Geoinformation Issues
Vol. 5, No 1 (5), 29–41/2013

Dual-Polarimetric signatures of vegetation – a case study Biebrza

Dariusz Ziolkowski
Institute of Geodesy and Cartography, 27 Modzelewskiego St., PL 02-679 Warsaw, Poland
Tel.: +48 22 3291991, Fax: +48 22 3291950, E-mail: dariusz.ziolkowski@igik.edu.pl

Iwona Malek
Institute of Geodesy and Cartography, 27 Modzelewskiego St., PL 02-679 Warsaw, Poland
Tel.: +48 22 3291992, Fax: +48 22 3291950, E-mail: iwona.malek@igik.edu.pl

Maria Budzynska
Institute of Geodesy and Cartography, 27 Modzelewskiego St., PL 02-679 Warsaw, Poland
Tel.: +48 22 3291992, Fax: +48 22 3291950, E-mail: maria.budzynska@igik.edu.pl

Abstract. The main objective of the research presented in this article is to analyse the polarimetric characteristics of three main types of natural vegetation occurring in the Biebrza National Park – forests, shrubs and non-forest land communities covering wetlands. The variability of many different polarimetric products of signal decomposition, depending on the type of vegetation, the microwave image acquisition period and the method of their preliminary treatment, was analysed. An attempt was also made to assess how much polarimetric methods can be useful for modelling biophysical parameters of vegetation. The study used six dual-polarized (HH and HV) ALOS satellite images recorded during the growing season in the years 2008, 2009 and 2010. The images were processed in parallel, using different parameters, in order to estimate the impact of the spatial resolution of images and methods of speckle noise filtering on the value of polarimetric characteristics of different types of vegetation. All methods of polarimetric signal decompositions available using ESA POLSARPRO 4.2 software were tested. Three of them, i.e. the Alpha parameter from the H/A/Alpha decomposition (Cloud and Pottier, 1996) containing information about the dominant scattering mechanisms and two types of entropy: the entropy from the H/A/Alpha decomposition and the Shannon Entropy were selected for further analysis.
The analysed years differed quite significantly from one another in the agro-meteorological conditions of plant growth. It was a cause of significant differences between the values of polarimetric characteristics in images recorded at the same season but in different years. During the growing season individual products of polarimetric signal decomposition are characterized by different variability. This demonstrates the dependence of different polarimetric characteristics on various biophysical parameters of the environment. It was observed that they are characterized by greater information content than the backscattering coefficient, especially if they are subjected to the process of increasing the resolution (oversampling). They can be used to model the biophysical parameters of vegetation.

Keywords: polarimetry, the Biebrza Wetlands, vegetation

Received: 13 March 2014 /Accepted: 30 April 2014

1. Introduction

Radar polarimetry is one of the most modern techniques of processing radar images. Using both the amplitude and phase of the radar signal recorded, it allows a comprehensive analysis of the vector nature of a polarized electromagnetic wave, thus providing additional information about the environment examined. The information on wave polarisation, which is contained in the backscattering coefficient, is strongly related to the geometric structure of a reflection, the shape and orientation of the object and its physical properties such as e.g. roughness and humidity. One of the main advantages of polarimetry is the possibility to identify different scattering mechanisms (single bounce scattering, double bounce scattering, volume scattering) (Lee and Pottier, 2008). The mixing of different scattering mechanisms, and their involvement in various individual pixels, often occur within a single pixel. This is especially true in such complex, in terms of structure, objects as forests and other types of natural vegetation. In different pixels which are characterized by the same amplitude different mechanisms can have different contribution.

This relationship has often been used in studies of vegetation; nevertheless, the use of radar polarimetry so far has been focused primarily on the use of these properties for image classification, in particular, various types of crops in agricultural areas (Cloude, 2010). The purpose of this article is to present the polarimetric characteristics of natural areas on the example of the Biebrza Valley. An attempt was also made to assess how polarimetric methods can be useful for modelling the biophysical parameters of vegetation.

So far, the research related to modelling biomass and other parameters of the vegetation in microwave images has been carried out mainly on the basis of the backscattering coefficient. This type of studies for forest areas have been conducted for many years, among others, by e.g. Le Toan et al. (1992), Lu (2006). Radar interferometry and polarimetric interferometry are also used for the purposes of modelling the biophysical parameters of forests (e.g. Balzter et al., 2007; Santoro et al., 2007; Thiel et al., 2009; Ziolkowski et al., 2013a). Studies related to modelling the biophysical parameters of vegetation and soil moisture in microwave images have been conducted for many years in areas covered by non-forest land communities, among others, in the Biebrza National Park (e.g. Dabrowska-Zielinska et al., 2009, 2012, 2013a, 2013b). Using the many years' experience so far in which backscattering coefficients have been used, and the availability of archival field measurements, an attempt was made to check to what extent radar polarimetry can bring a new value added to the studies carried out so far.

2. The study area

The study area is located between 53°12' and 53°4' of north latitude and 22°26' and 22°57' of east longitude and is located in the Biebrza Valley, within which the Biebrza National Park was established. The Biebrza Valley is the largest field depression in north-eastern Poland. It is an extensive swampy bog valley called, the "Biebrza Wetlands". The lie of the land in the Biebrza valley is generally flat. Its natural boundaries are marked by the surrounding forms of old-and young-glacial accumulation, on the border of which it is located.

In the area of the Biebrza National Park, three basic forms of plant habitats, i.e. forest communities, shrub communities and non-forest land communities, have developed in varied water and soil conditions. Figure 1 shows the classification of the plant communities of the study area (Gruszczynska et al., 2007).

Most forests are located in wetlands, and therefore there is the largest share of stands in the habitat type of alder and mixed forest swamp there. Sand dunes on the edge of the valley are covered with fresh coniferous and fresh mixed forests. The birch, the alder and the pine are dominant in these forests (www.biebrza.org.pl).

Non-forest land communities consist mainly of rushes and sedges (37.2% of the Biebrza National Park) and bogs (31.5% of the Biebrza National Park), (Matuszkiewicz et al., 1999).

A large role in shaping and maintaining plant communities of the type of non-forest ecosystems is played by water regime. Their change can cause significant transformations of these communities. There are three typical plant communities developed for specific water conditions, depending on the impact of flooding, in the Biebrza National Park.

In the first zone the following communities of the immersion zone have developed: *Pragmitetum communis, Phalaridetum arundinaceae, Glycerietum maximae, Oenantho-Rorippetum.* Their occurrence on the bottom of the Biebrza Valley is directly connected with the cyclic river flooding, and thus, indirectly, with the hydrogenic soils of the fluviogenic feeding system. The second type includes plant communities developed in the immersion/emersion zone, remaining under the influence of regular river flooding and ground waters. Under such a complex hydration the following communities have also evolved: *Thelypteri-Phragmiteyum*, *Caritetum gracilis, Caritetum elatae*, *Caritetum appropinquatae*. The third type of plant communities occurring in

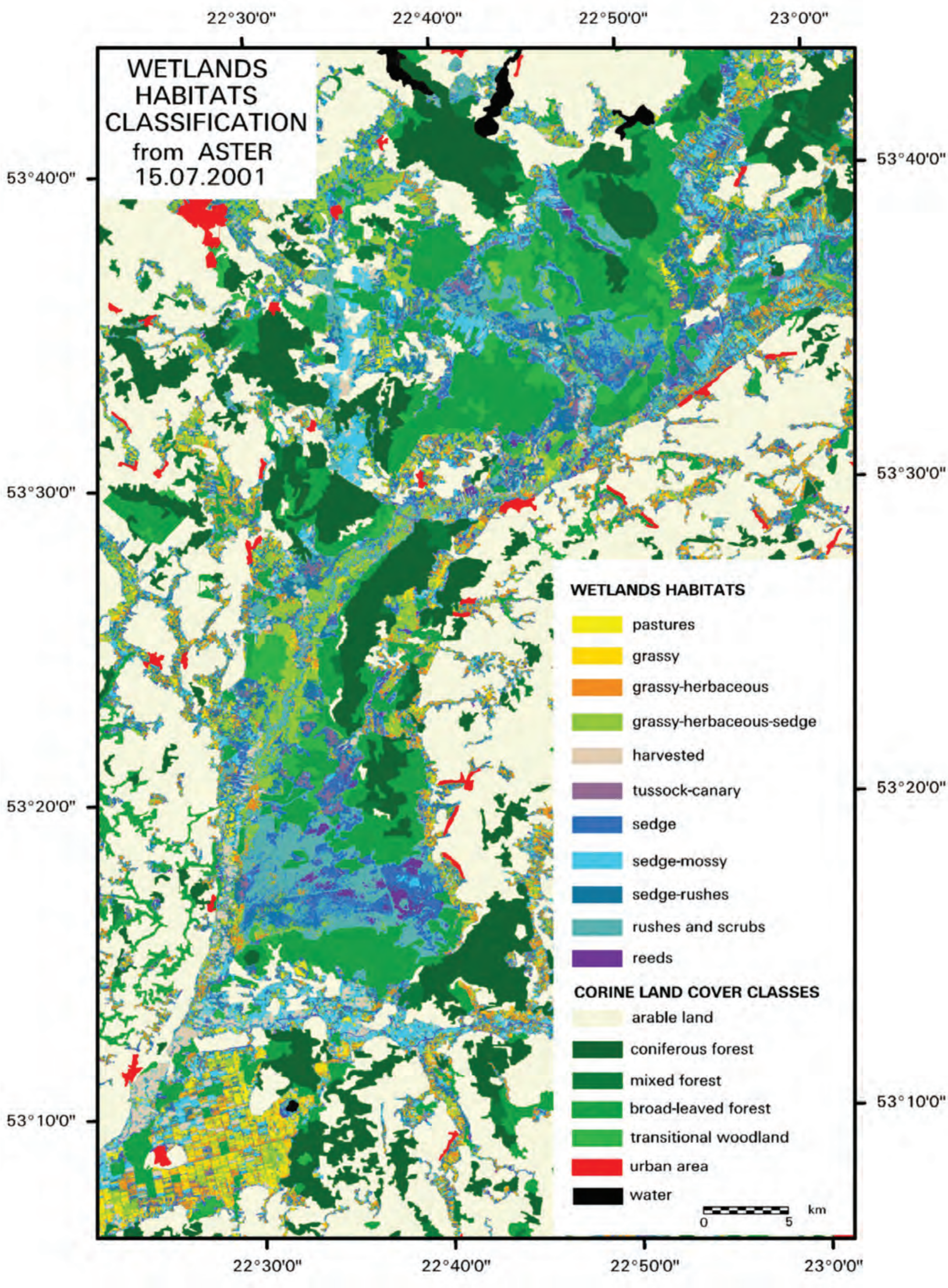

Fig. 1. The classification of non-forest land communities in the area of the Biebrza marshes made on the basis of the image from the ASTER sensor. CORINE Land Cover classification was applied for the remaining part of the area

the Biebrza Valley is formed by plants developed in areas fed by underground waters. They form the so-called communities of the emersion zone, which include the moss-sedgecommunities of the *Caricion-fuscae* relationship, the moss communities of the *Caricion-lasiocarpae* relationship and the meadows of the *Molinion* relationship, characterised by the fluctuating water level. The occurrence of soils with soligenic and topogenic feeding is directly related to the type of vegetation of the emersion zone in the Biebrza Valley. The changes occurring in forms of land use, soil drainage or starting the decession phase of organic matter result in transformations in plant communities. They consist in overgrowing, the intensification of the process of shrubbing or, in extreme cases, the afforestation of non-forest communities.

3. The data

The study used six SLC radar images from the ALOS satellite of the HH and HV polarizations, recorded on 12-05-2008, 12-08-2008, 30-06-2009, 15-08-2009, 30-09-2009 and 03-07-2010. These images were first processed in the ESA POLSARPRO 4.2 software, which was used to carry out all signal decompositions available for dual-polarized images. The imported images were processed in parallel, using different parameters, in order to estimate the impact of the spatial resolution of images and the methods of speckle noise filtering on the value of polarimetric characteristics of different types of vegetation. The images processed in the original resolution of 3×15 m, for which the polarimetric signatures have been counted in the smallest possible window of 3×3 pixels (without speckle noise filtering), the images after carrying out the process of multilooking to the resolution of 15×15 m without speckle noise filtering, and the images with a resolution of 15×15 m after speckle noise filtering using the boxcar filter in the window of 5×5 pixels were selected for further analysis. Thus obtained products of the polarimetric decomposition of the signal were then imported into the NEST program (Next esa sar toolbox) v 5.0.16. Then, using automatic co-registration methods, they were coregistered to one master image, with an accuracy of up to 0.1 pixel. Thus prepared images were then geometrized to the 1992 coordinate system (EPSG: 2180). The SRTM Digital Elevation Model, with a spatial resolution of 90 m, was used in the process of geometrisation. The images were then resampled using the nearest neighbour method, in order to avoid changing the pixel values in the process. In the case of original images, oversampling up to the resolution of 3×3 m was performed. In contrast, the images after the process of multilooking and the images after speckle noise filtering were geometrised to the ground resolution of 15 metres.

The study also used the results of archival field measurements performed in the Biebrza Valley in 2009, during two measurement campaigns conducted on 17–21 June 2009 and 28–31 July 2009. Since the dates of field measurements differ by about 10 to 15 days from the dates of acquisition of the images, therefore, the vegetation parameters were solely used for the analysis, without taking into account the information about the soil moisture.

4. The results and discussion

4.1. The polarimetric signatures of vegetation

Among the polarimetric products of signal decomposition generated during data processing three of them, i.e. the Alpha parameter from the H/A/Alpha decomposition (Cloud and Pottier, 1996) containing information about the dominant scattering mechanisms and two types of entropy: the entropy from the H/A/Alpha decomposition and the Shannon Entropy were selected for further analysis. All these parameters differ in the information content and according to the authors best reflect the diversity of polarimetric signatures of the vegetation within the study area (Ziolkowski et al., 2013b). The parameter values for all six images have been shown in Figures 2a, 2b and 2c. Each of these parameters demonstrates a very large variation within the study area depending on the type of vegetation, as well as a wide variation depending on the date of acquisition of each image.

The highest values of the Alpha parameter can be observed in coniferous and mixed forests with a predominance of conifers. For those stands, the Alpha parameter has similar values in all six images, although they are slightly higher for the image recorded on 12 May 2008. The parameter values indicate the advantage of volume scattering (values in

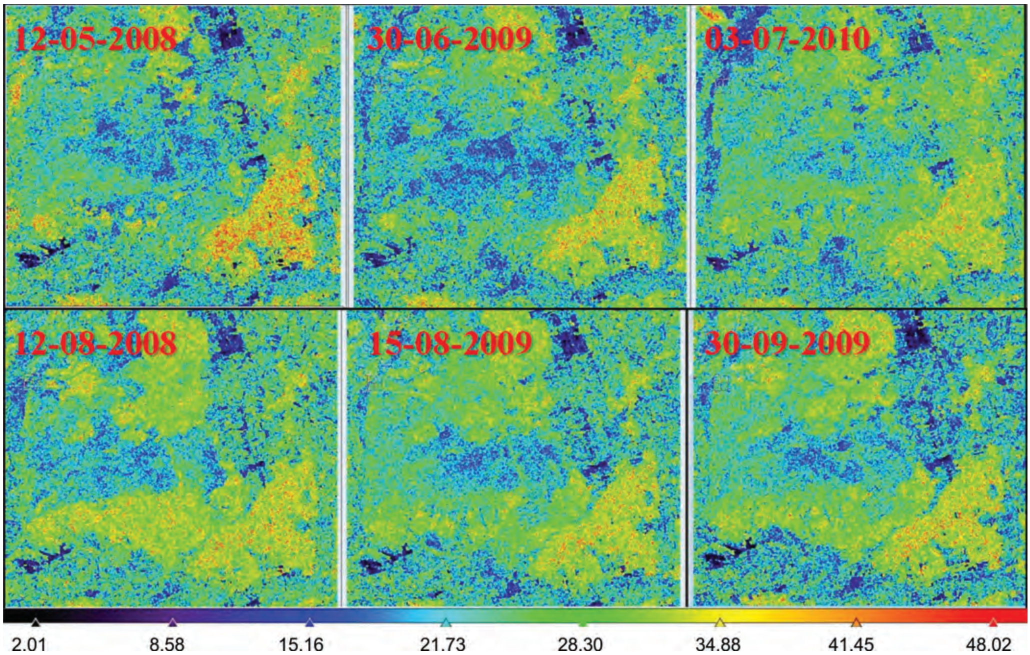

Fig. 2a. The distribution of values of the Alpha parameter from the H/A/alpha decomposition generated from the ALOS satellite images recorded on: 12-05-2008, 30-06-2009, 03-07-2010, 12-08-2008, 15-08-2009, and 30-09-2009 for a section of the study area

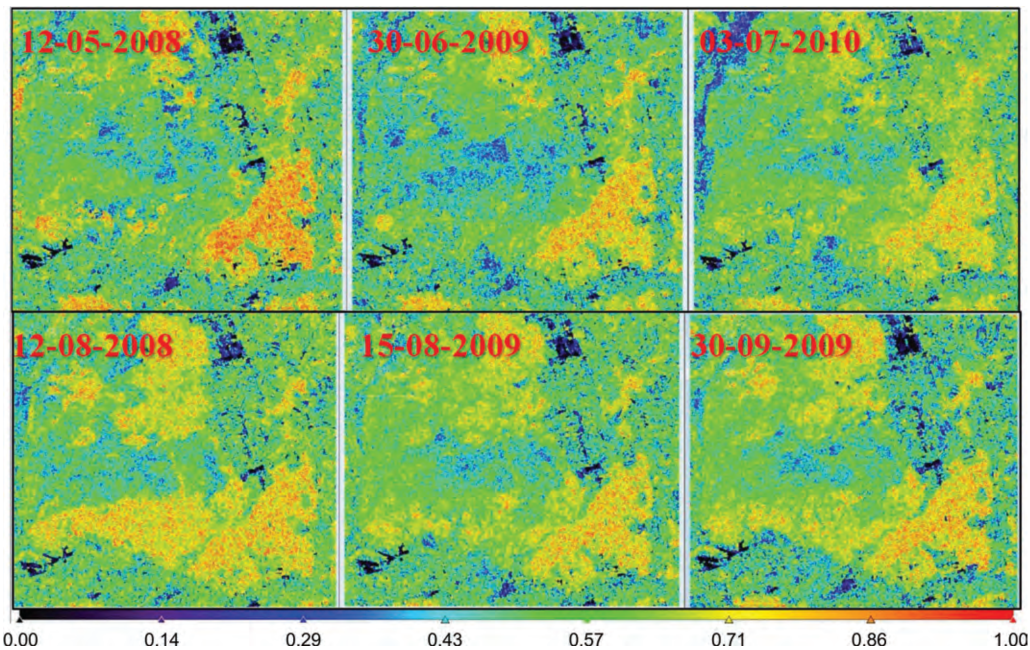

Fig. 2b. The distribution of values of the Entropy from the H/A/alpha decomposition

Geoinformation Issues
Vol. 5, No 1 (5), 29–41/2013

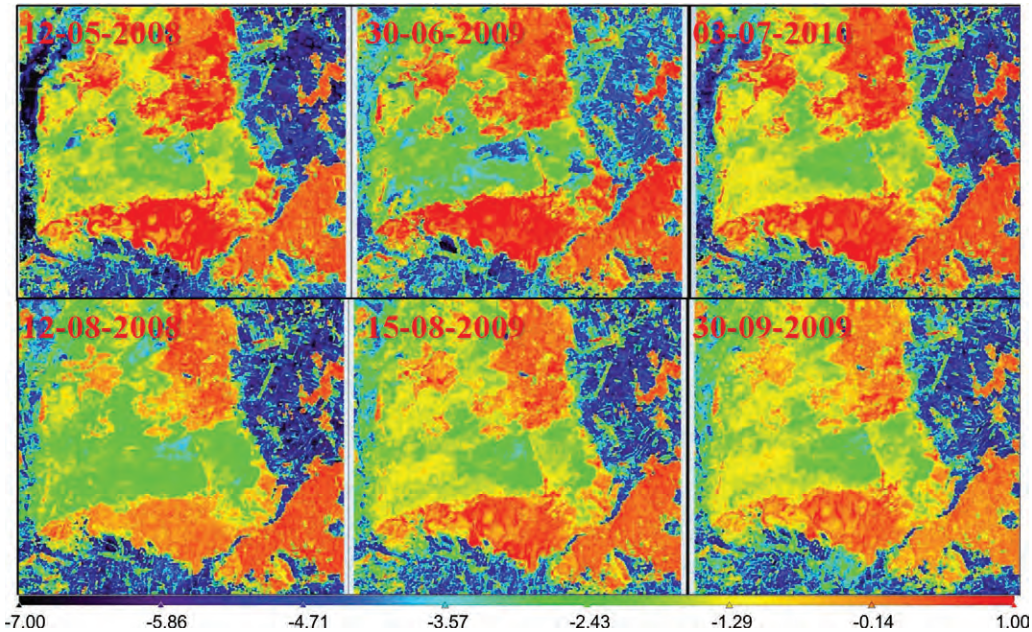

Fig. 2c. The distribution of values of the Shannon Entropy

the range of 40–50), and multiple reflections of the double-bounce type (values above 50), although there are also many pixels (mainly where there is the prevalence of deciduous stands) which are rather characteristic for a single reflection from the surface (less than 40).

The characteristics of the Alpha parameter for deciduous forests are completely different. They reach the values similar to those characteristic of coniferous forests only in the image registered on 12 August 2008. They are much lower in the other images. In deciduous forests there is also a greater variation of this parameter depending on the date of acquisition of the image. By far, they are the lowest in the images recorded in May and June (most of the values in the range of 15–30), and higher for the images from July, August and September (most values in the range of 25–45). Just as it is in the case of coniferous forests, there is a very wide variation of values within the class (the pixels characterizing all three main mechanisms of scattering).

Significantly lower values of the alpha parameter occur in areas covered by non-forest land communities. In vast majority they are the values characteristic for a single reflection from the surface, although there are also areas for which a large part of the pixels has a value characteristic for volume scattering. It seems that higher values of the Alpha parameter are observed in areas with higher vegetation, of higher biomass. Significantly lower values of the Alpha parameter can be observed in areas where swaths occurred.

For the images of entropy resulting from the H/A/Alpha decomposition the relationships observed are similar to those described for the Alpha parameter. Where there are higher values of the Alpha parameter, there are also generally higher values of entropy. Its scope can be in the range from 0 to 1. The highest values of entropy indicating almost complete depolarization of the microwave beam following the reflection of radiation from an object are observed in coniferous forests, while the lowest in the areas covered by non-forest land communities, especially those with the lowest biomass.

Images of the Shannon Entropy are shown in Figure 2c. A much greater diversity of parameter values depending on the type of land cover is characteristic of this parameter. By far, the Shannon Entropy takes the highest values for forests (deciduous, coniferous and mixed), whereas it is definitely the lowest for non-forest vegetation characterized by the lowest biomass. A much smaller diversity of values within individual classes, than in the case of the first two indicators, is also characteristic for the images of the Shannon Entropy. Similar values of the Shannon Entropy for all types of forests are the biggest difference compared to the first two indices, whereby in the images recorded in May and June, it is even higher for deciduous forests. The observation that the volatility of the values of this parameter during the growing season is very different for different types of vegetation is also very interesting. While for forest communities the value of Shannon Entropy decreases significantly between May and September, in the case of non-forest communities it clearly increases in most parts of the area.

For all three products of signal decomposition we can also observe a big difference in their values for the images recorded in the same period but in different years (pairs of images from 30 June 2009 and 3 July 2010, and 12 August 2008 and 15 August 2009). These differences probably arise from the different agro-meteorological conditions that occurred in respective years. In 2008, very favourable meteorological conditions occurred in the study area. The year 2009 was wetter and cooler than the previous one, while the year 2010 was by far the wettest and warmest of those considered. This resulted in differences in water regimes in different years and in the growth of plants.

Based on the available set of radar images one can also observe the different intensity of variability of individual polarimetric products of signal decomposition during the growing season. Considering, for example, only and exclusively the distribution of the values of the Alpha parameter and the Shannon Entropy for non-forest land communities in three images from 2009, it can be observed that in the case of the Shannon Entropy there is a very large increase in the value of this parameter between 30 June and 15 August, while in the next period, until 30 September, it remains almost constant. On the other hand, the Alpha parameter reaches its highest values in the image from 15 August, and then its value drops significantly, although not to such a low level as that on 30 June. This reflects the varying impact of individual environmental parameters (water regimes, soil, vegetation) on individual polarimetric products of signal decomposition. Thus, it can be concluded that they provide more possibilities of modelling them than the backscattering coefficient alone.

4.2. The impact of spatial resolution and speckle noise filtering on the results

The method of processing radar images, and especially their spatial resolution and the filtering process, have a very significant impact on the values of image parameters, as well as on their information content. This conclusion is obvious and it applies to all methods of radar image processing, both traditional ones based on the backscattering coefficient, as well as more advanced ones such as interferometry and radar polarimetry. Along with the progressive deterioration of spatial resolution of an image and the increasing of the filtering window, the variation of values within an image typically decreases (an increase in the minimum value, a decrease in the maximum one, and a decrease in standard deviation). This is a process which, although connected with the loss of a certain amount of information, is in many cases advantageous because it facilitates automatic image classification, and also often improves the possibility of quantitative modelling of biophysical parameters. An improvement in the correlation between the values measured in the field and the modelled values obtained from radar images, together with an increase in averaging their values in space or in time, has been suggested in several previous studies (e.g. Santoro et al., 2013). It is connected with the reduction of the noise present in an image as well as with the inaccuracy of the models used and the variability of biophysical parameters alone in space.

It should, however, be considered whether in each case such an action is advisable and really delivers desired results. In the opinion of the authors, in the case of analyses based on the polarimetric signal decomposition, such actions cause not only the averaging of values, but also change the meaning of the information obtained and can thus contribute to erroneous conclusions. This issue will be discussed on the example of the Alpha parameter, which is one of the parameters obtained during the H/A/Alpha decomposition. According to this model, areas with the value of the Alpha parameter in the range of 0–40 indicate a single signal reflection from the surface (e.g. relatively low and not very dense vegetation); 40–50 with typical volume scattering (dense foliage or crowns of trees), while the values in the range 50–90 are characteristic for multiple reflection (for example, in a forest – a reflection from tree trunks and heavy branches of trees). If in the immediate vicinity there are pixels that differ greatly between each other in the dominant scattering mechanism, and thus the value of the Alpha parameter (which is a typical situation for areas covered with dense vegetation), then averaging the values of this parameter in space completely changes the meaning of the information obtained. As a result, in an extreme situation and after their averaging objects characterised by a single reflection from the surface (low Alpha value), and multiple reflection (high Alpha values) occurring next to each other can provide completely false information on the volume scattering mechanism dominating in the area (average Alpha parameter values). This is very important even in the case of modelling forest biomass. If in a forest radar image recorded in the L-band there are pixels in which volume scattering dominates, it indicates a dominant reflection from the crowns of trees. In the case of a double bounce reflection we very likely deal with the reflection from trunks and thick branches. Since the parameters of crowns of trees and trunks are characterised by a completely different allometric relationship with biomass, therefore, disregarding these differences and using a single model of biomass for all pixels must lead to heavy errors that are characteristic of biomass models based on the backscattering coefficient. In connection with the above, it is clear that much better results of modelling are obtained in the case of increasing the sample surface area, reducing the spatial resolution of images, their filtering or averaging the information from multiple images in time. However, such actions lead to a reduction of the spatial resolution of the resulting information, or significantly multiply the amount of data selected for analysis. The second possible solution would be to use different models of biomass for individual pixel groups characterized by different dominant scattering mechanism.

Another aspect related to the influence of the spatial resolution and filtering of images on the possibilities of using polarimetry for modelling biophysical parameters of the environment is the mutual correlation of individual polarimetric products of signal decomposition with each other and with the backscattering coefficient. These correlations are certainly very different, however, in many cases, they depend directly on the spatial resolution of the resulting images and the method of filtering them. Figure 3 shows the relationship between the backscattering coefficient and the Shannon Entropy for an image from the ALOS satellite recorded on 12 May 2008. It is clear that the degree of correlation between both of these images increases very significantly with the decrease in spatial resolution and an increase in the degree of image filtering. This means that in the case of the spatial degradation of images in the process of multilooking and after speckle noise filtering, a vast majority of additional information contained in the Shannon Entropy image is lost relative to the backscattering coefficient. Thus, the use of these images as an additional source of information about the properties

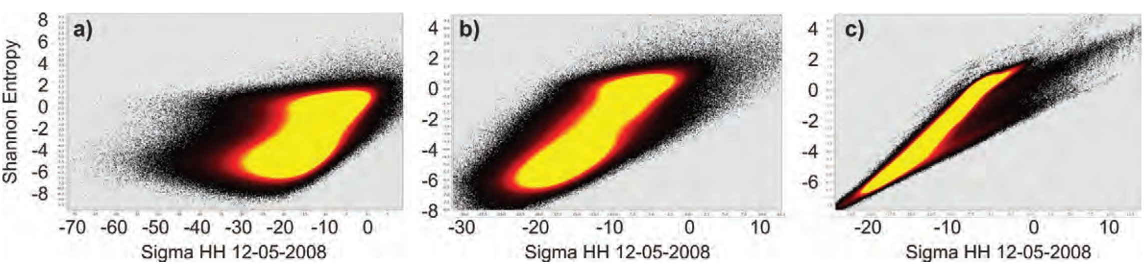

Fig. 3. The relationship between the backscattering coefficient and the Shannon Entropy for the image from the ALOS satellite (12-05-2008) with varying degrees of processing: a) an oversampled image – 3m ground resolution; b) an image after the multilooking process – 15 m ground resolution; c) an image after the multilooking process – 15 m ground resolution filtered using the boxcar filter in the 5×5 pixel window

of the imaged environment makes the most sense for images subjected to oversampling, and thus a process reverse in relation to that which is typically used.

4.3. The usefulness of polarimetric signatures for biophysical parameters retrieval

More detailed analyses of the relationship between the vegetation parameters obtained during field measurements and the polarimetric products of signal decomposition were carried out on the basis of the ALOS image recorded on 30-06-2009. Due to the lack of relevant data from field measurements for forest, all analyses were conducted in areas with marshy non-forest natural vegetation, which in this area consists mainly of reeds, sedges, moss-sedges and grasses. The analyses were conducted both in total for all types of vegetation as well as for each of them separately. Attempts to correlate the parameters obtained from field measurements confirmed the preliminary observations were made on all the images used in the analysis. Just as it is the case with the backscattering coefficient, the value of individual polarimetric products depends on a number of different environmental parameters at the same time. Thus, simple relationships practically do not exist and simultaneous modelling of multiple factors using multiple regression methods, which will be the subject of further research, is necessary in order to obtain satisfactory results. However, for low LAI values (range 0–3) a very high correlation with the image of the Shannon Entropy was observed (Fig. 4a), which was significantly higher than the corresponding correlation of LAI values with the backscattering coefficient, both for HH (Fig. 4b) and HV polarizations (Fig. 4c). The observed dependence is true for all types of marshy non-forest natural vegetation, regardless of its type. The values of field measurements shown in the above figure represent the LAI values obtained in the area of occurrence of sedge, moss-sedge and grass vegetation.

The second direction of the research was to determine whether the information about the polarimetric properties of individual scattering objects can be used to select those pixels that have a better correlation with the specified parameters of vegeta-

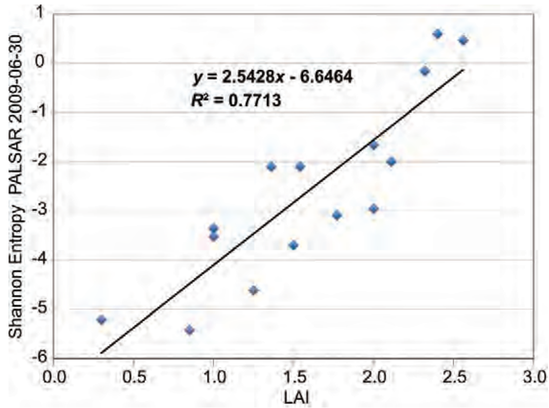

Fig. 4a. The correlation of the LAI (Leaf Area Index) index with the Shannon Entropy

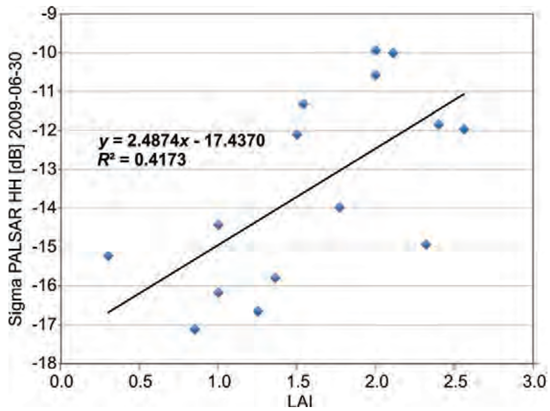

Fig. 4b. The correlation of the LAI (Leaf Area Index) index with the backscattering coefficient of an image in the HH polarization

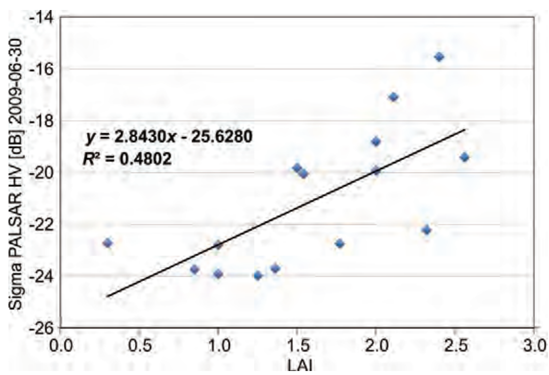

Fig. 4c. The correlation of the LAI (Leaf Area Index) index with the backscattering coefficient of an image in the HV polarization

tion than the entire population. The results of studies carried out for dry biomass using the Shannon Entropy will be presented as an example. Figure 5a shows a graph of the relationship between dry biomass and the backscattering coefficient in the HH polarization for all measurement points located in the area of occurrence of marshy non-forest natural vegetation. The distribution of these points is entirely coincidental. On the other hand, Figure 5b shows the relationship between the HV backscattering coefficient and the Shannon Entropy. Although both of these variables are not correlated with each other, it is clearly seen that some of the points are located along a predetermined straight line which has been marked in the figure. Only those and exclusively those points from the field measurements that are located within a certain distance from this straight line were selected for further analysis.

The correlation between the HH backscattering coefficient and dry biomass for points meeting the equation for the specific distance from the straight line is shown in Figure 6a and 6b. It is clearly seen that together with decreasing the distance of the points from the line the correlation between biomass and the backscattering coefficient increases. This means that only and exclusively for the pixels which are only part of the research area and meet the above equations regarding the distance from

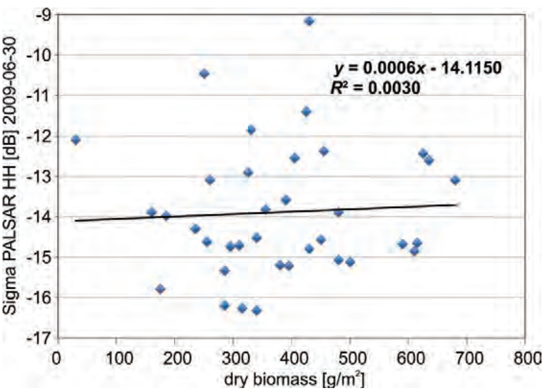

Fig. 5a. The relationship between dry biomass and the backscattering coefficient in the HH polarization for all measurement points located in the marshy area ‘with the occurrence of natural non-forest vegetation

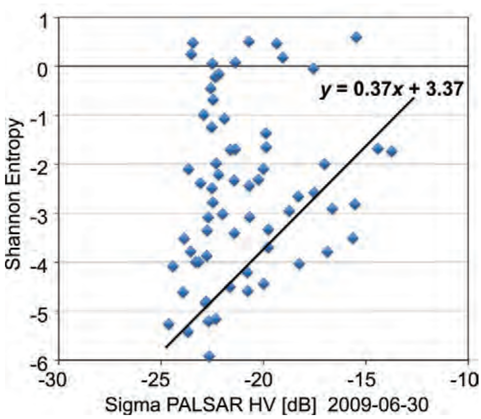

Fig. 5b. The relationship between the backscattering coefficient in the HV polarization and the Shannon Entropy

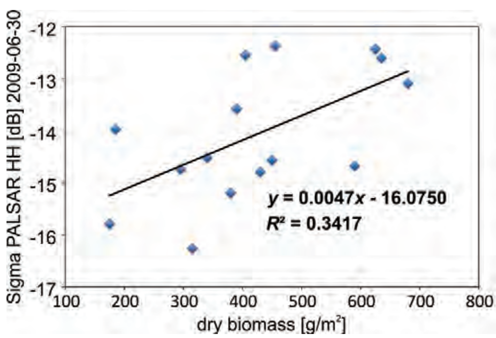

Fig. 6a. The correlation between the HH backscattering coefficient and dry biomass for the points satisfying the equation of a specified distance: d < 1.5 from the straight line

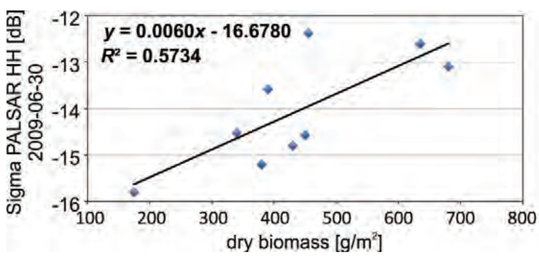

Fig. 6b. The correlation between the HH backscattering coefficient and dry biomass for the points satisfying the equation of a specified distance: d < 0.7 from the straight line

the marked line, it is possible to determine a simple relationship between the backscattering coefficient and biomass. For the remaining pixels characterized by a different relationship between backscattering and the Shannon Entropy, the relationships between the backscattering coefficient and biomass are different. With high probability, other parameters, such as soil moisture, have a greater influence on the backscattering coefficient. For the remainder of the population of pixels, therefore, one needs to develop more complex models, taking into account the simultaneous influence of various factors.

5. Conclusions

The presented preliminary results of the research indicate the usefulness of polarimetry for modelling biophysical parameters of vegetation. Individual products of polarimetric signal decompositions show high variability depending on the type of vegetation, the seasons and the current state of vegetation and water regime. They allow to obtain more information about the environment than the backscattering coefficient alone. The possibility to characterize pixels due to the mechanism of scattering the microwave radiation dominant in them appears to be the biggest advantage of polarimetry. Products of polarimetric signal decomposition such as, for example, the Shannon Entropy allow to select a specific subset of pixels characterized by stronger relationships between the backscattering coefficient and biomass than their entire population. If products of polarimetric signal decomposition are to be used for modelling the biophysical parameters of the environment, the pre-processing of images is essential. According to the authors, more reliable results can be obtained using the oversampling of original images in the SLC format, in the simultaneous absence of their filtration.

Acknowledgements

The authors expresses her gratitude to European Space Agency for providing ALOS images for the Projects: AOALO.3742 and C1P.7389. The authors are also grateful to the Director of the Biebrza National Park for providing necessary permission for carrying out the research work.

References

Balzter H., Rowland C.S., Saich P., (2007): *Forest canopy height and carbon estimation at Monks Wood National Nature Reserve, UK, using dual-wavelength SAR interferometry*, Remote Sensing Environment, Vol. 108, pp. 224–239.

Cloude S.R., (2010): *Polarisation. Applications in Remote Sensing*, Oxford University Press, p. 453.

Cloude S.R., Pottier E., (1996): *A review of target decomposition theorems in radar polarimetry*, IEEE Transactions on Geoscience and Remote Sensing, 34(2), pp. 498–518,

Dabrowska-Zielinska K., Budzynska M., Lavoie S., Hoscilo A., Bojanowski J., (2009): *Application of remote and in situ information to the management of wetlands in Poland*, Journal of Environmental Management, 90(2009), pp. 2261–2269.

Dabrowska-Zielinska K., Budzynska M., Kowalik W., Malek I., Gatkowska M., Bartold M., Turlej K., (2012): *Biophysical Parameters Assessed from Mircrowave and Optical Data*, International Journal of Electronics and Telecommunications, Vol. 58, No 2, pp. 99–104.

Dabrowska-Zielinska K., Budzynska M., Malek I., Tomaszewska M., Gatkowska M., Napiorkowska M., Ziolkowski D., (2013a): *Modeling of Vegetation parameters from microwave data*, 5th TerraSAR-X / 4th TanDEM-X Science Team Meeting, 10–14 June 2013, German Aerospace Center (DLR).

Dabrowska-Zielinska K, Budzynska M., Ziolkowski D., Gatkowska M., Tomaszewska M., Turlej K., Malek I., (2013b): *Performance of microwave data for assessment of Biomass, Soil Moisture and Carbon Balance for Wetlands*, ESA Living Planet Symposium, 9–13 September 2013, Edinburgh, UK.

Gruszczynska M., Dabrowska-Zielinska K., Malek I., (2007): *A Study of the Swamp Ecosystem of the Biebrza National Park Using Remote Sensing Methods*, Wszechnica Biebrzanska, Issue 3, meetings XX–XXIII, Osowiec – Twierdza, pp. 48–58.

Lee J.S., Pottier E., (2008): *Polarimetric radar imaging: from basics to applications*, Optical Science and Engineering Series, 143, CRC Press, p. 440.

Le Toan T., Beaudoin A., Riom J., Guyon D., (1992): *Relating forest biomass to SAR data*, IEEE Transactions on Geoscience and Remote Sensing, 30(2), pp. 403–411.

Lu D., (2006): *The potential and challenge of remote sensing-based biomass estimation*, International Journal of Remote Sensing, 27(7), pp. 1297–1328.

Geoinformation Issues
Vol. 5, No 1 (5), 29–41/2013

Matuszkiewicz A., Glowacka I., Jakubowski W., Kaminski J., Myslinski G., Sobczynski L., (1999): *A sampling of non-forest ecosystems protection, a diagnosis of the condition and an assessment of the natural values of the Biebrza National Park*, The Characteristics of the Vegetation of the Biebrza National Park, a typescript.

Santoro M., Shvidenko A., McCallum I., Askne J., Schmullius C., (2007): *Properties of ERS-1/2 coherence in the Siberian boreal forest and implications for stem volume retrieval,* Remote Sensing of Environment, Vol. 106, pp. 154–172.

Santoro M., Schmullius C., Pathe C., Schwilk J., Beer C., Thurner M., Fransson J., Shvidenko A., Schepaschenko D., McCallum I., Meaudoin A., Hall R., (2013): *Estimates of Forest Growing Stock Volume of the Northern Hemisphere from Envisat ASAR*, ESA's living planet symposium, 9–13 September 2013, Edinburgh, UK.

Thiel Ch., Thiel C.A., Schmullius C., (2009): *Operational Large Area Forest Monitoring in Siberia Using ALOS PALSAR Summer Intensities and Winter Coherence*, IEEE Transactions on Geoscience and Remote Sensing, 47(12), pp. 3993–4000.

Ziolkowski D., Bochenek Z., Hoscilo A., (2013a): *The relationship between backscattering coefficient and products of interferometric processing of TerraSAR-X stripmap images in forests of different type and age*s, 5th TerraSAR-X / 4th TanDEM-X Science Team Meeting, 10–14 June 2013, German Aerospace Center (DLR).

Ziolkowski D., Dabrowska-Zielinska K., Malek I., Tomaszewska M., Budzynska M., (2013b): *Soil and vegetation parameters derived from different Envisat and ALOS products – Single Look Complex and Precision Images*, ESA Living Planet Symposium, 9–13 September 2013, Edinburgh, UK.

www.biebrza.org.pl

Dwupolaryzacyjne charakterystyki roślinności na przykładzie obiektu badawczego Biebrza

Dariusz Ziółkowski
Instytut Geodezji i Kartografii, ul. Modzelewskiego 27, PL-02-679 Warszawa
Tel.: +48 22 3291991, Fax: +48 22 3291950, E-mail: dariusz.ziolkowski@igik.edu.pl

Iwona Małek
Instytut Geodezji i Kartografii, ul. Modzelewskiego 27, PL-02-679 Warszawa
Tel.: +48 22 3291992, Fax: +48 22 3291950, E-mail: iwona.malek@igik.edu.pl

Maria Budzyńska
Instytut Geodezji i Kartografii, ul. Modzelewskiego 27, PL-02-679 Warszawa
Tel.: +48 22 3291992, Fax: +48 22 3291950, E-mail: maria.budzynska@igik.edu.pl

Streszczenie Głównym celem badań prezentowanych w tym artykule jest analiza charakterystyk polarymetrycznych trzech głównych typów roślinności naturalnej występującej na terenie Biebrzańskiego Parku Narodowego – lasów, zakrzaczeń oraz porastających tereny podmokłe lądowych zbiorowisk nieleśnych. Przeanalizowano zmienność wartości wielu różnych produktów polarymetrycznych dekompozycji sygnału w zależności od rodzaju roślinności, terminu rejestracji obrazów mikrofalowych oraz sposobu ich wstępnego przetworzenia. Została podjęta również próba oceny, na ile metody polarymetryczne mogą być przydatne do celów modelowania parametrów biofizycznych roślinności. W badaniach wykorzystano sześć dwupolaryzacyjnych (HH i HV) obrazów z satelity ALOS zarejestrowanych w trakcie trwania sezonu wegetacyjnego w latach 2008, 2009 i 2010. Obrazy poddano wstępnemu przetworzeniu, wykorzystując do tego różne algorytmy i parametry, w celu oszacowania wpływu rozdzielczości przestrzennej oraz redukcji plamkowania na wartości sygnatur polarymetrycznych roślinności. Wykorzystano wszystkie algorytmy polarymetrycznych dekompozycji sygnału dostępnych w programie ESA POLSARPRO 4.2. Trzy z nich: Alpha i Entropia z dekompozycji H/A/Ralpha (Cloud and Pottier, 1996) oraz Entropia Shannona zostały wybrane do dalszych analiz.

Poszczególne lata, w których rejestrowane były obrazy radarowe, różniły się dość istotnie między sobą agrometeorologicznymi warunkami wzrostu roślin. Było to przyczyną znaczących różnic w wartościach charakterystyk polarymetrycznych na obrazach zarejestrowanych w tym samym terminie, ale w różnych latach. W trakcie trwania sezonu wegetacyjnego poszczególne produkty polarymetrycznej dekompozycji sygnału cechuje różna zmienność. Świadczy to o zależności poszczególnych charakterystyk polarymetrycznych od różnych parametrów biofizycznych środowiska. Zaobserwowano, że charakteryzują się one większą zawartością informacyjną, niż współczynnik wstecznego rozproszenia, zwłaszcza jeżeli zostaną poddane procesowi zwiększenia rozdzielczości (oversampling). Mogą zostać wykorzystane do modelowania biofizycznych parametrów roślinności.

Słowa kluczowe: polarymetria, Bagna Biebrzańskie, roślinność