



Weed and crop discrimination with hyperspectral indices

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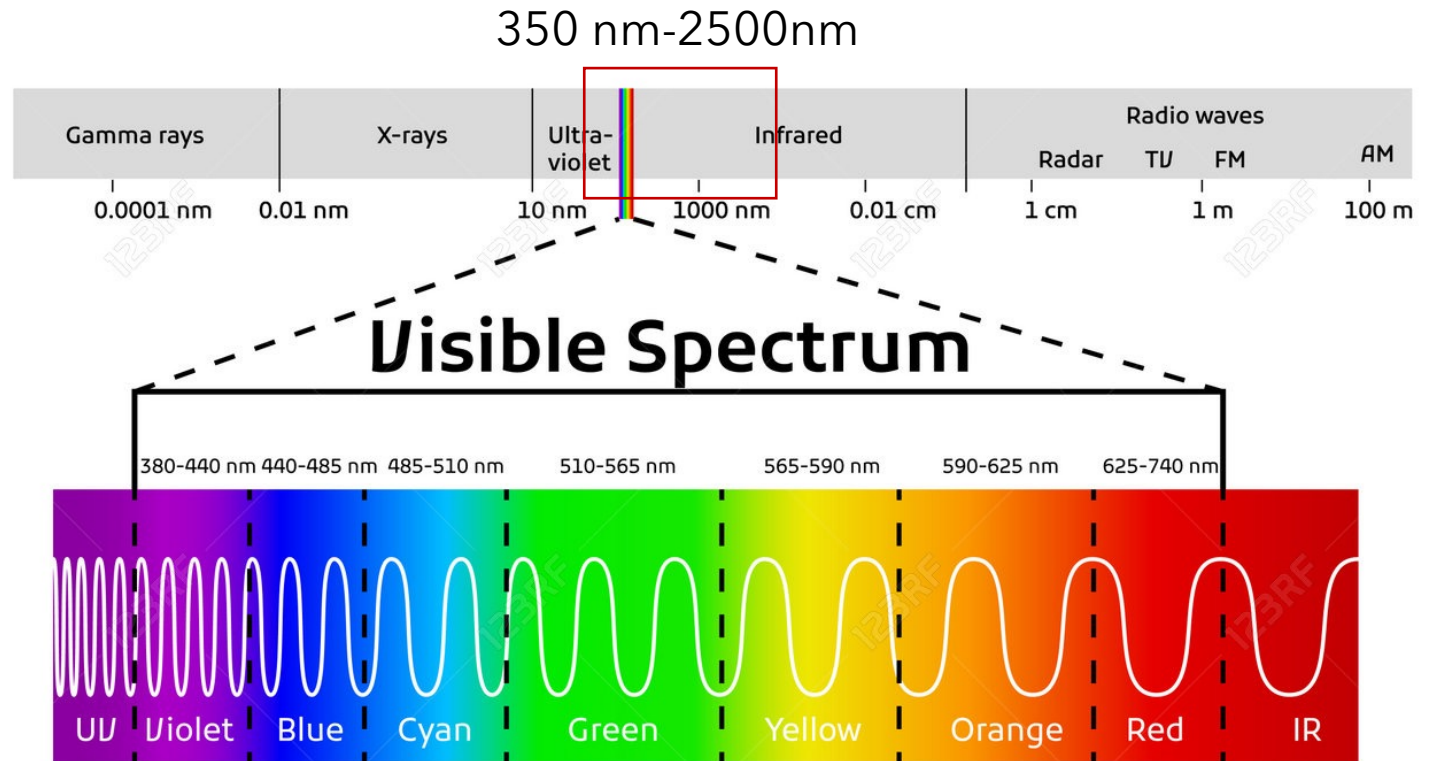
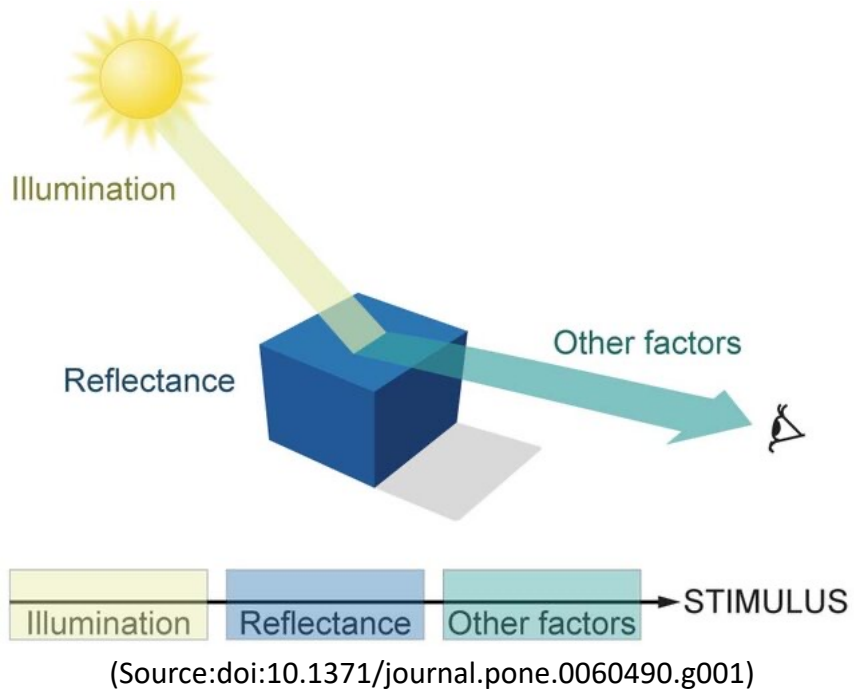
Italiadomani
PIANO NAZIONALE
DI RIPRESA E RESILIENZA



Hyperspectral data

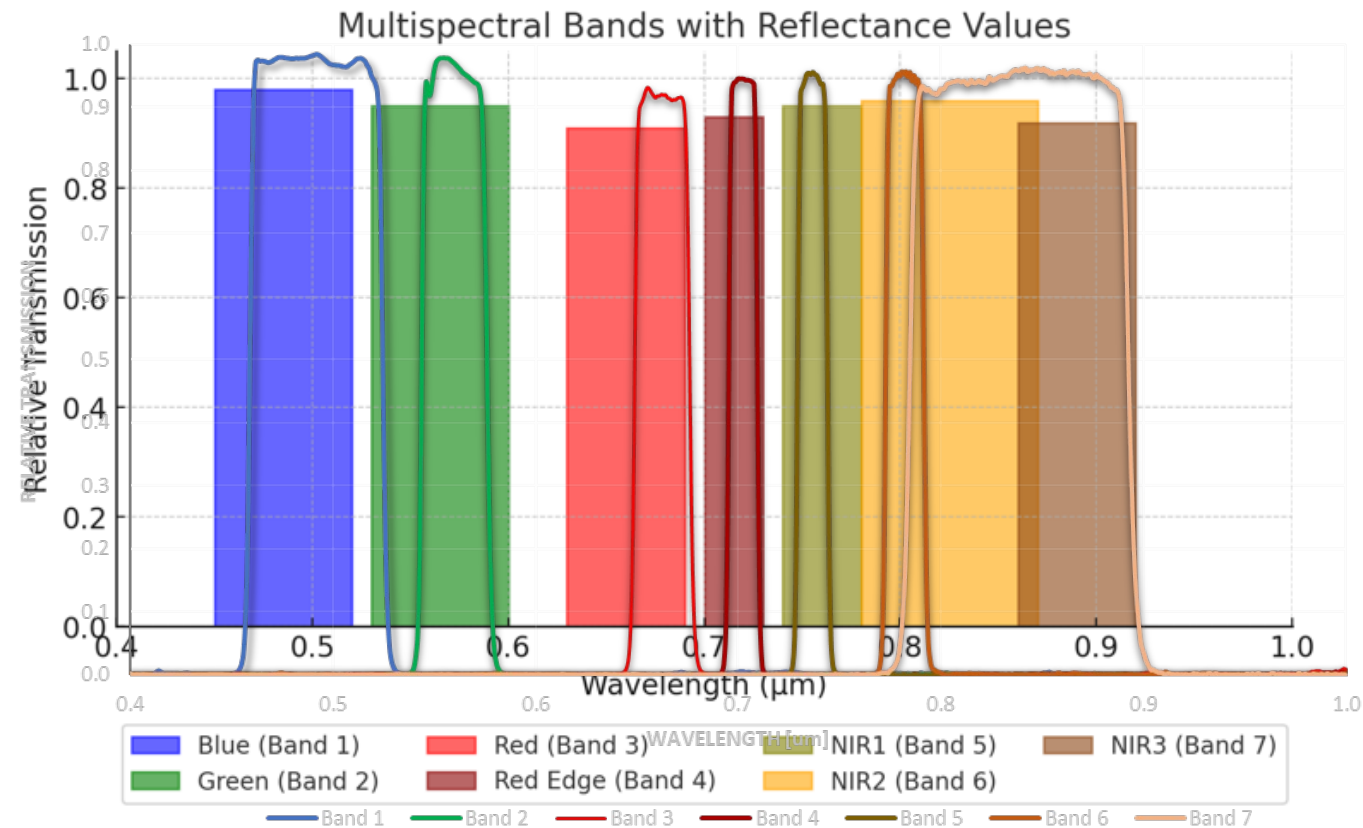
What is it? Why should we use it?

Light reflectance



Spectral data

- Spectral data = how much light is reflected in an area of the spectrum
- Multispectral data
 - Portions of the spectrum = bands
 - Bandwidth = 10nm-100nm
 - 6 - 10 bands per scan

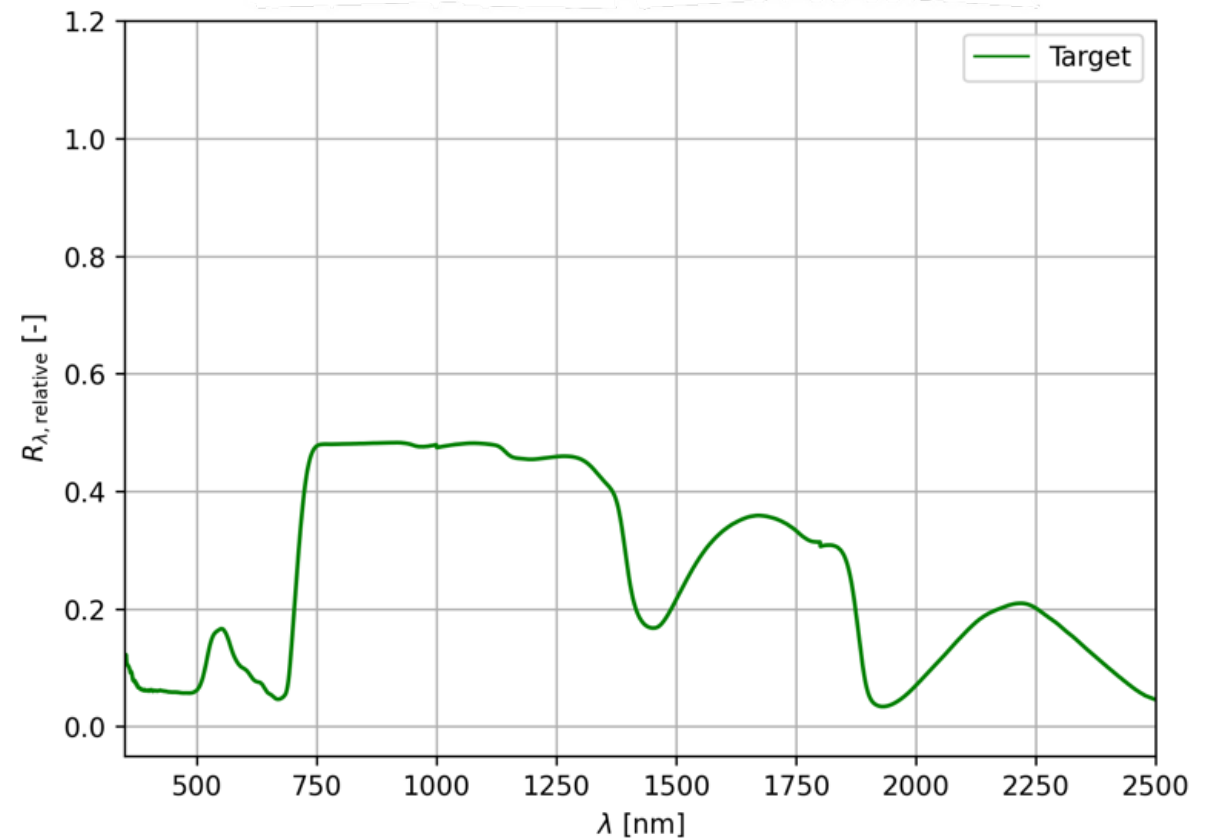


Hyperspectral data

- Bandwidth = 2 nm-10 nm

Range 350 nm-2500nm

- 100s to 1000 bands
- 2150 observations per scan



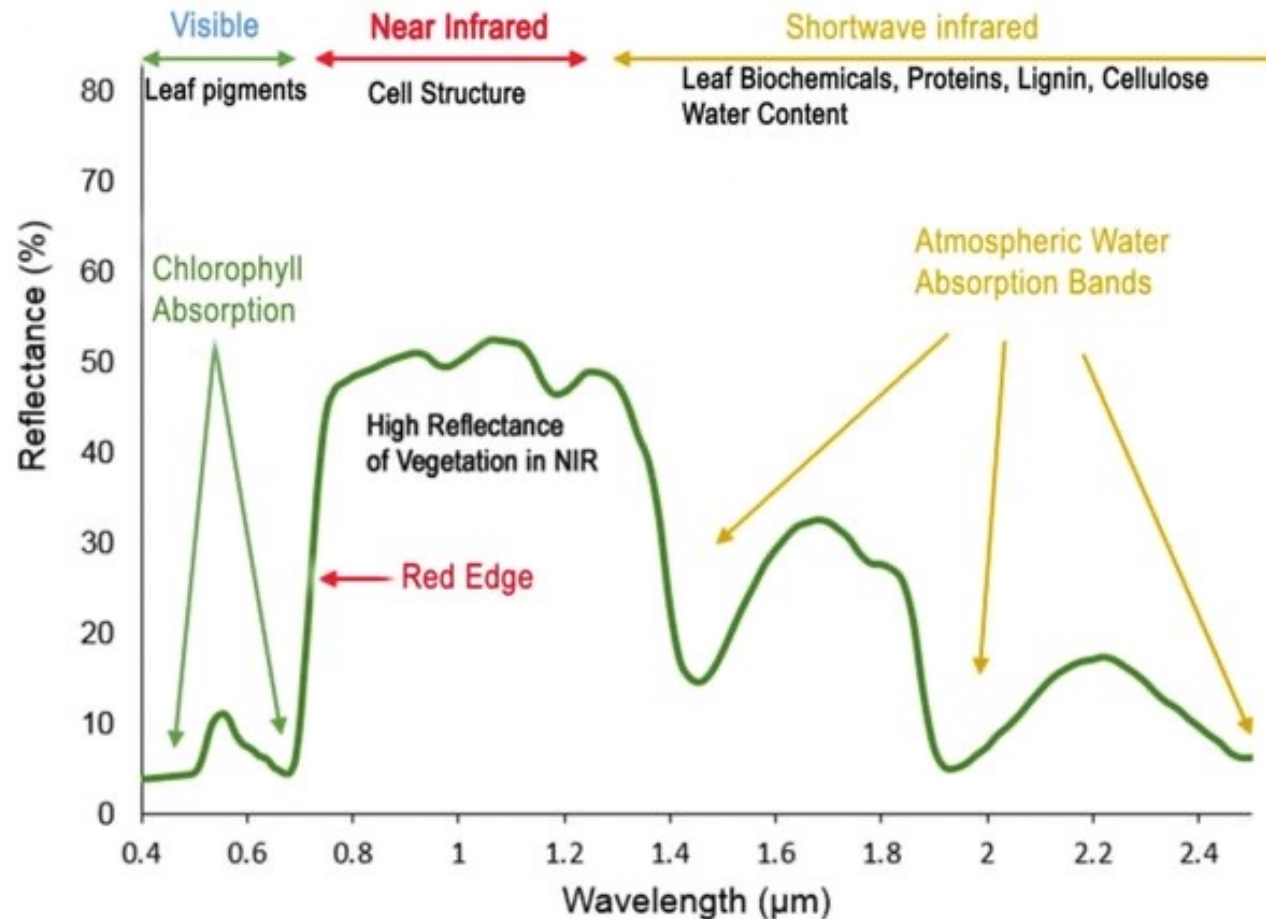
Hyperspectral data



- Heavier datasets
- Complicated analyses
- Variability between datasets

More data
=
More problems

9/19/25



- Crop physiology
- Yield estimation
- Fertilization
- Irrigation
- Pathology

More data
=
More information

Hyperspectral vegetation indices

Water pigments

Water Index
 $WDVI = (R_{850} - R_{705}) / (R_{750} + R_{705})$

(WI) = R_{900} / R_{970}

Pigment specific simple ratio
 $PSR = (R_{860} - R_{1240}) / (R_{860} + R_{1240})$
 (PSSR) = R_{800} / R_{675}

Dry matter

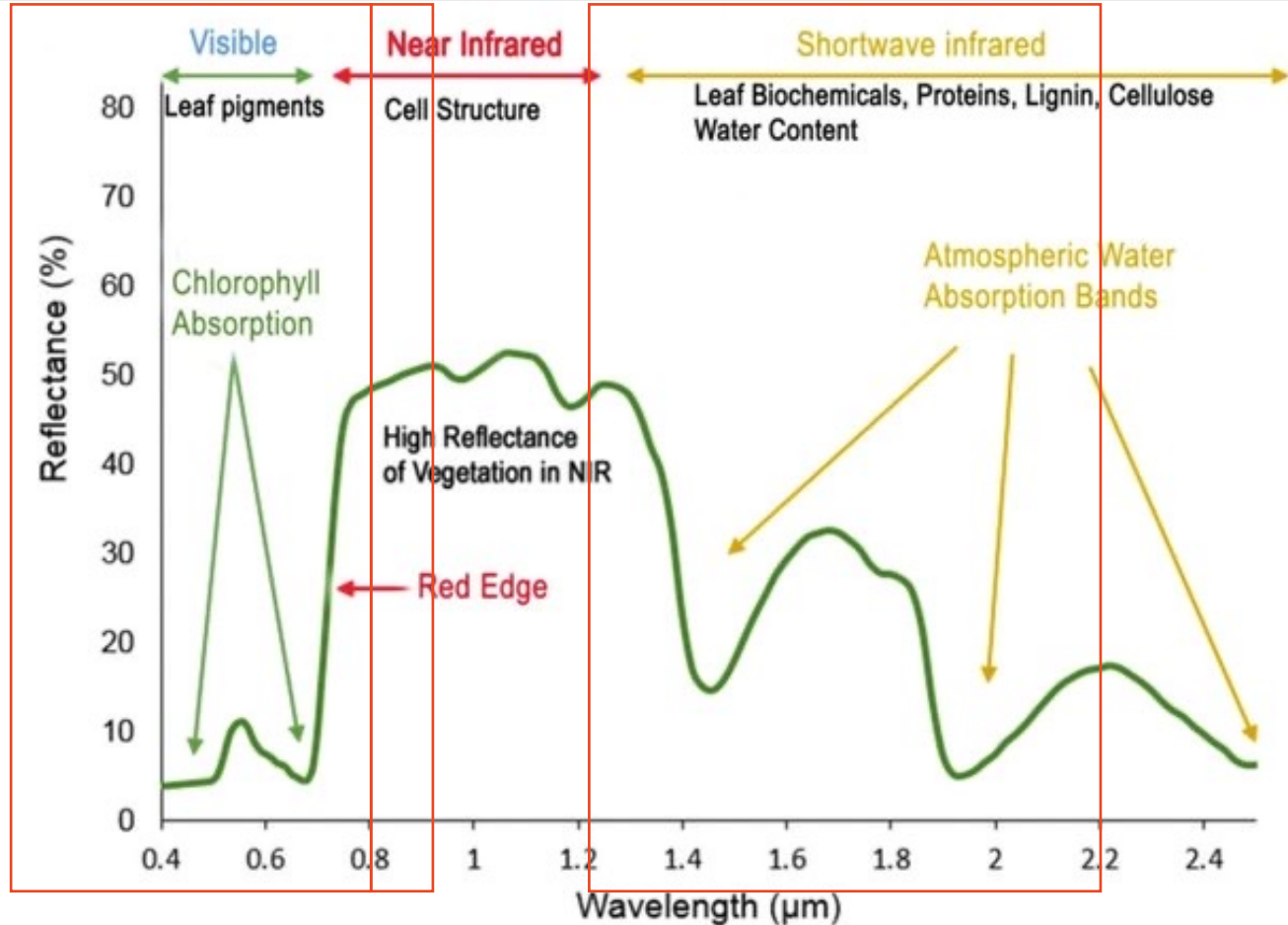
Carotenoid index

(CARI) = $(R_{412} / R_{675} - 1) / (R_{1649} + R_{1722})$

Moisture Stress index

(MSI) = R_{600} / R_{820}

(PSND) = $(R_{800} - R_{675}) / (R_{800} + R_{675})$



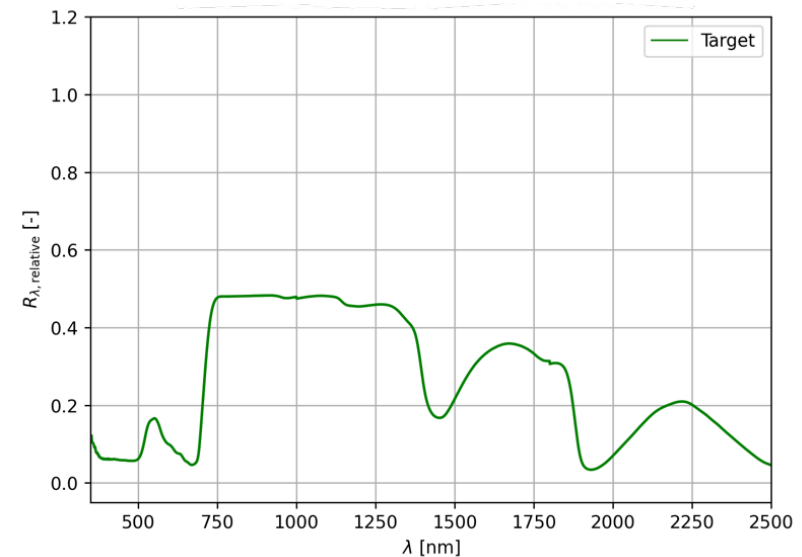
Crop/weed discrimination

Hyperspectral scan



4 leaves of at least **9 plants/species**

- Spectral signature (350 nm - 2500nm)
- Vegetation indices (21)
 - NDVI
 - PSSR
 - CARI
 - PSND
 - WI
 - NDWI
 - MSI
 - NDMI
 -



$$4 \times 9 \times 2150 = 77\,400$$

$$4 \times 9 \times 21 = 756$$

Crop/weed discrimination

Weed species of interest



Weedy Oat
Avena fatua
(AVEFA)



Papaver rhoeas
(PAPRH)



Polygonum aviculare
(POLAV)

Weed species of interest



Asperugo procumbens
(ASGPR)



Bromus sp.
(BROSS)



Diplotaxis muralis
(DIPMU)



Lolium multiflorum
(LOLMU)



Papaver rhoeas
(PAPRH)

Crops of interest



Cultivated Oat
Avena sativa



Barley
Hordeum vulgare



Wheat
Triticum aestivum

Crops of interest



False flax
Camelina sativa



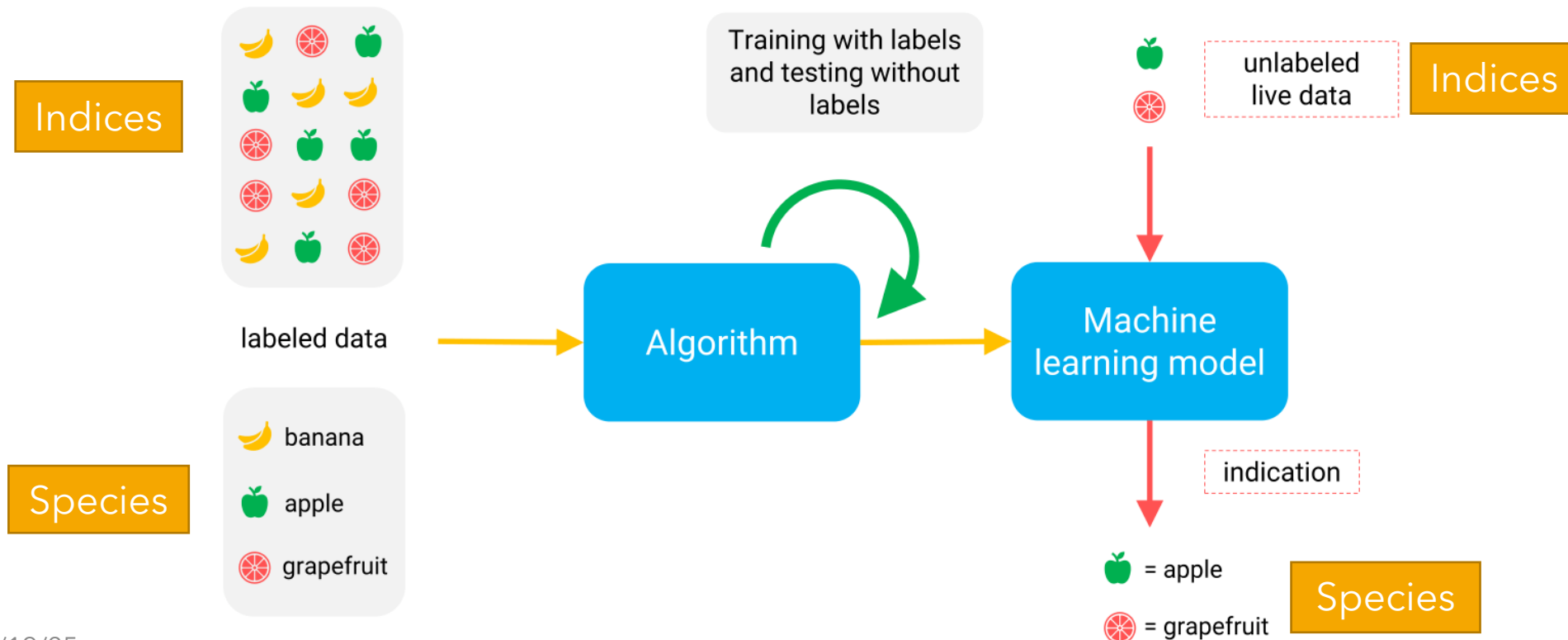
Canola
Brassica napus



Sage
Salvia verbenaca

Crop/weed discrimination

- Classify crop and weed species using Random Forest



Random forest results (21 indices)

Grugliasco

	AVEFA	Barley	Oat	PAPRH	POLAV	Wheat
AVEFA	100.0	0.0	0.0	0.0	0.0	0.0
Barley	0.0	50.0	10.0	0.0	0.0	40.0
Oat	11.1	0.0	66.7	0.0	0.0	22.2
PAPRH	10.0	0.0	0.0	80.0	10.0	0.0
POLAV	0.0	0.0	0.0	0.0	88.9	11.1
Wheat	13.8	3.4	0.0	6.9	0.0	75.9

Accuracy 0.763

Madrid

	ASGPR	BROSS	Camelina	Canola	DIPMU	LOLMU	PAPRH	Salvia
ASGPR	88.9	0.0	11.1	0.0	0.0	0.0	0.0	0.0
BROSS	0.0	80.0	0.0	0.0	0.0	20.0	0.0	0.0
Camelina	10.0	0.0	90.0	0.0	0.0	0.0	0.0	0.0
Canola	0.0	0.0	0.0	80.0	0.0	0.0	0.0	20.0
DIPMU	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
LOLMU	0.0	44.4	0.0	0.0	0.0	55.6	0.0	0.0
PAPRH	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Salvia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

Accuracy 0.868

Crop/weed discrimination - 3 step process

Input indices

```
graph TD; A[Input indices] --> B[Classify monocots/dicots]; B --> C[Classify crops/weeds]; C --> D[Classify species];
```

Classify monocots/dicots

Classify crops/weeds

Classify species

Random forest results (21 indices) - 3 step process

Grugliasco

	AVEFA	Barley	Oat	PAPRH	POLAV	Wheat
AVEFA	100.0	0.0	0.0	0.0	0.0	0.0
Barley	0.0	100.0	0.0	0.0	0.0	0.0
Oat	0.0	0.0	90.9	9.1	0.0	0.0
PAPRH	0.0	0.0	0.0	100.0	0.0	0.0
POLAV	0.0	0.0	0.0	12.5	75.0	12.5
Wheat	0.0	0.0	0.0	6.1	0.0	93.9

Accuracy 0.934

Madrid

	ASGPR	BROSS	Camelina	Canola	DIPMU	LOLMU	PAPRH	Salvia
ASGPR	85.7	0.0	14.3	0.0	0.0	0.0	0.0	0.0
BROSS	0.0	80.0	0.0	0.0	20.0	0.0	0.0	0.0
Camelina	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
Canola	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
DIPMU	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
LOLMU	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
PAPRH	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Salvia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

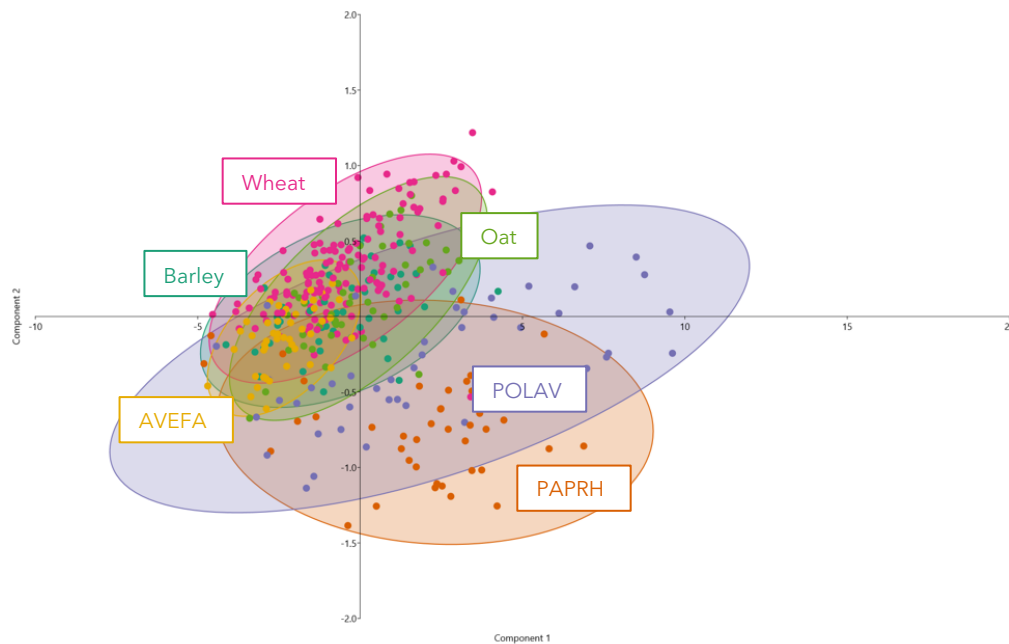
Accuracy 0.947



What if we reduced the
data even more?

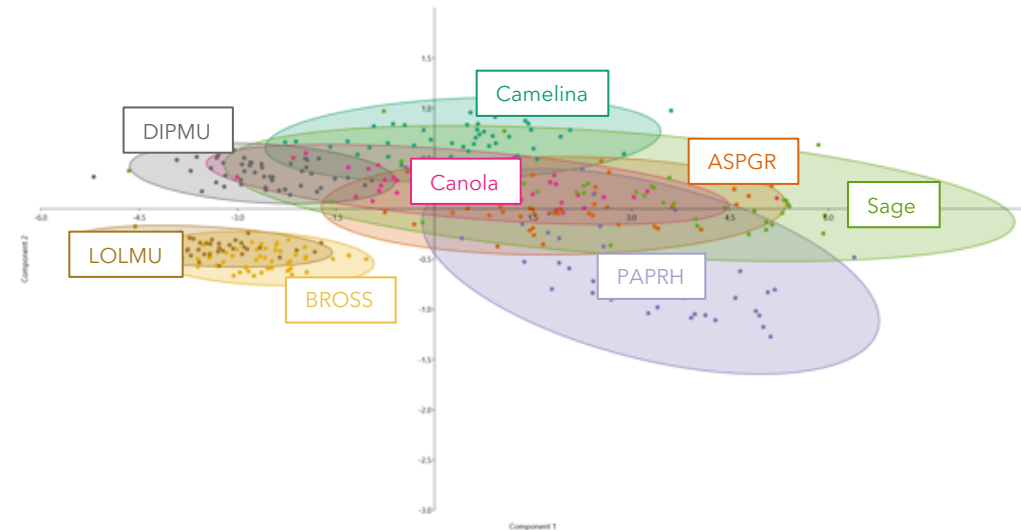
Principal component analysis results

Grugliasco



Component 1 explains **94,93%** of the variation

Madrid

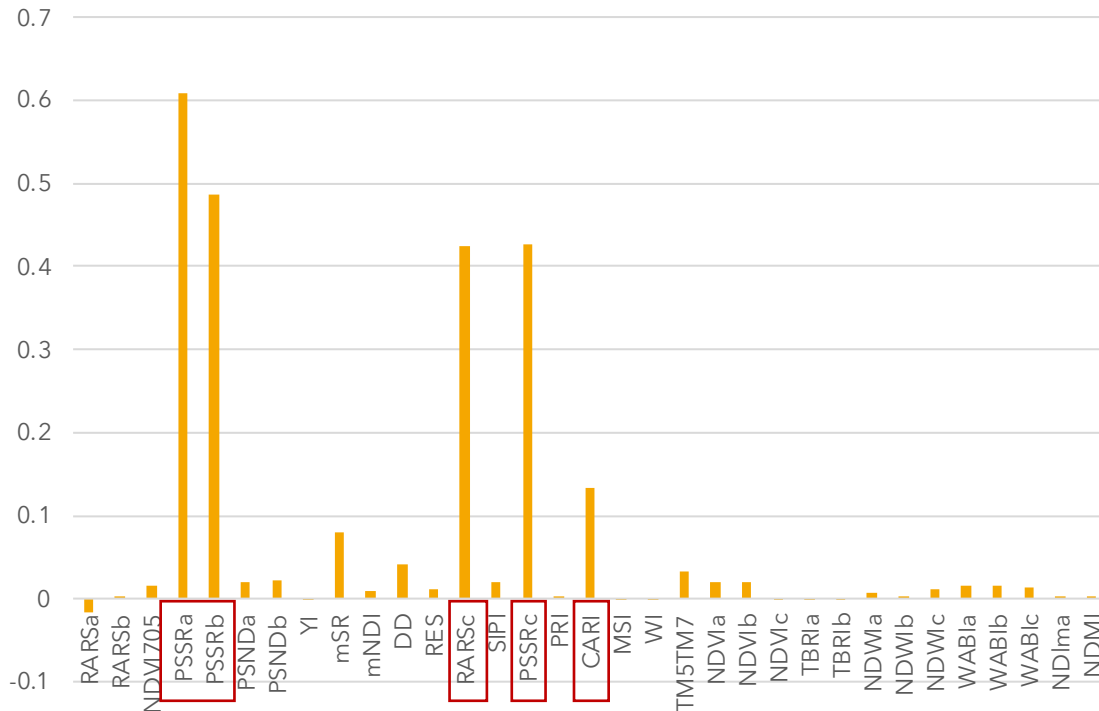


Component 1 explains **95,16%** of the variation

Principal component analysis results

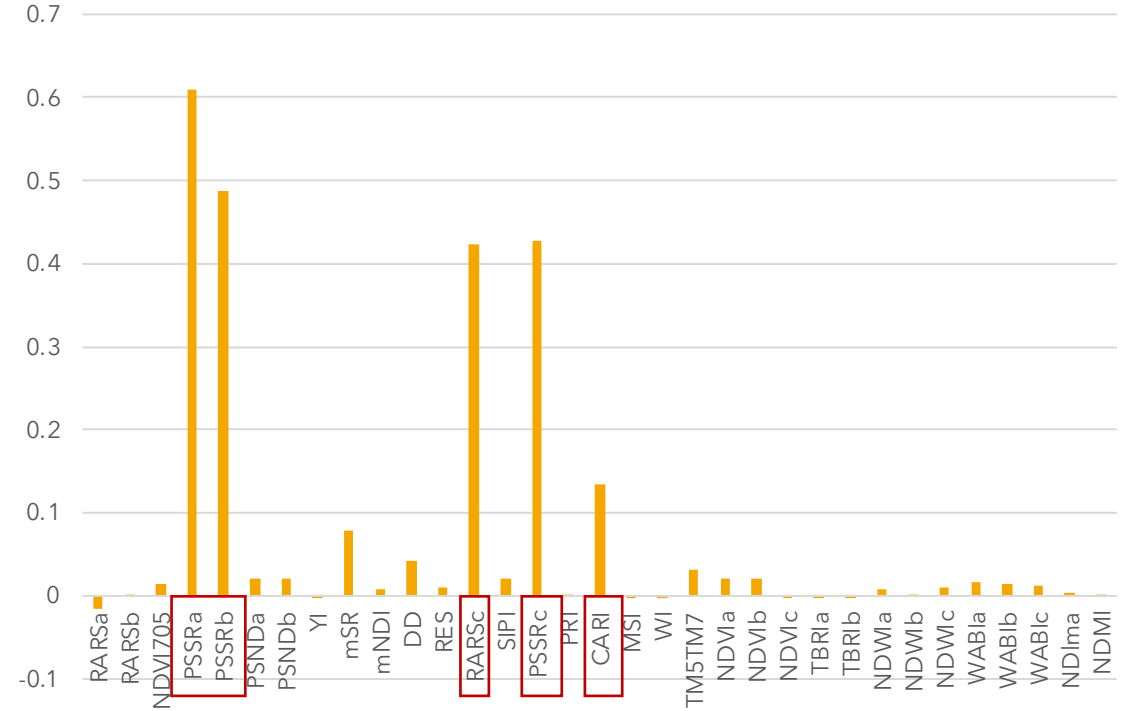
Grugliasco

Component 1 - loading plot



Madrid

Component 1 - loading plot



Random forest results (5 indices)

Grugliasco

	AVEFA	Barley	Oat	PAPRH	POLAV	Wheat
AVEFA	77.8	0.0	0.0	0.0	0.0	22.2
Barley	20.0	20.0	10.0	0.0	10.0	40.0
Oat	11.1	22.2	0.0	11.1	0.0	55.6
PAPRH	10.0	0.0	0.0	80.0	10.0	0.0
POLAV	11.1	0.0	0.0	33.3	33.3	22.2
Wheat	6.9	6.9	10.3	6.9	6.9	62.1

Accuracy 0.5

Madrid

	ASGPR	BROSS	Camelina	Canola	DIPMU	LOLMU	PAPRH	Salvia
ASGPR	33.3	0.0	11.1	11.1	0.0	0.0	33.3	11.1
BROSS	0.0	50.0	0.0	10.0	0.0	40.0	0.0	0.0
Camelina	0.0	0.0	80.0	0.0	0.0	0.0	0.0	20.0
Canola	10.0	0.0	0.0	70.0	0.0	10.0	0.0	10.0
DIPMU	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
LOLMU	0.0	44.4	0.0	0.0	0.0	55.6	0.0	0.0
PAPRH	0.0	0.0	0.0	22.2	0.0	0.0	77.8	0.0
Salvia	10.0	0.0	20.0	10.0	0.0	0.0	10.0	50.0

Accuracy 0.645

Random forest results (5 indices) + 3 step process

Grugliasco

	AVEFA	Barley	Oat	PAPRH	POLAV	Wheat
AVEFA	100.0	0.0	0.0	0.0	0.0	0.0
Barley	0.0	100.0	0.0	0.0	0.0	0.0
Oat	0.0	0.0	90.9	9.1	0.0	0.0
PAPRH	0.0	0.0	0.0	100.0	0.0	0.0
POLAV	0.0	12.5	0.0	0.0	75.0	12.5
Wheat	0.0	0.0	0.0	6.1	3.0	90.9

Accuracy 0.921

Madrid

	ASGPR	BROSS	Camelina	Canola	DIPMU	LOLMU	PAPRH	Salvia
ASGPR	92.9	0.0	0.0	0.0	0.0	0.0	7.1	0.0
BROSS	0.0	80.0	0.0	20.0	0.0	0.0	0.0	0.0
Camelina	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
Canola	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
DIPMU	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
LOLMU	0.0	0.0	0.0	0.0	11.1	88.9	0.0	0.0
PAPRH	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Salvia	0.0	0.0	0.0	0.0	0.0	14.3	0.0	85.7

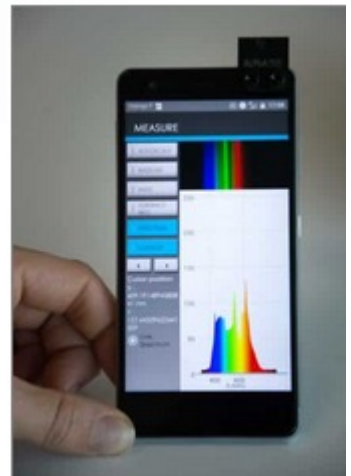
Accuracy 0.934

Take home message

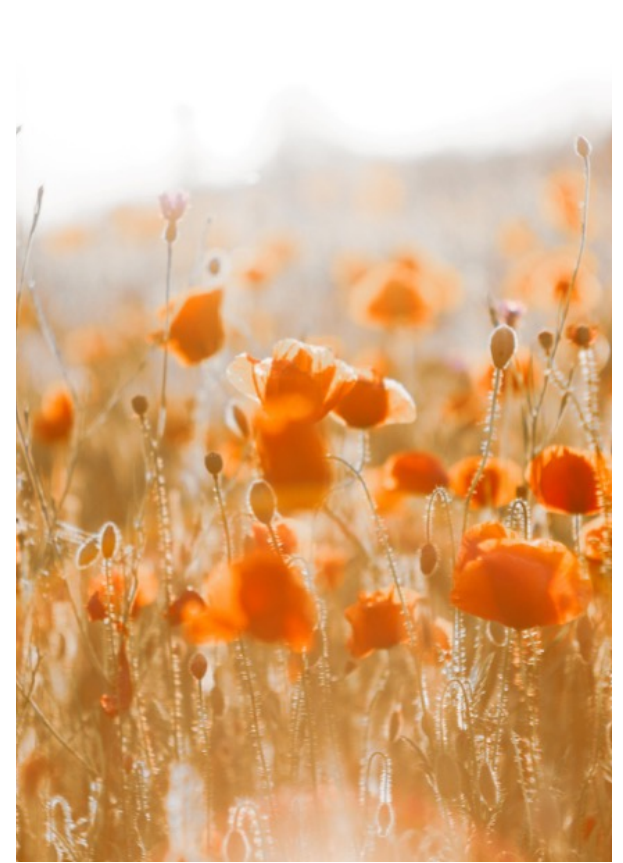
- Hyperspectral indices are robust in various conditions
- They allow to reduce the data load from 77400 to 756 and have good classification results
- The 3-step classification may be a promising approach

Future prospects

- Hyperspectral indices can be key in sustainable weed management and wild flora monitoring
- Hyperspectral technology won't be expensive for long! It's already possible to make spectral scans by smart phone (range: 400-750 nm; bandwidth: 10nm)



<https://www.axiomoptics.com/products/gospectro/>



Thank you for your attention!

Any questions?