NUMERICAL CHARACTERIZATION OF TIME SERIES DATA DERIVED FROM H/A/ALPHA DECOMPOSITION OF SENTINEL-1 IMAGES

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Introduction and objectives

Polarimetric radar data is applicable to identify different types of crops by examining their phenological profile [1]. The intent of my study is to analyse **which numerical parameters of phenological time series show significant difference between the types of crops** and so suitable for classification of crop types. Moreover, appropriate numerical characteristics would become input of a classification algorithm based on radar polarimetry.

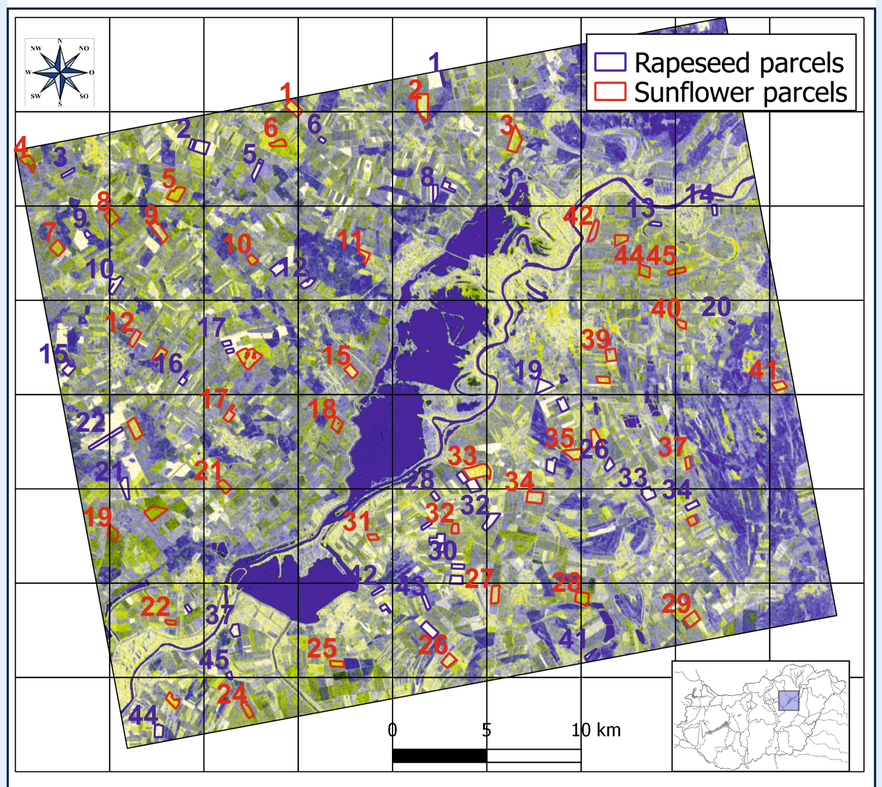

Fig. 1: Study area (R: Shannon, G: Shannon P, B: Shannon I)

The selected study area is the **surroundings of Lake Tisza, Hungary** (Fig. 1). Polarimetric descriptors were generated based on H/A/Alpha decomposition of covariance matrix [2] of Sentinel-1 dual-pol (VV+VH) images. The data was acquired in the **March-September period of 2016**, with 12-days time-resolution. The **45** parcels covered by rapeseed and the **45** by sunflower were selected randomly from a national database of the sown area of main crops. Time series of all the parcels were constructed from **ten descriptors**: alpha and its components, anisotropy, eigenvalues of covariance matrix (L1 and L2), Shannon entropy and its components. Out of the 900 profiles 4×2×45 are shown below (Fig. 2).

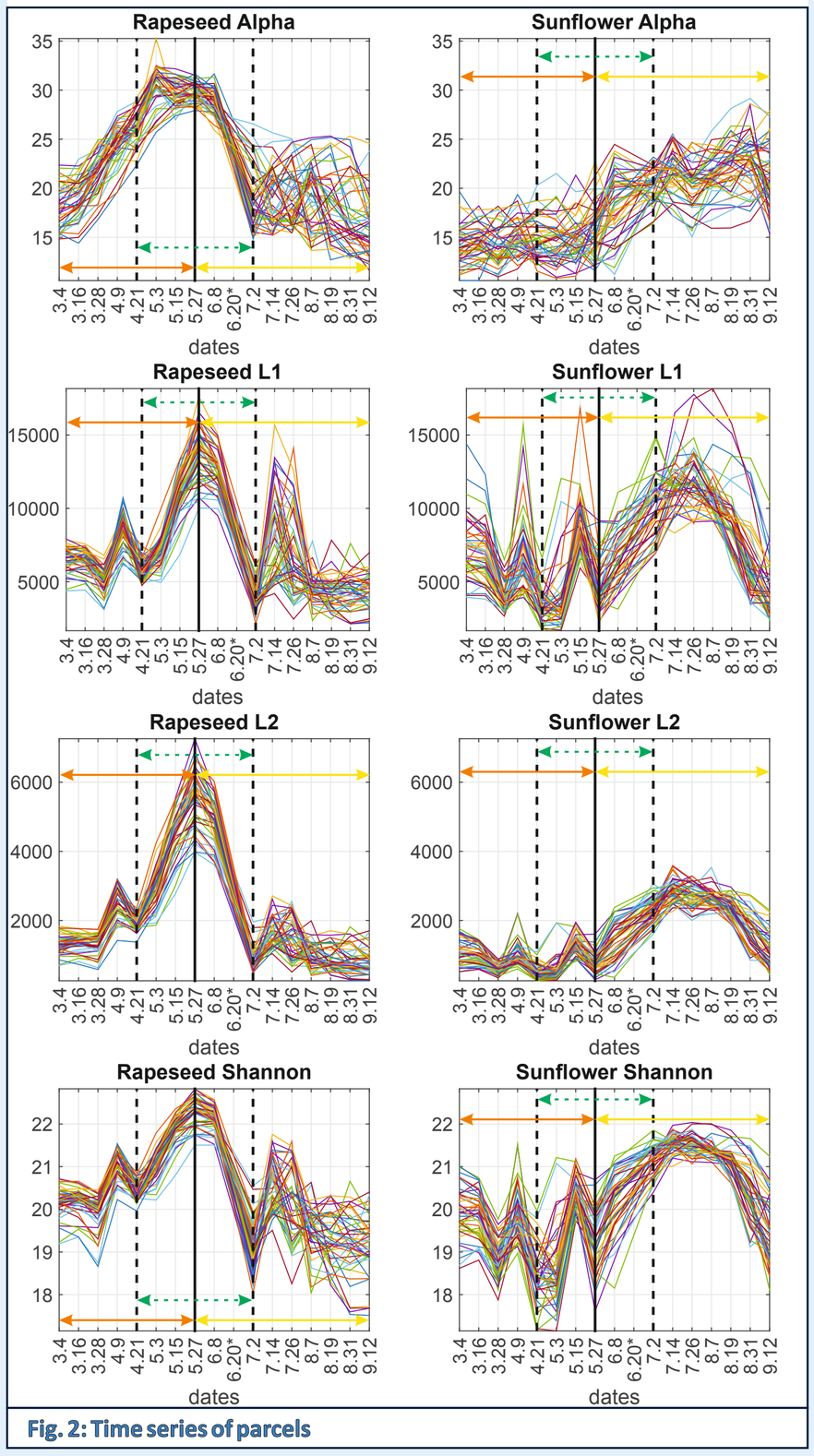

Fig. 2: Time series of parcels

Methods

A) The timeline was split into **3 intervals** and the following parameters of profiles in these intervals were examined: maximum, mean, standard deviation (std) and full width at half maximum (FWHM).

$$\mathrm{FWHM} = 2\sqrt{2\ln 2}\,\sigma$$

where σ is the standard deviation of the fitting Gauss function.

B) To analyse quantitatively the similarity between each data points and the means of the parcels, **distance matrices** were examined. Elements of matrices were counted with the form below, where *i* refers to dates, *j* refers to parcels:

$\sum_i \sum_j \left(rapeseed_j^i - rapeseed_{j_{mean}}^i\right)^2$	$\sum_i \sum_j \left(sunflower_j^i - rapeseed_{j_{mean}}^i\right)^2$
$\sum_i \sum_j \left(rapeseed_j^i - sunflower_{j_{mean}}^i\right)^2$	$\sum_i \sum_j \left(sunflower_j^i - sunflower_{j_{mean}}^i\right)^2$

Results and discussion

Date intervals		3.4. - 5.27.				4.21. - 7.2.				5.27. - 9.12			
Parameters of profiles in these intervals		max	mean	std	FWHM	max	mean	std	FWHM	max	mean	std	FWHM
Descriptors	Alpha	**100**	100	100	84	100	100	**64**	92	96	-	93	92
	Alpha1	100	100	100	78	100	100	90	98	100	-	99	92
	Alpha2	90	100	100	-	89	100	90	89	-	-	99	92
	Anisotropy	89	100	100	-	90	100	-	93	-	-	94	96
	Entropy	100	100	97	84	100	100	-	92	96	-	85	96
	L1	89	89	-	89	82	91	-	100	0	85	**-**	100
	L2	100	100	100	85	100	100	98	100	100	-	**99**	93
	Shannon	98	99	-	-	97	**100**	-	99	92	89	-	**100**
	Shannon Intensity	93	97	-	-	88	97	-	98	-	91	-	100
	Shannon Polarimetry	100	100	83	-	100	100	-	92	96	-	-	97

Table 1: Success of separating profiles based on their parameters (%)

A) Examining the three intervals severally, **minimum one parameter could be found for all descriptors, which separates totally rapeseed from sunflower.** The highlighted cells of Table 1 are represented on Fig.3 and explained below.

1. In the fore-part of the timeline, when rapeseed flowers and grows crop, sunflower has not sown yet, the maximum of alpha profiles splits them clearly (100%): maximum of rapeseed is higher.
2. In the middle of the timeline, during harvest of rapeseed and appearing of sunflower, the std of alpha profiles only partially separates them: with limit of 4 the result is 64%.
3. In the end of the timeline, when sunflower flowers and rapeseed has been already harvested, the std of the first eigenvalue (L1) shows non-separateness.
4. In contrast, in the same interval, the std of the second eigenvalue (L2) separates the plants well (99%).
5. Separation of Shannon profiles in the middle of the time series is possible based on the mean parameter: values are close to each other, but 20.5 is an appropriate limit (100%).
6. However, in the end of the time series only FWHM works well (100%): profiles of sunflower are similar to a Gauss function, rapeseeds' are typically not.

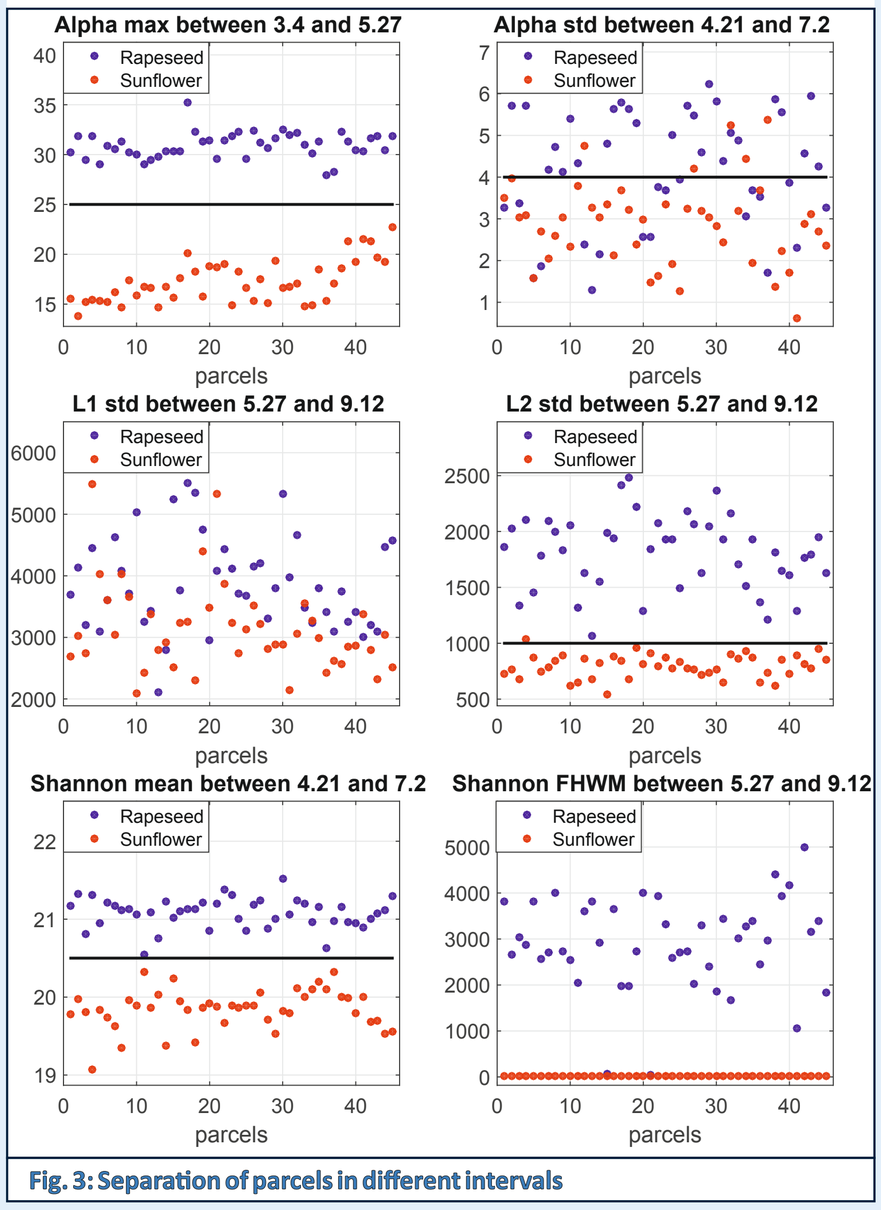

Fig. 3: Separation of parcels in different intervals

Descriptors	Distance matrices	
Alpha	4332	57209
	57530	4011
Alpha1	619	7633
	7882	370
Alpha2	619	7634
	7883	370
Anisotropy	1,83	23,96
	24,10	1,69
Entropy	2,03	24,50
	24,30	2,23
L1	1538862058	15437804872
	14343087048	2633579882
L2	154249814	3126116513
	3191152580	89213747
Shannon	**178**	**2123**
	2085	**215**
Shannon Intensity	150	1512
	1449	213
Shannon Polarimetry	9	103
	100	11

Table 2: Distance matrices

B) For all descriptors, the summed distances in the diagonal elements are greater than the off-diagonal ones (Table 2). **So the data values of one plant are closer to their mean values than the other plants'.** To validate that the groups of the two plants are certainly separate, cross-validation was performed. The results show the same for all descriptors either one rapeseed point is the "training data" (Fig. 4), or one sunflower.

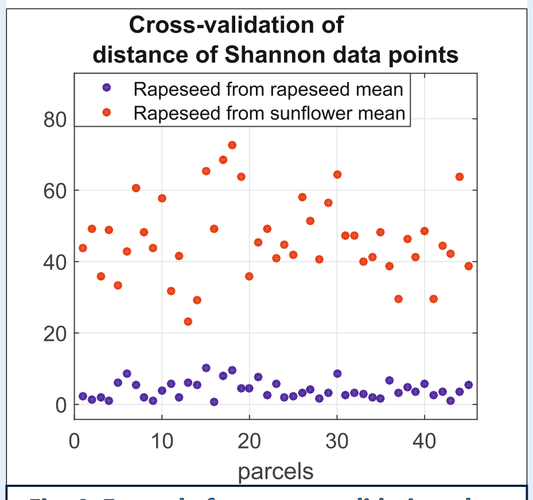

Fig. 4: Example for a cross-validation plot

Conclusion

In conclusion, **we have possibility to separate kinds of plants based on simple numerical parameters, which are derived from radar related phonological profiles.** Rapeseed and sunflower have temporal difference between their periods of life and we had a summer-long dataset, which two ease the separation. Later, increasing the number of examined types of plants, shorten the time interval, and so reduce the needed radar data are planned to increase the efficiency. These results could become one of the first steps of developing a classification algorithm based on radar polarimetry.

Acknowledgement

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References

[1] **Z. Friedl, G. Nádor, M. Rada, Gy. Surek:** Analysis of the main arable crops' phenology by polarimetric descriptors derived from H/A/alpha decomposition of Sentinel-1 time series data. Conference presentation, ESA-ESRIN PolinSAR 2017, Frascatti (2017)

[2] **J. S. Lee and E. Pottier:** Polarimetric radar imaging: from basics to applications. CRC Press, Boca Raton (2009), 398 pp