MAPPING OF STORM DAMAGES IN FORESTS USING TERRASAR-X SAR IMAGE DATA

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ABSTRACT

This study is carried out within the framework of the EU FP7-Project EUFODOS (European Forest Downstream Services - Improved Information on Forest Structure and Damages). The objective of EUFODOS is to develop monitoring services of forest degradation. To implement services which are as much adapted as possible to the user's needs, partnerships between forest authorities, research organisations and service providers were established.

Storms cause every year massive damages to the European forests. Out of the irregular harvestings due to abiotic damages 50% are caused by storms (1). A fast reaction from the forest owners is needed to prevent the fallen trees from further damages, e.g. bark beetle attacks. Therefore a fast and reliable mapping service of affected areas for forest authorities would be of great benefit.

On the 11.09.2010, the test side of the Polish EUFODOS partner was hit by a storm with wind speeds up to 80 km/h. The test site is located in western Poland, surrounding the city Gorzów Wielkopolski. 49% of the area is covered by forest, the main tree species is pine (2). In this area approximately 35.000 cubic meters of timber was damaged, that equals about a third of the annual felling.

In this study the capability of TerraSAR-X to map storm damaged areas is examined. The advantage of TerraSAR-X data is that it can be accomplished at nearly any weather conditions all over Europe with a high optional repetition cycle.

For the test site three TerraSAR-X scenes were acquired, one pre- and two post-storm Stripmap mode scenes with an azimuth resolution of 3 meters. All images are HH-polarized. The scenes were received in unprocessed SSC format (single look slant range).

During processing different numbers of look for the multilooking process were tested. Different filters like Gaussian Gamma, Frost, Lee and refined Lee were compared and examined. For mapping purposes the images were visually interpreted and the area of each plot was calculated. The results are validated with RapidEye scenes.

The results of visual interpretation show that it is possible to detect storm areas down to 0.1 hectare with TerraSAR-X Stripmap mode images.

INTRODUCTION

The FP7 project EUFODOS (European Forest Downstream ServicesServices - Improved Information on Forest Structure and Damage) uses data provided by the European Earth Observation Program GMES (Global monitoring of environment) to build up services for local, regional and national authorities for the assessment of forest damages, like storm, bark beetle and snow damages. These services will provide the user with information about the degradation status of their forests and will thus help them to decide about appropriate counteractive measures. The project started at the beginning of 2011 and will end at the end of 2013.

The role of Felis (Department of Remote Sensing and Landscape Information Systems, University Freiburg) within EUFODOS is the evaluation of new sensor data capabilities for storm and bark beetle damage detection.

The German radar satellite TerraSAR-X, which was built in cooperation of DLR and Astrium, was launched on June 15, 2007 (3). It operates in the so called X-Band which has a wavelength of 3.1 cm equating to 9.6 GHz. The height of the polar orbit is about 514 km, the revisit time is 11 days. Due to the various acquisition options, e.g. left or right looking and different incidence angles, every place in the world can be observed within 2.5 days. Also a large data archive is available. The short revisit timespan and also the advantage of radar waves to be nearly weather independent predestines TerraSAR-X as a sensor for storm detection in EUFODOS.

Different options to detect storm damages with radar data have been topic of research in several studies (4-9). Fransson et al. (10) indicated that two images are necessary to detect wind thrown areas, because variations in the backscattering can also be caused by other effects. Fransson et al. (11) suggested the use of satellite images with the same viewing geometry. Wang et al. (12) showed that it is possible to detect storm damages with two repeat pass X-Band images using interferometry, even on areas that were not cleared of fallen trees.

The main objective of this study is to develop a method for precise, reliable and fast detection of storm damaged areas in forests. For data pre-processing it is necessary to perform multilooking and filtering. To achieve the best results different numbers of looks and different filters are tested.

METHODS

The test site is located in the forest district Bogdaniec, Poland, directly at the border to Germany. The main tree species is pine, the relief is flat. A storm hit this area on the 11. September 2011 causing an amount of forces used timber of approximately 35.000 cubic meters.

For the area for which storm damages were reported one archive scene from June 12, 2010 of TerraSAR-X was available, two more were ordered and acquired with the same settings as the archive scene on October 20, 2011 and October 31, 2011 (table 1). Also RapidEye data was available for dates before and after the storm event. Scenes taken on June 2, 2011 and August 20, 2009 were used as pre-storm reference image. Due to too many clouds in the scenes taken in 2010 these could not be used. For detecting storm damages with RapidEye two scenes with optimal acquisition conditions taken on October 1, 2011 and October 16, 2011 were available.

Table 1: Acquisition details of the TerraSAR-X images

Acquisition mode	Date	Azimuth resolution	Range resolution	Incidence angle	Polarisation
Stripmap	2010-06-12	3.3 m	3.5 – 3.3 m	22 – 26°	HH
Stripmap	2011-10-20	3.3 m	3.5 – 3.3 m	22 – 26°	HH
Stripmap	2011-10-31	3.3 m	3.5 – 3.3 m	22 – 26°	HH

As a first step storm damages were determined in the RapidEye scenes. Unfortunately the storm damages occurred east of the stripmap mode scenes taken in October 2011 only. For the storm damaged areas also no archive data was available. But since in the area covered by the stripmap mode scenes clear cuts occurred between the acquisition dates these clear cut areas could be utilised for method test. 36 clear cut areas were chosen to test the method. The size of these areas varies between 0.08 and 0.37 hectare.

TerraSAR-X images were delivered in SSC format, this means the images are not processed. In order to get an image with few speckle as result, at first TerraSAR-X images were multilooked. As second step the multilooked images were co-registered to enable multi-temporal filtering. These co-registered images were then processed with all available filters within SARscape and afterwards a RGB image was produced by assigning each band to one acquisition date.

During multilooking different numbers of looks were applied to the images. The more looks are applied the more the spatial resolution decreases resulting in smaller file size and fewer speckles. During multilooking the pixels are assigned to a square shape, the range resolution is adjusted to the azimuth resolution. The parameters of the tested options are described in table 2.

Table 2: Five different Multilooking options were tested

Suggested by SARScape	Number of Looks in		Resulting in Resolution in		Difference between range and azimuth resolution	resampling to	Resulting File size
[Default value]	Range	Azimuth	Range [m]	Azimuth [m]	[%]	[m]	[MB]
Very High Resolution	1	1	4,47	3,44	13,0%	3,4	435
TerraSAR-X	2	2	8,94	6,89	13,0%	6,9	103
not suggested	3	4	13,41	13,77	1,3%	13,4	44
High Resolution	4	5	17,89	17,21	1,9%	17,2	27
not suggested	7	9	31,31	30,98	0,5%	31	9

12 different filters were then applied to each multilooking option. These filters are Mean, Median, Mode, Frost, Lee, Refined Lee, Anisotropic Non-Linear Diffusion (ANLD), Edge Preserving Smoothing (EPS), SLC Gaussian Distribution-Entropy MAP (SLC), Gaussian Gamma MAP and the multi-temporal filters De Grandi, ANLD. For all filters different options like window sizes and equivalent number of looks were tested. Afterwards the images were geocoded. Radiometric normalisation was executed and radiometric calibration was accomplished with help of the SRTM DEM.

After geocoding RGB images were produced by assigning each of the three images to one band, the pre-storm image was assigned to red, the two post-storm images to green and blue.

Within the resulting RGB images clear cut areas previously delineated with RapidEye data were also delineated and the size of these areas was calculated.

The areas delineated with RapidEye were then geometrically shifted to be in line with the polygons delineated with the RGB images. This step was necessary as geocoding of the TerraSAR-X images was not precise enough due to the unavailability of a precise DEM and additionally because of effects like shadowing and foreshortening which cause a shift of the areas.

RESULTS

Clear cut areas appear as turquois in the RGB images, because in the post storm images these areas have a higher backscattering value and as defined the blue and the green channels mix to turquois. When looking at the borders of the areas it can be observed that there appears shadowing, occurring red in the chosen channel combination, in front of the areas when looking from the sensors position (13). Areas behind the clear cut appear in a very bright turquois due to Overlay (Figure 1).

For an estimated tree height of 30 meters and the given incidence angle of approximately 24 degrees the effect of shadowing would occur on the border of the clear cut closer to the sensor for the length of 32.8 meters, overlay on the opposite side of the clear cut for 27.4 meters. Since these effects reduce the representation of the clear cut areas, these effects have been considered in the visual interpretation.

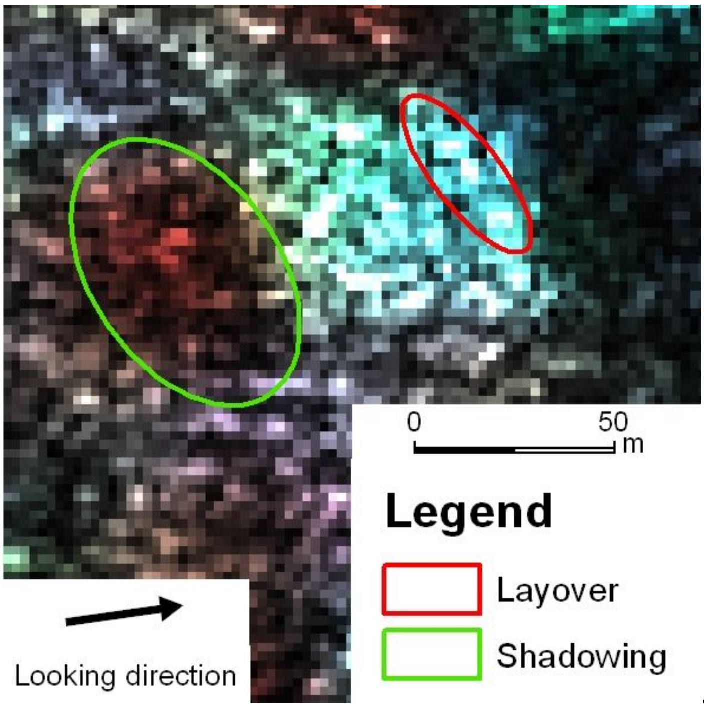

Figure 1: RGB picture resulting from images processed with 2x2 Looks and filtered with De Grandi.

With the majority of filters all clear cut areas could be found. In all images the area was underestimated. In nearly all images processed with fewer than 4 by 3 Looks all areas could be identified. The best results in estimating the sum of all areas were achieved with the images processed with the multi-temporal De Grandi filter and 2 by 2 Looks. The total area in this image was only underestimated by 7.5%. All clear cut areas could be identified. When applying 5 by 4 or more looks, best results with respect to estimating the total area were achieved with the Gamma Gaussian MAP filter (table 3).

Table 3: shows the best results with regard to the calculated area

Filter	**Looks**	**Area [m²]**	**Count**	**Accuracy assessment**
MT De Grandi	2x2	73014	36	100%

MT De Grandi	1x1	72028	36	100%
GGM	5x4	70636	36	100%
SLC	1x1	69167	36	100%
ANLD	1x1	67547	36	100%
GGM	9x7	66612	32	89%
RapidEye	**n.a.**	**78959**	**36**	**100%**

When comparing the areas of each clear cut area it can be observed that the calculated areas differed considerably between RapidEye and Radar RGB images (Figure 2).

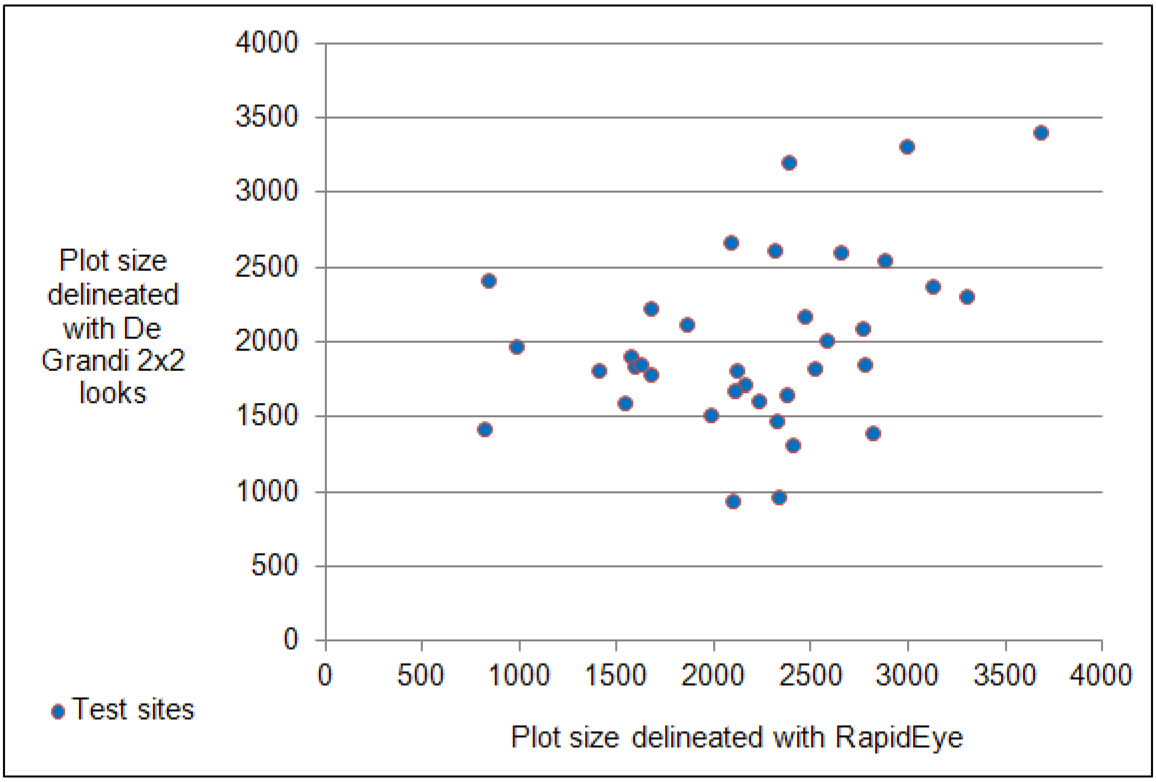

Figure 2: Comparison of the damage area size assessed with TerraSAR-X and RapidEye.

With an increase of applied looks the number of detected areas decreases, also the estimated area decreases. The shape of the areas blurs due to the more coarse resolution. On the other hand the radiometric resolution increases when applying more looks. Due to this clear cut areas appear much brighter in images processed with more looks. The detection of damaged areas is easier with images processed with more looks (Figure 3).

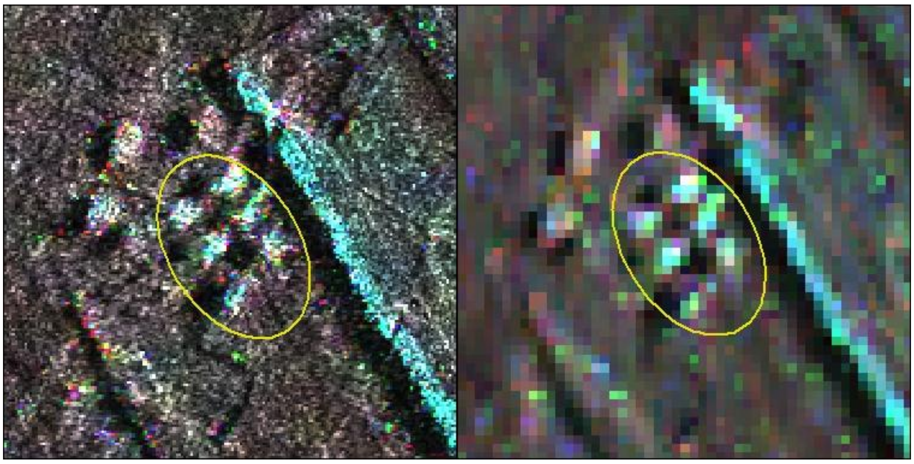

Figure 3: On the left the image was processed with De Grandi and 2 by 2 looks, on the right with the GGM filter and 9 by 7 looks

CONCLUSIONS

Concluding from the results on clear cuts, storm damaged areas can be detected with intensity data. Due to the higher radiometric resolution of images processed with more looks clear cuts can easier be separated from surrounding forest, with the drawback that the edges of the area are not as precise as in images processed with fewer looks and smaller areas cannot be detected. Another advantage of using images with more looks is a reduced processing time, as the file size of images processed with 9 by 7 looks is about 50 times smaller than of images that were processed with 1 by 1 looks. Due to the smaller file size of these images the further processing steps like filtering are executed much faster.

When comparing the results of different filters it can be observed that adaptive filters perform best. With the De Grandi filter applied to an image processed with 2 by 2 looks all areas could be detected and the sum of all areas could be estimated best. The sum of all areas was only underestimated by 7.5%.

When applying more looks best results were accomplished with the Gamma Gaussian Map filter. When applying this filter to images processed with 5 by 4 looks all areas could be detected and the total clear cut area was underestimated by 10.5%. Applying this filter to an image processed with 9 by 7 looks only 32 of the 36 areas were found and the total clear cut area was underestimated by 15.6%.

As one reason for the underestimation of the clear cut areas shadowing must be considered. Shadowing and foreshortening are sources of error, both have area reducing effects. For areas that are not square and have frayed edges these effects are particular strong (Figure 4). While foreshortening can relative easily be identified, it is much more difficult to estimate the quantitative effect of shadowing.

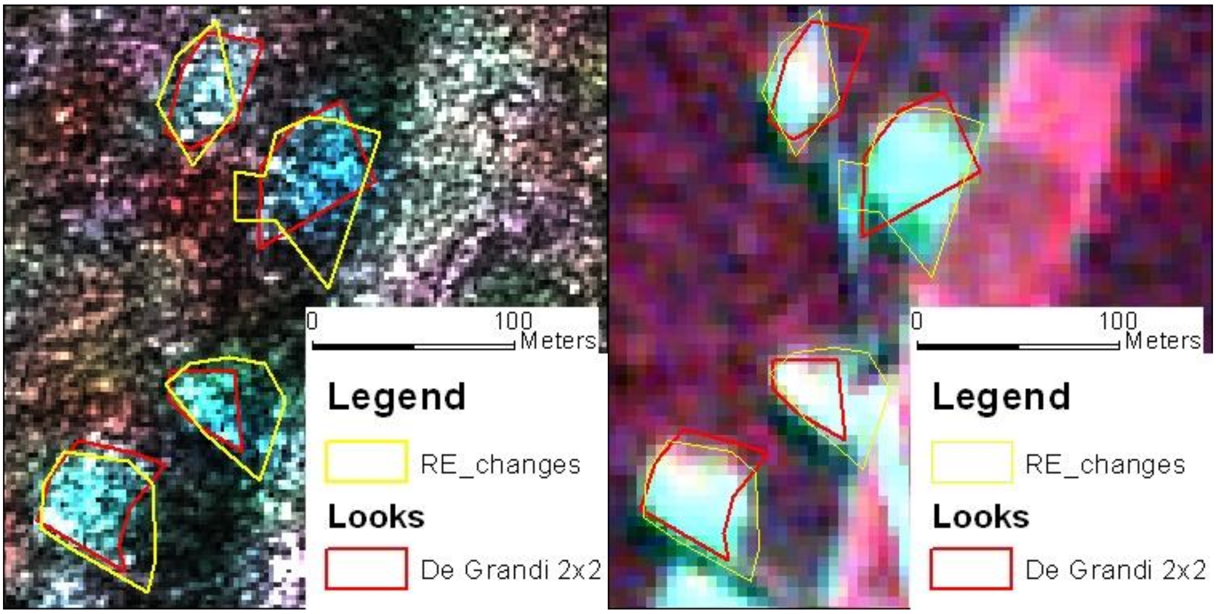

Figure 4: Comparisons of the assessment of clear cuts between TerraSAR-X processing options and RapidEye. The picture on the left side shows an image processed with the De Grandi filter and 2 by 2 looks, on the right a RapidEye image with the channels 5, 3 and 2 is shown. The yellow polygons show the delineation with RapidEye, the red polygons were delineated in the image processed with the De Grandi filter and 2 by 2 looks.

The use of a better DEM for georeferencing and radiometric calibration might improve the results (14).

The clear cut areas examined in this study show a higher backscattering than areas covered by forests. In areas affected by storms a higher backscattering could also be observed due to lying trunks. This implies that the results of this study are portable to a real storm event.

After a storm event fast information is needed. Often there is no information on the most affected locations, because of that large areas must be covered. Images with more looks can be processed much faster due to the smaller file size, furthermore areas can be found easier. Therefore these images are useful for a first estimation of the damage caused by a storm. For speckle reduction of images processed with more looks the Gamma Gaussian Map performs best.

As a second step affected areas found can be delineated more precisely. For this purpose an image with fewer multi looks and filtered with the multi temporal De Grandi filter should be used.

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REFERENCES

1 Albrecht A, D Schindler, K Grebhan, U Kohnle, H Mayer, 2008. Klimawandel und Stürme über Europa – eine Literaturübersicht. In: FORSTLICHE VERSUCHS- UND FORSCHUNGSANSTALT (Hg.): Wald und Klima. 2. Aufl. (FVA-einblick). http://www.waldwissen.net/wald/klima/wandel_co2/fva_sturm/fva_klima_sturm_artikel (last date accessed: 11 Jul 2012).

2 Matecki M, 2011: Forests in Poland 2011. Hg. v. Lasy Państwowe

3 Werninghaus R, S Buckreuss, 2010. The TerraSAR-X Mission and System Design. In: IEEE Trans. Geosci. Remote Sensing 48 (2): 606–614

4 Folkesson K, B Hallberg, G Smith-Jonforsen, L Ulander, J Fransson, M Magnusson, 2006. Automatic Detection of Wind-Thrown Forest in VHF SAR Images. In: 2006 IEEE International Geoscience and Remote Sensing Symposium 3599–3602.

5 Fransson J E, A Pantze, L E Eriksson, M J Soja, M Santoro , 2010. Mapping of wind-thrown forests using satellite SAR images. In: 2010 IEEE International Geoscience & Remote Sensing Symposium 1242–1245.

6 Ouchi K, H Wang , 2011. Assessment of typhoon-damaged forest by multi-temporal and multi-frequency POLSAR and InSAR datasets. In: Synthetic Aperture Radar (APSAR), 2011 3rd International Asia-Pacific Conference.

7 Ramminger G, M Dees, N Saidani, H Friedlaender, B Herrera, H Kahabka, B Koch, 2004. Konzepte für die Erfassung von Sturmschäden mit Fernerkundung und für die GIS basierte Risikoanalyse. Abschlussbericht Sturmmon.

8 Ramminger G, 2004. Erfassung von Sturmschäden mit Hilfe von modernen Radar-Fernerkundungssystemen. http://www.freidok.uni-freiburg.de/volltexte/1539/pdf/Dissertation.pdf (last date accessed: 11 Jul 2012).

9 Ulander L, A Gustavsson, J Fransson, M Magnusson, G Smith-Jonforsen, K Folkesson, B Hallberg, L Eriksson, 2006. Mapping of Wind-Thrown Forests Using the VHF-Band CARABAS-II SAR. In: 2006 IEEE International Geoscience and Remote Sensing Symposium 3684–3687.

10 Fransson J E, M Magnusson, K Folkesson, B Hallberg, G Sandberg, G Smith-Jonforsen, A Gustavsson, L M Ulander, 2007. Mapping of wind-thrown forests using VHF/UHF SAR images. In: IGARSS Barcelona 2007 2350–2353.

11 Fransson J E, M Magnusson, H Olsson, L E Eriksson, G Sandberg, G Smith-Jonforsen, L M Ulander, 2007. Detection of forest changes using ALOS PALSAR satellite images. In: IGARSS Barcelona 2007 2330–2333.

12 Wang H, K Ouchi, Y-Q Jin, 2011. Classification of typhoon-destroyed forests based on tree height change detection using InSAR technology. In: 2011 IEEE International Geoscience and Remote Sensing Symposium; IGARSS 1247–1250.

13 Breidenbach J, S M Ortiz, M Reich, 2010. Forest monitoring with TerraSAR-X: first results. European Journal of Forest Research, 5: 813–823.

14 Ortiz S, J Breidenbach, G Kändler, B Koch , 2011. Mapping forest types with TerraSAR-X imagery. In: TerraSAR-X Science Team Meeting. DLR. http://sss.terrasar-x.dlr.de/papers_sci_meet_4/oral/LAN0129_ortiz.pdf (last date accessed: 11 Jul 2012).