Assessing and monitoring water stress condition of arid vegetation using Remote Sensing

The Atacama Desert Northern Chile case

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Contents

- Background (What am I doing here?)
- Problem definition and PhD research
- Highlights for monitoring arid ecosystems
On Earth:

- 1569 million ha of arid areas
- 978 million ha of hyperarid areas (true deserts)
- Arid + hyperarid = 19.6% of terrestrial ecosystems
Background

Arid ecosystems = water demand problem

- Environmental impact assessment (EIA)
- Water management
- Biodiversity conservation
- Natural ecosystems
- Human consumption
- Industry (i.e. mining, fuel)
Assessing arid ecosystems is always a problem...

Because:
- Small dots or patches of vegetation within vast arid areas
- Presence of endemic / ‘weird’ species high adapted to water stress
  - Natural dynamic is unknown → responses to water stress unknown
  - High adaptations to live under water stress → symptoms are hard to detect and not evident in a short time
Examples: Frankincense tree in North Ethiopia
Examples: Saxaul shrublands in the Gobi Desert, Mongolia
More examples

- Rub Al Khali desert
- Arabian peninsula

- Saxaul shrublands in the Gobi Desert, Mongolia
- Namibia desert
My study area: Tamarugo forest in Atacama Desert
Tamarugo’s adaptations: avoiding direct sun irradiation

From Planophyle in the morning

To Erectophyle in the afternoon
Monitoring vegetation in Deserts

Don’t forget...

- Small dots within large desert areas

- Weird plants

Welwitschia mirabilis, Namibia desert
Tamarugo forest: where is it?

Just in Chile!

GIMMS NDVI 15 day composite
January 2006
6.000 m pixel resolution

Atacama Desert
Tamarugo forest: where is it?
Tamarugo forest: where is it?

Landsat 7 NDVI
Dec 2002
30 m pixel resolution

Pampa del Tamarugal
Tamarugo forest: where is it?
Tamarugo forest: where is it?
Tamarugo forest: where is it?
PhD research
How to assess and monitor arid vegetation using RS?

Remote sensing domain

- Historical Remote Sensing Imagery
  - Time series analysis

- Upscaling techniques

- Modern Remote Sensing Imagery & Spectroscopy
  - Remote Sensing analysis techniques

- Dynamic water condition in time
- Current water condition
- Water management
- Monitoring of future water condition
- Identification of non-natural water condition

Water condition of vegetation

Past  Present  Future
Monitoring arid ecosystems
Users of the monitoring system

- Chilean Environmental impact assessment system (SEIA)
- Iquique city and small towns
- Mining companies
- Tamarugo forest
- Managers of the P. del Tamarugal National Reserve
- NGO’s
Looking for good indicators

The ‘3x3’ experiment

- 9 plants in a climate chamber
- 15 day with NO water supply
- Spectral measurements
- Physiological measurements
Spectral response (under water stress)

No water stress → Under water stress

Leaf water content

Days 1 to 3

Days 12 to 14
Explaining changes in reflectance using SLC

Simulation v/s measurements

DAY 1 → DAY 14

Explained by:

✓ $C_w$ 0.023 → 0.011 (measured values)

✓ $LAI$ 1.08 → 0.85 (optimized values)

✓ $LIDF_a$ -0.30 → 0.14 (values close to zero: uniform distribution)
LAI and green fraction

Object-based estimations of green canopy fraction

LICOR measurements
Object based image analysis

- Using high spatial resolution imagery
- Identification of single trees
- Canopy polygons to extract spectral information
- Veg. indices calculated for each tree
WV2 – LAI – Green fraction

\[ \text{LAI (green+brown)} \times \text{Green fraction} = \text{Green LAI} \]
Highest values of NDVI in Winter (July)????

MODIS TERRA NDVI 2002-2012

1 MODIS’ pixel 250x250 m
Trees with GOOD water condition
Why higher in July?

NDVI from FieldSpec diary cycles
3 trees, 3 days
NDVI varies with Solar radiation!

FieldSpec experiment:
- Solar radiation increases
- Leaves moves to a more electrophile LIDF
- NDVI goes down
- Solar radiation in Summer higher than Winter
- NDVI values lower in Summer than Winter!
Monitoring water condition in time

MODIS:
- NDVI Terra > NDVI Aqua
- Terra more sensitive for detecting changes
- Seasonal effect (opposite to expected) due to LIDF adjusting
- ΔTerra-Aqua for early water stress detection?
No water, no movement!

Anatomical study in collaboration with U. de Chile (Dr. Paulette Naulin)
Impact for RS estimations

MODIS NDVI July = 0.44  
MODIS NDVI Sep = 0.35  
PULVINAR FACTOR= 0.25
Thanks for your attention.