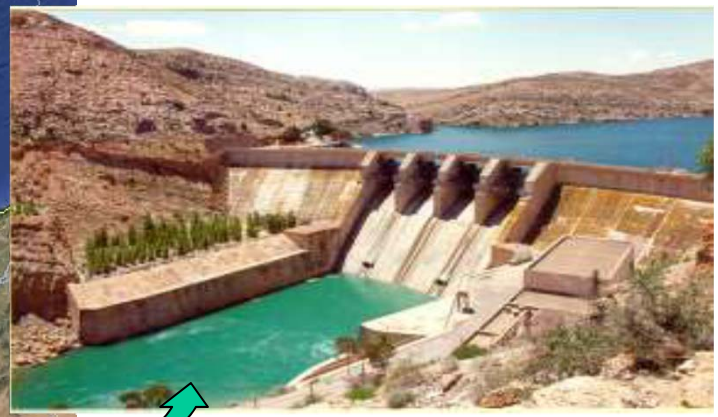
# Quantitative Assessment of Deforestation in Moulouya River Watershed (Morocco) Using an Innovative Remote Sensing Approach

*Fernando J. Aguilar [(a)], Abderrahim Nemmaoui [(a)], Manuel Á. Aguilar [(a)], Mimoun Chourak[(b)], Yassine Zarhloule[(c)], Andrés M. García-Lorca[(d)]*

*(a) Department of Engineering. University of Almería, Spain.*
*(b) National School of Applied Sciences, Mohammed the First University, Oujda, Morocco*
*(c) Technology High School, Mohammed the First University, Oujda, Morocco*
*(d) Department of Geography, History and Humanities. University of Almería, Spain.*

COOPTRUST Collaboration, Opportunity and Trust
PROGRAMA Cooperación Transfronteriza España-Fronteras Exteriores
Unión Europea
Fondo Europeo de Desarrollo Regional
*Invertimos en su futuro*

# Study Site

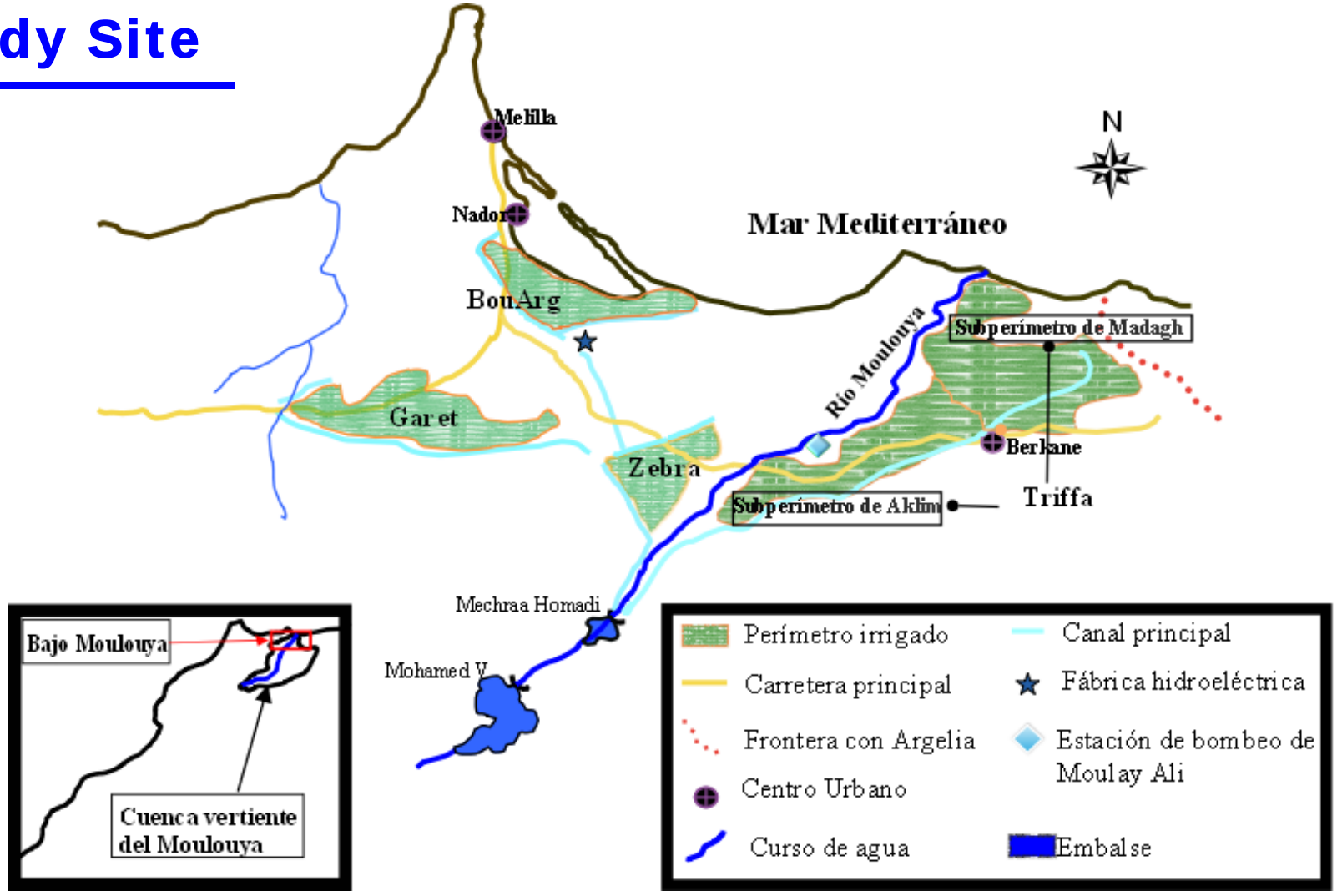
Watershed = 50000 Km2

Initial water storage capacity = 730 Hm3

High Silting Ratio

Current water storage capacity = 411 Hm3

# Study Site


Melilla
Nador
Mar Mediterráneo
N
BouArg
Río Moulouya
Subperímetro de Madagh
Garet
Zebra
Berkane
Triffa
Subperímetro de Aklim
Mechraa Homadi
Mohamed V
Bajo Moulouya
Cuenca vertiente del Moulouya
Perímetro irrigado
Canal principal
Carretera principal
Fábrica hidroeléctrica
Frontera con Argelia
Estación de bombeo de Moulay Ali
Centro Urbano
Curso de agua
Embalse

## Study Site

Alfa-Grass

Stipa tenacissima L.

Thymus vulgaris (Thyme)

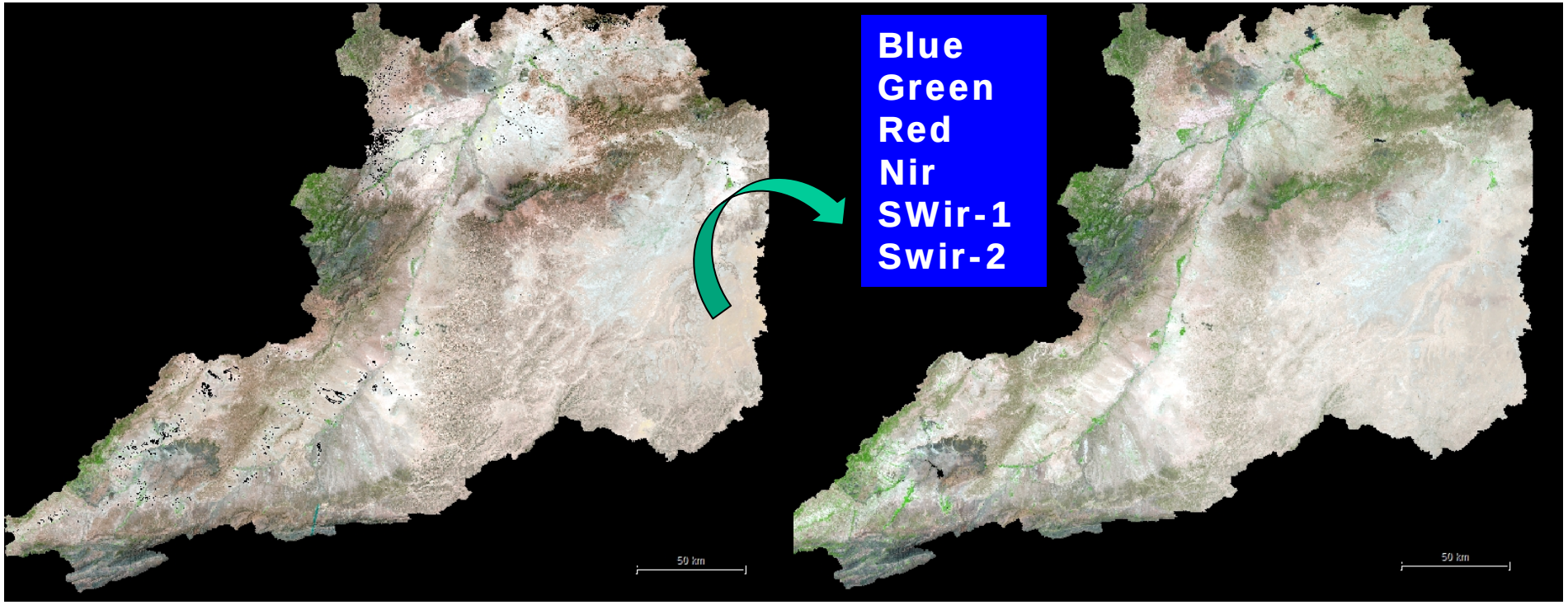
Rosmarinus officinalis (Rosemary)

Lavandula dentata (Lavender)

# Datasets

1984. Landsat 5 TM Orthomosaic

2013. Landsat 8 OLI Orthomosaic

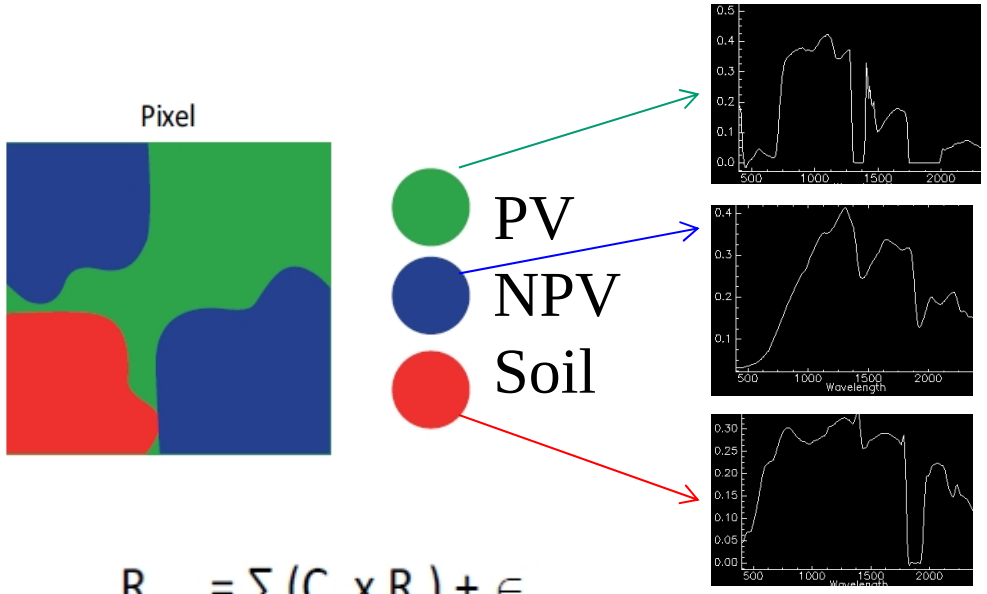



Radiometric correction (digital radiance at sensor) and Atmospheric correction ("6S" Model; Vermote et al., 1997) to obtain **ground reflectance images**

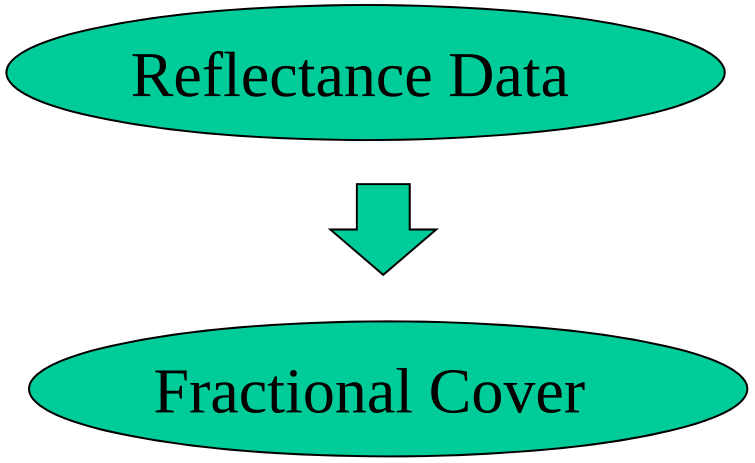
# Methods

## 1. Pixel-based Analysis. Spectral Mixture Analysis (SMA)

### Monte Carlo Unmixing Algorithm (AutoMCU)



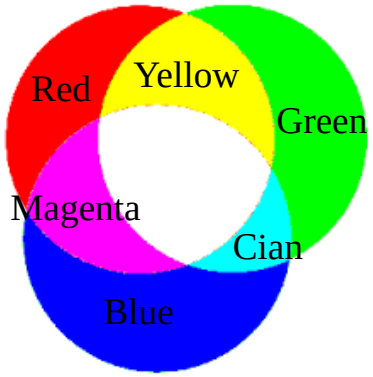

$$R_{pixel} = \sum (C_x \times R_x) + \in$$

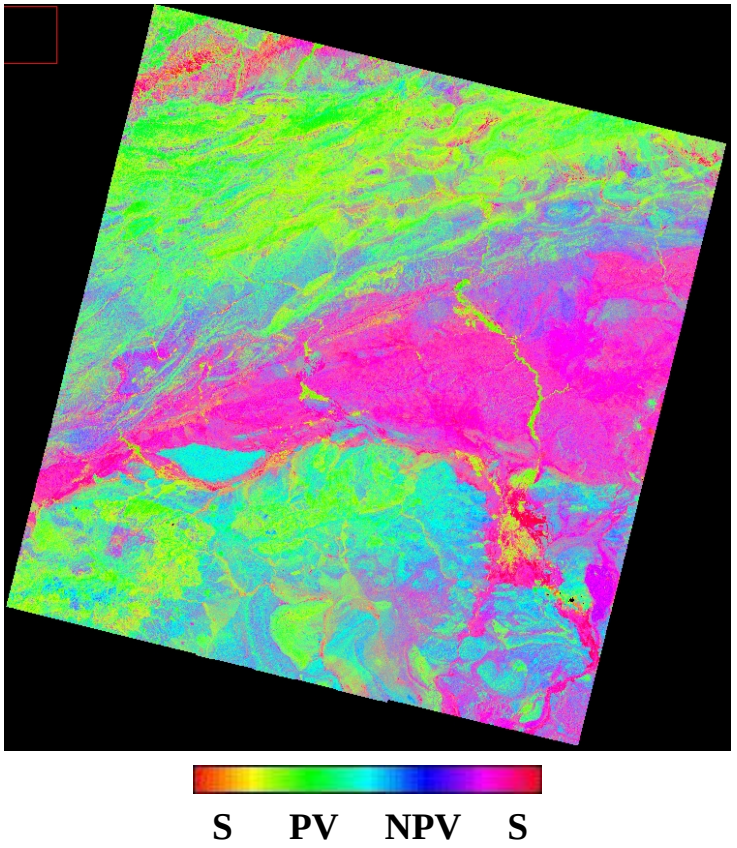


# Methods

## 1. Pixel-based Analysis. Spectral Mixture Analysis (SMA)

Non-forested areas appear predominantly as **dead vegetation (NPV)** and **bare soil (S)**.
Forested areas appear as **Live vegetation (PV).**
**Yellow tones** represent areas in which there is a mix of live vegetation and bare soil.



# Methods

## 2. Vegetation Indices

**Normalized Digital Vegetation Index**

$$\mathrm{NDVI} = \frac{Nir - Red}{Nir + Red}$$

**Modified Simple Ratio**

$$\mathrm{MSR} = \frac{\frac{Nir}{Red} - 1}{\left(\frac{Nir}{Red}\right)^{0.5} + 1}$$

**Normalized Differential Senescent Vegetation Index**

$$\mathrm{NDSVI} = \frac{SWir1 - Red}{SWir1 + Red}$$

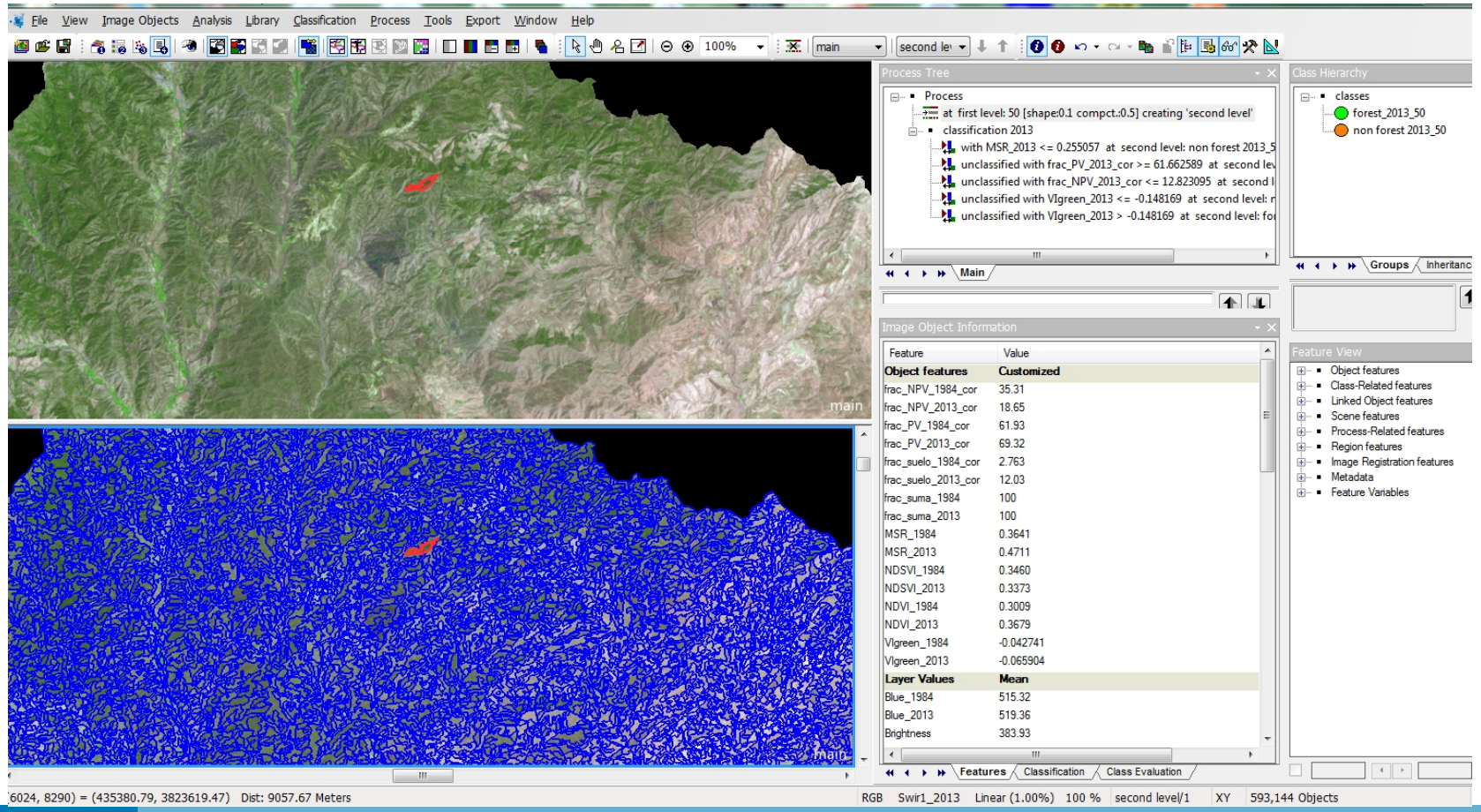
**Green Vegetation Index**

$$\text{Green VI} = \frac{Green - Red}{Green + Red}$$

# Methods

## 3. Object Based Image Analysis (OBIA)

**Red**
**Nir**
**SWir-1**



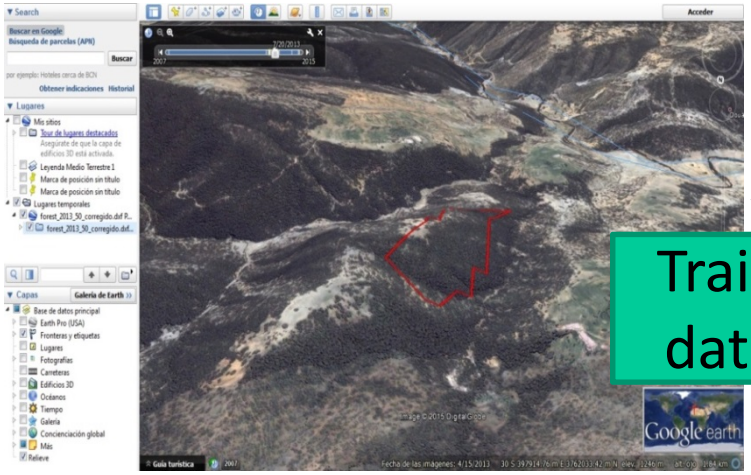
# Methods

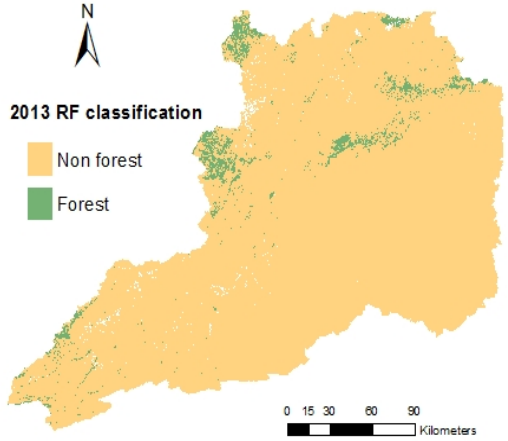
## 4. Classification and Accuracy Assessment

**RANDOM FOREST**

Object-Based Features Vector

$$\overline{v_i} = \begin{pmatrix} x_1 & x_2 & \dots & x_n \end{pmatrix}_i$$






Training and Validation dataset (1310 objects)

# Results

## 1. Features importance

| Features | Importance |
|---|---|
| NDVI_2013 | 1,000000 |
| Fraction PV 2013 | 0,977034 |
| Fraction Soil 2013 | 0,834373 |
| GVI_2013 | 0,773432 |
| MSR_2013 | 0,753162 |
| NDSVI_2013 | 0,748575 |
| Fraction_NPV_2013 | 0,615447 |

# Results

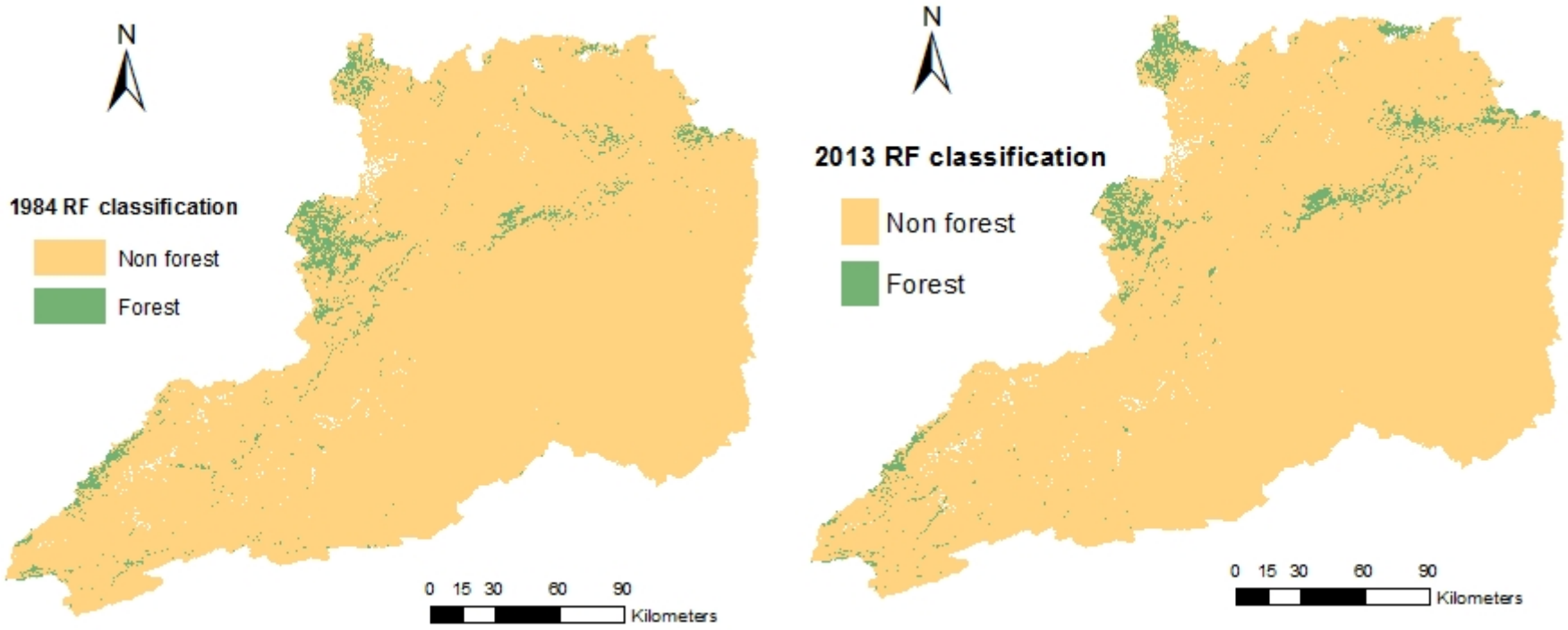
## 2. Accuracy Assessment

| | | Classification data predicted by Random Forest Model | | Total |
|---|---|---|---|---|
| | | Forest | Non Forest | |
| **Observed data (Ground Truth)** | Forest | 127 | 15 | 142 |
| | Non Forest | 16 | 247 | 263 |
| | Total | 143 | 262 | 405 |
| | **User's accuracy** | **Producer's accuracy** | **Overall accuracy** | |
| **Forest** | **88.81%** (CI: 82.47% to 93.47%) | **89.44%** (CI: 83.18% to 93.97%) | **92.35%** (CI: 89.31% to 94.74%) | |
| **Non Forest** | **94.27%** (CI: 90.73% to 96.76%) | **93.92%** (CI: 90.31% to 96.48%) | | |

# Results

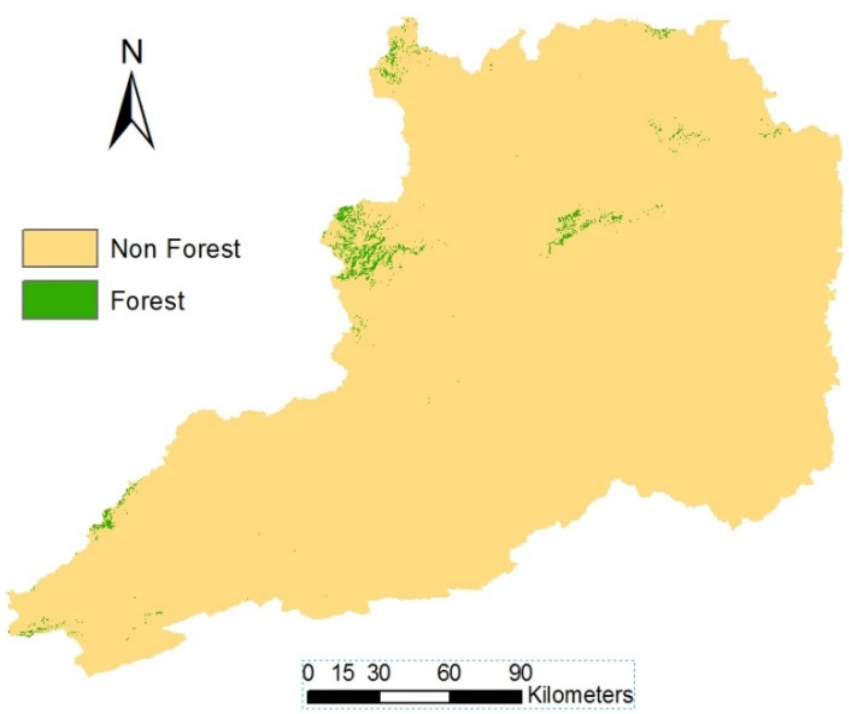
## 2. Classification Results

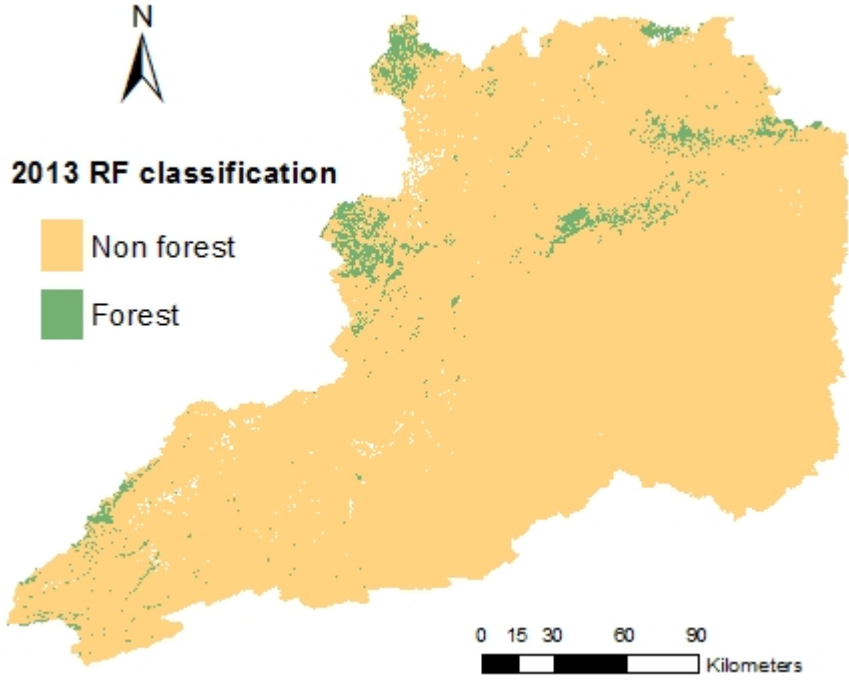
Random Forest 1984-2013. Forested areas increment around 8800 has (Δ 5.3%)



# Results

## 2. Classification Results (Pattern validation)




Tree cover in the year 2000, defined as canopy closure for all vegetation taller than 5 m in height. Data taken from Hansen et al. [19].

# Conclusions

The accuracy results attained in this work, specially the fact of working on a normalized and reduced set of features, make our approach highly recommended to multi-temporal monitoring of forest evolution at regional scale in arid and semiarid areas

This information can be used to assess the efficacy of past actions and design future strategies to preserve and improve the vulnerable and scarce forests located at the working area.

# Thank you very much for your kind attention

COOPTRUST
Collaboration, Opportunity and Trust

PROGRAMA
Cooperación Transfronteriza
España-Fronteras Exteriores

Unión Europea
Fondo Europeo de Desarrollo Regional
*Invertimos en su futuro*