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Integrated projections of land cover and land-use parameters in IWRM – Concept, methods and testing in the Western Bug River Catchment (Ukraine)

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Objectives

The future water cycle analogue to climate change will be influenced by the regional change of land use. The latter refers to the way of how humans employ the earth surface and may dynamic over time due to societal drivers such as land demand, urbanisation, and land management practices. In terms of integrated water resources management (IWRM), land use can be understood as all major pressures, dependencies and sensitivities of human activities with respect to the water cycle. To deal with the future land-use change a particular foresight approach is being developed that allows long-term projections of both land cover as the direct observable land surface and water-related land-use parameters which represent the interrelations between human activities and the processes of the water cycle. Results are expected to support an integrated assessment of climate change and land use scenarios.

Methodology

Conceptual frame

The following steps are seen as key for the projection of land use with its water-related parameters: First, a retrospective analysis of land-cover change serves as basis for a spatially distributed change detection. Second, current land cover together with field and geo data are used to describe the interrelations between land use and the water cycle. Third, results of change detection and its correlation with socio-economic developments lead to scenario-based projections of the future land cover. Fourth, water-related parameter of land use are projected in the future in line with land cover and the underlying scenarios. Empirical applicability is ensured through testing the concept in the catchment of the upper part of the Western Bug river (Ukraine).

Retrospective analysis of land-cover change

The investigation of land-cover change starts with an automatic classification of data for selected reference years. In the case of the Western Bug river catchment, empirical work addresses the years 1989, 2000, and 2010 due to reasons of societal transformation.

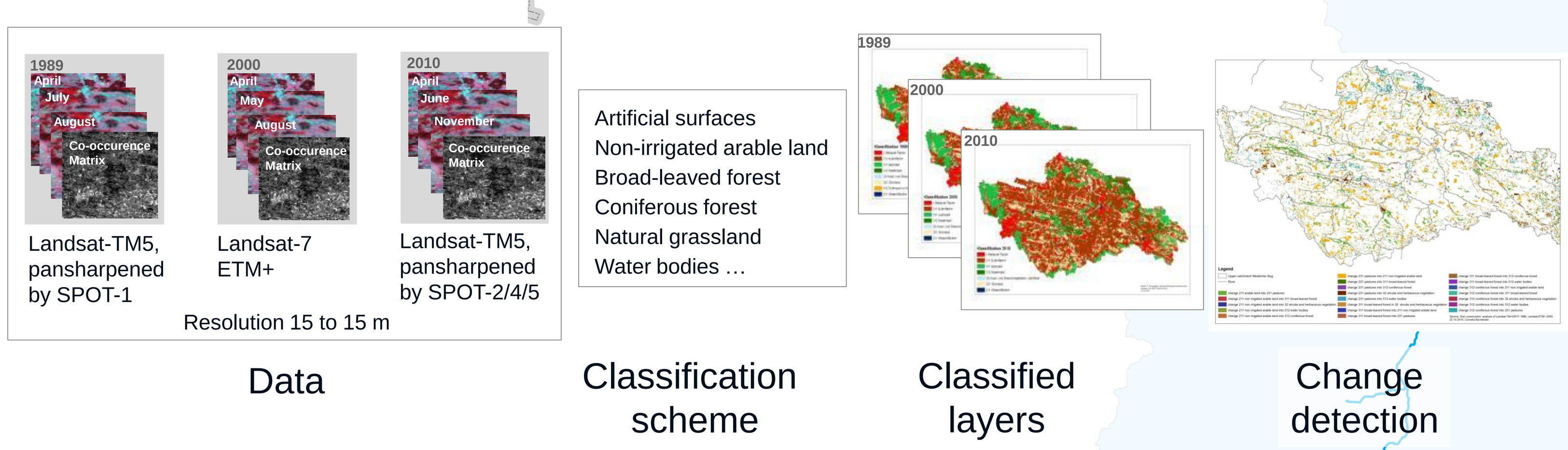


Figure 1: Derivation of land-cover from remote sensing data ends up in change detection.

For each reference year, multi temporal and supervised classification of multi sensoral remote sensing data is carried out using Landsat-5, which is pan-sharpened with SPOT-1/2/4/5-panchromatic channel for the year 1989 and 2010, and Landsat-7 (ETM+) for the year 2000. The resolution is 15 by 15 m. Selected grey level co-occurrence matrix layers, which are performed after Principal Component Analysis, support the classification. As classification system, CORINE Land Cover (CLC) is adapted. GIS-based change detection yields in statistic transition matrices and spatial patterns. They are the background for the derivation of initial propositions on the underlying rules of change appraising additional geo data. These transition rules are then examined by literature surveys and semi-structured interviews with land users.

Analysis of current water-related interrelations of land use

Based on the land cover, parameters are identified to describe the interrelations between human activities and the water cycle. To ensure a comprehensive view, all major processes of the water cycle are screened in order to detect relevant land-use parameters. A literature review focussing on land use in the case study areas led to 20 processes which are crucial for land use in general, 19 parameters with a particular meaning for urban land use and 23 parameters for rural areas excluding settlements.

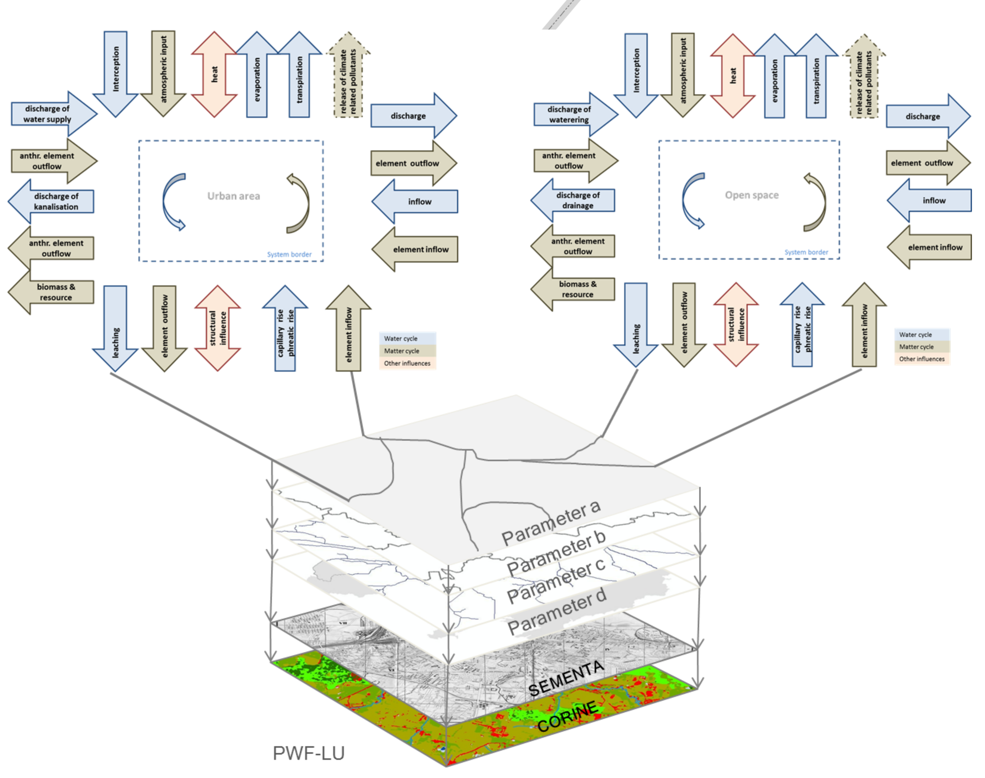


Figure 2: Scheme of water-related processes for urban structure types and vegetation structure types

Initial results

Land-cover change

The expanded statistical analysis points out systematic processes of land-cover change with e.g. urban area systematically extending on grass land and in the vicinity of existing settlements and infrastructure. Another systematic finding is that grass land gains from arable land but also losses to arable land. The other way round of gains and losses for arable land shows the concentration on nutrient rich sites for agriculture. According findings are translated in GIS-algorithms using the gained land cover, soil maps, infrastructure and settlement layers for areas that are prone to change in future to artificial surface.

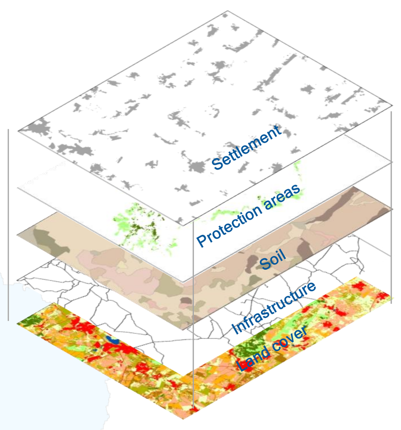
1989 - 2000	Persis-tence	Σ 1989	Σ 2000	Gross loss	Gross gain	Net change	Total change	Swap
1 Artificial Surface	8,0	9,0	10,0	1,0	2,0	1,0	2,9	1,9
211 Arable land	41,4	50,2	49,3	8,8	7,9	0,9	16,7	15,9
311 Decidous forest	12,8	13,9	16,3	1,1	3,6	2,4	4,7	2,2
312 Coniferous forest	3,0	4,7	3,8	1,7	0,9	0,9	2,6	1,8
321 Grass land	11,3	20,6	20,2	9,3	8,9	0,4	18,2	17,8
512 Water bodies	0,1	0,1	0,3	0,0	0,2	0,2	0,2	0,1

$$L_{ij} = (p_{i+} - p_{ij}) \frac{p_{+j}}{100 - p_{++}}$$

$$G_{ij} = (p_{+j} - p_{ij}) \frac{p_{ij}}{100 - p_{j+}}$$

Systematic processes of change

- Artificial surface gains from grass land, not from arable land
- Arable land gains from grass land
- Grass land gains from arable land
- ...



GIS-based transition rules

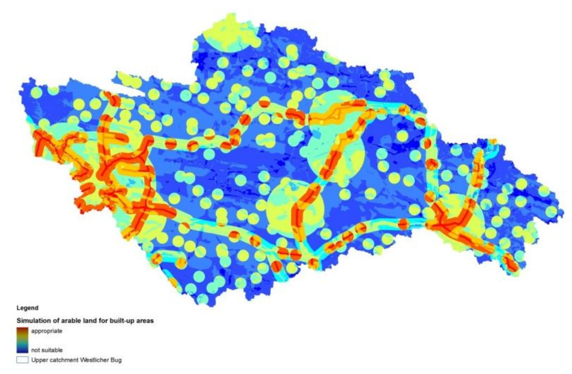


Figure 3: Statistic analysis yields in systematic processes of change and in GIS-based transition rules for potential future land-cover change.

Land-use parameters

Statistical analyses are carried out for each land use parameter involving parameter values from in-depth investigations at test sites. Urban structures including bloc and building information have been detected from land cover adopting settlement classifications to IWRM requirements and running the model SEMENTA© with local topographic data. Parameter values and urban structure are assigned to urban structure types (UST). Urban structure types include water related parameters for instance percentage of sealing. Since projections of parameter values require the inclusion of information in a consistent way, the GIS-based model PWF-LU (Parameter model on Water related Features of Land Use) is being designed.

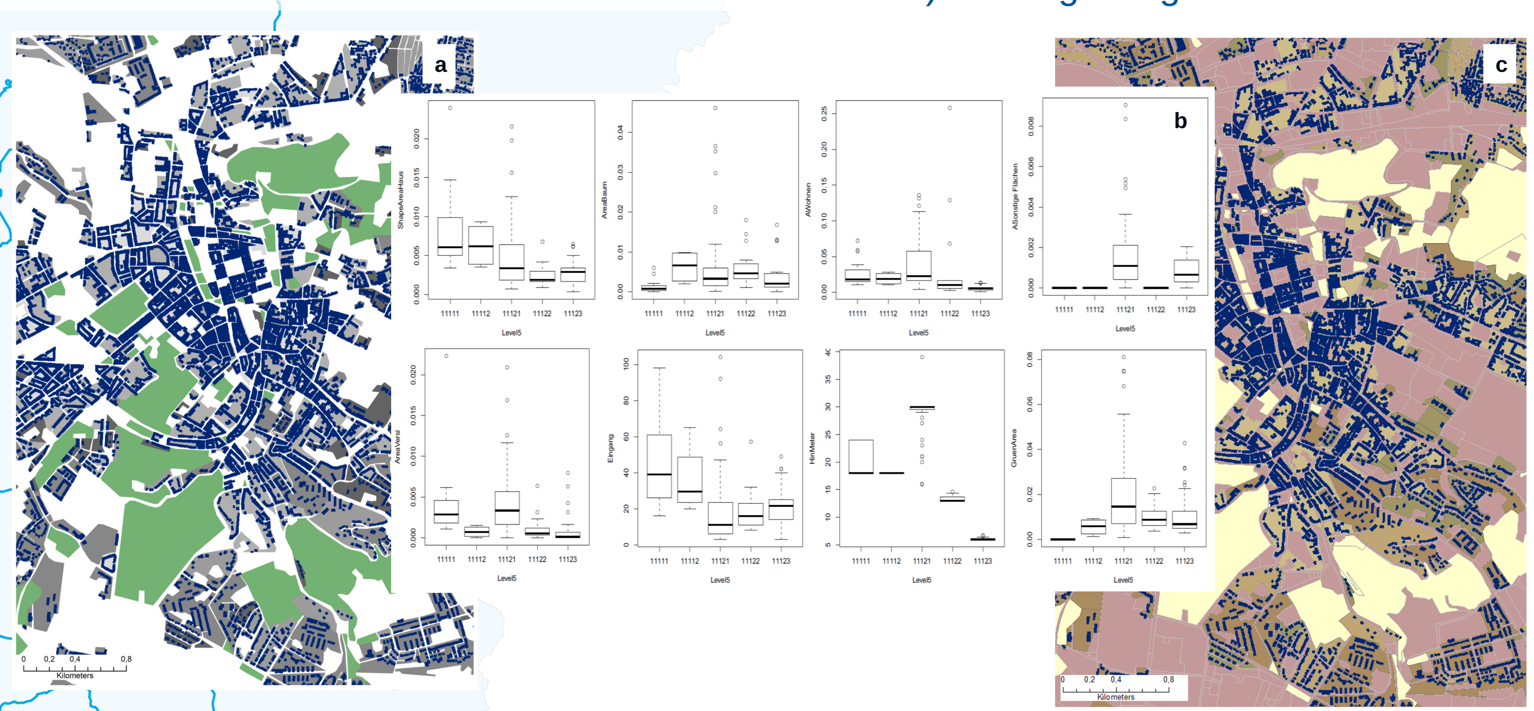


Figure 4: UST containing bloc and building information in Lviv (a). Statistical analysis of parameter values for UST (b). Linked water-related land use and urban structure. Example: percentage of sealing (c).

Conclusions and outlook

The focus on systematic transition rules delivers a consistent basis for future land-cover projection. Each land-cover class is linked with future potential areas for change which will be combined in a multi-criteria approach. A further step is to estimate the demands for land for each land-cover class using socio-economic data which correlate with the land-cover change.
Water-related land use parameter are not always correlated with land cover and therefore need to be assessed in more detail. This is especially true for parameter values related to IWRM. Furthermore, the PWF-LU model facilitates the uptake by various tools for coupled modelling of the water cycle and the impact assessment of future change.

References

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