Techniques for remote estimation of pigment contents and composition in terrestrial vegetation

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HyspIRI/GSFC

Products: Contents and composition of pigments in terrestrial vegetation

- Total chlorophyll content
- Total carotenoids content
- Anthocyanin content

Justification

Pigments relate to both the physiological status and the photosynthetic capacity of vegetation

- Chlorophylls absorb solar radiation and provide mechanisms for its utilization in photosynthetic reactions.

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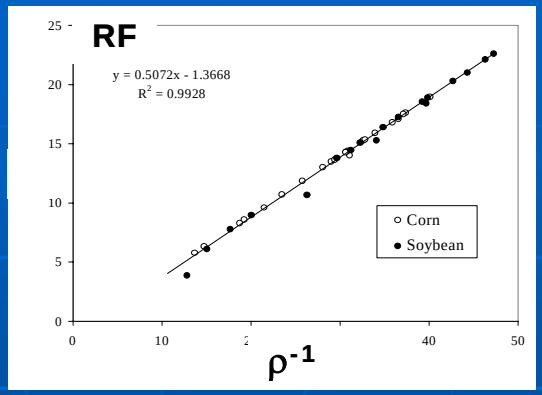
- The induction of anthocyanins biosynthesis occurs as a result of deficiencies in nitrogen and phosphorus, wounding, pathogen infection, desiccation, low temperature, UV-irradiation etc. Anthocyanins fulfil important physiological functions by being involved in the adaptation to numerous stresses and environmental strain reduction.

Basis for the product:

Three-band model for pigment content estimation

Kubelka-Munk remission function

$$f(\rho_\infty) = (1 - \rho_\infty^2)/2\rho_\infty \cong \rho_o^{-1}$$



Thus, ρ^{-1} relates to inherent optical properties of vegetation, a and b_b, at canopy level:

$$\rho^{-1}(\lambda) \propto [a_{pigm}(\lambda) + a_0(\lambda) + b_b]/b_b$$

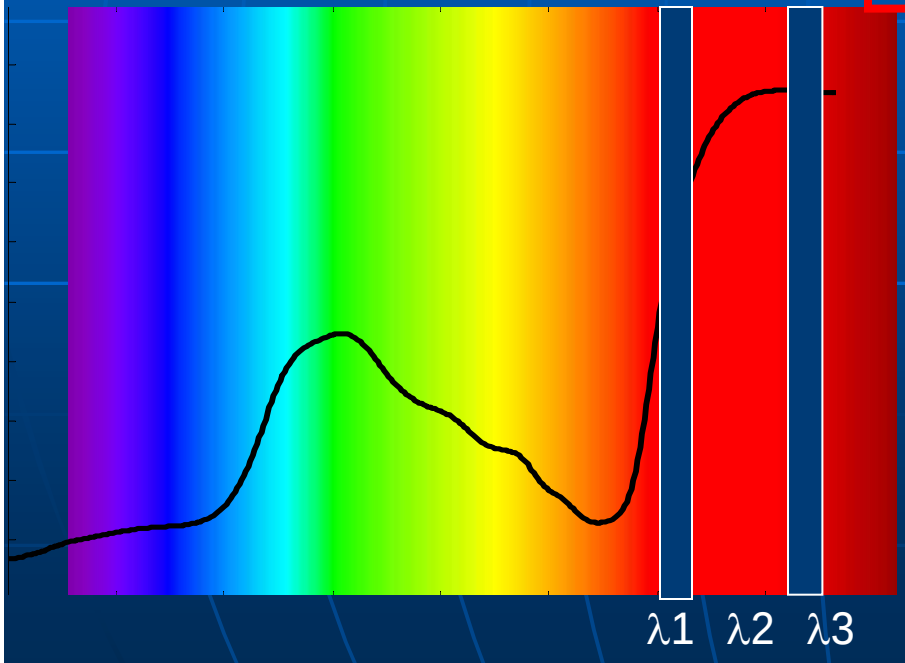
$$\text{Pigment} \propto [\rho^{-1}(\lambda_1) - \rho^{-1}(\lambda_2)] \times \rho(\lambda_3)$$

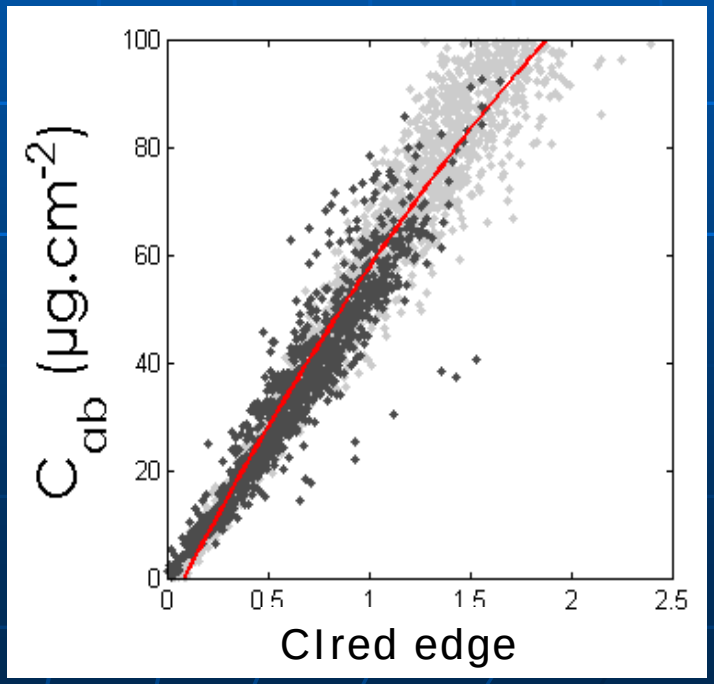
$$\rho^{-1}(\lambda) \propto [a_{chl}(\lambda) + a_0(\lambda) + b_b]/b_b$$

Chlorophyll-*a* Reflectance Index

$$CI_{chl\text{-}a} \propto [\rho^{-1}(\lambda_1) - \rho^{-1}(\lambda_2)] \times \rho(\lambda_3)$$

$$CI \propto \text{Chl-a} = (\rho_{NIR}/\rho_{red\ edge}) - 1$$





Gitelson et al., GRL, 2005, Feret et al., RSE, 2009

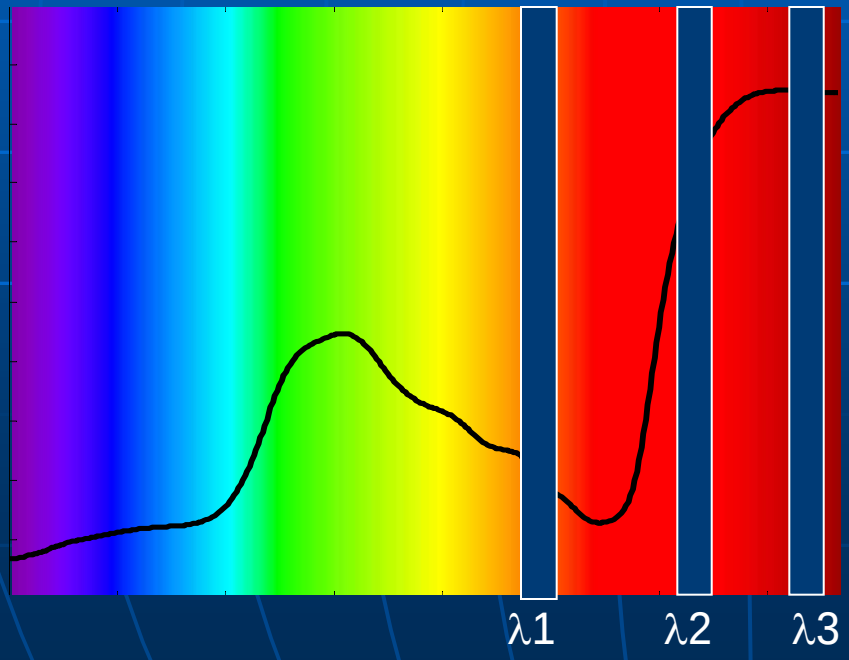
Why and how is HyspIRI able to uniquely provide it

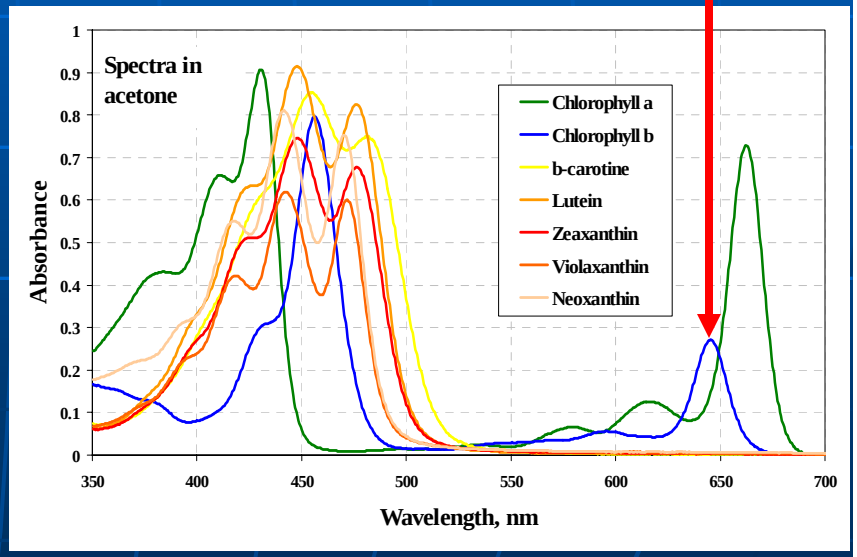
$$\rho^{-1}(\lambda) \propto [a_{chl}(\lambda) + a_0(\lambda) + b_b]/b_b$$

Chlorophyll-*b* Reflectance Index

$$CI_{chl\text{-}b} \propto [\rho^{-1}(\lambda_1) - \rho^{-1}(\lambda_2)] \times \rho(\lambda_3)$$

$a_{chl\text{-}a} + a_{chl\text{-}b}$ $\quad a_{chl\text{-}a}$ $\quad b_b$ $\quad$ Chl-*b*





$$\text{Chl-}b \propto CI_{chl\text{-}b} = (\rho^{-1}{}_{650} - \rho^{-1}{}_{720}) \times \rho_{NIR}$$

Why and how is HyspIRI able to uniquely provide it

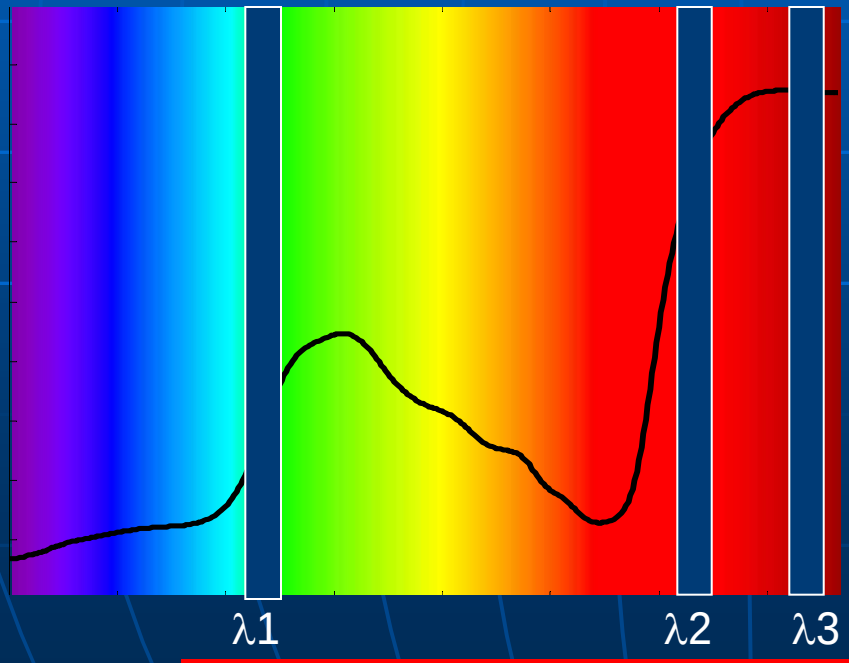
$$\rho^{-1}(\lambda) \propto [a_{chl}(\lambda) + a_0(\lambda) + b_b]/b_b$$

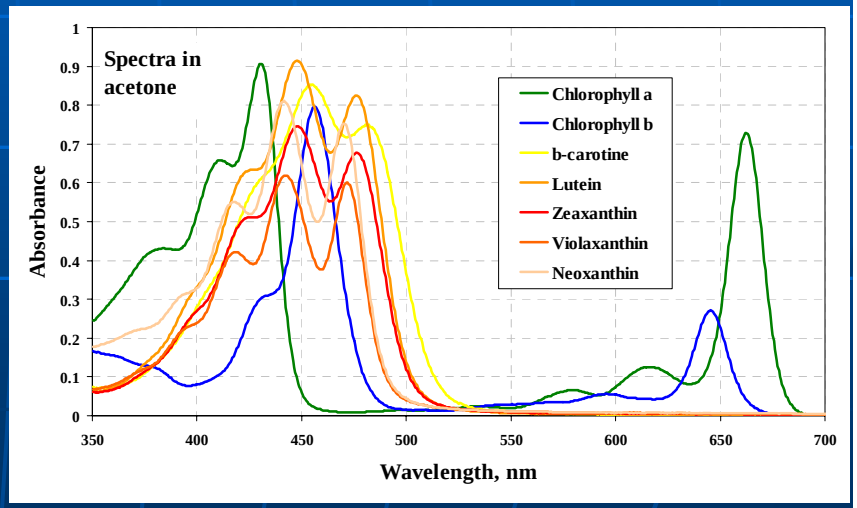
Carotenoids Reflectance Index

$$CRI \propto [\rho^{-1}(\lambda_1) - \rho^{-1}(\lambda_2)] \times \rho(\lambda_3)$$

Gitelson et al., 2002

$a_{car} + a_{chl}$ a_{chl} b_b





$$Car \propto CRI = (\rho^{-1}_{515} - \rho^{-1}_{720}) \times \rho_{NIR}$$

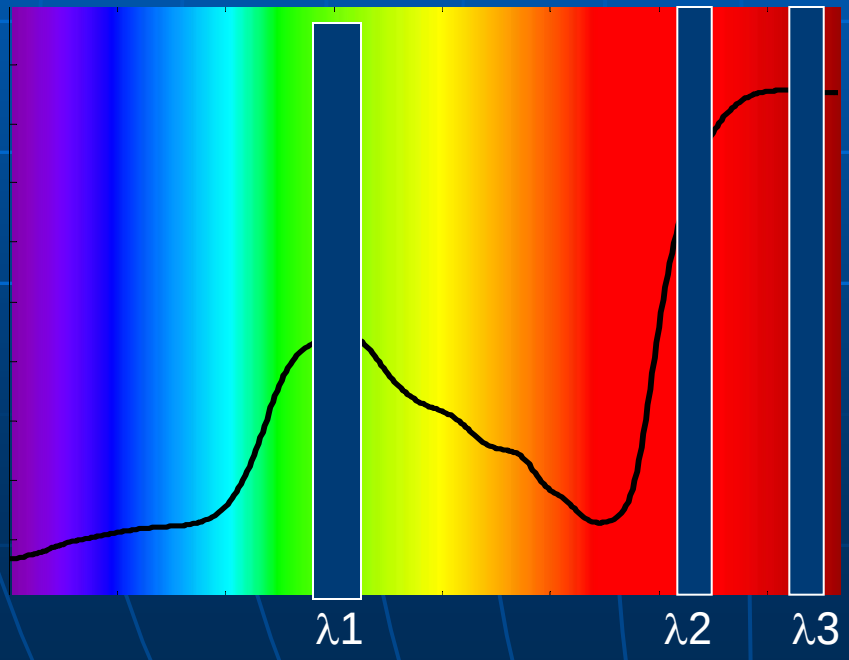
$$\rho^{-1}(\lambda) \propto [a_{chl}(\lambda) + a_0(\lambda) + b_b]/b_b$$

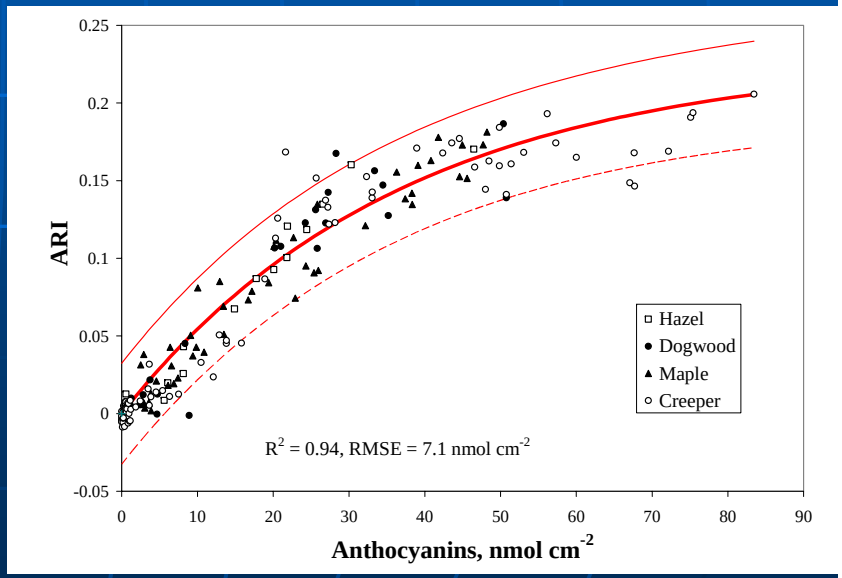
Anthocyanin Reflectance Index

$$ARI_{\text{red edge}} \propto [\rho^{-1}(\lambda_1) - \rho^{-1}(\lambda_2)] \times \rho(\lambda_3)$$

Gitelson et al., 2001

$a_{anth} + a_{chl}$ a_{chl} b_b

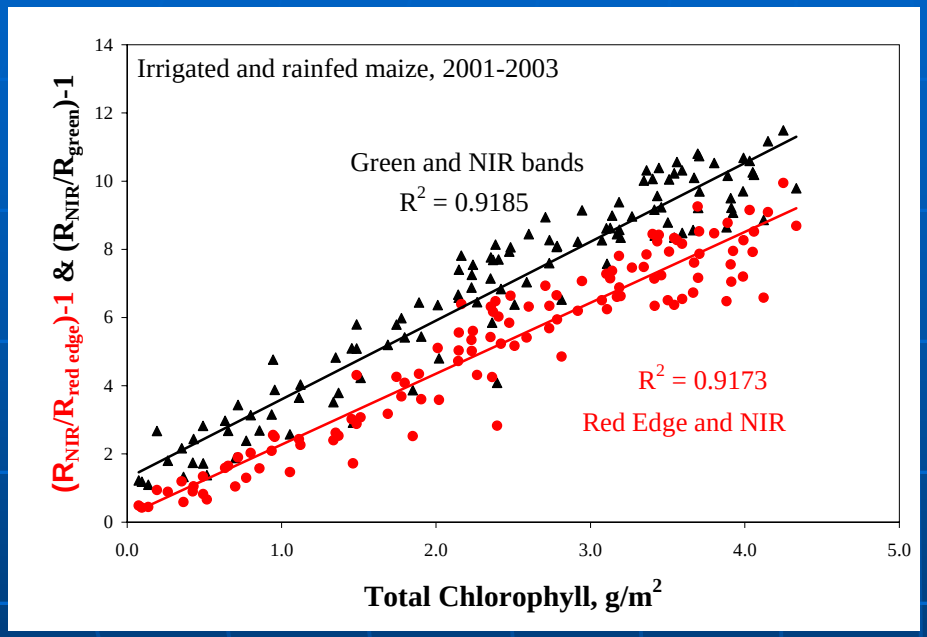




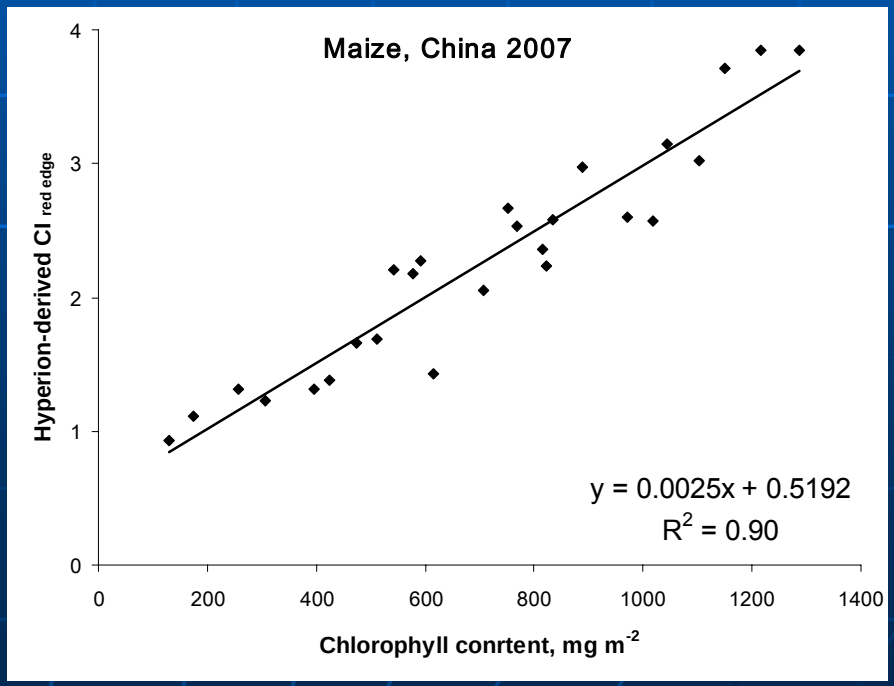
Gitelson et al., 2009

Anthocyanin levels (ARI) indicate physiological and biochemical changes from water stress (Asner, PNAS, 2004)

$$CI_{red\ edge} \propto [(\rho_{red\ edge})^{-1}-(\rho_{NIR})^{-1}]\times\rho_{NIR}$$



Gitelson et al., GRL, 2005



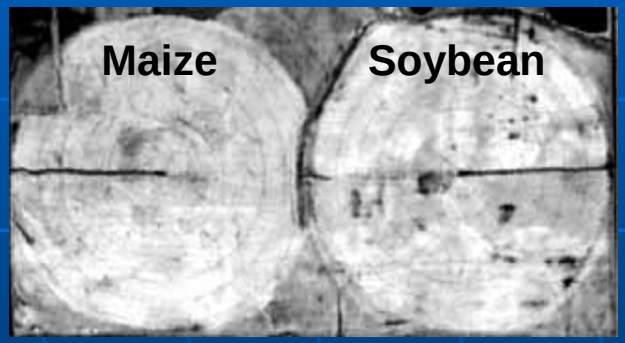
Wu et al., IJRS, 2010

Is the model species-specific?

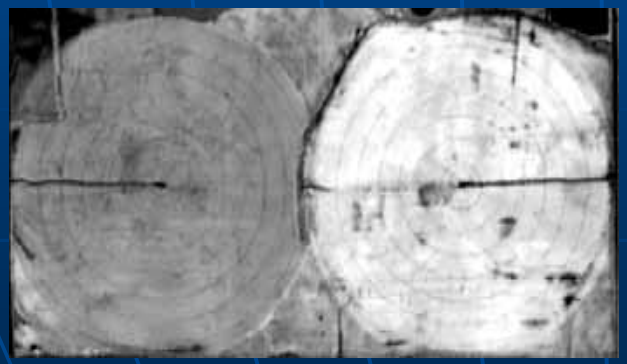
Chlorophyll content and green LAI were the same in both maize and soybean sites

AISA-Eagle Hyperspectral Imager

Red edge Model



Green Model



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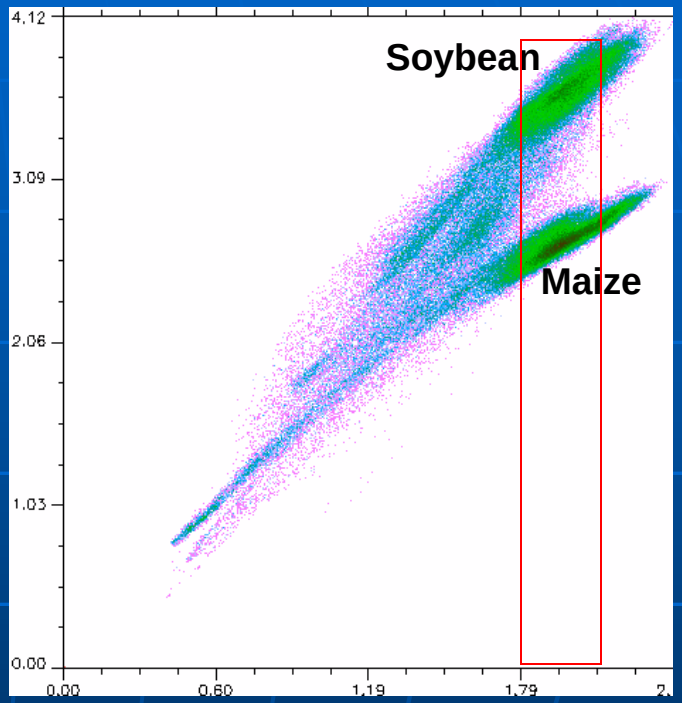
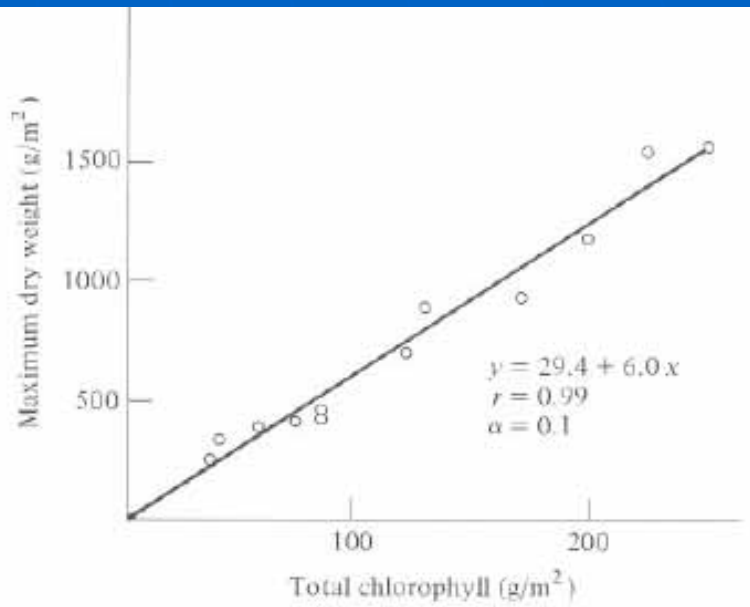


Red-edge Model

Narrow band red edge model is not species specific

GPP vs. Chlorophyll Content

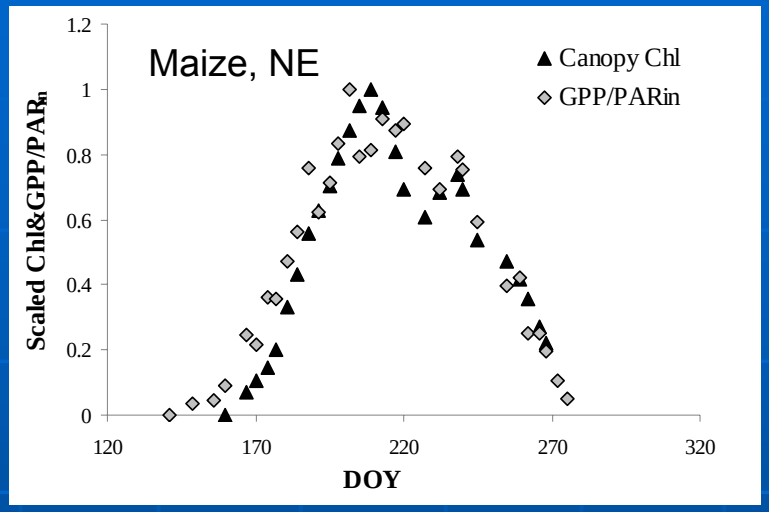
FIGURE 4–7. Relationship of productivity (as indicated by the seasonal maximum biomass) in meadows to total chlorophyll content at the same time. From Medina and Lieth (1964).

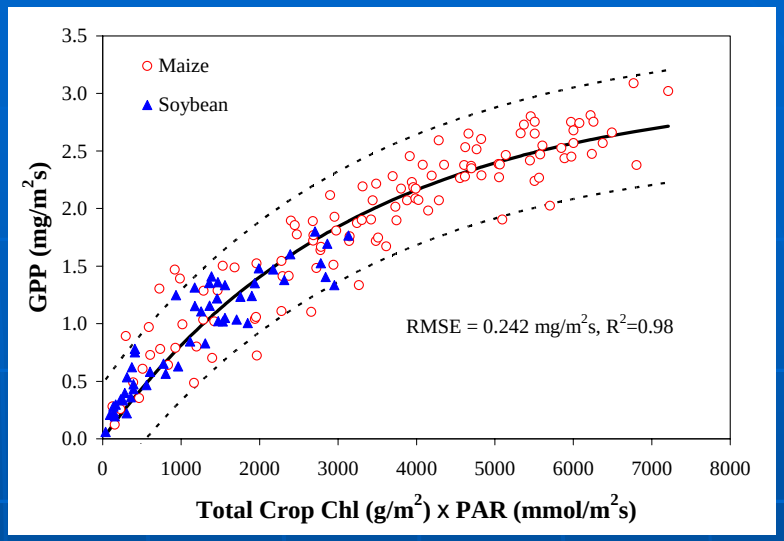


Medina and Lieth, Beitraege zur Biologie der Pflanzen, 1964

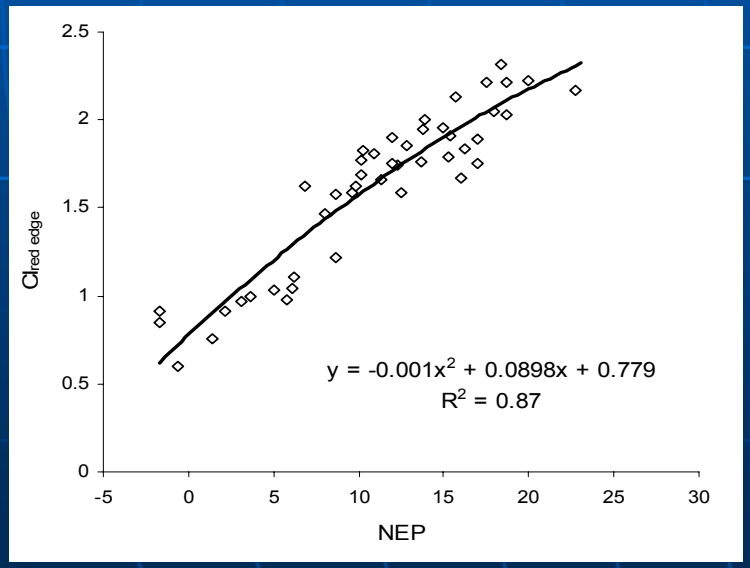
Primary Productivity of the Biosphere, (Lieth and Whittaker, Eds), Fig. 4-7, p. 102, 1975,

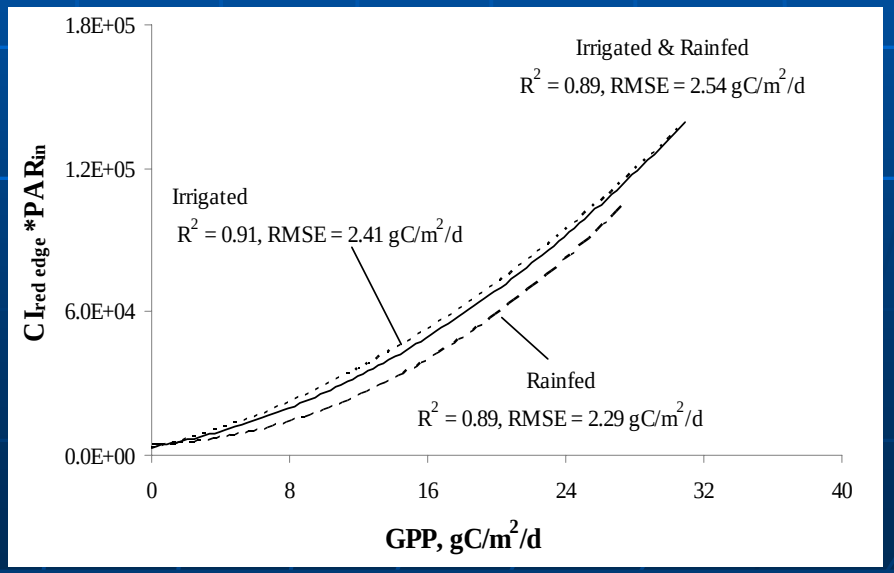
GPP vs. Chl





Gitelson et al., JGR, 2006



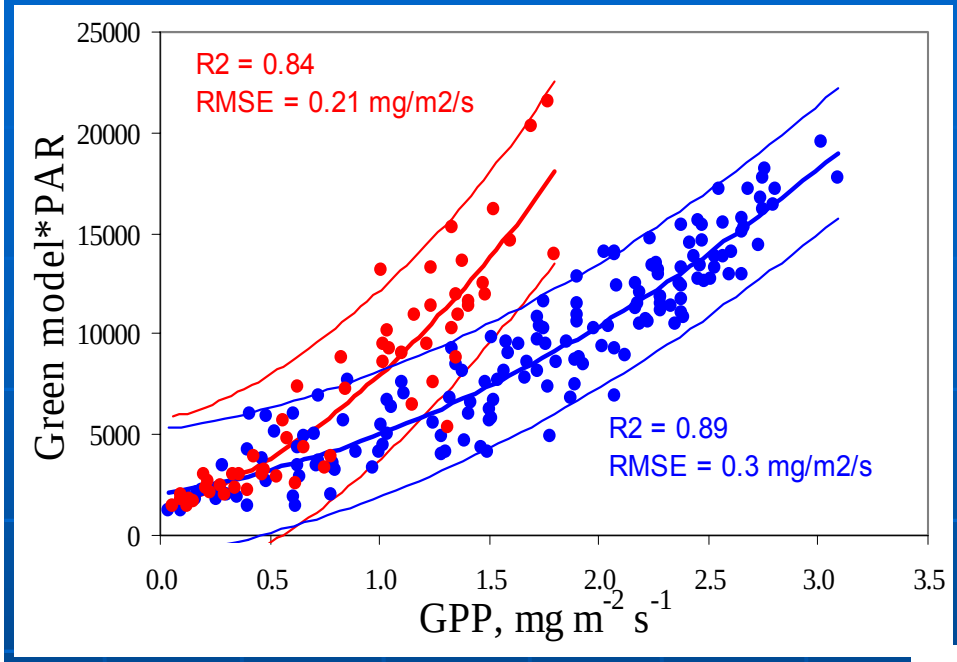


Deciduous forest, BC Canada

Courtesy of Thomas Hilker

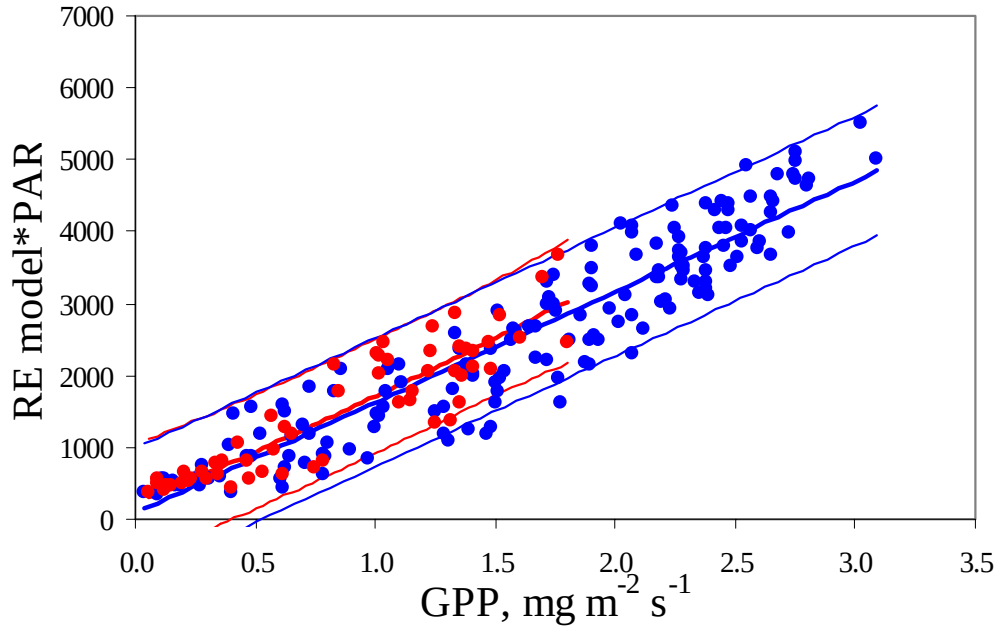
Yi et al., 2010

GPP estimation via Chl

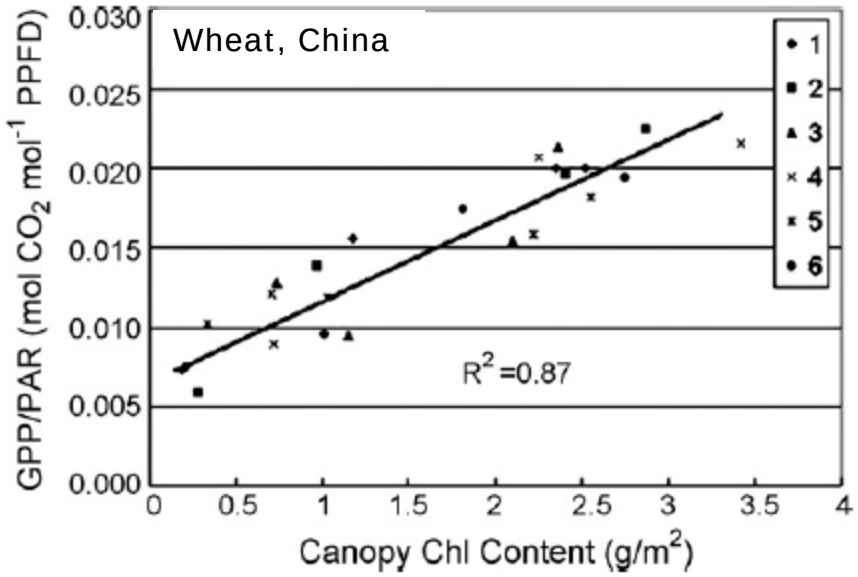


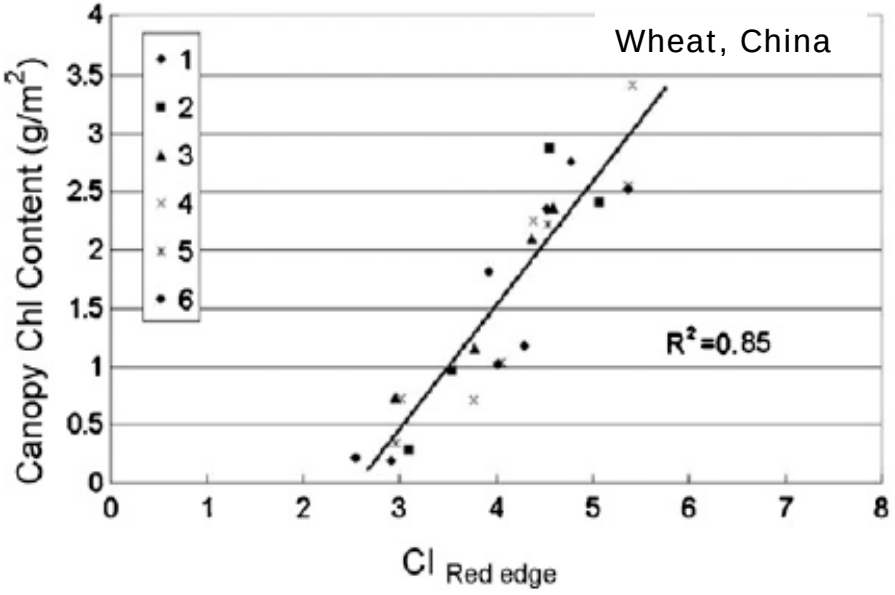
Maize

Soybeans



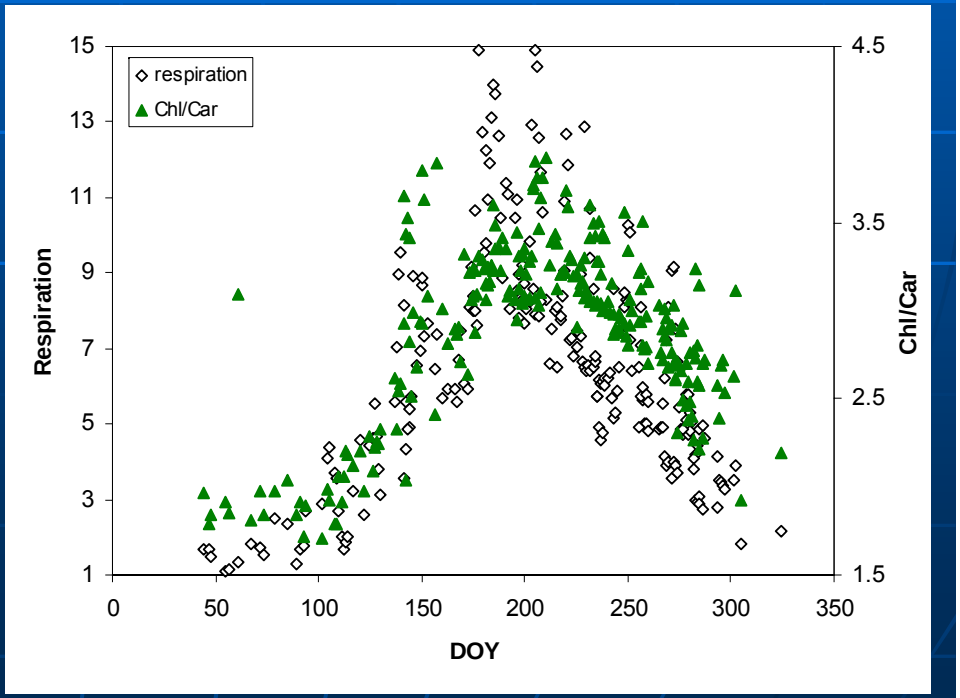
Chl → GPP → Cl





Car/Chl → Respiration

Coniferous forest, BC Canada



Wu et al, AFM, 2009

Courtesy of Thomas Hilker

1. Non-destructive detection of pigment contents in plant leaves

$$C_{pigment} \propto [R^{-1}(\lambda_1) - R^{-1}(\lambda_2)] \times R(\lambda_3)$$

Gitelson et al., 2003

Chlorophyll

710 - 770 - 770

Gitelson et al., 1994; 1996; 2003

Anthocyanins

550 - 700 - 770

Gitelson et al., 2001, 2009

Carotenoids

510 - 700 - 770

Gitelson et al., 2002

2. Non-destructive retrieval of chlorophylls, carotenoids and anthocyanins contents from canopy transmittance spectra

Thanks

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