_i) - \rho'(\lambda_1) \right\| \Delta\lambda_i$	Elvidge and Chen (1995)
1DZ_DGVI	First-order derivative green vegetation index derived using zero baseline	$1DZ\_DGVI = \sum_{\lambda 1}^{\lambda n} \left\| \rho'(\lambda_i) \right\| \Delta\lambda_i$	Elvidge and Chen (1995)
2DZ_DGVI	Second-order derivative green vegetation index derived using zero baseline	$2DZ\_DGVI = \sum_{\lambda 1}^{\lambda n} \left\| \rho''(\lambda_i) \right\| \Delta\lambda_i$	Elvidge and Chen (1995)

† The *a* (gain) and *b* (offset) are derived from the NIR vs. RED rock-soil baseline.
The L term (soil adjustment factor) in the SAVI ranges from 0 to 1 and is typically set to 0.5.
DGVI legend: i = band number; λ_i = center wavelength at the *i*th band; λ_1 = 626 nm; λ_n = 795 nm; ρ = reflectance; ρ' = first derivative reflectance; ρ'' = second derivative reflectance.

材料與方法

- 研究材料：甘蔗ROC 10號
- 種植地點：嘉義縣南靖糖廠下半天農場
- N-P_2O_5-K_2O：195-36-72 kg/ha
- 樣品採集：

依新植、採苗宿根、宿根及秋植等不同時期種植之田區而採樣。取得生育期60、90、360、540天之甘蔗植株，取第三完全展開葉進行色素含量及反射光譜測定。

- 以Porra等(1989)方法計算*Chl a*與*Chl b*的含量；採用Lichtenthaler (1987)的方法計算Car的含量。
- 葉片反射光譜以配備積分球套件之Hitachi U-3010光譜儀進行測定。光譜掃描速率為600 nm/min，波段範圍自200至900 nm，光譜解析力為1 nm。測定時以硫酸鋇白板為參考對比。葉片測定反射光譜時以葉脈間之區域為主，反射率為葉片反射輻射值對參考白板反射輻射值之比值。

Table 1. Pigment contents in sugarcane leaves at various developmental stages.

Photosynthetic pigment	Days after planting			
	60	90	360	540
Chl *a* (μg/g)	6918±149[†]	5749±132	4821±144	2271±44
Chl *b* (μg/g)	1803±19	1459±47	1343±96	634±22
Chl *a+b* (μg/g)	8721±155	7208±176	6164±230	2905±64
Chl *a/b*	3.84±0.08	3.94±0.06	3.60±0.18	3.58±0.08
Car (μg/g)	3636±105	3149±82	2816±75	1449±28
Car/Chl	0.42±0.01	0.44±0.00	0.46±0.01	0.50±0.00

† Data presented as mean ± standard error (SE). (n=4)

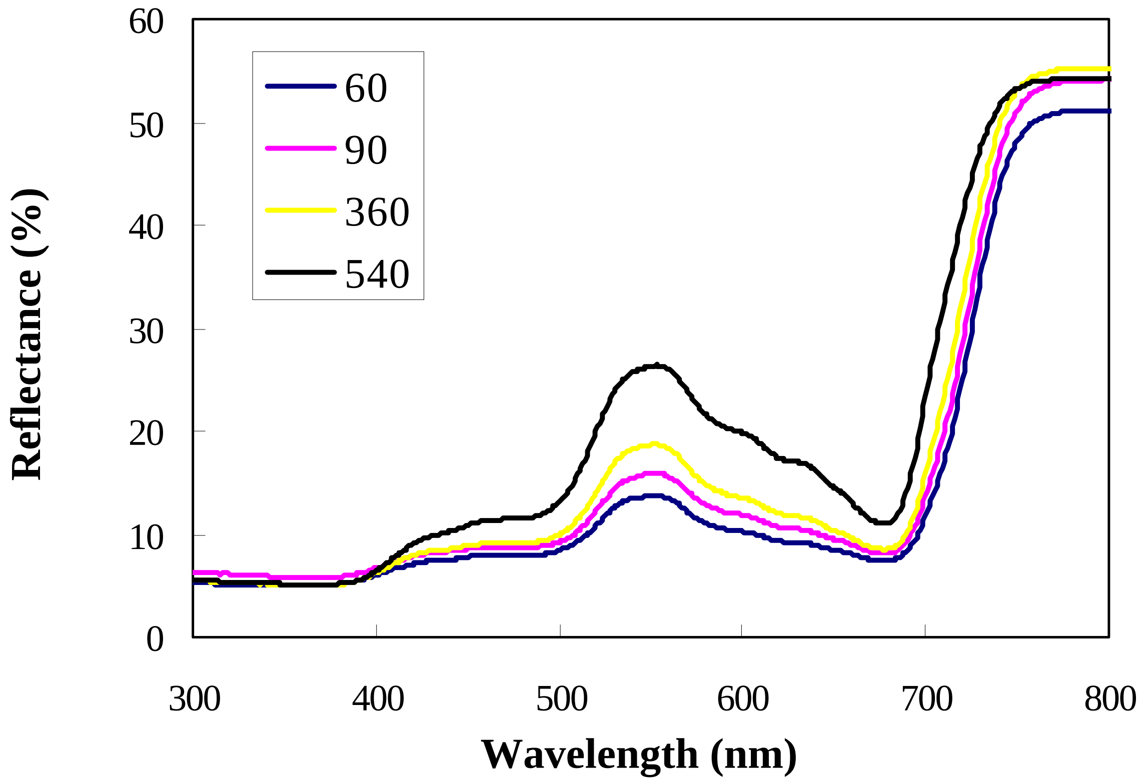


Figure 1. Reflectance spectra of sugarcane leaves at various developmental stages were detected from 300 to 800 nm at 60, 90, 360, 540 days after planting.

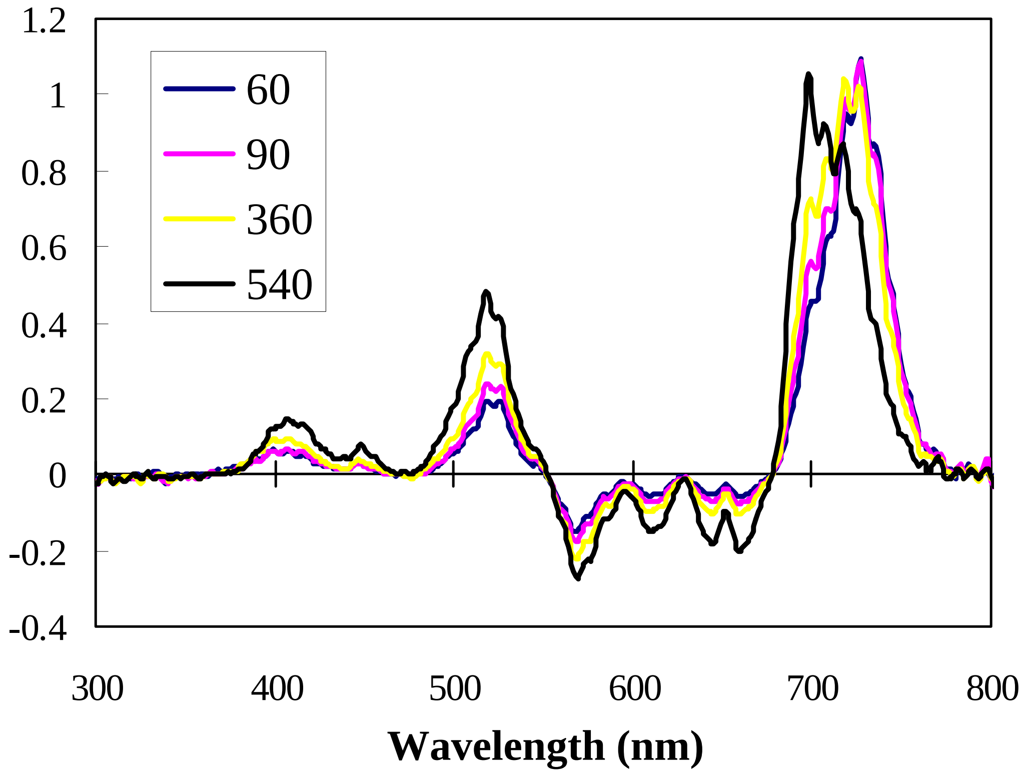


Figure 2. The first order derivative of reflectance spectra of sugarcane leaves was presented from 300 to 800 nm at 60, 90, 360, 540 days after planting.

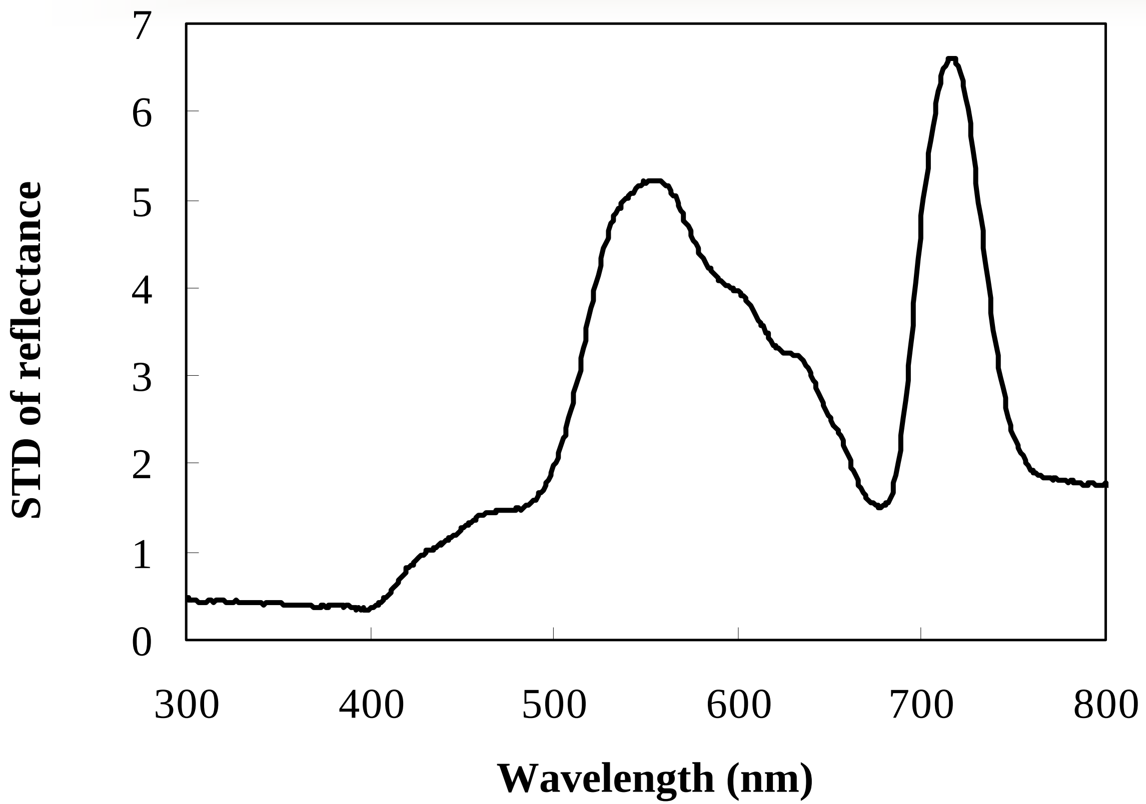


Figure 3. Standard deviation (STD) of reflectance for sugarcane leaves was presented from 300 to 800 nm.

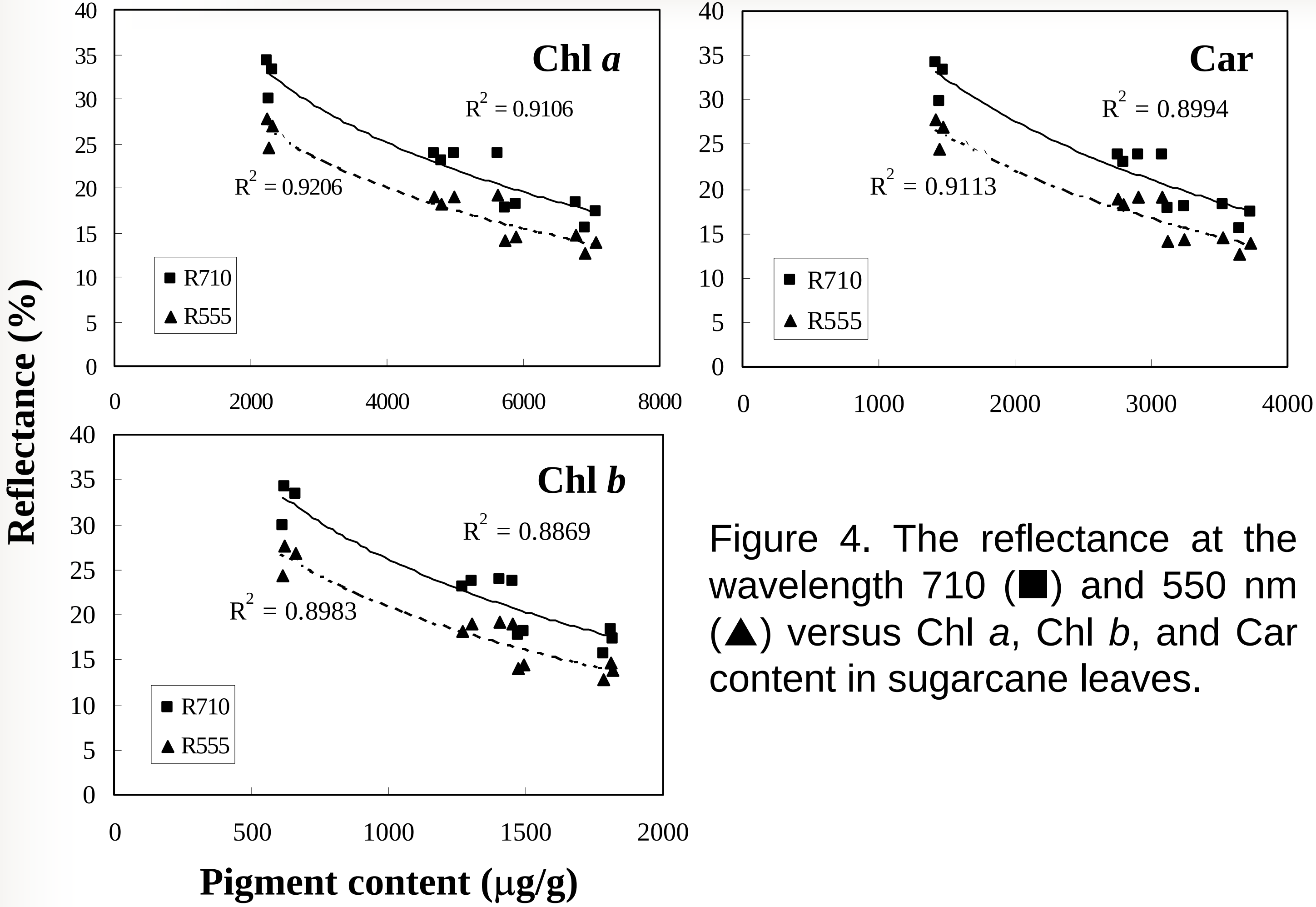


Figure 4. The reflectance at the wavelength 710 (■) and 550 nm (▲) versus Chl *a*, Chl *b*, and Car content in sugarcane leaves.

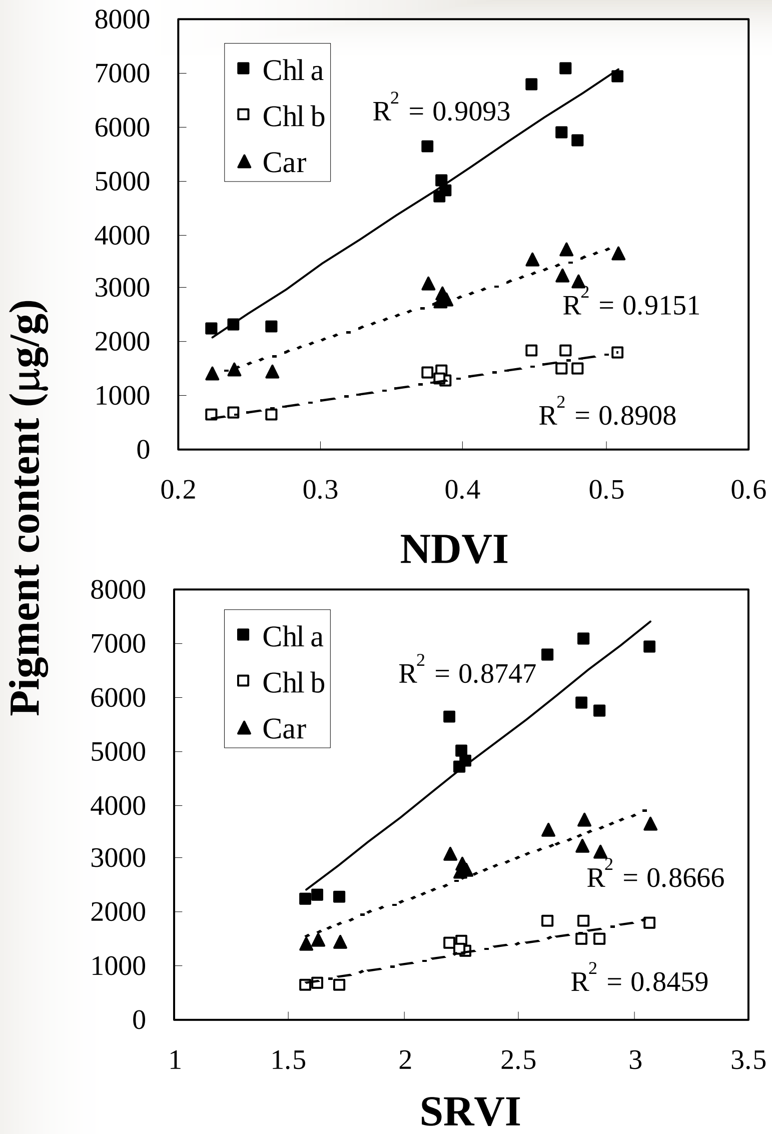


Figure 5. NDVI and SRVI calculated using *R710* and *R750* plotted versus Chl *a* (■), Chl *b* (□), and Car (▲) content in sugarcane leaves.

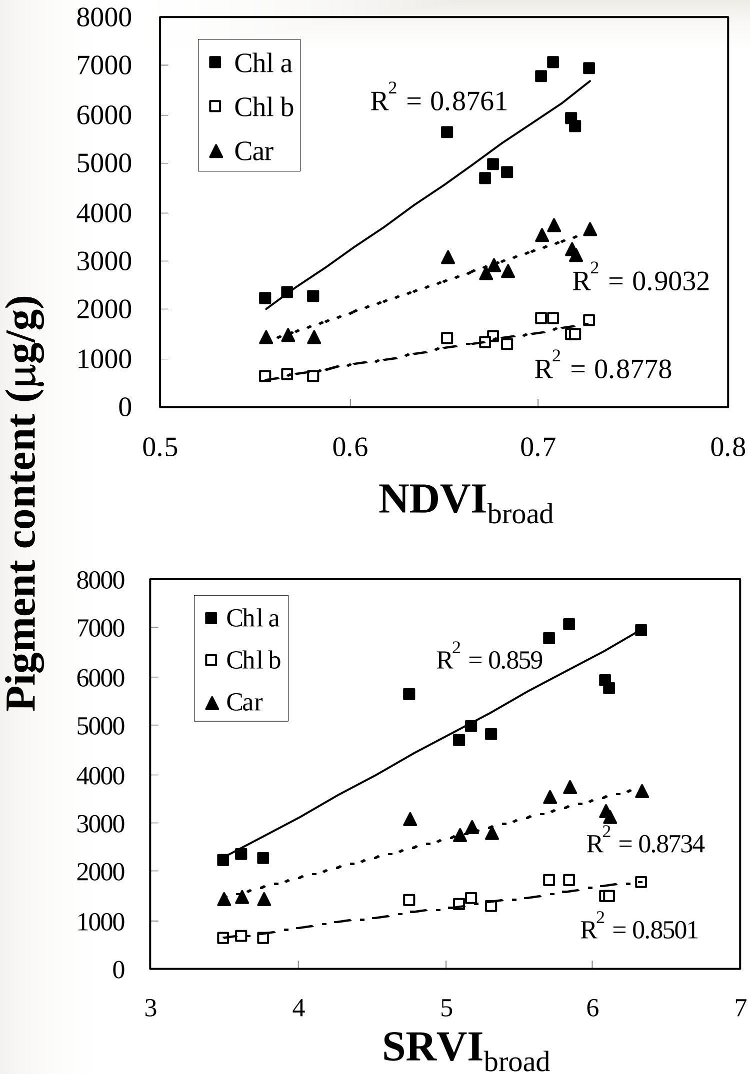


Figure 6. $SRVI_{broad}$ and $NDVI_{broad}$ calculated using broad-band reflectance plotted versus Chl *a* (■), Chl *b* (□), and Car (▲) content in sugarcane leaves. Red: 610-680 nm; NIR: 790-890 nm.

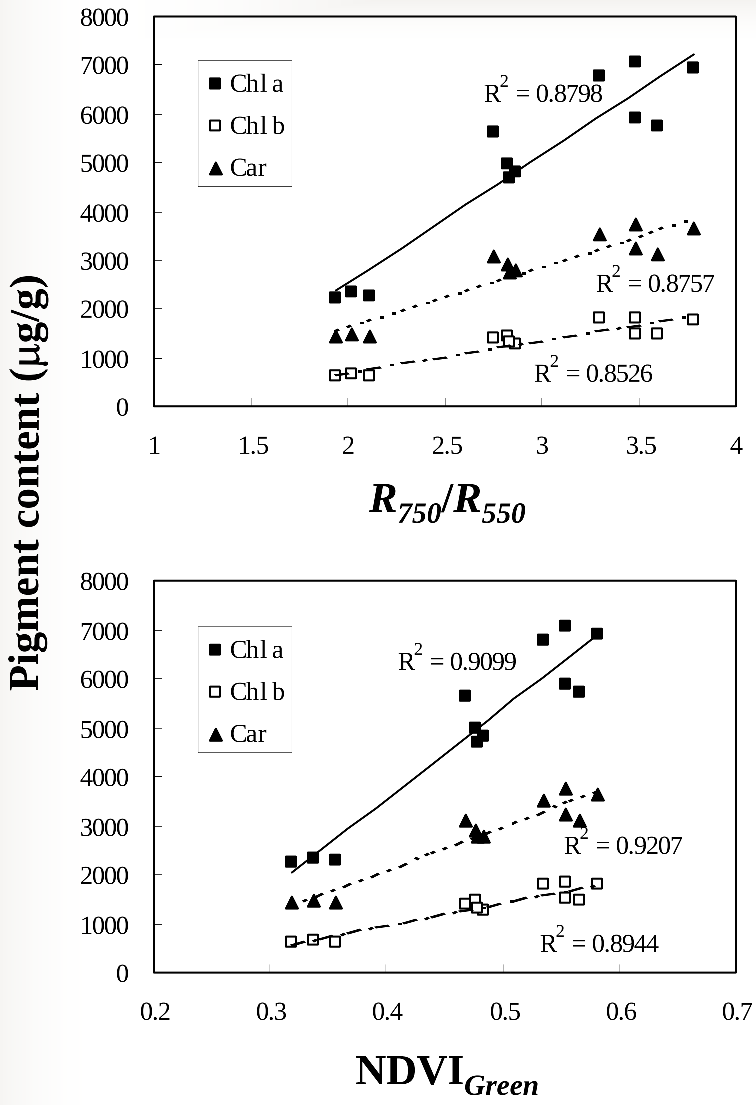


Figure 7. R_{750}/R_{550} ratio and $NDVI_{Green}$ versus Chl *a* (■), Chl *b* (□), and Car (▲) content in sugarcane leaves. Green NDVI calculated as $NDVI_{Green} = (R_{750}-R_{550})/(R_{750}+R_{550})$.

結 論

- 550 nm與710 nm之反射率對色素含量變化具有最大敏感度。
- 甘蔗葉片之Chl *a*、Chl *b*及Car三種色素含量與R_{750}、R_{710}及寬波段反射率計算之SRVI及NDVI具有顯著之相關性；
- 三種色素含量與R_{750}、R_{550}計算之IR/G及$NDVI_{GREEN}$亦具有顯著之相關性。
- 可以應用這些植生指數來進行葉片色素含量之遙測估算。

敬請指教