Geodesigning Climate Change Adaptation on a Regional Level through Shelterbelt Provision in the Jingjinji Area

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Abstract: More than 109 million people already live in the Jingjinji Area, the greater metropolitan area around Bejing and the number of inhabitants as well as land take for new housing is increasing dramatically. At the same time, the region is under threat from climate change, especially through desertification. The government has identified shelterbelt forests as appropriate adaptation measures. However, the designation of new shelterbelts has to be integrated in the wider regional planning process for the Jingjinji Area and this pilot study explores the potential of the geodesign framework and the Geodesignhub online platform for this monumental task. Four development scenarios and two evaluation models with constraint maps were set up a prior. Then, we conducted two workshops, partly remotely, with 12 participating landscape architecture PG and PhD students across the world. In terms of the planning task, the workshop resulted in a synthesis map of how housing, industry and commerce, the 2020 Winter Olympics, transport infrastructure, green infrastructure and particularly shelterbelts can be located in the Jingjinji area. Parallel, a process evaluation was conducted resulting in valuable feedback regarding the strengths and limitations of the geodesign framework and online tools for this case study.

Keywords: Geodesign, Jingjinji Area, desertification, shelterbelts

1 Introduction to the Jingjinji Area

The Chinese government has designated the greater metropolitan area around Bejing as Jingjinji Area (JJJ Area) including large parts of Tianjin Municipality and Hebei Province (Fig. 1). This huge area accounts for almost one ninth of the total economy of China and accommodated about 109,564,000 inhabitants in 2015. That said, the area is still very diverse, with Tianjin having the highest GDP per capita in China, whereas Hebei Province is about average. Population density also varies, with Bejing and Tianjin being the dense population centers in the region. Due to the rapid population increase, land take is taking place at a dramatic speed, e. g. the proportion of farmland of overall land use has decreased by 9.3 % from 2006 to 2013.

While urbanization of the JJJ Area is proceeding rapidly, some of the greatest challenges are imposed by climate change especially through desertification. The vulnerability of JJJ Area is increasing two folded: While the housing areas are growing in areas vulnerable to sand storms, climate change is likely to cause further desertification and more frequent droughts in the region. In the YANG et al. (2012) map, desertification and sand storm risk (Fig. 2) is illustrated in Fig. 3.

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Fig. 1:
Location of the JJJ Area
(source: Google Maps 2016)

A novel aspect of this study is the scale of the study area. Broadly speaking the study area was a bit less than the size of the United Kingdom. When dealing with projects of this scale, a number of issues around extremely large geospatial datasets, so called "big data", arise. With such a large study area, it is difficult to collect, manage, and analyse the large volume of data. Considering the scale of JJJ Area, we recommend a scale of data less than 1:100,000. The data set is provided by the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC) (http://www.resdc.cn), Data Center for National Geomatics Center of China (NGCC) (http://ngcc.sbsm.gov.cn/) and National Bureau of Statistics of China (NBSC) (http://data.stats.gov.cn), who all provide geographic and socioeconomic data at the Chinese national scale. Following the geodesign framework of STEINITZ (2012), we started with the evaluation models, which answer the question of how well a scenario is working by applying evaluation criteria contributed through the decision-making stakeholders. The first step in creating the evaluation models is to analyze which data are necessary for each model. Some of the data can be derived from other data sets. In this case, the evaluation is based on conventional land suitability and ordinal combination methods going back as far as HOPKINS (1977). In this project, we use ESRI ArcGIS and QGIS as the main tools to create the evaluation models. For the next step, we prepare two spreadsheets. The first one contains the relative parameters and their impacts on each evaluation model, which will result in a score map. For example, in the ecological system, the main parameters are elevation, slope, soil type, accumulated temperature and wetness index. There are different scores relative to each other and each parameter will have effects on its own on the evaluation model. The resulting score map shows relative differences, not absolute scores. The second spreadsheet contains the classification of scores, which transforms the score map into an evaluation map. There are four levels (not appropriate, capable, suitable and existing) in this project. For example, the lowest scores are classified as 'not appropriate' and so on for the other three levels. The final result is an evaluation map of each system. The final step will depend on how much detail is needed. We refine our final evaluation map iteratively through the filter model to discard unnecessary detail.

Once the maps are built, they have to be generalized. The maps are presented at an ordinal scale, i. e. they simply show an order of magnitude since there is no standard of measurement of differences for the entire study area. For example, housing suitability maps at this scale do not consider individual unoccupied parcels since such data would be too detailed. Instead, we had to derive the housing suitability map from other data such as population density. Because preparation and creation of maps at this scale is challenging, it was decided to study only five systems (Commerce & Industry, Ecology, Hydrology, Housing, and Transport). A trade-off between the resolution of data and performance that matches the limited resources of this case study was sought. Further comparative studies are needed to understand the complexities of data and ways large data can be handled at this scale.

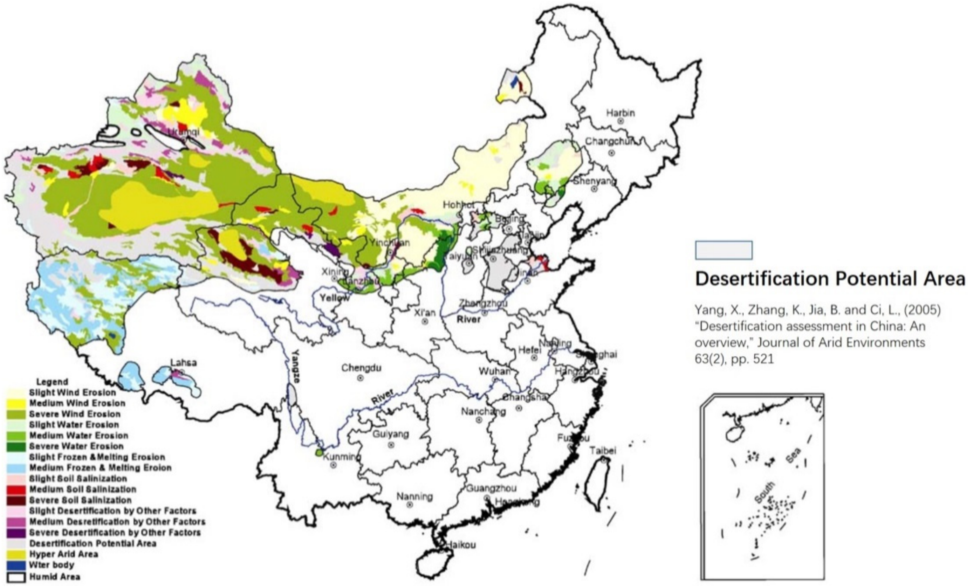

Fig. 2: Desertification potential area (YANG et al. 2012)

Fig. 3: Sandstorm in Chaoyang District, Beijing 2011

2 Shelterbelts as a Regional Climate Change Adaptation Measure

Since the Jingjinji Area is located on the North China Plain it has a temperate monsoon climate and is affected by summer and winter monsoon. It is cold and dry in winter, but rainy with high temperatures in summer. Vegetation communities are characterized by deciduous broadleaf tree species including *Fagus engleriana*, *Quercus acutissima*, *Tilia tuan* and *Betula* (WU et al. 2014). Due to the rapid development and population growth since 1980s, the original ecological systems in Jingjinji Area have been under threat and natural areas have been shrinking. That said, authorities in the Jingjinji Area realized the importance of green infrastructure to protect the area from further desertification. Currently, four major green infrastructure corridors are in place: The first one is Beijing-Hangzhou Grand Canal, which is the longest channel in the world and dates back 2500 years. The channel plays a key role in connecting the north and south of China and allowing agriculture on the North China Plain. Taihang Mountain is a natural barrier in the west of the North China Plain against the cold currents from the Northwest, holding warm and wet air from the Pacific Ocean on the plain.

The *Taihang Mountain Afforestation Project* aims to improve the ecosystem services for Jingjinji Area through shelterbelts. The International Union of Forest Research Organisations (SEPPAELAE, BUCK & KATILA 2009) defines shelterbelts as forested land spanning more than 0.5ha with trees higher than 5m, a canopy cover of more than 10% and width of more than 20m. Such shelterbelt forests are recommended as potential strategic and operational level climate change adaptation options.

In addition to the Taihang Mountain Afforestation Project, three other shelterbelt projects are ongoing: the Farmland Shelterbelt in the south, Coast Shelterbelt in the east and Three North Shelterbelt in the north of the Jingjinji Area (WANG et al 2010). Most of them were started in the 1980s, passed their second phase by 2010 and today they provide a basic green infrastructure for the Jingjinji Area. However, the future of the shelterbelts and potential expansions is still a key issue: shelterbelts need much financial support from the government and balancing shelterbelts with the other drivers in a sustainable development must be considered. How can they be integrated to enhance the supply of ecosystem services in the Jingjinji Area (DONG et al. 2008)?

3 Methods

Geodesign is an approach for integrating design and planning through the simulation of environmental impacts in Geospatial Information Systems (GIS) based on system theory. Key components of geodesign are collaboration with the various stakeholders of a project, and the systematic understanding of a study area and the evaluation of different scenarios through representation, process, evaluation, change, impact and decision models (STEINITZ 2012). Steinitz' theoretical geodesign framework has been implemented as a collaborative online software application under www.geodesignhub.com. For this project, two meetings were scheduled in 2016 using Geodesignhub: One hands-on workshop with most participants gathering at the University of Sheffield under supervision of the platform developer, and the second workshop facilitated remotely online.

The **scenario method** is part of Steinitz' geodesign approach and we applied the Scenario Axes Technique by VAN'T KLOOSTER & VAN ASSELT (2006) to prepare four scenarios for the JJJ Area in response to the two drivers Desertification and Urbanisation. These four scenarios were then presented to the workshop participants as input for further elaboration in the diagrams on the geodesign collaborative online platform.

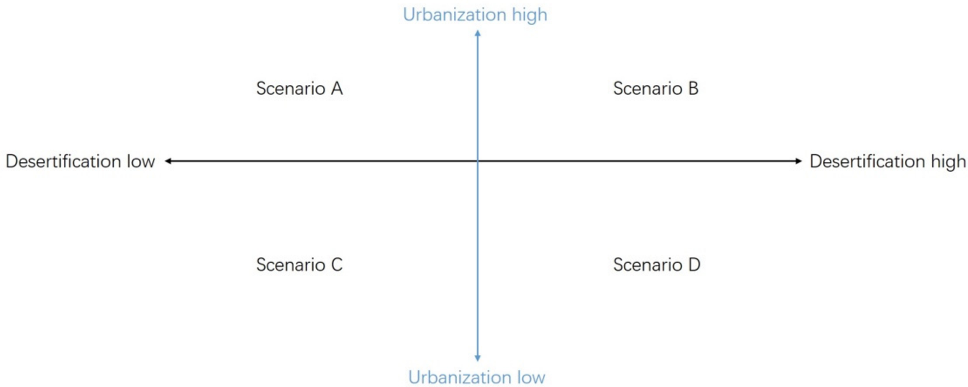

Fig. 4: Scenario axes *urbanization* and *desertification* defining four scenarios A–D. As illustrated in Fig. 4, the four different combinations of opposite directions of the drivers *Urbanization* and *Desertification* define four scenarios for the JJJ Area: A) Green mega-city, B) The "Dubai Model" (city in a desert), C) Green Olympics and D) Desert.

4 Results and Discussion: Scenarios for a Climate-resilient Future of the Jingjinji Area

Following the Geodesign framework, the next step was to set up the key evaluation models for the case study area, i. e. Commerce & Industry (Fig. 5), Ecology (Fig. 6), Hydrology (Fig. 7), Housing (Fig. 8).

On basis of these evaluation maps, the twelve workshop participants from around the world, including three Chinese landscape architects, created zoning (called "diagrams" on the Geodesignhub platform) for *Commerce & Industry* (Fig. 5), *Ecology including shelterbelt zones* (Fig. 6), and *Housing* (Fig. 8). The Hydrology (Fig. 7) evaluation map served to inform the *Ecology* zoning. These "diagrams" or zoning are the basis for the later evaluation of the different scenarios. In a larger study, additional diagrams would have been created but due to the limitations of this pilot study, we decided to focus on these two areas, which correspond to the underlying drivers Climate Change and Urbanization.

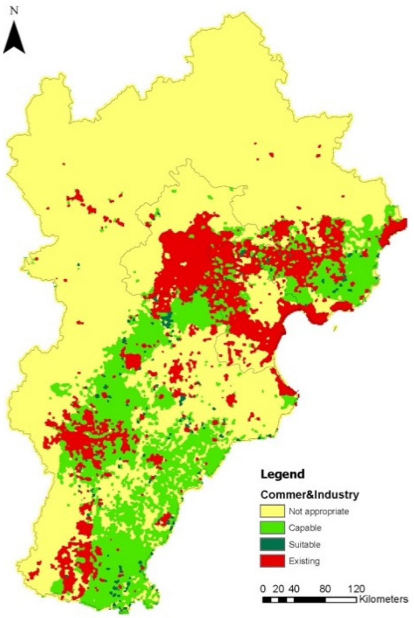

Fig. 5: Evaluation map Commerce & Industry

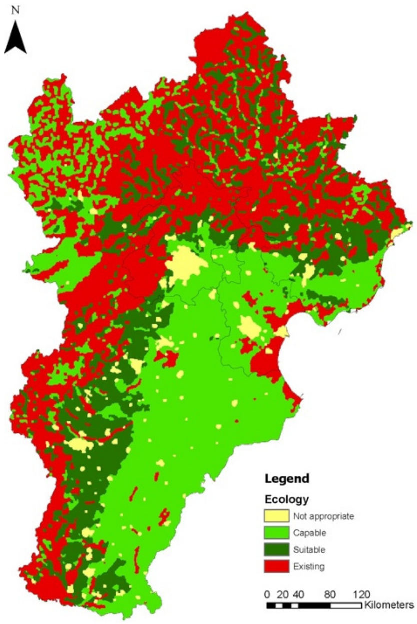

Fig. 6: Evaluation map Ecology

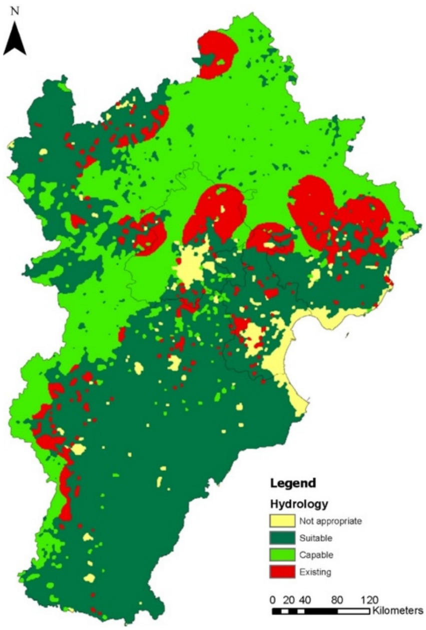

Fig. 7: Evaluation map Hydrology

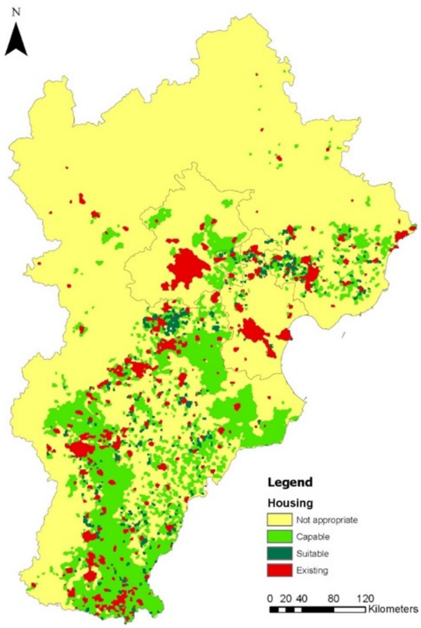

Fig. 8: Evaluation map Housing

Next, workshop participants overlaid diagrams from across the workshop group in synthesis and impacts maps. These synthesis maps were finally compared using the Geodesignhub functionality, e. g. comparing two maps next to each other and calculating a rough estimate of the costs of each synthesis map. Fig. 9 and 10 show the synthesis and impacts maps which were finally selected by the workshop participants.

After comparison and discussion, we arrived at the final plan of Scenario A (Figure 9). This design almost achieves the commercial & industrial target (2408/2845 km^2) and ecological target (7201/9375 km^2) and slightly exceeds the housing target (685/521 km^2). As can be seen from the impacts map (Figure 10), most designated areas have positive impacts (purple). The idea of the design is to combine the Beijing and Zhangjiakou Winter Olympic Games 2020, establishing 'green walls' along the boundary of the northwest Hebei Province to protect it from sandstorms. Building the Winter Olympic Forest Park in Zhangjiakou, which is located northwest of Beijing, can increase forest zones to mitigate desertification. The housing area and commercial and industrial areas are mainly located in the middle of Beijing and Tianjin. New transport routes for the Olympics will help the other small cities in sustainable development after the Olympics and receiving more support and resources from Beijing and Tianjin. The development of these small satellite cities will contribute to the sustainable development of the new shelterbelt zone.

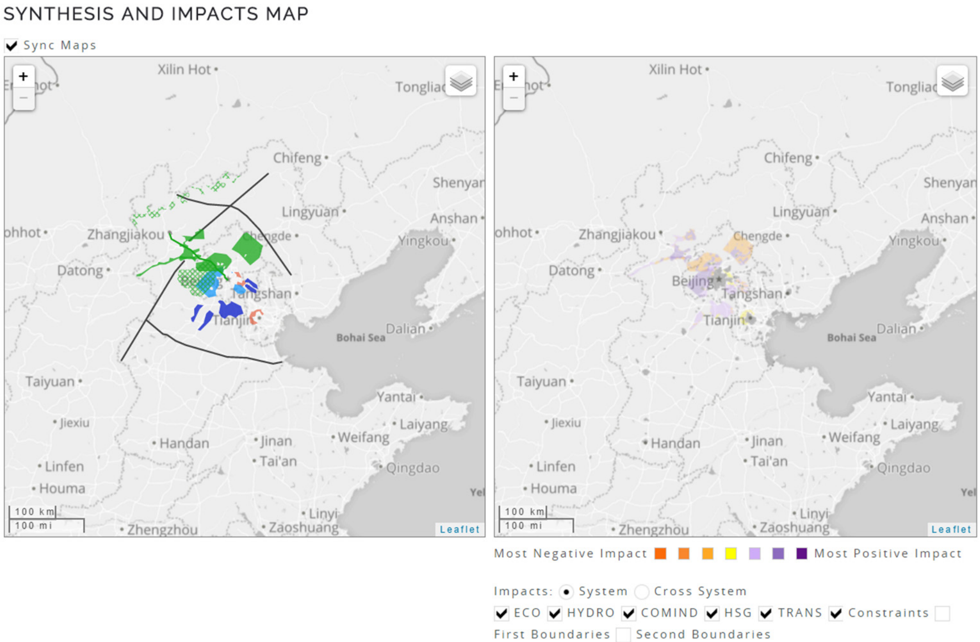

Fig. 9 and 10: Synthesis and Impacts Maps

Although multiple reports demonstrate that shelterbelts have not stopped desertification overall (Zhu & Wang 1990, Wang et al. 2003), some areas at risk of desertification have improved through shelterbelt projects. Furthermore, shelterbelts have mitigated the risk of sandstorms. According to Wang, Zhang, Hasi & Dong (2010), the frequency of sandstorms in

Jingjinji Area has decreased recently. Comparing climate data from 1950 to 2000, the lower frequency and intensity of high wind speeds may be the main factor here. WANG et al. (2010) also notes that shelterbelt plants have a low survival rate in the process of desertification and high costs of maintenance work for shelterbelt projects result in insufficient support for re-plantation. Therefore, the development of cities and counties close to the shelterbelt project is important and urgent. The shelterbelt needs to be connected with economic and ecotourism development to ensure its maintenance.

However, TAO WANG (2004) claimed in his report that the main problem of desertification in the north west of Jingjinji Area is mainly the result of human activities such as cultivation and deforestation. In other words, uncoordinated urbanization and economic development will contribute to increase desertification. Therefore, it is necessary to have science-based regional planning to balance economic and ecological development, which is exactly what we want to achieve through geodesign. The evaluation model and workshop are the specific methods to guarantee the balance.

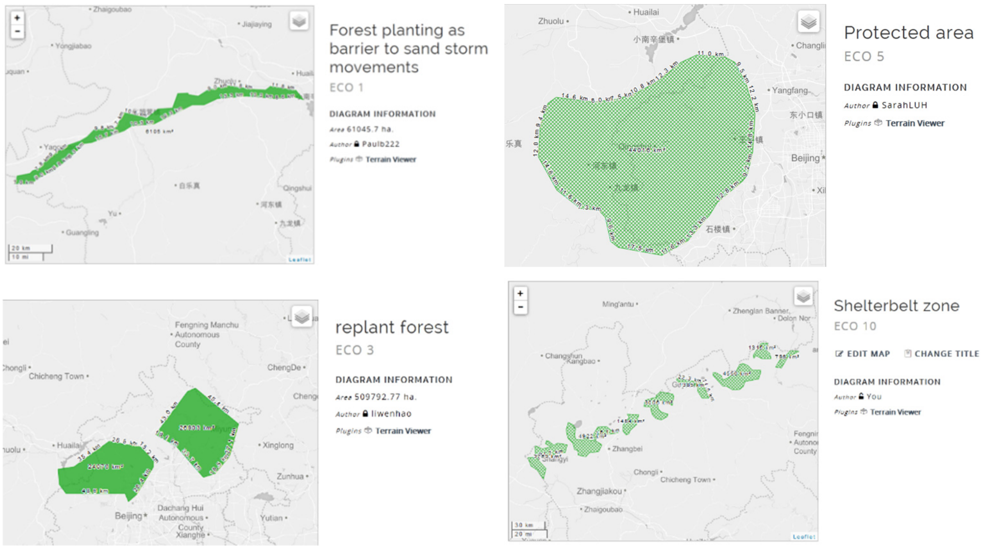

Fig. 11 – 14: Various proposed shelterbelt designations, zoom from Fig. 9 Synthesis Map

In the first designation, shelterbelts were designed as a *barrier* to stop sand storms from moving from the north to the south of JJJ Area. This 78.2 km barrier is based on the combination of the four parts of existing forest and afforestation projects (Fig. 11). The shelterbelt is located in an area which is suitable for planting according to the ecological evaluation model. The disadvantage of this design is that most of the replanting area will be hardly developed with commerce and housing in the next 50 years. However, the project could benefit from transport development. There is considerable need for transport development in the area of the barrier as demonstrated in the transport evaluation model. The barrier project could therefore benefit from synergies with the forthcoming transport project if landscape and transport planning are integrated.

The *protected area* (44,016 km^2) is located in the central JJJ Area and west of Beijing (Fig. 12). The main part of it is existing native forest. The biggest challenge in this area is the rapid development of commerce and housing in Beijing. This forest area, which is the "last defensive line" against desertification, is at risk of diminishing gradually because of Beijing's expansion.

The third designation (*replant forest*) is the combination between ecological and economical development (Fig. 13). This project consists of two big afforestation and protection projects (24,076 km^2, 26,903 km^2), while more than half of the project area is existing forest. The main target of the project is the protection and expansion of the existing forest as green belt restricting the overdevelopment of Beijing. Firstly, the majority of the project area is suitable for the replanting project. Secondly, parts of existing commercial areas and housing areas are designated for transformation into replanting areas or to increase the green belt. Furthermore, the project area can easily be linked to commercial and housing development. The existing transport infrastructure in this area is working well and more accessible transport lines are scheduled, which will also facilitate the development of ecological tourism and economical forest.

The idea of the '*Shelterbelt zone'* (Fig. 14) is similar to the first plan. According to the ecological evaluation model, the designers form a barrier to protect the central JJJ Area from sand storms and desertification. Different from the first design (Fig. 11), this project is closer to the source of desertification. There are few existing forest areas and many barren areas. The main challenge is to increase the survival rate of the planted trees. The limitation of this project is the higher cost with fewer positive results during early stages.

5 Workshop Feedback and Limitations of the Study

As part of his Master dissertation, WANG conducted a survey among the JJJ Area workshop participants. In summary, participants had a good impression of the Geodesignhub online tool, including the usability and the effectiveness for regional planning. Especially the collaboration opportunities were rated as very attractive and of high potential. In the wider context of geodesign, about half the participants believed that understanding the underlying geodesign theory is more difficult than the actual use of the tool. One participant for example raised questions regarding the different evaluation models, and the evaluation stage seems to be the most difficult part of the process to understand. However, it should be noted that not all participants had previous experience with geodesign or knowledge of the geodesign literature. It was noted that the hands-on workshop was most helpful in terms of training. If all meetings had taken place remotely, training might have been more difficult for some of the participants.

In this workshop, experts and students from around the world came together and collaborated. This included participants from Europe and mainland China. Most of the Chinese participants could understand English, but they were also able to understand with relative ease the design language facilitated by the tool using colours and text. The evaluation maps use a simple "red/yellow/green" colour scheme that is almost universal as discrete color-coding. This ensures that the cognitive load of processing the meaning of maps/diagrams and their implications is reduced and also communicated across cultures. Further testing and studies are required to assess the effectiveness of facilitating design language through geodesign.

This study also has implications on how to build collaborative design tools that enable physically remote people to collaborate in real time. Ideas are shared through enabling technologies for design collaboration that work in real time. In the second workshop, we had a participant from China work in real time with another in Germany and multiple in the UK using common messaging tools without the need for specialized apps or software. This kind of collaboration is now possible and further work on this project will involve experts on desertification to come together and develop a solution for the JJJ Area in collaboration with local experts and people in China. This study laid the ground for such remote collaborative problem solving.

Last not least, an interesting discussion about the role of "design" in this approach to geodesign came up: One participant asked whether such collaborative design across stakeholders, planners and computer experts is "design" work or rather "design improving work". However, this study was conceptualized as a pilot study to test the potential of geodesign for regional planning climate change adaptation in Jingjinji Area. Only a full geodesign workshop might give the full picture of the overall design process.

6 Conclusion

The utilization of geodesign for the planning of shelterbelts as regional climate change adaptation measure in the Jingjinji Area proved successful and resulted in two well-informed data-driven workshops with twelve participants from around the world. The parallel process evaluation resulted in additional suggestions of how to further optimize the process. We are positive that the process can now be repeated and scaled up to further regional planning workshops around this extremely interesting case study area.

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