Evaluation of Earth Observation Products and Their Potential for Crop Damage and Crop Loss Assessment. **The Case of Beacon Project.**

Earth Observation services in support of agriculture and Common Agricultural Policy

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AgroApps

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BEACON transforms the Agri-Insurance Sector…

From…

- **Weather Risk** — Uncertainty of Future Risk
- **Costs** — Higher Operational & Administrative costs
- **Market** — **Low market uptake & High Premiums**

To…

- **Weathe r Risk** — Accurate estimation of the potential losses and indemnities
- **Costs** — Remote Damage Estimation reduces Operational costs
- **Market** — High market uptake & Affordable Premiums

…by upscaling EO Data value

Drought damage assessment
Crop loss assessment

MODIS
composite NDVI data sets
NDVI Anomaly

Drought

Hailstorms damage assessment
Crop loss assessment

Sentinel-2
Change Detection
pre- post-damage imagery

Hailstorms

Floods damage assessment Flood extent & duration

Sentinel-2, Sentinel-1
Change Detection
pre- post-damage imagery

Floods

Wildfires damage assessment
Fire extent & severity

Sentinel-2
Change Detection
pre- post-damage imagery

Wildfires

Drought Damage Assessment

Satellite Drought Indicator

MODIS Terra GMOD09Q1 product

Daily surface reflectance data

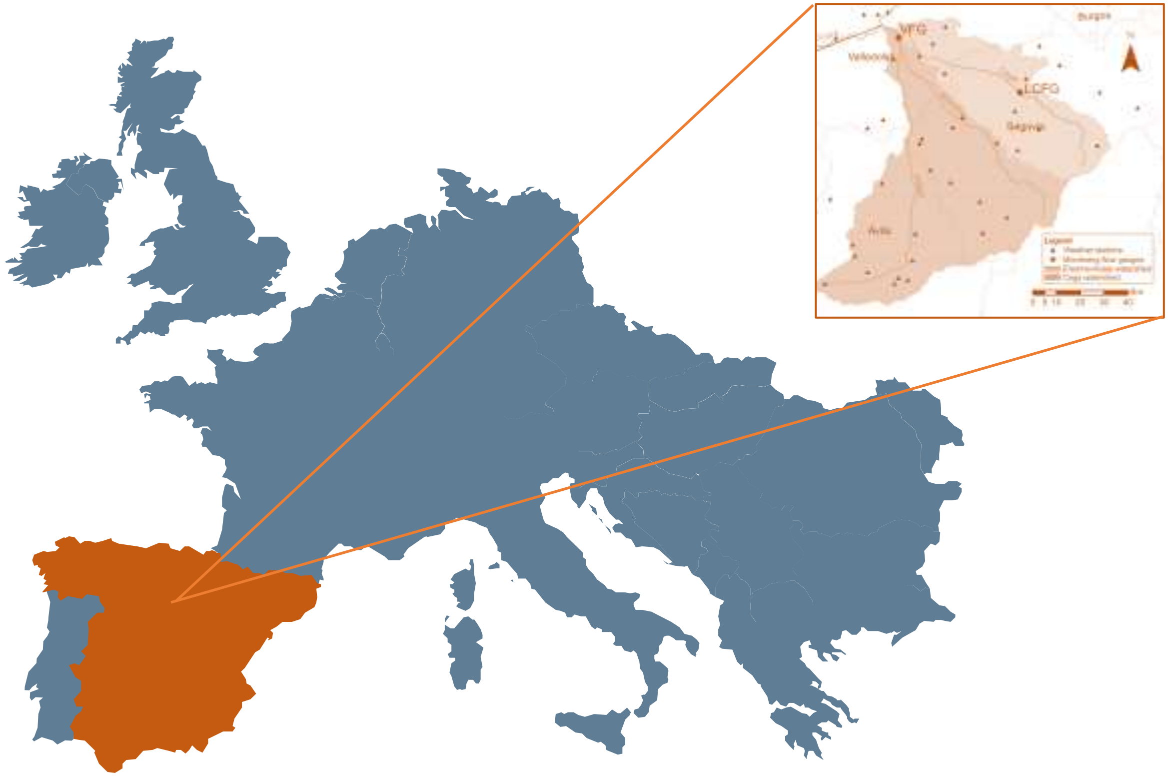
Satellite-derived vegetation indices products

8-day NDVI composite at 250 m spatial resolution

Historical NDVI composites available from 2001

Drought Damage Assessment

The Spanish use case



Data collection and preprocess

Geospatial Data

Year	Drought	Non-Damaged
2014-2015	12	-
2015-2016	-	117
2016-2017	95	53
2017-2018	13	-
2018-2019	42	-
2019-2020	-	109
Total	162	280

Crops	Rainfed wheat and barley
Region	Ávila and Segovia
Damage	10 – 100%
Parcel size	1 – 60 ha

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Satellite Data

MODIS NDVI 8-day composites (250 m resolution)

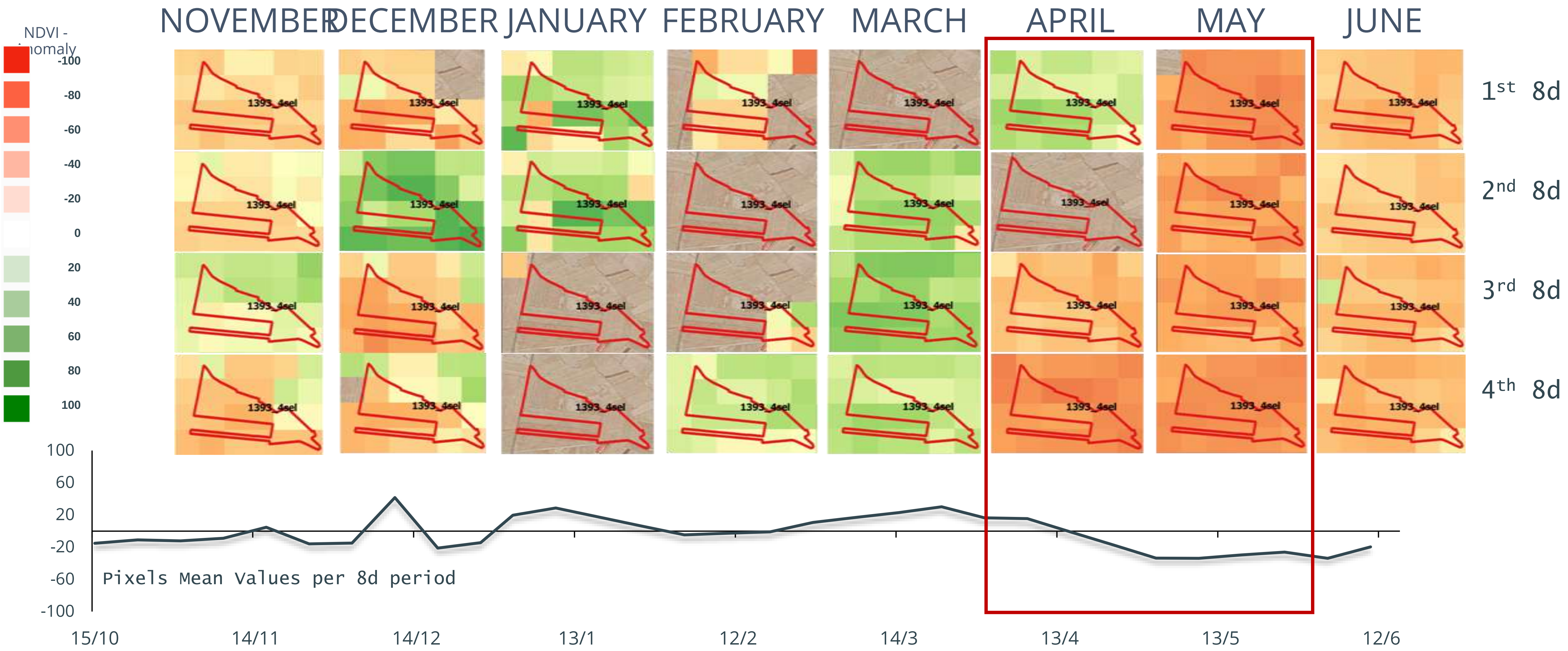
Relative NDVI Anomaly

$$NDVIA(\%) = \frac{NDVI_{current} - NDVI_{mean}}{NDVI_{mean}} \cdot 100$$

NDVI current is the current 8-day NDVI composite

NDVI mean is the average NDVI from 2001 for the same 8-day period

Relative NDVI – Anomaly calculation

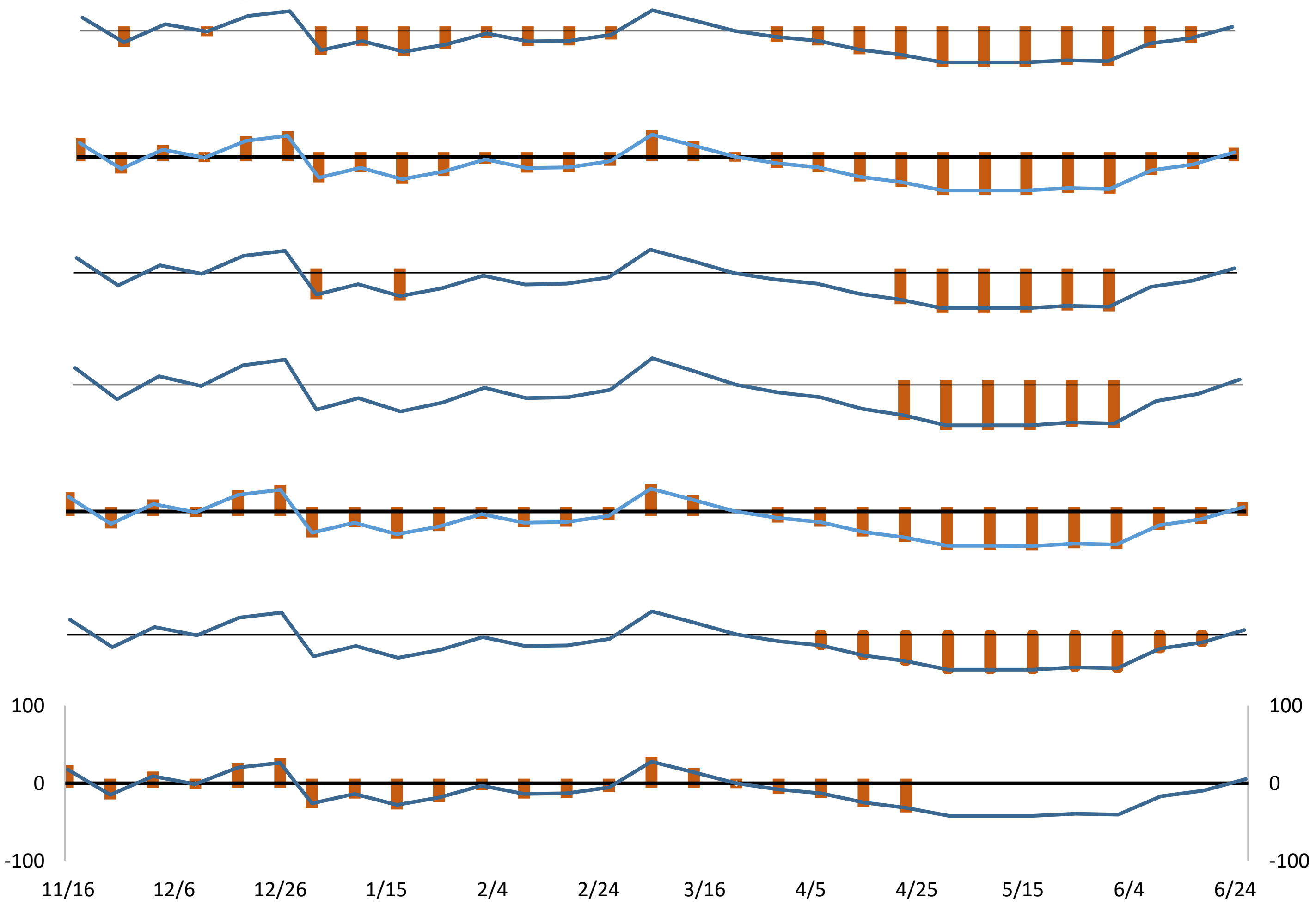


Drought Damage Assessment

- The approach was applied for both **rainfed wheat and barley.**
- **Only damaged parcels data were used.**
- **Different metrics of the NDVIA were tested.**

Indicator – Impact functions

Correlation between drought damage and NDVI Anomaly metrics



Drought Damage Assessment

- The late season NDVI-Anomaly **was moderately strong correlated with the damage.**
- Accumulation of absolute negative NDVI-Anomaly lower than -25% during May **was moderately strong correlated with the damage (r = 0.587)**

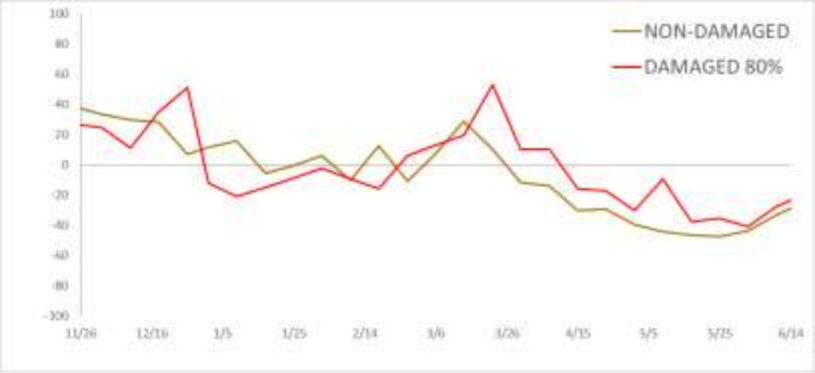
Indicator – Impact functions

x	Best fit for damage quantification (%)	RMSE (in %)	nRMSE	MAE (in %)	r
Accumulation of positive and negative NDVIA values throughout the growing season	sqrt(6472.31 - 1.53753x)	18.57	23.69	11.59	-0.140
Accumulation of positive and negative NDVIA values from sowing until 1st May	$(8.61906+0.000779977x)^2$	20.03	25.51	16.34	0.143
Accumulation of positive and negative NDVIA values from 1st April until harvest	$(7.97835-0.00489403x)^2$	20.49	27.24	15.67	-0.557
Accumulation of absolute negative NDVIA from 1st April until harvest	exp(3.70932+0.0434447sqrtx)	20.42	25.78	16.19	0.482
Accumulation of absolute negative NDVIA from sowing until 1st May	$\exp(4.34483-0.00000163952x^2)$	18.23	24.06	14.66	-0.170
Accumulation of absolute negative NDVIA lower than -25% throughout the growing season	$(7.43214+0.0995222\mathrm{sqrt}x)^2$	15.70	20.10	11.39	0.372
Accumulation of absolute negative NDVIA lower than -25% from 1st April until harvest	$(7.01467+0.154791\mathrm{sqrt}x)^2$	14.53	18.51	11.13	0.530
Accumulation of absolute negative NDVIA lower than -25% during May	exp(3.82504+0.0587201sqrtx)	18.67	23.14	14.89	0.587
Accumulation of absolute negative NDVIA lower than -25% during April and May (8 values)	exp(3.96415+0.0394364sqrtx)	18.80	23.64	14.04	0.504
Accumulation of absolute negative NDVIA lower than -25% during March, April and May (12 values)	exp(3.91805+0.0436961sqrtx)	22.78	29.21	17.81	0.558
Accumulation of absolute negative NDVIA lower than -25% during May and June (8 values)	exp(3.79778+0.0484829sqrtx)	19.22	24.99	14.10	0.629
Accumulation of absolute negative NDVIA lower than -25% during June (4 values)	exp(3.86061+0.0671895sqrtx)	18.60	23.20	14.12	0.560

Limitations of NDVI-Anomaly for claim-based insurance

- Results are crop and region specific. Are they PARCEL-SPECIFIC too?
- Does NDVIA reflect historically the same crop? Should all previous seasons (2001-2020) be used?
- How can we take into account the dynamics of the parcels?

NDVI-Anomaly of damaged and non-damaged parcels is similar:



The historical NDVI timeseries may not necessarily reflect previous wheat and barley crops at the same parcel, but also incorporation of other crops through a rotation program or even fallow land.

Results should take into account only wheat and barley cropping seasons. Seasons not affected by drought.

NDVI of damaged and non-damaged parcels is similar:

1. There is probably a lag between drought effects and NDVI (impact on vegetation reflected on NDVI)
2. The dynamics of a parcel are not apparent on EO data - NDVI. This is the reason yield prediction fails.
3. Damaged and non-damaged parcels should be examined separately.

Hail damage assessment

Change detection – VI differencing

$$DPI\,(\%) = \frac{VI_{pre} - VI_{post}}{VI_{post}} \cdot 100$$

Pre-damage Image Post –damage Image Result (DPI)

Sentinel-2 Optical VIs

Sentinel-2 Biophysical Parameters

Sentinel 1 Radar VIs

Hail Damage Assessment

The Serbian use case

The Serbian use case

Geospatial Data

Year	Hail			Non-Damaged		
	wheat	maize	soybean	wheat	maize	soybean
2015-2016	-	26	22	-	-	-
2016-2017	-	16	11	-	-	-
2017-2018	59	1	24	-	-	-
2018-2019	-	-	-	-	55	66
2019-2020	33	26	39	16	15	7
Total	91	69	86	16	70	73

Crops	Wheat, maize, soybean
Region	Vojvodina
Damage	5 – 100%
Parcel size	0.1 – 55 ha

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Satellite Data

Sentinel-1, Sentinel-2

Damage Percentage Index (DPI):

$$DPI\ (\%) = \frac{VI_{pre} - VI_{post}}{VI_{post}} \cdot 100$$

Sentinel-2 Optical VIs

NDVI, GNDVI, MCARI, REIP

Sentinel-2 Biophysical Parameters

LAI, fAPAR, fCOVER

Sentinel 1 Radar VIs

MPDI, VH/VV, VV and VH backscatter signals

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Hail damage assessment

- Object-(parcel)-based methodology.
- The approach was applied separately for **wheat, maize and soybean.**
- **SAR and Optical VIs** were tested against ground truth data**.**
- VI differencing in the in the **first available pre- and post-damage image.**
- **Only damaged parcels data were used.**

Simple VI differencing

Pre-damage Image Post –damage Image Result Damage (%)

Wheat

$$\frac{NDVI_{pre} - NDVI_{post}}{NDVI_{post}} \cdot 100$$

Metric	Value
Mean Error (ME)	-1.7%
Root Mean Square Error (RMSE)	20.4%
Coefficient of Residual Mass (CRM)	0.07
Correlation Coefficient (R^2)	0.23

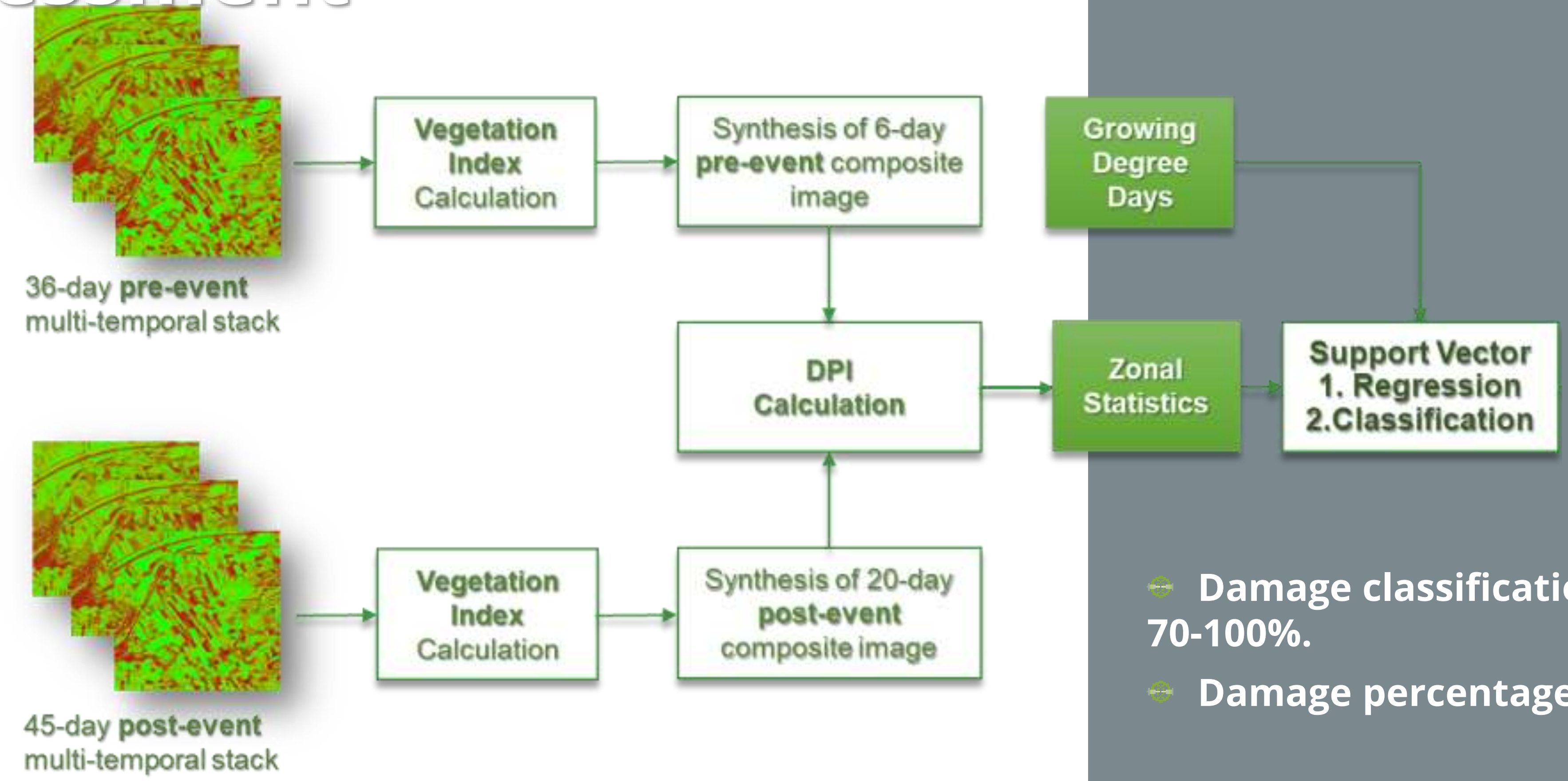
Maize

$$\frac{LAI_{pre} - LAI_{post}}{LAI_{post}} \cdot 100$$

Metric	Value
Mean Error (ME)	-3.1%
Root Mean Square Error (RMSE)	8.5%
Coefficient of Residual Mass (CRM)	0.17
Correlation Coefficient (R^2)	0.54

Machine learning for hail damage assessment

- Object-(parcel)-based methodology.
- A general model and three crop-specific models for wheat, maize and soybean.
- Two ML algorithms: i. Support Vector Machines (SVM) and ii. Random Forest (RF)
- Only optical VIs were used as training data.
- DPI obtained by the 6 days-pre and 20 days-post damage image.
- Damaged and non-damaged parcels were used.



- Damage classification 0-10, 10-30, 30-70 and 70-100%.
- Damage percentage.

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Machine learning for hail damage assessment

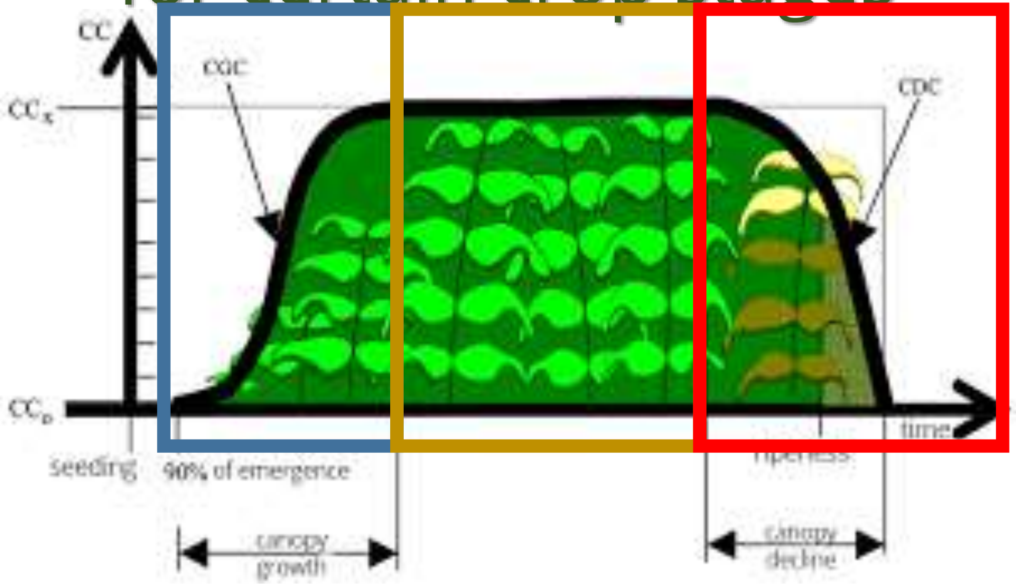
SVM Regression								
Crop	Outlier Detection	Feature Selection	RMSEC	R^2 Cali	RMSEV	R^2 Vali	RPD	RPIQ
All	PCA Res & Inf	All	1.89	0.99	17.53	0.21	1.13	1.14
Maize	PCA Maha	SBF	7.20	0.61	8.98	0.41	1.30	1.67
Soybean	PCA Maha	HS p-value	18.02	0.54	20.38	0.41	1.25	1.47
Wheat	PCA Maha	SBF	8.62	0.58	10.57	0.38	1.24	1.28

SVM Classification								
Crop	Outlier Detection	Feature Selection	Overall Metrics		By Class Metrics			
			Accuracy	Kappa		Precision	Recall	F1
All	PCA Maha	All	0.577	0.190	0-10%	0.53	0.98	0.69
					10-30%	0.92	0.27	0.42
					30-70%	NA	0	NA
					70-100%	NA	0	NA
Maize	PCA Res & Inf	All	0.620	0.280	0-10%	0.6	0.68	0.63
					10-30%	0.65	0.65	0.65
					30-70%	NA	0	NA
					70-100%	NA	NA	NA
Soybean	PCA Res & Inf	All	0.514	0	0-10%	0.51	1	0.67
					10-30%	NA	0	NA
					30-70%	NA	0	NA
					70-100%	NA	0	NA
Wheat	All Data	SBF	0.428	-0.060	0-10%	0.44	0.92	0.6
					10-30%	0	0	NA
					30-70%	NA	0	NA
					70-100%	NA	NA	NA

Limitations of DPI

- DPI is almost unable to discriminate damage during senescence and physiological maturity.

The ML regression model for damage percentage with change detection could work for certain crop stages



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