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Geoinformatics Application in Forest Fire Research (An Example of the Slovak Part of WARM Project)

- Introduction
- Slovak Approach and Experimental Study Area (ESA)
- SDSS for ESA
- Interesting Results
- Conclusions and Future Directions

Introduction

Europe experiences, on average, 60 000 wildfires annually.
Approximately 700 000 ha of wildland are destroyed each year.
Estimated € 1.5 billion in annual fire fighting and restoration costs.
In the Mediterranean region, approximately 500 000 ha of wildland are burnt each year.
Last 25 years have seen nearly a tripling in area burnt.

Introduction

Spain and Portugal most affected in the number, frequency, and size of wildfires, followed by Greece, Italy, and France.

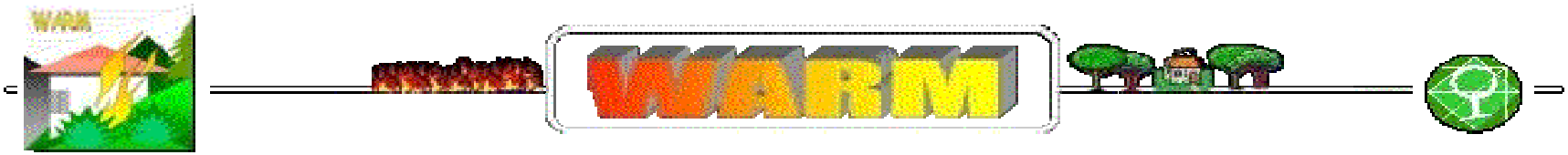
In Central European countries big loses due considerably higher price of forest production.

Specific problem in the intermediary zone between urban and agricultural and forest land.

Introduction

AUTO-HAZARD	**Automated Fire and Flood Hazard Protection System**
E-FIS	**Information System for Forest Fire Risk Management**
EU-FIRELAB	**Euro-Mediterranean Wildland Fire Laboratory**
FIRESTAR	**DSS for Fuel management and Hazard Reduction**
SPREAD	**Forest Fire Spread Prevention and Mitigation**
FIREGUARD	**Monitoring Forests at the Management Unit Level for Fire Prevention and Control**
WARM	**Wildlan-Urban Area Fire Risk Management**

Introduction



WARM project will characterise direct and indirect risks due to fires in the wildland-urban interface (W-UI) in Europe and provide a methodology and an information system to minimise losses of residences and other structures, while reducing social and environmental impact, throughout the assistance in the elaboration of rationalised encompassed wildfire defence plans.

TYPSA

algosystems

UNIVERSITÀ DEGLI STUDI DI TORINO
FACOLTÀ di AGRARIA
I CAMPI DELLA SCIENZA

CERTH

Schlumberger

TECHNICAL UNIVERSITY IN ZVOLEN

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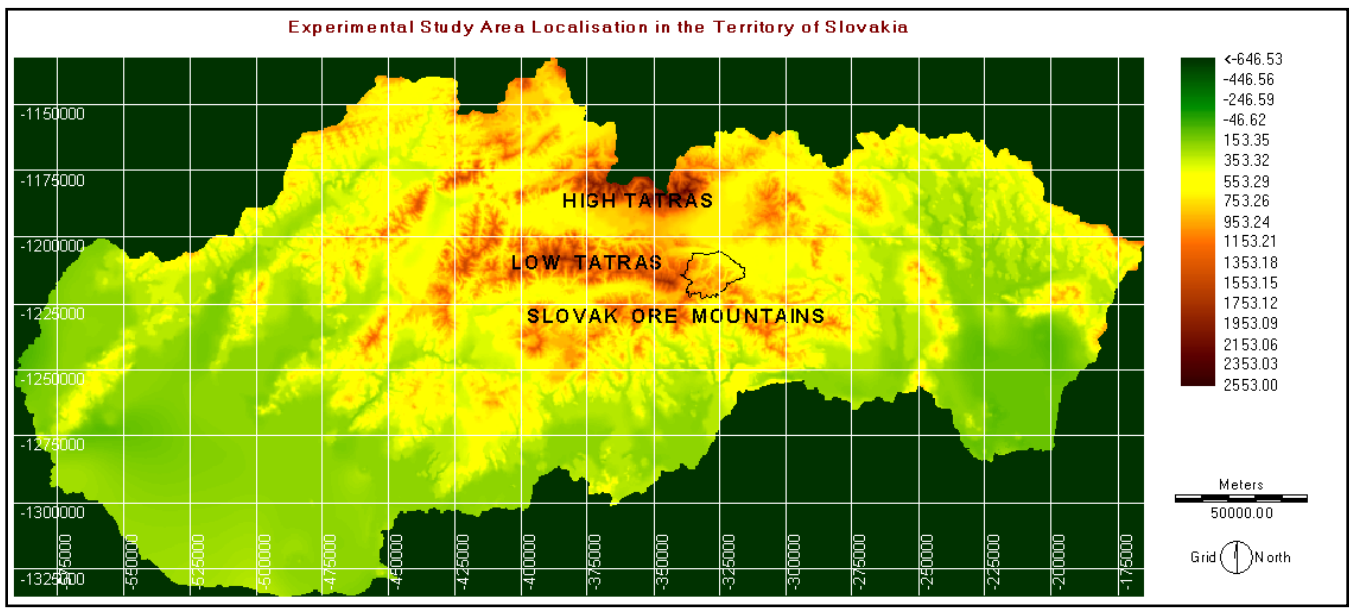
Introduction

Aim of the paper and presentation:

To present approach to the solution of Slovak part of the WARM project leading into proposal of the specific Spatial Decision Support System (SDSS) for the data management, prediction and fire suppression in the wildlan-urban interface area of the Slovak Paradise National Park (the experimental site of WARM project in Slovakia).



Slovak approach to the WARM solution
(from the perspective of the geoinformatics application)

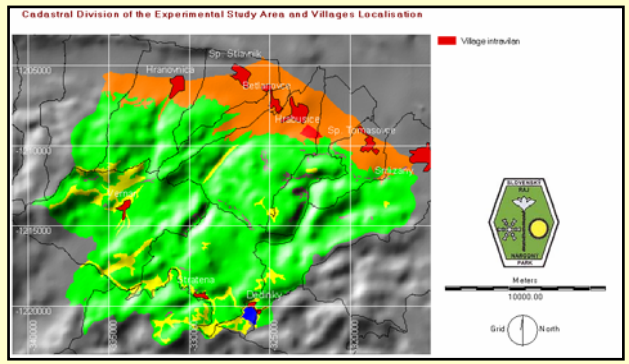
Mapping of the land structures within ESA,
Description of their fire vulnerability,
Description of the (forest) fire behavior and consequences,
Design and building of the database of fire occurrence and behavior,
Identification of fire risk occurrence for different land and man made structures,
Analyses and evaluation of fire losses,
Design of the specific Spatial Decission Support System for fire dataManagement and planning of fire defense and suppression.

Experimental Study Area – The Slovak Paradise National Park territory

North-Eastern part of the Slovak Ore Mountains,

Area 270 km^2, 200 km2 of forests,

Rocky, steep relief (limestone, karstfields),



Altitudes from 470 to 1500 m,

Shallov soils (rendzinas)

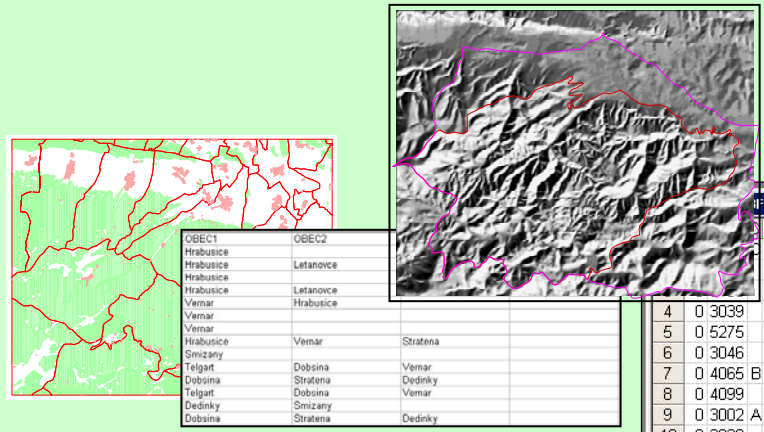
Low precipitation (rain shadow of High Tatras Mountains)

8 villages with population about 12 000, extreme pressure of turists (500 – 600 000 visitors annually)

SDSS for (forest) fire data management, fire prediction and suppression

Three essential components:

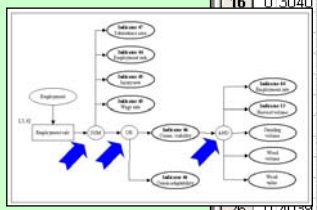
1. **Data for SDSS building,**



OBEC1	OBEC2	
Hrabusice		
Hrabusice	Letanovce	
Hrabusice		
Hrabusice	Letanovce	
Vernar	Hrabusice	
Vernar		
Vernar		
Hrabusice	Vernar	Stratena
Smizany		
Telgart	Dobsina	Vernar
Dobsina	Stratena	Dedinky
Telgart	Dobsina	Vernar
Dedinky	Smizany	
Dobsina	Stratena	Dedinky

	D	E	F	G
	P	OP	PLOCHA	CISLO
	0	0	266461	4
	0	0	208675	3
4	0 3039	0	0	199505	28
5	0 5275	1	0	191581	555
6	0 3046	0	0	189825	26
7	0 4065	B 1	0	178250	703
8	0 4099	0	0	178148	670
9	0 3002	A 1	0	177268	54
10	0 3038	0	0	175617	31
11	0 5274	0	0	169958	557
12	0 3016	0	0	169119	73
13	0 3271	B 1	0	165916	228
14	0 3036	A 0	0	165522	32
15	0 5270	0	0	164856	558
16	0 3040	0	0	161547	27
		1	0	161110	763
		0	0	160373	677
		0	0	159945	428
		1	0	158236	494
		0	0	156309	513
		A 1	0	155724	527
		A 0	0	155319	37
		B 0	0	147782	217
		A 0	0	146234	433
26	0 4039	A 0	0	145187	454
27	0 5360	A 1	0	144802	310
28	0 5333	A 0	0	144376	544
29	0 4047	0	0	142966	427
30	0 3065	A 0	0	141709	40
			0	141046	515
			0	140509	701

2. **Results of fire database analysis**
   – knowledge base content,



3. **Catalogue of typical fire occurrence situations.**

Data for SDSS building

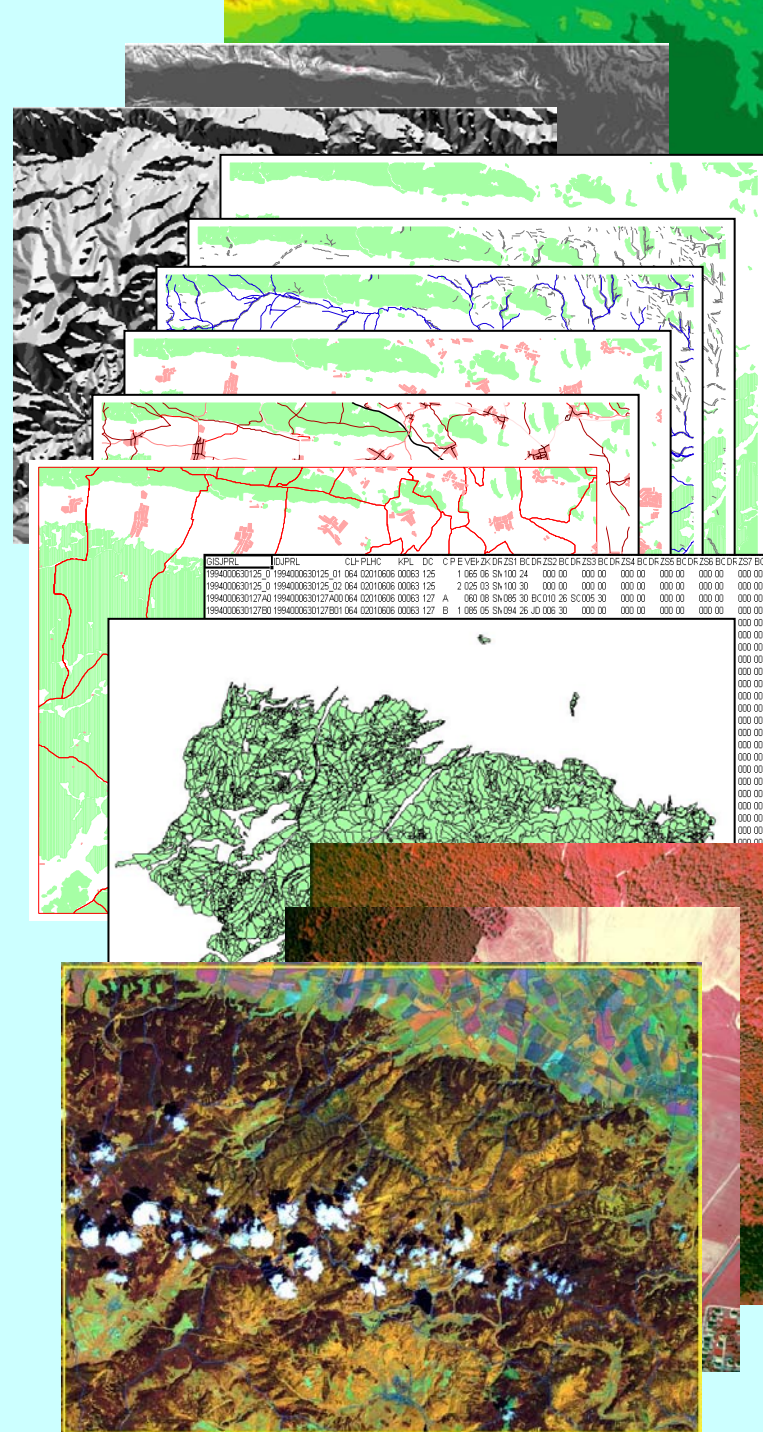
A. Basic data

Digital Terrain Model

Layers of Basic map
of Slovak republic 1: 50 000

Forest management plan data
and maps

Aerial photos
and satelite imagery Landsat



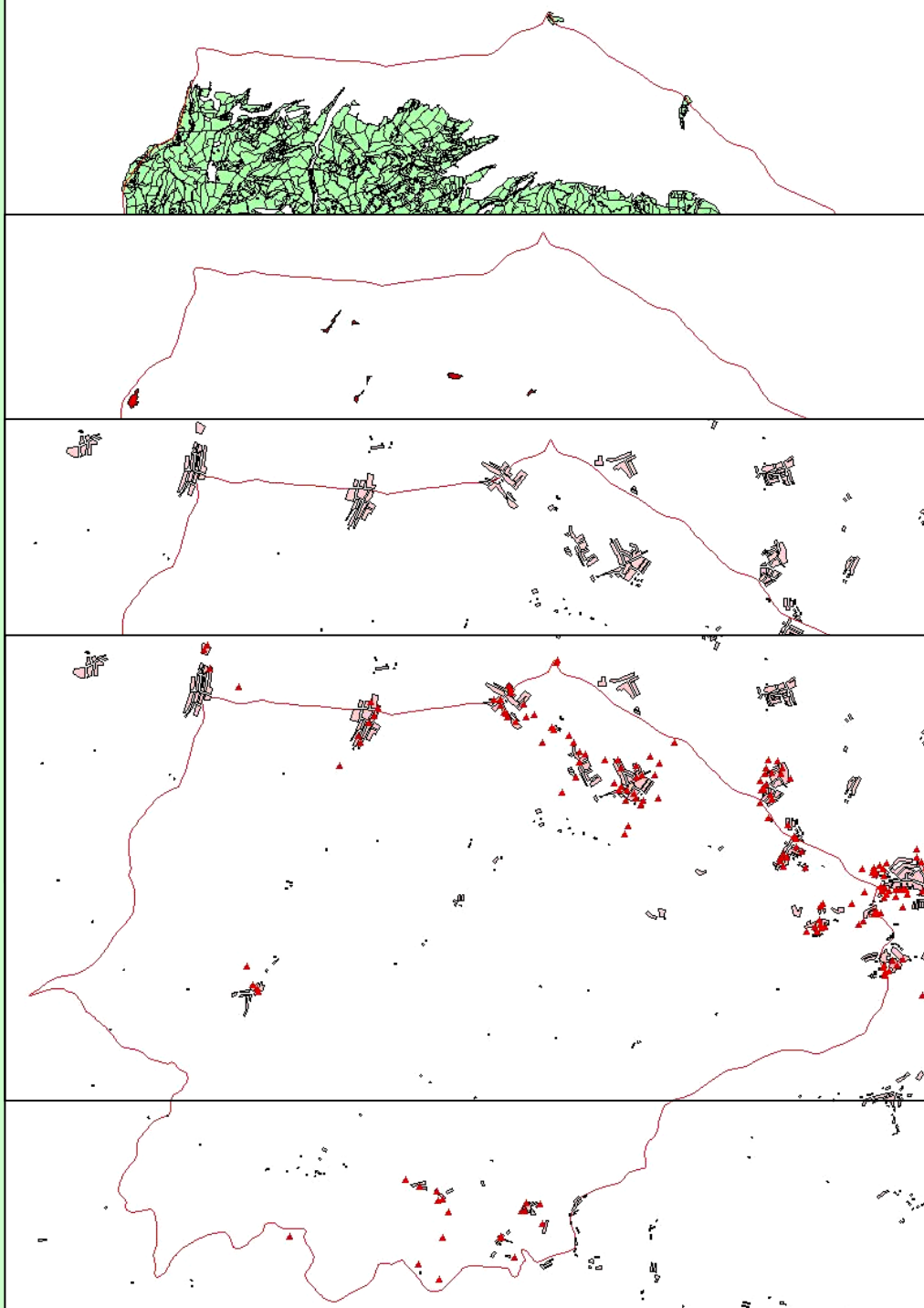
Data for SDSS building

B. Forest and other fire database

Fire localisation

Fire description

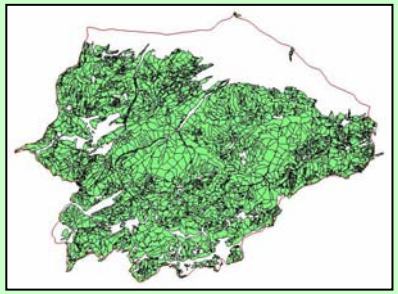
Shape	Id	Fireid	Fire	Fire_c
Polygon	0	1	13a,b	188/00
Polygon	0	2	15, 21	019/81
Polygon	0	3	1, 11	019/81
Polygon	0	4	15a,b	115/95
Polygon	0	5	74	164/94
Polygon	0	6	146a	013/98
Polygon	0	7	146b	018/78
Polygon	0	8	33	017/86
Polygon	0	9	28	017/86
Polygon	0	10	102	103/93
Polygon	0	11	104a,b	103/93
Polygon	0	12	99	063/01
Polygon	0	13	98	063/01
Polygon	0	14	97	063/01
Polygon	0	15	291a,b	044/92
Polygon	0	16	288	044/92
Polygon	0	17	220	046/98
Polygon	0	18	221	046/98
Polygon	0	19	210	031/76
Polygon	0	20	168	037/92
Polygon	0	21	275a	5406/92/022
Polygon	0	22	279a,b	5406/92/022
Polygon	0	23	595	090/95
Polygon	0	24	629	090/95
Polygon	0	25	605	052/92
Polygon	0	26	564	5406/90/24
Polygon	0	27	55	1339/78/014
Polygon	0	28	491	5406/92/022
Polygon	0	29	143a	5707/98/206
Polygon	0	30	151	048/87
Polygon	0	31	148	5406/93/113
Polygon	0	32	157	706/00/123
Polygon	0	33	156	052/92
Polygon	0	34	141	5707/98/206
Polygon	0	35	290	5406/93/44
Polygon	0	36	430	5406/93/876

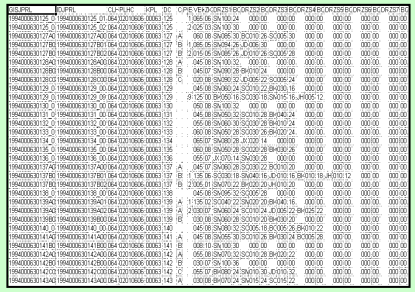


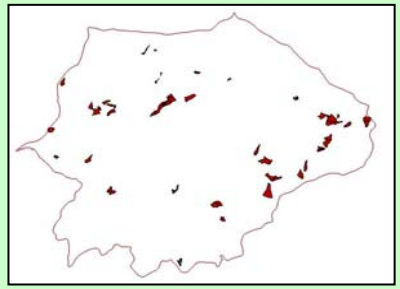
Results of fire database analysis – input to the knowledge base content

Results of forest conditions analysis – forest stand vulnerability according to their tree species composition and age

Inputs:





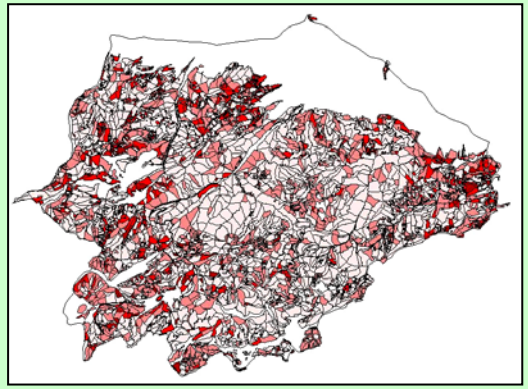


Tree species areas in particular age classes for whole ESA territory.

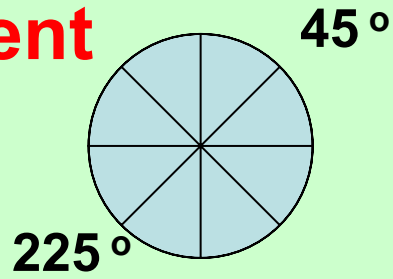
Areas destroyed by fire in particular age class for tree species.

Output:

Vulnerability of every stand in ESA territory.



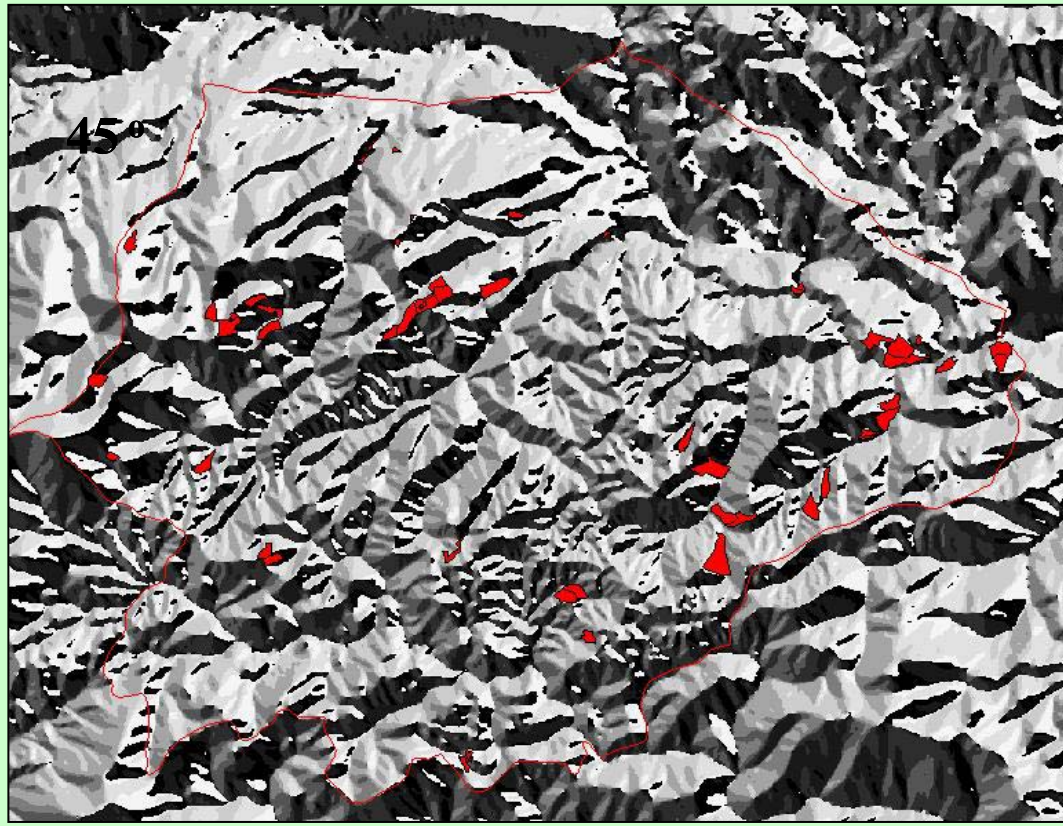
Results of fire database analysis – input to the knowledge base content



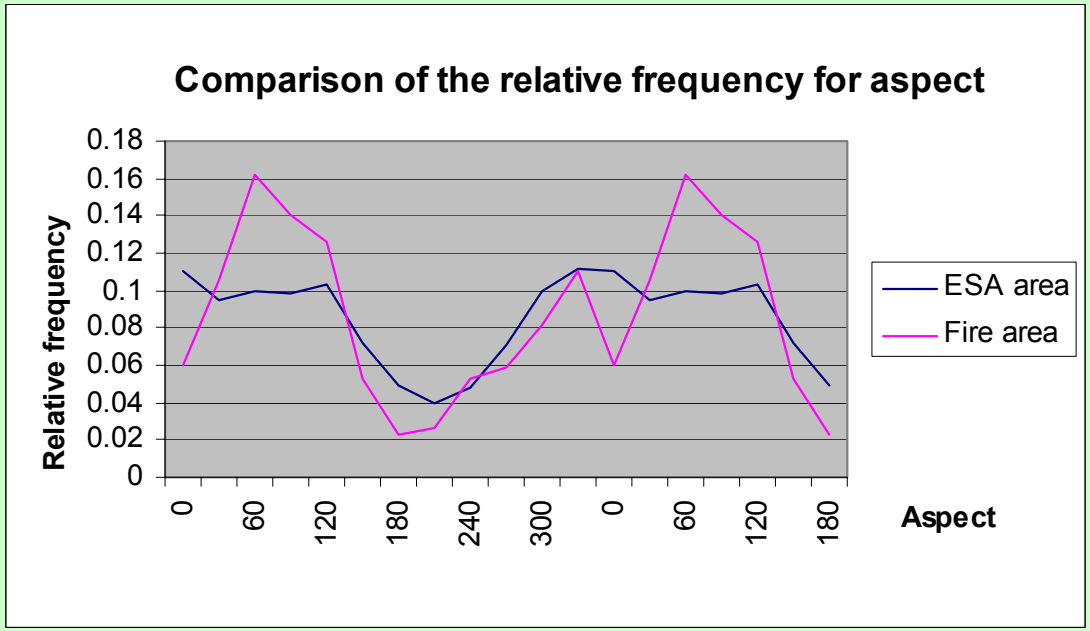
Results of geographic conditions analysis

Aspect (as azimut from North)

Average aspect of individual fire area , °		Share of fire number in class, %
below	45	0
45 . 1 –	90	12
90 . 1 –	135	31
135 . 1 –	180	23
180 . 1 –	225	76 10
225 . 1 –	270	15
270 . 1 –	315	3
over	315	6



Results of geographic conditions analysis



Factor	Category	Area in ESA, ha	Area destroyed by fire, ha	Relative frequency of fire occurence
Aspect	60 to 160	6 575.8	213.4	0.032439368
	160 to 60	13 471.4	265.4	0.019700275
Altitude	450 to 775	5 297.7	215.8	0.040730437
	more then 775	14 749.5	262.9	0.017826415
Slope	0 to 15	7 513.1	205.2	0.027321400
	more then 15	12 534.1	273.5	0.021821219

Catalogue of typical fire occurrence situations

- Continuous forest cover,
- Transportation corridors,
- Scattered buildings,
- Agricultural and industrial facilities,
- Agricultural land,
- Continuous urban areas (villages).

Results of forest conditions analysis – forest stand vulnerability according to their tree species composition and age

Methodology:

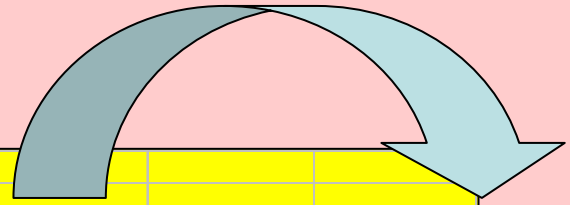
Estimation of the probability of forest stand destruction according tree composition and age.

Fitting of empirical distribution function of destroyed areas for every tree species and age by Weibull probability distribution W(c, gama) and its distribution function (Kouba, 2002, von Gadow, 2000).

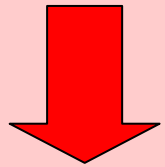
$$F(t) = 1 - e^{-c \cdot t^{gama}}$$

Agreement testing by Kolmogorov – Smirnov test.

Results of forest conditions analysis



Probabilities of destruction i.e. vulnerability



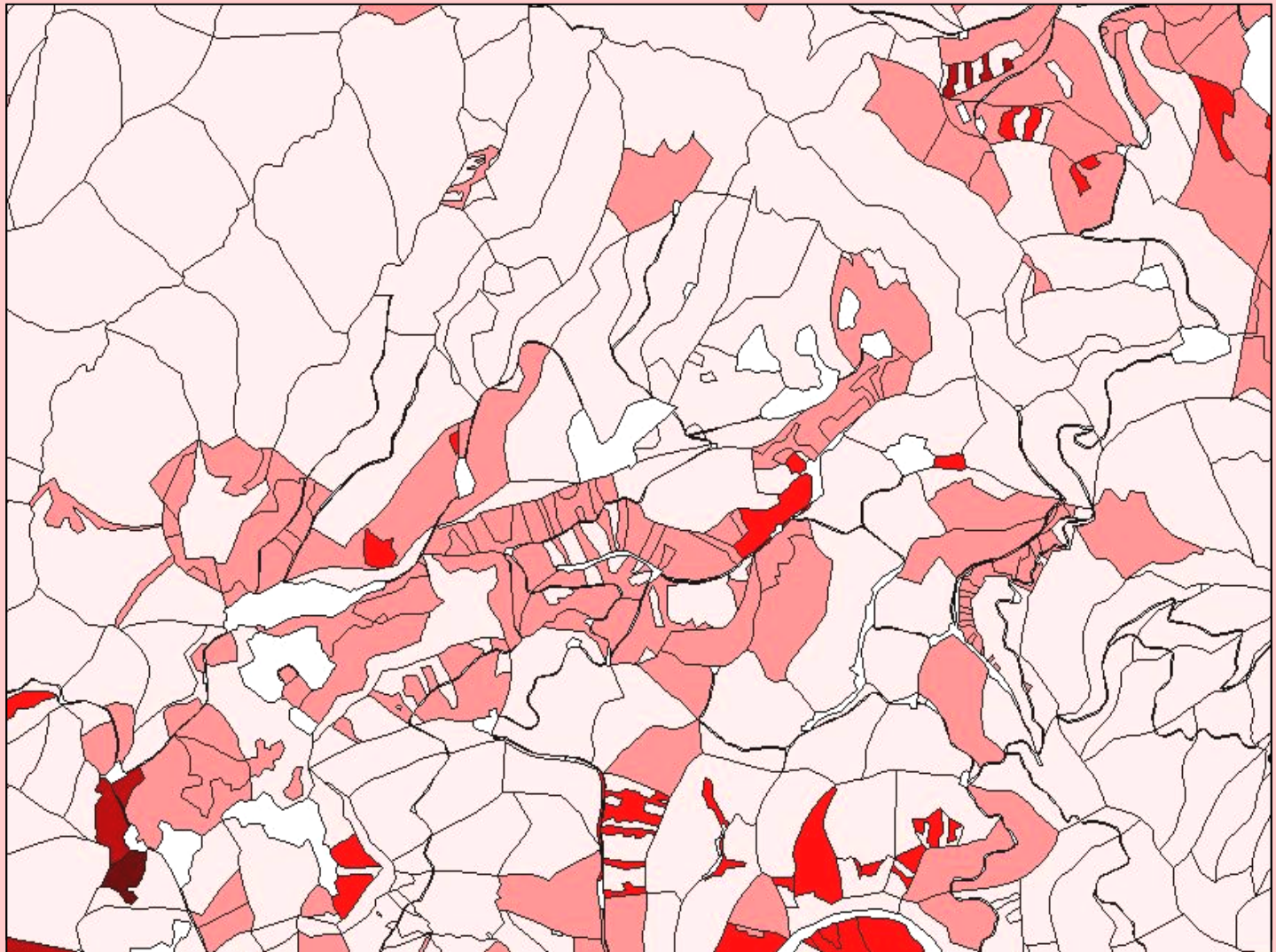
SLOVAK PARADISE		(1991-2000)			
Tree-species:		PINE			
Years	Areas	Destroyed	Proportion	Distr.function	
(t)			h(t)/H(t)	F_n(t)	H(t)
	(ha)	(ha)			
10	228.8650	0.7400	0.003233347	0.130432888	1183.0
20	173.1550	1.2000	0.006930207	0.409996717	1183.0
30	356.2400	0.7000	0.001964967	0.489263299	1183.0
40	276.7150	0.0000	0.000000000	0.489263299	1183.0
50	443.0400	0.0000	0.000000000	0.489263299	1183.0
60	1101.8440	0.0000	0.000000000	0.489263299	1183.0
70	983.3060	5.9000	0.006000167	0.731309401	1183.0
80	752.3790	0.0000	0.000000000	0.731309401	1183.0
90	1988.0450	0.0000	0.000000000	0.731309401	1183.0
100	4197.7780	27.9600	0.006660667	1.000000000	1183.0
110	1286.1300	0.0000	0.000000000	1.000000000	1183.0
120	1614.1900	0.0000	0.000000000	1.000000000	1183.0
130	1394.6510	0.0000	0.000000000	1.000000000	1183.0
140	1061.7480	0.0000	0.000000000	1.000000000	1183.0
150	1227.1750	0.0000	0.000000000	1.000000000	1183.0
160	2307.4900	0.0000	0.000000000	1.000000000	1183.0
170	1227.2800	0.0000	0.000000000	1.000000000	1183.0
180	675.6700	0.0000	0.000000000	1.000000000	1183.0

Years	Distr.function	Theor.functior	Difference		Probability
(t)	Fn(t)	F(t)	Fn(t) - F(t)	delta F(t)	p(t)
10	0.130432888	0.203006061	0.072573173	0.203006061	0.005032389
20	0.409996717	0.341181302	0.068815415	0.138175242	0.003425275
30	0.489263299	0.448983823	0.040279476	0.107802520	0.002672355
40	0.489263299	0.535813635	0.046550336	0.086829812	0.002152455
50	0.489263299	0.606935112	0.117671813	0.071121477	0.001763056
60	0.489263299	0.665823943	0.176560644	0.058888831	0.001459816
70	0.731309401	0.714963406	0.016345995	0.049139463	0.001218136
80	0.731309401	0.756211102	0.024901701	0.041247696	0.001022504
90	0.731309401	0.790998646	0.059689244	0.034787544	0.000862361
100	1.000000000	0.820452581	0.179547419	0.029453935	0.000730144
110	1.000000000	0.845473112	0.154526888	0.025020531	0.000620243
120	1.000000000	0.866788111	0.133211889	0.021314999	0.000528385
130	1.000000000	0.884991636	0.115008364	0.018203525	0.000451254
140	1.000000000	0.900572234	0.099427766	0.015580598	0.000386233
150	1.000000000	0.913934224	0.086065776	0.013361990	0.000331235
160	1.000000000	0.925414011	0.074585989	0.011479787	0.000284577
170	1.000000000	0.935292779	0.064707221	0.009878768	0.000244888
180	1.000000000	0.943806492	0.056193508	0.008513713	0.000211049

Tree species groups: Pine, Spruce, Fir, Larch, Broadleaved

Results of forest conditions analysis

Vulnerability of forest stand analysis – risk of fire occurence



Prior probabilities

p(t) – probability that 1 ha of forest at age (t) years will be destroyed by fire during common year (factors: tree species composition, age)

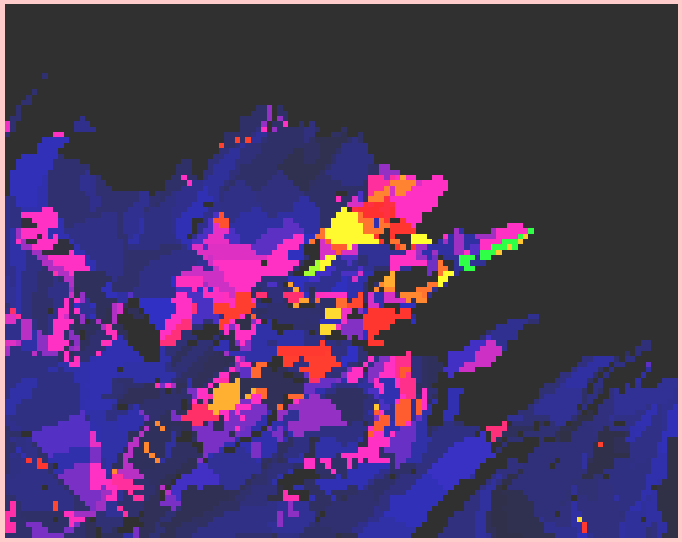
Conditional probabilities

1. Conditional factor: Aspect
2. Conditional factor: Altitude
3. Conditional factor: Slope
4. Conditional factor: Distance from nearest road
5. Conditional factor: Distance from nearest urban area

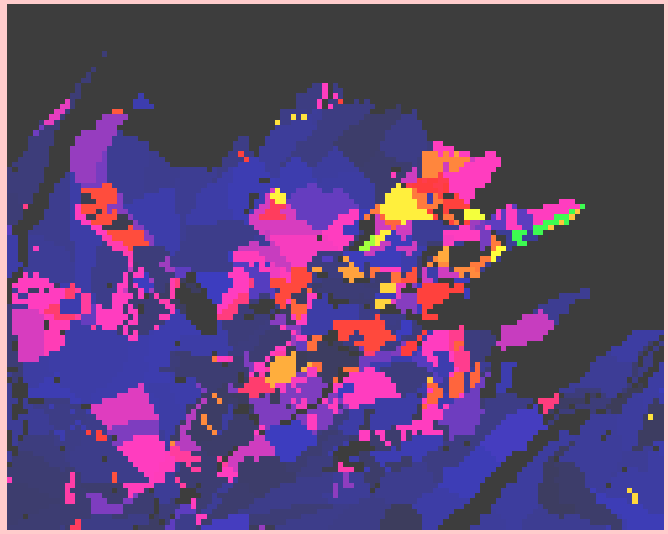
Calculation of the posterior probabilities using Bayes' formula

Calculation of conditional probabilities

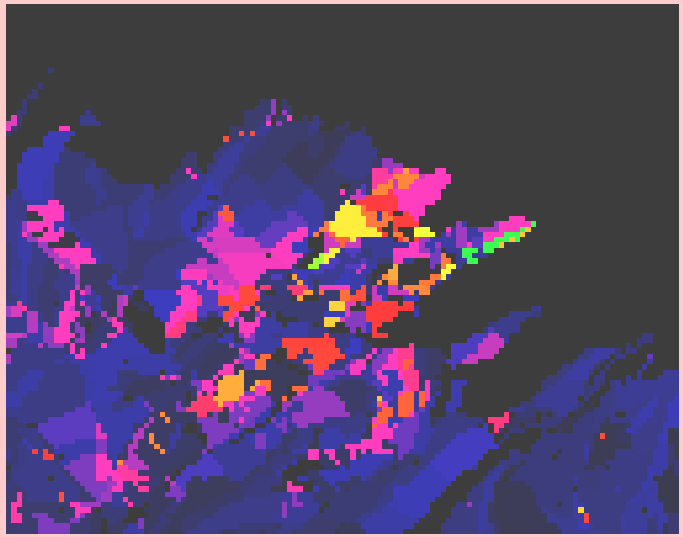
p(t) composition, age



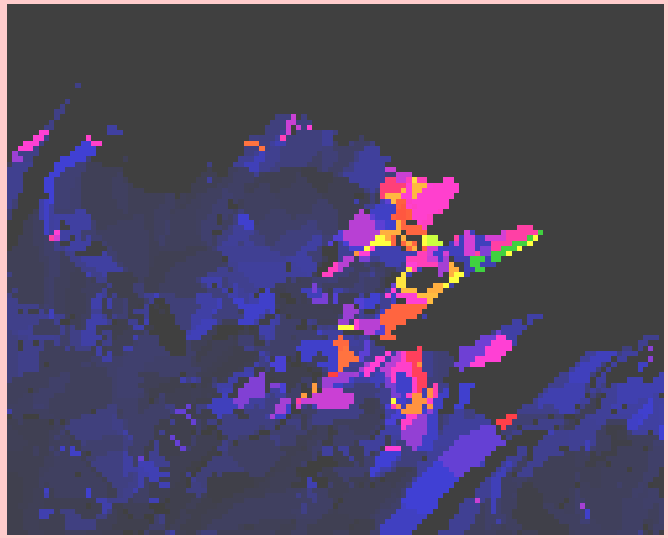
p’(t) composition, age, aspect



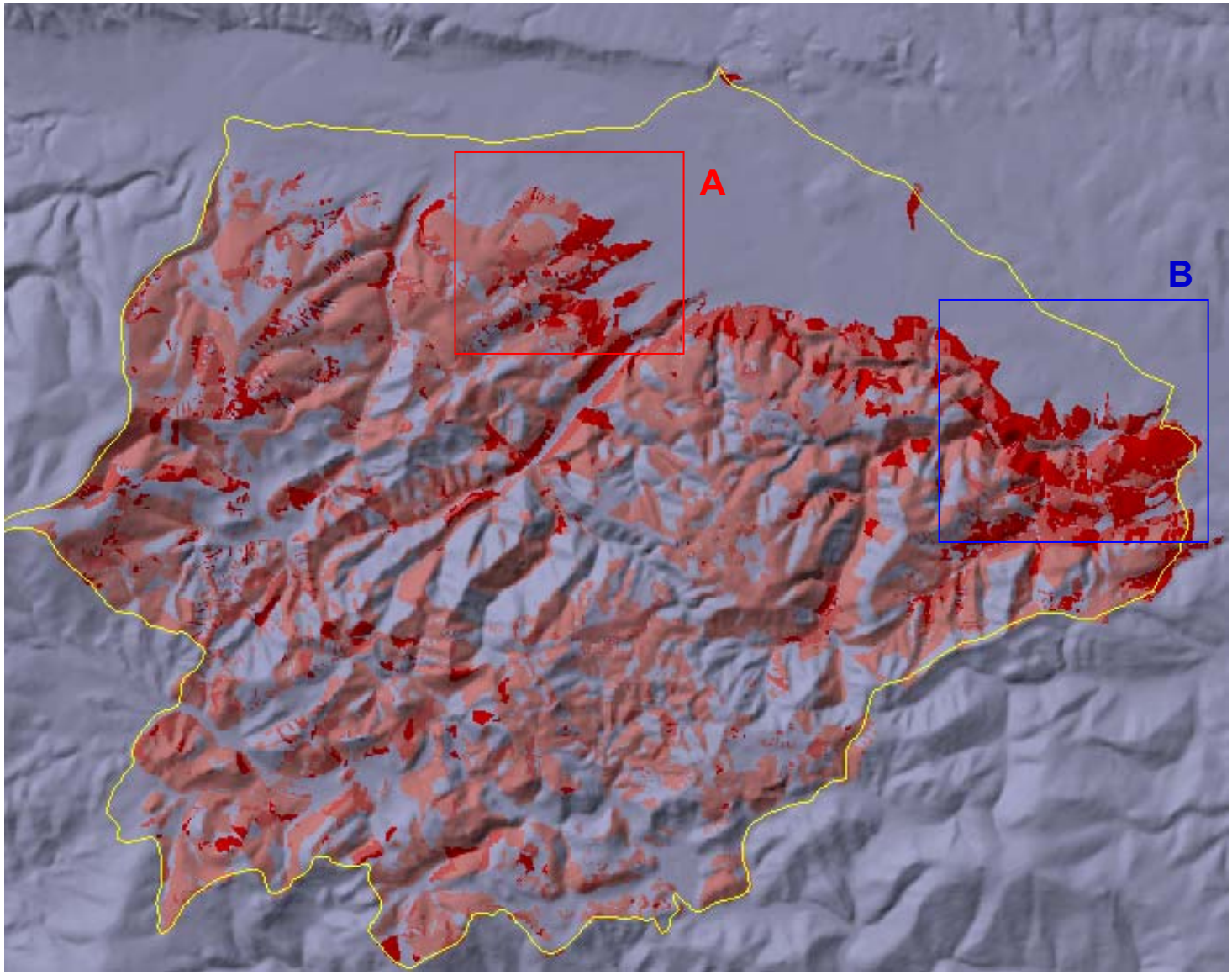
p’’(t) composition, age, aspect, slope



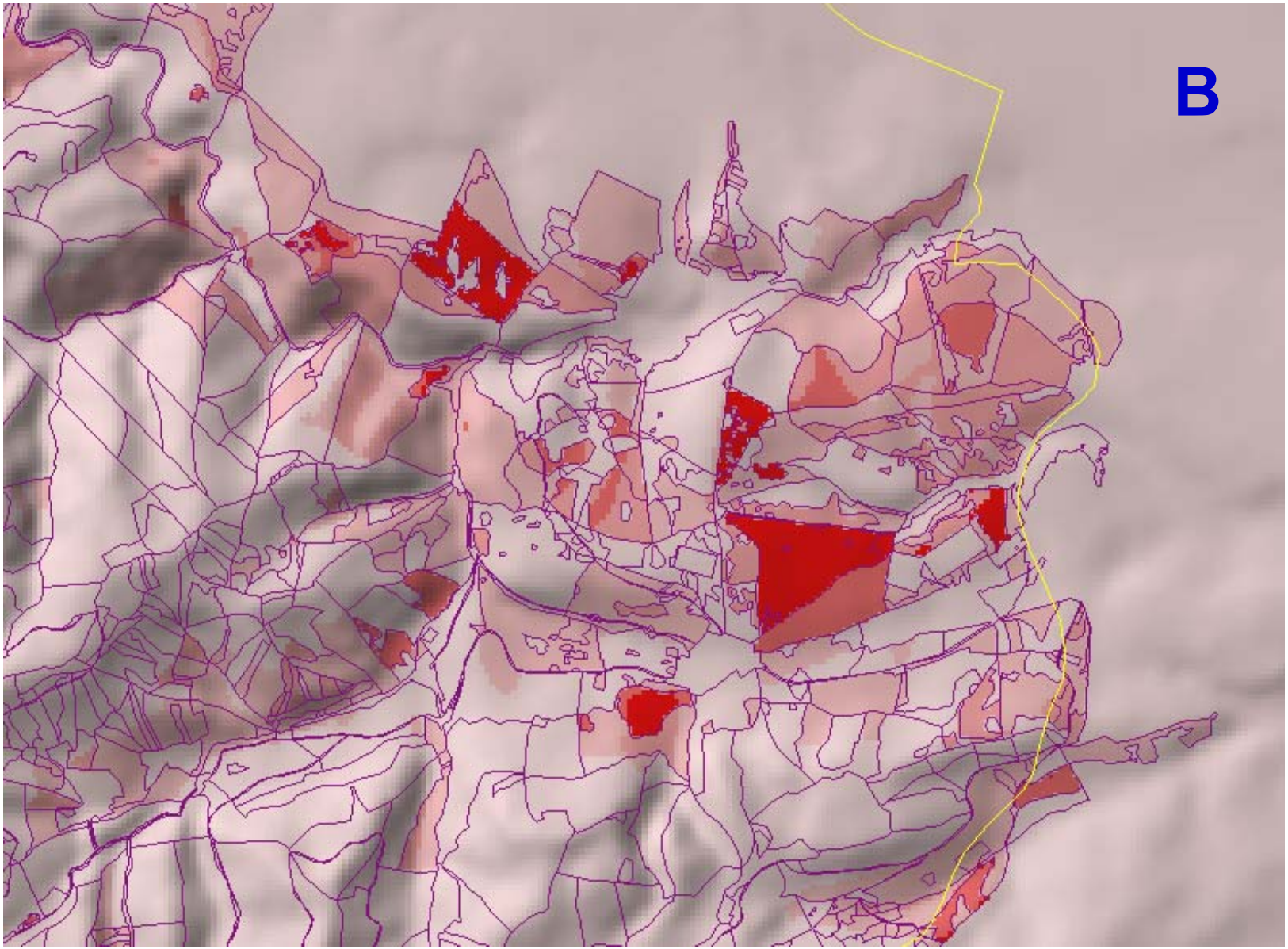
p’’’(t) composition, age, aspect, slope, altitude



Map of the total forest fire hazard (tree species, age, aspect, slope, altitude)



Map of the total forest fire hazard (tree species, age, aspect, slope, altitude), Detail B



Overlay operation:

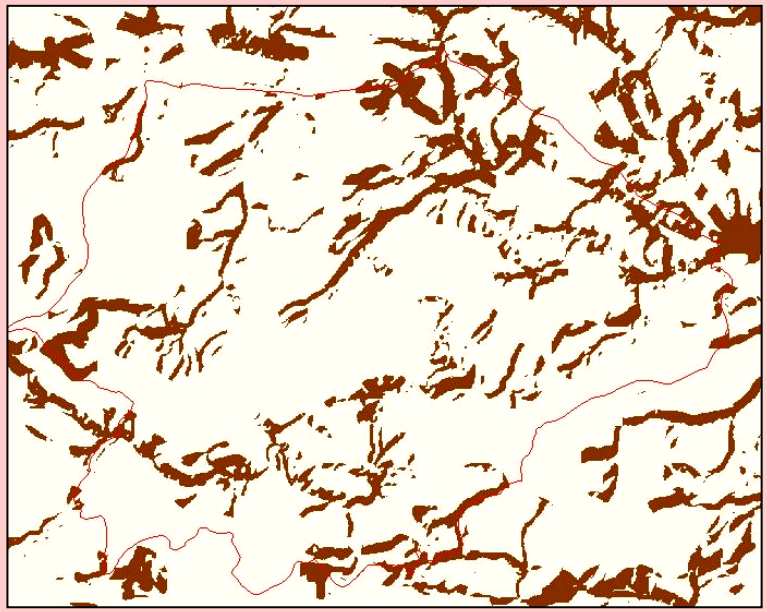
south east aspect

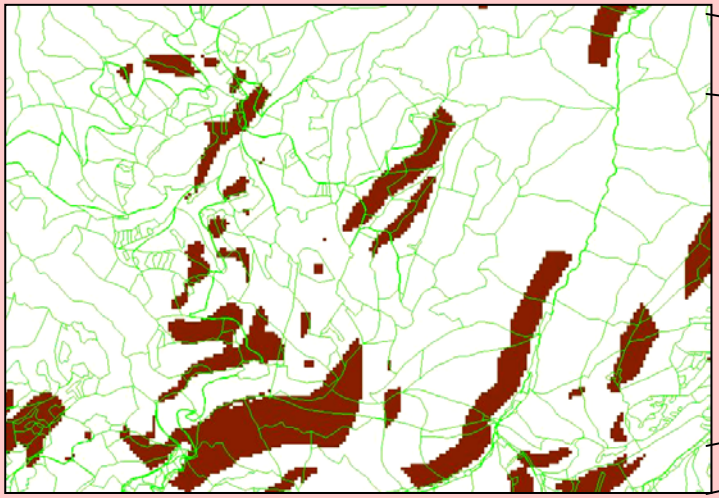
and

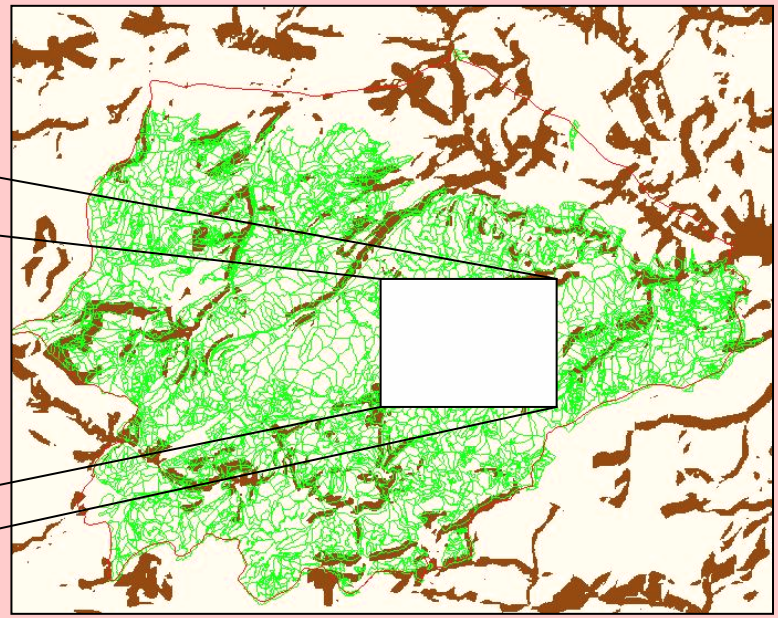
200 m zone to road

and

1000 m zone to urban area

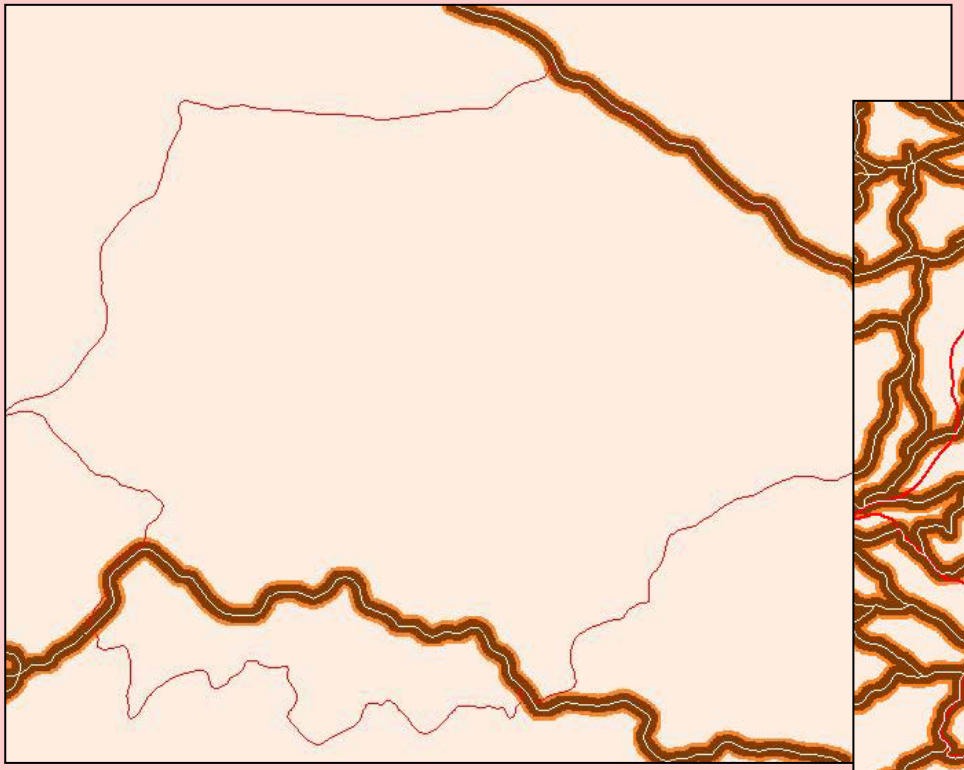






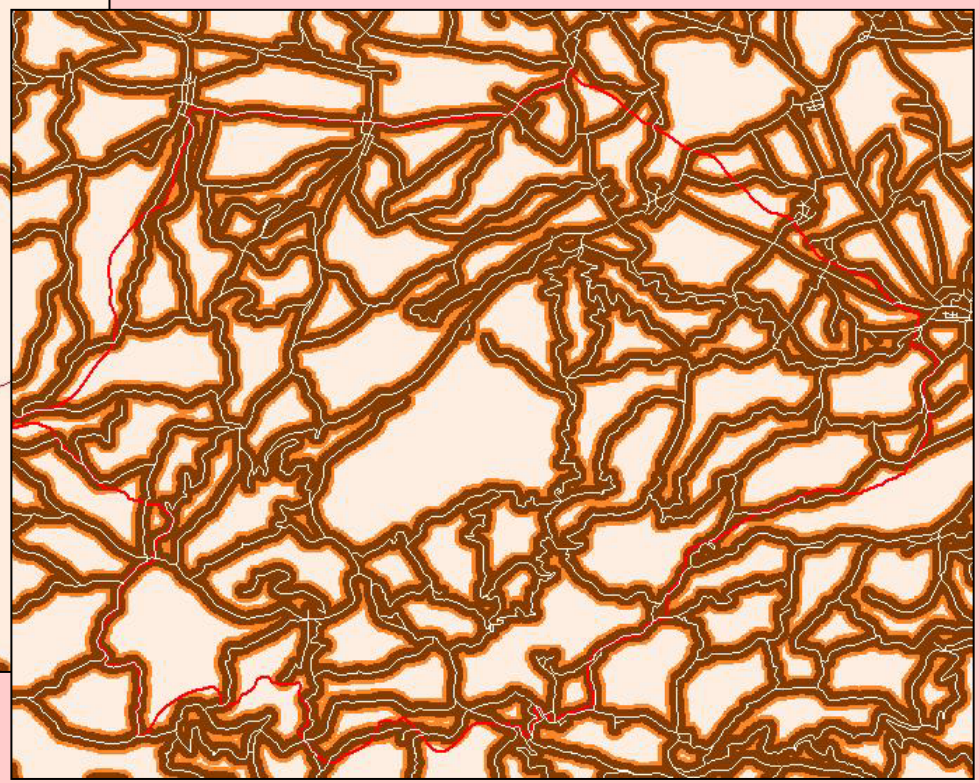
Fire occurrence situations geographical delineation and documentation

Transportation corridors



Railways – 100 and 200 m

Roads – all types - 100 and 200 m



Conclusion and future directions

It is possible to build SDSS for (forest) fire data management in Slovak Paradise National Park using Arc View, EMDS and related GI technologies.

There are prepared sufficient data sources for needs of modeling and new data derivation for SPNP territory.

Analysis of forest and other fire data offers useful information for SDSS knowledge base building.

It was prepared catalogue describing vulnerability of landscape structures in SPNP territory.

It is possible to evaluate particular scenarions and situations regarding forest fire occurence and defense using SDSS data, knowledge base and standard GIS tools.

Conclusion and future directions

Except of commented results:

Analysis of soil erosion risk due forest fire occurrence,

Analysis of the meteorological conditions – fire weather indices calculation,

Forest property insuration models derivation,

Analysis of the decreasing of forest soil expectation value,

Accessibility of the territory using network and surface analyses.

Conclusion and future directions

Future needs and refinements:

Preprocessing of the most important information on data in scale 1 : 10 000 and grid resolution 10 m.

Using of the RS techniques for information refinement and fulfilling.

Implementing of the network analyses tools and surface modelling tools to the distance modelling.

Knowledge base building for urban and agriculture fire using its database analysis results and the same also for meteorological conditions of fire and fire defense.

Next rules for fire occurence and structures vulnerability derivation.

User intreface building and specific tools implementing.

Thank you for your attention

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