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
Background: 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)
- Human consumption
- Industry (i.e. mining, fuel)
- Natural ecosystems
- Water management
- Biodiversity conservation
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

Management guide for sustainable production of frankincense

A manual for extension workers and companies managing dry forests for resin production and marketing.

Mulugeta Senenti
Haddemariam Kassa
Examples: Saxaul shrublands in the Gobi Desert, Mongolia
More examples

Rub Al Khali desert
Arabian peninsula

Murzut desert, Libya
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
Tamarugo forest: where is it?

Just in Chile!

GIMMS NDVI 15 day composite
January 2006
6.000 m pixel resolution
Tamarugo forest: where is it?

MODIS NDVI
16 day composite
Dec 2008
500 m pixel resolution

Pampa del Tamarugal
Tamarugo forest: where is it?
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2 Groundwater aquifers:
• Pampa del Tamarugal
• Llamara

4 areas, 4 salt flats!
• Zapiga
• Pintados
• Bellavista
• Llamara
PhD research
How to assess and monitor arid vegetation using RS?

Remote sensing domain

- Historical Remote Sensing Imagery
  - Time series analysis
  - Dynamic water condition in time

- Upscaling techniques

- Modern Remote Sensing Imagery & Spectroscopy
  - Remote Sensing analysis techniques
  - Current water condition

- Water management
  - Physiological measurements
  - 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
- Managers of the P. del Tamarugal National Reserve
- Mining companies
- Tamarugo forest
- 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)

Leaf water content

No water stress → Under water stress

Days 1 to 3

Days 12 to 14
Explaining changes in reflectance using SLC

Simulation v/s measurements

DAY 1 → DAY 14

Explained by:

- **Cw**: 0.023 → 0.011 (measured values)
- **LAI**: 1.08 → 0.85 (optimized values)
- **LIDFa**: -0.30 → 0.14 (values close to zero: uniform distribution)
Sensitivity analysis

RS features for assessing **Leaf Area Index (LAI)**

- **NDVI**
- **Chlorophyll red edge index**
Sensitivity analysis

RS features for assessing **Canopy Water Content (CWC)**

![Graph showing relationship between Water Index (WI) and Canopy Water Content (CWC)]

- Water index
- Derivative [1015-1050nm]

\[ y = 1.797E-05 + 6.822E-03 \times x \]
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
Object based image analysis
OBIA validation dataset
Next steps

- Upscaling analysis
- Time series analysis of Landsat and/or Modis data
Example MODIS time series

MODIS NDVI composite 16 days

Trends 2008 – 2010
Thanks for your attention.