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Deciding on Climate Change Adaptation Measures: A Living-Lab-Approach Profiting from VGI in an Interactive Mapping-Service

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Abstract

A great variety of local sectors, e. g. water management, urban planning, agriculture, forestry, regional development, soil protection, nature conservation, and others, is nowadays concerned with deciding on climate change adaptation measures. Sectoral departments perceive that it is necessary to build bridges between different administrational offices due to various dependences and interactions. Increasing heavy rainfalls, for instance, are an often-mentioned threat that is caused by climate change in certain regions. Heavy rainfalls lead to flooding on the one, and soil erosion on the other hand. Flooding, as well as erosion, cause damages for buildings, road networks, and other infrastructures. Both events can also have negative aftermaths for agriculture (loss of arable land) and settlements (landslides, accumulation of mud on roads or in gardens). To mitigate such threats, it is often desirable not to start single, sectoral actions, but to develop measures that take into account comprehensively the different perspectives from relevant sectors.

Meanwhile, the BebeR-project, a collaborative network within which all relevant actors participate in the decision-making processes on climate change adaptation measures, was finished as a follow-up of the foregoing project KLIMPASS (https://klimpass.de/). Spatial data and web-map-services played a central supporting role to enable fair collaboration and decision making, as this paper will show.

Keywords: GIS, GI-Services, Living Lab, VGI, climate change adaptation

1. Introduction

"Adaptation (…) refers to the actions that countries will need to take to respond to the impacts of climate change that are already happening, while at the same time preparing for future impacts. Successful adaptation activities also call for the effective engagement of stakeholders - including national, regional, multilateral and international organizations, the public and private sectors, and civil society and the management of knowledge for adaptation at each step" (UNFCCC 2017).

The development of measures to mitigate implications of climate change requires collaboration between the sectors that are affected. Collaboration, however, requires the willingness to work together in a cross-sectoral way. Second, collaboration can be implemented differently. Classic face-to-face workshops should not be replaced at all, but can be complemented through adequate IT support effectively. In Corona times like currently, this seems to be self-evident. Within the BebeR-project, which was finished before the Pandemic began, it was obvious that due to varying actors a commonly coordinated course of action on the local scale had to be implemented aiming at accomplishing sustainable results. The actors collaborating within BebeR were, among others, various representatives from different sectors such as water management, regional planning, agriculture, forestry, nature protection, and others. Furthermore, NGOs (e. g. farmer's associations), enterprises, and the public were included. The professional contexts were diverse, and therefore different goals, interests and opinions about the "best" measures to mitigate climate change threats resulted. The challenge was to integrate the various views: Rainfall, for instance, can have impacts that "(...) are not only related to precipitation itself, but also the socioeconomic aspects of the population involved" (Araujo Moreira et al. 2017).

To achieve an effective communication process between the different participants it was decided to establish a common database and supporting IT services. A digital discussion forum was implemented which enabled online debate of specific subjects. Furthermore, an interactive web-map-service was implemented. The project leader had to perform three roles:

- As a coordinator, it was important to establish the network and enable communication.

- As a moderator, it was necessary to lead the discussions and to guarantee a balanced consideration of the different, sectoral views.
- As a software developer, it was essential to conceptualize and implement an interactive, web-based mapping system to provide spatial information to all relevant actors.

During project work, it became clear that BebeR represents a structure that is today known under the term "Living Lab": "A kind of giant sandbox in which there is the freedom to explore—creatively and collaboratively—the technological, environmental, economic and societal aspects of sustainability" (UBC 2018), thus focusing on problems of climate change.

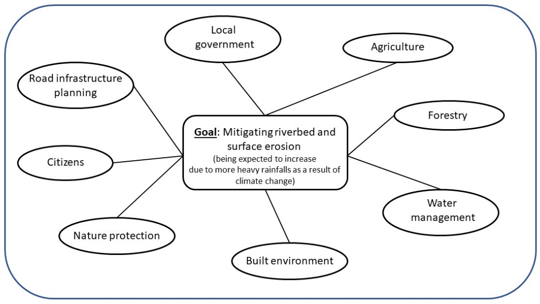

Figure 1. Stakeholders within the BebeR-project: Intensive collaboration was required to develop sustainable measures in the field of climate change adaptation.

2. The living lab approach

The collaboration of stakeholders from different organizations, administrations, and universities as well as citizens, was of crucial significance during the project BebeR. The aim of the project was on climate change adaptation measures with a focus on mitigating soil erosion. Soil erosion occurs in the pilot area, a mountainous district in the middle of Germany, mainly in two forms, riverbed erosion on the one hand, and surface erosion on the other. The development of measures to mitigate soil erosion required the involvement of different sectors: water management administrations had to be included due to their responsibility for a regulated runoff in river catchments. Agriculture has a natural interest in mitigating erosion due to the threat of losing arable land. Existing forest, as well as single trees, are endangered to be lost due to erosion, whereas planting of adequate species can contribute to reduce erosion, especially along river banks or on slopes, thus indicating that experts from forestry had to be involved. Local governments play a role, because strong surface erosion events at slopes can lead to mud flows that pollute settlements, roads, sidewalks and gardens. Large loads of eroded materials in rivers and along slopes can lead to accumulations of substrates and stress drainage systems. In some cases, roads and bridges are endangered directly due to bankside erosion and finally citizens were claiming the threat of losing parts of their personal properties close to rivers. Figure 1 shows most of the stakeholders that were to be integrated in the BebeR-project consortium.

2.1 Collaboration in living labs

The establishment of an effective collaboration between the various stakeholders required to set up a partner network. "Teamwork", however, does only partly explain what is required. Within BebeR, collaboration meant the inclusion of the stakeholders in all project phases and concerning all steps that had to be carried out when

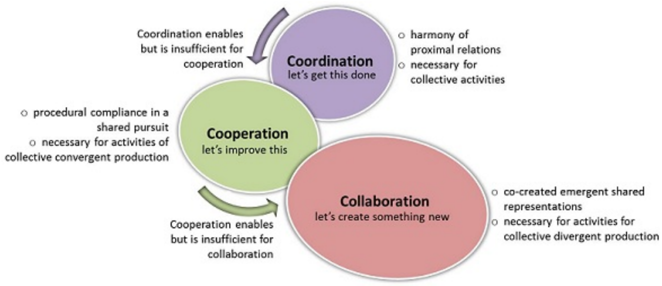

Figure 2. Relationships between three central elements of "teamworking" (Source: Young and Schottenfeld 2014).

deciding on adaptation measures. Collaboration in such a sense "is a working practice whereby individuals work together to a common purpose to achieve business benefit" (AIIM 2018).

While figure 2 distinguishes between the three terms, collaboration can also be interpreted as involving coordination, and cooperation. In such a sense, two types of collaboration can be differentiated, both having significance for the BebeR-project (AIIM 2018):

- Synchronous, where everyone interacts in real time, as in online meetings, through instant messaging, or via Skype, and

- Asynchronous, where the interaction can be time-shifted, as when uploading documents or annotations to shared workspaces, or making contributions to a wiki or an online forum, or blog.

Both types, synchronous and asynchronous, had significance due to the aim of integrating people from different sectors. Synchronous and asynchronous collaboration did not exclude each other. Instead, both types completed the set of analogue and digital tools that were applied aiming at achieving effective communication structures.

2.2 The project framework

The BebeR-project has been carried out from March 2017 to February 2020. Apart from vulnerability assessments, thus resulting in the goal of developing vulnerability maps using the online spatial service mentioned before, erosion rates were calculated based on the USLE equation (Benavidez et al. 2018). Results were visualised based on a 3D model of two river catchments that were chosen as pilot test areas (Figure 3). Grounded on the vulnerability assessment and the results of erosion simulation, the development of concrete measures to mitigate erosion was envisaged. Comprehensive, multi-sector discussions led to a prioritization of potential measures. Finally, a multicriteria analysis was carried out to assess whether the prioritization process was done adequately.

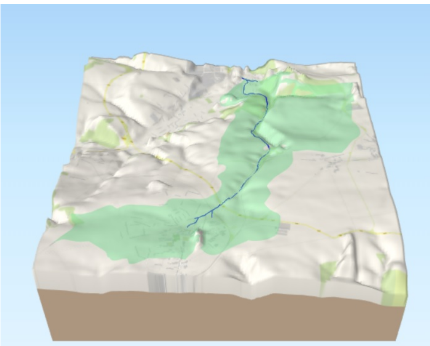

Figure 3. DEM of the pilot catchment "Regenbeek" (Source: https://vulnerabilitaetskarte.klimpass.de/)

2.2.1 IT-support for collaborative decision-making

The development of adaptation measures to mitigate soil erosion required the use of adequate electronic workspace that can be applied by all concerned partners within the living lab framework (Brennan et al. 2012). Open GIS-tools, as they were developed within BebeR, help to overcome geographical barriers as well as time constraints by allowing all stakeholders to:

1. access the information necessary (passive involvement)
2. provide their own input and (active participation)
3. engage in a constructive discourse with other stakeholders (active participation)
4. participate in the research for new findings (co-production).

Whereas point 1 refers to a passive involvement of stakeholders, point 2 means to interact with the tools, however, an active participation is needed. This is also true concerning point 3, and 4.

2.2.2 Citizen Science and VGI

According to a Green paper, "Citizen Science" has been used to define a series of activities that link the general public with scientific research. Volunteers and non-professionals contribute collectively in a diverse range of scientific projects to answer real-world questions (Cohn 2008). Both, citizens' contributions and researchers' attitudes, encompass a wide set of activities at multiple scales." (Socientize Consortium 2013; see also Goodchild 2007). This citation fits with the citation that "Citizen scientists collect more than data. They gather meaning" (Louv, R., 2012). Within the BebeR-project, volunteers were partly included due to the fact that they were able to provide important facts concerning the following aspects:

- description of soil erosion events, provide historical data
- identification of critical water levels in rivers and possibly related erosion events
- notification of damages occurring as consequence of extreme weather events, e. g. heavy rainfall, thus causing erosion

There is much discussion about the pros and cons of VGI as a kind of open data, and this will not be deepened here. Van Loenen et al. stated, for instance: "In a rather naïve way, it was thought that open data could be used directly by everyone, by all citizens and businesses", but they conclude that this is not the case (Van Loenen et al. 2018).

Within the BebeR-mapping service, further open data sources were considered. This concerns for example the topographic background, using OpenStreetMap. However, other open mapping services can be included. The map in Figure 5 presents partly some of the data layers that can be selected interactively to produce decision supporting cartographic output. These layers are coming from administrative offices, as well as open sources (Figure 4). The inclusion of open data, however, was a severe point of discussion during meetings with project partners. Whereas some open data layers were accepted as being qualitatively adequate, e. g. datasets on invasive neophytes provided via a VGI project and widely accredited as useful information (Figure 4), other open datasets were seen critically due to quality constraints. Before this data has been made accessible by everyone via the mapping service, a qualitative check-up was made. Especially according to the administrative actors, such a step of quality control has been seen as indispensable. If such mechanisms do not exist, there is a certain reticence especially among these project participants, as project experiences showed. This concerns also topographic open data, which has its reasons in differences between datasets. Jackson et al., for instance, discovered differences in positional accuracy and completeness (Jackson et al. 2013), which led to some confusion among users.

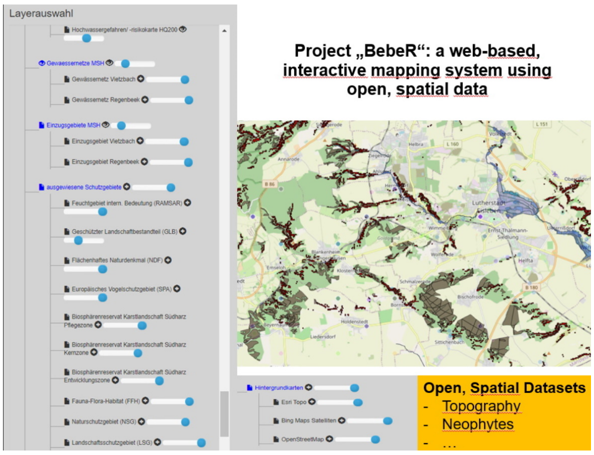

Figure 4: Integration of administrative and open data (e. g. topography) and VGI (e. g. invasive neophytes) layers in the interactive map service (Source: https://vulnerabilitaetskarte.klimpass.de/)

2.2.3 Online-Map-Services

The BebeR website was one of the most important tools to communicate a) between the different project partners and b) to store, analyze and visualize spatial data. Users were enabled to produce maps to support the understanding of processes within the test catchments on the one hand, and to identify vulnerabilities and opportunities to mitigate harmful events on the other. The two main components of the website are briefly described in table 1.

Table 1: Components of the BebeR website

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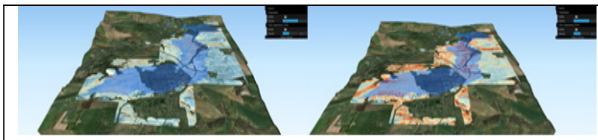
<tr><td colspan="2">
Two central components of the BebeR-Website</td></tr>
<tr><td>Interactive web mapping service</td><td>Discussion forum</td></tr>
<tr><td>Users get insight into the environmental and socio-economic situation of the pilot region. They can use basic geographic data and prepared maps, showing adaptation measures. Furthermore, they can generate their “own” maps interactively. Such maps can be published via the project website and be discussed and modified in cooperation with stakeholders. Citizens can participate in such discussions via a digital forum.</td><td>Users can critically review planned adaptation measures and discuss them among all actors online. The forum is open for project partners (internal area) and citizens (open area). In such a way, the forum is also important to include the public and guarantee more transparency in view of the future scenarios. Citizens can argue for other or possibly more suitable decisions taking into account that local people sometimes have important knowledge about local conditions which are possibly prone to be ignored by administrational units.</td></tr>
<tr><td colspan="2">Additional functions: Apart from the two components mentioned above, the BebeR-Website includes information about the project, project events, publications, presentations, etc.

Note: there is currently no direct link between the two components; using the maps <u>and</u> commenting on them requires changing between the functionalities, which is possible easily with very few klicks.</td></tr>
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The users come from different fields. First of all, the actors participating in the BebeR-project were using the mapping system very often. Furthermore, practitioners from administrative units used prepared maps (e. g. erosion simulations), and produced new, “own” views on specific regions within the pilot area. Due to the fact that the system is open, citizens and other users are invited to apply the data.

2.2.4 Data and Software availability

Project information, spatial data layers and the services mentioned within this paper are available under https://klimpass.de. However, some information is only accessible after registration which can be requested as mentioned on the webpage.

3. Collaborative development of measures to mitigate soil erosion

Using the tools mentioned in table 1, the development of climate change adaptation measures under explicit consideration of inputs of all relevant actors that have access to the website was supported effectively. The mapping system enabled project participants to look at or use interactively administrational, open and VGI data, e. g. to overlay them or to use simulation results. The discussion forum supports the dispute about optional planning alternatives. This includes the debate about different outcomes concerning the simulation of potential measures that result from the inclusion of different climate change scenarios that are proposed by the IPCC. Finally, a selection of "best measures" had to be carried out, thus provoking debate again. The inclusion of citizen science approaches was important to enhance the data- and knowledge base on the one hand, furthermore it made possible to consider the opinions of local people about the planned activities. This is also important in view of acceptance and appreciation of planned measures. In such a way the living lab approach that was applied within BebeR proofed to be adequate due to the complexity of different opinions and arguments of the various participants.

Figure 5a, presents an exemplary map that shows areas vulnerable to soil erosion, thus integrating soil data, a digital elevation model, and other layers provided by the web map service.

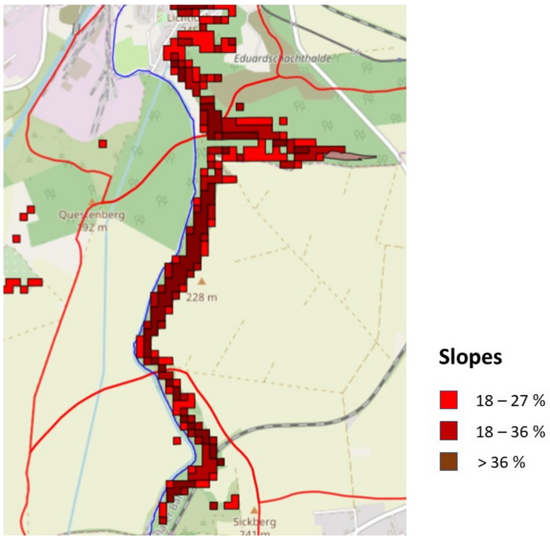

Figure 5a. Exemplary map of areas vulnerable to soil erosion due to slope gradient

Figure 5b presents a map that resulted from the application of a common soil erosion formula (USLE). It shows erosion rates that can be expected under differing climate change scenarios.

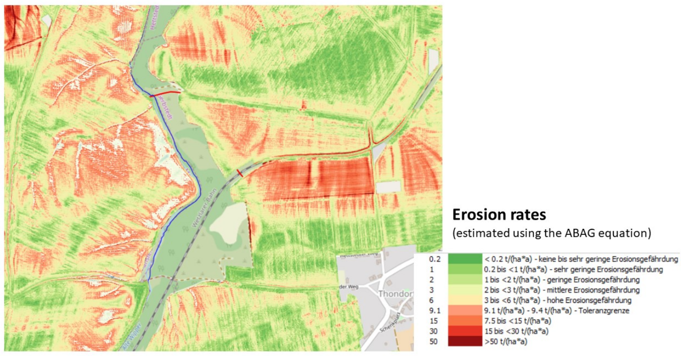

Figure 5b. Potential erosion rates, estimated under assumption of a specific climate change scenario (Source: https://vulnerabilitaetskarte.klimpass.de/)

Based on such spatial analyses, a final multicriteria analysis, carried out using the system "PRIMATE", was applied after a comprehensive discussion of the criteria and their weightings between the project partners. The result confirmed that the building of a rain storage reservoir would be a high prioritized measure in this catchment (Figure 5a, 5d). The reservoir would lead to reduced runoff and flow velocity and therefore to diminished riverbed erosion on the one hand, and it would mitigate surface runoff due to lower water quantities running down the slopes. Figure 5c presents the results of the multicriteria analysis. The framed column shows the highest score for the rain storage reservoir.

Maßnahmen	Regenrück-haltebecken (Rain Storage Reservoir)	Mäander	Kaskaden	RR_Kanalnetz	Versickerung
Eingangsfluss (F+)	5,264	3,897	1,666	3,962	2,402
Ausgangsfluss (F-)	1,404	2,610	4,918	2,304	4,167
Nettofluss	3,86	1,287	-3,252	1,658	-1,765
Rang	I	IV	XI	II	X

Figure 5c. Results of the multicriteria analysis aimed at prioritization of potential measures: a rain storage reservoir achieved Rang I

The question, where to build the reservoir, was a siting analysis task that was supported by the web map service as well. Figure 5d points on areas that were excluded from being suitable for a rain storage reservoir, thus integrating different spatial layers and the simulation results. The polygons left and right of the river indicate regions that were not suitable to build a reservoir due to reasons formulated by the different project stakeholders within the framework of the multicriteria analysis (Figure 5d). Only some areas were left as a result of this analysis; they were visualized, textually described and suggested to the regions council for planning a rain storage reservoir.

The additional view on VGI data in other areas of the pilot region showed that specific invasive neophytes spread around running waters and lakes and impair other species, e. g. those that are on the red list of threatened species. Auxiliary measures completed the plan aiming at avoiding an unsupervised dispersion of such invasive plants.

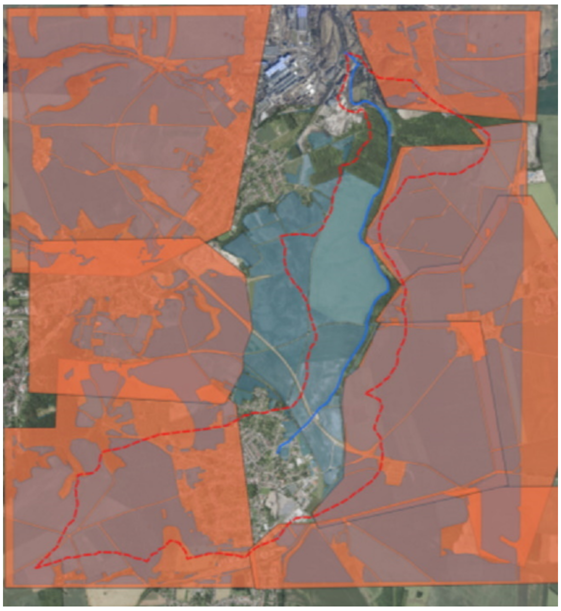

Figure 5d. Map presenting exclusive areas for building a rain storage reservoir that was highly prioritized by all project partners as suitable measure.

4. Conclusions

The mitigation of harmful consequences of climate change plays a major role on the regional, and local scale. This initial discovery led to the implementation of a collaborative network of different actors within the project BebeR. Within this project, the reduction of erosion within small river catchments that are vulnerable to heavy rainfall was envisaged. To achieve measures to mitigate erosion, different stakeholders from academics, administration, practitioners, part of a collaborative network, or living lab.

The BebeR-project shows that a university, especially in terms of its function as a knowledge broker and facilitator, confirms its role as an anchor institution, a term that was introduced by Wilson (2012), see also UBC (2018). The idea of "living labs", as it was applied in the project BebeR, can be stressed due to its effectiveness and clear advantages in terms of the integration of theory, methodology and practice (Pundt and Heilmann 2020).

The interactive web map service, accessible for all stakeholders within BebeR, is a vital example that spatial data, administrational and citizen science-based (e. g. VGI), and corresponding services are helpful means to accompany decision making in complex, multi-stakeholder projects. The discussion forum adds online functionalities that can support the debates that occur during the pathway to decide on prioritized solutions, the latter carried out using a multicriteria analysis software. The integration of analogue project management methods and digital services was appreciated by the project partners as being very effective during spatial decision-making processes in a collaborative living lab environment like BebeR.

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