FunOpEC: Functional relationships between ecosystem characteristics and services – operationalising the concept of „ecosystem condition”

Final report

The interest towards the background analyses to support the applications of ecosystem assessments (particularly for operationalising the concept of ecosystem condition) has been continuously growing in the last years, for which the targets and the main elements of the work plan of the project could be kept. Meanwhile, after the second year, the PI of the project was changed, for which a half-year transition period was needed (waiting also for the financer's decision about the permission on continuing the project). Because of these, and some other topic-related aspects, some modifications had to be made in the workplan (to be detailed below, in the relevant places). And, although the results of the work are available, some of the last written publications are under review or under preparation.

Besides focusing on the preparation of journal papers and conference presentations, we also involved early-career scientists in the work. Some of the results of this project, and also some from the follow-up works, will be parts of the PhD of three young colleagues (Attila Novák, Csenge Lékó-Kacsova, Péter Palásti).

We present our results below in the order of the main and subtopics (parts of the work plan), with the emphasis on presenting the coherence between them, and how the detailed evidence syntheses and field-based studies built upon the results of theroretical groundwork analyses.

1. THEORETICAL GROUNDWORK: RESEARCH EXPERIENCES WITH THE CASCADE MODEL, AND CRITERIA DEVELOPMENT IN INDICATOR SELECTION

1.1. Systematic review of the use of ecosystem service indicators: the aspects of cascade level and spatial anchor

The detailed mapping of the relationships between ecosystem condition (EC) and ecosystem service (ES) indicators (for different ecosystems, ecosystem services and contexts) need the common and clear understanding of these terms, and especially the placing of ES indicators on the suitable cascade level (CL). Another important aspect is the spatial anchor (which shows whether the indicator values are assigned spatially to their source ecosystems, or to the beneficiary communities. We analyzed the existing literature base of ecosystem assessments from the point of view of these two, criteria, which was the first evidence synthesis, carried out in the frame of our project.

The baseline database was a pool of 82 peer-reviewed papers (about ecosystem asessment performed in Europe), which was also used in one of our previous evidence synthesis works (Czúcz et al. 2018). The methodology was a „classical” systematic review (aggregative review with a quantitative approach), with a simple coding system (the CLs with their generally used numbers: 1 = benefits, 2 = actual use, 3 = capacity, 4 = condition; spatial anchor: 0 = indicators that were mapped at their source ecosystems, 1 = indicators that were spatially assigned to beneficiaries). For the identification and classification of ecosystem services, we used the CICES categorization of ESs.

The results show that basically almost all services can be measured at all CLs, but there are some clear tendencies: provisioning services are measured mainly on lower CLs, as they need a considerable amount of human input, and the related benefits are easily observable and measurable (this is the case also for cultural services). In contrast, regulating services function without any human addition and have high mean CLs. This also means a stronger connection of these services to ecosystem capacities. Meanwhile, there are some ESs, which can be characterized with relative large variance in CL scores. These are mainly water-related provisioning ESs (drinking and non-drinking water), but also a few regulating services, like flood control – this can be indicated with the help of landscape characteristics (GIS assessment), or through its estimated benefits. Besides the unclarified theoretical aspects and its high practical relevance, this was among the reasons of choosing flood control for detailed analysis in the relevant phase of the project.

Considering spatial anchor, the majority (>90%) of the mapping studies used the source-anchored approach, but there are some „mixed" cases, with the combination of spatial information linked to source ecosystems with spatial information linked to beneficiaries. This is not misleading, as this comes from the characteristics of the referring ecosystem servcies (like flood control, which is special from the point of view that the demand for the ES can be met by the supply of neighbouring or even distant ecosystems (Syrbe and Grunewald 2017 – also discussed in the project: Vári et al. 2022).

Generally, we could conclude that intuitive interpretation of ecosystem services, or the preference for specific cascade levels in the indicator selection process call for a higher level of stndardization in ES assessments (e.g. clear specification of cascade level for every indicator could be recommended). And the methodological inconsistencies, together with the wide range of possible subjective decisions in the workflow, may decrease the robustness and transparency of traditional quantitative evidence syntheses (this was among the reasons for turning to qualitative synthesis methods, to be discussed later).

The results were published in: Czúcz et al. 2020

1.2. Operationalising the „ecosystem condition" concept: selection criteria in integrated assessments

In the first years of ecosystem assessments and related research activities, the services provided by ecosystems were connected primarily to biodiversity. Later, it was clarified that there are a number of other (biotic and abiotic) attributes, that have major role in keeping the quality, health and service providing capacity of ecosystems. This led to the emergence of the concept of ecosystem condition. Despite the dynamically growing amount of literature and related results containing measured or modelled data on ecosystem condition, there are no clear guidance documents or set of criteria for harmonized work. This would be inevitable for the formation of a much bigger and more representative background database for EC-ES assessments (like that of our project's core task).

The selection criteria were identified in the frame of a collaborative process, based on the results of a small, targeted systematic review. A keyword search was performed in Google Scholar, and after eligibility assessment in different steps, a final pool of 12 papers remained. By interpreting those that were used in this background database, we introduced the following criteria (and groups of them) for the selection of ecosystem condition characteristics and metrics in integrated assessments:

Conceptual criteria: Intrinsic relevance, Instrumental relevance, Directional meaning, Sensitivity to human influence, Framework conformity

Practical criteria: Validity, Reliability, Availability, Simplicity, Compatibility

Ensemble criteria: Comprehensiveness, Parsimony

Our (and other) evidence synthesis results on EC-ES contribute mainly to the Conceptual criteria (Intrinsic and instrumental relevance). The need for the sensitivity of selected indicators is represented in a later phase of the project, in the qualitative synthesis on urban microcliate regulation (data collected on the manipulation of indicators). Directional meaning and framework conformity are essential in practice-oriented applications (like ecosystem accounting). Availability and simplicity often emerge as an aspect in ecosystem condition indicator selection, which was observed also in our detailed evidence synthesis analyses (to be discussed later). Ensemble criteria are taken into consideration mainly in cross-comparison studies on indicator effects and performances (which are very informative for analysis of EC-ES connections, though they are represented in lower numbers).

The compiled list of selection criteria served as a direct input to the methodological document of the System of Environmental-Economic Accounts – Ecosystem Accounts (SEEA EA 2021), which was approved as an international statistical standard by the UN.

The results were published in: Czúcz et al. 2021a

2. THE SELECTION AND USE OF INDICATORS OF ECOSYSTEM CONDITION AND SERVICES IN NATIONAL ECOSYSTEM ASSESSMENTS

National projects have an outstanding role among integrated ecosystem assesments. A large share of related methodological developments have been carried out in the frame of the MAES (Mapping and Assessment of Ecosystems and their Services) process of the European Union, following the related targets set by the EU (EU Biodiversity Strategy 2020 Target 2 Action 5 – EC 2011). Most of the methodological support was provided by an international working (expert) group, in which some members of our research group were represented. The national assessment projects used a quite high amount of funding, and mostly had strong methodological backgrounds. Because of that, their results can provide a good basis for other assessments, practical applications (like ecosystem accounting) and more in-depth analyses in specific subtopics, like ours on EC-ES connections. Therefore (and according to the original work plan of FunOpEC), we treated national ecosystem assessments separately, and analyzed the EC-ES indication questions in detail, as distinct subtasks in our project.

2.1. Application of the cascade model in Hungarian National Ecosystem Services Assessment

The Hungarian National Ecosystem Assessment (MAES-HU) was one of the few national projects, where the cascade model was used not only as a background concept, but with a complete assessment on more than one level. This enabled either the selection or development of ecosystem capacity or service models, using literature-confirmed data on EC-ES relationships, or, if building ES models without explicit EC indicators, the improvement of the relevant knowledge base (possible targets of analysis of EC-ES relationships). The whole MAES-HU project was delivered with the strong involvement of expert and stakeholder inputs (through their repesentatives), which provided a high level of robustness and acceptance of the selected indicators, among interested experts and communities within the country. Based on the completed maps and lists of indicators, and on post hoc theoretical work in our research group, the following findings could be made: the expert groups decided not to regard abiotic components in themselves as reflecting EC, but as biophysical background variables (e.g. physical soils properties, slope) – as they are stable topographic or physico-geographical components, this is in line with the „Sensitivity" criteria, set in our earlier work (Czúcz et al. 2021). And this was needed for the selection of EC indicators, which are interpretable in a normative context (comparison with „Theoretical best possible condition"). Ecosystem service capacity (the potential of an ecosystem to deliver ES) was also assessed and mapped; maximum capacity can also be defined, which is achieved only under optimal ecosystem condition. Together with the assessments of actual use and benefits, these methodological specificities can be summarized in an „extended cascade" model, presented in Fig. 1.

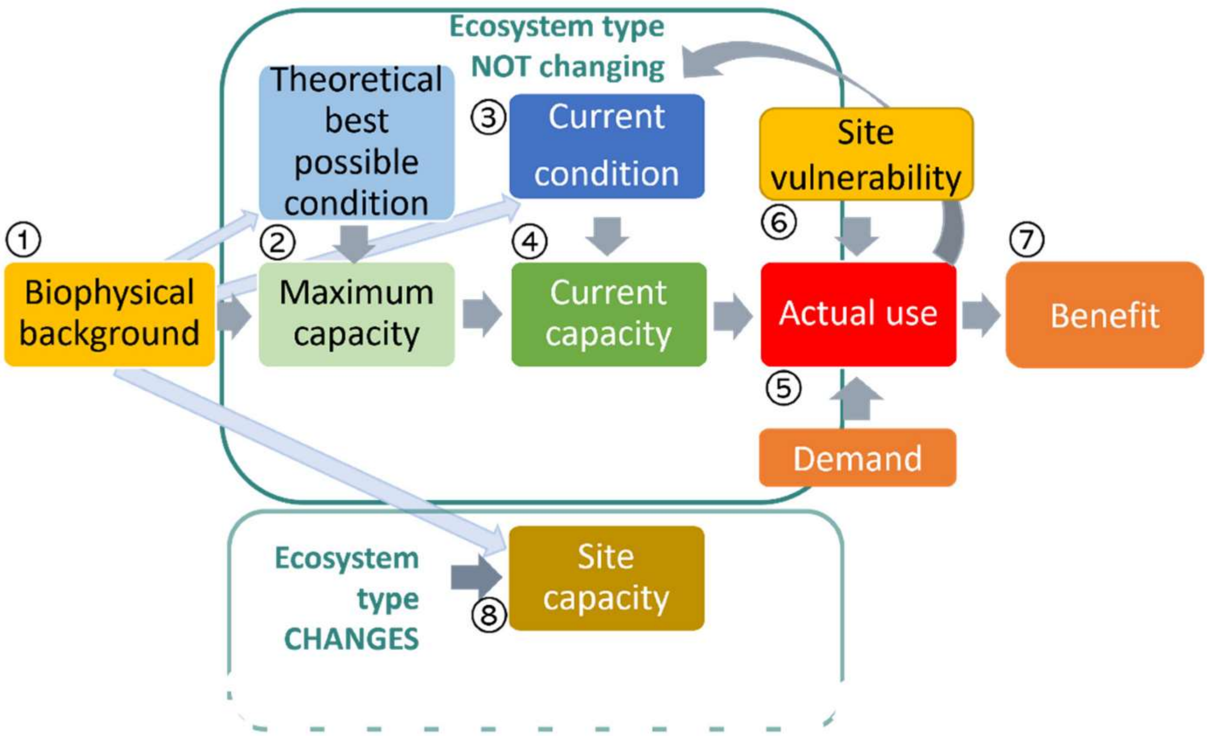

Figure 1.: Extended cascade, suggested as an outcome of MAES-HU assessment: (1) biophysical background as separate from ecosystem condition, (2) maximum ES capacity that is achieved only under optimal ecosystem conditions, (3) the current condition of the ecosystem and (4) the current capacity to deliver ES. (5) The actual use of ES depends on current capacity as well as on the demand from society and can be also influenced by (6) site-specific relevance or site vulnerability. (7) This results in an increase in benefit/human well-being. For all these items, the ecosystem type does not change. If it does, (8) a site capacity can be assessed for a specific ES in a different ecosystem (in terms of what ES could another ecosystem type provide (Vári et al. 2022a)

Two types of ecosystem condition indicators were designed in the relevant parts of the project. „General" condition indicators are not specific for a certain ES, but rather aimed at describing the level of human impact on ecosystems, and ensure the functioning of several ecosystems: soil fertility, naturalness and habitat diversity. The other group of „ES-specific" condition indicators contained metrics, which provide the basis for the production of a specific ES, or have a well-documented influence on it (e.g. share of green spaces and water surface for urban ecosystem services, or carbon stocks for global climate regulation).

As this was the first country-wide assessment, with a number of data availibility issues, some of the selected metrics could not meet the requirements of regular monitoring, and only a limited number of condition (and other) indicators can feed into ecosystem accounts. This aspect has to be taken into consideration in other countries and other cases as well (e.g. in other focused evidence syntheses), when evaluating the potential policy applications of different ecosystem indicators.

The results were published in: Vári et al. 2022a

2.2. The use of ecosystem condition and service indicators in European ecosystem assessments

By the second half of our project (until 2021-22), most of the national ecosystem assessment projects in Europe have come to an end, and the results had been pubilshed. This made the compilation of targeted methodological comparison and synthesis studies possible, about the use of EC and ES indicators. Some members of our research group initiated the sharing of relevant information (among experts from several countries), which was delivered in the frame of two sessions in international conferences, and through an online survey. For EC indicators, the newly developed Ecosystem Condition Typology was applied (Czúcz et al. 2021b) thus being one of the first studies implementing that), and information was collected also about the type of methods applied for assessing EC, and whether EC indicators were integrated into ES models. For ESs, the list of services assessed were recorded, together with information about the levels at which ESs were assessed, the types of methods used, and whether monetary valuation was performed.

Concerning the results, a general observation is that the conceptual framework of the EU MAES projects is becoming more and more harmonised. Ecosystem condition was mapped and assessed in every projects. The most popular ECT classes were landscape characteristics (ECT class C1, used by 85% of Member States), followed by physical state characteristics (A1) and compositional state characteristics (B1) (both used by 77%). Concerning the ES indicators, there is no consistency between the assessments in the use of cascade levels. There is a huge heterogeneity in the number of ESs assessed (between 5 and 56). The most frequently targeted ES s were culticated crops, erosion control, hydrological cycle and flow regulation.

We could conclude that with these series of national assessments, the ecosystem condition has become the leading concept on the relevant level of the cascade (reflecting ecosystem quality and integrity), after the related terms of „structures and processes", „supporting services" or „ES capacity". Though the use of anthropogenic pressure or management variables as EC indicators obscure EC-ES relationships, they are used relatively often in national MAES assessments (with 37% of the used EC types representing ancillary data – which do not meet the strict SEEA EA definition of EC). According to our data, 85% of the national assessments surveyed reported the integration of EC indicators into the modelled flow of ES. It could also be confirmed, that in these types of assessments, low effort methods (statistical/literature data) are dominant sources for the assessments. This can be considered as a limitation from the point of view of studying EC-ES relationships, which was among the reasons of involving primary (field-based) data in our analyses (see later).

The results were published in: Vári et al. 2024

3. TARGETED EVIDENCE SYNTHESES ON THE RELATIONSHIPS BETWEEN ECOSYSTEM CONDITION AND SELECTED SERVICES

The core task of the project was to carry out comprehensive evidence syntheses on the connections between indicators of ecosystem condition and ecosystem services, in some selected subtopics. The originally planned method for that was the traditional system review, for which we had experiences before the project as well (Czúcz et al. 2018). But after complementing the introductory systematic review (task 1.1. in our project, presented above), and after exploratory analyses with some services, we could make the following observations:

The concept of ecosystem services (and also ecosystem condition) is a boundary object: the underlying ecological processes can be strictly defined, modelled in most cases, and therefore they form a good base for quantitative evidence syntheses. Meanwhile, the human (subjective) perception of ecosystem services (to which it is not easy to assign indicators and models) is of equal importance in an assessment process. Besides that, there is a very large heterogeneity in the selection of indicators and methods, sometimes even the common understanding of basic terms is lacking in a number of potentially relevant studies. These facts decrease the integrity, robustness or even the applicability of the traditional aggregative methods in this topic. Therefore, we turned to qualitative synthesis methods, where the emphasis is not on aggregation, but rather on interpretation, which provides the possibility of exploiting expert knowledge in forming synthesizing concepts and arguments (and quantitative analyses have less importance in the synthesis making process).

3.1. Mechanisms and relevant ecosystem characteristics for the ecosystem service of flood regulation

Flood regulation is one of the most important regulating ecosystem service in Hungary, and as the intensity and frequency of severe floods is rising in many parts of the world, its global importance is growing, in the context of climate change. Besides that, as it was found in our introductory systematic review (task 1.1. in this project, Czúcz et al. 2020), the indication and assessment methods are quite diverse, there is no dominant cascade level, and the studies are mixed from the point of view of spatial anchor. But this low level of coherence may provide the possibility of studying the relevant ecosystem characteristics, and make a targeted synthesis.

A literature search was performed, with a modification of the search strategy of a similar study (Smith et al. 2017), and keeping studies that test and document at least one relationship among an EC indicators and an ES indicators, referring to European study areas. Our study was a „side-project” connected to the work of the expert group responsible for the assessment of the service in the MAES-HU project.

One of the most important results is that there is a need to distinguish between two different flood regulating mechanisms of natural ecosystems, even if they are in the same group in an ecosystem service classification: an incipient flood regulation preventing floods, and a posterior process mitigating already accumulated floods in the floodplain. And the ecosystem charactecrics that can be assigned to the two different mechanisms are obviously different too: in the case of the preventing type of flood regulation, structural characteristics, mainly with the name „vegetation cover" are mentioned. This (and similar metrics) indicate the structural elements of ecosystems that intercept precipitation, or which are important for water retention in some way, within the catchment. The amount of reduced runoff water depends also on soil sealing and soil characteristics. The share of (im)permeable or (im)pervious surfaces are implemented mainly in studies dealing with the service in urban aras. From the attributes of soil quality, hydraulic characeteristics are the most important. Concerning the factors influencing the mitigating type of flood regulation, the most important characteristic regarding flood risk is the presence and the amount of floodable ecosystems or retention space. An interesting and also important aspect (with considerable management relevance) is that biomass has a controversial role in this case: dense vegetation increases rughness and thus causes lower conveyance. Meanwhile, besides keeping the connectivity in the landscape and the potentially positive biodiversity effects, vegetation cover protects artificial defence measures (e.g. dykes) against the force of flood waves. The main mechanisms and relevant ecosystem characteristics can be seen in Fig. 2.

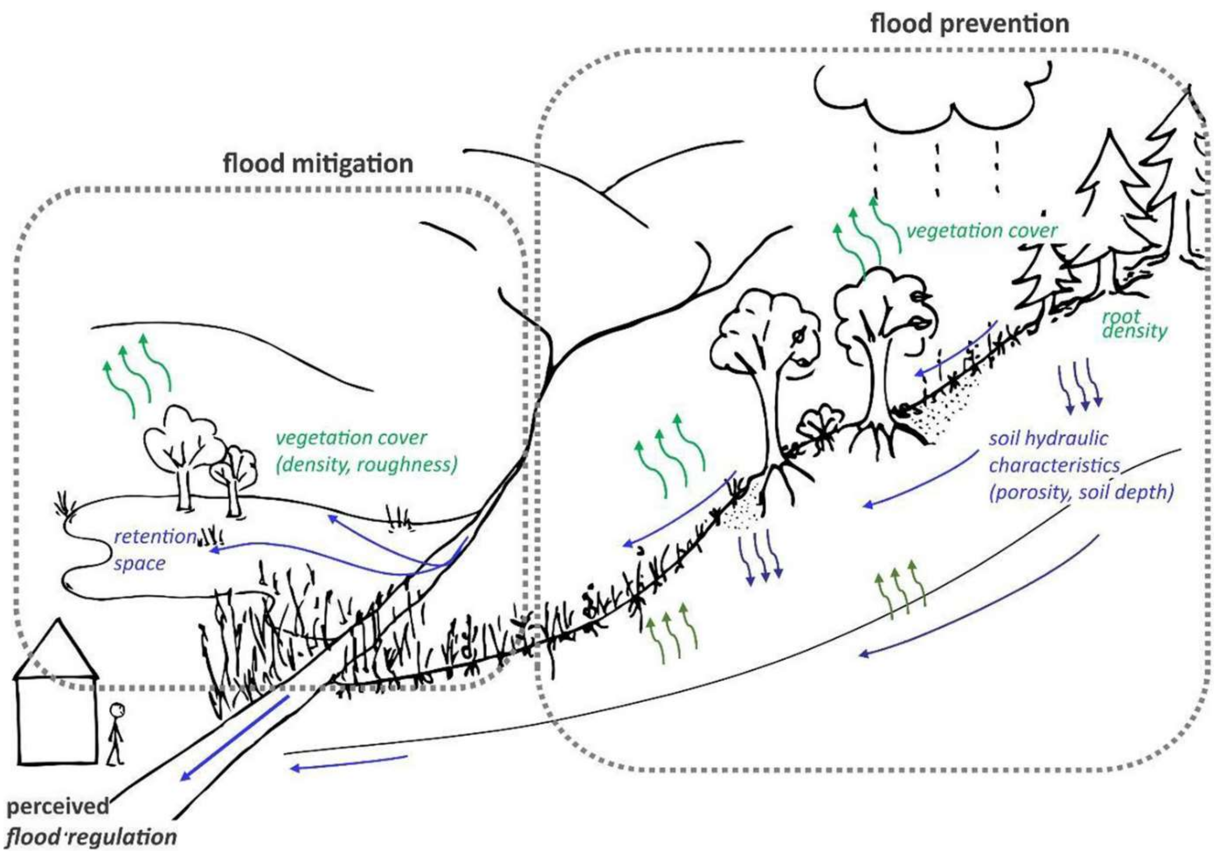

Figure 2: Two different mechanisms of flood regulation: 'prevention' in the whole catchment, and 'flood mitigation' along the streams in the floodable areas with relevant ecosystem characteristics (green italics for vegetation related, blue italics for abiotic), ecosystem functions (mechanisms) (bold), and human perception of ecosystem services (bold italics) (Vári et al. 2022b)

As many ecosystem assessments do not regard abiotic components as an ES (like MAES-HU), therefore, it is sometimes difficult to handle retention space consistently in this framework.

The results were published in: Vári et al. 2022b

3.2. The relationship of ecosystem condition and ecoosystem services in the case of urban microclimate regulation – a Critical Interpretive Synthesis

The ecosystem service of urban microclimate regulation became one of the focus topics in the project after the changes in the project staff. The reasons why there is a need to turn to qualitative synthesis (methodological heterogeneity, lack in the consistency in the use of the basic terms and concepts, etc.) is relevant also for this ES. From the possible qualitative synthesis methods, the Critical Interpretive Synthesis was chosen, which can be characterized with an iterative approach in refining the research question, searching and selecting from the literature (Barnett-Page and Thomas 2009). The theory development is more emphasized than methodological characteristics in the quality appraisal of the reviewed papers. Besides that, it is also true that the process behind the ES can be described well with such indicators, that could fit well in the context of ES assessments. And a high amount of information, which could be usable in the synthesis making process can be a target of quantitative analysis. Because of that, a mixed approach with quantitative and qualitative analysis steps was implemented in our work. The keyword set applied in the literature searching process was formed and fine-tuned in a multi-step process (to have papers, which are relevant for the assessment, but do not use the terminology of ecosystem assessments (like „ecosystem service”, „ecosystem condition”), and at the same time, to keep the size of the database which can be handled operatively. We analyzed all of the abstracts found with the keyword set (N = 1228), with a smaller number of assessment criteria. After a prioritization process, a final pool of 120 papers were analyzed in full-text, from which data was collected about the use and methodological aspects of ecosystem service indicators (e.g. cascade level of ES indicators, remote sensing / stakeholder input / model-based assessment, type and direction of EC-ES links, etc.).

Using the results of the quantitative analysis, one possible delineation (as a result of our expert-based interpretation) of the types of the studied articles (as synthetic constructs):

- Studies using land cover, vegetation index or similar characteristic as EC indicator and land surface temperature regulation as ES indicator (covering more than half of the studied literature base

- Empirical studies with on-site measurements of air temperature (ES)

- Model-based assessment on the micro scale, sometimes using thermal comfort indices as ES indicator

- Explicitly policy-oriented articles

Based on our results, we also set some probosable directions of further research for a better understanding and paralel utilization of the complex assessment of EC and ES in urban microclimatic studies. Our findings confirm the suitability to rely on ecosystem extent data for EC indication in urban ecological studies. Remote sensing-based analyses could have a higher role in micro-scale studies, and thus support calculation of human thermal comfort metrics, which are closer tot he indication of human well-being (which is in the focus of ES approach).

Direct comparison of EC indicators in an ES context would highly support relavant urban green space planning applications.

The results were presented in: Kolcsár et al. 2023, and will be published in: Kiss et al. 2024 (in prep.)

3.3. Qualitative evidence synthesis on the assessments of honey provisioning capacity

The another Critical Interpretice Synthesis carried out in the frame of the project, was about an ecosystem service, which is quite underrepresented in the relevant literature, the honey provisioning capacity. Although there is a wealth of knowledge about the practical aspects of honey production and the related floral resources, the process is rarely studied in ES assessments. This is the reason why we decided to make an introductory study, about the types of biophysical assessments and models, which should be a very important part of the knowledge base of any kind of more detailed analysis of the ES. But it is also true, that the diversity of analysis methods and the approaches for indicator selection call for an interpretive type, qualitative synthesis in this case as well.

Scopus and Web of Science platforms were screened for studies, which assess a specific case study site, describe a well-documented methodological model and input data, and develop an indicator of the honey provisioning capacity. After a two-step eligibility screening, a pool of 16 papers were analysed in detail.

The main result of the synthesis was the typology of the biophysical models for the assessment of honey provisioning capacity:

A) Rule-based matrix models

These contributions consist of two main data taypes. The first is some type of geographical map, classifying the space into ecological categories (like ecosystem types). The second type of data is non-spatial, and has the role to express honey provisioning capacity (for the ecological categories). Some examples of this model type are simple expert scoring based assessment, or maps with multicriteria decision analysis techniques (MCDA).

B) Extended rule-based models

The rule-based matrix models give a very simplified description of the process. The improvement can take into account the foraging area (flight range) of the bees (by integrating it into a GIS workflow, e.g. with a moving window operation). Thus the model calculates the resources available, in a given location (possibly from the perspective of a hypothetical bee colony). A possible structure of an extended rule-based GIS model can be seen in Fig. 3.

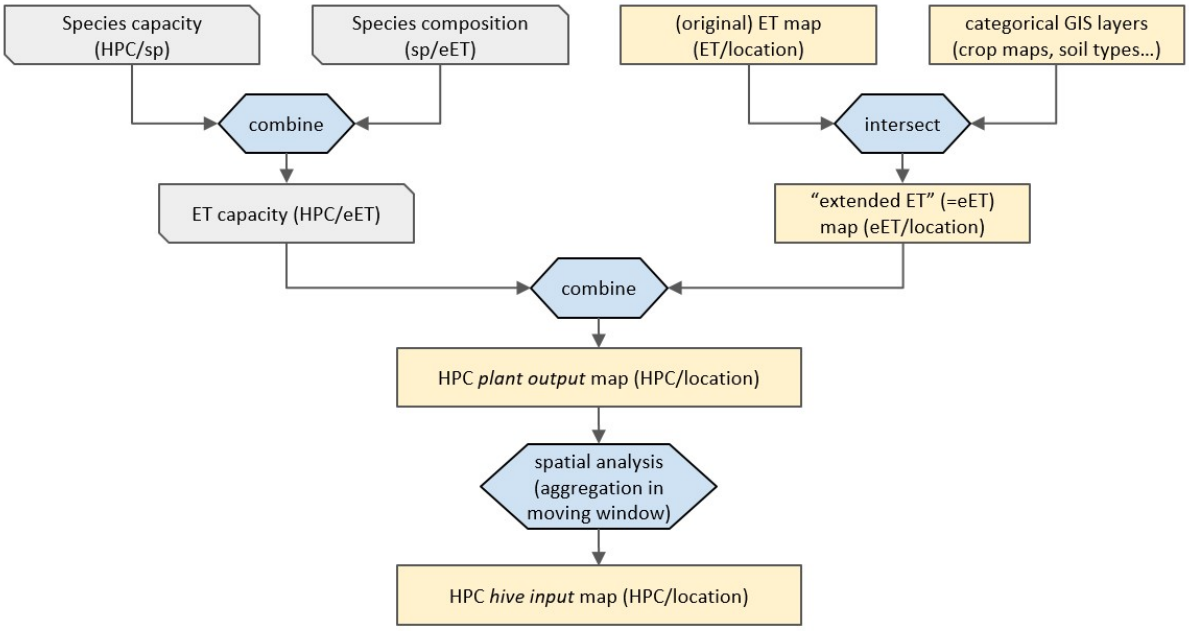

Figure 3: Extended rule-based GIS models for honey provisioning capacity (HPC), including extensions of the simple rule based model scheme with a spatial aggregation modelling bee foraging (Ausseuil et al. 2018; Smith et al. 2021, cit. Arany 2024)

C) Predictive statistical models

These papers use empirical, mathematical models, establishing statistical relationship between predictor variables and the measured values of a given ES. Using the developed models, spatial predictions can be carried out in other relevant areas.

The results were published in: Arany 2024, and will be published in: Arany and Czúcz 2024 (in prep.)

4. ECOSYSTEM CHARACTERISTICS RELEVANT FOR SELECTED ECOSYSTEM SERVICES – FIELD-BASED CASE STUDIES IN RARELY STUDIED ECOSYSTEM TYPES

In the original work plan, „mini case studies" were planned in Central Eastern and Southern East European karst areas, but because of the changes in the research staff during the project, they could not be delivered. On the other hand, we observed in the previous studies of the project, that a considerable share of ecosystem assessments (e.g. national projects) are based only on literature data. But it is still true that the existing knowledge is two small to form a strong evidence base for studying EC-ES relations, for a number of ecosystem services. It is particularly true for such ecosystem types, in which any kind of ecosystem assessments have rarely been carried out. New, empirical data from these ecosystems, with special focus on EC, ES and their connections would be quite valuable, not only for such, mostly theoretical questions like in our present project, but also in related practical applications.

4.1. Connections between physiological attributes as ecosystem condition indicators and ecosystem services in an urban tree stand

The ecosystem services provided by urban trees (and other elements of green infrastructure) are gaining more and more importance in ecosystem service research. But, as our results also highlighted (subtask 3.2., see above), there are considerable gaps in the knowledge about the micro-scale effects of trees from the point of view of microclimate regulation. And particularly about the opposite effect, the impact of environmental factors on tree physiological attributes (which can be treated as ecosystem characteristics in our context), and as further effect, on ES provision.

For the targeted analysis of these questions, an urban tree stand had to be chosen in almost the same location, but with different microclimatic conditions. A street with two lines of *Tilia tomentosa* trees was chosen, for which we had some relevant and usable results from our previous studies (Kacsova et al. 2021). The main microclimatic difference is that one side of the street gets considerably more direct sunlight (for which we handled them as „sunny" and „shadow" sides of the street). We chose 10 trees (5 pairs, with sunny and shadow trees in each pair), the physiological data was measured in the laboratory on collected leaves, and parallel meteorological measurements (air temperature, relative humidity) were made with ADL Optin sensors. Air temperature data was used to calculate growing degree days (GDD), which can be considered a better indicator of thermal conditions in plant ecophysiological studies. Insolation was calculated with a GIS-based model (using the building database of the city), in SAGA GIS environment (Fig. 4.).

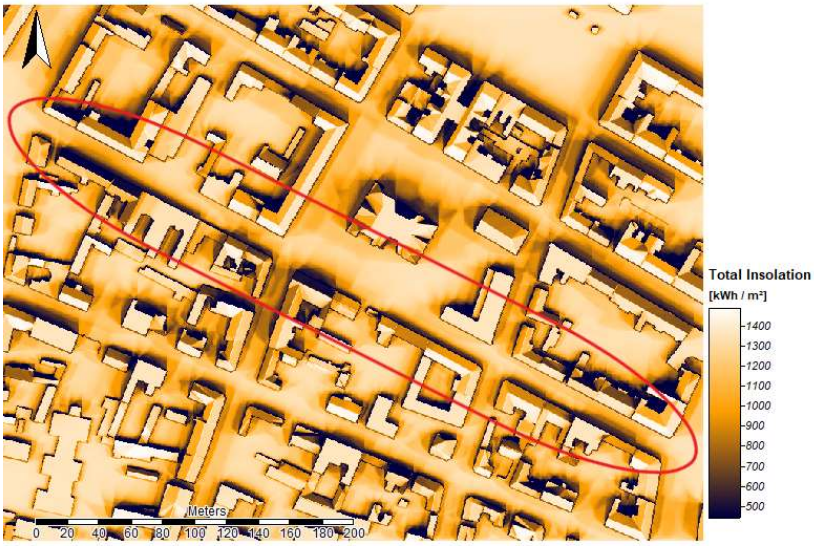

Figure 4: The spatial pattern of insolation in the Gutenberg street study area and its surroundings

The measured tree physiological attributes were Relative Water Content (RWC), Chlorophyll A, B and carotenoids. Two-sample t-tests were carried out to analyse the differences (i.e. the effect of microclimatic conditions) in the studied parameters. The connections between different physiological attributes, and between microclimate and physiology (which can be interpreted as EC-ES relationships) were analyzed with Pearson correlations.

The results show that although there are visible differences between microclimatic conditions between the two sides of the street, its effects on tree physiological effects are complex and different in the case of different parameters. The differences between the average values of daily maximum temperature can reach 3 degrees C (Fig. 5.).

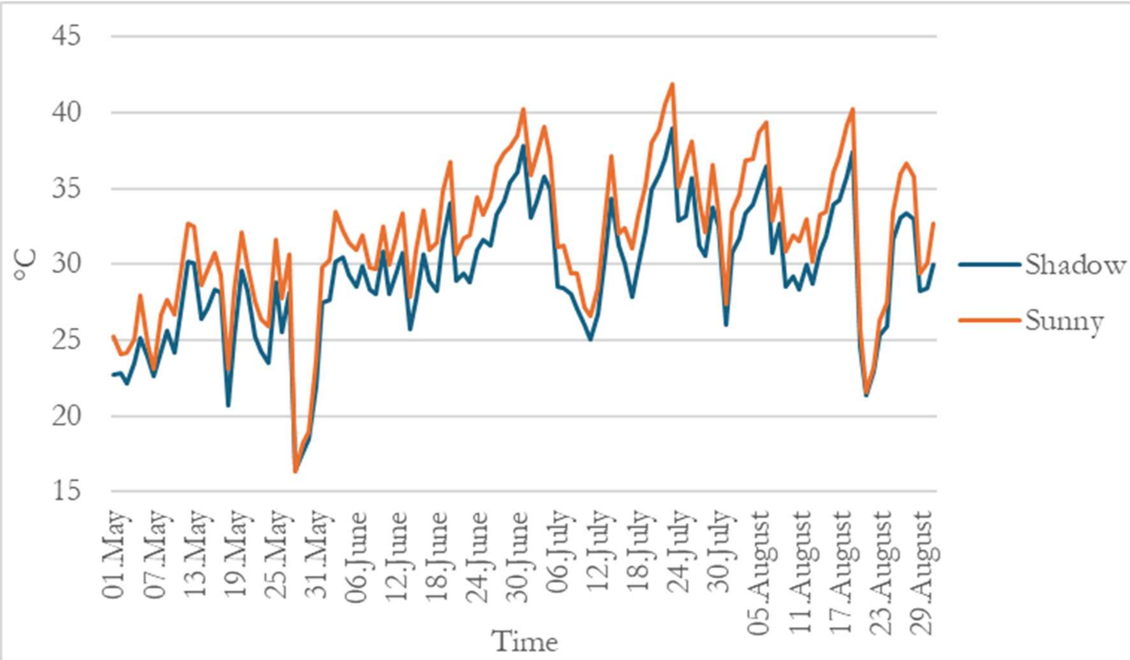

Figure 5: Daily maximum values of air temperature, averaged for the shadow and sunny sides of the street, between May and August 2022

Concerning the pigment values, the correlation values (all of which are significant) of GDD values representing the previous 1 week are higher than those of 1,2 or 30 days before. The Relative Water Content is lowly correlated with the studied environmental factors, the 30-day GDDs and insolation values are relatively higher (Table 1).

	Chl_sum	Chl_a	Chl_b	Car	β-car	RWC
RH% 1DB	-0.2413	-0.2519	-0.2032	-0.2072	-0.1348	0.007621
RH% 2DB	-0.2786	-0.2929	-0.2290	-0.2303	-0.1597	-0.08502
1DayB	0.4012	0.4317	0.3034	0.3830	0.3712	0.13743
2DayB	0.4624	0.4926	0.3631	0.4428	0.4274	0.14475
1WeekB	0.4970	0.5192	0.4176	0.5077	0.4972	0.078957
30DayB	0.2739	0.2625	0.2938	0.3329	0.3181	-0.31885
Insol1DB	0.3811	0.4071	0.2962	0.3885	0.3576	0.22972
Insol2DB	0.3787	0.4044	0.2948	0.3878	0.3576	0.22338
Insol1W	0.3723	0.3973	0.2902	0.3844	0.3554	0.21099

Table 1: r values ($p < 0.01$) of Pearson correlations between the measured physiological parameters and environmental factors (in the whole tree stand). RH% 1DB-2DB: Relative Humidity 1 day before - 2 days before; 1DayB, 2DayB, 1WeekB, 30DayB: Growing Degree Days 1-2-30 Day(s) Before, 1 Week Before; Insol1DB, Insol2DB, Insol1W: total insolation 1 day before, 2 days before, 1 week

before; Chl_sum: chlorophyll sum, Chl_a: chlorophyll-a Chl_b: chlorophyll-b; Car: carotenoid, B-car: beta-carotene; RWC: relative water content

Using the two-sample t-test, we identified a significant difference between the two sides regarding physiological characteristics. This difference, however, manifested differently in pigments and RWC. For RWC, the sunny side exhibited higher mean values, whereas the shaded side showed higher mean values for pigments.

The studied physiological attributes can be considered as good metrics of tree health (as a part of ecosystem condition), and, according to our results, they reflect microclimatic conditions and related differences quite well. These have clear effects on ES provision, for which further similar measurements would be needed to get a clearer understanding of the micro-scale patterns of EC-ES relationships in urban enviroenments. Moreover, as there are some promising results on the satellite-based mapping of some of the studied physiological attributes (e.g. chlorophyll, water content), our results confirm the need for the use of remote sensing methods in micro-scale assessments in urban microclimatic studies, which was observed as a result of relevant evidence synthesis (see subtask 3.2. above).

The publication on the results is under review: Lékó-Kacsova et al. 2024

4.2. Ecosystem capacities and services in terrestrial aquaculture

Freshwater aquaculture, though it has important role in fish production worldwide, is quite underrepresented in ecosystem services studies. Because of that, we had to design an exploratory study. It means that as there are quite low amount of methodological experiences (and even very low amount of ecological data), an integrated assessment with complex biophysical methods would have been exceeded our resources. Instead, we used participatory methods, also because besides making maps and the other parts of assessments, the exploitation of expert and stakeholder knowledge provided the possibility to get more in-depth information about relations between ecological structures, values and services.

The study area was the fishpond system of White Lake (near Szeged, Hungary), and the participatory mapping tasks were carried out with a group of so-called „key informants", in the form of structured interviews, followed by a focus group session to make a consensus. Though mentioning some aspects of ecosystem condition, an outcome of our preliminary studies and the first interviews, that the concept of „potential service providing capabilities" would form a good base to reflect on the ecological quality of the studied ecosystem types, and which could ba a target of comparison with the actual use of the relevant services. For the latter, we introduced a new method, called „hotspot-warmspot mapping". Its two categories shows the actual usage of the ecosystem services in the study area: 1) Hotspots: frequently used habitat patches that could be considered as the main sources of an ecosystem service; 2) Warmspots: rarely or mildly used used habitat patches with only a little contribution to the use of an ecosystem service compared to hotspots.

Concerning the results, a high share of habitats (particularly the wetlands) have high ES capability values, for most of the studied services. These areas are mostly hotspot areas too. But if they can be regarded only as warmspot areas (which means underutilization), it still indicates good ecosystem condition and the possibility of sustainable use. Artificial or semi-natural habitats could have a role in the utilization of ecosystem services provided by other (distant) ecosystems. This calls for the consideration of spatial anchor in studies with parallel assessment of EC and ES (as it was found in our first (1.1.) task of the project, Czúcz et al. 2020).

The results were published in: Palásti et al. 2022

CONCLUSIONS, FURTHER STEPS:

The detailed evidence synthesis works for the three selected topics confirmed the observations of our introductory evidence synthesis and the national assessments' review, that there is quite a high heterogeneity among the different ESs in either the use of complex attributes of ecosystem assessments (like cascade level), or even in the common understaning of basic terms and processes, if we handle the topic in an EC-ES context (like in the case of flood regulation). Meanwhile, for the development of a systematically organized, robust and operative framework for making the use of the knowledge on EC-ES relationships (to enable systematic indicator selection, mapping and other GIS procedures, etc.), there is a crucial need to carry out similar evidence synthesis tasks for many ecosystems and ecosystem services. In our opinion, the qualitative synthesis methods (e.g. Critical Interpretive Synthesis, which was tested and used in this project) could form a good methodological base for that. These follow-up works can provide the possibility of the dissemination of the project's results, which we have already started with the help of the former PI of the project. The results, the databases and methodological guidances could be used also in those practical application fields, where there is a clear and growing need for expertise in ecosystem assessments, to help indicator selection, mapping and modelling (like ecosystem accounting and biodiversity finance).

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