Influence of forest modeling on LAI and chlorophyll content estimation with radiative transfer inversion for a woodland savanna

Thomas Miraglio[1,2] Karine Adeline[1] J.P. Gastellu-Etchegorry[3]
Margarita Huesca[4] Susan Ustin[4] Xavier Briottet[1]

[1]ONERA, DOTA/POS, Toulouse

[2]Université Fédérale Toulouse Midi-Pyrénées

[3]CESBIO, Toulouse

[4]CSTARS, University of California, Davis

Plan

Context

Figure: A mediterranean forest.

Mediterranean woodland savannas are highly heterogenous, with low Leaf Area Index (LAI) and Canopy Cover (CC): canopy modeling should rely on 3D Radiative Transfer Models (RTM).

The DART model has been chosen for this study.

Objectives

- A widespread method to estimate Chlorophyll (C_{ab}) and LAI from remote sensing is inversion of hyperspectral acquisitions using LUTs (Look-Up Tables) generated by radiative transfer models (RTM).

- The objective of this work is to evaluate the influence of forest representation within the DART model on LAI and C_{ab} estimation precision over sparse forests.

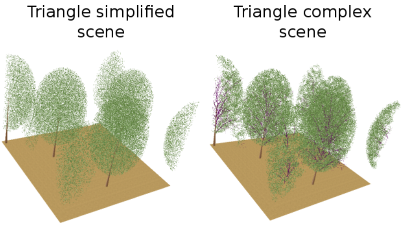


Figure: Different DART modelings of the same scene.

Data

Both hyperspectral acquisitions and field data are available at Tonzi Ranch for summer 2014.

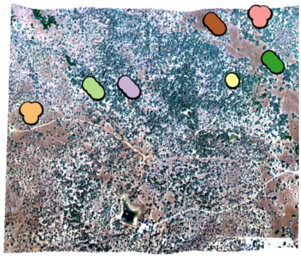


Figure: Field data locations within the site.

Figure: Tonzi Ranch woodland savanna.

Field data:

- Leaf biochemistry data measured in laboratory
- LAI derived from DHP using the Hemiview software

Method

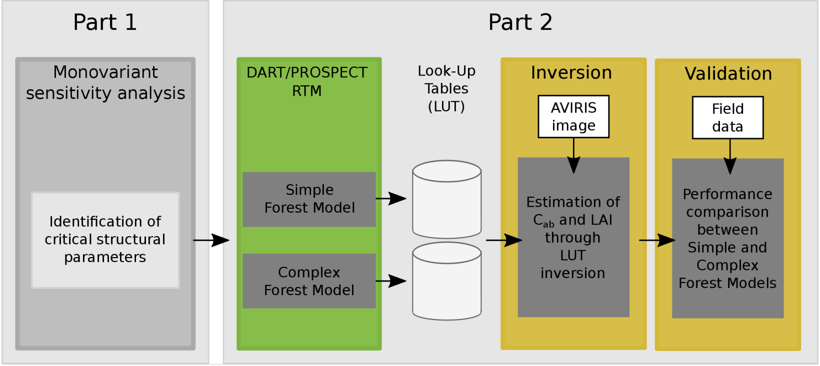
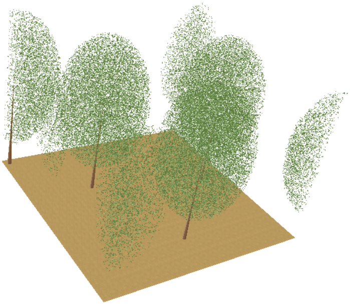


Figure: Flowchart of the methodological approach.

DART modeling

Simplified Forest Model:

- ellipsoïdal crowns
- no branches
- homogeneous crowns
- spherical LAD
- mean tree height



Biochemistry	**LAI** $[m^2.m^{-2}]$	**CC** [%]
200 different (C_{ab},C_{ar},EWT,LMA) combinations	0.4 0.8 1.3	30 50 90

Table: Base characteristics of the modeled scenes.

Sensitivity analysis

Sensitivity study on

- Vegetation indices: gNDVI (C_{ab}) and NDVI (LAI)
- Reflectance spectra: 0.5-0.75μm (C_{ab}), 0.75-2.45μm (LAI)

Parameter	**Base**	**Sensitivity**
LAD	spherical	erectophil
branches	none	modeled
clumping	none	50% holes, heterogeneous radial distribution
tree height	mean	mean +/- standard deviation
bark reflectance	*Quercus Douglasii*	*Pinus sabiniana*

Table: Variable parameters of the sensitivity analysis.

$$gNDVI = \frac{R780 - R550}{R780 + R550}$$

$$NDVI = \frac{R833 - R677}{R833 + R677}$$

Variations induced by the structural parameters will be compared to reference values corresponding to uncertainties of $5\mu g.cm^{-2}$ C_{ab} and $0.2m^2/m^2$ LAI.

Sensitivity analysis results

	C_{ab}		LAI	
	gNDVI diff. [%]	**SAM** 0.5-0.75μm [°]	**NDVI diff.** [%]	**SAM** 0.75-2.45μm [°]
Reference	2.6	0.66	7.4	1.30
LAD	1.0	***1.38***	***5.4***	0.76
branches	***2.6***	***0.83***	3.6	0.74
clumping	0.5	***0.64***	2.4	0.32
tree height	0.2	0.25	1.0	0.15
bark reflectance	0.1	0.10	0.3	0.10

Table: Median absolute relative differences between the base cases and their modified counterparts.

- Vegetation indices: LAD and branches have a significant influence on both VI
- Reflectance spectra
  - C_{ab}: LAD, branches and clumping all have strong effects
  - LAI: no single structural parameter is critical, combinations may be

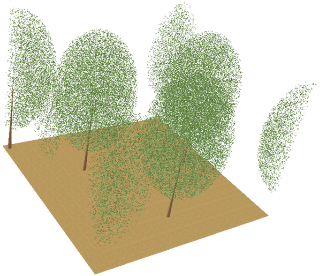
DART modeling

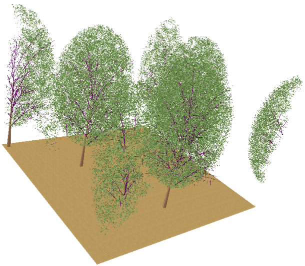
Simplified Forest Model:

- ellipsoïdal crowns
- no branches
- homogeneous crowns
- spherical LAD
- mean tree height

Complex Forest Model:

- ellipsoïdal crowns
- **branches**
- **leaf clumping**
- **erectophil LAD**
- mean tree height





AVIRIS image inversion

Parameters	Range	Step		# values
CC	10-90	20	%	5
LAI	0.1-1.9	0.3	$m^2.m^{-2}$	7
C_{ab}	10-60	10	$\mu g.cm^{-2}$	6
C_{ar}	2-22	4	$\mu g.cm^{-2}$	6
C_m	0.001-0.016	0.003	$g.cm^{-2}$	6
C_w	0.001-0.021	0.004	cm	6

Table: Variable input parameters used for the LUT generation.

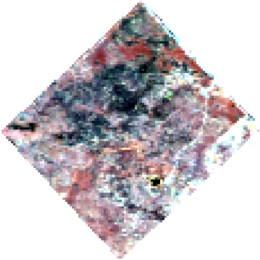
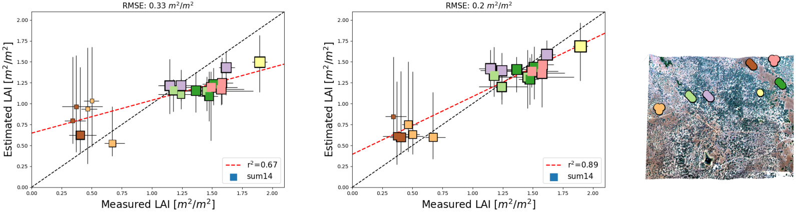


Figure: AVIRIS RGB composition - summer 2014.

Two LUTs are generated:

1. "SFR" LUT using the Simplified Forest Model
2. "S" LUT taking into account the structural elements identified in the sensitivity analysis

Performances: LAI estimations

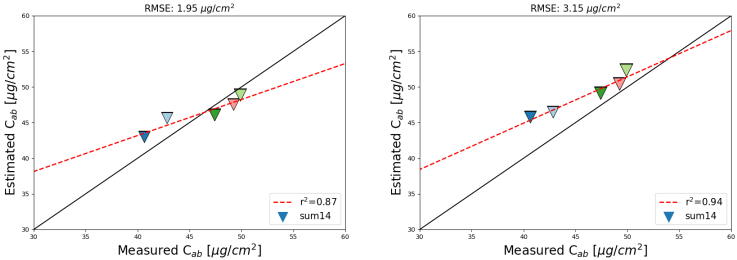


(a) SFR LUT (b) S LUT (c)

Figure: LAI estimations using the SFR scenario (a) and the S scenario (b). Marker colors correspond to location within the site (c). Inversion done using NDVI as a criterion.

LAI estimations with the S model have lower RMSE and better coherency.

Performances: C_{ab} estimations



(a) SFR LUT

(b) S LUT

Figure: C_{ab} estimations using the SFR scenario (a) and the S scenario (b). Inversion done using gNDVI as a criterion.

No clear gain in C_{ab} estimations: RMSE is higher, as is R^2.

Low number of validation points: more data is needed.

Conclusion and limitations

Conclusion

- LAD, clumping and branches have a significant influence on the scene reflectance spectra and common VI of sparse forests
- Taking tree structural elements into account within the RTM improves LAI estimations
- C_{ab} estimations however seem not to be improved, but few validation points are available yet

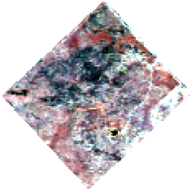
Limitations

- Soil reflectance influence has not been considered
- Different tree distributions within the DART elementary scene may be considered: only one was modeled in this study

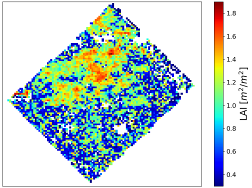
Perspectives

- Additional validation data will be added, as AVIRIS images and field data are available for summers 2013, 2016 and fall 2013
- Include the PROSPECT parameter N in the sensitivity analysis
- Benefits from precise tree modeling within DART using TLS data will be assessed (collaboration with Crystal Schaaf, UCB)

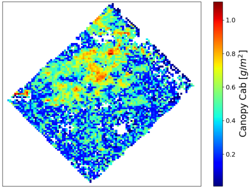
Thank you for your attention.



Tonzi - summer 2014



LAI



Canopy C_{ab} content