RAMI workshop

# A beta version of a novel RT simulator tool to simulate reflectance at canopy level

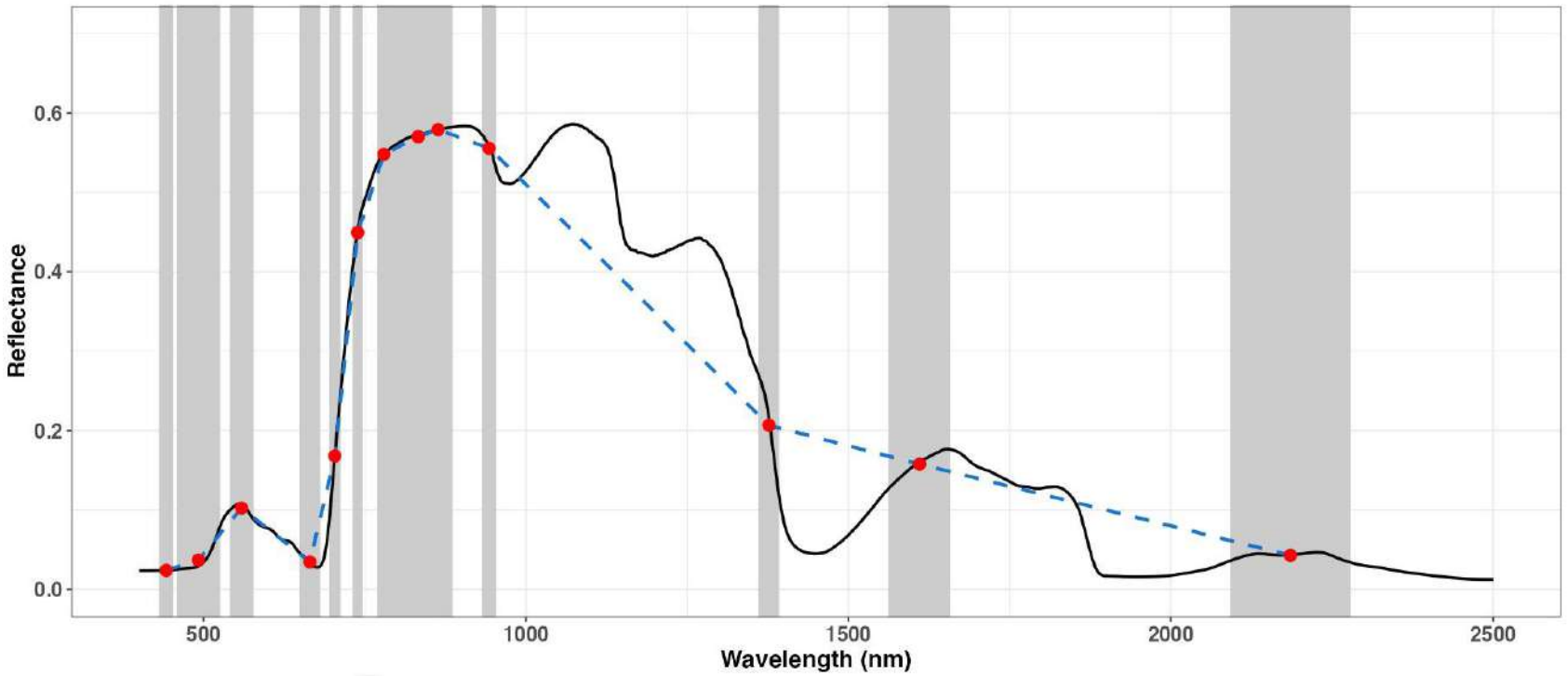
**C. Camino**, Bolyn C., P. S. A. Beck

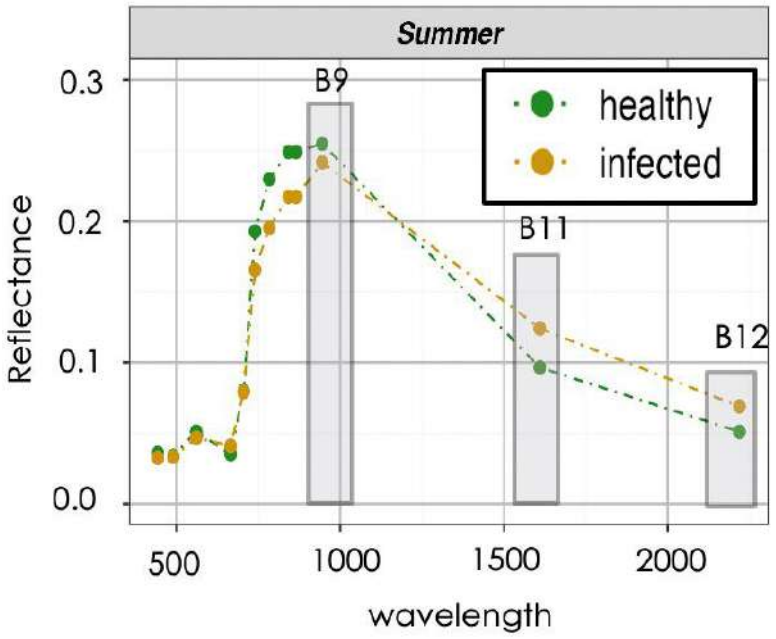
***7-9th June, 2023***

European Commission (EC), Joint Research Centre (JRC), Ispra, Italia.

# Motivation

To contribute to the remote sensing community's understanding of spectral domains .

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# Motivation

1. To contribute to the remote sensing community's understanding of spectral domains.

2. To make it easier to test RTmodels when studying forest canopies.

3. To make it easier to link spectral features and physiological plant traits.

Highly relevant for the the early detection of biotic forest disturbances (e.g., insects and pathogens)

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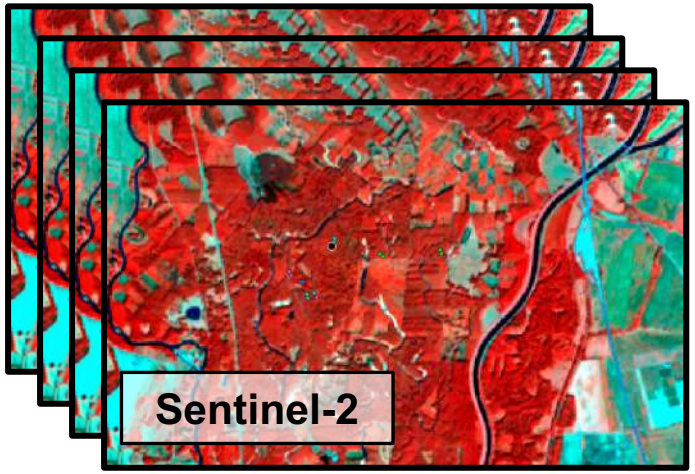
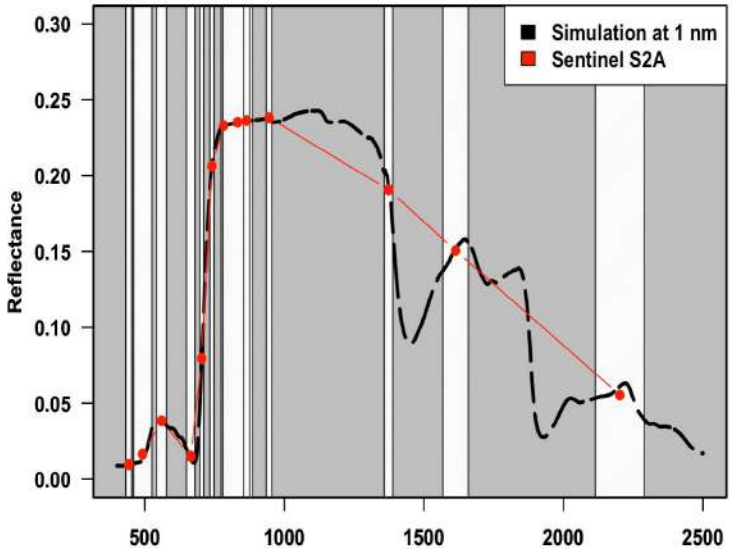
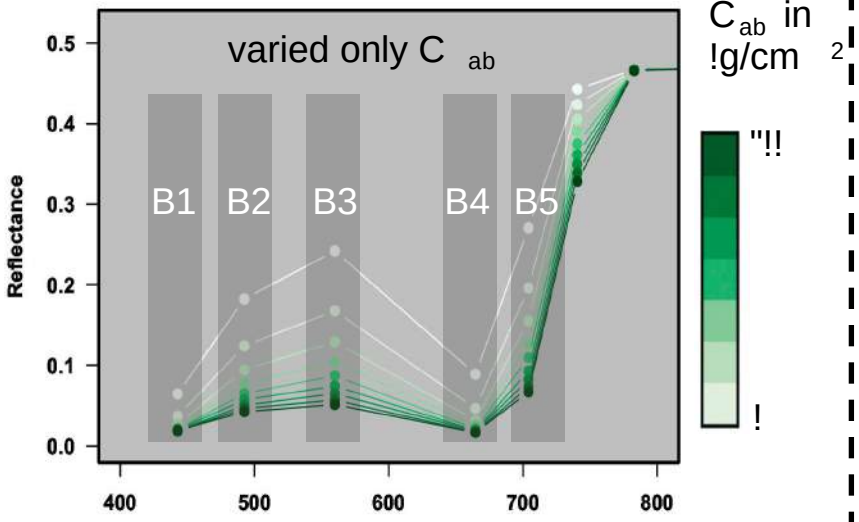
# Plant trait -based Forest Health Monitoring

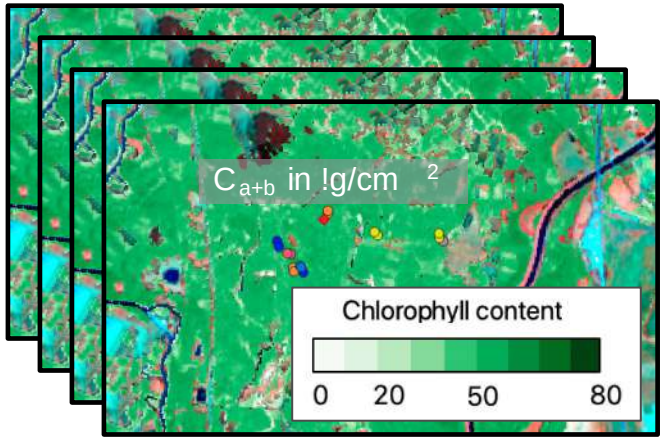
## Copernicus



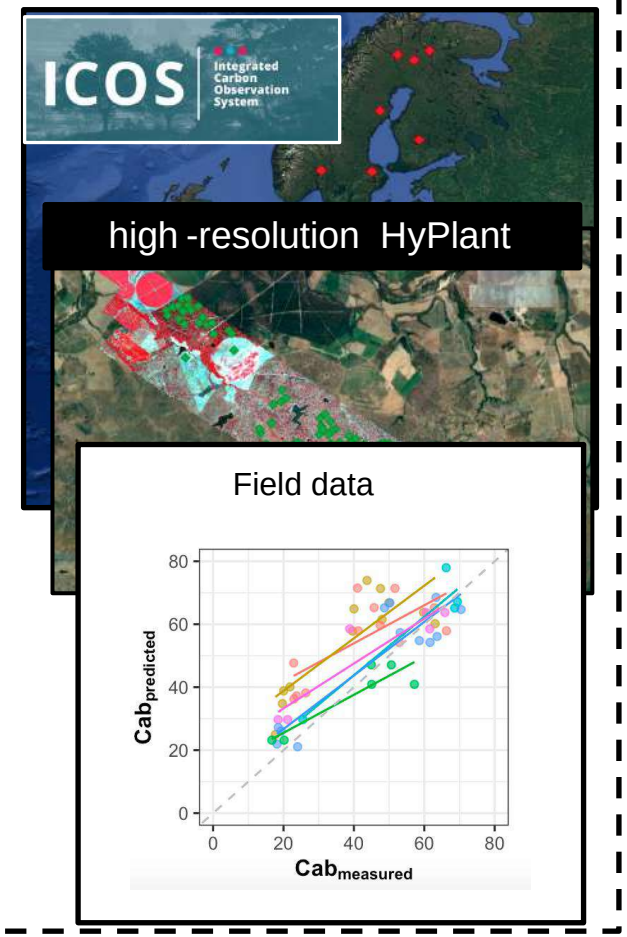

## Radiative transfer models




Plant traits for detecting disturbances

## Validation

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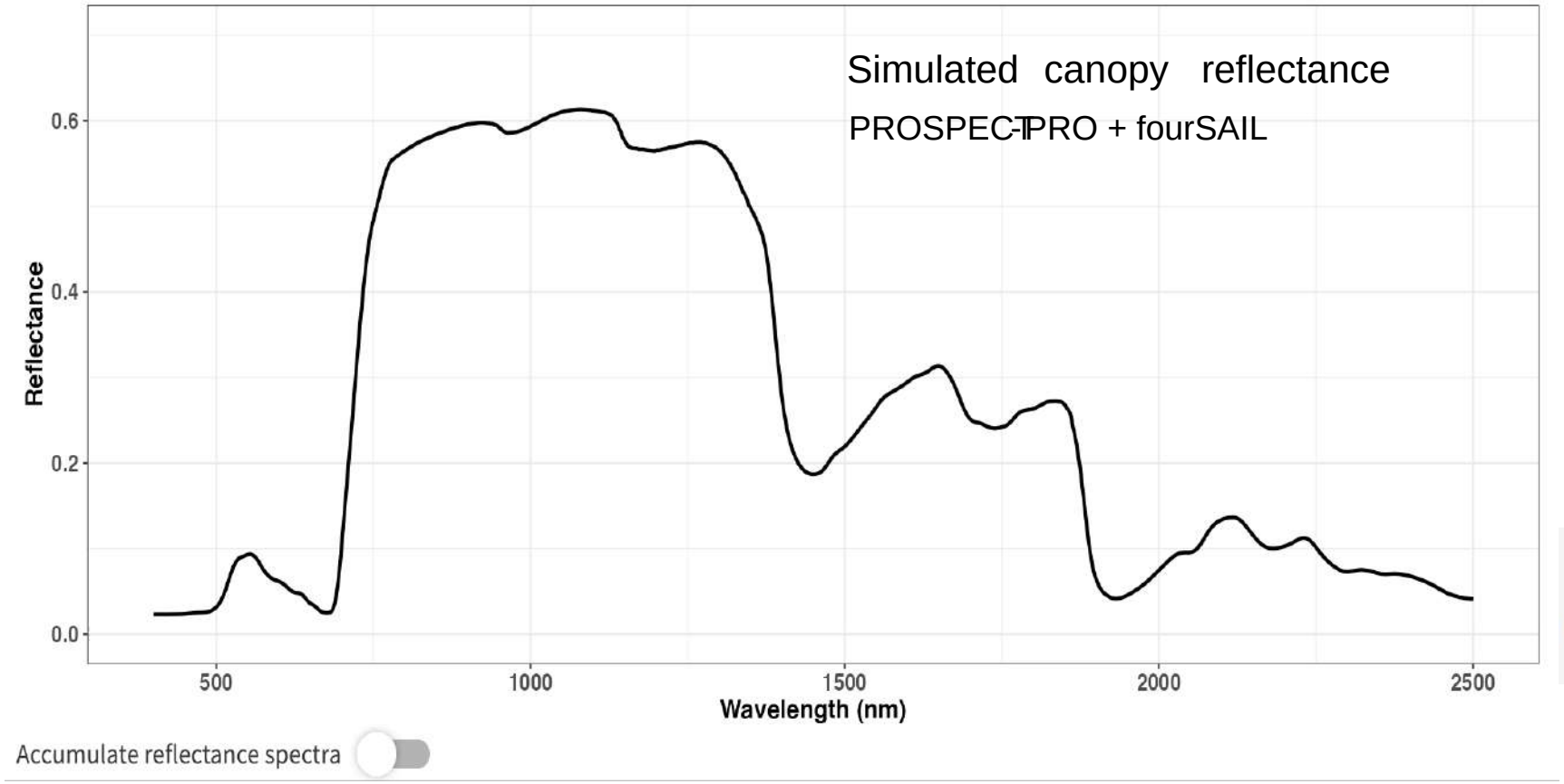
# An online RT reflectance simulator

The RTsimulator is an online framework to model reflectance at canopy scales



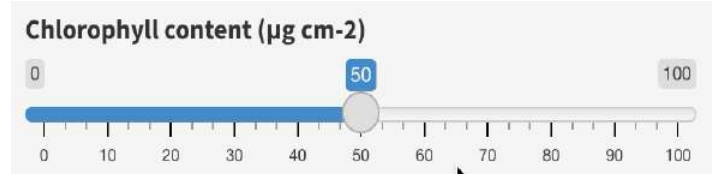

- RT simulator based on:

ToolsRTMpackage

SCOPEinRpackage

- Shiny environment

(Web framework for developing web apps using R)




Changes in chlorophyll content on real time

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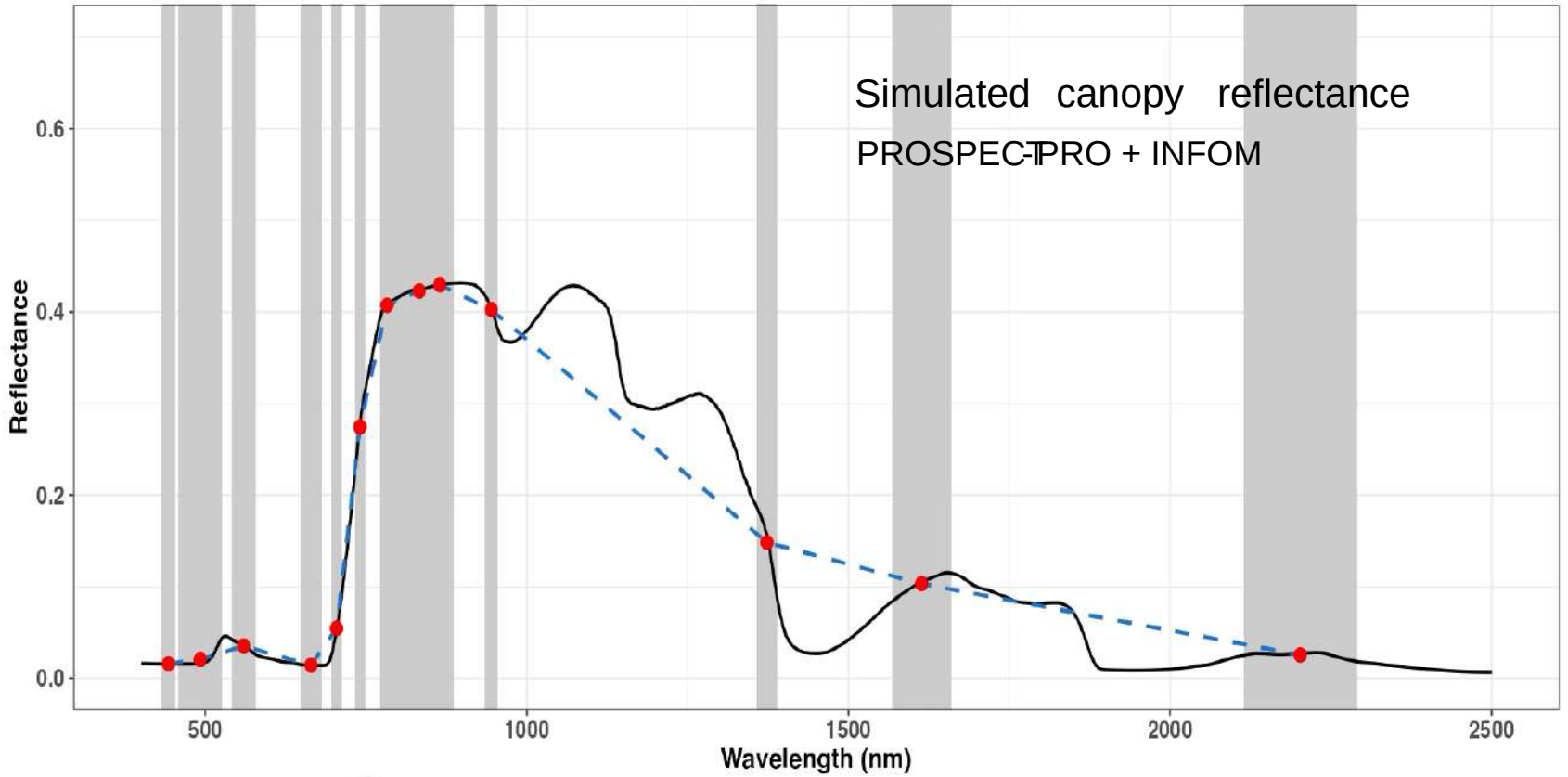
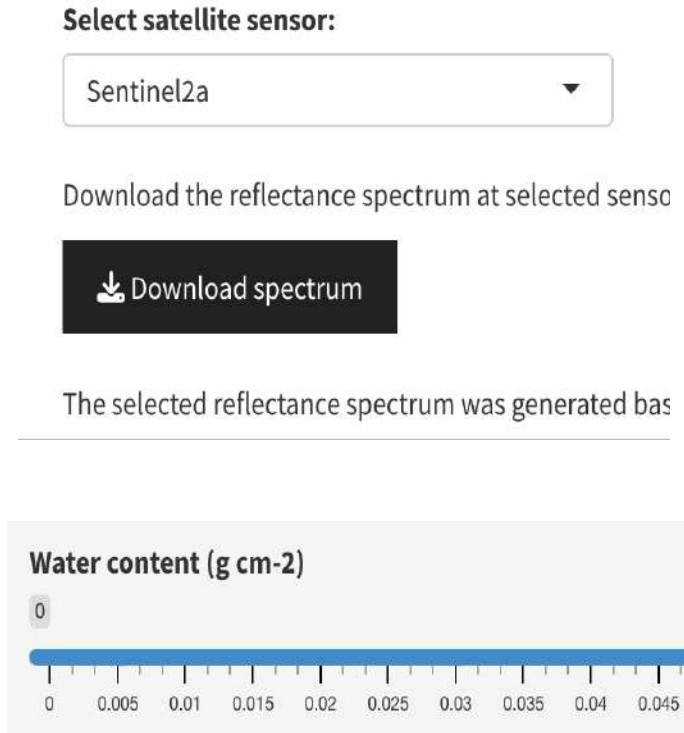
# An online RT reflectance simulator

Effect of plant traits on the canopy reflectance at several spectral resolutions




Changes in water content on real time

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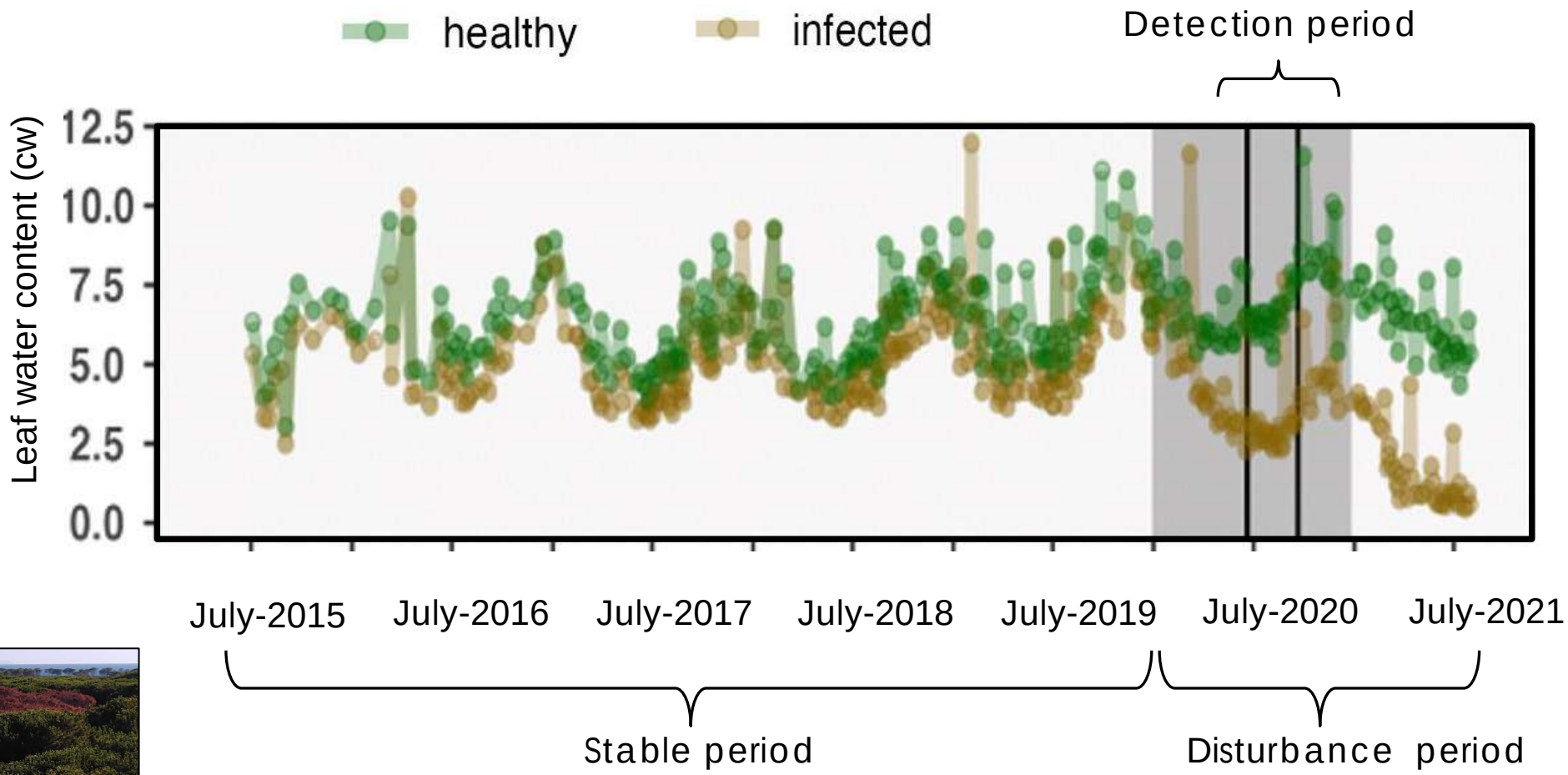
# SWIR for detecting forest disturbances

Healthy areas

Infected areas


Predicted Cw: An hybrid ML approach, Sentinel-2 and RT models

Camino et. al. (2023)

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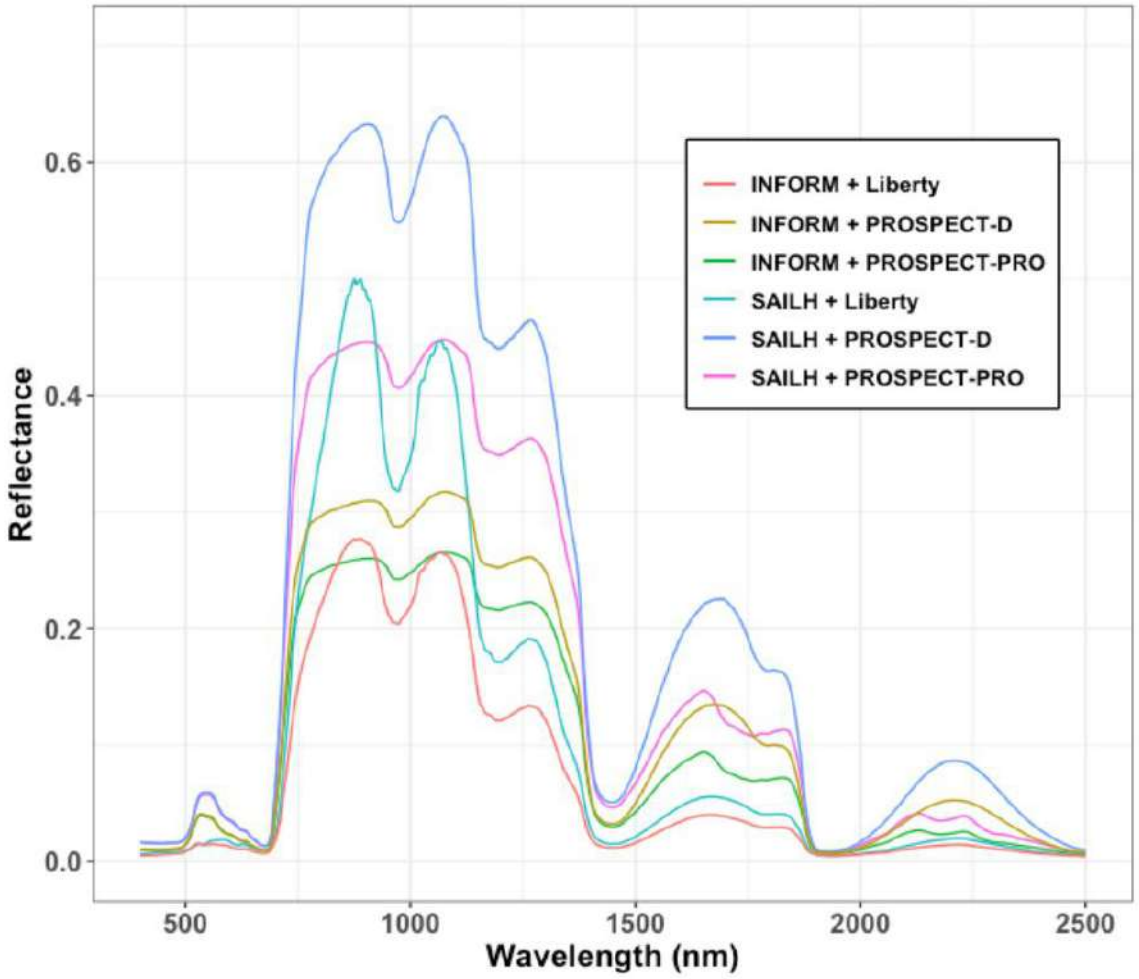
# ToolsRTM package

**ToolsRTM is a package to simulate reflectance based on several RT models**




Leaf models

- Liberty model for conifers canopies.
- PROSPECT model (D and PRO).
- FLUSPECT model (B and CX-B).

Canopy models

- INFORM model.
- fourSAIL model.
- fourSAIL2 model.

Several functions

- Spatial mapping of plant traits.
- LUT generator.
- Inversion methods for plant trait retrievals.

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# ToolsRTM package

Inversion methods to retrieve plant traits implemented in the ToolsRTMpackage

hybrid ML methods: SVM, NNet, RF, Gradient boosting and Ensemble

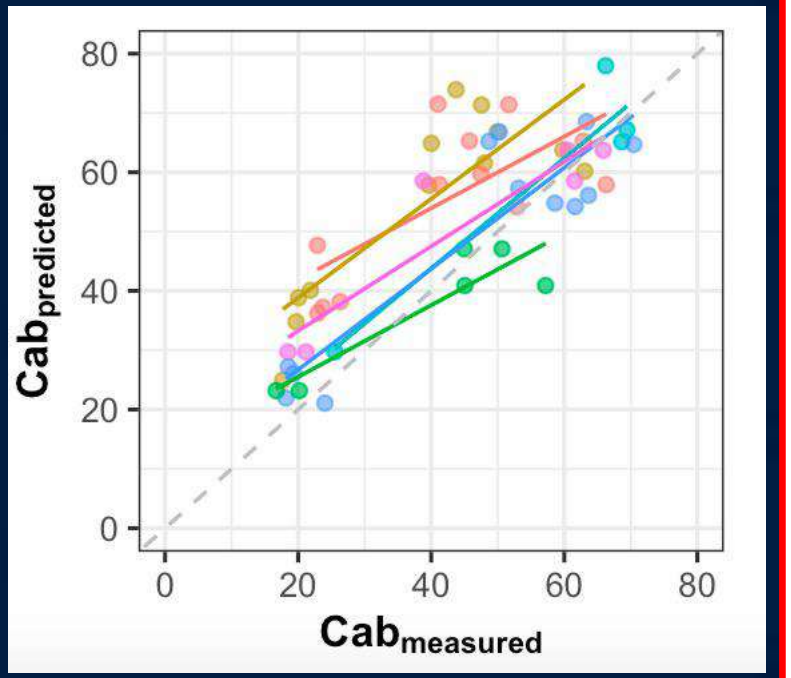
```
ML.preds <- getML.inversion(LUT = LUT.Table,split = 0.8,setseed = 123,input = 'Cab',
            method = 'SVM', # options: 'SVM','RF','GB','nnet','Ensemble'
            Field.data = data.field.sb, acron = '_obsv')
```

hybrid ML methods: deep ML models (CNN and hidden layers)

```
model.prep<-getMLmodel(dataset=LUT[,c(depVar[i],inputs.to)], depVar='Cab',model='CNN',
                       optimizer = 'adamax',
                       batch.size=batch.size,n.epochs=n.epochs, save.model=T, path.model='Models/',
                       prop.split=c(0.8,0.2),
                       data.trans='preProcess',method.preProcess='Normalize', depVar.trans=FALSE)
```

Traditional methods based on a merit function (e.g., RMSE)

```
inv.RMSE<-ToolsRTM::InversionOpt(rfl.sensor=rfl.sensor,
                                 rfl.prosail=rfl.prosail,
                                 LUT=LUT,
                                 wave=wave.vnir.swir,
                                 n=nSamples,
                                 method='merit-RMSE',
                                 nOpt=100)
```

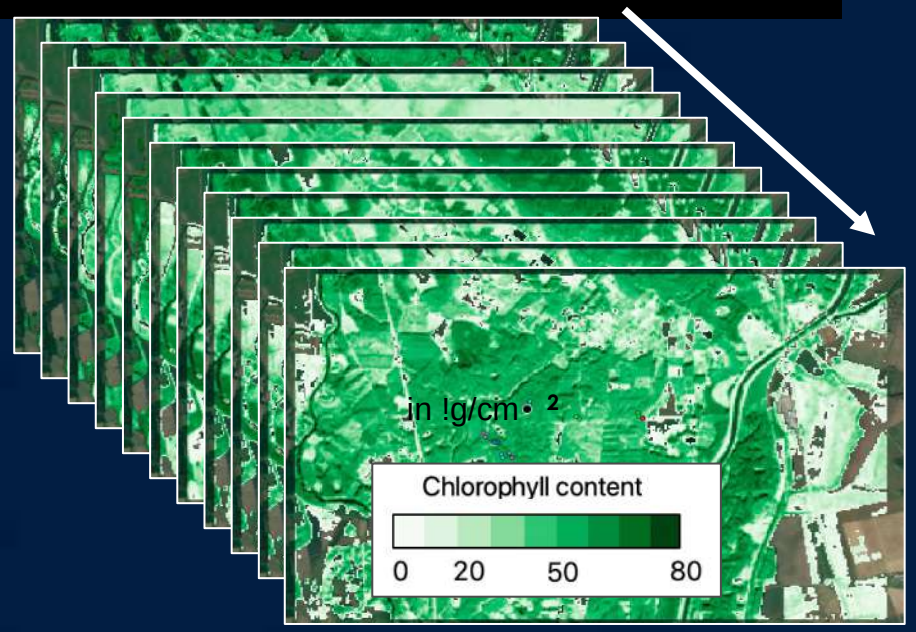


# ToolsRTM package

Spatial mapping of plant traits by coupling RTmodels and Sentinel-2

Integrating RT with Sentinel-2 for getting spatial maps based on the best correlated spectral indicator

```
spatial.maps<-getSpatialTrait(rasterFiles = files.sensor[i],
                              ForestLayer = path.with.forest.mask,
                              Sensor='Sentinel2a',saveFile = path.export,
                              proj = 3035,
                              shapeLayer = paths.with.shape,
                              model.ML = model.nne$Cab$model,
                              trait = 'Cab',factorR=factorSE)
```




LUT generator functions

- Generate random inputs for each RT model
  - Normal or uniform distribution
  - Correlation between traits
  - LUT + Sims adapted to specify sensors

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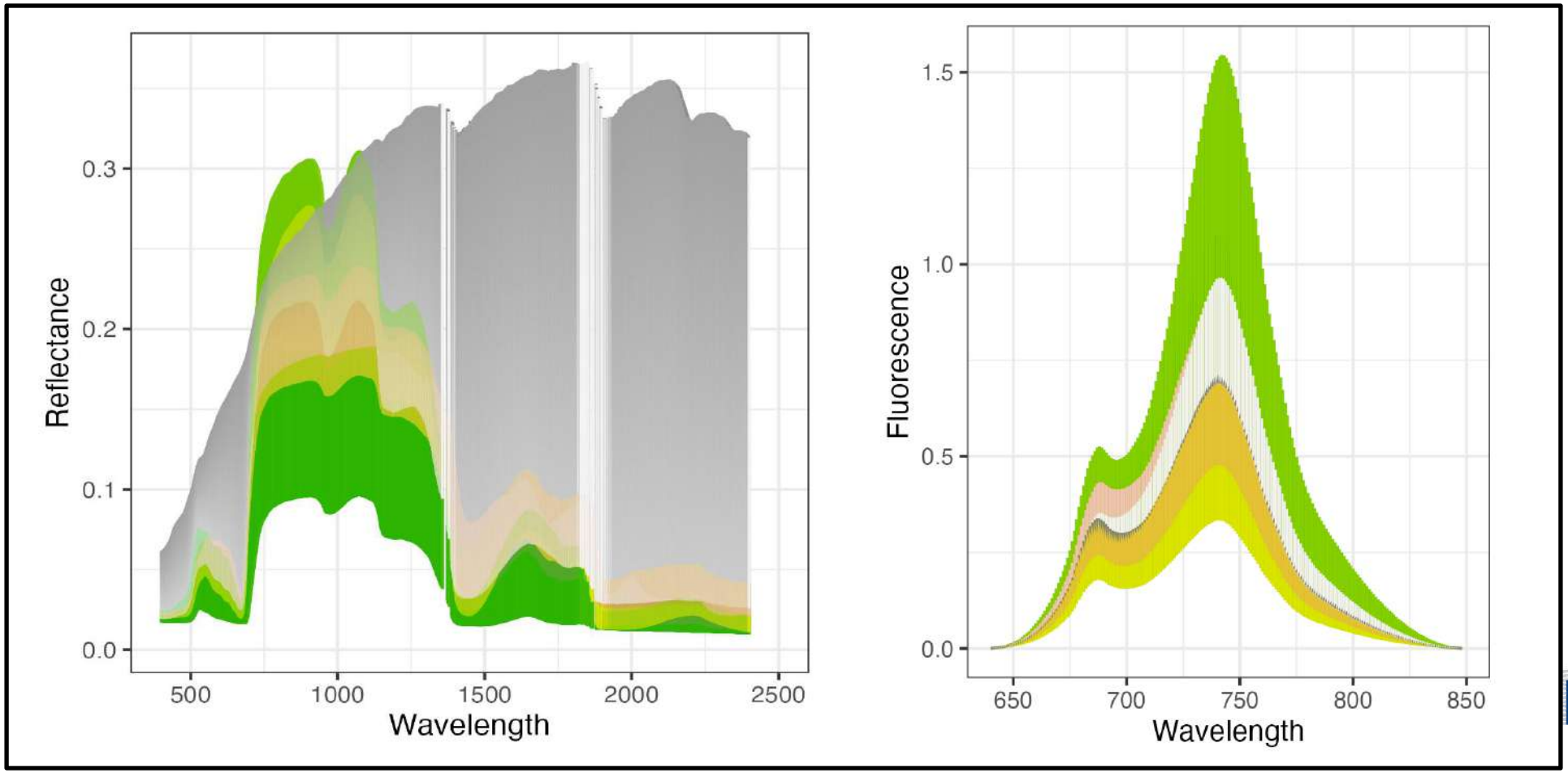
# SCOPEinR package

**SCOPEinR is a package to simulate reflectance using the SCOPE model**

SCOPE Soil Canopy Observation, Photochemistry and Energy fluxes radiative transfer model

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# SCOPEinR package

Running the SCOPEmodel in R

## Configure main options for SCOPE and get LUTs

```
# 1. Get options for running SCOPE model
options<-read.table('input/setoptions.csv',header=T, sep=',')
SCOPEinR::data.opts
```

e.g., estimate fluorescence ; vertical profiles, adding soil spectrum, É

## Get the LUT with main inputs for simulations

```
# 2. get LUT table
N.Samples = 500
LUT <-getLUT.SCOPE(inputLUT=inputLUT,nLUT=N.Samples)
## get correlation between traits
LUT <- getCor(n_inputs = 2 ,setseed = n_seed,distribution = 'Uniform',nLUT = N.Samples, rho = 0.20,
              Varnames = c('LIDFa','LIDFb'),MinRage = c(-0.5,-0.5), MaxRange = c(0.2,0.2))
```

# SCOPEinR package

Running the SCOPEmodel in R

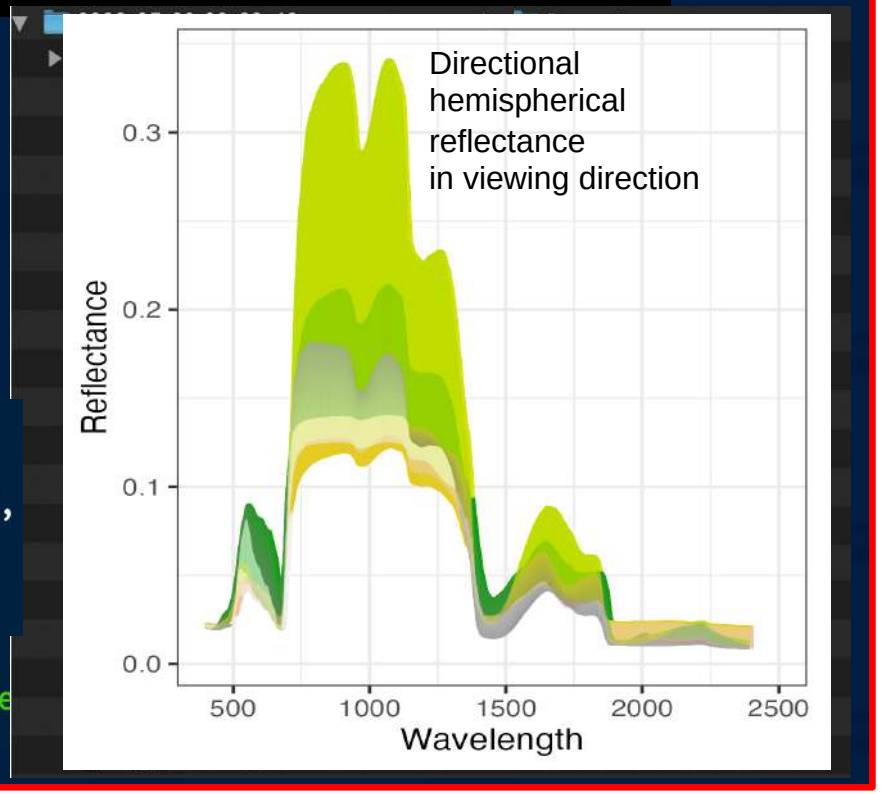
## Run the SCOPE model

```
# 3. Run the SCOPE model
db.sim <-get.SCOPE(LUT=LUT, n.LUT = N.Samples,options.SCOPE=options,
                   optipar=SCOPEinR::optipar2021.Pro.CX,
                   leaf.model='fluspect-CX',canopy.model='fourSAIL',
                   get.outputs = 'ALL', get.plots = F)
```

## Save the main outputs and generate additional plots

```
# 4. Save main outputs
get.SCOPE.outputs(data.sim = db.sim, N.sims=N.Samples,LUT=LUT, path.out ='outs/',
                  get.more.inputs=c('refl','lidf','LIDFb','Ft_Fo','rdo'),
                  get.plots=T)

## 5. Get addtional plots
get.SCOPE.plots(path.files=subdirectories[6], plant.trait=traits, get.plots='reflectance
```

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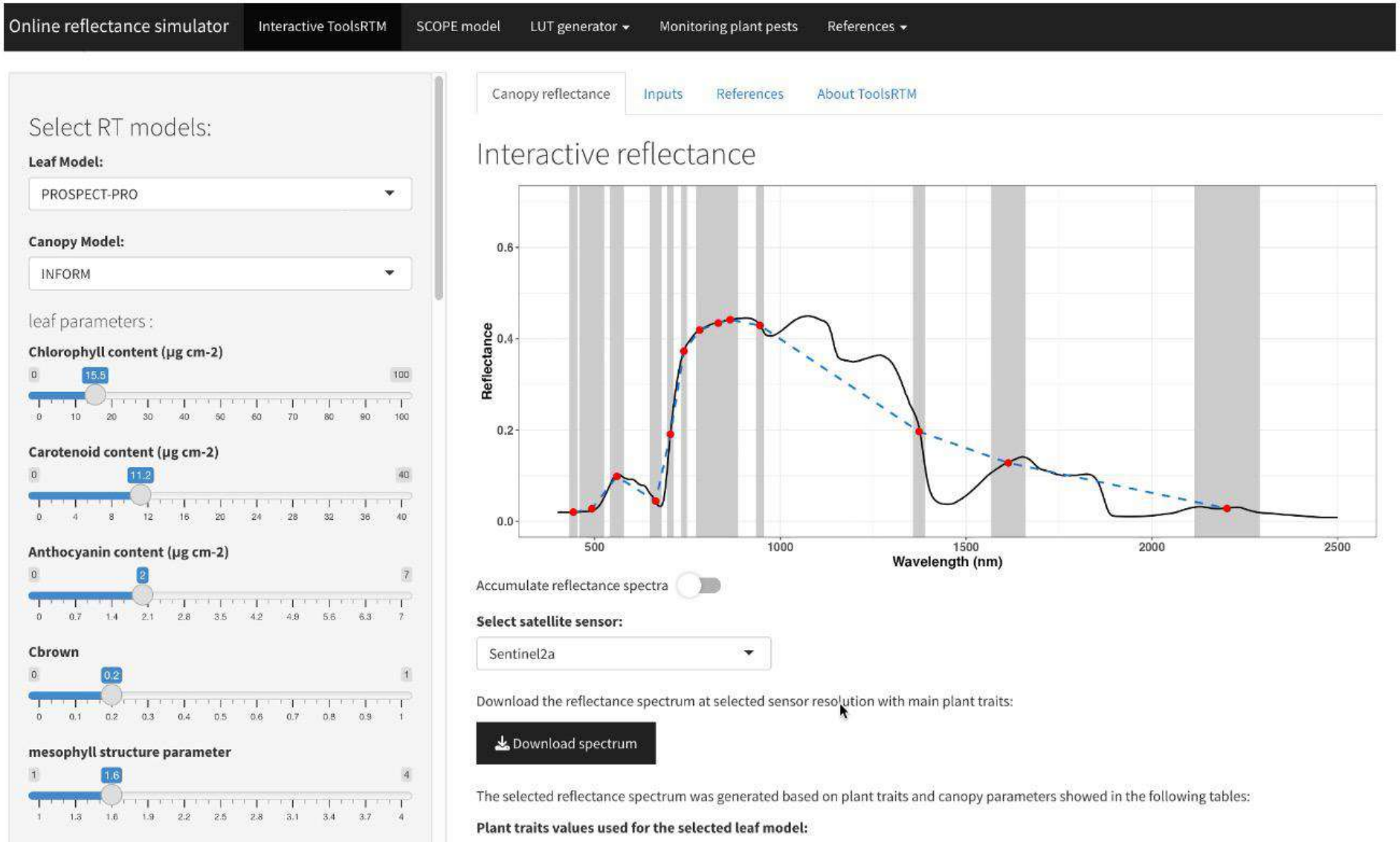
# On-the-fly RT Simulations of canopy reflectance




Main R packages:

- ToolsRTMpackage

Dependencies:

- Shiny package
- hsdar package

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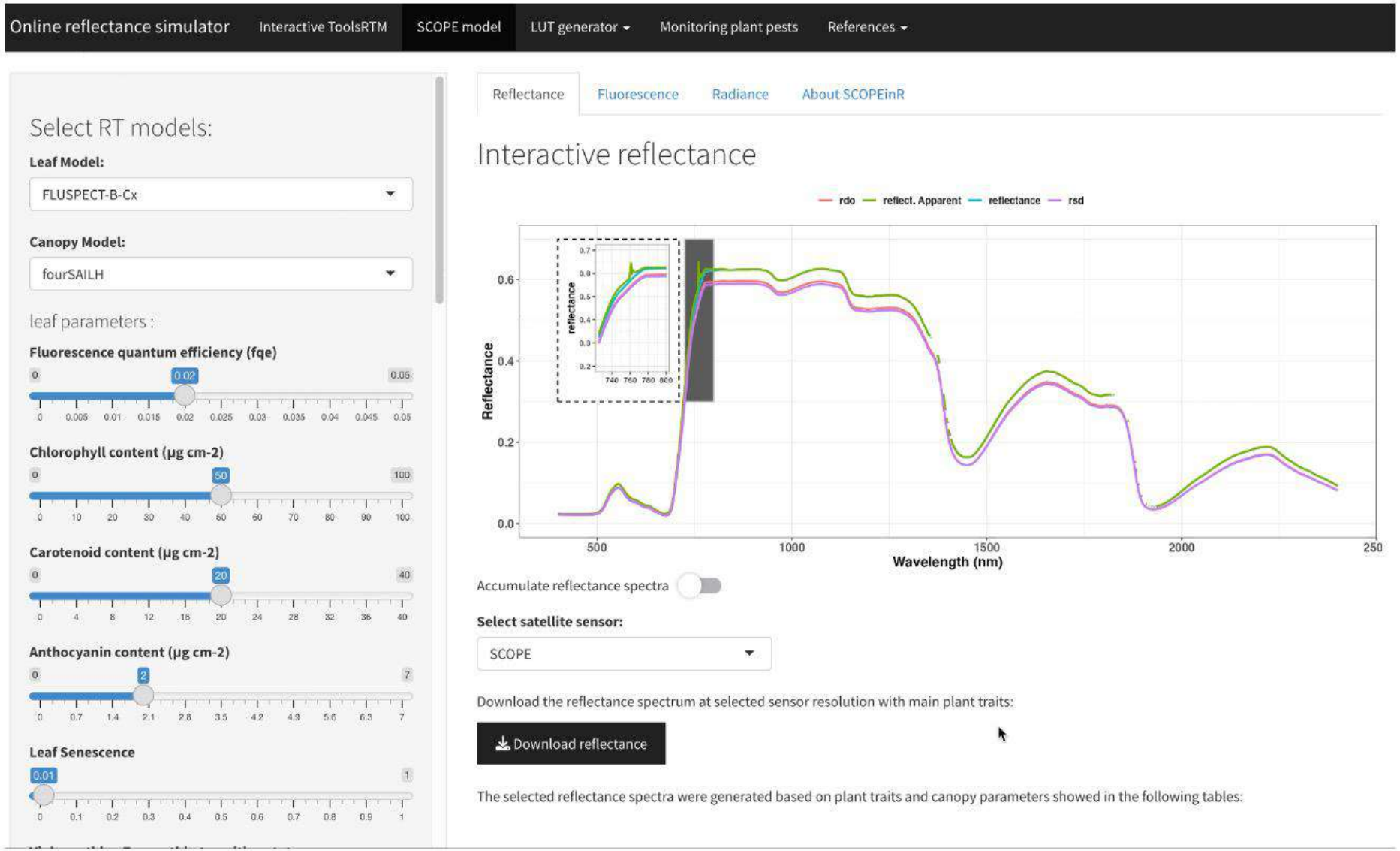
# On-the-fly RT Simulations with the SCOPE model




Main R packages:

- SCOPEinRpackage

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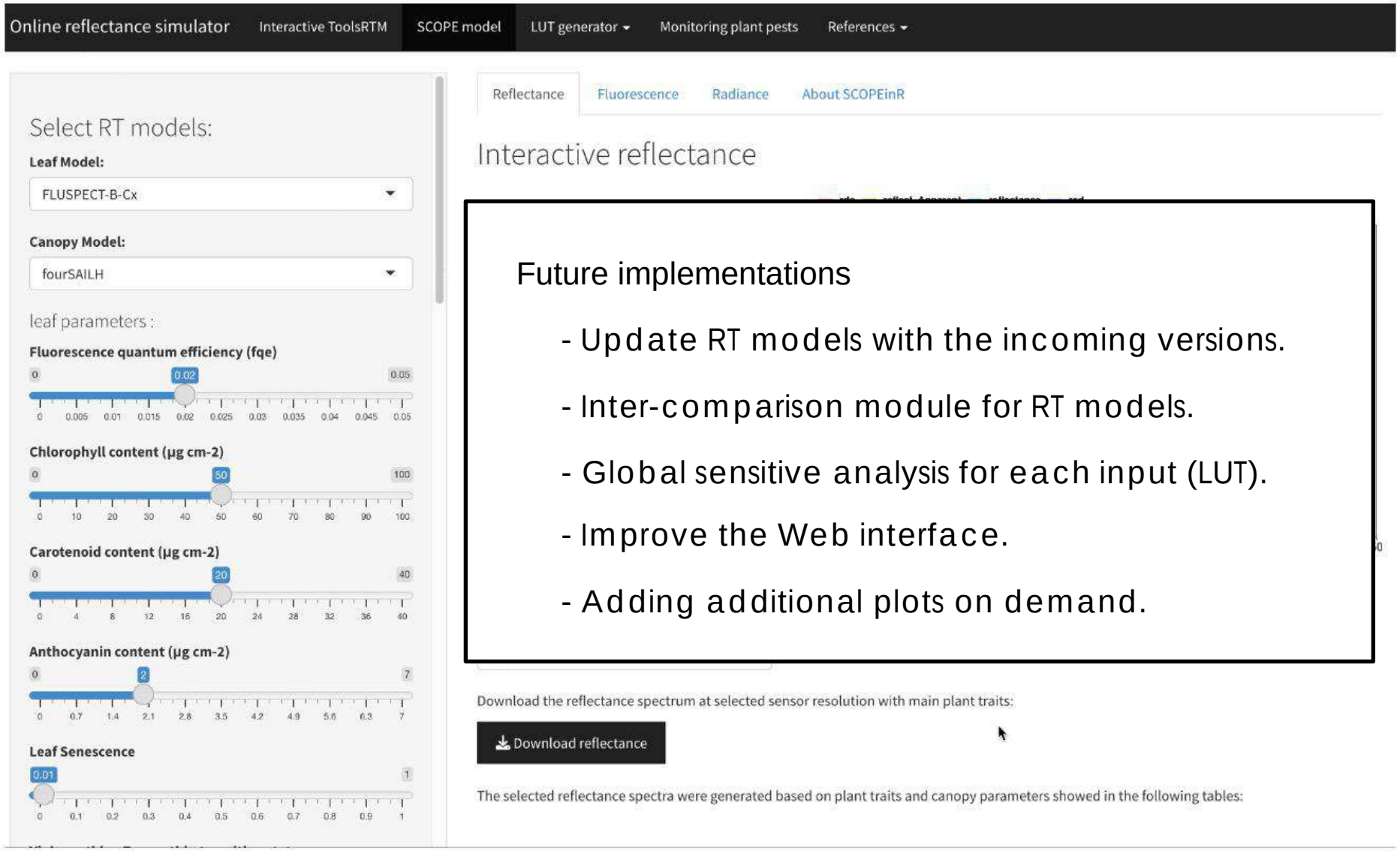
# On-the-fly RT Simulations with the SCOPE model




Future implementations

- Update RT models with the incoming versions.
- Inter-comparison module for RT models.
- Global sensitive analysis for each input (LUT).
- Improve the Web interface.
- Adding additional plots on demand.

Main R packages:

- SCOPEinRpackage

Dependencies:

- Shiny package
- hsdar package

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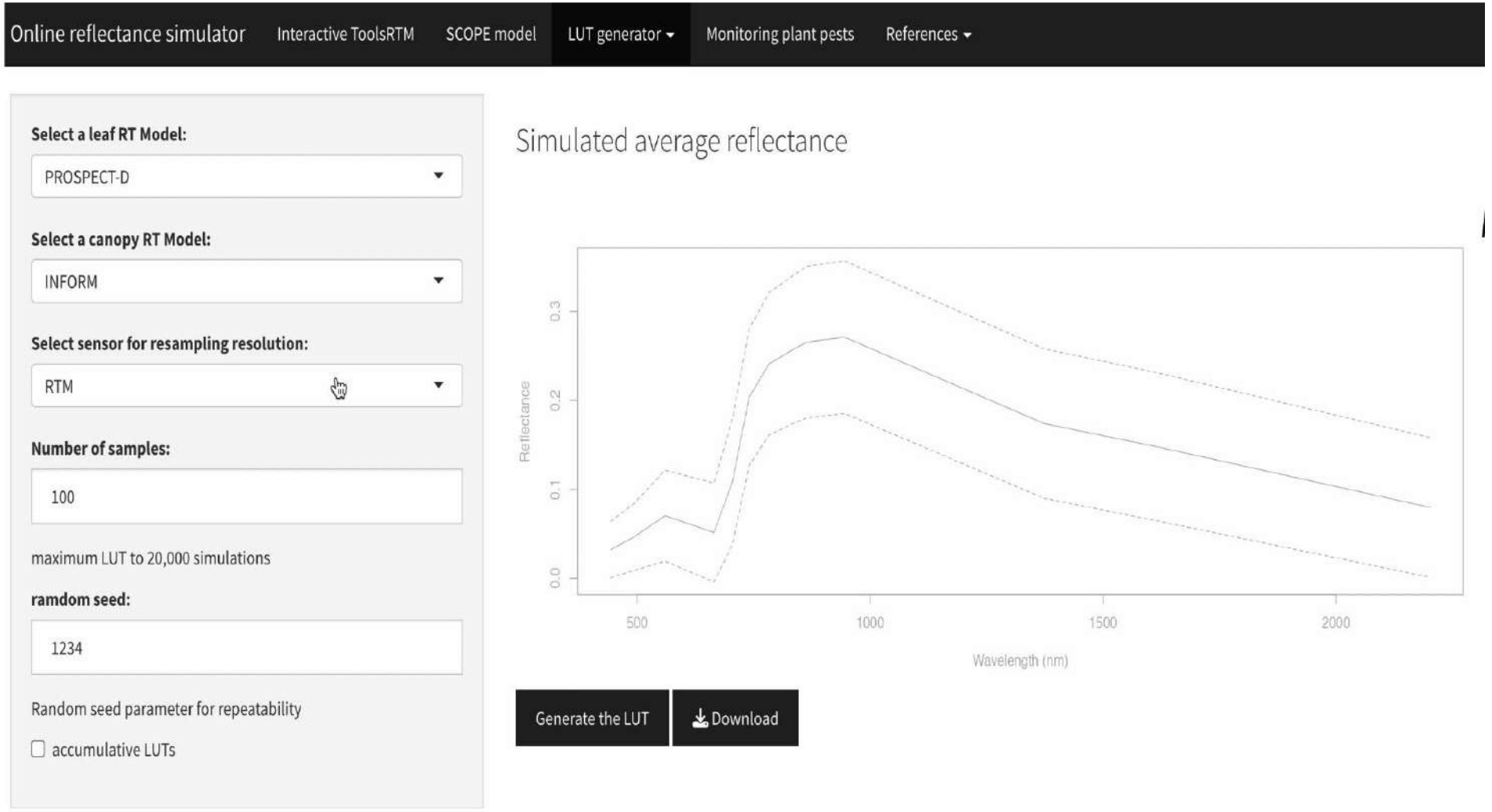
# LUT generator  for specific satellite sensor

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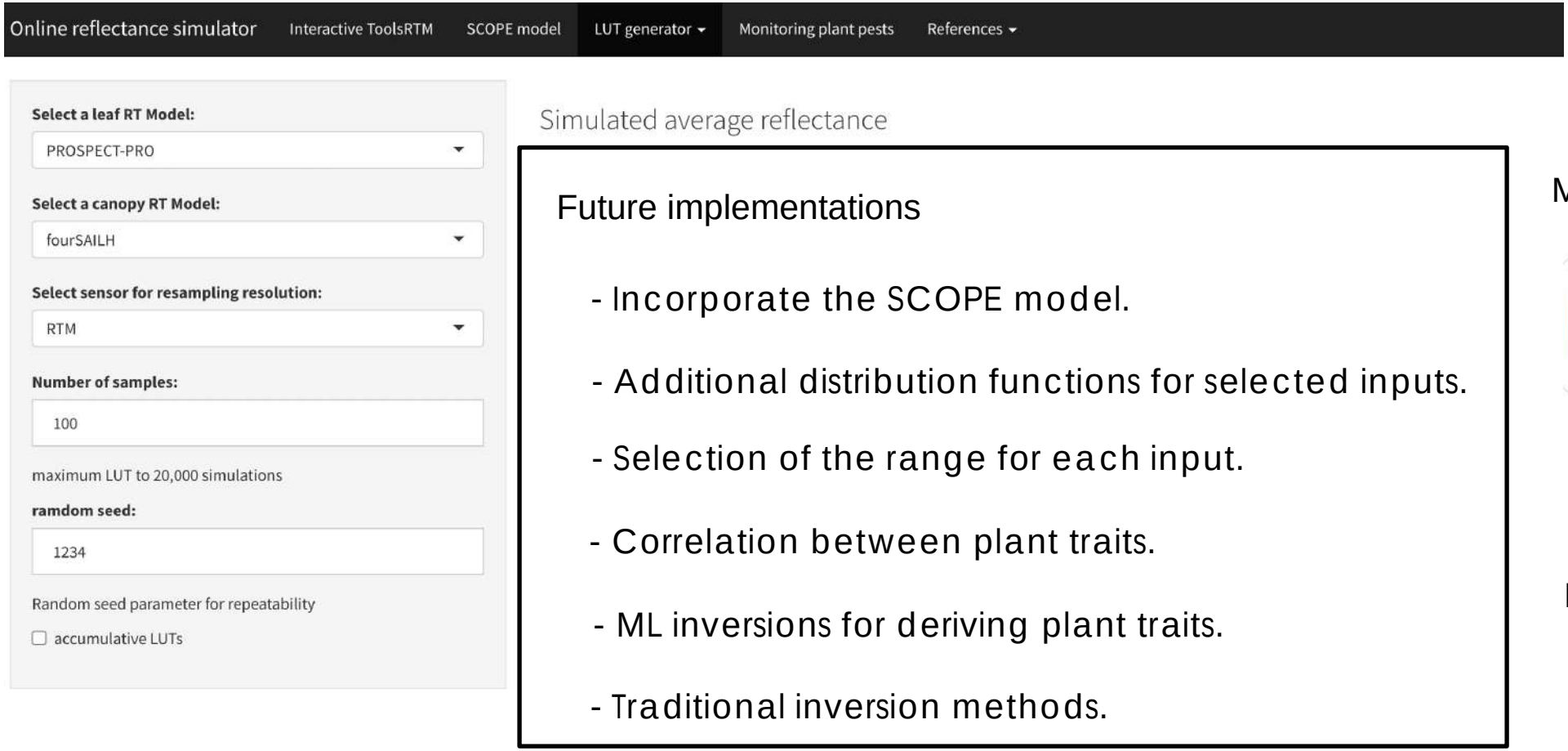


Future implementations

- Incorporate the SCOPE model.
- Additional distribution functions for selected inputs.
- Selection of the range for each input.
- Correlation between plant traits.
- ML inversions for deriving plant traits.
- Traditional inversion methods.

Main R packages:

- SCOPEinRpackage
- ToolsRTMpackage

Dependencies:

- Shiny package
- hsdar package

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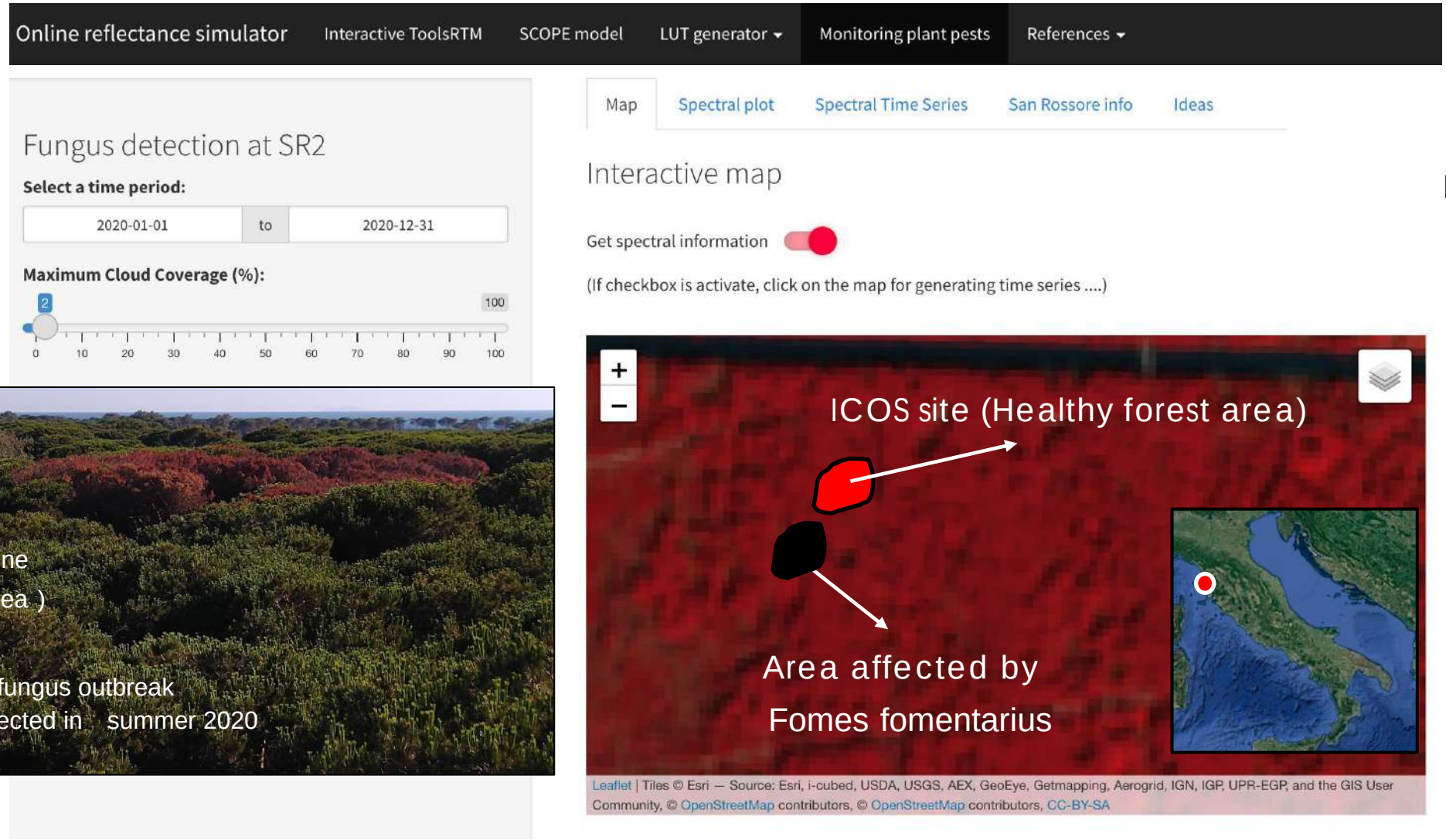
# Monitoring forest disturbances with RT models







Main R packages:

- SCOPEinRpackage
- ToolsRTMpackage

Dependencies:

- Shiny package
- rgee package

Study case : In the surrounding forest areas of ICOS flux tower in San Rossore, Italy.

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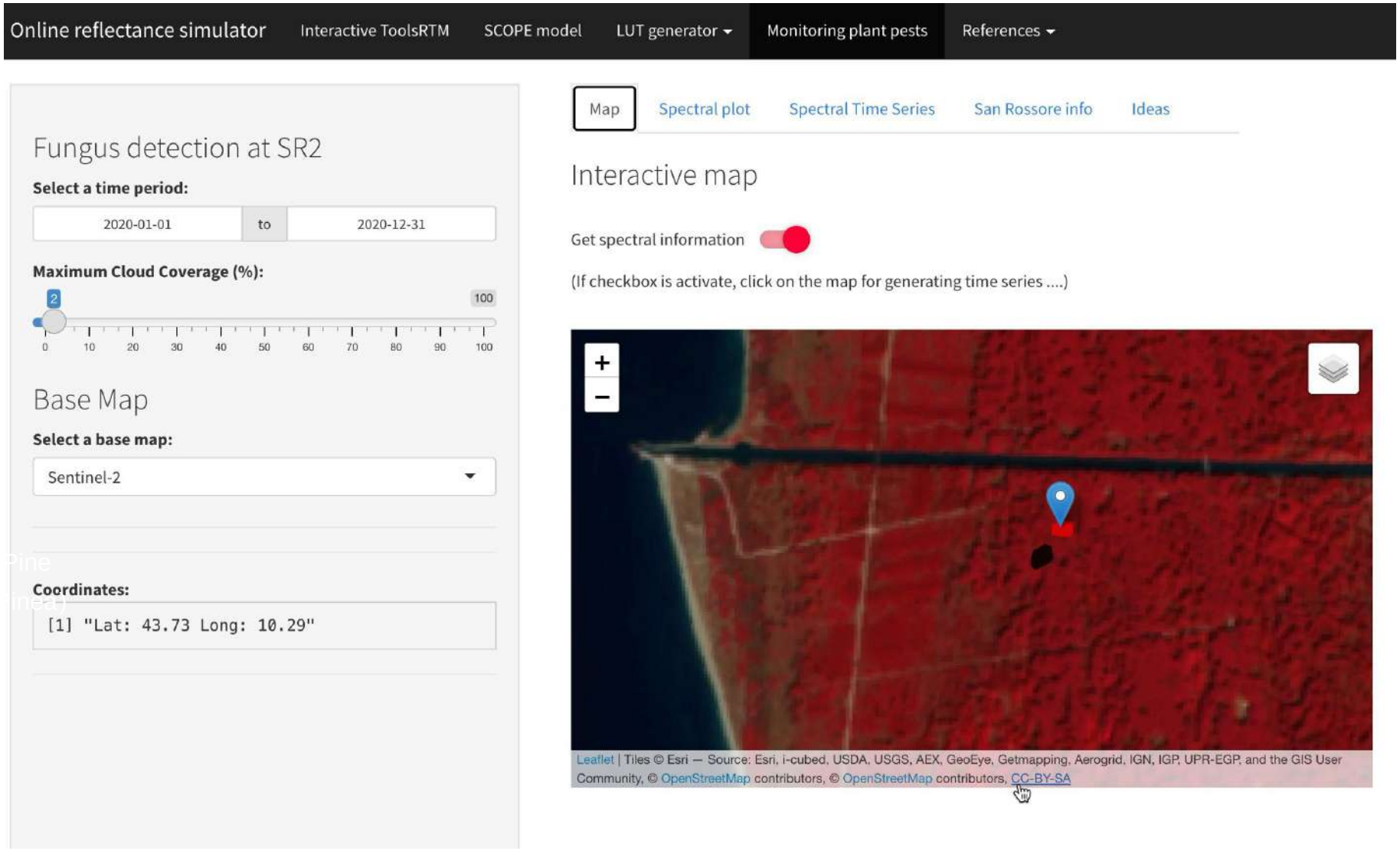
# Monitoring forest disturbances with RT models

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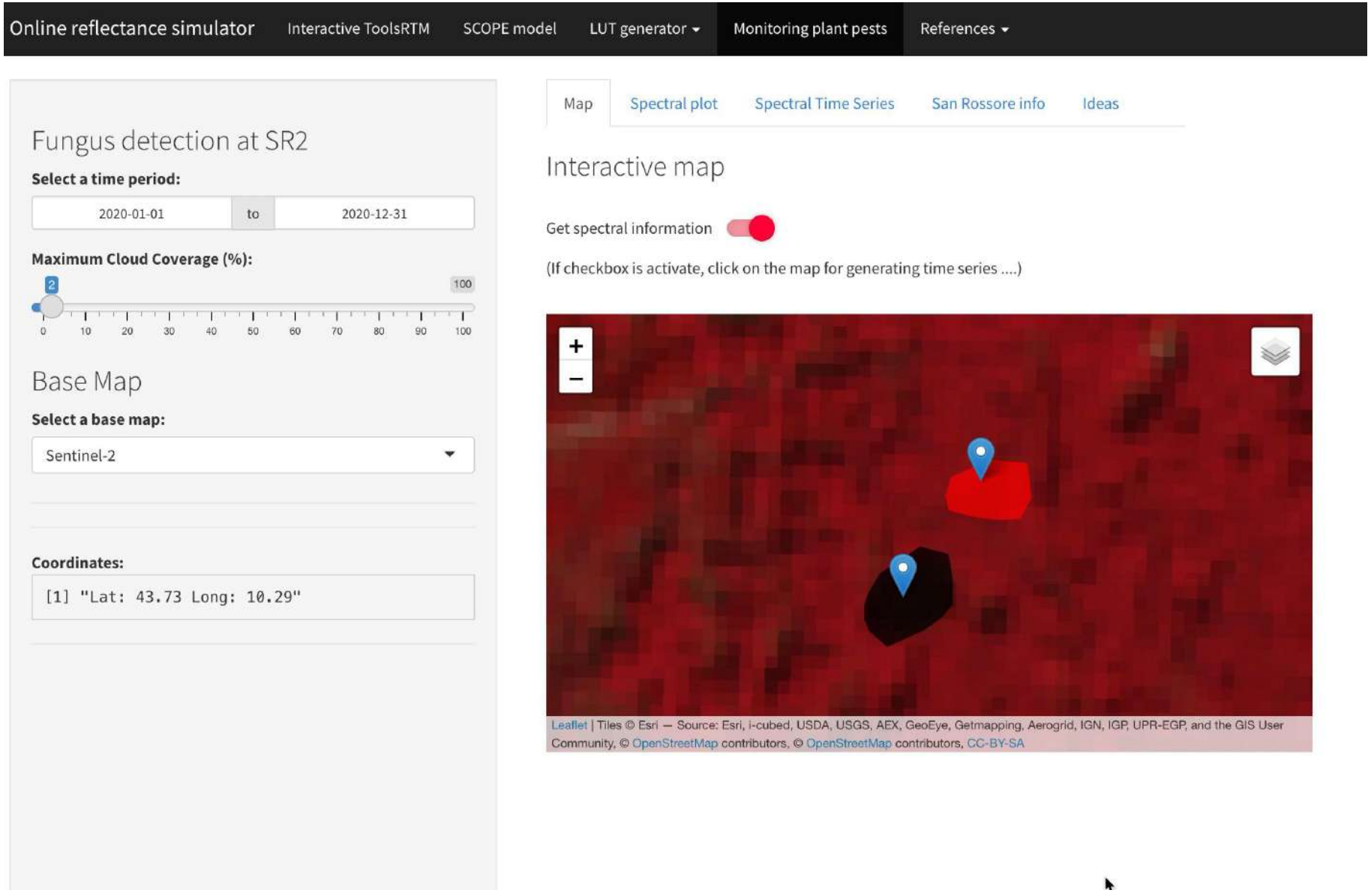
# Monitoring forest disturbances with RT models




Main R packages:

- SCOPEinRpackage
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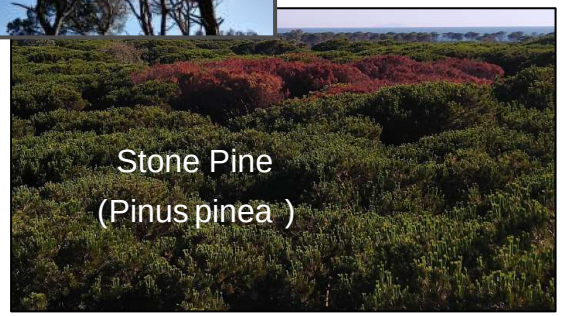
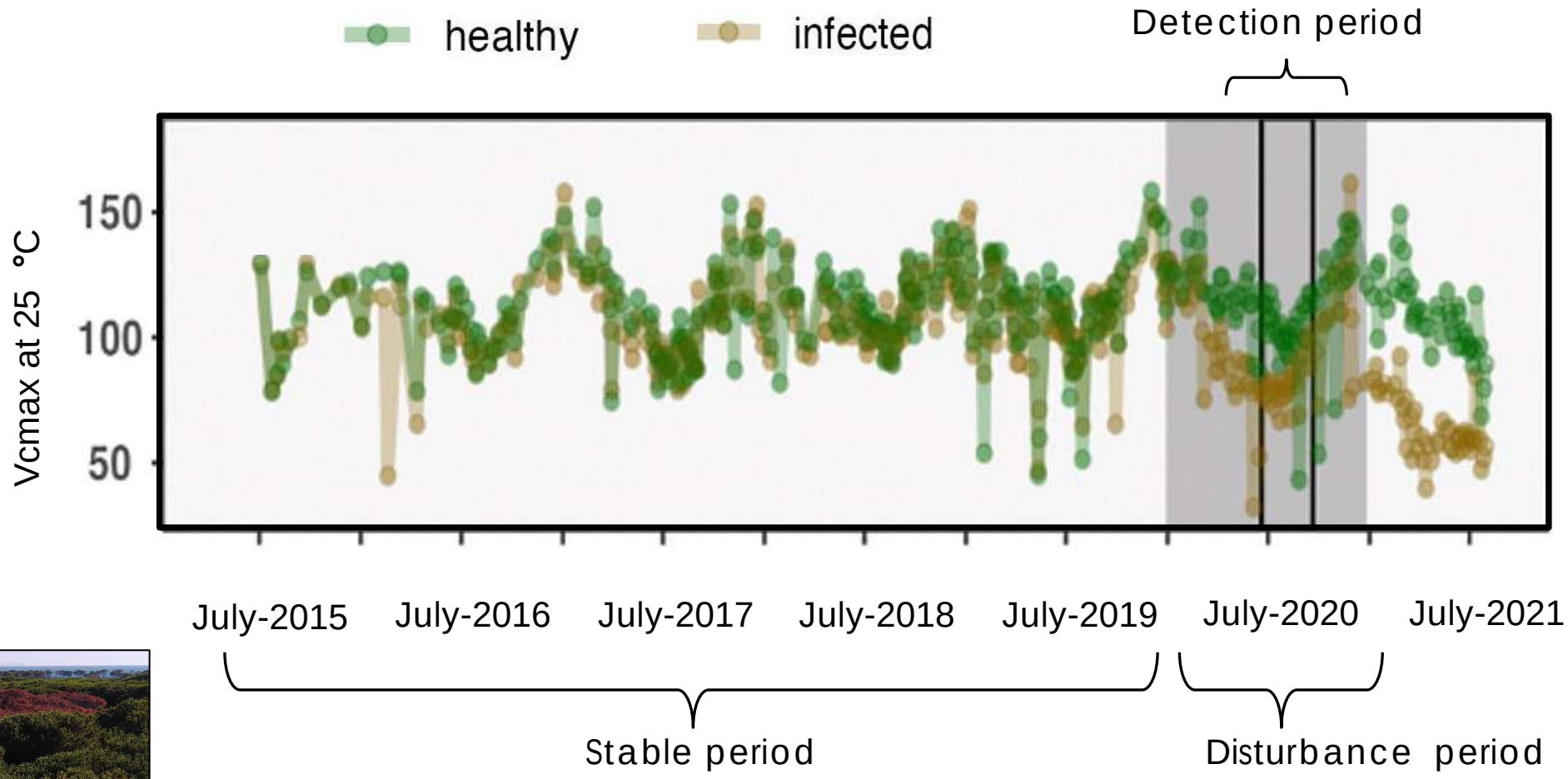
# Vcmax for forest disturbance monitoring

Healthy areas

Infected areas




Camino et. al. (2023)

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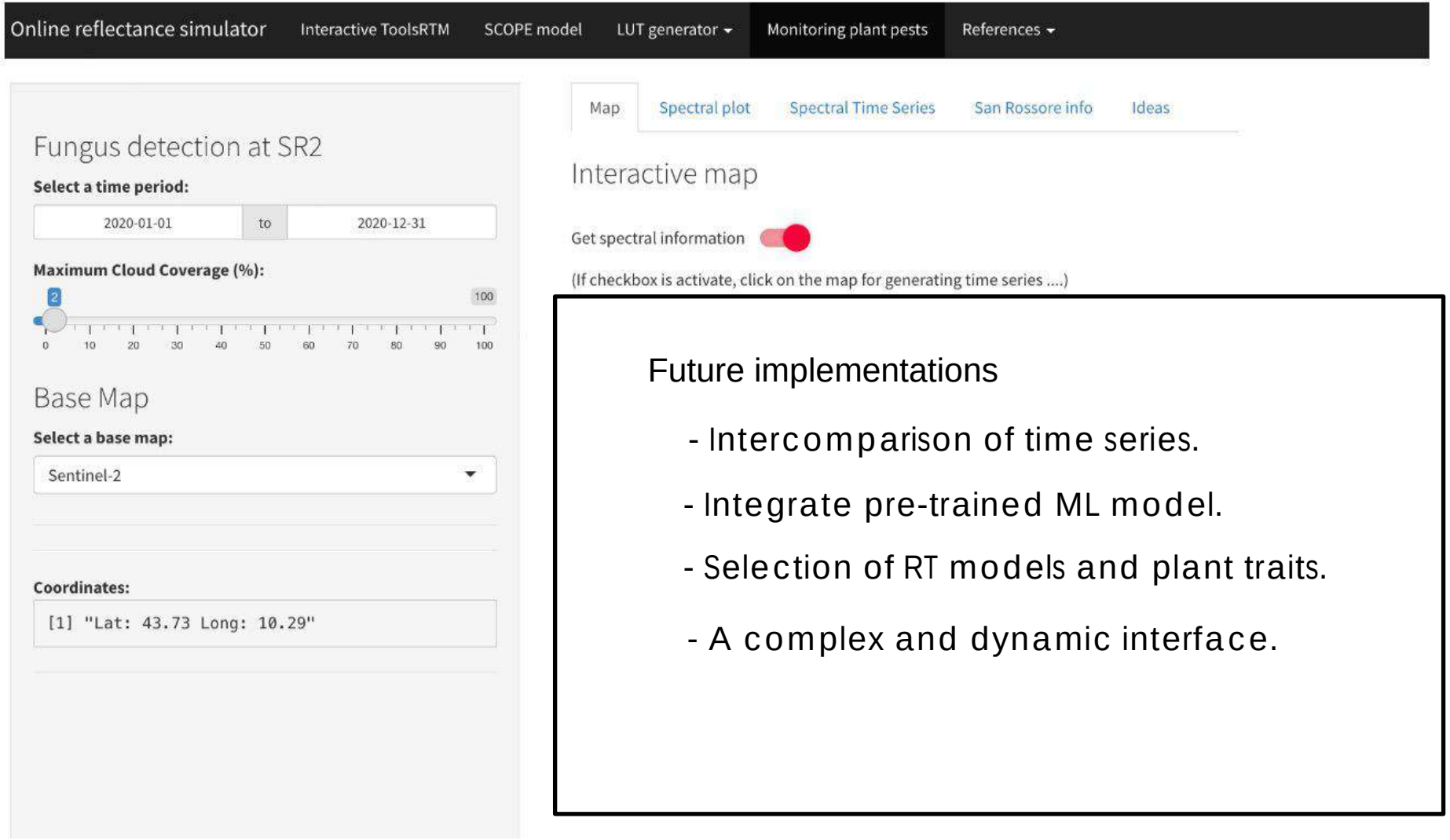
# Monitoring forest disturbances with RT




Future implementations

- Intercomparison of time series.
- Integrate pre-trained ML model.
- Selection of RT models and plant traits.
- A complex and dynamic interface.

Main R packages:

- SCOPEinRpackage
- ToolsRTMpackage

Dependencies:

- Shiny package
- rgee package

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# Conclusions

! RTTools for monitoring the physiological traits of forests using biophysical models is crucial to develop accurate methods for the early detection of pest epidemics .

" Integrating RT models and satellite imagery is needed to support forest health monitoring activities in near -real -time .

# Our online RT Simulator supports the use of RT models to understand the spectral response of plant traits changes related to forest disturbances .

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# Next steps

1. Establish collaborations with model developers (YOU) and model users

2. Publish the RTsimulator with the R packages by the end of the year.

3. Add useful functionalities and additional RTmodels.

# Thanks for your attention !

**Contact:** Carlos.Camino-Gonzalez@ec.europa.eu

Special thanks to main authors of RT models:

SCOPE model:

- Yang et al., (2020) and Van der Tol et al. (2009, 2014)

FLUSPECT model:

- Vilfan et al., (2016; 2018)

PROSPECT model:

- Jacquemoud et al., (1990); Feret et al. (2017, 2021)

Liberty model:

- Dawson et al., (1998); Di Vittorio et al., (2009).

FourSAIL & fourSAIL2 models:

- Verhoef & Bach H, 2007, (2016; 2018)
- Verhoef et al., (2007)

INFORM model:

- Atzberger (2000) and Schlerf et al., (2006)