Habitat mapping and monitoring in Alpine regions using multi-temporal RapidEye data

Anastasia Polychronaki[1], Nadine Spindler[1], Barbara Stoinschek[2], Alexander Schmidt, Marc Zebisch[1], Kathrin Renner[1], Claudia Notarnicola[1] and Ruth Sonnenschein[1]

[1]EURAC Research, Institute for Applied Remote Sensing, Viale Druso 1, 39100 Bolzano, Italy;anastasia.polychronaki@eurac.edu
[2]EURAC Research, Institute for Alpine Environment, Viale Druso 1, 39100 Bolzano, Italy;barbara.stoinschek@eurac.edu

Abstract. In this work we investigated the potential of multi-temporal RapidEye data to map and monitor habitats in Alpine regions. Support vector machine classifier was employed to map different land-cover types using four RapidEye images. Results showed that the classifier mapped the different types with high accuracy (85%). The land-cover types were subsequently reclassified into habitat types using a spatial kernel approach. Findings suggest that the inclusion of solar radiation layers in the classification procedure as well as the use of multi-temporal images improves the classification accuracy by 4% and 10%, respectively. The last step of our methodology involved the assessment of the conservation status of the habitat types. The assessment was based on the area coverage of shrubs and trees of specific habitats as an indicator for poor quality. Our analysis showed that 92% of the habitats were characterized by outstanding conservation status.

Keywords. Support vector machines, conservation status.

1. Introduction

Natural and semi-natural habitats in Alpine regions are experiencing a loss of biodiversity due to human activities, such as tourism, changes in agriculture, land-use change and infrastructure development. To protect such ecologically sensitive areas, the NATURA 2000 network was established under the Habitat Directive (92/43/EEC). NATURA 2000 obligates every EU member state to report on the quality status of habitats every six years, and to assess the status up-to-date maps of the distribution of the habitats are a prerequisite. Traditional methods used for habitat mapping involve time-consuming and labour-intensive field surveys. In contrast, Earth observation (EO) data cover wide areas with a high temporal frequency, and therefore can rapidly and cost-effectively provide the necessary information for mapping habitats

Remote sensing has shown to be a valuable tool for mapping habitats [1]-[5], but as yet, the potential of remote sensing has not been fully investigated for mapping habitats in Alpine regions. Therefore, the aim of this work was to map and monitor habitats in Alpine regions using satellite imagery. In particular, we investigated the potential of support vector machines (SVM) classifier to map habitat types and we assessed the conservation status of specific habitat based on shrub and tree encroachment. Furthermore, we investigated whether 1) the inclusion of solar radiation layers can compensate for radiometric distortions due to topographic effects, and 2) using multi-temporal satellite imagery can improve the classification accuracy of different land-cover types. Findings suggest that including the solar radiation layers as well as exploiting the temporal changes of specific types improves the overall classification accuracy.

2. Methods

2.1. Study area and datasets

The study area of Rieserferner-Ahrn Nature Park, which is part of the Natura 2000 network, was selected for this investigation. The Park, located in the Northeast of South Tyrol, covers an area of 313 km2 with elevation ranging from 890 to 3,480 m above mean sea level. Spruce forests are dominating the area while larch and Swiss pine mark the tree line (1,900 to 2,200m a.s.l.). Above the tree line the vegetation is composed of alpine meadows, pastures and natural grasslands. The park includes 18 different Natura 2000 habitat types out of 83 alpine habitat types which can be found in the whole European Alps.

The available EO data for this work included multi-temporal RapidEye Level 1B data acquired at four different dates (22-07-2009, 29-07-2009, 03-10-2009, and 31-07-2010). RapidEye 1B data offers five spectral bands, namely, Blue (440-510 nm), Green (520-590 nm), Red (630-685 nm), Red Edge (690-730 nm), and NIR (760-850 nm) at a spatial resolution of 6.5m. Auxiliary data included RGB orthophotos and a Digital Elevation Model (DEM) (2.5m). Four solar radiation layers, one for each RapidEye image, were generated from the available DEM. In addition, a very detailed thematic map of vegetation types produced from field work by experts was available for the test site Prettau. The test site is located on the northern part of the Nature Park and covers 13km2.

2.2. Habitat mapping methodology

Our methodology initially involved pre-processing of the images. All images were orthorectified using Toutin’s model, [6] and Ground Control Points (GCPs) that were manually selected from the orthophotos. The radiance values of the RapidEye images were then transformed in Top-of-Atmosphere reflectance values [7]. Next, a mask was created to exclude clouds and shadows from the classification procedure.

Considering that Natura 2000 habitats cannot be regarded as homogeneous patches of a single or few dominant species [5], we followed a two-level procedure to derive the final product: at level one (lower level) the multi-temporal RapidEye data were classified into land-cover types which were subsequently reclassified at level two (higher level) into habitat types. The classification scheme was defined using the unsupervised Iterative Self-Organising Data Analysis Technique (ISODATA) algorithm. The clusters were evaluated and labelled using the thematic map of the vegetation types and labels were assigned to each cluster. The final classification scheme included twelve land-cover types: water bodies, shrubs, mountain pines, natural grasslands, semi-natural grasslands, nutrient rich grasslands, wetlands, scree, pioneer vegetation, rocky slopes, forest and alder trees. The land-cover types were subsequently translated into habitat types to arrive at the second classification level which was defined based on experts’ knowledge and on different characteristics of each habitat, such as altitude and minimum area of coverage [8], [9] (Table 1).

Traditional image classification techniques such as ISODATA and Linear Discriminant Analysis (LDA) have been used in similar studies to create land-cover maps [10], [5]. In this work, we investigated the potential of the advanced SVM classifier [11], [12]. Following the definition of the classification scheme, samples were collected for training and validation purposes for each land-cover type. The SVM classifier was applied using the RapidEye images together with the solar radiation layers.

In addition, we tested whether: 1) the inclusion of solar radiation layers can improve the classification accuracy as a solution to compensate for the radiometric distortions caused by the topography, and 2) the use of multi-temporal images can improve the classification accuracy of complex habitats types.

Next, the reclassification of the land-cover types to habitat types [13] was carried out using the Spatial Reclassification Kernel (SPARK) approach of Thoonen et al. [14]. This procedure is based on a moving window (kernel) approach which centres one pixel at a time and then analyses its surrounding composition of land-cover types.

Table 1. Classification scheme. Table shows the land-cover types and their relevant habitats as well as additional characteristics used during the post-processing.

Land-cover type	Habitat type	Natura 2000 code	Elevation of habitat class	Minimum coverage area (m^2) of habitat class
Water bodies	Natural eutrophic lakes	3150	-	-
Shrubs Mountain pine	Alpine and boreal heaths	4060	from 1800m to 2400m	2500
Natural grasslands	Siliceous alpine and boreal grasslands	6150	from 1700m to 2800m	1000
Semi-natural grasslands	Species rich nardus grasslands	6230	from 300m to 2200m	100
Nutrient rich grasslands	Mountain hay meadows	6520	from 1000m to1900m	100
Wetlands	Transition mires and quaking bogs	7140	from 900m to 1300m	-
Scree Pioneer vegetation	Siliceous scree of the montane to snow levels	8110	above 800m	1000
Rocky slopes	Siliceous rocky slopes with Chasmophytic vegetation	8220	above 300m	1000
Forest	Acidophilous Picea forests of the montane to alpine levels	9410	from 600m to 1600m	5000
	Alpine Larix Decidua and /or Pinus Cembra forests	9420	from 1600m to 2200m	5000
Alder trees	-	-	-	-

In the final step of our methodology, we assessed the conservation status of the habitats. The assessment was carried out to monitor the quality of habitat patches to establish measures for protecting sensitive habitats. Until now there is no consistent indicator scheme for each habitat available. Thus we assessed the status following the approaches of the German working group of the federal states for nature protection ‘Deutsche Landerarbeitsgemeinschaft Naturschutz’ (LANA) [15] and the Austrian federal states [9]. Both approaches include a list of indicators and thresholds for each habitat to assess the quality and distinguish between three levels of conservation status, namely A: Outstanding conservation status, B: Good conservation status and C: Average to limited conservation status. A and B are favourable conditions, while C is an unfavourable condition which has to be avoided. From the available list, we calculated a remote sensing-based disturbance indicator: the percentage of shrub and tree coverage for the specific habitats. Calculations were based on the land-cover and habitat maps.

3. Results

The results of our analysis indicated that SVM classifier mapped the different land-cover types with high accuracy: 85% overall accuracy and 0.81 kappa coefficient. A significant ($p< 0.05$) increase of the overall accuracy was achieved when the solar radiation was added (85%) in the classification procedure compared to only using the multi-temporal RapidEye data (81%). Results of the analysis showed that the accuracy of grasslands increased significantly ($p< 0.05$) (in some cases by 20%) due to the exploitation of the phenological changes which were represented in the spectral variability. The final habitat map was presented to an expert to assess its quality given the lack of reliable information to quantitatively assess the accuracy of the map. It was concluded that the habitat borders were represented in a satisfactory way [13] (Figure 1).

In addition, results from assessing the conservation status of the habitats revealed that 92% of the area under investigation is characterized by outstanding conservation status in terms of tree and shrub encroachment (Figure 1).

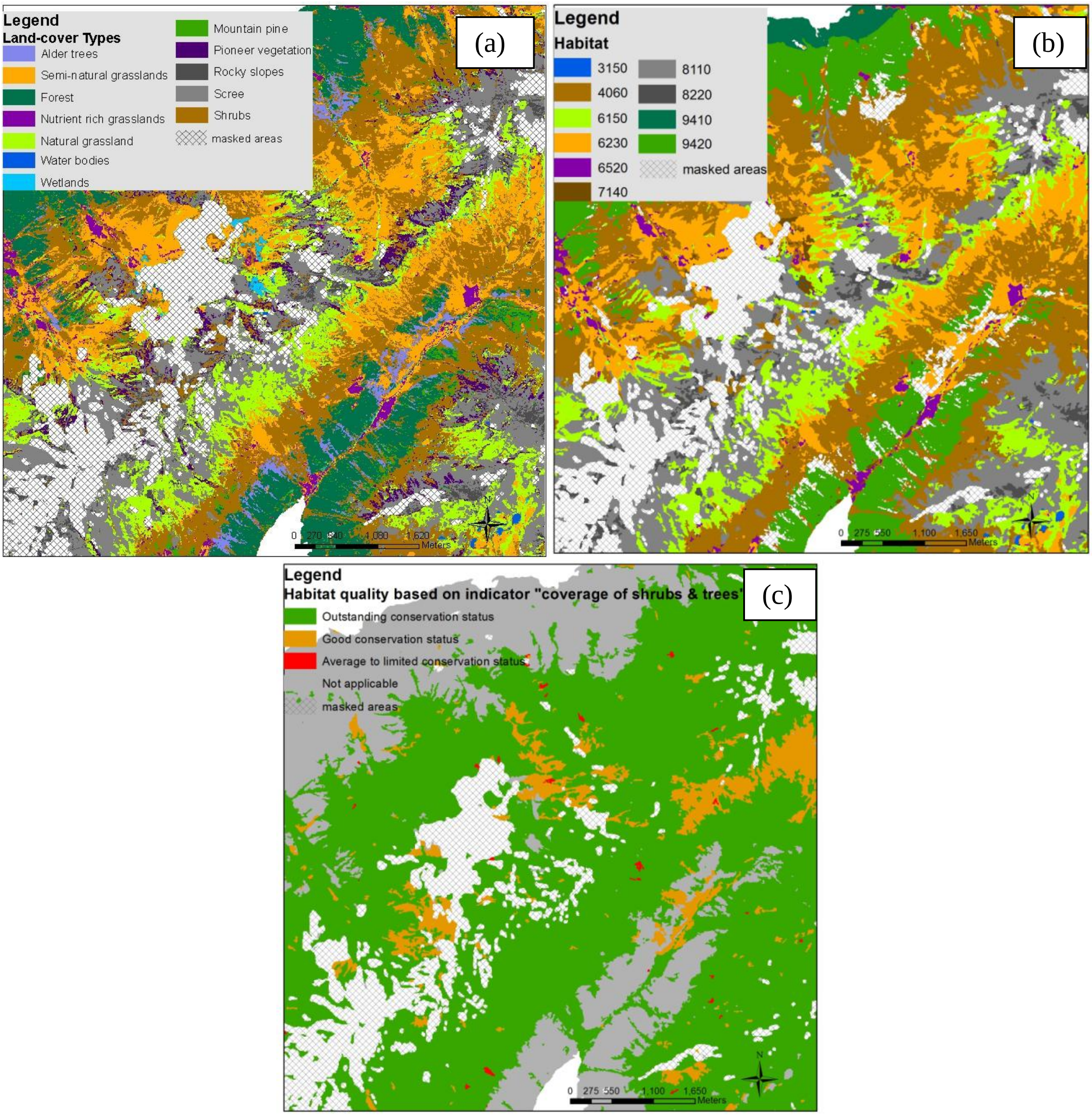

Figure 1. Classification result of land-cover types (a) and habitat types (b). The conservation status was assessed using the disturbance indicator area coverage of shrubs and trees (c). All maps in this figure show a subset of the study area.

4. Conclusions

In this work, we developed an indirect classification method to map habitats in Alpine regions using multi-temporal RapidEye images. In particular, the satellite images were initially classified to land-cover types using SVM classifier. In a subsequent step, the land-cover types were reclassified to habitat types using a spatial kernel approach. Findings from this work revealed that the inclusion of solar radiation layers in the classification significantly improved the accuracy of the different land-cover types (85% and 81% overall accuracy with and without using the solar radiation layers, respectively). Thus, it could be suggested that the use of solar radiation layers can overcome classification difficulties related to radiometric distortions due to topographic effects. Furthermore, the use of multi-temporal images improved the overall classification compared to using mono-temporal data (from 75% to 85%) as well as the classification accuracy of different grasslands types by exploiting their temporal changes. Also, we calculated the shrub and tree encroachment disturbance indicator for each habitat patch and we found that the nature park is dominated by habitats with outstanding conservation status.

Overall, the proposed method could be considered for application on an operational basis for mapping and monitoring habitats in Alpine regions given the easy access and relative low cost of the RapidEye imagery. Future work includes investigating whether advanced methods for topographic correction of the RapidEye images could further improve the classification accuracy.

References

[1] Bock, M., Xofis, P., Mitchley, J., Rossner, G. & Wissen, M., 2005. *Object-oriented methods for habitat mapping at multiple scales-Case Studies from Northern Germany and Wye Downs, UK*. Journal for Nature Conservation, 13 (2-3), 75-89.

[2] Keramitsoglou, I., Sarimveis, H., Kiranoudis, C. T., Kontoes, C., Sifakis, N. & Fitoka, E., 2006. *The performance of pixel window algorithms in the classification of habitats using VHSR imagery*. ISPRS Journal of Photogrammetry and Remote Sensing, 60 (4), 225–238

[3] Hufkens, K., Thoonen, G., Vanden Borre, J., Scheunders, P. & Ceulemans, R., 2010. *Habitat reporting of a heathland site: Classification probabilities as additional information, a case study*. Ecological Informatics, 5 (4), 248–255.

[4] Hernado, A., Arroyo, L., Velazquez, J. & Tejera, R., 2012. *Objects-based image analysis for mapping Natura 2000 habitats to improve forest management*. Photogrammetric engineering and remote sensing, 78 (9), 991-999.

[5] Thoonen, G., Spanhove, T., Vanden Borre, J. & Scheunders, P., 2013. *Classification of heathland vegetation in a hierarchical contextual framework*. International Journal of Remote Sensing, 34 (1), 96-111.

[6] Toutin, T., 2003. *Error Tracking in IKONOS Geometric Processing Using a 3D Parametric Model*. Photogrammetric Engineering & Remote Sensing, 69 (1), 43-51.

[7] RapidEye Image Product Frequently Asked Questions (FAQs) 2010. v.1.0, RapidEye AG

[8] Lasen, C. & Wilhalm, T., 2004. Natura 2000 - Lebensräume in Südtirol. (Autonome Provinz Bozen-Südtirol Abteilung Natur und Landschaft, Hrsg.). Bolzano: Autonome Provinz Bozen-Südtirol.

[9] Ellmauer, T., (HRSG.) 2005. Lebensraumtypen des Anhangs I der Fauna-Flora-Habitat-Richtlinie. Entwicklung von Kriterien, Indikatoren und Schwellenwerten zur Beurteilung des Erhaltungszustandes der Natura 2000-Schutzgüter (Bd. 1-IV, Bd. III). Wien: Im Auftrag der neun österreichischen Bundesländer, des Bundesministerium f. Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft und der Umweltbundesamt GmbH.

[10] Keramitsoglou, I., Kontoes, C., Sifakis, N., Mitchley, J. & Xofis, P., 2005. *Kernel based re-classification of Earth observation data for fine scale habitat mapping*. Journal for Nature Conservation, 13 (2-3), 91–99.

[11] Pal, M. & Mather, P.M, 2005. *Support vector machines for classification in remote sensing*. International Journal of Remote Sensing, 26 (5), 1007-1011.

[12] Mountrakis, G, Im, J., & Ogole, C., 2011. *Support vector machines in remote sensing: A review*. ISPRS Journal of Photogrammetry and Remote Sensing, 66 (3), 247–259.

[13] Schmidt, A., 2012. Conversion of a remote sensed vegetation classification to a habitat map: Comparing spatial kernel and object-based approaches (Master Thesis). Faculty of Geography of the Philipps-Universität Marburg, Marburg/Lahn.

[14] Thoonen, G., Spanhove, T., Haest, B., Vanden Borre, J. & Scheunders, P., 2010. *Habitat mapping and quality assessment of heathlands using a modified kernel-based reclassification technique*. IGARSS (S. 2707–2710). IEEE International Geoscience & Remote Sensing Symposium, Honolulu, USA: IEEE.

[15] BFN, 2010. *Bewertung Des Erhaltungszustandes Der Lebensraumtypen Nach Anhang I Der Fauna-Flora-Habitat Richtlinie in Deutschland*. Bundesamt für Naturschutz, Germany.