A LAND USE DATA UPDATE TOOL FOR RULE-BASED QUERY OF REMOTE SENSING OUTPUTS

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Abstract:

Time series of land use data need to be properly comparable for monitoring purposes. Since different raw data have to be used, a lot of mistakes can appear. In order to avoid such mistakes, we updated our land use data with minimal alteration by help of an appropriate rule set. The original geometry remains completely. New borders and attributes are added. One of the new attributes indicates the cause of each individual change. A new developed tool exploits actual remote sensing raster data by a set of rules, updating existing land use vector data. This tool working as decision system is available as ArcView extension. The user can define its own rules, depending on the peculiarities of its data. The program explores the extent of changed pixels within an individual land use polygon and decides the way to update data. The approach is tested on different areas including the biosphere reserve “Oberlausitzer Heide- und Teichlandschaft”. Despite we used the relatively coarse LANDSAT data; many landscape changes were automatically detected in the fine-scaled landscape mosaic. Since the tool is applicable to other regions and finer raw data, we expect, the extension will serve as good assistance for similar tasks.

1. INTRODUCTION

1.1 Motivation

Worldwide, great efforts are undertaken to provide current land use data. But the specific problems of its update are scarcely discussed. Some time later each data owner need more actual information and has to decide about a new creation or update the existing data. A new acquisition with a current method and better data seems to be quicker and better suitable for actual purposes. But if you think about it, apart from the expenses, there appear some critical questions: Mostly, the inaccuracies of old data are well known, but what about the faults of a new set? Which modifications of data prove real landscape changes, whereas many modifications result from another sensor, a new acquisition method, or the correction of former faults? Recent studies of landscape change, based on historical maps and older remote sensing data (BASTIAN & RÖDER 1996, NEUBERT & WALZ 2000, ULLRICH 2005), show further problems comparing different time periods: Geodetic discrepancy, different scales, the enlargement or shift of roads, the growth of treetops, variable water levels, seasonal variations, and different interpretation resp. classification modes can cause a sham of changes.

Particularly for purposes of monitoring (SYRBE 2002), nature protection and landscape planning (Bastian 1999) a comparability of different time cuts is essential (LAUSCH 2000). If time comparison belongs to the tasks of data analysis, the questions above cannot be solved later. The manner of update must consider the task of change detection already from the outset, like the CORINE project (KEIL ET AL. 2002, HÖLZL 2003) and other primary remote sensing approaches (WERNER 2002) do it. But in most cases, the acquisition method is not especially directed to change detection, because former data are not involved, new sources or new methods should be used. Therefore, a proper method of data integration is needed, preserving the present information.

1.2 Goals of the study

Our method doesn't aim to create new land use data sets. On the contrary, it is designed to integrate new land use information into existing vector data. By this way, several sources can be used, fragmentary or fuzzy data are applicable, and the detection of pseudo changes will be minimized. The full information of former land use data is preserved and a new specification is given containing the type of change. Each individual change can be retraced to its source and to the original state. The method allows a successive update of multiple time cuts. But as main objective, artificial intelligence should be integrated in terms of rules, containing the knowledge about possible changes in a landscape. A GIS tool was to be created, performing the rules and changing data accordingly. Only assured changes have to be gathered. An information void or uncertainty leads to maintenance the old specification instead. Faults of non-detected changes are more possible than pseudo changes.

2. DATA AND STUDY AREA

The existing land use data were derived from the "CIR - Biotoptypen- und Landnutzungskartierung" of German state Saxony, provided by the Saxon "Landesamt für Umwelt und Geologie" (LFUG 2000). The biotope data result from an interpretation of colour-infrared (CIR-) aerial views of 1992 to 1993. In order to give a good base for land evaluation, statistics, planning and modelling, we had re-classified the GIS-data from about 240 biotope types to 23 land use types (see legend Fig. 4, SYRBE 2002), largely comparable to STABIS (cf. DEGGAU 1995). Additionally, the vector geometry was generalized by eliminating polygons below 0.5 hectares.

From the start, a complete update of land use data for the whole territory was intended. We ordered Satellite data from LANDSAT 7 ETM+ sensor covering Saxony. The selection, considering cloud cover and season, resulted in satellite images from 24.09.2000 (east part) and 14.08.2000 (west part). The ETM+ ground samples at three different resolutions: 30 meters for visual and near-infrared bands 1-5, and 7, 60 meters for the thermal-infrared band 6, and 15 meters for the panchromatic band 8. For our land use analysis, band 6 was not used, whereas we refined bands 1-5, and 7 by merging the spatial information of band 8. With it, the ground resolution of the processed images is constant 15 meters (NASA 2006). Obviously, this resolution is very coarse for the detection of some land use types. Only extensive parcels with homogeneous cover could be reliably recognized. In order to fill the resolution gap we tested different approaches.

A set of investigation areas was spread out. Two of them are situated in the east periphery of Leipzig and in the north periphery of Dresden. Here we tried to use data from ground biotope mapping (LFUG 1995) for the update of the smallest plots. Furthermore, data of the Müglitz catchment were updated, where we used only orthophotos. The last and largest investigation area is the biosphere reserve "Oberlausitzer Heide- und Teichlandschaft", where we used satellite images and CIR-aerial views together. The results section (5) brings into focus this area (Fig. 1).

Titel:

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Figure 1: Test area biosphere reserve "Oberlausitzer Heide- und Teichlandschaft"

We sought for co-operation with regional planning association and agreed the classification of land use and the encoding of changes especially with the regional planning association "Oberes Elbtal/Osterzgebirge". Other regional planning associations use conformable codes and classifications. On this base, a GIS tool for data integration was created, that is adjustable to several data and suitable for other regions also.

3. METHOD

The integration of raster data into a polygon land use data set is realized using the popular ESRI's software ArcView and its extension "Spatial Analyst". Out focal investigation area was divided first into training and test parts. A floodplain of about 16 km² served as training field for aerial view interpretation, prospected by ground truth in 2000 and later. The processed data set amounted 4100 patches. 85 % of them were treated both, with aerial views and satellite date in order to create the rules above, and to test the method. 600 patches (15 %) of them were kept out preliminary in order to evaluate the rules finally.

The biosphere reserve administration supported colour-infrared aerial views of the whole reserve area. We used field observation data from a soil mapping campaign covering the training floodplain around the flight period. Inside the main area except the test and training sides, we investigated only aerial views comparing to the floodplain. A ground truth campaign was carried out in the most difficult mining area finally.

We processed the satellite images by ERDAS IMAGINE 8.6. First steps were the projection to the coordinate system used and a resolution merge. A wood mask was calculated and the signature training was iterative enhanced according the particularities of investigation area. Finally, a supervised classification was performed, extracted the signature from training sides shared over the biosphere reserve, with four results: the crisp (first) classification, two fuzzy classifications (second and third), and a neighborhood filtering of the first one, eliminating single outstanding pixels. The tested classification accuracy outside of the training sides was very different. Several fallow (30 %) and edge types (58 %) showed the lowest accuracy. Settlement was also a difficult land cover class with only 69 % hit rate. Arable fields and water (both 94 %) were quite good detectable, while some shallow and overgrown ponds caused the most water failures. We get the best results for grassland (97 %) and arable fields (98 %).

The remote sensing outputs were transformed into GRID data sets, which are readable by ESRI programs. Running Spatial Analyst, the vector land use data and the GRID data sets are processed as follows. Firstly, the data of our investigation area were clipped out of the region-wide shape. Than, we added new items reading “Status”, “Fnneu” and “Fnalt” to attribute table. All existing land use attributes are maintained in the Fnalt column. New land use types will be assigned into the Fnneu column. After the whole treatment the Fn (current land use) item will be updated by the values of Fnneu, which stay fragmentary themselves. The information what happened and what to do with an individual polygon is assigned to the column Status with the codes of Tab. 1.

Table 1: Status codes indicating land use data changes

Status code	Reason and Action (concerning an individual polygon)
0	no landscape change
1	change the geometry but not the attribute (remain part after secession)
2	change the attribute but not the geometry
3	change both geometry and attribute (separated part)
4	insertion new island polygons
5	revision by field survey necessary
6	new data creation (without data up to now)
7	correction an improper derivation from biotope mapping
8	revision an mistakenly old biotope mapping
9	correction an improper geometry of old biotope mapping

The program-aided processing needs an integration of (actual) land cover data into the (old) land use shape. Therefore, the following steps were necessary.

1. Individual GRID data sets for each land cover type had to be created (function map calculator).
2. A land cover specific column of the attribute table was calculated, containing the percentage of that land cover type in relation to the polygon area (functions: summarize zones / join / calculate).
3. Equal operations were done with the fuzzy classifications, the filtered classification set and also for the buffered core areas of each polygon.

LANDSAT images are particularly suitable for large homogeneous patches. Therefore, only polygons exceeding 5000 m² were treated by our satellite data. Smaller and more diverse plots must be updated by aerial views only. We sorted the original land use polygons by its area and treated them beginning with the largest. We compared the aerial view interpretation with the land cover statistics of each individual plot. According to our experiences from other test areas in Saxony, we stated rules connecting the proportion of different land cover types with the necessary update actions (vs. Tab. 1). If an attribute modification occurred, also the new land use type was to be detected.

The established rule set was tested and improved stepwise in relation to the further polygons. Geometrical changes (cutting polygons or insertion of island polygons) and other special measures (Status code > 3) were done by hand according the aerial view structure. Finally, the far eastern test part of biosphere reserve was computed using only the rule set and the satellite images. We used the aerial views in order to control the update results, and we compared the changes found with the true land cover variation.

4. THE UPDATE TOOL

This program is available as an extension of the GIS software ArcView 3.2. It includes an algorithm for the automated processing of land-use charts using vector data. The input data set has to be a shape, the proprietary ArcView data format. The rules are defined by user-set parameters.

After the extension is activated, the program menu appears in an open window and offers two functions: first defining the rule parameters and second processing the rules. The program structure results from the attribute table structure of the vector data set. Rows represent the land use polygons. Attributes of land use polygons are described in columns. The algorithm makes use of column values and lays down conditions and conclusions.

The algorithm begins with a selection from existing information, especially land use class and polygon area. The minimum area depends on the pixel-resolution of remote sensing raster data. A selected polygon will be compared with the current land use information. As written above, this information comes from the land cover type classification of a raster data set. To express the applied rules as value ranges or threshold values, the land cover types are added into the vector data table as percentages.

In the following, the process will be explained by means of an example (Fig. 2). For instance, if the selection is a farmland polygon (FN = 41) larger than one hectare (Area >= 10000), the algorithm asks for a corresponding land cover type in the attribute table. The polygon is changeable in respect to its attribute only (Status = 2) since it has more than 10000 m² (Area = 10000). Only polygons over two hectares (Area = 20000) should be changed in its geometry (Status = 3). In the case that less ten percent of the pixels correspond to other land cover types but farmland (Fnrest <= 10), it will be supposed that no land use change has happened and no modification of the polygon geometry has to be done. Otherwise (Fnrest > 10), a land use change may be possible. Manual processing has shown that farmland can change to grassland, fallow, afforestation, and water, with respect to either the whole polygon area or just a part of it.

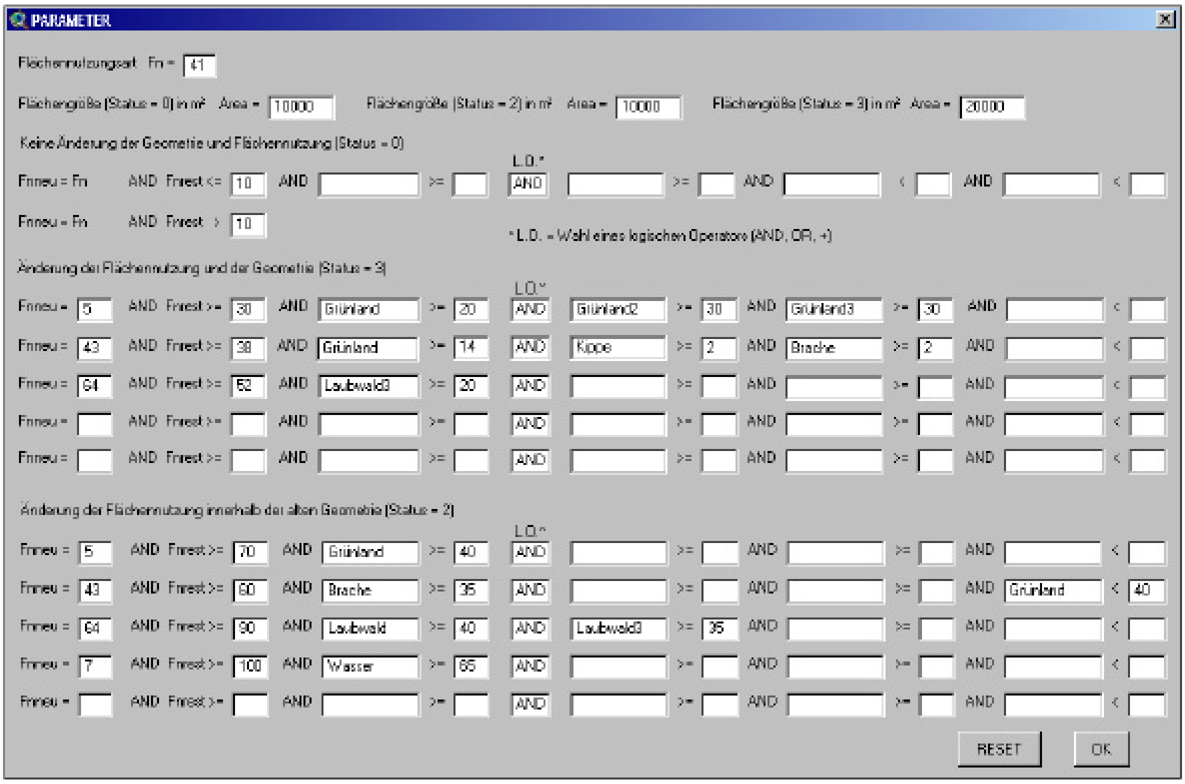

Figure 2: Parameter dialog of the update tool for adapting rule

Modifications depend on the extent of pixels that do not correspond to farmland. To determine a new land use, a certain number of pixels with corresponding land cover types must be detectable. Besides the crisp classification results, also second and third results of fuzzy classification is evaluated. Our example shows the four mentioned possibilities.

1. Change of land use attribute *and* geometry (Status = 3):
   - Grassland (Fnneu = 5) is assigned, when other land cover types but farmland exceed 30 % (Fnrest >= 30), and grassland exceeds in crisp and fuzzy classification 20 resp. 30 % (Grünland(..3) >= 20 .. 30).

- Fallow (Fnneu = 43) is assigned, when other land cover types but farmland exceed 38 % (Fnrest >= 38), grassland exceeds 14 % (Grünland >= 14), bare soil exceeds 2 % (Kippe >= 2), and fallow exceeds 2 % (Brache >= 2).
- Afforestation (Fnneu = 64) is assigned, when other land cover types but farmland exceed 52 % (Fnrest >= 52), and deciduous forest exceeds in 3rd fuzzy classification 2 % (Laubwald3 >= 2).

2. Change only the land use attribute and *maintain the original geometry* (Status = 2):
   - Grassland (Fnneu = 5) is assigned, when other land cover types but farmland exceed 70 % (Fnrest >= 70), and grassland exceeds 40 % (Grünland >= 40).
   - Fallow (Fnneu = 43) is assigned, when other land cover types but farmland exceed 60 % (Fnrest >= 60), fallow exceeds 35 % (Brache >= 35), and grassland falls below 40 % (Grünland < 40, outside right).
   - Afforestation (Fnneu = 64) is assigned, when other land cover types but farmland exceed 90 % (Fnrest >= 90), and deciduous forest exceeds in crisp and fuzzy classification 40 resp. 35 % (Laubwald >= 40, Laubwald3 >= 35).
   - Water (Fnneu = 7) is assigned, when other land cover types but farmland equal 100 % (Fnrest >= 100), and water exceeds 65 % (Wasser >= 65).

During processing, only the values of land use attributes are changed automatically in the attribute table. A status number describes, how data was updated. When the algorithm has detected changes in the polygon geometry, the geometry must be modified manually evaluating the value “Status” after run. The program is very simply constructed. It provides a range of possibilities to define parameters, such as rule conditions and soil cover types, which can vary with different data in different regions. But the rules cannot be saved. So the tool needs to be improved if rule sets of different land-use classes are to be more easily retrieved.

5. RESULTS

The land use update of first investigation areas Leipzig (843 m²) and Moritzburg near Dresden (47 km²) resulted in a good knowledge about necessary steps and usable GIS functions. These activities yielded about 40 rules, confirmed and tuned in numerous cases. Simultaneously, we scrutinized the possibility to integrate data of the selective biotope mapping (LfUG 1995). This attempt revealed a limited suitability even of the smallest plots. While, for instance, 74 % of the Moritzburg investigation area were feasible by LANDSAT data, the selective mapped biotopes covered only 2 % of this region. 24 % had to be updated by other sources including field survey. This rate was very unsatisfying in consideration to the immense effort transforming the selective biotope data.

Our third investigation area, the Müglitz catchment (214 km²), was treated only by aerial views. The in other respects successful activity confirmed the unacceptable expenditure in regard to larger regions. The biosphere reserve, our fourth and focus test area, was treated by satellite data and aerial views in combination. We attempted to integrate the remote sensing output rule-controlled into our land use data set. Tab. 2 gives a summary of approved rules, according to the former land use type. All polygons remained unchanged (Status 0) if they had more than 90 % proportion of the same land cover like former land use type. If rules countered each other, a preceding change was overwritten by successive rules.

Table 2: Rule set of land use change based on proportions of land cover pixels ([1] coniferous forest)

Former use type	New use type	Sta tus	Former %	New %	Different use %	Arable land %	Forest %
mine / dump	water	2	< 40	>= 14	>= 60		
mine / dump	fallow	2	< 32		>= 68		>= 17
mine / dump	fallow	3	< 40		>= 60		>= 63
arable land	See Fig. 2 and section 4!						
arable fallow	afforestation	3	< 25	>= 40	>= 85		
arable fallow	grassland	2	< 10	>= 35	>= 90	< 10	
arable fallow	arable land	2	0	>= 50	100	(>= 50)	
grassland	arable land	3	< 60	>= 30	>= 40	(>= 30)	
grassland	mine/dump	3	< 62	>= 20	>= 38		
grassland	arable land	2	< 10	>= 60	>= 90		
grassland	afforestation	2	0	>= 85	100		< 70[1]
grassland	coniferous f.	2	0	>= 70	100		
grassland	mine/dump	2	0	>= 90	100		
mixed forest	water	3	< 40	>= 43	>= 60		
coniferous forest	mine/dump	3	< 80	>= 50	>= 20		
coniferous forest	arable land	3	< 15	>= 60	>= 85	(> 60)	
coniferous forest	traffic	2	< 15		>= 85	>= 24/< 50	>= 24
coniferous forest	settlement	2	< 5	>= 10	>= 95		
coniferous forest	mine / dump	2	0	>= 97	100		
deciduous forest	mine / dump	3	< 60	>= 10	>= 40		
deciduous forest	mine / dump	2	0	>= 90	100		
copse	mine / dump	2	0	>= 89			
arid succession	mine / dump	2		>= 90			
arid succession	coniferous f.	2		>= 91			

Fig. 3 shows the new land use data set of the biosphere reserve valid for 2000. Because of its peripheral situation and the protection status, there appear sparse land use changes. Most variances happened in the mining area of north corner. They show the results of recultivation, water management, and succession. Other changes affected the proportions of arable land, fallow, and grassland. These changes are predominantly indications of crop rotation processes. Most other changes, especially building activities, were small-sized and therefore badly recognizable on the LANDSAT image.

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Figure 3: Updated land use of biosphere reserve "Oberlausitzer Heide- und Teichlandschaft"

Using satellite data, especially the land use types arable land, grassland, mining area, deciduous forest, coniferous forest, mixed forest, and water (exceeding running waters) were sufficient detectable. In contrast, all other land cover changes required a comparison with aerial views. But the above-mentioned land use types cover larger areas. Regarding only patches exceeding 1 hectare, the proportion of sound detectable land use types in biosphere reserve is about 73 %. Edge effects can cause considerable error, even concerning large polygons. Since pseudo changes are detected by rules, which must be rejected manually later, particularly the effort increases. The quality of evaluation was essentially better, if the polygons exceeding 1 hectare were buffered analyzing only the land cover statistics of the core areas. Our results show, that particularly larger grassland, water, and forest were proper detected using the core statistics. With it, depending on type, 3 – 34 % area proportion could be rescued from false modification.

The outer east 15 % of biosphere reserve was a test area, covering altogether 600 patches. 351 patches exceeding 1 hectare were processed by the rule set only. Unfortunately, this is a very natural region with large forest areas and rather few landscape changes. Because the land use variety is low, the most rules were not applied. From 22 land use changes, only 9 changes were detected. The other 13 alterations appeared the first time, thus no according rule existed.

6. DISCUSSION AND CONCLUSIONS

The presented method and GIS tool allow a knowledge-based update of land use data. Existing land use information will be updated with caution, only proved changes will take effect. Therefore, former and updated geometry go together. This is a qualification for use especially in landscape planning and monitoring. Even though the inclusion of selective biotope mapping doesn't proved very useful, this attempt demonstrated the possibility of integration very different data. Just as well, analysis of time-lapse satellite images, of thematic maps, and other foreign sources are applicable. The also tested classification probability of some land cover classes proved the results indeed, but yielded a bad cost-value ratio. However, fuzzy classification results as well as the statistics of buffered core areas were successfully applicable.

From the start, we prefer LANDSAT data because of its regular and long time availability. Particularly, the actual offers of automatic classified land use data (Borg et al. 2004) and the low costs seemed beneficial. Despite all efforts adjusting the method to the raw resolution, LANDSAT images proved inappropriate for the fine scale in focus (1:20000 to 1: 50000). Particularly, the automatic generalization by homonymous GIS function caused more subsequent work revising artefacts than it helped to ease the work reducing small-sized plots. But more and more high-resolution satellite images are offered today, that will be more suitable to the presented attempt.

A combination of satellite images (for large polygons) and aerial views (for the small and diverse patches) proved satisfactory. The amount of work will be reduced if the proportion of rule-based update is higher than the quantity of remaining patches that must be updated manually. Different investigation areas were shared across Saxony representing the most common landscape types (lowland, upland, mountains; and suburban, agrarian, mixed, forested). The resulting set of rules should be transferable after adjustment. Of course, the parameters have to be customized to each raster data set and to other circumstances. The biosphere reserve was a very difficult area because of its small-sized structure and the rare land use changes. The unfavourable statistics, especially regarding to the test area don't disqualify the method as a whole, but as well the area choice as the discrepancy between ground resolution of remote sensing data and map scale.

The method of rule-based land use update proved oneself on the whole. The most critical land use class is the so-called seeded grassland. According the demands of nature protection, it was allocated to arable land use type because of its slight biodiversity and a status in law like arable land. But the land cover is grassland nevertheless. Our solution, the identification by a time series of aerial views (grassland more than 3 years in succession) was expensive, imprecise, and led to multiple misunderstandings. We suggest refusing a special treatment of this meadow subclass by remote sensing at all.

As well without the ArcView tool, the update method with status variable, maintain geometry and former versions has approved under application by diverse co-workers and an other association. Particularly the best usable GIS functions are known now. The rule set must be completed by rules concerning settlement and trade, but on the basis of high-resolution remote sensing data. The tool is usable by widely different rules anyway. Two tasks remain. Firstly, a possibility to save the rules can be realized surely easy if demanded. But secondly, the machine-aided change of geometry seems to be a more complex problem.

7. ACKNOWLEDGEMENTS

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References

BASTIAN, O.; RÖDER, M. (1996): Beurteilung von Landschaftsveränderungen anhand von Landschaftsfunktionen - am Beispiel zweier Testgebiete im sächsischen Hügelland – in: Naturschutz u. Landschaftsplanung 28 (10) 302-312

Bastian, O. (1999): Landschaftsbewertung und Leitbildentwicklung auf der Basis von Mikrogeochoren – in: Steinhardt, U. u. M. Volk [Hrsg.]: Regionalisierung in der Landschaftsökologie. Fachtagung am UFZ Leipzig 31.3.-2.4.1998, 287-298

Borg, E.; Fichtelman, B.; Günther, A. (2004): Automatische Auswertung von Fernerkundungsdaten als Grundlage einer standardisierten Strukturanalyse. – in: Walz, U.; Lutze, G.; Schultz, A.; Syrbe, R.-U. (Hrsg.)(2004): Landschaftsstruktur im Kontext von naturräumlicher Vorprägung und Nutzung – Datengrundlagen, Methoden und Anwendungen. IÖR-Schriften, 43, 109-118

Deggau, M. (1995): Statistisches Informationssystem zur Bodennutzung – in: Wirtschaft und Statistik 12, 1965

DLR (2006): Scientific Data Pool. http://www.dlr.de/caf/anwendungen/projekte/projekte_nutzung/landsat/scientific_data_pool/

Hölzl, M. (2003): Corine Landcover - Erfahrungen bei der Aktualisierung und Abgabe von Landbedeckungsdaten. – in: R. Grillmayer, W. Schneider (Hrsg.): Geodaten zur Landbedeckung in Österreich, 5.12.2003, 22-23

Keil, M.; Mohaupt-Jahr, B.; Kiefl, R.; Strunz, G. (2002): Das Projekt CORINE Land Cover 2000 in Deutschland. – in: Dech, S. et al. (Hrsg.): Tagungsband 19. DFD-Nutzerseminar, 15.-16. Oktober 2002, 95-104

Lausch, A. (2000): Raum-zeitliches Monitoring von Landschaftsstrukturen in der Tagebauregion Südraum Leipzig mit Methoden der Fernerkundung und Geoinformation. UFZ-Bericht Nr. 12/2000, Leipzig, 185 pp.

LfUG Sächsiches Landesamt für Umwelt und Geologie (Hrsg.): 1995: Biotopkartierung in Sachsen, Kartieranleitung. Materialien zu Naturschutz und Landschaftspflege 3/1995

LfUG Sächsisches Landesamt für Umwelt und Geologie [Hrsg.](2000): Color-Infrarot-(CIR)-Biotoptypen- und Landnutzungskartierung. Materialien zu Naturschutz und Landschaftspflege, Dresden, CD-ROM

NASA National Aeronautics and Space Administration (2006): The Enhanced Thematic Mapper Plus. http://landsat.gsfc.nasa.gov/about/etm+.html

Neubert, M.; Walz, U. (2000): Der Landschaftswandel im Raum Pirna - eine Untersuchung auf der Grundlage des Amtlichen Topographisch-Kartographischen Informationssystems und des Vergleiches historischer topo-graphischer Karten. Mitteilungen des Landesvereins Sächsischer Heimatschutz 1/2000, Dresden, 19-27

Syrbe, R.-U.: Aktualisierung generalisierter Landnutzungsdaten aus älteren CIR-Biotopinformationen mit Landsat 7. – in: Dech, S. et al. (Hrsg.): Tagungsband 19. DFD-Nutzerseminar, 15.-16. Oktober 2002, S. 113-125, http://www.dfd.dlr.de/dfd/workshop/dfd_19/papers/syrbe.pdf

Ullrich, F. (2005): Analyse Struktureller und funktionaler Aspekte des Landschaftswandels auf Basis digitaler historischer Karten am Beispiel des Kartenblattes Plauen/Vogtland, Diplomarbeit, TU Dresden, SAW

Werner, C. (2002): Einsatzmöglichkeiten räumlich hochauflösender Satellitendaten in Landschaftplanung und Naturschutz: Beispiele der Auswertung von IRS-1-C-D-Daten, Habilitationsschrift, Technische Universität Berlin