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JOINT USE OF SVAT MODEL AND LSA SAF PRODUCTS FOR DIAGNOSES AND FORECAST OF VEGETATION STATE AND FIRE DANGER OVER SOUTHEASTERN EUROPE

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Introduction

Based on using NWP-, SVAT- models output and LSASAF products the work is focused to evaluate different approaches for assessment dry land surface state anomalies as related to fire risk environment. The capacity of available fire risk indexes for the region of Eastern Mediterranean, including an initial assessment of the applicability of fire danger classes of the new Fire Danger Index of IDL, Portugal (Miguel et al., 2018) has been performed. Fire Weather Indexes based on CFFWS and Indexes accounting the vegetation state using root zone moisture deficit are considered. Additionally, a Complex approach combing meteorological conditions and soil moisture deficit as a measure of vegetation fuel dryness to diagnose and forecast fire danger is proposed.

The evaluation procedure is generally based on the qualitative/quantitative comparisons between Indexes and towards reference data, which include information for the actual fire events detected ((number and burned area); Fire Radiative Power according LSASAF FRP-Pixel product)). Comparative analyses are based on using smoothed averaged courses of corresponding indexes versus the reference fire parameters. To quantify the usefulness of the forecasts, contingency tables are elaborated to indicate different levels of fire danger probabilities in terms of 'Yes/No' of actual fires occurrence. Overlaid graphical analyses of the seasonal (Jun-Aug 2016 & 2017) dynamics of Indexes curves towards actual fire characteristics have been developed to demonstrate the sensitivity of risk rating.

A. Methodology - Dataset

Approach

- SVAT modeling: Surface analysis scheme at NIMH
  - Modeling of Soil Moisture
  - Quantification of Soil Moisture Deficit
- Statistical indicators and criteria
- Evaluation of Indexes score
  - Comparative analyses between indexes
  - Comparative analyses Indexes vs. Reference data
  - Qualitative & Quantitative approaches

Fire Risk Indexes, FRIs

Operational LSA SAF products via EUMETCast

- LSA SAF Fire Risk Maps, FRM

Regional Operational products at Bulgaria domain

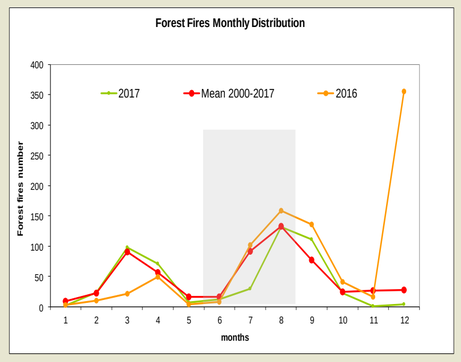
- SMDIFD, Bulgarian SVAT approach, based on data from ECMWF NWP model
- Complex Fire Danger Indexes: Complex (LSASAFFRM & SMDIFD); two new versions, ComplexNew, 1-2 (FDI & SMDIFD)

Pre-operational version of FDI

- **Fire Danger Index,** FDI developed at Instituto Dom Luiz, Faculty of Sciences, University of Lisbon .

Data set

- June-August 2016 & 2017
- Fire Risk Indexes
- Reference data
  - Number of fires (State Forest Agency, SFA; Ministry of Inner Affairs, MIA databases) from ground observations
  - Burning vegetation – Dry Grass, DG; Forest Fires, FF
  - Total burned area, TotR (according SFA & MIA)
  - LSA SAF FRP-Pixel product detections and FRE (MW)
- Target region – Bulgaria, Southeastern Europe.

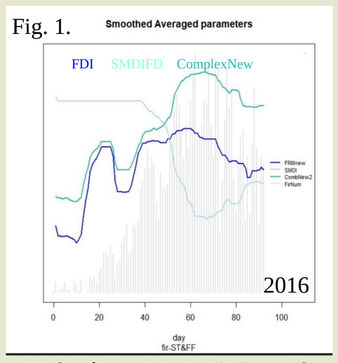


B. Qualitative analyses of Interrelations between FRIs

1. Seasonal DG&FF Fire distribution (grey bars) & variation of FRIs

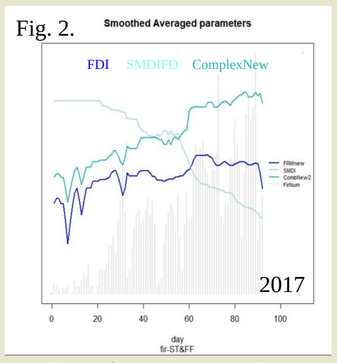
To characterize fire activity, 3 types of Indexes are applied: - FDI / LSASAFFRM *(based on FWI);* - SMDIFD (*based on Soil Moisture Deficit);* - Complex/ComplexNew *(based on FRM/FDI & SMD)*

Fig. 1.



Higher fire activity in 2016 , a peak at the end of Jul, beginning of Aug

Fig. 2.



Lower fire activity in 2017 with a peak at the end of Aug

2. Behavior of FRI towards actual fire characteristics

Fig. 3.

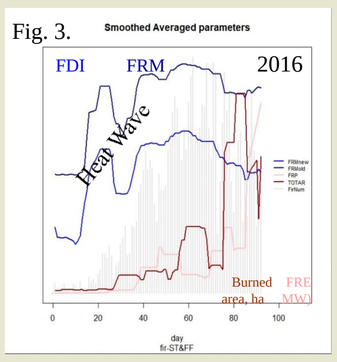
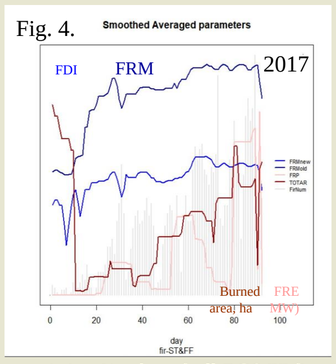


Fig. 4.



The course of Indexes in parallel to fire characteristics: Number of all DG&FF fires *(grey bars)*, Burned area (ha), Fire Radiative Energy (MW) according LSA SAF FRP-Pixel product

For both 2016, 2017:

- There is no strong relation between number of fires, total area burned and Fire Radiative Energy (FRE).
  - For 2017 these correspond to the peak of fire number.
  - For 2016 there is no one to one correspondence between level of fire risk in respect to meteorological and land surface conditions and burned area.
- The maxima of Burned area and FRE are at the end of August

Fig. 5.

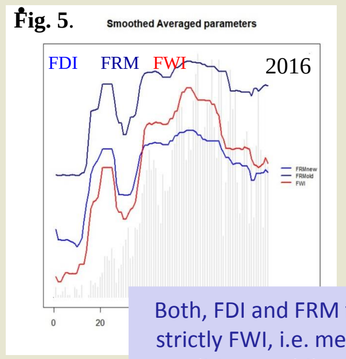
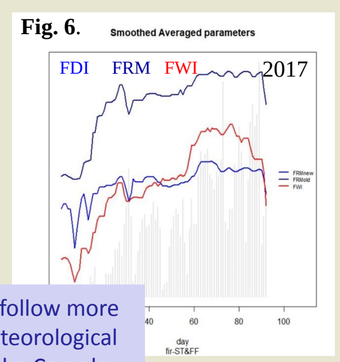


Fig. 6.



Both, FDI and FRM follow more strictly FWI, i.e. meteorological conditions , while the Complex Index reflects also SMD (fuel dryness).

The course of FDI and ComplexNew *(in a 5-level scale) are* differing:

- 2016: ComplexNew and SMDIFD (in an opposite way) follow the dynamics of fires (Jun-Aug); FDI does not strictly follow the fire activity: Comparatively similar high values for June and Aug, whereas the number of fires varies significantly;
- 2017: ComplexNew shows an increasing trend in parallel to SMDIFD decreasing at the end of Aug along with increase of fire number; FDI is almost constant with a slightly descending trend;
- SMDIFD for both years at the end of July starts to decrease along with increase of number of fires.

ComplexNew FRI course follows fire activity more strictly than FDI.

Acknowledgements:

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C. Quantitative analyses of Interrelations between FRIs

1. Relation between FRIs

Table 1. SPEARMAN correlation matrix based on all INITIAL DATA in case of DG and FF fires for the test period

2016, DG, n = 180 973				2016, FF, n = 21 782			
FRIs	FDI	LSASAF FRM	SMDIFD	**FRIs**	FDI	LSASAF FRM	SMDIFD
FDI	1.00	0.69	-0.35	FDI	1.00	0.74	-0.40
FRM	0.69	1.00	-0.43	FRM	0.74	1.00	-0.44
SMDIFD	-0.35	-0.43	1.00	SMDIFD	-0.40	-0.44	1.00
2017 DG, n =128 121				2017 FF, n = 15 861			
FDI	1.00	0.60	-0.35	FDI	1.00	0.66	-0.36
FRM	0.60	1.00	-0.39	FRM	0.66	1.00	-0.39
SMDIFD	-0.35	-0.39	1.00	SMDIFD	-0.36	-0.39	1.00

Initial dataset: Dataset of daily values of corresponding index for three months (Jun-Aug) for all locations/coordinates with fire occurrence in case of : Dry Grass, DG; Forest Fire, FF:

- FDI and LSASAF FRM are differing each other
  - There is a moderate correlation between them (0.6 -0.74), with a stronger correspondence in case of FF occurrence;
- SMDI is negatively correlated with FDI and LSASAF FRM
  - The decreasing soil moisture leads to increase of fire risk and negative correlation.

2. Relation between FRIs and Number of fires occurrence

Table 2. Correlation matrix based on SMOOTHED AVERAGED DATA, in case of DG and FF fires for the test period

FRIs	FDI	LSASAF FRM	SMDIFD	Complex	Complex New
2016_DG, n = 180 973	0.59	0.55	-0.11	0.34	0.38
2017_DG, n = 128 121	0.77	0.84	-0.83	0.89	0.91
2016_FF, n = 21 782	0.49	0.55	-0.70	0.71	0.69
2017_FF, n = 15 861	0.63	0.68	-0.76	0.75	0.79

Smoothed averaged data for FRIs on a 10 days quantitative bases are used.

- Reasonably, all Indexes are not sensitive to indicate the risk of so small fires: There is a better correlated with number of fires in 2017 then in 2016, when a larger number of small fires (less than 10 ha) are observed (see Table 1);
- Among the other indexes, SMDIFD shows the lowest score (-0.11 for 2016), because of its nature: It reflects the soil moisture availability in a deep layer and thus is not indicative of small DG-fires (the number of small DG fires: 3886 for 2016 vs. 2314 for 2017);
- FDI / LSASAF FRM are better correlated with the number of DG fires than with the number of FF: DG-fires are more strongly influenced by weather conditions, i.e. from meteorological fire risk, while in case of FF, fuel dryness due to soil moisture deficit in a deep layer is also important;
- The Complex FRI (all versions) is better correlated with the number of FF than LSA SAF indexes (all versions) with an exception for small DG fires in 2016. The Complex FRI accounts for SMD in addition to meteorological fire risk that significantly improves the correlation. The highest score is shown by CombNew index, which combines the weather conditions and vegetation state and reflects more efficiently the fire risk, especially regarding the FF.

3. Relation between FRIs and Burned area/Fuel type

- Small fires: All Indexes are not indicative for fire occurrence.
- Moderate and Large fires: there is progressively increase of percentage of fire events with the increase the level of fire risk.
- Examples: good / poor performance of Indexes:

Score of the FDIs regarding fire severity
(*Number of fires, Total burned area, FRE*)

Table 3. Very good performance of FDI: all 3 months 2017, ST&FF

	BURNED AREA, ha			Percentage of fire occurrence		
FDI	<10	<100	≥100	%<10	%<100	%≥100
1	165	6	0	96.5	3.5	0
2	1110	76	14	92.5	6.3	1.2
3	892	63	14	92.1	6.5	1.4
4	261	21	5	90.9	7.3	1.7
5	26	4	1	83.9	12.9	3.2

Table 4. Poor performance of FDI: 2017_FF all 3 months

	BURNED AREA, ha			Percentage of fire occurrence		
FDI	<10	<100	≥100	%<10	%<100	%≥100
1	8	1	0	88.9	11.1	0
2	29	9	8	63.0	19.6	17.4
3	54	13	7	73.0	17.6	9.5
4	39	9	3	76.5	17.6	5.9
5	10	3	1	71.4	21.4	7.1

Table 5. Very good performance of ComplexNew: all 3 months 2016&2017, DG&FF

	BURNED AREA, ha			Percentage of fire occurrence		
Complex New	<10	<100	≥100	%<10	%<100	%≥100
1	6	0	0	100	0	0
2	1739	112	8	93.5	6	0.4
3	2092	148	16	92.7	6.6	0.7
4	2277	222	47	89.4	8.7	1.8
5	304	45	8	85.2	12.6	2.2

Table 6. Good performance of SMDIFD (in an opposite way than for the other indexes): all 3 months 2016, DG&FF

	BURNED AREA, ha			Percentage of fire occurrence		
SMDIFD	<10	<100	≥100	%<10	%<100	%≥100
1	1153	137	21	87.9	10.5	1.6
2	1240	122	16	90	8.9	1.2
3	147	15	0	90.7	9.3	0
4	1549	99	8	93.5	6	0.5
5	3	0	0	100	0	0

- There is no good correspondence between released Fire Radiative Energy and the level of fire risk (not presented).

4. Sensitivity analyses of fire risk classes

Table 7. Contingency table characterizing fire occurrence
(*number of fires and % of all cases with corresponding level of fire*

2016	Index	FDI		LSA-SAF-FRM		Complex (FRM-SMDI)		ComplexNew (FDI-SMDI)	
	Scale	Number	YES,·%	Number	YES,·%	Number	YES,·%	Number	YES,·%
	1	198	0.3	0	0	15	1.2	3	0.1
	2	460	1.2	250	0.4	441	0.6	665	0.8
	3	1017	1.7	515	1.3	998	1.6	1014	1.6
	4	849	2.0	1852	2.0	1163	1.8	895	1.9
	5	93	2.3					40	2.2
2017	1	167	0.4	0	0	9	1.7	··3	0.1
	2	1145	2.1	247	0.5	294	0.6	857	1.0
	3	945	2.4	461	1.5	749	1.9	945	2.7
	4	276	2.6	1856	2.8	1400	3.3	607	3.4
	5	31	4.4					14	4.9

Recommendation: To be considered somehow SM or SMD in FRI.

- All Indexes indicate relevant distribution of fire occurrence according to the fire risk level (from green to red)
- FDI gives less 'false' alarms than LSA SAF FRM *in 'green'* level, having better discrimination of fire risk environment
- Complex Index gives less 'false' alarms than FDI at 'green' level of fire risk
- Accounting for regional SMD and related fuel dryness can reduce the risk overestimation at low levels of fire risk (green/yellow) thus improving the indexes score.

5. Comparison of the Indexes

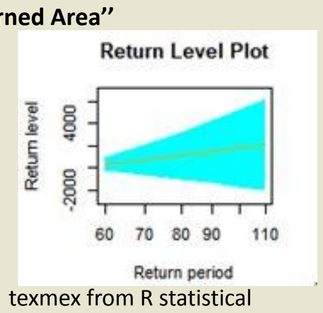
	Index	AIC	BIC
1	Complex	51134.44	51177.33
2	ComplexNew	51434.35	51488.04
3	LSASAF FRM	51943.76	51986.78
4	FDI	52408.77	52462.55

- The fire risk indexes are classified according to their correlation with the number of fire occurrence by using Logistic Regression technique.
- The lower the values of Akaike information criterion (AIC) Bayesian information criterion (BIC), the stronger the relation between the index and the fires occurrence.
- The complex indexes show better model behavior but more studies are still needed to confirm this point.

6. Return period of fire occurrence: Pareto model for "Total Burned Area"

Model	AIC
NULL Model, no covariates	1592.930
xi= ~FWI	1594.719
phi=~FWI, xi=~FWI	1593.494
phi= ~FWI	1591.539
phi= ~FWI+P87.5	1588.282
phi=~FWI+P95.5	1586.224
phi=~FWI+P91.5	1585.298
phi=~FWI+P91.5+SMDI	1587.287
phi=~FWI+P91.5+Comb	1586.925
phi=~FWI+P91.5+CombNew2	1585.763
phi=~FWI+P91.5+CombNew1	1585.548
phi=~FWI+P91.5+FRMold5x5	1584.252
phi=~FWI+P91.5+FRMnew5x5	1584.896

	FWI	FDI	P91.5%
1	0.11	1.0	0.00
2	11.82	1.5	0.12
3	23.52	2.0	0.25
4	35.23	2.5	0.38
5	46.94	3.0	0.50
6	58.65	3.5	0.62
7	70.36	4.0	0.75
8	82.06	4.5	0.88
9	93.77	5.0	1.00



- For calculations the package texmex from R statistical analyses system is used.
- First results indicate probability plot of fire occurrence >4000 ha for whole territory of Bulgaria