GRASSLAND INTENSITY IN THE POLISH AND SLOVAKIAN CARPATHIANS - A METHODOLOGICAL CLASSIFICATION APPROACH

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ABSTRACT

Grassland ecosystems in Europe are often areas of high biodiversity, especially in mountainous regions. Their natural value and vulnerability strongly depend on their degree of use intensity. It is therefore important to develop methods to assess grassland use intensity for large areas in an affordable way. To do so, the border region between Poland and Slovakia in the Carpathians is very functional presenting vast areas of variously used grassland due to differing agricultural policy before and after the fall of the Iron Curtain. The aim of this study is to assess these differences in terms of grassland intensity and to develop a classification method using field and remote sensing approaches. First, we differentiated random sample points at grassland in both countries in one of five intensity use classes using indicator species. Second, we used those samples as ground truth data to link them with spectral information from remote sensed data and test for spectral discrimination. Comparison of the field data shows a higher amount of abandoned grassland in Poland than in Slovakia. Besides, no other differences between the two countries were detected. The classes *intensive meadow* and *grassland abandonment* could be separated through their spectral features with a Jeffries-Matusita distance of 1.86. On the whole, equally statistical tests on spectral separability revealed that intensities are highly similar in their spectral signatures. The spectral and field assessed similarity in terms of use intensity between the two countries is surprising given the fact that Slovakian agriculture policy resulted in increasing use intensity while in Poland land use was kept at a small-scale level.

Key words: Land use change, grassland intensity, Carpathians, land reform, indicator species, spectral separability

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1. INTRODUCTION

"Human driven changes in the terrestrial surface of the earth hold wide-ranging significance for the structure and function of ecosystems in the earth's surface […]" (Turner et al.2007). The importance and characteristics of global environmental change are nowadays prominent in environmental research (MEA 2005, IPCC 2007), since people realized how severe the effects of land-cover and land-use changes on ecosystems are. As a consequence, land change science has emerged as a fundamental component in sustainability research (Turner et al.2007). But not only sharp changes in land use (e.g. from forest to agriculture or vice versa) are affecting ecosystem structures and functions, also different intensities of use have to be considered. Yet observation and monitoring of different land-use intensities is deficient compared to the investigation of land-use change, but is assumed to be of the same importance (Franke et al. 2012). The same is true for grasslands that are often put in second place in terms of their importance for and threats due to human-driven changes.

As "goldmines of plants used for food" (White et al. 2000), grasslands are a major provider of ecosystem services for humanity. Defined as "areas dominated by grassy vegetation and maintained by fire, grazing, and drought or freezing temperatures" (White et al. 2000), grasslands facilitate food, genetic-material, fresh-water as well as regulation services, such as the stabilization of slopes and the regulation of water runoff, air and water quality.

Grassland that is mainly used as meadow or pasture is sensitive to its management. The intensification of grassland-use or the abandonment of grassland can provoke severe consequences for the environment, including degradation of natural resources (e.g. biomass, soil, water), loss of biodiversity, and limitation of ecosystem services (e.g. carbon sequestration) (Sullivan et al. 2010). In order to adjust conservation schemes for grasslands, the spatial evaluation of agricultural land use intensity is of great importance.

One third of the Carpathians is covered by open and semi-natural habitats, predominantly grassland. Over the years, traditional and extensive farming practices on meadows and pastures have shaped a unique pattern of habitats. Especially meadows are of great species richness and enhance local species diversity. In the past, the Carpathian grasslands were cut twice a year in combination with occasional grazing. However, since the reduction on agricultural subsidies, increasing economic costs and a transfer to a market economy, less productive or barely accessible grasslands are increasingly being abandoned (Baur et al. 2006). “Recently, most of these meadows remain unknown and they are seriously endangered by succession and afforestation” (Seffer et al. 2010). As a result, the open landscapes are disappearing, a phenomenon which is particularly visible in the Western Carpathians (WWF 2001). These drastic changes in land-use and intensity are the result of the great socio-economic shifts occurring right after the breakdown of the USSR. As a consequence of the economic transformation to a liberalized market, the management of grassland also changed due to new ownership structures. However, this transformation did not proceed in the same way in all countries within the borders of the former USSR, but resulted in political and socioeconomic differences on local and regional levels. Therefore, the Carpathian Ecoregion is very suitable for a cross-border comparison, particularly as the region is environmentally relatively homogeneous (Seffer et al. 2010, Kümmerle et al. 2006). As mentioned before, Poland and Slovakia have experienced political differences, for instance in restitution. Since “Poland does not have a [formal] restitution law” large-scale privatisation of arable land has not occurred as in most of its neighbouring states (Csáki et al. 1999). In contrast, Slovakia implemented an own restitution act in 1991, right after independence, which allowed refugees and displaced persons large-scale compensation via once confiscated lands (Leckie 2007). Today, the effects are possibly still existent in management strategies and should therefore be observable when comparing both countries in the study region.

The aim of this study is to assess the spatial patterns of grassland intensities under the conditions of different political and socio-economic developments in the Polish and Slovakian Carpathians and to answer the following research questions:

What are the differences in grassland - in terms of management intensity - between Poland and Slovakia (i, ii), and can these differences be derived and mapped from spectral imagery (iii)?

Our specific objectives within this framework are:

(i) To assess grassland intensities in the field from indicator species

(ii) To compare grassland intensity in Poland and Slovakia

(iii) To test the spectral discrimination of grassland intensities in multi-spectral imagery

2. Study Area

The study area is located in the border region between Poland and Slovakia in the northern foothills of the Carpathians with an extent of 3525km² (cf. Fig. 1).As the area is characterized by hilly terrain, the altitude varies between 100–600m. The dominating bedrock is flysh, a composition of sedimentary rocks comprising sandstones, conglomerates, marls, shales and clays which were formed during the period of mountain building (Pelzer 1991). Like the Alps the Carpathians were formed during the Alpine orogenesis in the late Mesozoic and early Cenozoic before 98 to 36 Mio years (Green Ukraine 2012). The main soil types are brown earth, slope soil, and plastic soil. With an average yearly temperature of 7.6°C and a yearly accumulated precipitation of 810 mm the climate is moderately cool and humid (Pelzer 1991).

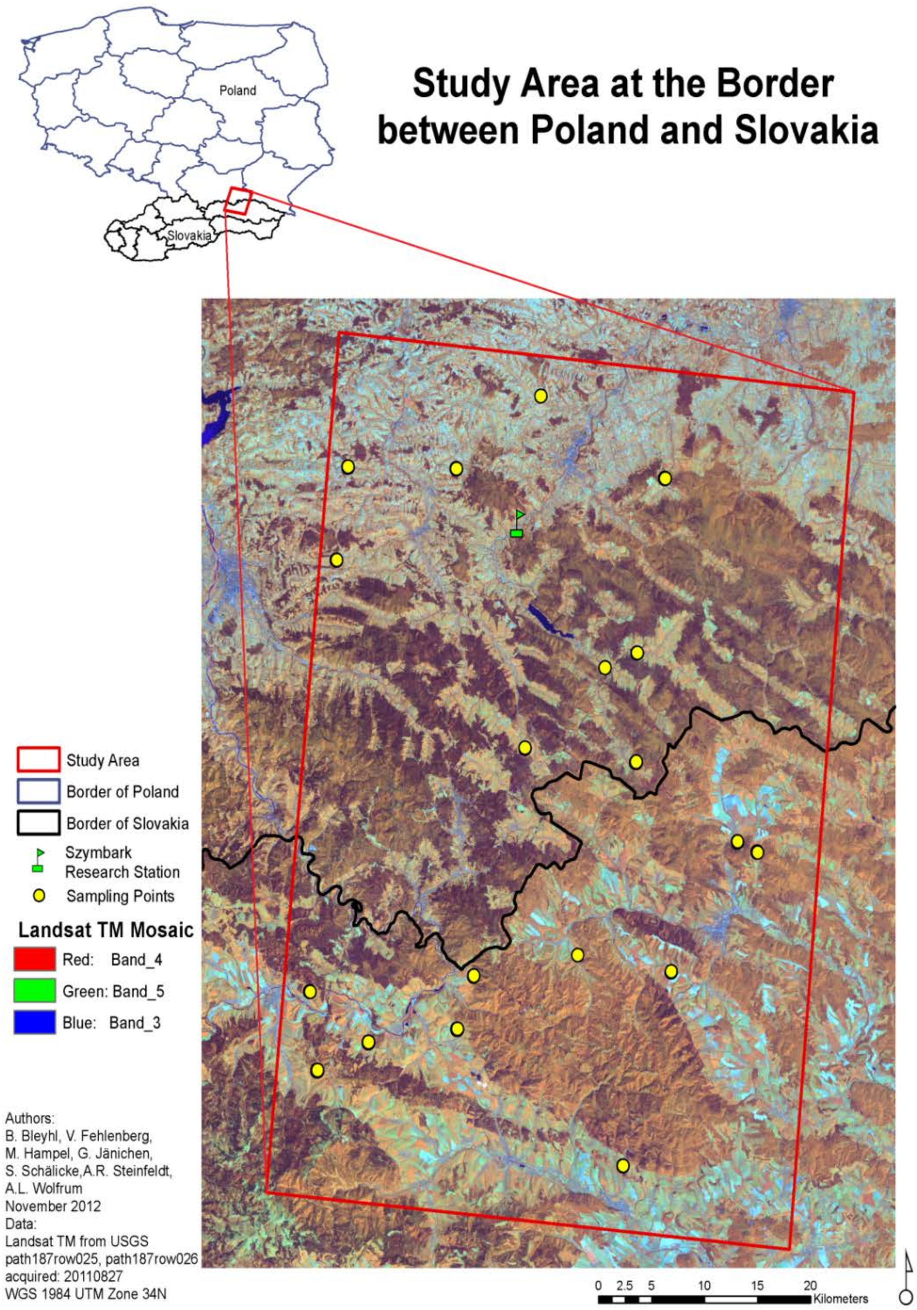

Fig. 1: General map of the study area in the Carpathian Mountain Range and sampling points for field approach.

The potential natural vegetation in our study region is dominated by forests and open habitats. The forests of the territory mostly contain fir and beech as well as oak mix forests (Pelzer 1991). The open habitats show a massive diversity, although they cover a considerably smaller area than the forests. They include 1. calcareous grasslands which contain *montane mesophilous meadows* of the alliance *Polygogno bistortae – Trisetion flavescentis*, which mainly occur as small islands, 2. fens maintained by traditional farming methods and 3. the valuable rare 'poloniny' meadows which nowadays just remain in protected areas (DBU 2010). Above the tree line in the sub-alpine and alpine areas natural open habitats are very limited they contain a high number of endemic species (WWF 2001).
The grasslands in the Carpathians were mainly found by human activity, where grazing cattle have destroyed the dwarf pine vegetation and the forests (WWF 2001).

3. DATA AND METHODS

Our method was divided into two different approaches using different sets as of indicators for grassland intensity: The in situ approach was applied to sample ground truth data in the study area during a field trip for a comparison of the grassland intensity situation. This includes a qualitative description of the status quo from the species composition and further indicators that can be seen in the field and a descriptive statistical analysis to check if differences can be quantified from recorded data.
The second approach using remotely sensed data examined the possibility to spectrally discriminate between different intensities of grassland-use on multi-spectral imagery. The data collected during the field trip, was applied as ground truth data to link the spectral information with the grassland intensity classes defined in the field.

3.1 DATA AND METHODS FOR THE FIELD APPROACH

Differentiation between management intensity in mowing and grazing was assessed from indicator species respectively species composition (Ellenberg 2010, Aichele 2010) and other indicators such as input of machinery, occurrence of cattle, cow dung, and fences. The following five classes of intensity can be derived from these indicators (cf. Fig. 2):

- *Intensively used pastures* (1.1) were identified by "Geilstellen" (patches of tall dark-green grasses growing on last year's feces) and a high concentration of species with a high grazing tolerance, namely *Poa trivialis*, *Ranunculus acris/ repens* and *Urtica dioica*. The latter also indicates high nitrogen concentrations and therefore stands for urine deposits (Dierschke & Briemle 2002).
- *Extensively used pastures* (1.2) were indicated by a preponderance of species with a lower grazing tolerance, namely *Dactylis glomerata*, *Dactylorhiza maculata* and *Bromus inermis* mixed with species with a middle high grazing tolerance, such as *Cynosurus cristatus* (Dierschke & Briemle 2002).
- Indicators for *intensively used meadows* (2.1) were a great abundance of *Alopecurus pratensis,* which has a relatively high mowing tolerance and is a very valuable forage plant (Dierschke & Briemle 2002). Other indicator species were *Lathyrus pratensis* and *Trifolium repens/ pratense,* which are able to fix atmospheric nitrogen, *Taraxacum spec.,* which indicates fertilization and *Ranunculus acris/ repens.* An additional indicator was lane grooves.

- *Extensively used meadows* (2.2) were characterized by species with a low mowing tolerance like *Mentha longifolia*, *Galium aparine* and *Nardus stricta* as well as a variety of species with a middle mowing tolerance like *Holcus lanatus*, *Vicia cracca* and *Galium saxatile* (Dierschke & Briemle 2002). Sporadic bushes also stood for extensive usage.
- Young woody plants in a higher concentration (10-60%, not dominant) indicated *grassland abandonment* in an early succession stage (3). This class was included because other studies (e.g. Kümmerle et al. 2008) indicated that the use of some of the grassland areas ceased in the last decade and we expected to find many sites which were still grassland but out of use.

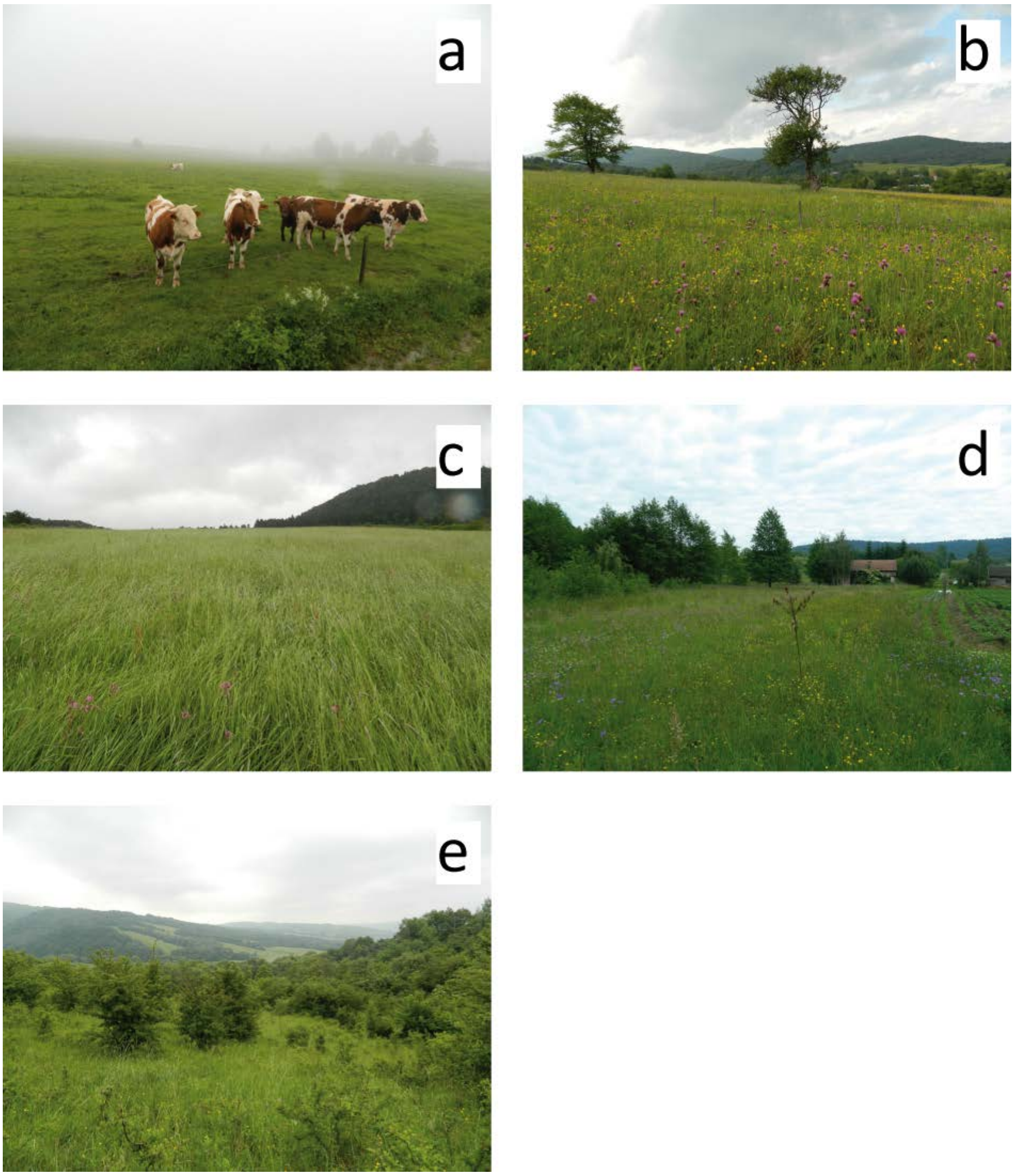

Fig. 2: Examples for grassland classes gathered in the field: a: intensively used pasture (1.1); b: extensively used pastures (1.2); c: intensively used meadows (2.1); d: extensively used meadows (2.2); e: grassland abandonment (3). Own photographies.

For sampling ground truth data, we used a clustered random sampling design consisting of 20 plots, 11 in Slovakia and 9 in Poland using a geographic information system (ArcGIS 10 and Geospatial Modelling Environment). Every plot of 90m² contained nine points distributed consistently in a 30m distance to each other so that 9 Landsat pixels were covered in one cluster. The central point was randomly chosen via GIS and the 8 surrounding points calculated in 30m distance to north, east, south, and west. To assure the sample points being located only at grassland, we used the CORINE land cover classification from 2006 (CORINE land cover 1994) by masking and merging the three land cover classes "pasture", "natural grassland" and "Land principally occupied by agriculture with significant areas of natural vegetation" later referred to as *CORINE grassland mask*. For ensuring the accessibility of the plots in the field, roads (Open Street Map layer) were buffered in a range of 500 m. Finally the random points were generated in the overlapping areas of masked classes and buffer (cf. Fig. 3).

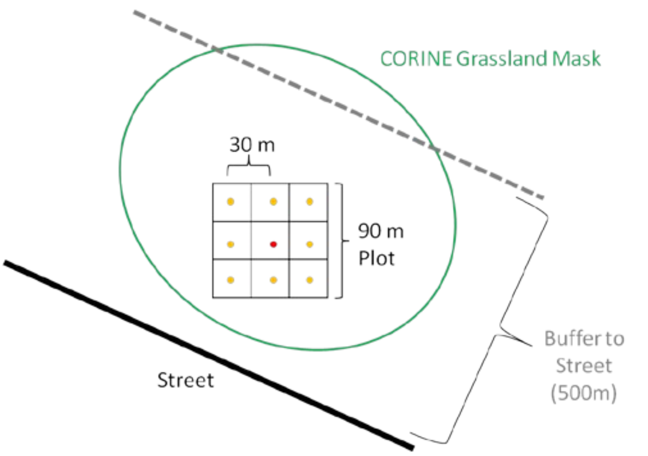

Fig. 3: Clustered random sampling design for one plot. Red point = randomly selected central point (within *CORINE grassland mask* and 500m buffer to a street). Yellow points: Calculated neighbours (30 m distance from red point).

To detect the points in the field we used the Global Positioning System (GPS-receiver: Garmin E-Trex Venture HC) with an accuracy of ±6m. Samples with dominance of woody plants or on non-agricultural area (parks, gardens) were omitted. We assigned all the other points to one of the five classes. Therefore we checked the criterions and indicators described above in a field of view of 10m diameter around the point. The set of 180 sample points that was recorded during the field trip was then corrected for misclassified and inaccessible points. The total number of samples for the analysis resulted in 113 (49 in Poland and 64 in Slovakia).

3.2 Data and Methods for the Remote Sensing Approach

3.2.1 Remote Sensing Data

Multi-spectral imagery was provided by the United States Geological Survey (USGS). Two footprints of the Landsat 5 satellite with the Thematic Mapper sensor onboard were downloaded since the study area is located in the overlap region (cf. Fig. 1). The footprints, p187r025 and p187r026 (pathXXXrowXXX tiles from World Reference System WRS), were available on Standard Terrain Correction T1-level providing radiometric, geometric, and topographic accuracy. Thus misclassification due to radiometric or spatial displacements was avoided due to a high signal-to-noise ratio and geometric accuracy provided by USGS pre-processing (Lillesand & Kiefer 2000). Furthermore the acquisition date was chosen to be close in time to our field work time frame in June with lowest possible cloud contamination of 0% (cf. Tab. 1). Since both footprints are acquired on the 27th August of 2011 they represent green-peak vegetation for the study region with a high phenological stability by avoiding leaf-out in spring or leaf coloration in autumn (Lillesand & Kiefer 2000).

TAB 1: List of Landsat imagery with acquistion date used for assessing grassland intensity (pathXXXrowXXX tiles from WRS).

pathXXX rowXXX (WRS)	Acquisition date (yearmonthday)	Cloud contamination	Sensor	Number of used bands	Pixel size	Level
path187row025	20110827	0 %	TM	6	30m	L1T
path187row026	20110827	0 %	TM	6	30m	L1T

3.2.2 METHODS FOR THE REMOTE-SENSING APPROACH

Since imagery was available on T1-level without any cloud contamination, further pre-processing required none as stacking bands 1-5 and 7 (excluding the thermal infrared band 6), mosaicking both footprints, and sub-setting the mosaic accordingly to the chosen study area. Mosaicking was facile since imagery was acquired the same day and changes in reflection (e.g. due to solar angles, satellite trajectory etc.) were negligible (cf. Fig. 4).
To test the spectral discrimination of the classes assessed in the field (cf. Objective iii in chapter 1) two approaches were used:
At first the calibrated digital numbers (DNs) of the 6-band mosaic were extracted for the sampling points from the field in a Geographic Information System (ArcGIS 10). The resulting values were explored using a statistical software package (IBM SPSS Statistics) giving statistical parameters for a descriptive statistical analysis (cf. Annex 1). Since every sample point was used to extract the DNs of the 6-band mosaic stack, the distribution of DNs per band for every classified sample point was available (cf. 4.1).
In a second approach, a digital image processing software (ENVI 5.0) was used to compute the separability at all sampling points. The separability is expressed as the statistical distance between the distributions of spectral classes. This required an unsupervised classification (ISODATA) that categorizes the spectral information of the mosaic into clusters. The ISODATA algorithm (Iterative Self-Organizing Data Analysis) classifies images via spectral pattern recognition (ENVI 5.0). The spectral pattern recoginition method manipulates pixel-by-pixel the spectral information to mutually exclusively assign classes to spectral clusters. Therefore the class means of spectral information are calculated and the remaining pixels are clustered around the means using minimum distance techniques. In the next iteration new class means are calculated and pixels are reclassified by merging or splitting former clusters. The iteration proceeds until less pixels change class than a certain threshold or a maximum number of iterations is achieved (Tou & Gonzalez 1994). The algorithm was set to stop classifying if a pixel change threshold of 5 will be obtained or if 10 iterations will be executed. Following the Jeffries-Matusita Distance (J-M Distance) was calculated, which is a measure looking not only at differences between the class-means but also at the values around the mean by using the covariance matrix of the signature additionally to mean vectors (Lillesand & Kiefer 2000, Canty 2010). It is defined as:

$$J_{ij} = \int_x \left\{ \sqrt{p(x \mid \omega_i)} - \sqrt{p(x \mid \omega_j)} \right\}^2 dx$$

where J_{ij} is the J-M Distance of the spectral classes ω_i and ω_j that are being compared and $p(x \mid \omega_i)$ and $p(x \mid \omega_j)$ are the values of the ith and jth spectral class probability distributions

at the position x, i.e. the likelihood that the correct class is ω_i or ω_j for a pixel at position x (Richards & Jia 2006).
Since the focus is put on grasslands, the output of the unsupervised classification was masked using the *CORINE grassland mask* again. Visual interpretation and descriptive statistics were used to check whether spectral clusters can be differentiated within the *CORINE grassland mask* and if those spectral classes can be exclusively assigned to the intensity classes recorded in the field.

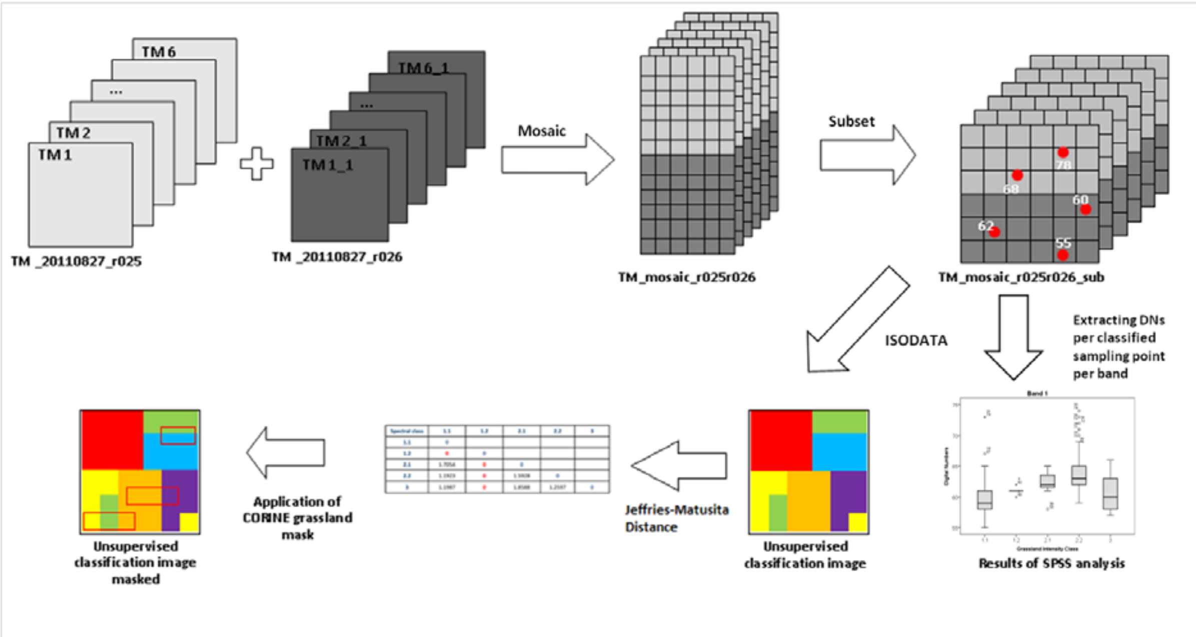

Fig. 4: Flowchart depicting applied methods used for the remote sensing approach.

4. Results and Discussion

4.1 Results and Discussion for the field Approach

Nine of the 99 sample points in Slovakia were pastures and they were all extensively used. In Poland we had 26 pastures and 76.9% of them were extensively and 23.1% were intensively used (Fig. 5). The facts that the total number of pastures in Slovakia is that low and that all of them are located in one area unfortunately inhibit further conclusions.
We did not find any differences in the degree of intensity for meadows between the two countries. The relative amount of intensively used meadows (36% in both countries) and extensively used meadows (64% in both countries) is the same although we expected to see a higher proportion of intensively used grassland in Slovakia than in Poland because Slovakia had – like most other socialist states under the Soviet model of agriculture – very large farms, even larger than the average in land-rich market economies like the USA or Canada (Lerman et al. 2004). Poland was an exception to this model since large scale collective farms never have been the same issue as in Slovakia. Poland's agriculture was characterized by small individual farms and only 20% of land had been collectivized while in former Czechoslovakia the proportion was with 91% collectivized land much higher (Csaki et al. 1994). Those large farms still play a prominent role in Slovakia (Lerman et al. 2004) and we expected our data to evince that too.

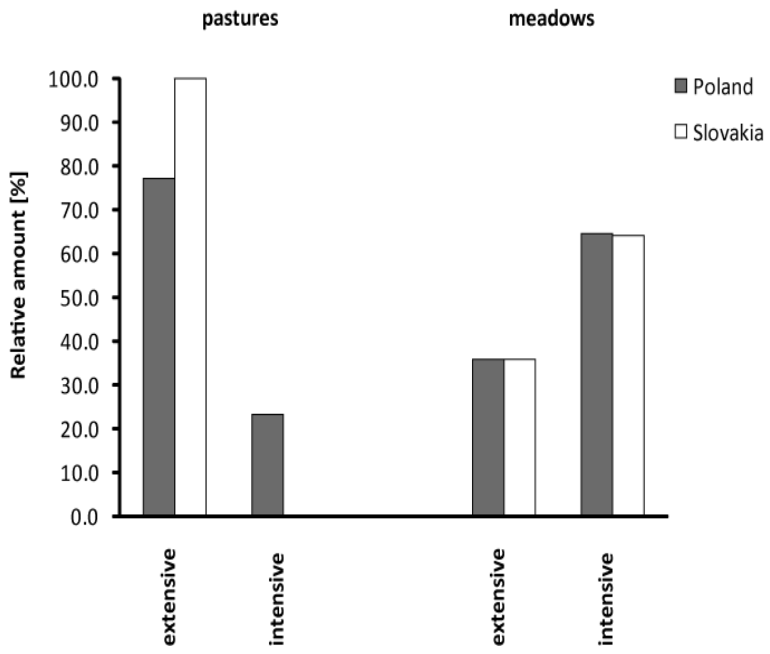

Fig. 5: Relative amount of extensively and intensively used grassland (pastures and meadows in Poland and Slovakia).

An aftereffect of this situation can be seen for the class *grassland abandonment*: 18.4% of the sample points in Poland and 7.8% in Slovakia were abandoned grassland showing signs of succession. The higher amount of these areas in Poland can be explained by the fact the country has and had a larger amount of small and individually used grasslands often providing goods for only one household (subsistence agriculture) (Lerman et al. 2004). This way of farming is more and more changing - as it already happened in many other European regions especially in mountainous areas (Meeus 1993, Tappeiner et al. 2008). Technological progress together with market intensification and specialization in agriculture has led to the abandonment of areas that are difficult to reach or to cultivate because they are no longer profitable and succession is changing them rapidly (Baldock et al. 1996, McDonald at al. 2000). As in Slovakia individually small scale farming was not applied, those marginal lands were out of use for more than 50 years and therefore do not show signs of former land use anymore. Nevertheless, Kümmerle et al. (2008) detected a higher proportion of abandoned farmland for Slovakia than for Poland. The differing results are probably a consequence of different definitions of abandoned farm- or grassland. Our method only included grassland from CORINE which does not comprise other farmland and reforested land. A large part of abandoned farmland in the study of Kümmerle et al. (2008) consisted of large patches of fallow land in the southern plains, probably of cropland.

In Poland we found 14 meadows (28.5% of sample points in Poland) and 50 in Slovakia (78.1% of sample points in Slovakia). This great disparity cannot be found elsewhere in the literature and is probably smoothed by a bigger sample size in a future study.

Comparing the other classes between Poland and Slovakia we can not see the consequences of different agricultural models for recent land use through our data. This can partly be explained by the small number of sample points we were able to use. A high number of them (37%) was located in land that was misclassified by CORINE or not accessible for us. However, it was very difficult to identify different states of intensity using merely indicator species since they could have been missed when not apparent due to grazing or mowing. Conducting a full vegetation survey and determining the plant communities can cope with this problem since every plant would have been classified – also grazed and mown ones. Another problem we discovered was that our conception of "intensive" land use evolved outside mountain regions in Germany where the degree of intensity is higher than in the Carpathians. We did not find any intensively used grassland patch among our sample points that was shaped by only one or two dominant species. In general, transition between the two concepts of "intensive" and "extensive" is very fuzzy. Consequently we involved patches into "intensive grassland" that showed the highest degree of usage, but were not intensively used compared to intensive grassland outside of the Carpathians. It was therefore difficult for us to exactly find a boundary between intensively and extensively used grassland that matches for the Carpathians. This can also be seen in our results: 52 out of 180 sample points were extensively used grassland (25 in Poland and 27 in Slovakia). Combined with the fact that 67 points were misclassified in CORINE or not accessible due to property right and even included that 47 points were located in intensively used grassland this still shows that most sample points were located in extensively used grassland.

4.2 Results And Discussion for The remote sensing approach

Data exploration in SPSS revealed that variations in the DN distribution for each band among grassland intensity classes are relatively small. As can be seen in the box plots (cf. Fig. 6) for the five grassland intensity classes assessed in the field, median, quartiles, and whiskers are similarly distributed in each band. This is also evidenced by further statistical parameters (cf. Annex 1): Within the range of the 8-bit data format a difference between the highest and the lowest mean of e.g. 3.6 DNs for band 1 is negligible. The most significant difference can be observed in band 5 – MIR from 1.55 to 1.75 µm - that is indicating vegetation and soil moisture content. The difference between highest and lowest mean in band 5 is at least 13.67 DNs. It turned out that inadequate data availability for class 1.2 - extensive meadow - was problematic: Since only a few sample points were classified as *extensive pastures*, the sample size was too few to obtain a valid distribution of its DN values.

The lack of data for class 1.2 was also influencing the calculation of the J–M Distance. It is a statistical measure sensitive to the variation of the values as it needs the mean vector and a covariance matrix – both not computable for class 1.2. Ergo the pairwise comparison led to an error (cf. Tab. 2).

The J-M Distance ranges from 0 to 2 with 2 indicating highest separability and values less than 1.5 indicating spectral similar classes (Lillesand & Kiefer 2000). The results show that some of the classes had a high J-M distance value e.g. was class 3 from class 2.1 separable with a distance of 1.86. This was expectable since an intensive meadow 2.1 differs in phenology and vegetation structure from a succession area with lignified plant types e.g. shrubs on former grassland. More interesting is that an intensive pasture (1.1.) is fairly separable from an intensive meadow (2.1) with a value of 1.71. Only one J-M Distance value for different intensities within one grassland class was promising: an intensive meadow (2.1) can be separated from an extensive meadow (2.2) with a value of J-M distance of 1.59 that is just above the threshold for spectral similarity.

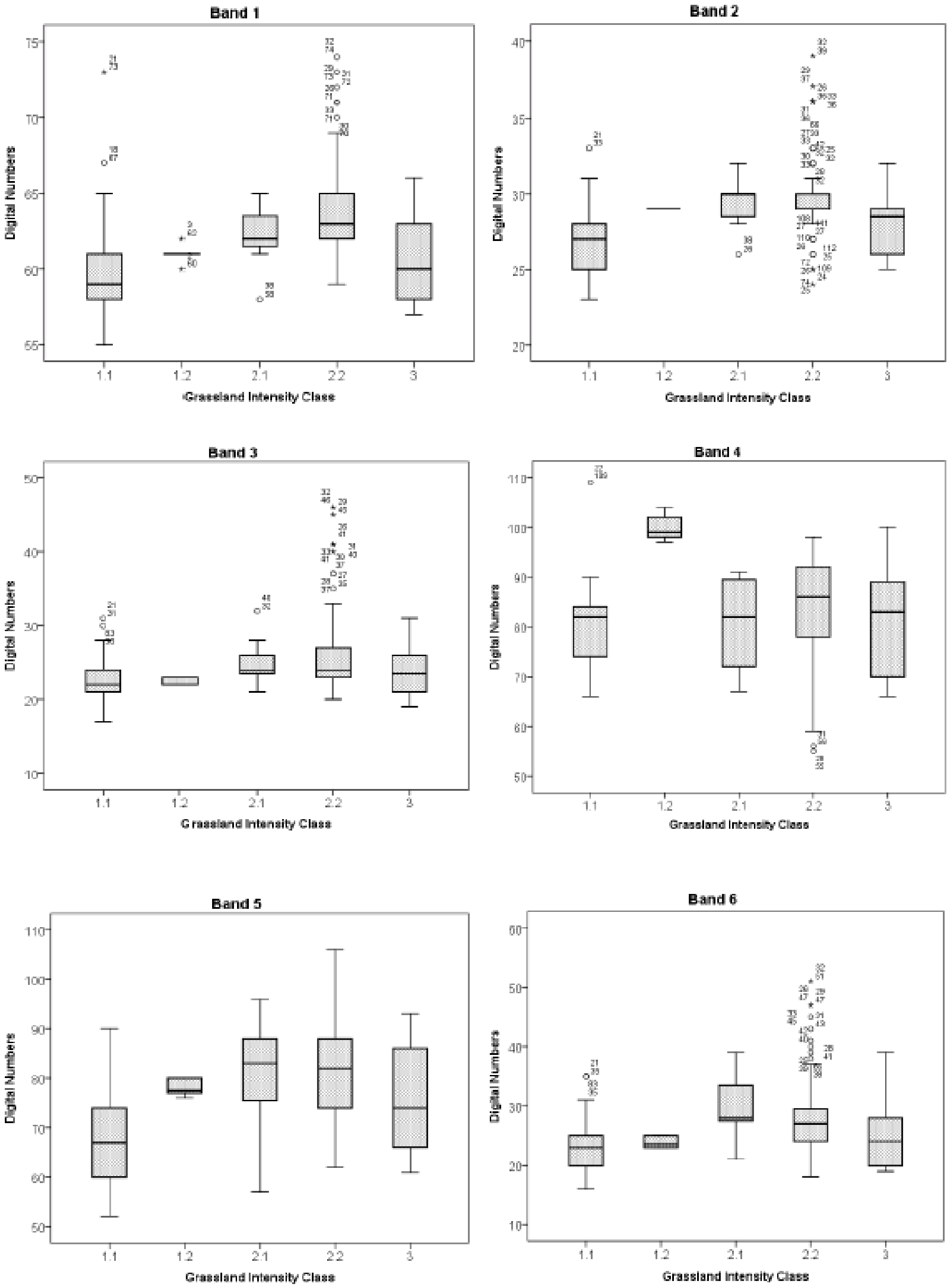

Fig. 6: Box plots representing the five grassland use intensity classes with median, quartiles, and whiskers of DNs per band of the stacked Landsat TM-mosaic (Scale of y-axis varies, but not influencing the comparison within one band).

TAB 2: Divergence Matrix to Evaluate Pairwise Class Spectral Separability by Jeffries-Matusita Distance.

Spectral class	1.1	1.2	2.1	2.2	3
1.1	**0**				
1.2	**0**	**0**			
2.1	1.7054	**0**	**0**		
2.2	1.1923	**0**	1.5928	**0**	
3	1.1987	**0**	1.8588	1.2597	**0**

This encouraging result could not be supported by the unsupervised classification result (cf. Fig. 7). The classification algorithm was first applied to the whole mosaicked image resulting in 30 spectral clusters (cf. Chapter 3.3). Applying the subset led to the exclusion of spectral clusters and resulted in 23 remaining . To identify the spectral clusters representing grassland intensity classes, the *CORINE grassland mask* was applied again and spectral classes were extracted in a GIS. It emerges that only a few spectral classes comprise grassland - class 7, 8, 9, 10, 11, and 12 (cf. Fig. 7). It was expected that they are exclusively related to the intensity classes recorded in the field. Unfortunately no pattern of relation could be identified: The calculation of the mean spectral cluster among the *CORINE grassland mask* revealed that in general all intensity classes are represented by the spectral cluster 9 To account for minor deviations in the spectral signal, the number of spectral clusters might have been extended in the ISODATA algorithm.

The results of the remote sensing method are clearly influenced by inherent data characteristics: The spectral resolution of the multi-spectral Landsat imagery is rather low. The number and dimension of the wavelength intervals is relatively large in range but limited to a few broad bands. Thus, the characteristics of the spectral signature of grassland intensity types may not be acquired at this since differences are too few if only determined by the plant physiology and phenology of the species. Hyperspectral data tackles the issue of low spectral resolution data by acquiring data in hundreds of spectral bands. It will become more relevant when satellites with hyperspectral remote sensing instruments onboard will be launched (cf. EnMAP project). Furthermore the spatial scale might be too coarse: The spectral signature of a whole species composition is summarized on a 30m pixel. Thus it was anticipated that differences - merely observable in a 10m radius on the field (cf. Chapter 4.1) - are depicted in a mixed spectral signal on 900m². Franke et al. (2012) achieved positive results for mapping grassland intensities when using RapidEye data with a spatial resolution of 6m. Additionally reliability of the approach used is based on the accuracy of the CORINE land-cover data from 2006 that was used to mask regions of interest within the study area.

A general major issue of using remote sensing data is that no proof is given that status quo of the grasslands during the field trip was the same as during image acquisition that was done one year before the field trip. Status quo is strongly linked to individual management decisions of the land owner that can change at short notice. For example might dry climatic conditions in one year motivate the land owner to mow earlier while changes in the agricultural subsidiary system might call for breaking grassland to cultivate market crops. All these influences on decision-making are neither depicted in remote-sensing data nor in CORINE land-cover data from 2006 and are always concerned as the problem of *linking people to pixel*. Information about management in the long-term could be extracted from

MODIS time-series. For example the EVI could be evaluated in a time-series analysis to understand whether trends in phenology are stable over time and management practices can be extracted (Kümmerle and Estel 2012, personal communication).
As delineated in the introduction (cf. Chapter 1) a spatially explicit mapping of grassland intensities is highly valuable in order to adjust conservation schemes. But since discrimination was insufficient, a supervised classification using field data for training and validation was revised.

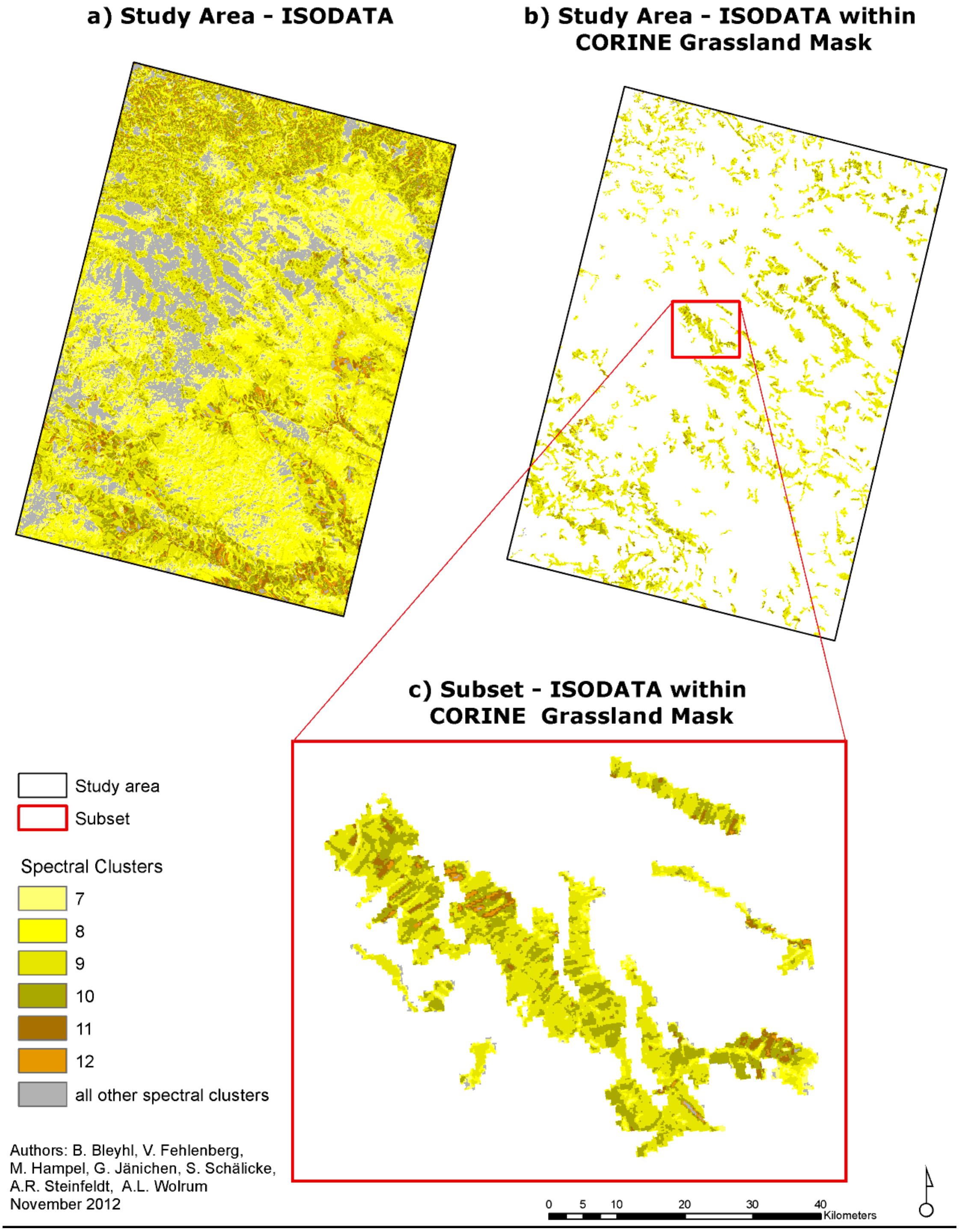

Fig. 7: Maps of unsupervised classification approach using ISODATA. a) shows all resulting spectral clusters within the study area with non-relevant clusters in grey. b) shows all resulting spectral cluster within the study area but as extracted using the CORINE grassland mask. The number of relevant spectral clusters was reduced to 6 out of 30. c) shows a subset of b).

5. CONCLUSION AND OUTLOOK

Regarding our research questions neither differences in management intensity of grassland between Poland and Slovakia were detected for our study area nor could our recorded grassland-intensity classes be derived from Landsat TM5 spectral imagery. With respect to our specific objectives, the assessment of grassland intensities in the field from indicator species (i) was challenging but worked adequately to distinguish different management intensity classes. Nevertheless, as the assessment of indicator species can be easily adulterated, we recommend a full vegetation survey for future studies on this subject. The comparison of grassland intensity in Poland and Slovakia (ii) did not reveal substantial differences. Stating the classification results of our sample points in more detail, we found more grassland abandonment in Poland (18.4%) than in Slovakia (7.8%), and more meadows in Slovakia (78.1%) than in Poland (28.5%), whereas there were very few pastures in Slovakia (9 sample points). As our findings are based on only 49 sample points in Poland and 64 in Slovakia, they might be relativized a bigger sample size. The spectral discrimination of grassland intensity classes in multi-spectral imagery (iii) worked well for the grassland abandonment class (J-M distance from intensive meadow: 1.86), and intensive pasture was well separable from intensive meadow (J-M distance: 1.71). Intensive meadows were separable from extensive meadows with a J-M distance of 1.59. With valid ground truth data the approach should be reapplied on data with a higher spectral, spatial, or temporal resolution that might capture intensities better. However, the research field of land use intensities, especially of grassland intensities, are of high importance and this study delivers some approaches of classification and mapping which are worth to be taken in consideration in future research projects.

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ANNEX:

Statistical parameters from data exploration in SPSS for each band at all classified sample points.

TM band	***Class***	***Sampling points per class***	***Mean (Q_{cal})***	***Median (Q_{cal})***	***Standard deviation (Q_{cal})***
1	1.1	29	60.1	59	3.78
	1.2	6	60.34	61	0.63
	2.1	8	62.13	62	2.1
	2.2	55	63.76	63	3 .64
	3	14	60.86	60	3.11
2	1.1	29	26.93	27	2.187
	1.2	6	29	29	-
	2.1	8	29.38	30	1.768
	2.2	55	29.91	29	2.882
	3	14	28.29	28.50	2.199
3	1.1	29	22.66	22.00	3.415
	1.2	6	22.67	23.00	.516
	2.1	8	25.00	24.00	3.423
	2.2	55	26.78	24.00	6.327
	3	14	24.00	23.50	3.595
4	1.1	29	80.34	82.00	8.260
	1.2	6	99.83	99.00	2.714
	2.1	8	80.63	82.00	9.985

	2.2	55	83.18	86.00	10.985
	3	14	82.14	83.00	11.455
5	1.1	29	67.86	67.00	9.819
	1.2	6	78.00	77.50	1.673
	2.1	8	80.75	83.00	12.127
	2.2	55	81.22	82.00	10.602
	3	14	75.50	74.00	10.181
6	1.1	29	23.24	23.00	4.808
	1.2	6	23.83	23.50	.983
	2.1	8	29.75	28.00	5.600
	2.2	55	29.00	27.00	7.591
	3	14	25.50	24.00	5.893