

Smrekovi gozdovi in okoljske spremembe

Jurij Diaci, Andrej Rozman

- 1 Okoljske spremembe in gozd
- 2 Nazadovanje smreke v Sloveniji in Evropi
- 3 Prilagajanje gozdov na okoljske spremembe
 - 3.1 Sanacije ujm in kalamitet
 - 3.2 Izbira drevesnih vrst
- 4 Zaključki



1 Okoljske spremembe in gozd

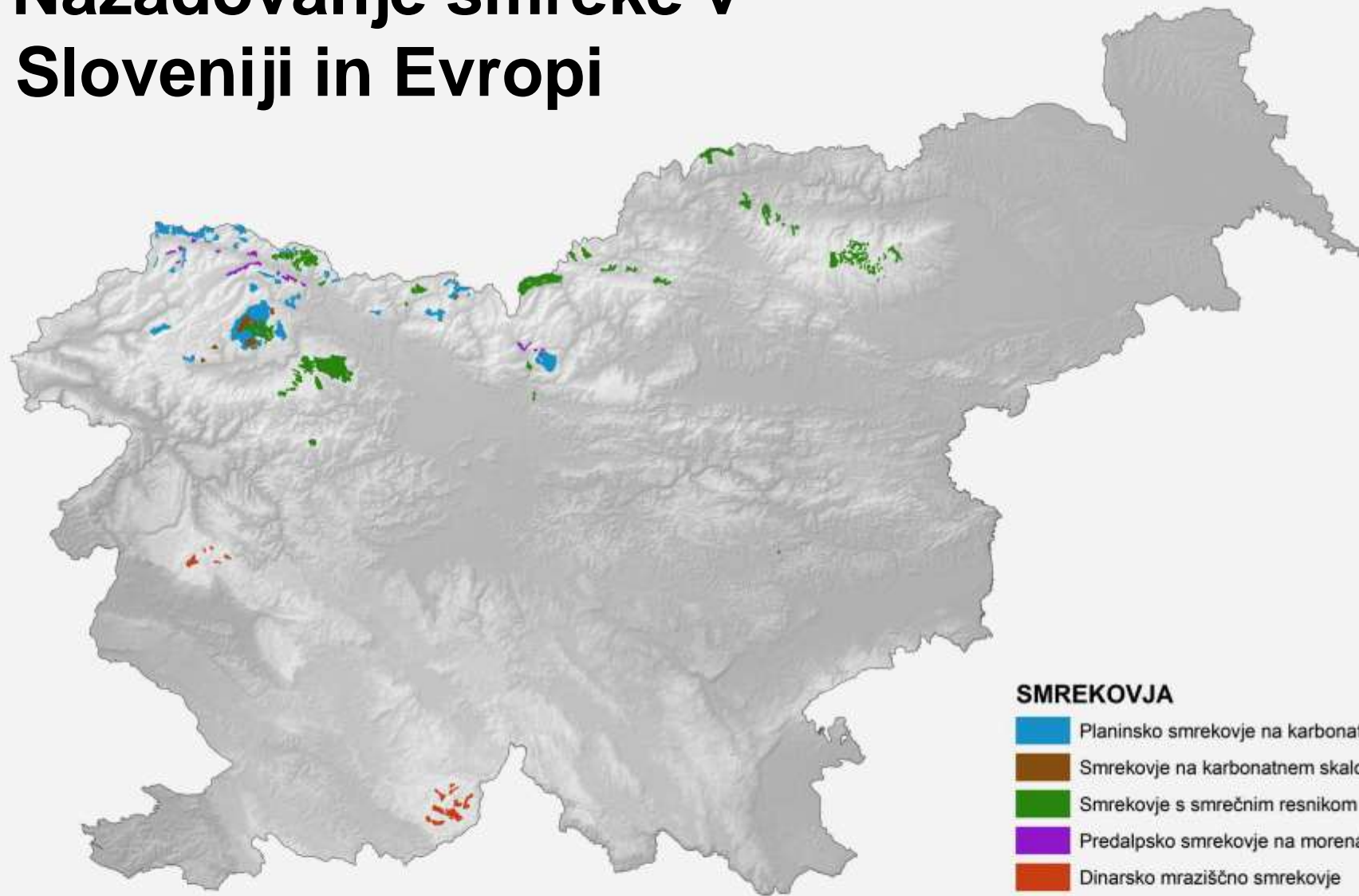
- podnebne skrajnosti: naravne motnje - ujme, suše¹
- onesnaženje: ozračja, tal
- škodljivi tujerodni organizmi: npr. hrastova čipkarka, jesenov ožig
- spreminjanje rabe tal (npr. krčenje gozdov)
- ...

- erozija, zbijanje tal, poškodbe sestoja²
- nepravilna nega, umetna obnova³
- prevelike gostote rastlinojede divjadi⁴
- ...

} ***vplivna sfera
gozdarstva***

POSLEDICA: kaskadni učinki škodljivih dejavnikov in nazadovanje ekosistemskih storitev (Neue Waldsterben)

2 Nazadovanje smreke v Sloveniji in Evropi



SMREKOVJA

- Planinsko smrekovje na karbonatu
- Smrekovje na karbonatnem skalovju
- Smrekovje s smrečnim resnikom
- Predalpsko smrekovje na morenah
- Dinarsko mraziščno smrekovje

Unraveling the drivers of intensifying forest disturbance regimes in Europe

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Abstract
Natural disturbance like wildfires, windthrow and insect outbreaks are critical drivers of composition, structure and functioning of forest ecosystems. They are strongly climate-sensitive, and are thus likely to be distinctly affected by climate change. Observations across Europe show that over recent decades, forest disturbance regimes have intensified markedly, resulting in a strong increase in damage from wind, bark beetles and wildfires. Climate change is frequently hypothesized as the main driver of forest disturbance. **Old changes in forest structure and composition are associated with management activities such as planting, thinning, and increasing stand basal volume (i.e. 'forest change') also strongly influence susceptibility to disturbance.** Here, we show that from 1950 to 2010, forest change overruled in the same order of magnitude as climate change to the increase in disturbance damage in Europe's forest. Climate change was the main driver of the increase in area burnt, while changes in forest extent, structure and composition particularly affected the variation in wind and bark beetle damage. For all forest disturbance agents, damage was most severe when conducive weather conditions and increased forest susceptibility coincided. **We conclude that a continuing trend towards more disturbance-prone conditions is likely for large parts of Europe's forest, and can have strong detrimental effects on forest carbon storage and other ecosystem services.** Understanding the interacting drivers of natural disturbance regimes is thus a prerequisite for climate change mitigation and adaptation in forest ecosystem management.

Keywords: bark beetle, climate change, European forest ecosystem, forest management, natural disturbance, wildfire, wind
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Introduction
Natural disturbance like wildfire, windthrow and insecticide as well as insect-induced tree mortality are critical drivers of composition, structure and functioning of forest ecosystems (Franklin *et al.*, 2002). They are strongly climate-sensitive, and are thus likely to be distinctly affected by climate change (Glebe *et al.*, 2010; Bala *et al.*, 2010; Nebeker & Schipler, 2010; Saxe *et al.*, 2010). Intensifying disturbance regimes (i.e. increases in disturbance frequency and severity) are expected to be among the most detrimental impacts of climate change on the services that forest ecosystems provide to society (Harber *et al.*, 2010). Disturbance have already increased distinctly throughout the Northern Hemisphere in recent decades, and in western North America, for instance, these changes have been largely attributed to changes in climate (Cannon *et al.*, 2004; Weisberg *et al.*, 2006; Lebel *et al.*, 2009). Disturbance regimes in European forests, too, are expected to be strongly climate sensitive (Loren *et al.*, 2010; Nebeker & Schipler, 2010; Schellhaas *et al.*, 2010). Just as in the forests in western North America, they also have a long history of intensive management. Management-mediated changes in forest extent, composition and structure (hereafterward referred to as forest change) also strongly influence susceptibility to disturbance (Dirig *et al.*, 2017; Seidl *et al.*, 2019). In many areas of Europe, for instance, disturbance-prone over-aged conifer stands have been succeeded over natural natural and deciduous forests (Purkayast *et al.*, 2010). Furthermore, changes in land-use patterns and agricultural practices over the last century have affected forest age structure and increased forest area as well as standing timber volume, thus raising the 'stakes' at risk of being damaged by disturbance (Kinnaird, 1994; MCTFE, 2007). Analyses of disturbance events at local and regional scales have previously addressed the roles of different disturbance drivers (Dobbertin, 2002;

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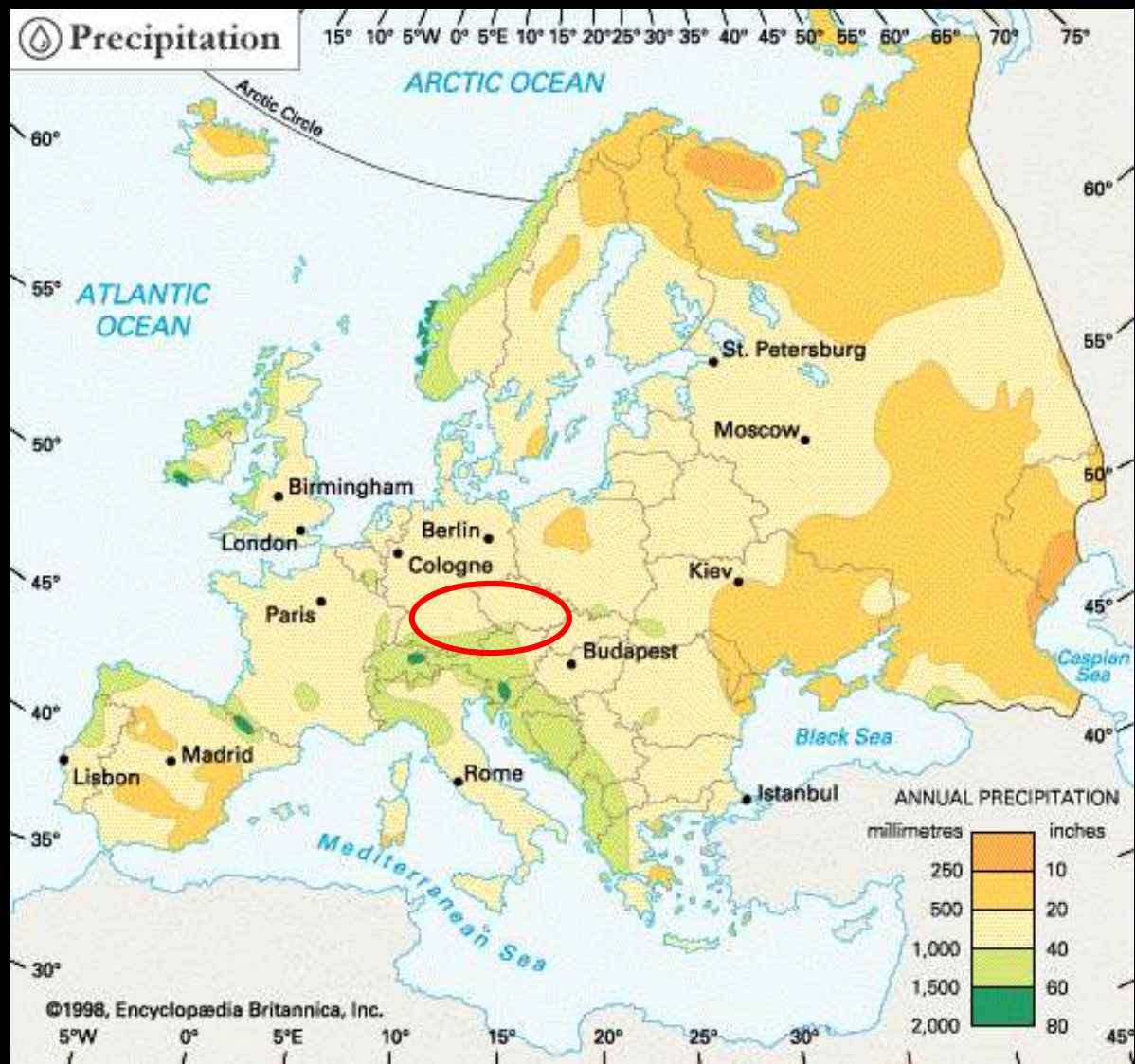
RESEARCH ARTICLE

Do bark beetle outbreaks amplify or dampen future bark beetle disturbances in Central Europe?

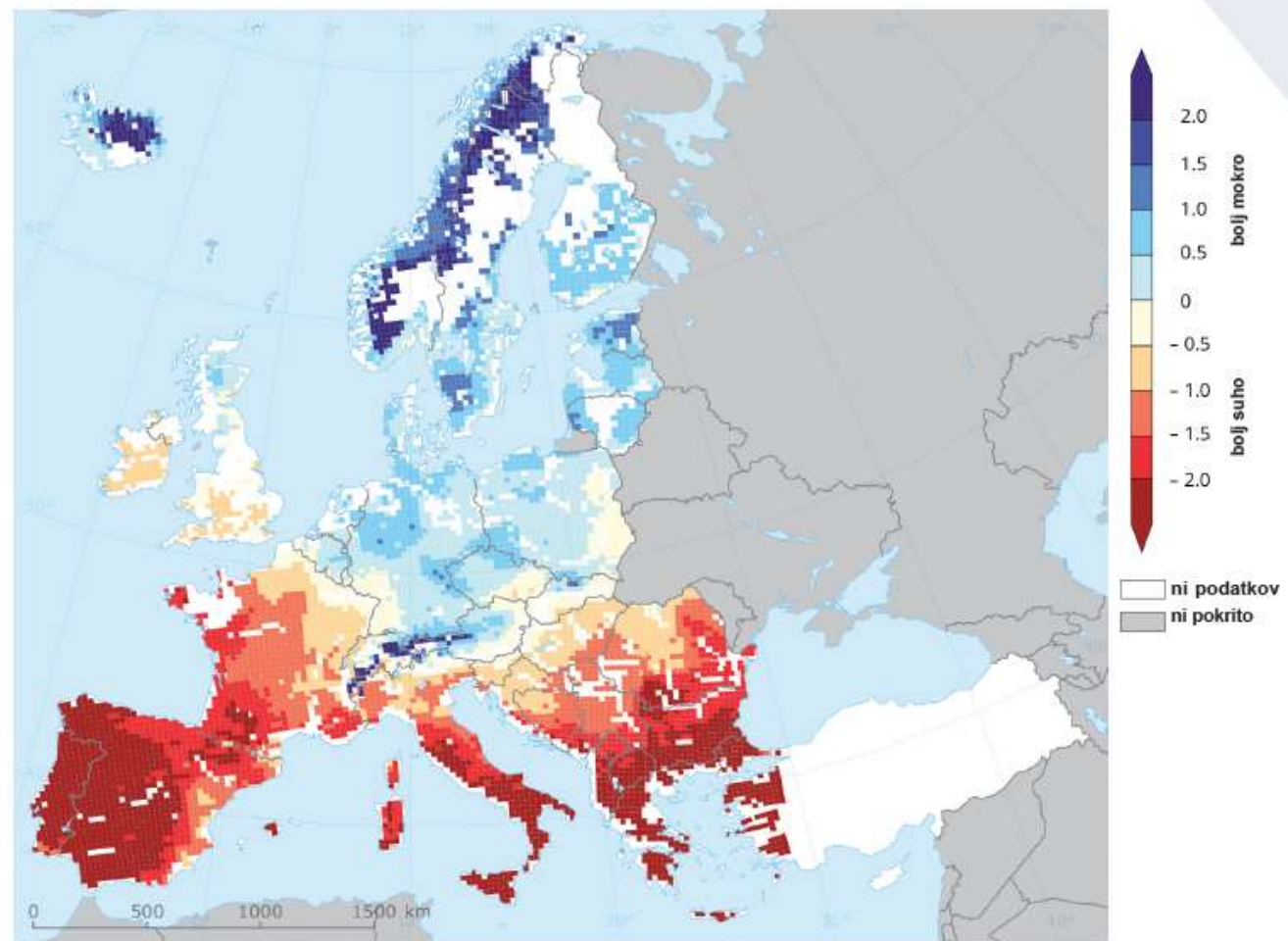
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Abstract
1. Bark beetle outbreaks have intensified in many forests around the globe in recent years. Yet, the legacy of these disturbances for future forest development remains unclear. Bark beetle disturbances are expected to increase further because of climate change. Conversely, feedbacks within the disturbance regimes of growing forests, for example, whether bark beetle outbreaks are amplifying future bark beetle activity through the initiation of an over-aged cohort of trees or dampening it through increased structural and compositional diversity.
2. We studied bark beetle–vegetation–climate interactions at the Bielefeld National Park (Germany), an area that is termed by unprecedented bark beetle activity in the recent past. We studied the effect of future bark beetle outbreaks on forest structure and composition and analysed how disturbance-mediated forest dynamics influence future bark beetle activity under different scenarios of climate change. We used process-based simulation modelling in combination with machine learning to disentangle the long-term interactions between vegetation, climate and bark beetles at the landscape scale.
3. Disturbances for the European spruce bark beetle were strongly amplified by climate change, increasing between 55% and 221% compared to reference climate. Bark beetle outbreaks reduced the chances of harmful spruce (Picea abies L. Mill.) on the landscape, increasing compositional diversity. Disturbances decreased structural diversity within stands in diversity and increased structural diversity between stands by diversity. Overall, disturbance-mediated changes in forest site composition dampened future disturbance activity by reduction of up to 20% and did not fully compensate for the amplifying effect of climate on it. **Therefore, our findings indicate that the recent disturbance events**



<https://www.britannica.com>



Projekcija spremembe vlažnosti tal v poletnem času v prihodnosti.
 Prikazana je razlika med obdobjema 1961–1990 in 2021–2050 za
 emisijski scenarij SRES A1B (Evropska agencija za okolje, 2017).

<https://meteo.arso.gov.si/met/sl/climate/change/>

2.1 Preprečevanje

- višinski pasovi za smreko v deležih PNV¹:
 - 0-500 m
 - ± 500-1000 m
 - + 1000-1600 m
- pospešena sanacija enovrstnih nasadov izven naravnih rastišč², krajše obhodnje³
- gozdni red (težava po ujmah)
- redno (5-6 let) gospodarjenje
- neposredni ukrepi varstva gozdov



Reducing rotation age to address increasing disturbances in Central Europe: Potential and limitations

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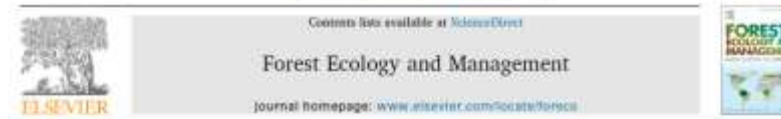
ARTICLE INFO

Keywords:
Forest disturbances
Climate change
Disturbance management
Wind and bark beetle
Forest damage

ABSTRACT

Forest disturbance regimes are intensifying in many parts of the globe. In order to mitigate disturbance impacts a number of management responses have been proposed, yet their effectiveness in addressing changing disturbance regimes remains largely unknown. The strong positive relationship between forest age and the vulnerability to disturbances such as windstorms and bark beetle infestations suggests that a reduced rotation length can be a potent means for mitigating the impacts of natural disturbances. However, disturbance mitigation measures such as shortened rotation lengths (SRL) can also have unintended consequences on ecosystem services and biodiversity, which need to be considered in their application. Here, we used the process-based landscape and disturbance model LANDIS to investigate the effects of SRL on the sustainability of a 16,000-ha forest landscape in Central Europe to wind and bark beetle disturbances. We experimentally reduced the current rotation length (between 100 and 115 years) by up to -40% to 10% in increments, and studied effects on disturbance dynamics under current and future climate conditions over a 500-year simulation period. Simultaneously, we quantified the reduced effects of SRL on forest carbon stocks and indicators of biodiversity. Shortening the rotation length by 40% decreased disturbances by 14%. This effect was strongly diminished under future climate change, reducing the mitigating effect of shortened rotation to -5%. Carbon effects were uneven in the initial decades after implementation: Reducing the rotation length by 40% caused a spike in harvested timber volume (+92%), decreased total forest carbon storage by 6% and reduced the number of large trees on the landscape by 20%. The long-term effects of SRL were less pronounced. At the same time, SRL caused an increase in tree species diversity. Shortening rotation length can reduce the impact of wind and bark beetle disturbances, but the overall efficiency of the measure is limited and decreases under climate

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Forest management history is an important factor in bark beetle outbreaks: Lessons for the future

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ARTICLE INFO

Keywords:
Disturbance
Forest pests
Forest sites
Forest management
Conservation biological control
Tree species competition

ABSTRACT

Historical management practices could have a strong effect on the current status of forests and therefore affect the potential for outbreaks of forest pests. We tested whether forest management history and forest tending of Norway spruce affects the potential for bark beetle outbreaks after large disturbances. We also assessed the effect of the proportion of spruce under epidemic situations and different altitudes. For this survey we used long-term data on sanitary felling and forest inventory data. Forest management history was defined by the change in the forest compared to the natural forest composition and was divided into four classes of change in tree species composition. We compared the proportion of spruce and sanitary felling because of bark beetles with the different classes of change in tree species composition. Forest tending was analyzed by looking at how the proportion of retained cut in relation to the planned cut affected sanitary felling. The analysis was done with Bayesian modeling including both spatial autocorrelation and random effects. There was a strong association between the change in the forest tree species composition and the proportion of Norway spruce and sanitary felling because of spruce bark beetles. Interactions were observed between epidemic periods, the proportion of Norway spruce and altitude. Altitude had a negative influence and the proportion of Norway spruce had a positive influence on sanitary felling. During epidemic periods, sanitary felling was amplified at lower altitudes and in areas with a higher proportion of Norway spruce. Furthermore, there was a negative association between the proportion of retained cut in relation to the planned cut and sanitary felling in periods after abiotic stress. It is therefore suggested that monocultures of Norway spruce should be converted to mixed forests and that maintenance of the forest should be improved to increase resistance to bark beetle outbreaks.

1. Introduction

In recent decades, forest pest outbreaks have become increasingly common, with devastating effects on the economy (Baill et al., 2016; Morin et al., 2012). In many cases climate change has increased the

management that increases resistance and resilience. Unfavorable site characteristics and local factors influencing host health or creating problems with already problematic forest pests (B 2014).

Many unfavorable stand characteristics and local factors

3 Prilagajanje gozdov na okoljske spremembe

- raznomerni mešani gozdovi (sestojno podnebje, okrevanje)¹
- prilagojenja redna nega: vitalnost > stabilnost > kakovost > razdalje, kolektivna stabilnost



Raznomerni gozdni sestoj na dinarskem območju Slovenije takoj po vetrolomu leta 2004, ki je odstranil večino nadraslih dreves. Dobro razvita drevesa spodnje in srednje plati so ostala pretežno nepoškodovana in omogočajo hitro okrevanje gozda. (foto: T. A. Nagel)

3.1 Sanacije ujm in kalamitet

- sanitarna sečnja: pozitivna renta, zdravje gozda
- čim manjše poškodbe pomladka, tal, preostalega sestoja¹
- sukcesijski razvoj
- presoja pomladka²
- saditev odpornih vrst (bukev?)
- setev, puljenke
- divjad
- situacijska nega





Bamberški mestni gozdovi na severnem Bavarskem leta 2018: iz nasadov smreke in bora, v mešani trajni gozd hrasta, bukve in bora



Primerjava naravne obnove (levo, sredina) in umetne v letih 2012 in 2021 in na trajnih raziskovalnih ploskvah na vetrolomni površini Črnivec iz leta 2008 (foto: G. Fidej, F. Blatnik)

3.2 Izbira drevesnih vrst

Domače vrste (70+):

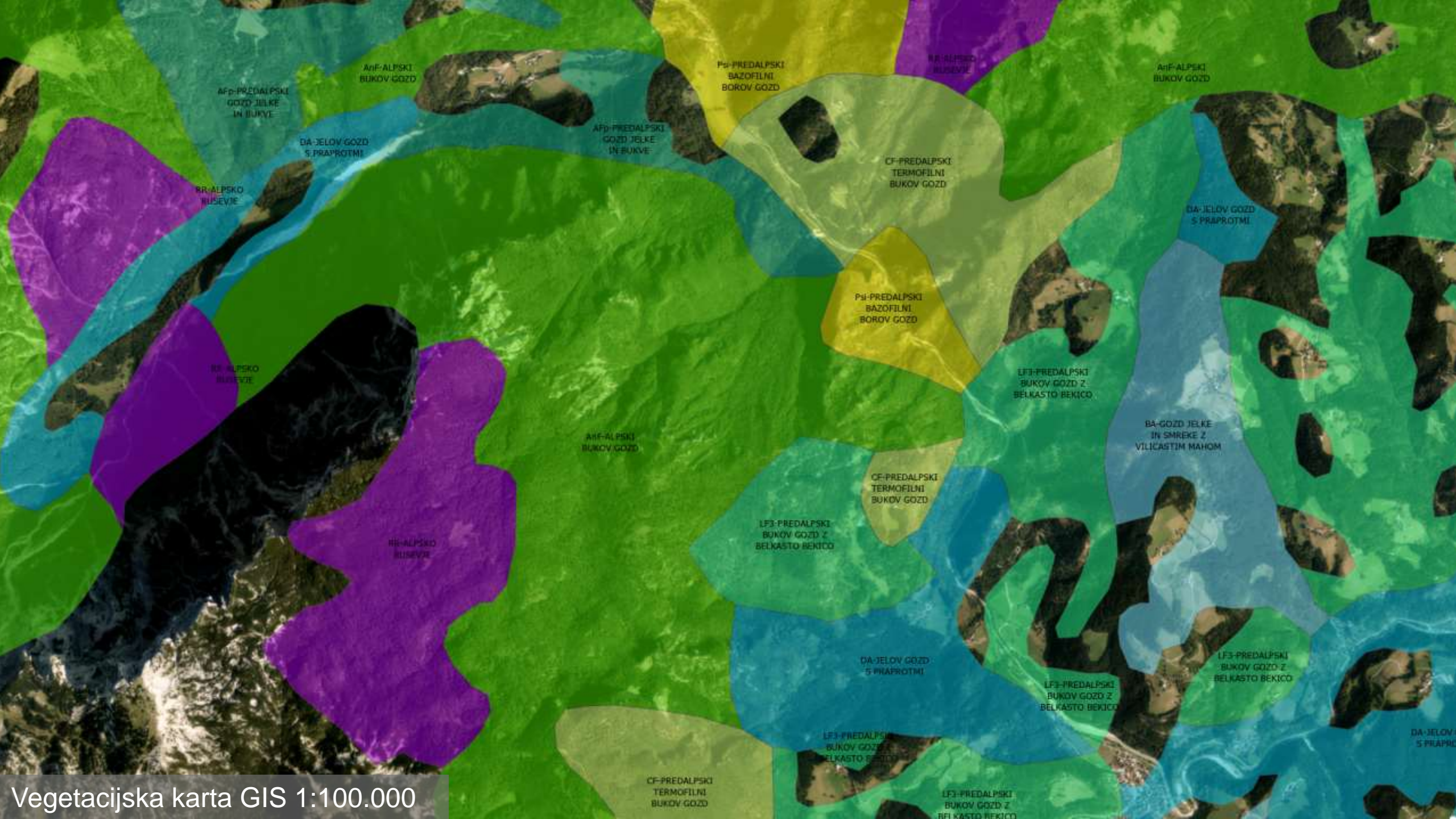
- jelka, problem objedanje
- rdeči in črni bor
- macesen (sudetski)
- listavci (hrasti, bukev, pl. listavci, breza)
- manjšinske drevesne vrste (jerebika, brek)

Tujerodne drevesne vrste:

- duglazija (silikat, rastišča od bukve proti gradnu)¹
- Pro Silva / FSC 10 % deleža = 20 % vrednosti



(foto: T. Pirc)



Vegetacijska karta GIS 1:100.000

D69			Luzulo-Fagetum var. geogr. Cardamine trifolia																
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q			
Sifra	Stara	Slovensko ime	Novo latinsko ime	sm	jel	bor	mac	bu	poljski jesen	veliki jesen	gorski javor	gorski brest	lipovec	lipa	češnja	ostrol. javor			
				Smreka	Jelka	Bori	Macesen	Bukev	Mali jesen	Veliki jesen	Gorski javor	Gorski brest	Lipa in lipovec	Lipa in lipovec	Češnja	Ostrolistni javor			
21	565	275	Primorsko hrastovje in črnogabrovje na apnencu	Aristolochio luteae-Quercetum pubescentis											2				
22	566	0	Primorsko hrastovje na flišu in kislejši jerovici	Molinio litoralis-Quercetum pubescentis															
23	567	0	Puhavčevo kraškogabrovje	Quercu-Carpinetum orientalis															
24	568	0	Črnikovje	Ostryo-Quercetum ilicis															
25	581	121	Osojno bukovje s kresničevjem	Arunco-Fagetum	3	1	3	80		1	3	1							
26	591	111	Preddinarsko-dinarsko toploljubno bukovje	Ostryo-Fagetum var. geogr. obtusatum				75			2			2					
27	592	112	Predalpsko-alpsko toploljubno bukovje	Ostryo-Fagetum var. geogr. Anemone trifolia	3		5	75			2			2					
28	593	71	Primorsko bukovje	Seslerio autumnalis-Fagetum				70			2			2		1			
29	600	261	Podgorsko-gorsko lipovje	Tilio-Aceretum platanoidis						10	10			10	20				
30	601	263d	Pobočno velikojesenovje	Hacquetio-Fraxinetum excelsioris						35	30		5	5	5	3			
31	611	25	Gorsko obrežno sivojelševje, črnojelševje in velikojesenovje	Alnetum incanae						25	5		3	10	1				
32	612	0	Orogeno vrbovje	Lamio orvalae-Salicetum eleagni	20					20									
33	621	241	Bazoljubno rdečeborovje	Genisto januensis-Pinetum silvestris	5														
34	622	0	Obrežno rdečeborovje	Alno incanae-Pinetum sylvestris	10														
35	623	242	Bazoljubno črnoborovje	Fraxino orni-Pinetum nigrae	5			5											
36	631	81d	Preddinarsko gorsko bukovje	Lamio orvalae-Fagetum var. Dentaria polyphyllus	2	3		85			1	2	2		1	1			
37	632	84	Predalpsko gorsko bukovje	Lamio orvalae-Fagetum var. Dentaria pentaphylos	2	2		1	80		4	5	2		1	1			
38	633	82	Primorsko gorsko bukovje	Lamio orvalae-Fagetum var. geogr. Sesleria autumnalis				85			1	3			2	1			
39	634	83	Alpsko bukovje s črnim telohom	Anemono trifolio-Fagetum var. geogr. Helleborus niger	20	5		10	61			2							
40	635	94	Alpsko bukovje s snežno belo bekico	Anemono trifolio-Fagetum var. geogr. Luzula nivea	10	5		6	74			2							
41	636	122	Bukovje s polžarko	Isopyro-Fagetum					75		3	15	5		2				
42	637	123	Javorovo bukovje	Stellario montanae-Fagetum					70			25	5						
43	638	0	Bukovje z dlakavim slečem	Rhododendro hirsuti-Fagetum	1	2			68			5							
44	641	161	Dinarsko jelovo bukovje	Omphalodo-Fagetum var. geogr. Calamintha grandiflora	5	40			50			3	2						
45	642	171	Predalpsko-dinarsko jelovo bukovje	Omphalodo-Fagetum var. geogr. Saxifraga cuneifolia	5	35			55			4	1						
46	643	172	Predalpsko jelovo bukovje	Homogyne sylvestris-Fagetum	15	30		5	45			3	1						
47	651	262d	Gorsko-zgornjegorsko javorovje z brestom	Omphalodo verna-Aceretum pseudoplatani		2			5		20	60	10		3				
48	661	181	Dinarsko jelovje na skalovju	Neckero-Abietetum	15	70			10			4							
49	671	211	Smrekovje na karbonatnem skalovju	Asplenio viridae-Piceetum var. geogr. Omphalodes verna	45	45			5			4							
50	672	212	Predalpsko smrekovje na morenah in pobočnih gruščih	Laburno alpini-Piceetum	80	5		2	7			4							
51	681	91	Preddinarsko visokogorsko bukovje z zasavsko konopnico	Cardamini savensi-Fagetum		1			78		5	10	5		1				
52	682	92d	Dinarsko zgornjegorsko bukovje s platanolistno zlatico	Ranunculo platanifolii-Fagetum var. geogr. Calamintha grandiflora		2			87		1	8	2						
53	683	92d	Predalpsko zgornjegorsko bukovje s platanolistno zlatico	Ranunculo platanifolii-Fagetum var. geogr. Hepatica nobilis	5	5		5	80			4							
54	684	101	Dinarsko podalpsko bukovje	Polysticho lonchitis-Fagetum var. geogr. Allium victorialis					95			4							
55	685	102	Predalpsko-alpsko podalpsko bukovje	Polysticho lonchitis-Fagetum var. geogr. Salix waldsteiniana	2	1		2	92			2							
56	691	221	Planinsko smrekovje na karbonatni podlagi	Adenostylo glabrae-Piceetum	73	10		10	5			1							
57	692	223	Dinarsko mraziščno smrekovje	Lonicero caeruleae-Piceetum	95	3													
58	701	0	Macesnovje	Rhodothamno-Laricetum	15	5		72	5										
59	702	281	Alpsko ruševje	Rhododendro hirsuti-Pinetum prostratae	20	5		70											
60	703	282	Dinarsko ruševje	Hyperico grisebachii-Pinetum mugo															
61	711	42d	Kisloljubno gradnovo belogabrovje	Castaneo-Fagetum sylvaticae	10							3		3		1			
62	731	132	Kisloljubno gradnovo bukovje	Hieracio rotundati-Fagetum					65		1	1				1			
63	741	251	Kisloljubno rdečeborovje	Vaccinio myrtilli-Pinetum sylvestris var. geogr. Castanea sativa	5														
64	751	151	Kisloljubno bukovje z rebrenjačo	Blechno-Fagetum	3	3			80										
65	752	142	Predpanonsko podgorsko bukovje	Festuco drymeiae-Fagetum var. geogr. Polystichum setiferum					80		2	2		1		1			
66	761	262d	Javorovje s praprotni	Dryopterido affini-Aceretum pseudoplatani					5		40	45	5	1	1	1			
67	771	202	Jelovje s praprotni	Gallo rotundifolii-Abietetum albae	20	60			12		2	2							
68	772	204	Jelovje s trikrpim mahom	Bazzanio-Abietetum	30	65			3			2							
69	781	141	Kisloljubno gorsko-zgornjegorsko bukovje z belkasto bekico	Luzulo-Fagetum var. geogr. Cardamine trifolia	15	15		5	65										
70	782	154	Kisloljubno gorsko-zgornjegorsko bukovje z zasavsko konopnico	Cardamini savensi-Fagetum var. geogr. Abies alba	20	20			60										
71	783	201	Kisloljubno gorsko-zgornjegorsko bukovje z zasavsko konopnico	Luzulo albae-Abietetum var. geogr. Alliosium rotundatum	10	50			10										

Spremenjenost

- ≤20
- ≤40
- ≤60
- ≤80
- ≤100



Mešani sestoji
domaćih vrst s
sudetskim
macesnom in
duglazijo v
okolici
Lenzburga (CH)

4 Zaključki

- kaskadni učinki negativnih dejavnikov gospodarjenja in okoljskih sprememb ogrožajo gozdove¹
- zmes in struktura sestojev nista najboljši²
- prilagajanje: raznomerni, mešani gozdovi, kjer je redno gospodarjenje³
- sanacija: naravna obnova z spopolnitvijo (puljenke)⁴
- velike možnosti domači vrst⁵, vendar (pre)objedanje po divjadi
- tuje vrste, kjer so že vnesene
- situacijska nega⁶
- preizkušanje novosti