LIVE FUEL MOISTURE CONTENT MODELING USING SPECTRAL, METEOROLOGICAL AND TOPOGRAPHIC DATA IN THE VALENCIAN REGION

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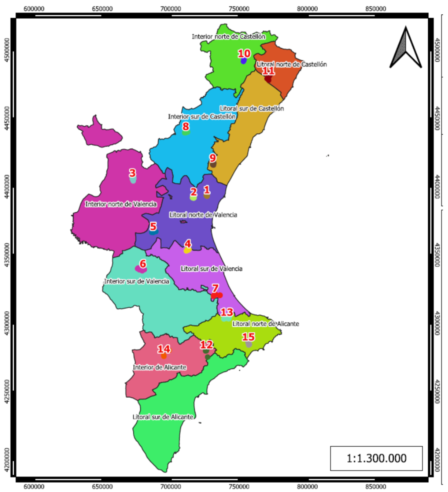
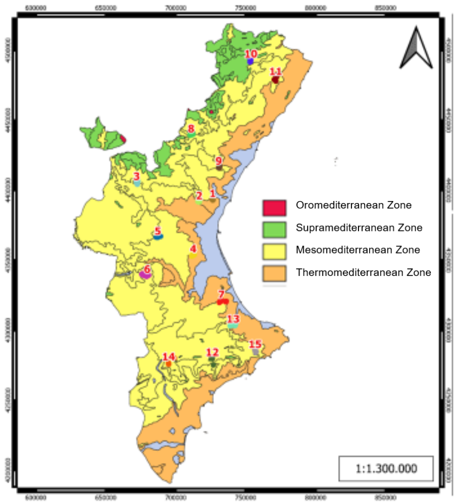
INTRODUCTION

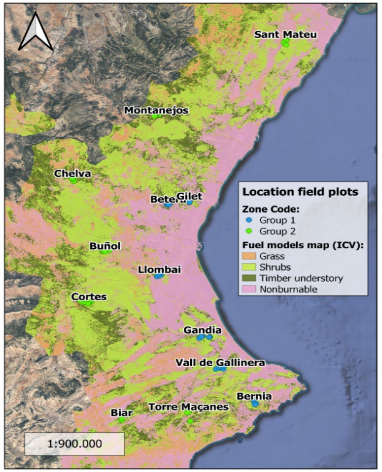
Wildfire is one of the most impactful natural disasters that can occur in any forested area. In recent years, the **frequency and intensity** of wildfires **have increased** significantly due to climate change, human activities, and natural factors. One of the most important factors to consider in **relation** to **forest fires** is the live fuel moisture content **(LFMC)**. It is a crucial parameter for fire managers to **estimate** the fire danger level, **predict** fire behavior, and **plan** fire suppression activities.

STUDY AREA AND FIELD DATA

$$LFMC = \frac{Wf - Wd}{Wd} * 100$$







Field data : LFMC Mediterranean species of Spain

Area: Valencian Region, Spain

Number of study clusters: 15

Sampling frequency: biweekly

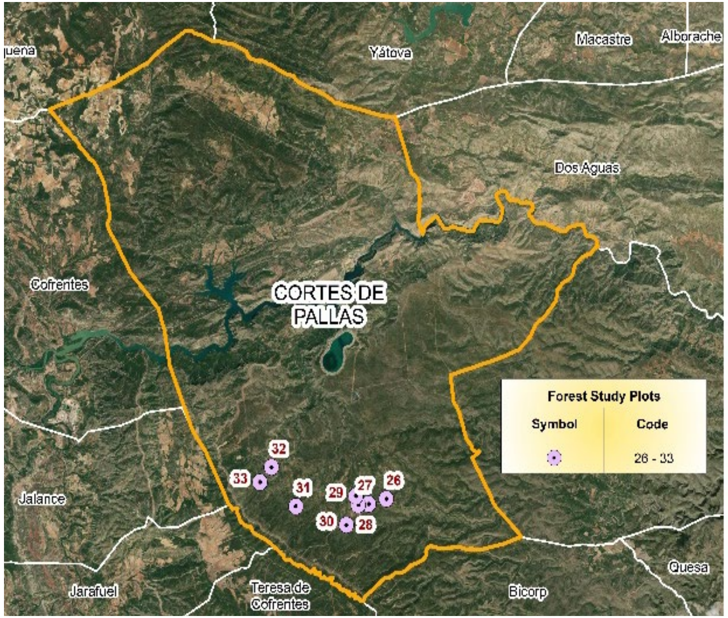
Study period: June 2020 - November 2021

Number of study plots: 88

Data collection radius: 10 m

Total number of observations per species and plot: 36

CHARACTERISTICS OF THE PLOTS



Location of the study plots in Cortes de Pallas

- **Main fuel types** considered: **SH4, SH5** and **TU2, TU3**. They correspond to shrubland and woodland, correspondingly.
- **Elevation:** between **175** and **1050 masl**.
- **Slope:** 1.34º - 36.1º
- The most representative species considered for the measurement of LFMC were ***Pinus halepensis, Pinus pinaster, Quercus coccifera, Quercus ilex, Juniperus oxycedrus, Ulex parviflorus, Rosmarinus officinalis*** and ***Cistus albidus.***
- Indicator parameter for the LFMC estimations: **weighted average** of **all the species** from each plot and the **LFMC of *Rosmarinus officinalis***.

OBJECTIVES

GENERAL OBJECTIVE

Evaluate and compare different methodologies used for estimating LFMC for *Rosmarinus officinalis*

SPECIFIC OBJECTIVES

- Use different spectral, meteorological and topographic variables as predictors
- Fit and evaluate designed and validated LFMC models.
- Analyze the advantages and disadvantages of the designed models

PREDICTOR VARIABLES

Spectral

NMDI (Normalized Multi-band Drought Index)
TCARI (Transformed Chlorophyll Absorption Index)
EVI (Enhanced Vegetation Index)
Vgreen (Vegetation Index-Green)
NDMI (Normalized Difference Moisture Index)
OSAVI (Optimized Soil Adjusted Vegetation Index)

Meteorological

Agencia Estatal de Meteorología

p60 (accumulated precipitation in the 60 days*)
t60 (average daily temperature in 60 days*)
HUmin15 (average in the last 15 days* of the minimum daily relative humidity)

Topographic

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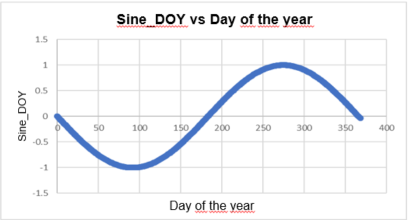
slope
altitude
orientation

Seasonal

DOY_SIN
DOY_COS



[0, 366]

$[-\pi, \pi]$

DOY_ SIN
DOY_ COS

* before to data collection in the field

METHODOLOGIES

1

Linear Models

A statistical method for modeling the linear relationship between LFMC and multiple independent variables.

2

GAM - Generalized Additive Models

An extension of linear models that allows for nonlinear relationships through smooth functions

3

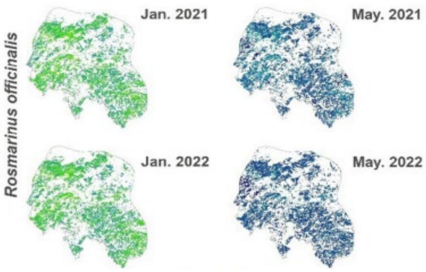
Random Forest

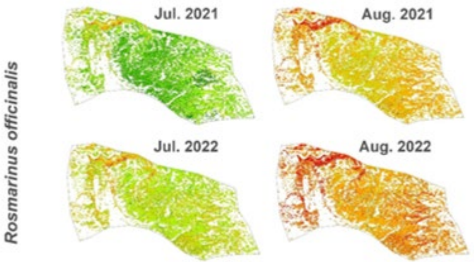
An ensemble learning method that constructs multiple decision trees and merges them to improve prediction accuracy.

4

Growing Season Index

A generalized phenology model based on meteorology that allows studying the duration and intensity of the vegetation growing season and better understanding this cycle and its relationship with climatic conditions.

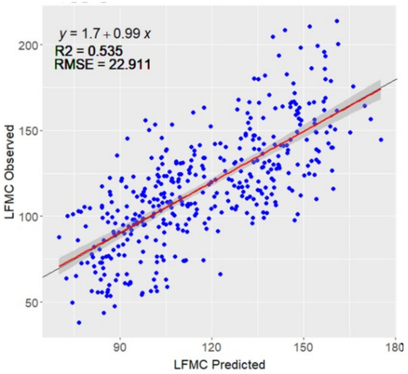


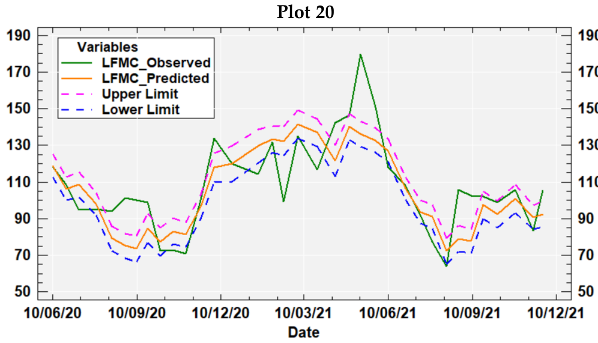


RESULTS

Linear Models

G[1]	Ft[2]	Sp[3]	Formula	Coef[4]	P value	R^2 adj[5] (%)	RMSE[6]	MAE[7]	MBE[8]	# sites
M-M[9]	Sh[10]	Ro[11]	Intercept Vgreen_10mS NMDI_10mS DOY_SIN p60 slope	32.9 68.9 198.2 -23.4 0.1 -1.3	0.03 0.0004 2.5e-10 <2e-16 8.5e-10 5.5e-11	52.1	22.9	18.5	-0.02	15



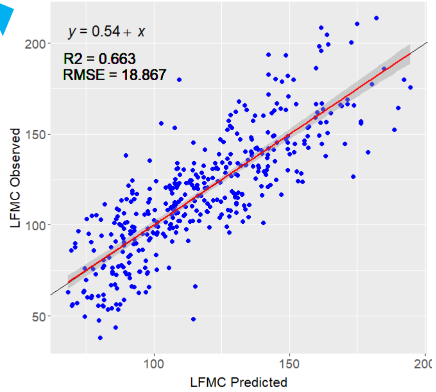


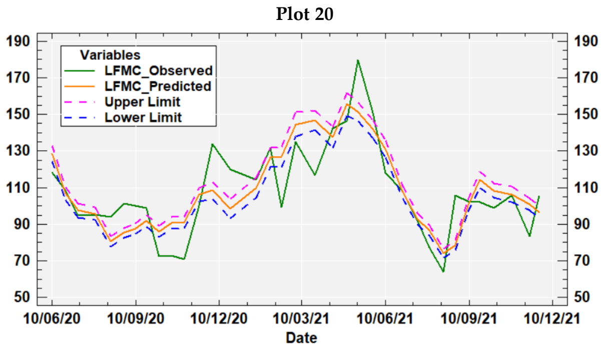
[1] G: group; [2] Ft: fuel type; [3] Sp: species; [4] Coef: model coefficients; [5] R^2 adj: adjusted R^2; [6] RMSE: Root Mean Square Error; [7] MAE: Mean Absolute Error; [8] MBE: Mean Bias Error; [9] M-M: Meso-Mediterranean Zone; [10] Sh: shrub; [11] Ro: LFMC of *Rosmarinus officinalis*.

A: SH4 plot, B: TU2 plot,
Credits: Generalitat Valenciana, “Fuel Types”, Province: Valencia

GAM - Generalized Additive Models

Ft[1]	Sp[2]	Formulation	Parameters[3]	P value	[4]R^2 adj. (%)	RMSE	MAE	MBE[5]
Sh[6]	Ro[7]	LFMC=f(a,	a = 4.62	<2e-16	65.0	19.7	15.3	0.023
		s(Vgreen_10mS),	s(Vgreen_10mS)	0.0069				
		s(NMDI_10mS),	s(NMDI_10mS)	5.6e-05				
		s(doy),	s(doy)	<2e-16				
		s(p60),	s(p60)	<2e-16				
		s(Zone code),	s(Zone code)	<2e-16				
		s(Xcoord,Ycoord))	s(Xcoord,Ycoord)	<2e-16				





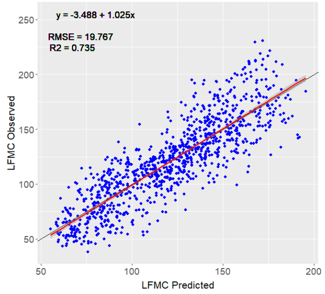
- **Incorporates smooth functions (e.g., splines) of predictors.**
- **Requires careful selection of smoothing parameters.**

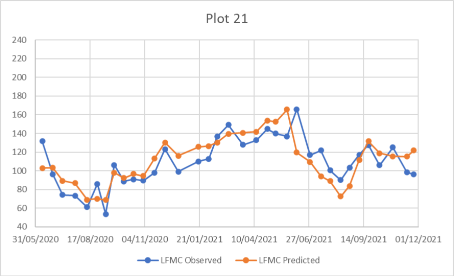
[1] Ft: fuel type; [2] Sp: specie; [3] Parameters: model coefficients; [4]R^2 adj: adjusted R^2; [5] MBE: Mean Bias Error; [6] Sh: Shrub; [7] Ro: LFMC of *Rosmarinus officinalis*

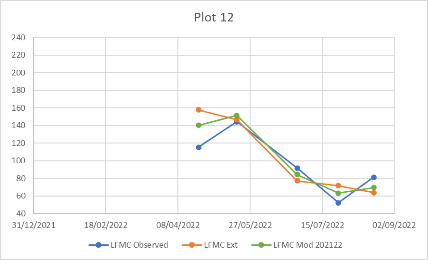
Random Forest Models

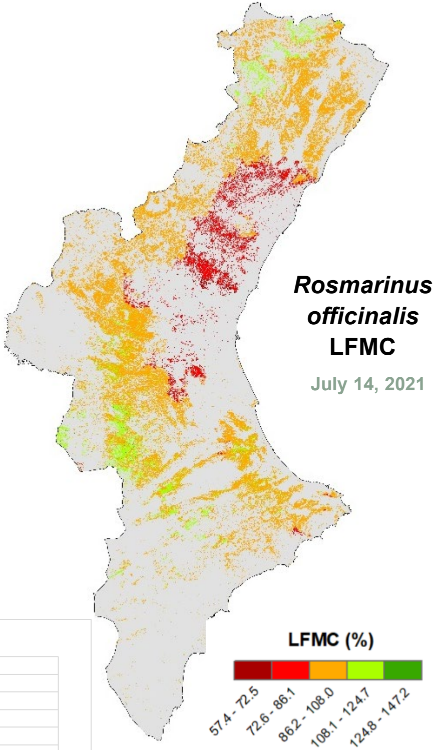
Variables of the model to estimate LFMC of *Rosmarinus officinalis* in SH4 plots

Ft[1]	Sp[2]	Selected variables	R^2 (%)	RMSE	MAE	# sites
Sh[3]	Ro[4]	DOY_SIN DOY_COS p60 t60 HUmin15 TCARI_OSAVI_10mS[5] Ycoord	74.9	19.6	15.5	31



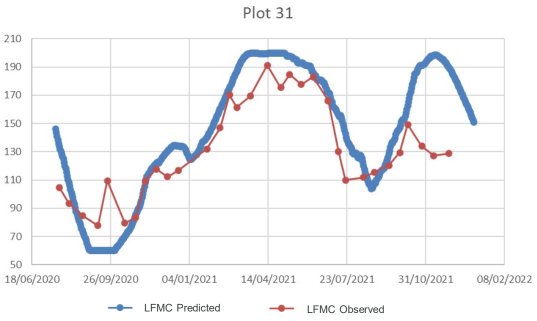






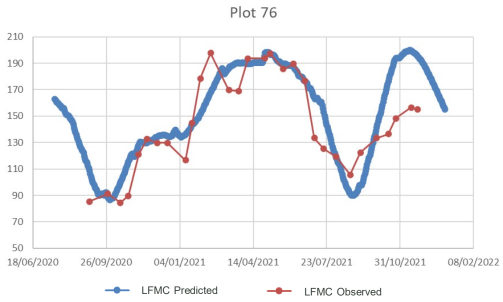
[1] Ft: fuel type; [2] Sp: specie; [3] Sh: Shrub; [4] Ro: LFMC of *Rosmarinus officinalis*; [5] TCARI_OSAVI: TCARI/OSAVI

Growing Season Index



LFMC of *Rosmarinus officinalis*; Cluster: 6; R^2: 75.2%

used to train the model



LFMC of *Rosmarinus officinalis*; Cluster: 13; R^2: 71.25%

Parameter	Value
alfa_temp	-20
beta_temp	0
alfa_vpd	1000
beta_vpd	5000
alfa_photo	30500
beta_photo	36000
alfa_prcp	20
beta_prcp	40
Greenup Threshold - GU	0.0
Max_LFMC	200
Min_LFMC	60

This method needs daily meteorological values of variables such as **temperature, precipitation, relative humidity, vapor pressure deficit, and photoperiod.** Through these and a series of calculations, GSI values are obtained, which are then transformed into LFMC values. Based on these results, the respective prediction models are built for the different study areas, which in this case are the municipal terms where the LFMC data were collected.

Temporal evolution of field observed values (red line) and predicted values of *Rosmarinus officinalis* LFMC (blue line)

CONCLUSIONS

- Spectral variables are able to represent LFMC changes at **spatial and temporal levels**, but in order to **improve the fit** it is convenient to **use information** related to precipitation, temperature, relative humidity, topography and seasonal factors (DOY_SIN, DOY_COS).
- According to the results obtained, each model has advantages and disadvantages that must be taken into account prior to implementation:
    - Best Overall: Random Forest. It is versatile, handles complex data well, and is robust to overfitting and noise. However, it requires significant computational resources and tuning.
    - Best for Interpretability and Simplicity: Multiple Linear Regression. It is easy to interpret and implement, but limited to linear relationships and sensitive to assumptions, (something that we want to avoid in the estimation of the LFMC).
    - Best for Flexible Modeling: Generalized Additive Models. These offered flexibility in capturing nonlinear relationships but can be complex to tune and interpret.
- The GSI methodology has begun to be implemented in the Valencian region and is currently being worked on.

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THANKS!

DO YOU HAVE ANY QUESTIONS?

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