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ABSTRACT

A steadily growing repository of publicly available land use and land cover (LULC) data holds great potential for addressing pressing challenges, e.g., associated with climate change or profound societal and economic transformations. However, significant portions of this data remain underutilised. This article exemplifies the practical applicability of harnessing such data for advancing spatial planning within the Rhineland mining area, Germany – a region currently undergoing significant structural shifts induced by the upcoming coal phase-out. The study features a three-pronged approach, integrating and overlaying numerous diverse datasets. First, we conduct a comprehensive assessment of ecosystem services (ES) in the region (1). Moreover, we present an evaluation of areas (un)suitable for future settlement development based on multiple constraints (2). Finally, we offer community-level analyses assessing the most suitable future land use focus, considering current LULC and ES information presenting three primary options: settlement, agriculture and natural/recreation (3). Findings are conveyed at various levels of spatial and informational granularity. We show spatially differentiated patterns of combined ES pronunciation, constraints for settlement development, and the suitability for the mentioned land use categories being meaningful in both the detailed and the reduced representation. This accommodates distinct planning requirements and audiences, spanning from regional to urban land use planning and from informing laypersons to providing knowledge to planning professionals. The approach possesses wide-ranging applicability and adaptability. It should encourage practitioners/planners to explore untapped potentials within open data for shaping planning processes and informing stakeholders. Primary benefits include objectifying and optimising planning processes while promoting their acceptance.

ARTICLE HISTORY

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1. INTRODUCTION

Challenges for urban and regional planning arise from a number of processes and factors varying in composition and relevancy with the respective geographical and societal setting. Climate change and its effects can be regarded as almost universally affecting planning. For Europe, according to the most recent IPCC (Intergovernmental Panel on Climate Change) assessment report (AR 6), amongst others, rising temperatures, heat extremes and heatwaves, decreasing cold extremes, and changing precipitation patterns characterise the expected consequences of climatic changes. Adding to that, the sub-region of Western and Central Europe, including Germany, will also encounter more pluvial and river flooding on the one hand and more droughts on the other hand (Intergovernmental Panel on Climate Change [IPCC], 2021). Additionally, there are society-based developments like the ongoing demographic aging in Germany, which recent immigration of predominantly younger individuals could not significantly slow down (Statistisches Bundesamt [Destatis], 2019). Finally, former industrial or mining regions feature a further set of challenges arising from the necessary structural changes after the end of the industrial era. In Germany, the Ruhr area, the country's former coal and steel powerhouse, is still in its transition (Kiese, 2019; Röhl, 2019). For the Rhineland mining area in the western part of North-Rhine Westphalia (NRW), the critical phase of transformation will start with the end of coal mining, while planning for the time after is already gearing up (Berkner et al., 2022; Greiving et al., 2022).

Besides challenges, e.g., in the form of changes just mentioned, increasing in numbers, diversity and urgency, the toolbox with the means for tackling and managing them is not stagnant either. An abundancy of (geo)data with land use and land cover (LULC) information has been and is becoming freely and easily available, enabled, amongst others, by initiatives like the global collaborative and open-source mapping platform OpenStreetMap (OSM) (OpenStreetMap contributors, 2023), the EU-wide INSPIRE directive (INSPIRE Directive (Infrastructure for Spatial Information in the European Community), 2007), or the open government framework in NRW on the regional level (Ministerium für Heimat, Kommunales, Bau und Digitalisierung des Landes Nordrhein-Westfalen, 2023).

In the face of an accelerated coal phase-out in the study area regarded here (see below), the pressure on politics and planning to provide viable and sustainable visions for the region is increasing. While managing and deciding under a variety of changing circumstances is everyday business in planning, the described bundle of challenges, from climate change to the end of coal mining, raises the expectations towards actors and stakeholders involved in the respective planning process. Efficiency and reliability in every aspect are thus essential more than ever. This is particularly relevant for the establishment of data foundations as a basis for further discussion and implementation. In this paper, we intend to showcase exemplary best-practice applications of open (geo)data on LULC to enhance successful planning in a heavily changing area that is facing a variety of demands arising from structural changes induced by the coal phase-out (e.g., population and employment changes) and beyond (e.g., climate change) as mentioned at the beginning of this chapter. Currently, there is limited research focused on the nexus between open data and urban, spatial or landscape planning (assessing the potential and challenges of open data in China: Hao et al., 2015; Long & Liu, 2016). We concentrate on open space and regional land use planning. Hereby, besides landscape metrics (Walz, 2011), the concept of ecosystem services (ES), which can often be analysed with open data, plays an important role (see, e.g., Albert et al., 2014; Albert et al., 2016; Babí Almenar et al., 2018; Deppisch et al., 2022; Galler et al., 2016; Grunewald et al., 2021). We apply the ES definition provided in a previous publication (Klopfer et al., 2022), based on seminal publications in ES research (Costanza et al., 1997; MEA, 2005; TEEB, 2010), according to which we understand ES as advantages that people directly or indirectly derive from ecosystems and which can be assigned a value. Although the ES concept facilitates an improved understanding of ecosystem functions and their communication, as underscored by practitioners (Grunewald et al., 2021), its integration into the planning process remains nascent. When considered, it is often done in a restricted and non-binding manner (Ronchi, 2021; Wei & Zhan, 2023). Moreover, ES research appears to prioritise methodological and conceptual studies over practical applications, as indicated by findings from Longato et al. (2021) and Qiu et al. (2022). This is particularly remarkable, as mapping and modelling, integral components of ES presentation, offer a valuable evidence base for planning and decision-making (Wei & Zhan, 2023). Overly technical implementations can compromise user-friendliness, problem orientation and accessibility, with a tendency to prioritise the scientific aspect over audience and stakeholder engagement (Wei & Zhan, 2023). In the context of nature-based approaches, generally, mainstreaming to improve implementation in urban environments is also described as an intricate process (Adams et al., 2023). We chose the ES approach here over more recent concepts like Nature's Contribution to People (NCP) (Díaz et al., 2018), as, after a long phase of concept and methodology building, there is a strong demand for practice applications since the concept has already gained traction (Burkhard et al., 2023).

As previously indicated, planning and analyses within its framework serve multiple uses. Especially for contested planning projects, it is crucial to engage in good communication. In German planning, participation is profoundly rooted (Hague et al., 2003). For example, it is prominently featured in §3 BauGB (federal building code) regarding zoning plans (*Bauleitpläne*) (BauGB, 2023/last modification by Art. 1 G 07/280/2023 I Nr. 221). Hereby, the quality of communication influences the acceptance and the stance of the informed (e.g., regarding a national park: Fienitz et al., 2022). Emotions play an often underestimated role in planning processes while plans should offer both emotional and cognitive meaning to be appealing, and emotions are found especially influential in communication processes (Hoch, 2006). To ensure objective, comprehensible information for this type of communication, data and material need to be tailored for the purpose. One factor that is adjustable and should be adapted to the respective audience is the complexity and level of detail of analyses presented. For exemplary assessments, our study shows how that can be taken into account, without losing relevant information. We present both a detailed and a complexity-reduced version of every evaluation done in the framework of the article to be able to react on potential audience needs. Various levels of detail can be beneficial for planning and communication projects by addressing the diverse emotional responses and intentions of individuals. This is especially important for planners, who tend to ignore emotions and thrive to act entirely rational (Baum, 2015). In this context, the ES concept is credited with the ability to provide a sound, objective communication base while simultaneously addressing the demand and supply of selected services for a variety of stakeholders (Mager et al., 2022).

Our study area (see Figure 1) comprises the counties of Düren, Euskirchen, Heinsberg, the Rhein-Erft-Kreis, the Rhein-Kreis-Neuss, the district (*Städteregion*) of Aachen as well as the City of Mönchengladbach. Being entirely part of the federal state of North Rhine-Westphalia, the study region borders Rhineland-Palatinate in the south and Belgium as well as the Netherlands in the west. In the east, the river Rhine with the major cities of Cologne and Düsseldorf partly represents the boundary. The central and the southwestern part of the region are heavily forested (including the Eifel low mountain range). Currently, based on data from the Basis Digital Landscape Model (Basis DLM) (BKG, 2020), the study area comprises approximately 78.7% open spaces (all areas outside settlement or traffic areas). When excluding forested areas (including groves), the remaining open spaces account for 54.3%, leaving 24.4% for forests and groves. Agricultural use covers 52.2% of the area, with cropland alone making up about 37.7%. Water bodies occupy only around 1.4% of the total area. The region is characterised

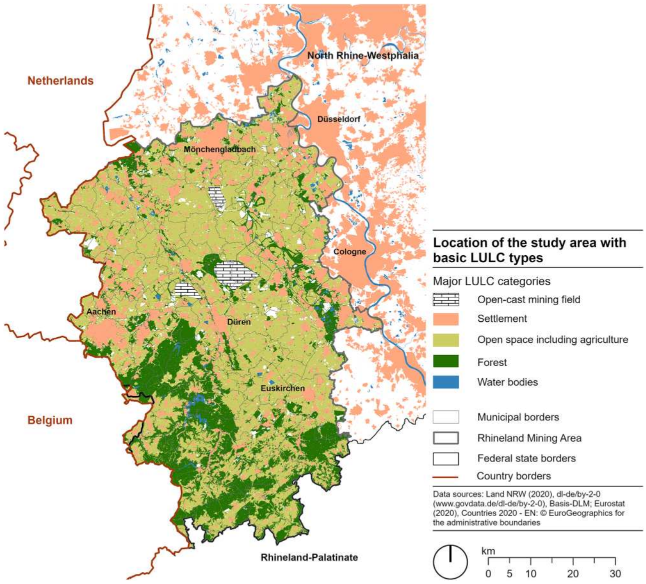

Figure 1. Location of the study area featuring major LULC categories.

by a dominance of open space in contrast to settlement and traffic areas, with agricultural land use, particularly cropland, prevailing.

The soon to be post-mining landscape of the area features a very special setup for regional and local planning. Post-mining landscapes usually exhibit previously unknown landscape structures due to the substantial changes taking place (Zukunftsagentur Rheinisches Revier [ZRR], 2019). Special attention should be directed toward conservation, protection and restoration of often times multi-functional open spaces (e.g., for reforestation: Avera et al., 2015; Hüttl & Weber, 2001). Soil and groundwater pollution, as well as reduced stability of morphological structures, are among the potential consequences that may emerge following the implementation of the coal phase-out (Alves Dias et al., 2018; Oei et al., 2020). In the fall of 2022, under the impression of the Russian attack on Ukraine and to ensure energy security, said phase-out, originally planned for 2038, was shifted ahead by eight years to 2030 (MWIKE NRW, 2022). Thus, planning for the post-coal future has become more pressing than ever. Owing to ongoing structural changes, the area has seen increased research activities. Many future-oriented concepts and strategies exist on various spatial levels, mostly rather local and thematically narrow (Klopfer et al., 2022). Here, the *Zukunftsagentur Rheinisches Revier* (regional development agency Rhineland mining area) (ZRR) can be seen as a key player, bundling and evaluating relevant open space concepts and strategies situated in the study area or at least substantially touching it (ZRR, 2019). In this context, the Economic and Structural Programme 1.1 of the ZRR (WSP = *Wirtschafts- und Strukturprogramm*) holds a pivotal role. It includes guidelines and goals for the region, it summarises all the fundamental strategies and objectives for a successful structural transformation in the Rhineland region and brings together harmonised solutions for impending challenges (ZRR, 2021). Missing, however, is a spatially explicit analysis efficiently utilising available data to help realise the abovementioned concepts and strategies. For any transformation of the agricultural or building sector, e.g., it is important to know where action should be taken. However, in this article, we do not promote any kind of data supremacy, but hold it crucially important to exhaust all resources, especially utilising all the lower hanging fruits, to quickly gain reliable insights.

In order to illustrate the applicability of data on future land uses derived from various open sources in the planning process and its potential to inform and convince the stakeholders involved, including the public, we chose three analyses, each with a distinct topical focus. These stand exemplarily for the breadth of use cases. Furthermore, all three touch on challenges of the study area arising from structural changes and beyond (see above). First, we present a comprehensive assessment of combined ES in the study area. Hereby, highly multifunctional and thus sensitive to negative influences areas should be identified. Depending on the context, the analysis can be used as a raster with 25 m cell size or aggregated to the community (municipal) level. To further reduce complexity, we offer a simplified map that only depicts whether a certain area's evaluation is above or below the average level of ES pronunciation. This first analysis does not imply any specific planning recommendation for future land use but is rather intended as a factual information versatile in use. Second, we exemplarily show an analysis that does give direct advice for the planning practice. We do so in evaluating the suitability of land for further settlement expansion according to a set of variables. As for the ES combination described above, the findings and the information given to people involved can be reduced or extended depending on the respective audience or agenda as areas can either be described just with the two categories 'go to' and 'no-go' respective to settlement development. Otherwise, four levels of restrictions and their potential spatial co-occurrence can be shown for more in-depth insights. Finally, we extend our scope to three potential future land use categories that are agricultural use (1), settlement (2) and space for nature and recreation (3). Clearly, these three can only serve as examples out of many possible future land uses. We combine a variety of data and variables to inform about the suitability for the three mentioned land use categories. As done for the ES analysis, a more (25 m raster) and a less (community level) detailed result is provided. Finally, on the community level, the aptitude for the three uses is given in a comprehensive combined analysis. Thereby, communities can be categorised more precisely as suitable for one or two dominant uses.

2. METHODOLOGY

While most of the input datasets are provided in a vector format (e.g., DLM or soil information), a few were only available as rasters: groundwater recharge (100 × 100 m), and elevation model (25 × 25 m). To ensure consistency in data resolution over all our analyses and results, we decided to aggregate all data on 25 m raster cells as the frequently used elevation model features this resolution and, more importantly, as the raster format in general facilitates the extensively executed overlaying procedures. ArcGIS Pro was used for the geographical analyses and cartography (Esri, 2022).

The integrated analysis as an attempt to assess and display the quality and pronunciation of selected ES in the study area was already previously presented in a publication by the authors (Klopfer et al., 2022). The datasets and analyses combined here are thermic compensation function, biomass production potential (soil values), surface runoff regulation, groundwater recharge, groundwater protection as well as recreation and habitat function/services. For more detailed information on calculations and data, see Klopfer et al. (2022). Subsequently, the value ranges of the respective variables are divided into the equal-sized classes 'low', 'middle' and 'high' represented by numeric values from one (low) to three (high). For example, if an input ES features values between one and nine in our study region, we assign the label 'low' to the range from one to three, 'middle' to four to six, and 'high' to seven to nine. Finally, the rasters are overlaid with an equal weight. As we have seven input factors, the value range for the combination reaches from seven (lowest) to 21 (highest). Hereby, high values stand for highly multifunctional areas in which many of the regarded ES feature strong pronunciations. For lower scores, the opposite is true. Finally, we provide another presentation of the data as we create a second map, which shows the combined values in only two categories, above and below the average of all raster cell values.

For the determination of the (sustainable) suitability of further settlement expansion on a certain land area, we map connected built-up-areas (residential, industrial and commercial areas, and others – *Ortslagen*), forested areas, strictly protected areas, biotope networks and soil values above 55 as restricting factors (on a 25 m raster). Thereafter, we create one cartographic representation of the study area where the occurrence of any limiting factor results in a 'no-go' area and one more detailed map indicating the count of restrictions present for a certain region. Zones free of any limiting factor are considered 'go to' areas for settlement development while the rest is marked as a 'no-go' zone.

For the final set of map-based analyses, we consider twelve input factors. For all of them we determine the influence on the suitability for the land use types agriculture, settlement or nature/recreation of a specific spatial unit. We include the surface runoff regulation function, the share of intensively used agricultural land, soil values, the recreation function (result of another combined valuation), the share of water areas and of grass-/pastureland, the groundwater protection function, the habitat function (also already a combination), the groundwater recharge function, strictly protected areas, slope and the share of forested area.

Table 1 shows the evaluation of each factor towards the three land uses with a short justification. It has to be determined how a high value/high valuation of a certain factor influences the suitability for the three land uses regarded. High level is defined here by featuring values that lie in the upper quartile. So, when, e.g., the forested area in a certain community is higher than in 75% of all municipalities regarded, it is considered a high value for forested areas and is thus exerting its specific effect (according to the table) on the land use suitability. There are four levels of influence (strong positive influence on suitability for the respective land use = ++, positive influence = +, no influence/irrelevant = 0, negative influence = –). Subsequently, we build quartiles from the determined ranges of potential summed up values (e.g., for agricultural use the range is from 4 to −9). We first map the valuations for each of the three land uses on a 25 m raster aggregation and also summarised on the community level – categorisation therefore based on quartiles resulting from a spatially weighted mean calculation to obtain one value for each community. Finally, we combine all three datasets in one map. Whenever a community features an upper quartile valuation for any use, representing the best aptitude, it is attributed 'dominant suitability for xy'. The same is valid for a third quartile rating with the suitability a little less distinct (while still above average). When a spatial unit features two land use suitabilities with an evaluation in the third or upper quartile, we assign the respective community a transition zone with two recommended focus uses in the future. The datasets used for the described analyses stem from the German federal state of North-Rhine Westphalia (partly modified from other sources for NRW) (BKG, 2020; Geobasis NRW, 2020; Geologischer Dienst NRW, 2017; LANUV, 2017, 2018, 2019, 2020), the Federal Agency for Nature Conservation (BfN) (BfN, 2010), and the EU (European Environment Agency [EEA], 2016).

Figure 2 provides a flowchart of the described methodological approach. The three analyses featured in the framework of this article are hereby depicted as possible applications utilising a subset from the plethora of open data available to contribute to the abundance of urban and regional planning tasks.

3. RESULTS AND DISCUSSION

The results section is divided into sub-sections presenting and analysing the maps created for the combined ES evaluation (1), the no-go/go to assessment (2) and finally the land use suitability analyses (3).

Table 1. Factors included in the land use suitability evaluation with respective valuations and explanations.

Input factor/ function/ES	Valuation for nature/ recreation	Explanation	Valuation for agriculture	Explanation	Valuation for Settlement	Explanation
Share of intensively used agricultural land	–	High anthropogenic overprint – negative for landscape aesthetics	++	Landscape preconfigured	**0**	Rezoning might be necessary
Share of water areas	+	Presumably closeness to nature and strong aesthetic appeal	–	Water pollution possible	–	Destruction of natural areas
Share of grass-/ pastureland	+	Low anthropogenic influence	**0**	Similar land use	–	Destruction of areas relatively close to nature
Share of forested area	+	Presumably closeness to nature and strong aesthetic appeal	–	Destruction of habitats, deforestation	–	Destruction of habitats, deforestation
Strictly protected areas	+	Closeness to nature, biodiversity, aesthetics	–	Destroys habitats	–	Destruction of nature areas
Slope	+	Dynamic topography often connected to enhanced appeal	–	Not suitable for some uses	–	Issue for settlement/ construction
Soil values	**0**	No discernible impacts	++	High yields expected	–	Destruction of valuable soils
Groundwater protection function	**0**	No discernible impacts	–	Contamination possible	–	Contamination possible
Groundwater reproduction function	**0**	No discernible impacts	–	Contamination possible	–	Contamination possible, land sealing
Flow regulation function	**0**	No discernible impacts	–	Worsened percolation	–	Worsened percolation
Habitat function	++	Biodiversity, close to nature	–	Monotone landscape, less biodiversity	–	Destruction of nature
Recreation function	++	Highly suitable for recreation	–	Conversion of recreational areas	+	Good local nature-based recreation
Range	–1 to 9		–9 to 4		–10 to 1	

Notes: Valuations are: ++ = strong positive influence, + = positive influence, 0 = no influence/irrelevant, – = negative influence. When a factor fulfils the condition of featuring an upper quartile value, a ++ adds two to the total valuation, a + adds one, a 0 does nothing, and a – subtracts one. Thus, e.g., for a settlement with ten –, one +, and one 0, the possible total value range is minus ten to one as depicted in the table.

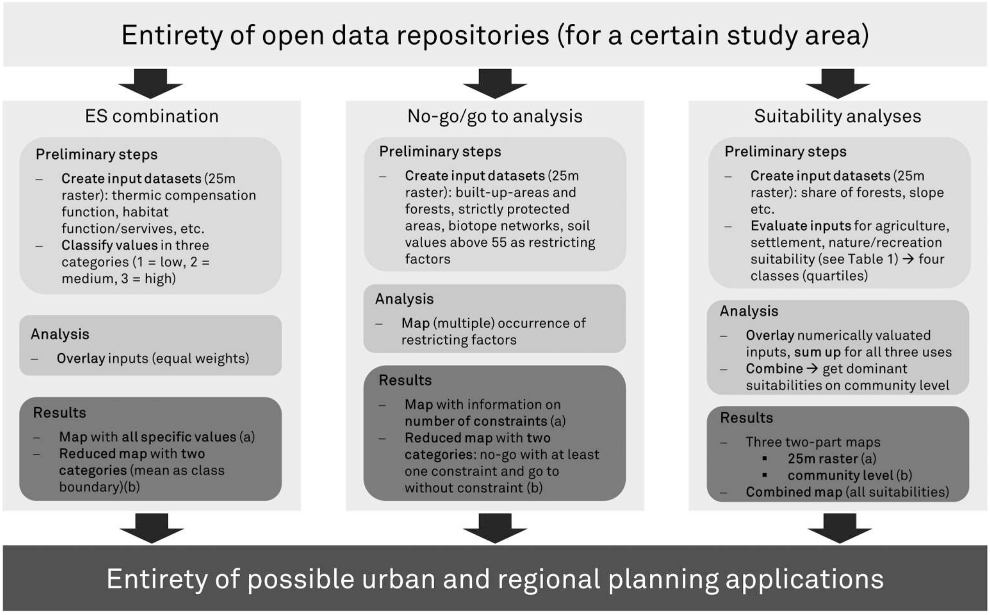

Figure 2. Flowchart representing the methodological steps taken in the course of the analyses featured.

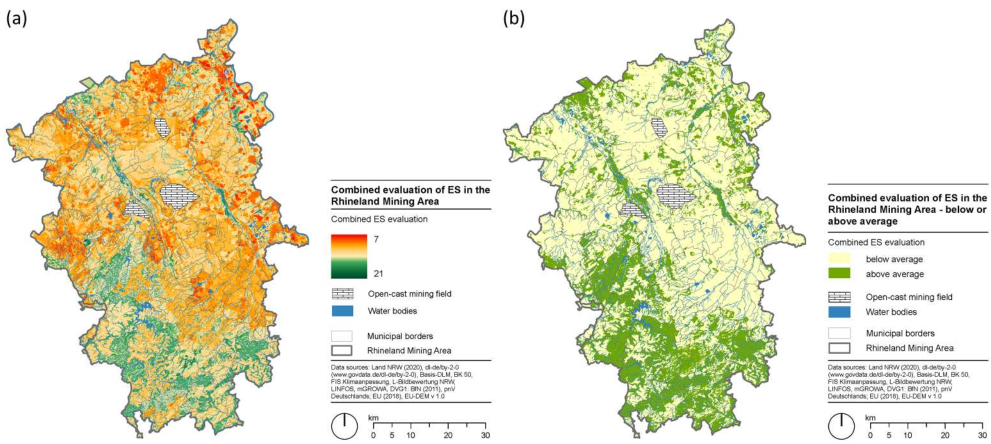

Figure 3. Results from combining seven ES – detailed representation including all specific values (a) and reduced to two categories with the mean as class boundary (b).

3.1. Combined evaluation of ES in the study region

Figure 3 shows the ES based evaluation of the study area that was already featured in an earlier publication dedicated to open space in the area (Klopfer et al., 2022). The region basically exhibits a duality, with its southern and southwestern parts on the one hand characterised by open spaces, forests and highly functional areas with combined ES values up to around 20 and green colours (maximum is 21 – all seven ES valued with three). The northern and northeastern portions on the other hand feature extensive settlements, intensive agriculture and less high quality, multifunctional areas expressed by lower ES combination values and red colours. However, the described division is not strictly homogeneous. In the north/northeast, there are patches and linear structures (often following river or creek courses) of high quality, exhibiting multifunctional spaces. In areas with a high variation in values and intersecting dominant land uses, conflicts can arise. These conflicts might involve overarching fundamental land uses like nature/recreation, agriculture and settlement, which are dealt with in detail below. An exemplary, hypothetical highly contested conflict zone could possess excellent soils for agriculture, might be located within high-quality biotope networks, and planned settlement development areas. From an open space perspective, it is crucial to protect, preserve and eventually expand higher valued zones beyond the larger and rather homogeneous highly functional regions. These 'islands' can be of great strategic value for recreation (particularly in the densely populated Rhine valley, where further population growth is expected) or as valuable links and stepping stones for habitat/biotope corridors within their 'weaker' environments. Especially the future open pit lakes and their surroundings have to be focused since they feature the potential for comprehensive restructuring opportunities. Here, also in recent visions, resulting from the multiple commissioning concerning a spatial strategy (Raumstrategie 2038+), a focus is laid on open space/natural space development within mixed land uses (ZRR, 2022).

While Figure 3a provides a very detailed local observation of ES multifunctionality, Figure 3b facilitates the results. In the latter map, there are only two colourings describing areas that feature above or below average evaluations regarding the ES overlay. In the sense of the above-described audience-related communication, the reduced map can serve as a means to provide a first preliminary overview, e.g., for citizens at a participation or information event, to get an early impression and an easy entry point regarding the data used and discussions to follow. In general, when there is not much time for lengthy explanations or the audience's expertise is rather limited, and scientific details play a secondary role (for the time being) the right map is quite useful. However, for detailed planning and further planning steps, the higher resolved analysis might be the mean of choice. Anyways, the duo gives planners some flexibility and a widened repertoire to fulfil their tasks in communicating, convincing, explaining and so on. It is also imaginable to sequentially utilise both variants during a planning process, starting with the reduced version for introductory purposes and transitioning to the detailed version once a solid knowledge base and discussion foundation have been established.

3.2. Assessing settlement development no-go and go to areas

Figure 4 offers insights on where settlement development in the study area should be located in the future. It is immediately noticeable that there are parallels regarding the location of highly evaluated regions in Figure 3 (ES) and the location of areas featuring three or four no-go constraints in Figure 4a. This is not surprising given the fact that the constraints regarded here are also to a certain degree part of the ES combination assessment. For some areas, the characterisation as no-go or go to region is rather hypothetical as there is no settlement development to be expected. For other areas, like the *Rheinschiene* (Rhine valley), that are supposed to grow fastest in the future, special attention is needed. This is generally true for existing settlement structures that usually feature constraints in their surroundings, as historically, settlement was not always placed under sustainability, natural protection or land use efficiency aspects. Remarkable are highly constrained (three or four limitations present) zones in the neighbourhood of both of the southern pit mines (Inden in the west and Hambach in the east). These areas have to be given particular consideration in the context of the restructuring of the mining landscape (see also previous section on ES). While map (a) features detailed information on where one, two, three or four of the regarded constraints (forests, strictly protected areas, biotope networks, soil values > 55) co-occur, map (b), similar to Figure 3b, only depicts areas burdened by at least one constraint (labelled no-go) in a yellowish colour and areas without constraints (labelled go to) in green. Assuming that all four limiting landscape factors are equally important in hindering planned settlement developments, the right map provides sufficient information without

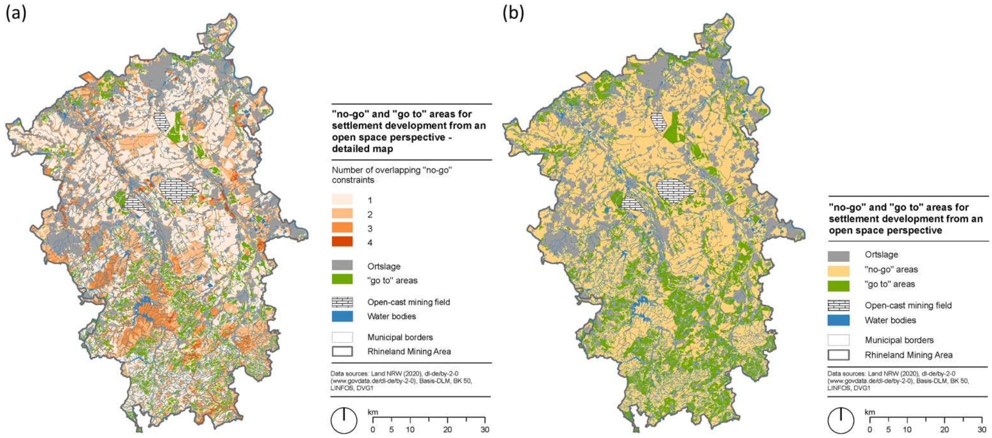

Figure 4. No-go and go to areas for settlement developments – detailed representation including information on the number of constraints at each location (a) and reduced to two categories: no-go with at least one constraint and go to without constraint (b).

complicating things. The left map (a), however, allows for a more profound decision-making basis by presenting gradations in the severity of restrictions. Areas can thus be characterised as being strict (e.g., three or four accumulating restrictions) or soft (e.g., less than three restrictions) no-go areas. Depending on the planning phase or context, like mentioned in the ES related paragraph above, either of the analyses might be the instrument of choice. The detailed analysis furthermore allows for prioritisation based on the number and type of constraint(s) found at a certain place. When, e.g., agriculture is of major (economical, societal and/or political) significance somewhere, the protection of areas with high soil values might be paramount and more important than protecting a forest. The opposite can be true when an ecologically important forested corridor is located in the area of a planned development. Consequently, settlement development would rather be favoured in agricultural areas. These examples also clarify the need for in-depth information on the respective restrictions and the basic direction of municipal development to act accordingly. Naturally, every decision in favour of a specific land use comes with the exclusion or limitation of others and thus conflicts. These are focused below in Section 3.3. The characterisation of potential settlement areas as done here serves as another example for the application of adaptable open data analyses in regional and urban planning contexts. It can be used to inform the land use designations in future regional or urban plans and to compare it with standing regulations. As the plans that's contents have to be coordinated often come from very different times, sometimes decades apart, the most important asset of analyses like ours might be the applicability as an input for plan changes needed to promote a current planning process.

3.3. Overarching land use suitability

The next four figures are dedicated to the land suitability analysis with the first three featuring the land uses/land use categories regarded here (agriculture, nature/recreation, settlement) in detail. Unlike the ES and the settlement go to/no-go analyses discussed above, these assessments do not incorporate content variations at different levels of detail; instead, it concentrates on the level of aggregation. While the left maps (a) show area-specific results, the right maps (b) depict the outcomes aggregated on the community level with the mean values for the municipality categorised in quartiles. Like for the two already discussed analyses, the use in various planning contexts comes to mind. Here, the community level assessments can be seen as

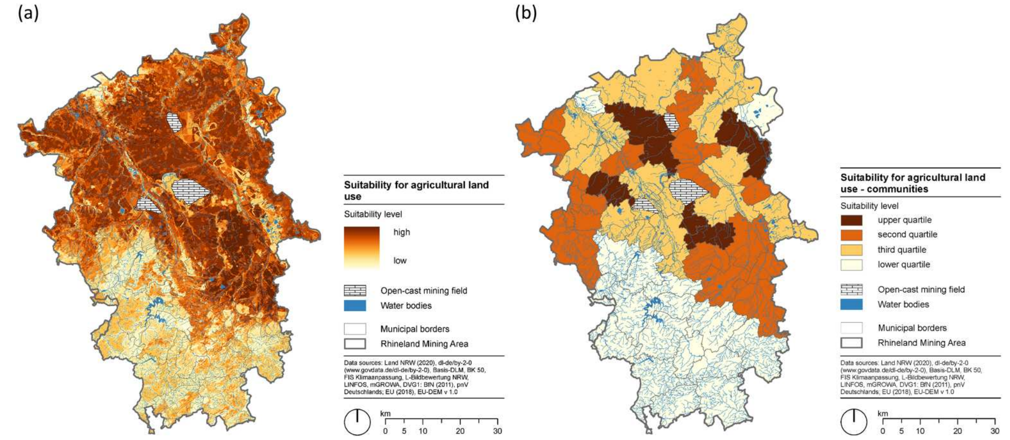

Figure 5. Suitability analysis for a future focus on agricultural land use – 25 m raster (a) and aggregated on the community level (b).

providing general guidelines for superordinate regional planning or to enhance an easy access of any project. Once the framework and the general directions are clear, the detailed analysis comes into play differentiating intra-community variation.

Agricultural land use suitability (Figure 5), as expected, is high in areas characterised by present agricultural uses like in the central east and the north of the study area. Low suitability is found in the rather natural, forested and highly multi-functional (see Figure 3) areas in the southwest and also along the river Rur in the north/central east. High suitabilities near the river Rhine in the east carry the potential of conflict with expected population and thus settlement growth in the area. The detail map clearly shows that transitions between better and worse suitability can be both abrupt and smooth in the study area.

The second set of maps (Figure 6) is dedicated to recreational, nature-oriented land use appropriateness. Here, the south/southwestern part with its forests and protected areas (see once more Figure 3) stands out with high values. High suitabilities in the rest of the study area are only found in smaller patch form. However, these islands, especially those located close to population centres like along the Rhine, are of great importance, as they are most

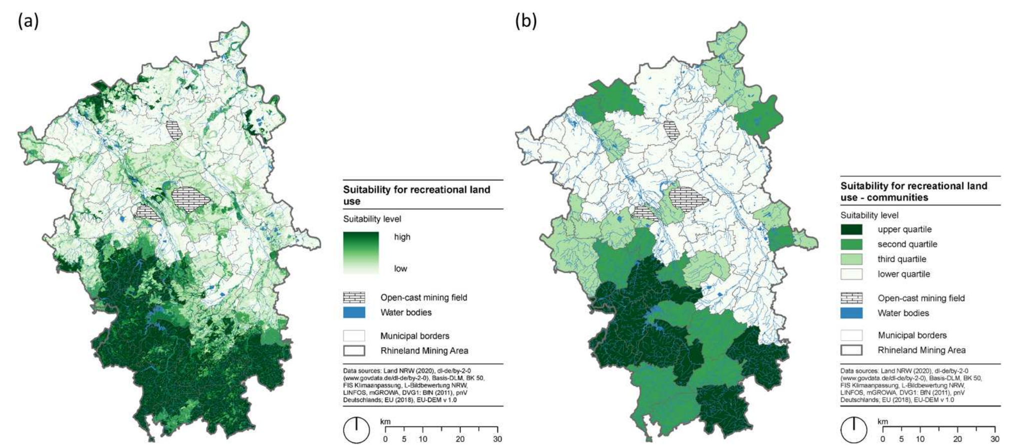

Figure 6. Suitability analysis for a future focus on recreational/natural land use – 25 m raster (a) and aggregated on the community level (b).

desperately needed by large population groups and thus threatened at the same time. This conflict between recreation/nature and settlement structures is particularly delicate as settlements and the dwellers living there need close-by recreational lands. High valued areas around todays open pit mines are also to be considered for future green/blue infrastructure connections and networks including the planned pit lakes and their surroundings.

Finally, settlement suitability is shown in Figure 7. High values are found in the more agricultural regions in the central/east areas and the north that are also suitable for that land use (see Figure 5 above). Zones with lower values are located in the south/southwest where areas that are more natural were identified as suitable for nature/recreational use (Figure 6). Remarkable here is that only parts of the region bordering the Rhine exhibit high settlement suitabilities. Land use conflicts are thus to be expected there. Comparing Figure 7 with the no-go/go to analysis (Figure 4) reveals that here the southwest is generally not appropriate for settlement development while in the no-go/go to map some areas there are constraint free. This highlights the crucial importance of keeping in mind what factors with what weights were used for the respective analysis.

Figure 8 shows the overlay of the three suitability evaluations presented above on the community level. Suitabilities regarding the analysed land use types are split in quartiles and displayed for any municipality once they are in the 4th (upper) or 3rd quartile. Being in the 4th quartile means that the respective community features the highest suitability for the regarded land use and being in the 3rd stands for high a suitability. There are communities featuring one land use suitability in these quartiles and others that are characterised by two land uses in the said quartiles (both in 3rd or one in 3rd and one in 4th). An uncontested clear nature/recreational use focus can be discerned in the southwest with two outliers in the north. Adjacent to the homogeneous region suitable purely for nature-oriented uses in the south, there are two communities that are falling in the 3rd suitability quartile for recreation and agriculture. According to the analysis presented, settlement should be located in the eastern (central) part of the study area where it is heavily contested by agricultural uses (3rd quartile). One community in the central-east of the study area falls in the 4th settlement suitability quartile and the 3rd recreational. Agriculture is often not part of a suitability conflict, but if it is, it is with settlement. In the central eastern zone, 3rd quartile agriculture co-occurs with 4th quartile settlement while otherwise it is mostly agriculture 3rd and settlement 3rd. Two communities in the study area remain without dominant suitability according to our analysis. Most of the planning advice

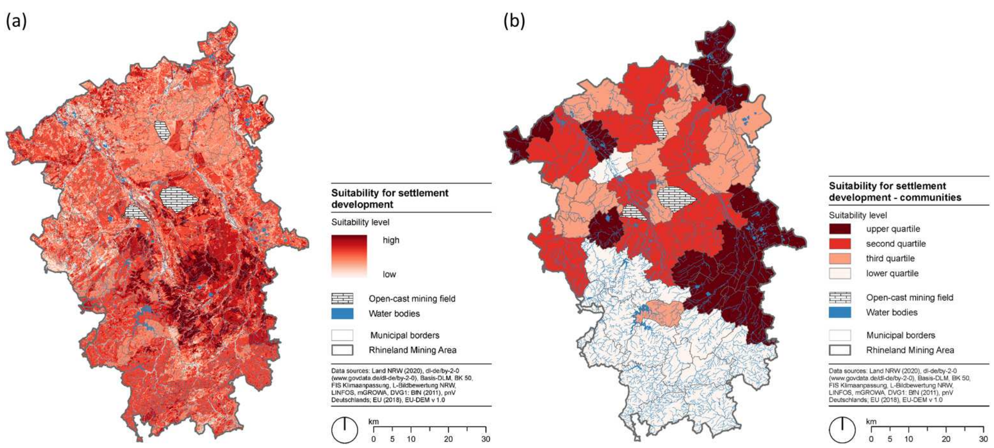

Figure 7. Suitability analysis for a future focus on settlement development – 25 m raster (a) and aggregated on the community level (b).

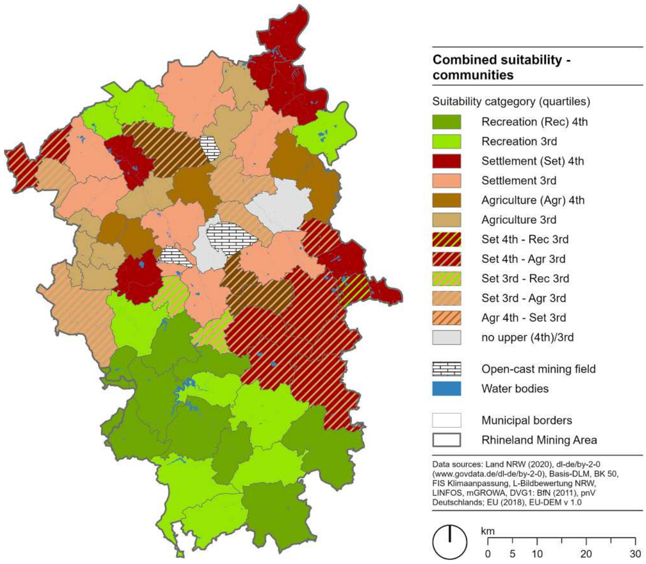

Figure 8. Combined suitability assessment regarding agricultural, nature/recreational and settlement as overarching land uses on the community level.

that can be derived from the analysis at hand regarding future dominant land uses affirms the actual status quo and the anticipated development (e.g., population growth along the Rhine valley). That does not mean, that we encourage a 'leave it as it is' approach to future land use planning as planning also is never fully data-driven and objective. Instead, we advocate for a planning approach characterised by prudence, careful consideration and the incorporation of constraints, especially given the profound changes expected after the coal phase-out. Many communities in the vicinity of the mining pits do not feature single dominant land use suitabilities according to our approach, which leaves room for creativity there as already emphasised in the sections above describing the previous analyses. This is encouraging news for all stakeholders involved in planning the post-mining landscape, as a variety of diverse plans and visions for the zone are feasible in the context of the scope of our analysis. This is generally true also for 3rd/3rd quartile communities where the chosen path for the future depends on political and societal will. It is important to take into account that even an uncontested 4th quartile appropriateness for either land use does not mean this community should from now on focus to become a 100% agricultural, settlement or close to nature/recreational municipality. Hereby, it has to be noted that a dominant suitability for agriculture on the aggregation level of communities does not mean that the whole entity is suited for intensive future agricultural land uses. The overall multifaceted real character of any sub-area in question has to be regarded always. A high suitability can, on the one hand, emerge from a homogeneously distributed high suitability for a certain land use. On the other hand, it can also be the result of a clustered, very high suitability in about half of the community and no dominant suitabilities in the rest. Our results are thus rather to be understood as rough guidelines and decision-making support, e.g., for regional planning, urban land use planning and overarching development goals as to what direction makes the most sense regarding the analysed data.

Besides displaying the wide range of application opportunities of open data in planning processes, our insights contribute to various stakeholders involved. Against the background that 'challenges in ES knowledge's actual use and its effect on policy and practice remain' (Wei & Zhan, 2023, p. 216), we propose an integrative framework that operationalises and capitalises ES (and (open) data in general) in the planning process to overcome the attested 'limited public involvement' (Grunewald et al., 2021, p. 10). Regarding green space planning in Berlin, Kabisch states that a best practice definition is needed for citizen involvement from the outset (Kabisch, 2015). With our dual approach regarding data/result representation (more/less details) we are addressing this issue, while we also extend the conclusion by Grunewald et al. that the wording used when integrating ES in planning practice should be as simple as possible (Grunewald et al., 2021) to the graphical presentation of information. The assumptions made above regarding the application and meaningfulness of various levels of detail are confirmed by the results of Warren-Kretzschmar and von Haaren's study that affirms that various types of visualisation are needed for various phases of planning and spatial levels (Warren-Kretzschmar & Haaren, 2014). Furthermore, providing a better evidence base helps to prevent negative outcomes that may well occur following citizen engagement (Wamsler et al., 2020). Moreover, citizen science regarding ES, which is often limited to sample collection and analyses (Schröter et al., 2017), can benefit from a more efficient way of knowledge dissemination. Finally, our approach, providing data-based information, tailored to audience needs, appears to be a promising strategy to mitigate or even prevent potential problems arising from emotions in planning processes – as described by, e.g., Hoch and Baum (Baum, 2015; Hoch, 2006).

3.4. Limitations

Our approach has its share of shortcomings. Some of the limitations are common to all analyses conducted in the framework of this article and some are individual. While as mentioned above, data availability for a wide range of categories is getting better, for some fields and regions it is still scarce. In the German context, many datasets are provided and curated by one of the 16 federal states, some by counties and some by municipalities. For any study beyond the local, county or state level, this can lead to frustration and potentially insuperable challenges. Generally, however, more and other data as well as variants in weighting of influencing factors could have been included in the respective analyses. Especially for ES calculations, it is always challenging to select and weigh data (van Oudenhoven et al., 2018). In our approach, as we analyse a region encompassing diverse landscapes and conditions, we aim to maintain a balanced emphasis on all aspects. We do so to prevent the undue prioritisation of a particular aspect, which might be more pertinent in one of the numerous sub-regions. It is important to acknowledge that, depending on the specific research focus, assessment standards, legal requirements and political objectives, different weightings and input parameters may be equally valid. For establishing weights as well as to construct hierarchies, diverse techniques and approaches exist. Thus, for further research, the involvement of experts from different research backgrounds such as ecology, sociology, economics or landscape planning in the form of interviews or the utilisation of systematic literature analyses might be beneficial. In addition, combining data of many different sources is a possible cause for uncertainties. As our goal is not to reach the highest level of accuracy in describing, e.g., one ES, but rather to highlight the possibilities the use of open data features for various planning processes, we consider our approach as viable. On a higher level, also our choice of exemplary analyses can be criticised. Nonetheless, we think our compilation demonstrates the fruitful use of open data in planning with relevant examples for the study area. Furthermore, the selection of aggregation levels substantially impacts the results and how they are interpreted, as discussed earlier. The comprehensive suitability analysis exhibits some more specific deficiencies. Here, the evaluation of the inputs was done subjectively based on the authors' knowledge (see Table 1). For future analyses of this kind that might be part of real planning processes, interviews with experts and/or systematic literature analyses could enhance salience. Our valuation system with the four levels (–, 0, + and ++) can also be critically questioned. More categories like adding a '– –' class are thinkable. These shortcomings, however, are at the same time also potential strengths and opportunities as the approach is adaptable to not only varying data availabilities but also to political, societal or planning requirements in the specific situation.

4. CONCLUSIONS

In this paper, we showed how the available diversity of open data on LULC can be utilised to inform planning processes in various ways and for different requirements based on three sample analyses with the Rhineland mining area as the case study area. First, we evaluated open space landscape functionality with an ES combination approach. The insights gained here, inform about highly multi-functional spaces that, especially in less high-valued neighbourhoods, need attention regarding their protection. Second, regarding the specific planning challenge of defining settlement development zones, we presented a cartographical evaluation of where several constraints are found defining the degree to which an area is a no-go for settlements. This representation could inform politics and planning about the feasibility/meaningfulness of planned developments or their integration in regional plans, e.g., as priority zones. Third, we introduced a comprehensive suitability analysis for future land uses with three general development paths (agricultural, recreational and settlement development use). Especially for regional planning and the strategic orientation of communities and regions, this assessment might be beneficial. As we want to cover a wide range of application areas in the realm of planning, we presented the respective results in variants. For the ES and the no-go/go to assessment, we produced two different levels of content granularity, while for the single land use suitability maps, we generated cartographic representations with two different spatial resolutions (25 m raster and community aggregation).

From our results, several insights and conclusions can be drawn. Firstly, through the exploration of three thematically diverse exemplary use-cases, we have demonstrated the potential of open (geo)data to support and shape a wide range of planning needs and tasks – especially those particularly relevant in our study area. Additionally, our approach, which involves providing analysis results adapted from a content and aggregation perspective in the form of maps, underscores the ability to furnish diverse audiences and stakeholders in participation or administrative planning processes with tailored information. Finally, the chosen approach, partly employing ES for information transfer and communication, highlights ES' capacity for objectifying contents (see also Mager et al., 2022) and mitigating the influence of emotions. By implementing all three aspects mentioned – the enhanced utilisation of available open (geo) data (1), variable visual and cartographic communication (2) and the application of ES analyses for knowledge dissemination (3) – we can significantly enhance future planning, making it more reliable, comprehensible and accepted.

To further advance the research presented, the next step could involve the conceptualisation of case studies that simulate or take on real planning processes. This will allow for a more comprehensive evaluation and exploitation of the approach's potential. Such studies may include comparing various infrastructure project variants or calculation methods. Additionally, exploring different study areas with diverse baseline conditions and various dataset compositions opens up further avenues for research. Here, expanding the focus on other countries might be another interesting step. In the European context, nations like Austria that also adopted the INSPIRE directive would be compelling study areas (Federal Ministry of Finance, 2023). Hereby, potentially varying levels of directive adoption could either limit or enhance data operationalisation for planning. Apart from that, countries like Switzerland, that are not bound to the INSPIRE directive, can be intriguing to research. The Swiss national Open Government Data (OGD)

Strategy (Federal Office of Topography, 2023) and its implications for data availability and quality could be compared to the data landscape of INSPIRE countries and beyond. Extending the scope to areas outside of Europe might also provide new insights as open data availability can vary substantially in large nations like China or the US. Moreover, an experimental and scientifically guided implementation within an actual planning project could be the next logical progression. Over the course of this, monitoring the advancement and the outcomes, ex ante and ex post evaluations provided by the involved stakeholders and planning practitioners as well as external observers in the form of interviews or surveys can be integrated. On a broader conceptual level, designing and offering training programmes for administrative staff and planning offices engaged in relevant projects is worth considering. These programmes have the potential to raise awareness towards diverse audiences and their specific demands and needs. Training can also be practical in equipping participants with the skills to discover, integrate and effectively utilise open data for a wide range of planning purposes.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author (FK), upon reasonable request.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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