



Remote sensing- assisted mapping of bark beetleinduced tree mortality

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monitoring of stand dynamics in Białowieża Forest supported with remote sensing techniques Conference @ BIAŁOWIEŻA, 2016





- Integral part of forest ecosystems
- Strongly influence the forest structure, composition and function
- Influence the forest spatial and temporal patterns



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- Biological agents account for over 60% of all calamities in European forest ecosystems
- Large-scale forest disturbances
- Mostly by *Ips typographus* L. in conifeorus and mixed stands
- Effects on:
 - growth forms
 - wood production (living biomass)
 - landscape aesthetics



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UNIVERSITÄT WÜRZBURG Example: Forest disturbance caused by Ips typographus L.



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Multitemporal and time series of optical imagery can help to assess the trajectories in space and time



















Photos by S.Thorn







Photos by S.Thorn

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non-attacked in 2003

old-attacked in 2003





attacked 2003







attacked 2001



Latifi, H et al. 2014. *Env. Monit. Asses.* 186: 441-456

non-attacked in 2003

old-attacked in 2003







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attacked 2003

attacked 2002

...a real challenge for optical remote sensing



attacked 2001



Latifi, H et al. 2014. *Env. Monit. Asses.* 186: 441-456

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- I. Spatial separation \rightarrow damage types (common classes)
 - I. Green-attacked
 - II. Red- attacked
 - III. Grey-attacked

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Traditional optical solution includes e.g. using vegetation indices



www.exelisvis.com

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Groups of Vis:

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II. RNDI which incorporate correction factors E.g. SAVI

- III. Derivative indices (narrow band)
 - E.g. Red edge position techniques

E.g. NDVI or Simple Ratio (SR)

Ratio and Normalized Difference Indices (RNDI)

UNIVERSITÄT WÜRZBURG How to separate the damage classes?

- IV. Indices which calculate areas (integral-based)
 - E.g. Triangular VI (TVI)

Groups of Vis:

- I. Ratio and Normalized Difference Indices (RNDI)
 - E.g. NDVI or Simple Ratio (SR)
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 - E.g. SAVI
- III. Derivative indices (narrow band)
 - E.g. Red edge position techniques
- IV. Indices which calculate areas (integral-based)
 - E.g. Triangular VI (TVI)
 - V. One approach: calculating the angles within a spectral triangle, instead of its area



Fassnacht, F.E, Latifi, H. et al. 2012. *Int. J. Appl. Earth Obs. Geoinf.* 19: 308-321



- Approach within the BFNP
- 27417 Indices fom all possible band combinations of 39 narrow band HyMap-channels in the VIS–NIR spectral range(0.455–0.986 µm)
- Genethic Algorithm for feature selection
- 6 response classes including damage and non-damage stages, drawn form aerial orthophotos

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- 27417 Indi triangles b narrow bai range(0.4
- Genethic /
- 6 response
 stages, dra

Blue: heavy damage Yellow: medium damage





3 of 9139 of 39 IR spectral

lon-damage

Fassnacht, F.E, Latifi, H. et al. 2012. *Int. J. Appl. Earth Obs. Geoinf.* 19: 308-321



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Results of GA



Fassnacht, F.E, Latifi, H. et al. 2012. *Int. J. Appl. Earth Obs. Geoinf.* 19: 308-321



Results of GA



Table 1

Confusion matrix of the best GA run using NC classifier for 2500 solutions. Producer's and user's accuracy are additionally given as measures of the overall prediction per class. Percentages of correctly classified samples are marked in gray.

2	Heavy dam	Med dam	Green dam	Coniferous	Broadleaved	Bare Soil
Heavy dam	0.800	0.117	0	0.013	0	0.004
Med dam	0.171	0.792	0	0.031	0.003	0
Green dam	0	0	0.971	0.007	0.003	0
Coniferous	0.016	0.090	0	0.95	0.001	0
Broadleaved	0	0	0.028	0	0.989	0
Bare soil	0.013	0.001	0	0	0.004	0.996
Producers's accuracy	0.800	0.792	0.971	0.95	0.989	0.996
User's accuracy	0.902	0.727	0.989	0.889	0.973	0.969
Overall accuracy	0.9052		Kappa	0.888		2



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Table 4

Confusion matrix of the best GA-run using NC classifier for 2500 solutions. The descriptions follow those from Table 1.

	Heavy dam	Med dam	Green dam	Coniferous	Broadleaved	Bare soil
Heavy dam	0.884	0.203	0.006	0	0	0.009
Med dam	0.094	0.626	0.099	0.002	0	0.002
Green dam	0.015	0.1	0.702	0.123	0.009	0
Coniferous	0	0.034	0.168	0.873	0.002	0
Broadleaved	0	0.008	0.025	0.002	0.989	0
Bare soil	0.006	0.03	0.001	0	0	0.988
Producer's accuracy	0.884	0.626	0.702	0.873	0.989	0.988
User's accuracy	0.862	0.715	0.739	0.803	0.967	0.952
Overall accuracy	0.8438		Kappa	0.811		

Fassnacht, F.E, Latifi, H. et al. 2012. Int. J. Appl. Earth Obs. Geoinf. 19: 308-321

Visual inspection of SVM results





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Coordinate System: WGS 1984 UTM Zone 33N Projection: Transverse Mercator Datum: WGS 1984



- Overestimation by classifying "green attacked" class
- "medium" and "high" damage classes were not completely separable
- No field data available → green damage separation infeasible

Fassnacht, F.E, Latifi, H. et al. 2012. *Int. J. Appl. Earth Obs. Geoinf.* 19: 308-321

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Is there any way to map the early stages of tree mortality?



Fassnacht, F.E, Latifi, H. et al. 2012. Int. J. Appl. Earth Obs. Geoinf. 19: 308-321



Does this framework help?

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- Multispectral, Multitemporal data → freely available
- Area-based scale \rightarrow compromise the details
- Terminology: let's rename the classes to approximate the terms
- High-density sampling from aerial imagery

Julius-Maximilianssample points drawn from reference sets **UNIVERSITÄT** WÜRZBURG 5430000 5430000 2001 5425000 5425000 **Does this** 5420000 Multispe available old attacked attacked 2008 5415000 old attacked attacked 2007 attacked 2001 attacked 2006 Area-bas non attacked non attacked - Terminol 380000 385000 390000 395000 380000 385000 390000 5430000 5430000 2008 terms

High-der -



Latifi, H. et al. 2014. Env. Monit. Asses. 186: 441-456

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confusion matrix of classified SPOT 2008



confusion matrix of classified SPOT 2011

202

UA=86.05%

attacked 2010

PA=89.5%

190

200

200

200

200

200

PA=59.5%

UA=59.5%

attacked 2009

classified

Latifi, H. et al. 2014. *Env. Monit. Asses.* 186: 441-456

old attacked





Latifi, H. et al. 2014. *Env. Monit. Asses.* 186: 441-456



- Take-Home messages:
 - visually-identifiable infested patches can be accurately classified
 - Medium- and green stages (i.e. current year-1 and current year-2) are mostly comissioned or omissioned
 - Non-attacked class may contain green-attack
 - Decessive factors in classification:
 - Quality of reference data
 - Size of infested patches
 - Spatial resolution of imagery



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Do further refinements (topographic info., object scale) improve the results?

		WGS	84/UTM Zone 33N			WGS	84/UTM Zone 33N
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Latifi, H. et al. 2014. *Env. Monit. Asses.* 186: 441-456

UNIVERSITÄT WÜRZBURG High-end object-base framework



- 11-years of Landsat and SPOT data (one scene per year)
- Full object-based paradigm
- Testing:
 - Object size
 - Object aggregation
 - Pan-sharpening imagery
 - LiDAR DTM for deriving topographical metrics
 - Texture metrics

Indust-Maximilians- WURZBURG Acquisition date (areal images) Acquisition date (ataellite images) Band : sensor Band : NIR Band 2: red Band 3: green 0.08.2001 13.10.2001 SPOT 2 Band 1: NIR Band 2: red Band 3: green Band 2: red Band 3: red - 111-year time - Full object-ba - Testing: - Object si - Object a - Pan-sha - LiDAR D - Texture r II.08.2003 25.09.2003 LANDSAT 5 TM Band 1: blue-green Band 3: red Band 4: NIR Band 5: SWIR - Object a - Pan-sha - LiDAR D - Texture r 0.08.2004 IO.08.2004 LANDSAT 5 TM Band 1: blue-green Band 3: red Band 4: NIR Band 5: SWIR - Texture r 0.08.2005 19.09.2005 SPOT 2 Band 4: NIR Band 2: green Band 3: red Band 4: NIR Band 2: SWIR - Object a - Pan-sha - LiDAR D - Texture r 0.08.2005 19.09.2005 SPOT 2 Band 7: SWIR Band 2: red Band 2: red Band 2: red Band 2: red Band 2: red Band 3: green 07.09.2006 II.09.2007 08.10.2007 SPOT 2 Band 1: NIR Band 2: red Band 3: green 01.08.2007 08.10.2007 SPOT 2 Band 1: NIR Band 2: red Band 3: green 31.08.2008 06.11.2008 SPOT 4 Band 1: NIR						
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Band 3: green					Band 3: green	
20.08.2009 24.08.2009 LANDSAT 5 TM Band 1: blue-green		20.08.2009	24.08.2009	LANDSAT 5 TM	Band 1: blue-green	
Band 3: red					Band 3: red	
Band 4: NIR					Band 4: NIR	
Band 5: SWIR					Band 5: SWIR	
22.08.2010 21.09.2010 LANDSAT 5 TM Band 1: blue-green		22.08.2010	21.09.2010	LANDSAT 5 TM	Band I: blue-green	
Band 2: green		and the second street			Band 2: green	
Band 3: red					Band 3: red	
Band 4: NIR Band 5: SWIR					Band 4: NIR Band 5: SWIR	
Band 7: SWIR					Band 7: SWIR	
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Band 2: red 5-785					Band 2: red Band 3: green	5-785

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ÜRZBURG	30.08.2001	13.10.2001	SPOT 2	Band I: NIR Band 2: red	
11 year time	01.10.2002	30.09.2002	LANDSAT 7 ETM+	Band 3: green Band 1: blue-green Band 2: green Band 3: red	
Full object-ba	11.08.2003	25.09.2003	LANDSAT 5 TM	Band 4: NIR Band 5: SWIR Band 7: SWIR Band 1: blue-green Band 2: green Band 3: red	
 Object si Object a Pan-sha Applicati 	03.09.2004	10.08.2004	LANDSAT 5 TM	Band 4: NIR Band 5: SWIR Band 7: SWIR Band 1: blue-green Band 2: green Band 3: red Band 4: NIR	
- Texture r	30.08.2005	19.09.2005	SPOT 2	Band 5: SWIR Band 7: SWIR Band 1: NIR Band 2: red	
	07.09.2006	11.09.2006	SPOT 4	Band 3: green Band 1: NIR Band 2: red	
	16.09.2007	08.10.2007	SPOT 2	Band 3: green Band 1: NIR Band 2: red Band 2: green	
	31.08.2008	06.11.2008	SPOT 4	Band 3: green Band 2: red Band 3: green	
	20.08.2009	24.08.2009	LANDSAT 5 TM	Band 1: blue-green Band 2: green Band 3: red Band 4: NIR Band 5: SWIR	
	22.08.2010	21.09.2010	LANDSAT 5 TM	Band 7: SWIR Band 1: blue-green Band 2: green Band 3: red Band 4: NIR Band 5: SWIR	
	22.08.2011	24.09.2011	SPOT 4	Band 7: SWIR Band 1: NIR Band 2: red Band 3: green	Progress in Physical 5-785

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ÜRZBURG	30.08.2001	13.10.2001	SPOT 2	Band I: NIR	
				Band 2: red	
				Band 3: green	
	01.10.2002	30.09.2002	LANDSAT 7 ETM+	Band I: blue-green	
				Band 2: green	
11 yoar timo				Band 3: red	
ii-year time				Band 4: NIR	
Full object be				Band 5: SWIR	
				Band 7: SWIR	
Testing	11.08.2003	25.09.2003	LANDSAT 5 TM	Band I: blue-green	
Testing:				Band 2: green	
				Band 3: red	
- Object s				Band 4: NIR	
				Band 5: SWIR	
- Object a	and the second se	Sector and the sector of the		Band 7: SWIR	
	03.09.2004	10.08.2004	LANDSAT 5 TM	Band I: blue-green	
- Pan-sha				Band 2: green	
i un onu				Band 3: red	
- Annlicati				Band 4: NIR	
- Applicati				Band 5: SWIR	
Toxturor				Band 7: SWIR	
- Texture I	30.08.2005	19.09.2005	SPOT 2	Band I: NIR	
				Band 2: red	
	10/10/00/02/00/00			Band 3: green	
	07.09.2006	11.09.2006	SPOT 4	Band I: NIR	
				Band 2: red	
				Band 3: green	
	16.09.2007	08.10.2007	SPOT 2	Band I: NIR	
				Band 2: red	
	20200000000000000	 		Band 3: green	
	31.08.2008	06.11.2008	SPOT 4	Band I: NIR	
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				Band 5: SWIR	
		100000000000		Band 7: SWIR	
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				Band 2: green	
				Band 3: red	
				Band 4: NIR	
				Band 5: SWIR	
				Band 7: SWIR	Drager
	22.08.2011	24.09.2011	SPOT 4	Band I: NIR	Fildle
				Band 2: red	5-785
				Band 3: green	0100

ess in Physical



Object-based set-up



Latifi, H. et al. 2014. *Progress in Physical Geography.* 38(6): 755-785

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- Scale level (necessary for good delineation of the boundaries of features)
 - = 50 for Landsat scenes
 - = 70 for SPOT scenes
 - = 50 for pan-sharpened images (2001, 2002, 2005 and 2011)
- a higher scale value = higher variability within each object
 = larger objects
Object-based set-up



- Scale level (necessary for good delineation of the boundaries of features)
 - = 50 for Landsat scenes
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- = 50 for pan-sharpened images (2001, 2002, 2005 and 2011)
- a higher scale value = higher variability within each object
 = larger objects
- Object aggregation (merging adjacent objects) → representing over- and under-segmentation
 - 0, 25, 50 and 75%



Object-based set-up



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Object-based set-up



- Object metrics
 - Area
 - Compactness
 - Roundness
 - Form factor
 - No. of holes
 - Mean and STDV
 - Texture (3×3 kernel)
 - Mean/STDV, Mean/STDV of texture from DTM

Results I- Predictor Importance



Latifi, H. et al. 2014. *Progress in Physical Geography.* 38(6): 755-785

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TXAVG_B1 TXAVG_B2 TXAVG_DTM TXVAR_B1 TXVAR_B2 TXVAR_DTM

Landsat time series

DLR

SPOT time series

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4 -2 -

AVG_B1

AVG_B2

AVG_B3

AVG_DTM

STD_B2

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Landsat time series

DLR



SPOT time series

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DLR

SPOT time series

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SPOT time series

DLR

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Results II- performance



OA% across the entire dates





Cohen's Kappa % across the entire dates

segment merge level %

DLR

OA%



Kappa%

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18





100





Cohen's Kappa % across the entire dates

25

Ó



Α

Β 100 95 year 90 --- 2001 - 2002 85 - 2003 -- 2004 80 2005 Cohen's KAPPA % - 2006 - 2007 75 - 2008 - 2009 70 - 2010 - 2011 65 spatial enhancement 60 - non-enhanced -- enhanced 55 availability years with both 50 -· years with non-enhanced 45 40 -. Progress in Physical

50

segment merge level %

75



'55-785

18





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DLR

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Summary:

- Deadwood and intact stands
 - classified nearly perfect (PA and OA > 95%)
 - UAs slightly lower than PAs → Marginal commission error
- Current year
 - showed highly variant PA trend
 - UA rates were, however, mostly consistent
- Current year -1
 - No systematic improvement by the use of pan-sharpened data
 - The UA and PA values hardly exceeded 90%
 - Generally increased PAs (i.e. reduced omission errors) by increasing the segment merge level
- Current year -2
 - Nearly same observations as in case of "current year-1" class

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Results

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IV- Probability surfaces for correct classification















- Medium resolution EO data could be leveraged to classify tree mortality, provided that:
 - The image Acquisition dates lie near to the reference data collection
 - An object based paradigm is applied
 - The infested patches conform the spatial resolution of the imagery
 - The right classifier is employed
 - The classes are realistically defined
 - Terrain information is there \rightarrow DTM or DSM
 - An in-depth assessment of uncertainty is on-board !

Latifi, H. et al. 2014. *Progress in Physical Geography.* 38(6): 755-785

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Limitations

- The lack of narrow-band informaiton on Rededge and SWIR domains
 - Suggestions: RapidEye or Sentinel II data (yet in shorter time spans)



Limitations

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- The lack of narrow-band informaiton on Rededge and SWIR domains
 - Suggestions: RapidEye or Sentinel II data (yet in shorter time spans)
- Heterogeneity of object forms, sizes and texture
- Segment merging level and pan-sharpening are still of uncertain status for their contribution to mapping quality





Limitations

- The lack of narrow-band informaiton on Rededge and SWIR domains
 - Suggestions: RapidEye or Sentinel II data (yet in shorter

Take-Home messages

- Early detection of tree mortality by mid-res optical data still is (and further remain) a challenge
- Coupling the inherently-uncetain reference (in whatsoever form) and satellite-based EO data adds to the complexity

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DOY



MODIS curve











RapidEye Curve







UNIVERSITY does spatial-temporal data fusion work?





STARFM (Gao et al., 2006. IEEE Trans.Geosci..Remote Sens.

Fusion results

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Date	R ²	RMSE	MAE
2011.04.19	0.54	0.13	0.11
2011.07.12	0.53	0.13	0.11
2011.10.22	0.53	0.13	0.11






























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