"Pimp your landscape" – an interactive land-use planning support tool

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Abstract

In the context of the INTERREG IIIA project IT-Reg-EU (http://boku.forst.tu-dresden.de/IT_Reg_EU/index.html) the tool "Pimp your landscape" (P.Y.L) was developed for solving land-use management conflicts in the Euro-Region Neisse. P.Y.L is a web-based tool with focus on visualizing and evaluating changes in the land-use pattern. Information on the land-use pattern is based on CORINE LAND COVER 2000. The maps are divided in sections of 10 x 10 km size. Each pixel in the maps represents the dominating land-use type of the 100*100 m² area. By clicking a pixel a new land-use type is assigned. The impact of each land-use type on different landscape functions is ranked on a relative scale from 0 (worst) to 100 (best). The ranking is based on indicator sets and expert knowledge. The user can choose between two modi: the Expert mode enables to include regional expert knowledge into the evaluation and to define a rule set, representing planning restrictions. The Game mode allows regional citizens to appraise the effects of planning measures. Application areas are participatory planning, management planning conflict solution and education. Tests with different user groups showed that i) further landscape functions, ii) refined evaluation of the land-use form impacts, and iii) neighbourhood relationships between different land-use forms should be integrated.

Keywords: land-use management planning, land-use management support systems, computer-based support, web-based tool, land-use impact assessment.

WIT Transactions on the Built Environment, Vol 100,
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/GEO080221

1 Introduction

A growing need to consider many different and often conflicting societal targets in sustainable land-use management has posed considerable challenges for land-use planners (Blaschke [1]; Massam [11]; Tippett et al. [16]). Classic answers like e.g. intuitive or schematic approaches seemed to be not furthermore appropriate for such multifaceted problems. This raised the demand for solutions, which are able to integrate multiple stakeholder perspectives and various temporal and spatial scales (Kiker et al. [8]; Lenz and Peters [9]; Tyrvainen et al. [19]). Management support systems (MSS) and Spatial Decision Support Systems (SDSS) allowing for participatory approaches have proved to be most useful for complex, strategic problems that cannot be completely supported by algorithms and analytical solutions (Janse and Konijnendijk [7]; Turban et al. [17]; Volk et al. [21]). The systems should give support by (a) providing an overview of the problem area, (b) assessing the impact of each possible management strategy, (c) comparing the management alternatives and (d) estimating the preferences of different stakeholders or stakeholder groups (Booltink et al. [2]; Hurni [6]; Leung [10]; Rauscher [13]). Because MSS and SDSS are based on formalized knowledge, their application in management support has facilitated decisions that are reproducible and as rational as possible. The use of MSS and SDSS helps to better integrate knowledge on how different land-use management types and strategies affect the regional income, biological diversity and public services such as the provision of drinking water and recreation facilities. Furthermore, land-use management planning aspects dealing with border crossing questions as addressed by Natura 2000 or the EU Water Framework Directive (EU-WFD) can be supported by MSS and SDSS.

Beyond this background, "Pimp your landscape" (P.Y.L.) was developed for solving land-use planning conflicts between forestry, water management, nature protection and tourism in the Euro-Region Neisse. This 13,500 km^2 trans-national area is situated between Czech Republic (~ 25%), Germany (~25%) and Poland (~50%) Actually, about 1.7 million people live in the region. Main land-use types are agriculture and forestry (86%). Settlement and infrastructure amount to around 7%. Water bodies, the land-use form of highest trans-national interest due to flood protection and water provision, amount to around 2% of the surface area. About 162,100 companies are established in the region and the unemployment rate is highest in Poland and Germany (14-29%) (www.neisse-nisa-nysa.org).

The region, part of the so called "Black Triangle", was since the mid of 20th century one of the most industrialized areas in Europe. It is still characterized by severe environmental problems concerning the border crossing water bodies, the forests and the soils. The current environmental status is affected to a large extent by political and economic as well as demographic changes taking place during the last 15-20 years. For most of the landscape-related environmental topics, this change has lead to a considerable improvement of air and water quality. Nowadays, the EU Water Framework Directive (EU-WFD), Natura 2000 targets and the up-coming EU Soil Protection Directive are posing border-crossing planning challenges along the Neisse River. Furthermore, EU infrastructural planning corridors request transboundary regional development coordination. In addition, the up-coming tourist industry demands for well working infrastructure systems. The question of the area-related prioritisation of the land-use targets is one of the major regional and transnational problems.

The presented paper intends (a) to introduce the background and development basis of "Pimp your landscape" (P.Y.L.), (b) to describe the conception of the tool and (c) to discuss possible application areas and development perspectives.

2 Material and methods – user needs analysis and expert consultation

P.Y.L. was designed in an iterative approach, starting with a Delphi study-based analysis of the user needs on how to design an optimal management support and conflict solving tool. First, the envisaged tool was tested as paper based version. The results of this test and an accompanying expert consultation delivered the basis for the further technical development. Expert consultation and literature analysis were also used for referencing the evaluation of land-use changes to existing studies and knowledge. A final user test served for refining the system and identifying development needs and technical weaknesses.

Fig. 1 resumes the development steps of P.Y.L.

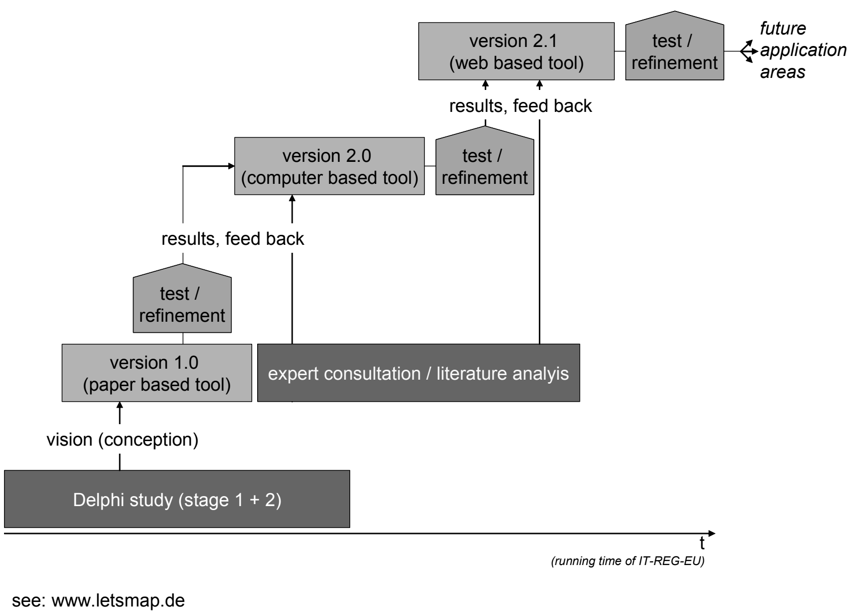

Figure 1: Development steps of P.Y.L. Some steps such as Delphi study and expert consultation were organized partially in parallel to other steps such as test phases and technical refinement.

2.1 User needs analysis – Delphi study approach

The development background of P.Y.L. is defined by border crossing land-use management and planning targets in the Euro-Region Neisse concerning forestry, water management, nature protection and tourism. The different stakeholder groups behind are partially collaborating on the realization of EU-directives like Natura 2000 and EU-Water Framework Directive. Partially they compete by addressing the same areas for different land-use targets. Thematically oriented expert groups (EUREX working groups) in traffic, economy, tourism, water, forestry, crisis management, health, history, statistics and education form the actually most important instrument for exchanging and discussing conflicts, conflict solutions and common strategies. These expert groups and here especially the working group forestry were inquired considering their visions for improving the exchange within and especially between the groups.

To analyze the users' needs, a Delphi approach was chosen (Cooke [3]; Dalkey and Helmer [4]; Scholles [15]; Turoff and Linstone [18]): Van Paassen et al. [20] used this approach e.g. to develop computer models facilitating the capability of learning about sustainable land-use in rice-cultivating regions. White et al [22] developed an empirically based area-type model with the assistance of the Delphi method. In contrast to opinion polls with random choice of the participants and missing opinion feedback, the Delphi method is thought to exclusively obtain a certain consensus among individuals holding special knowledge on the issue of interest (EVALSED [5], Schmidt-Thomé [14]). This approach seemed to fit well for the idea to address the experts involved in the EUREX working groups. Another advantage is the anonymity of Delphi participants, which allows them to interact, rethink, and compare their thoughts in a "non-threatening forum" without being influenced by each other's opinion (Miller [12]).

In the presented study, 32 experts, mainly from the EUREX working groups, their cooperating institutions and administrations participated in two Delphi stages. Representatives from forestry (46%), nature protection (33%), water management (11%) and regional planning (tourism, 10%) in Czech Republic, Germany and Poland were involved. Two groups of experts were differentiated: Group I (40% of the participants) participated at a stage of the Delphi study called "2b", which was preceded by a workshop on existing management supporting system solutions. This stage was carried out to see, how training aspects impact expert opinion. For this reason, these results of this stage 2b are later on presented separately. Group II (60%) did not participate at this workshop. In stage 1 of the Delphi study, the following questions were posed (in three languages):

A. What kind of information sources are you generally using to prepare interdisciplinary planning decisions?
B. Which tools are you using to visualize the planning process and to support your decision?
C. How do you think, an optimal support system should look like that helps to prepare the necessary information and support you as a decision maker?

For each question, a set of alternatives was offered, which were asked to be evaluated on a scale from 1 (= always / most desirable) to 6 (= never / most undesirable). Additionally, free comments were possible. In stage 2 and 2b, only question C) was repeated. The Delphi study delivered the basis for the conception of P.Y.L., which was first realized and tested as paper based tool (version 1.0) to get a preliminary feed back and refinement option from the involved experts before designing a computer based version (2.0). This was again tested with the experts from the EUREX working groups, related institutions and organisations before being published as open-access web tool (version 2.1, see www.letsmap.de).

2.2 Expert consultation and literature analysis

One of the major user needs was to evaluate changes in the land-use pattern with regard to their effects on different landscape functions. Therefore, an expert consultation supported by literature analysis was carried out. A set of typical regional land-use forms was evaluated according to their impact on water quality, biodiversity / ecology, income / economy and tourism / aesthetics. To achieve comparability between the different indicator systems and formats, which are used for impact analysis, a scale from 0 (= most negative effect) to 100 (= most positive effect) was introduced, to which all results from expert knowledge and publications were referenced. Temporal aspects (i.e. changing impact with ongoing development of a land-use specific ecosystem) and neighbourhood relationships (e.g. changed impact in dependence from the neighbouring land-use forms) were not yet considered in this analysis. The following sources were used:

- *water quality* – expert consultation (Helmholtz Centre for Environmental Research - UFZ, Dept. of Landscape Ecology (Leipzig, Germany); TU Dresden, EUREX working group water)
- *income / economy* – literature analysis (forestry: “Wald-Verkauf nach dem EALG den fünf neuen Bundesländern. Dreifache Ersatzeinheitswerte für Waldflächen in EUR/ha.” BVVG Bodenverwertungs- und -verwaltungs GmbH, MoritzDruck, Berlin 2002., Statistisches Bundesamt Deutschland, SBD Internet: www.bundeswaldinventur.de, pasture: - “Deckungsbeitrag II für Stilllegung”, SMUL “Veränderte Landnutzungssysteme in hochwassergefährdeten Gebieten” Heft 12 10. Jahrgang 2005, agriculture: Bayerische Landesanstalt für Landwirtschaft Internet: www.lfl.bayern.de, Statistisches Bundesamt Deutschland, SBD Internet: www.bundeswaldinventur.de) and expert consultation (wetland, waterbodies and grassland, urban and industrial areas (Helmholtz Centre for Environmental Research - UFZ, Dept. of Landscape Ecology (Leipzig, Germany); TU Dresden, EUREX working group water))
- *biodiversity / ecology* – literature analysis (Kompensationsverordnung – KV “Verordnung über die Durchführung von Kompensationsmaßnahmen, Ökokonten, deren Handelbarkeit und die Festsetzung von Ausgleichsabgaben“ laut Hessische Naturschutzgesetz., Statistisches Bundesamt Deutschland, SBD Internet: www.bundeswaldinventur.de)

- *tourism / aesthetics* – expert consultation (Chair for Strategy and Landscape Development, TU Munich)

3 Results

3.1 User needs analysis

The results from the Delphi study proved that in general all kinds of information sources are used to make decisions and that no particular preference could be noticed for any specific information source (question A). However, for the planning and decision process, computer- and communication supported instruments are clearly preferred against paper based instruments (question B). Here, GIS and Office solutions were the most common instruments to design planning processes and to support decisions, followed by databanks and paper based map-material like forestry-, forest-function-, and biotope type-maps. Further options were special report programs from internal information systems. The definition of an "optimal system" seemed to be very subjective (question C). Especially in the first stage of the Delphi study, the experts proposed a wide range of "optimal" solution possibilities. In the second stage, online-portals and professional information and expert systems were most popular, followed by best practice manuals and decision trees. Stage 2b of the Delphi study revealed training effects: Compared to stage 2 including all experts, the participants of the workshop on existing management support systems gave in question C a higher score to so called "New Formats". They gave also a more detailed description of what they understand by an optimal solution: a computer-based tool for visualizing and evaluating effects of regional planning measures focussing on changes in the land-use form and including recommendations for best practices and land-use management. The tool was demanded to be simple to use, to be designed in the form of a computer game and it should be accessible for anyone at anytime.

3.2 Expert consultation and literature analysis

Expert consultation and literature analysis resulted in a table estimating the region specific land-use pattern impact on regional land-use functions. In the Euro-Region Neisse, water quality, biodiversity / ecology, income / economy and tourism / aesthetics were defined as major land-use functions (Tab. 1). The land-use types were defined on the basis of the CORINE LAND COVER (CLC) 2000 classification. Fig. 2 describes the process of regional adaptation and abstraction of the CLC 2000 classification to a reduced number of land-use types, which were evaluated in P.Y.L. The reduction of the numerous CLC 2000 classes was necessary, because expert knowledge and published indicator systems did not support the impact assessment of all land-use types.

Bundling expert knowledge and knowledge from publications on the impact of different land-use types on landscape functions brought up another problem: The indicator sets used for different land-use types showed a brought variety. This complicates a comprehensive referencing of the land-use impacts on the described scale from 0 to 100 and demands for further research. Tab. 1 should therefore be considered as suggestion with regional reference to Euro-Region Neisse and not as generalizeable proposition.

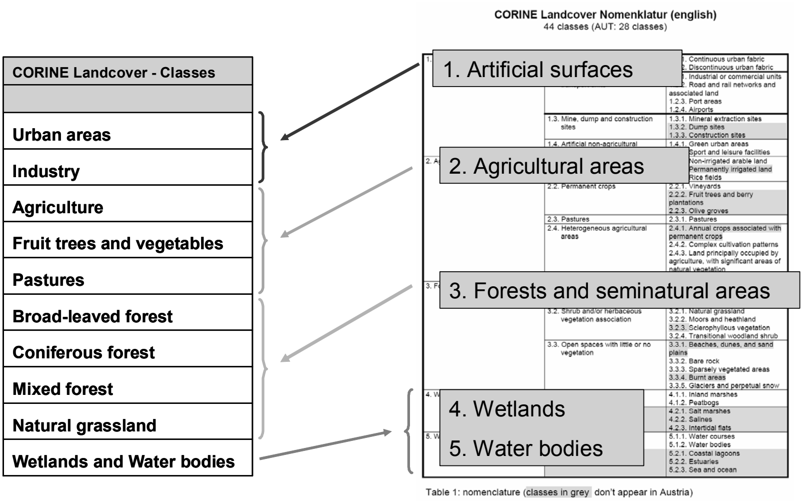

Figure 2: Regional adaptation of the Corine2000 classification as basis for evaluating the impact of land-use types.

Table 1: Regional evaluation table for land-use form impact.

CLC 2000 land-use forms	**value for land-use function**			
	water quality	*economy*	*ecology*	*tourism / aesthetics*
urban areas	0	100	0	0
industry	0	100	0	0
agriculture	20	80	30	20
fruit trees and vegetables	30	75	35	40
pastures	60	60	35	50
deciduous forest	80	30	100	80
coniferous forest	50	40	60	60
mixed forest	80	35	100	90
natural grassland	70	5	100	90
wetlands & water bodies	100	5	100	100

3.3 Conception of P.Y.L. – user interface and technical development

Based on the Delphi-study results and the paper based version feed-back, P.Y.L. was developed as a web-tool for simulating and training the effects of land-use pattern changes. Information on the land-use pattern is based on CORINE

LAND COVER (CLC) 2000 maps (spatial resolution 100*100 m² = 1 Pixel). Additionally maps of highways and water bodies are extracted from the topographic map of the region in the scale of 1:100.000. The maps are divided in sections of 10 x 10 km size and transferred into GIF-format to reduce the transfer time to the browser of the user. Each pixel in the maps represents the dominating land-use type of the 100*100 m area. By clicking a pixel it is possible to assign a new land-use type: a selection box pops up with the land-use forms to be chosen. A click on the desired land-use type (e.g. coniferous forest) assigns this new land-use form.

The impact of each land-use type on water quality, income / economy, biodiversity / ecology and tourism / aesthetics based on indicator sets and expert knowledge is ranked on a relative scale from 0 – 100 (cp. section 3.2). A legend, which can optionally be activated by mouse click, informs the user about the colours of the land-use types and their impact value for the different land-use functions on the scale from 0 - 100. For the displayed map segment, the average values for water quality, economy / income, ecology / biodiversity and tourism / aesthetics are displayed as trend table and in the form of a star diagram. The average values result from the number of pixels in the segment, the assigned land-use forms and their impact values according to Tab. 1. Changes of the land-use pattern are permanently visualised in a trend table in form of trend arrows (tendency: upwards / downwards / remaining equal) and in a star diagram, where the comparison to the start situation is highlightened by coloured graphs. Regional minimum values for each of the land-use functions can be introduced in order to demonstrate undesirable development trends (e.g. unilateral maximization of economy without consideration of ecology). At the beginning, a dummy value of 20% of the actual average value is set for each of the land-use functions, which however can be changed by the user. The thresholds are displayed in the star diagram as red dots, and respectively in the table as “critical value”. Any exceedance of this threshold results in a warning message and the “critical” move can be revised. The user however has the option to continue also without revising the move: this opens the option to compensate the momentary threshold exceedance by subsequent moves.

P.Y.L. is designed as combined game / expert system. The game modus is thought for users without professional background, who would like to acquire basic knowledge about effects of land-use pattern changes in their region. Here, experimental experience and fun in using the tool are the leading development vision to motivate the users. In the game modus, users are allowed to make any change of the land-use form and pattern, they want to test. At the start of the game modus, the users are asked to assign an optimization target, i.e. they must decide which of the land-use functions is defined as target function. To create a “game feeling”, the playing time is limited: the user can choose between a playing time from 1 up to maximally 10 minutes and after the first click on a pixel, the playing time runs. It is possible to play against other users, when choosing the same map, target function and playing time. In this case, a score list is displayed at the end of the game, ranking the users according to their results in maximizing the target function and the number of moves they needed for. To quicken the game, the user can choose between different raster sizes (1*1 = basic resolution of 100*100m², further options vary from 2*2 until 16*16): this offers the possibility to change all pixels in one raster with one click, assumed they belong to the same land-use form. Independently from the raster sizes, the basic resolution of 100*100 m is used to calculate the number of moves in the game. At the end of the game, it is possible to look once again at the game process in slow motion by mouse click on “Replay”. This option is thought to enable the user to visualize the planning process and to see with which moves he achieved the end result. Fig. 3 shows a screen shot of the game modus.

The expert modus was conceived for regional planners and professionals from forestry, water and environmental management. The development vision was to provide a tool for training and exchange on planning targets. The expert modus offers the user a wide range of modification possibilities in the game environment by the administration level. Here, the users are allowed to modify and to introduce their special estimation on land-use form impact on land-use functions.

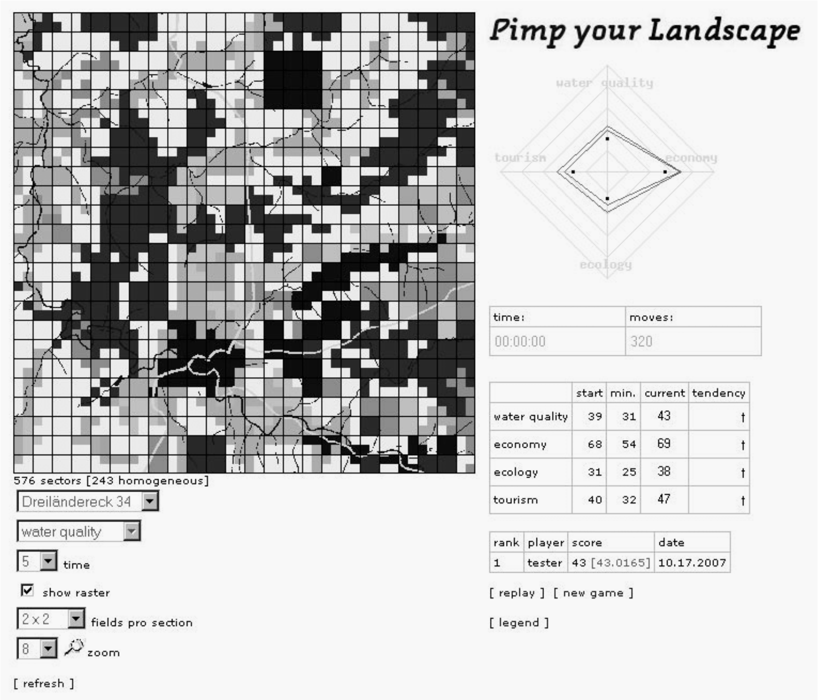

Figure 3: Screen shot of the P.Y.L. game modus.

They can also set minimum / maximum thresholds for the average values of each land-use function in the region, which cannot be exceeded for the regional land-use functions to avoid unilateral optimization. The administration level provides therefore a matrix for flexible rule handling and a module for modifying the evaluation table and the minimum / maximum thresholds. This modification options in the expert modus affect also the functionality in the game modus: it is possible to adapt e.g the evaluation basis of P.Y.L. to a specific regional situation through expert knowledge and to use the game modus as kind of participatory e-Government tool to enable the exchange between expert driven and citizen desired regional development. This is actually tested in the context of open cast mining restoration in the vicinity of Markkleeberg.

In the expert modus, rules are introduced, which represent restrictions in the free development of the land-use pattern given by regional planning targets or EU-directives such as EU-WFD, Natura 2000, EU Soil Protection Directive or the Biodiversity Convention. The restrictions for changing the land-use pattern in dependence from the land-use form and its localization to neighboured land-use forms were transferred into allowed or forbidden moves. Taking Natura 2000 as an example, e.g. forests, natural grassland, wetlands are not allowed to be changed. A minimum quota of x% of natural grassland, forest and wetland must be kept (threshold). Coniferous forest is allowed to be transformed into deciduous forest but not vice versa. These rules can be adapted by the user on the administration level of P.Y.L. In the expert modus, no time limitation is given. The pixels can be changed as long as the rules admit it. Only the user decides when he has reached the optimal situation. After 50 moves the user has the possibility to click on “Replay” to look at the previous game-process. Furthermore, the user can intervene in the “Replay” process and thus change moves he did before. This is advantageous in cases where he doubts about the usefulness of decisions for planning targets referring to the displayed results in the trend table and the star diagram. This avoids the necessity to start P.Y.L. again at any time when the user is not satisfied with his results.

One of the major development challenges of P.Y.L. was the combination of permanent and modifiable map details without using GIS functionalities with their extremely high complexity. Furthermore, it was demanded that each pixel should contain the full information not only about the major land-use type but also about the presence of permanent details like water bodies, streets, etc. Therefore, a colour code management enabling the identification, administration and allocation of colour codes was introduced. Furthermore, a map management module was integrated. The module supports displaying the proportion of the landscape-maps. A main functionality is linking information on permanent details like streets, water bodies and railways with the pixel properties. This data aggregation technology allows for an optimised loading time of the maps and a fast actualization of the land-use pattern per mouse click. Additionally, zoom functionality is supported, which helps the user to adapt the game surface optimally to his technical facilities (e.g. size of the screen). Also the handling of different raster sizes for enabling large scale changes is a result of this special aggregation technology.

4 Application areas and development perspectives

4.1 Application areas

P.Y.L. is a powerful instrument to demonstrate effects of changes in land-use pattern. P.Y.L. can easily be adapted to any region considering the map material, the evaluation basis, planning restrictions and the land-use functions to look at. The main aim of the here presented tool was to create a discussion and conflict solution basis for regional planning stakeholders in the Euro-Region Neisse. Their major interest was how to deal with border crossing planning restrictions resulting from Natura 2000 and EU-WFD.

In a respective workshop, experts from water management, nature protection and forestry from Czech Republic, Germany and Poland were asked, to optimize the land-use pattern according to their needs (a) without any restrictions and (b) with planning restriction. Fig. 4 shows the results from this test.

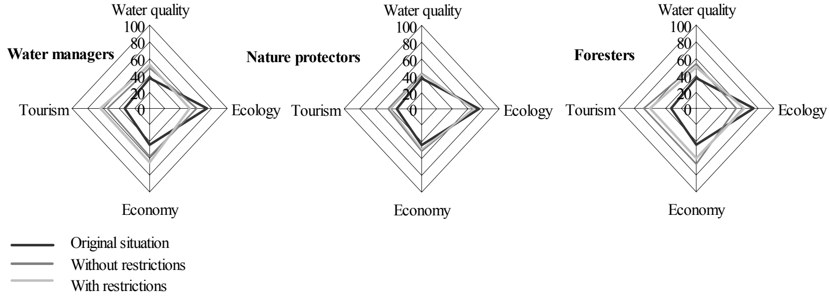

Figure 4: Evaluation results of a stakeholder test run with experts from water management, nature protection and forestry.

All three groups followed different planning visions and experienced the effects of planning restrictions. The water managers achieved almost a balance of the four landscape functions with and without planning restrictions. The group nature protection avoided major changes in the land-use pattern and learned from the evaluation results that their strategy endangered their target to increase the function “ecology”. The foresters experienced that especially the planning restrictions of Natura 2000 restricted slightly their intention to increase the function “economy”. At the end of the test, the groups achieved a compromise for an optimal land-use pattern, which satisfied the needs of the different stakeholders and considered the different national planning targets in the three country corner of the Euro-Region Neisse. Apart from the use as transboundary land-use management system, P.Y.L. can also be used for participatory approaches in regional planning. One example is open cast mining restoration in the vicinity of Markkleeberg near Leipzig. Here, the expert modus is planned be adapted to the regional experience and knowledge in land-use form impact on ecology, regional income, regional recreation facilities and water quality. The game modus is used as e-Government tool and allows the citizens to test their visions of how to design the former open cast mining area and to make propositions to the regional planners. The evaluation functionality of P.Y.L. supports in this case the citizens to argue better, why they propose a certain planning alternative, i.e. which target function they wish to be optimized. In the vicinity of Dresden, P.Y.L. is planned to be used to test different land-use pattern with regard to their effects on the regional climate change mitigation strategy.

Here, expert knowledge, measurement costs and government aid possibilities will be brought together to identify regional activity corridors and to propose a land-use form overlapping development strategy for policy support.

In the context of the EU-programme "Education for sustainable development", P.Y.L. is proposed to be adapted for the application in environmental pedagogic in the border area between Czech Republic and Germany of the Euro-Region Neisse. The intention is, to train the ability of pupils to understand complex ecosystem processes in landscape context and to further the trans-national exchange between regional education facilities.

4.2 Development perspectives

Test runs of the version 2.1 (web-tool) revealed a number of user demands and development perspectives of P.Y.L. One of the major challenges to be realized is the consideration of neighbourhood relationships between the different land-use forms and localization effects of a distinct land-use form in the landscape. This would help to evaluate more realistic the impact of land-use pattern changes on the landscape functions. Furthermore, temporal effects, e.g. changing impact of a land-use form such as forestry on a land-use function such as water quality over time should be considered in the future. Here, research on suitable indicators, indicator systems and approaches of comprehensive bundling of different indicators is an ongoing task in the P.Y.L. development. Much easier to be realized in the future are some technical demands such as zoom functionality in the maps, help desk and multilingual support. A precondition for broader use of the web-tool is the optimization of the map material. Actually, a predefined set of maps based on CLC 2000 is integrated in P.Y.L., which does not yet allow for a free choice of the region to be considered. Here, further technical development and linking to open access material is necessary. The future vision is to combine P.Y.L. with web-GIS applications in the context of e-Government solutions.

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