Table of Content

Learning with GI
Thomas Jekel – Robert Vogler – Alfons Koller (Eds.)

GI_Forum 2019, Issue 2
Page: 3 - 9
Short Paper
Corresponding Author:
gisszymon@gmail.com
DOI: 10.1553/giscience2019_02_s3

Beyond 3D Building Modelling: Citizen Science for 3D Cultural Mapping

Szymon Chmielewski[1], Cait Bailey[2] and Adam Gawryluk[1]
[1]University of Life Sciences in Lublin, Poland
[2]MDI Biological Laboratory, Maine, USA

Abstract

This paper discusses a research-in-progress project engaging citizens in the collaborative 3D reconstruction of special urban features (SUFs) – visual works of art located in urban public spaces. While most artists modelling urban public spaces use basic 3D building models, these models do not include visual artworks. Because urban planners use artists' models when designing urban public spaces, we believe it is necessary to incorporate SUFs into 3D city models to help urban planners and artists visualize urban spaces more effectively. To achieve this goal, we propose a bottom-up approach to the geographic visualization of SUF cultural assets (i.e. cultural mapping) which so far has not been undertaken as a citizen science project. The main aims of this project are to engage citizens in contributing to 3D SUF models and to familiarize them with citizen science. The method includes crowdsourcing SUF data and analysing it using 'structure from motion' (SfM) algorithms. After a 6-month campaign in Lublin, Poland, this project has so far resulted in 271 observations and 144 collaborative 3D models, creating a 3D open-data product which can be used for further culturally sensitive urban planning purposes.

Keywords:

cultural mapping, citizen science, 3D city models, Anecdata

1 Introduction

3D city models provide a sophisticated virtual environment for spatial analysis, both in professional 3D GIS software and on the Web. These models serve as communication tools between urban planners (Ranzinger & Gleixner 1997; Koziatek & Dragićević, 2017) and policymakers (Batty et al., 2000), while also helping to improve public participation in sustainable urban planning processes (Wanarat & Nuanwan, 2013). 3D city models typically consist of three basic layers: elevation models, building models and vegetation models. Buildings are the most dominant feature of the urban environment and serve as the most significant feature in 3D city models (Biljecki, 2017). Smaller and more complex objects are often missed, despite their importance to the visual characteristics of a city. Because of their profound aesthetic and artistic qualities, these are classified as Special Urban Features (SUFs) (Crowhurst & Henry, 1987), and our preliminary study is an attempt to incorporate SUFs in

3D city models. SUF typically refers to public visual art (Nasar, 1989), or artworks created with the participation of community members and selected artists, which are located in urban public spaces (Jasmi, & Mohamad, 2016). Because urban planners use artists' models when designing urban public spaces, we found it advisable to incorporate SUF models into 3D city models in order to extend urban planners' and artists' abilities to visualize urban spaces, and to extend the capability of 3D city models to help implement a culturally sensitive urban policy (Kagan et al., 2018; Redaelli, 2012).

Cultural mapping, or the process of collecting and analysing data on cultural assets, including SUFs (Cauchi-Santoro, 2016), is a key aspect of public participation in cultural planning (Duxbury 2015, Redaelli, 2012). As a bottom-up process engaging local communities to gather and analyse data on cultural assets (Redaelli, 2015; Duxbury, 2015), cultural mapping can be viewed as a citizen science (CS) task. The aim of this project is to engage citizens in contributing to 3D SUF models and to familiarize them with CS. This study answers the question of how successful cultural mapping can be undertaken as a CS project. It was carried out in the city of Lublin in eastern Poland, which was a contestant to become the European capital of culture in 2016.

The potential of CS, understood as public participation in scientific research (Bonney et al., 2009), arises from the participation of volunteers (Haklay, 2018). The fuzzy boundaries of CS definitions and applications (Haklay, 2013) also allow for its extension to include opportunities for learning science. This research-in-progress paper discusses the use of a free CS geoweb platform (Kar et al., 2016) to host a 3D cultural mapping project. The proposed framework enables the collaborative 3D reconstruction of SUFs, where participants not only collect observations but also analyse them using structure from motion (SfM) software. Moreover, as an academic project, it also aims to turn students into citizen scientists (Harlin et al. 2018).

2 Development method

The method used in the '3D visual art project' fits into the general CS workflow (Bonney et al., 2009). However, the project's multiple strands and interdisciplinary nature call for special considerations in the framework's design. The three-step method consists of (1) SUF photo crowdsourcing, (2) 3D reconstruction, and (3) data fusion and WebScene publication (Figure 1).

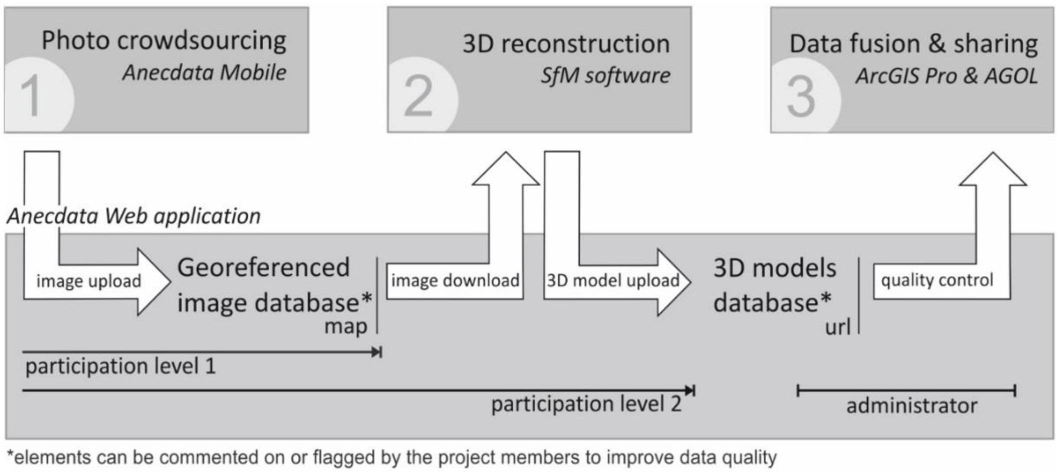


Figure 1: Flowchart of the method along with citizens' engagement levels: level 1 – photo crowdsourcing only; level 2 – uploaded image analysis and 3D model reconstruction.

2.1 Crowdsourcing geotagged photos

The project uses existing CS geoweb infrastructure to collect and share observations. Because it requires uploading and downloading high-resolution images, we decided to use Anecdata.org, an online citizen science platform used by a wide range of research projects across the world. In the context of this study, citizens use the Anecdata.org mobile app to capture multiple geo-referenced photographs of SUFs. The photographs are then immediately available for viewing, comment and download.

2.2 Reconstruction of 3D models and WebScene presentation

Of the various 3D modelling methods (scanning, photogrammetry, CAD-based and rule-based), we decided to use SfM 3D reconstruction due to its availability to any citizen who has the capacity to take photos. Furthermore, the proposed wizard-based SfM software is simple enough for use by citizen scientists. Our workflow recommends using Zephyr 3DF, but volunteers are free to choose another package as long as it supports the Collada or OBJ format. Zephyr 3DF is a turn-key solution which automatically analyses objects in images to infer the orientation of the camera. Once it determines the angles and distances from which each image was captured, it generates a 3D model mesh and stitches the images together to create a model texture. The user then shares their completed SUF model via the URL. To train volunteers in 3D reconstruction, workshops are held periodically at the University of Life Sciences in Lublin as well as at the local 'Warsztaty Kultury' media lab.

2.3 Data fusion and WebScene publication

Completed submissions on the Anecdata.org platform consist of a URL linking to the user-generated model, an image preview of the 3D model, as well as all the original photographs which were used for 3D reconstruction. Members can comment on user-generated models if they appear to have errors, or to share links to other 3D models proposed by other members. Low-quality models and content not suitable for SfM can be marked by project participants for administrator review. Project administrators choose models for publication and update the WebScene periodically using ArcGIS Online.

3 Results

3.1 The crowdsourcing campaign results

The project started in the middle of October 2018 as part of the GIS Day event at the University of Life Sciences in Lublin. 59 participants registered, of whom 35 (59.3%) said they were willing to collect photos. Because of University computer lab's time limitations, only 28 people were eventually invited to participate, received technical instruction, and were briefed on the project's goals. This initial photo collection campaign was carried out over 4 days (10–13 October), and 1,734 photos were uploaded. The most active volunteer was '@bk-Marlena', who uploaded 490 photos over the course of the campaign. A total of 55 visual art objects were photographed, including 30 sculptures, 4 installations, 3 building façades, and 18 small architectural objects. So far (June 2019), the project has 87 members, of whom 69 are students and 18 are Lublin residents recruited at a 'Warsztaty Kultury' media lab workshop on 25 April. In total, 432 observations have been submitted, of which 391 are located in Lublin. Over half of the observations recorded in Lublin (69.3%) meet the requirement of having the 10 or more photos to make them useful for further 3D reconstruction. Currently, the project hosts 144 links to 3D models which are used for further WebScene publication.

The project webpage (https://www.anecdata.org/projects/view/442) provides a 2D map of observations where project progress can be tracked. So far, the most recognizable visual art object in the Lublin case study is the 'Hand' sculpture by Paweł Pawluk (Figure 2).

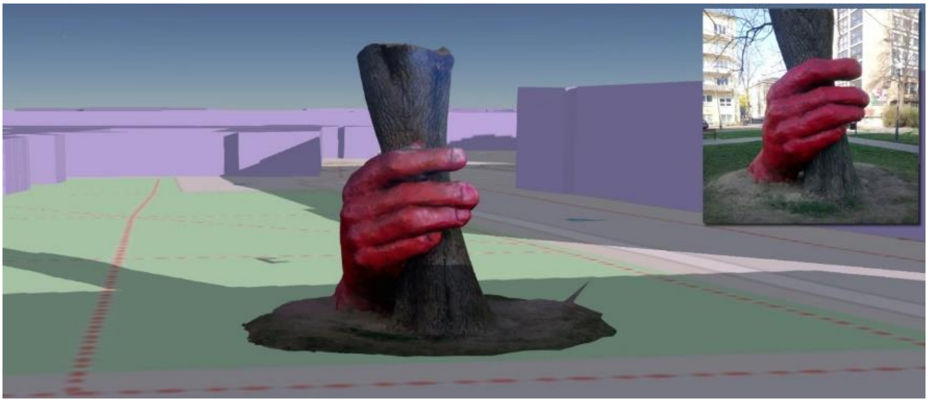


Figure 2: 'Hand': original image (top right) and 3D WebScence (main image).

3.2 The results of Geoweb platform parameter adjustment

The fruitful collaboration with Anecdata.org has resulted in technical improvements to the geoweb platform. Since January 2019, all photos are stored and shared in high resolution (3,200 x 2,400 pixels) and up to 50 images per single observation upload. The Anecdata team updated their online image galleries to provide improved image previews, as well as the ability to re-order images so that reconstructed 3D models appear first. 'Visual Art 3D' users' photos are annotated with the following attributes: city, GPS status, visual art category, and an optional description. Basic statistics on the project members and the number of their observations are available. Both the Web and the mobile versions of Anecdata provide a link to 3D City WebScene, which allows a virtual tour through reconstructed SUFs.

3.3 WebScene visualization

The scene uses a default digital elevation model with customizable basemaps; the building models are represented at LoD1 using subdued colour. The panel on the right allows the viewer to switch layers and conduct shadow analysis. The user can navigate between reconstructed models via bookmarks at the bottom of the scene view (Figure 3), or by zooming to the selected layer. The scene is shared as a link (https://arcg.is/0zPCPD) and can be viewed in any web browser.

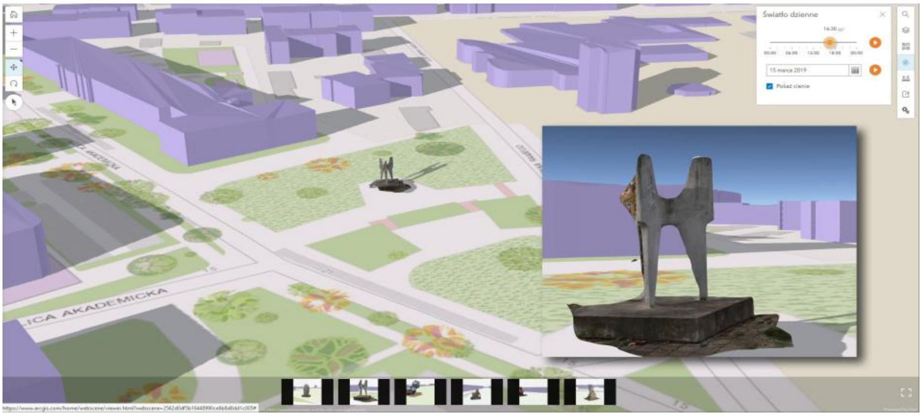


Figure 3: The Raabego sculpture – SUF visualization with shadow casting.

4 Conclusions

In this study, we apply citizen science to the field of cultural mapping by integrating SUFs with 3D city models to help urban planners and artists visualize urban space more effectively. This is not a trivial task. From a technical point of view, the image collection, 3D reconstruction and visualization could certainly be implemented as a Platform As A Service (PAAS) cloud service (see e.g. Tefera et al., 2018), which would streamline user experience and reduce the number of software products used in this case study. Other similar, non-expert but citizen-driven case studies of producing image-based 3D models (Rahaman, Champion & Bekele, 2019) confirm the demand for SfM-ready CS platforms. This study, by using Anecdata, overcomes the basic technical limitations of most CS geoweb platforms: most limit the resolution of uploaded images and file size. For example, Epicollect5 allows unlimited images, but the resolution is reduced to 1,024 pixels and images are highly compressed. The CitSci and GeoODK mobile platforms do not compress images as much, but they impose a limit on file size. Unfortunately, this reasonable policy makes them unsuitable for storing photos for 3D reconstruction. In conclusion, the technical limitations of geoweb platforms makes neo-photogrammetry (Leberl, 2010) difficult to use in citizen science.

The study results also yield social conclusions regarding citizens' engagement. If crowdsourcing is defined here as data collection and CS is data collection and analysis, then this project makes both activities possible and allows participants to adjust their involvement according to their skills levels. Tasks that may seem simple to professionals, such as taking photos for SfM reconstruction, may prove difficult for the general public. Providing hands-on interactive training for teachers and engaging students and volunteers in workshops (Harlin et al., 2018) allows them to teach each other how to reconstruct and visualize the city's cultural assets and thereby become citizen scientists.

Acknowledgements

Mobile app development was funded with a Maine Technology Institute Seed Grant #SG5554 and funding from the Alex C. Walker Foundation. We also thank Agnieszka Wojciechowska and Ewa Orzeszko from medialab 'Warsztaty Kultury' for organizing two citizen science workshops for Lublin city-dwellers.

References:

Batty, M., David, C., Steve, E., Mordechai, H., Stefan, K., Naru, S., et al. (2000). Visualizing the City: Communicating Urban Design to Planners and Decision Makers. London: CASA, UCL Working Paper 26.

Biljecki, F. (2017). Level of detail in 3D city models. PhD thesis, TU Delft, 353 pp.

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V. and Shirk, J. (2009). Citizen science: A developing tool for expanding science knowledge and scientific literacy. *BioScience*, 59(11). 977–84. DOI:10.1525/ bio.2009.59.11.9

Cauchi-Santoro, R. (2016). Mapping community identity: Safeguarding the memories of a city's downtown core. *City, Culture and Society*, *7*(1), 43–54

Crowhurst, L., Henry, L. (1987). *Livable cities – People and places: Social and design principles for the future of the city*. Southampton and New York: Gondolier Press.

Duxbury, N. (2015). *Cultural Mapping as Cultural Inquiry: Introduction to an Emerging Field of Practice*. Duxbury N., Garrett-Petts, W.F., MacLennan, D. eds. Routledge Advances in Research Methods: Cultural Mapping as Cultural Inquiry. Florence, KY: Taylor and Francis.

Haklay, M. (2013). Citizen Science and Volunteered Geographic Information – overview and typology of participation in Sui, D.Z., Elwood, S. and M.F. Goodchild (eds.), *Crowdsourcing Geographic*

Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice. Berlin: Springer. pp 105-122 DOI: 10.1007/978-94-007-4587-2_7

Haklay, M. (2018). Participatory citizen science. In: Hecker, S., Haklay, M., Bowser, A., Makuch, Z., Vogel, J. & Bonn, A. *Citizen Science: Innovation in Open Science, Society and Policy*. UCL Press, London. (pp. 52-62).

Harlin, J., Kloetzer, L., Patton, D., Leonhard, Ch. (2018). Turning students into citizen scientists. in: Hecker, S., Haklay, M., Bowser, A., Makuch, Z., Vogel, J. & Bonn, A. *Citizen Science: Innovation in Open Science, Society and Policy*. UCL Press, London

Jasmi, M. & Mohamad, N. (2016). Roles of Public Art in Malaysian Urban Landscape towards Improving Quality of Life: Between Aesthetic and Functional Value. *Procedia - Social and Behavioral Sciences*, *222*, 872–880.

Kagan, S., Hauerwaas, A., Holz, V., & Wedler, P. (2018). Culture in sustainable urban development: Practices and policies for spaces of possibility and institutional innovations. *City, Culture and Society*, 13, 32-45. https://doi.org/10.1016/j.ccs.2017.09.005

Kar, B., Sieber, R., Haklay, M., & Ghose, R. (2016). Public Participation GIS and Participatory GIS in the Era of GeoWeb. *Cartographic Journal*. https://doi.org/10.1080/00087041.2016.1256963

Koziatek, O., & Dragićević, S. (2017). iCity 3D: A geosimualtion method and tool for three-dimensional modeling of vertical urban development. *Landscape and Urban Planning*, *167*, 356 367. https://doi.org/10.1016/j.landurbplan.2017.06.021

Leberl, F. (2010). Time for Neo-Photogrammetry. *GIS Development*, *14*. 22-24.

Nasar, J.L. (1989). Perception, cognition and evaluation of urban places. In Altman, I & Zube E.H. (Eds). *Public Places and Spaces*. New York and London: Plenum Press

Rahaman, H., Champion, E., & Bekele, M. (2019). From photo to 3D to mixed reality: A complete workflow for cultural heritage visualisation and experience. *Digital Applications in Archaeology and Cultural Heritage*, *13*. https://doi.org/10.1016/j.daach.2019.e00102

Ranzinger, M., & Gleixner, G. (1997). GIS datasets for 3D urban planning. *Computers, Environment and Urban Systems*, *21*(2), 159–173. https://doi.org/10.1016/S0198-9715(97)10005-9

Redaelli, E. (2012). Cultural Planning in the United States: Toward Authentic Participation Using GIS. *Urban Affairs Review*, *48*(5), 642–669. https://doi.org/10.1177/1078087412441158

Redaelli, E. (2015). Cultural mapping – analysing its meanings in policy making. In: Duxbury, N., Garrett-Petts, W.F., MacLennan, D., (eds.) *Cultural Mapping as Cultural Inquiry*. Routledge Advances in Research Methods, Florence, KY: Taylor and Francis, pp. 86-98.

Tefera, Y., Poiesi, F., Morabito, D., Remondino, F., Nocerino, E., & Chippendale, P. (2018). 3Dnow: Image-Based 3D Reconstruction and Modeling Via Web. *ISPRS – International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII 2*, 1097–1103. https://doi.org/10.5194/isprs-archives-XLII-2-1097-2018

Wanarat, K., & Nuanwan, T. (2013). Using 3D Visualisation to Improve Public Participation in Sustainable Planning Process: Experiences through the Creation of Koh Mudsum Plan, Thailand. *Procedia - Social and Behavioral Sciences*, *91*, 679–690. https://doi.org/10.1016/j.sbspro.2013.08.469

GI_Forum 2019, Issue 2
Page: 10 - 23
Full Paper
Corresponding Author:
pablo.cb@live.com
DOI: 10.1553/giscience2019_02_s10

Associations of Body Mass Index with Food Environments, Physical Activity and Smoking

Pablo F. Cabrera-Barona[1], Myriam Paredes[1] and Donald Cole[2]
[1]Facultad Latinoamericana de Ciencias Sociales, Ecuador
[2]University of Toronto, Canada

Abstract

This paper identifies spatial patterns of body mass index (BMI) and obesity in the Metropolitan District of Quito, Ecuador, by applying spatial autocorrelation. We identified BMI hotspots in eastern rural parishes, and hotspots of obesity in northern urban parishes. We then explored associations between distances to food outlets, physical activity and smoking (independent variables), and BMI and obesity (BMI > 30) (dependent variables) by applying global regressions (GR) and geographical weighted regressions (GWR). Smoking was found to be significantly negatively associated with BMI and obesity. Distance to supermarkets was found to be negatively associated with obesity.

Keywords:

BMI, obesity, smoking, physical activity, food outlets

1 Introduction

Malnutrition is a major health burden in developing countries (Müller & Krawinkel, 2005). Increasingly, people in developing countries are influenced by obesogenic environments (Chopra & Darnton-Hill, 2004). In lower- and medium-income countries, economic transitions may be associated with changes in human food-consumption, such as increasing consumption of processed foods (Poobalan & Aucott, 2016). Additionally, the increasing consumption of fast foods is associated with weight gain (Niemeier et al., 2006). Ecuador is a medium-income developing country where obesity and being overweight are endemic. For instance, obesity and being overweight are practically three times more prevalent among children of school age compared with pre-school children, and excess weight and obesity combined affect 62.8 % of adults (Freire et al., 2014).

The association between health outcomes, individual health-related variables and food environments is of great interest for public health interventions (Lytle & Sokol, 2017). Body mass index (BMI) and obesity have been associated with objective and subjective context-level and individual-level variables (Alasmari et al., 2017; Fraser et al., 2012; Morland, Diez Roux, & Wing, 2006). Obesity is defined as a BMI > 30 kg/m2. Local food environments and diet have been comprehensively analysed using respondent-based perceived measures and geographical methods (Caspi et al., 2012; Lytle & Sokol, 2017; McKinnon et al., 2009; Moore et al., 2008). Research about food environments has considered access to healthcare from multiple dimensions: availability, geographical accessibility, affordability, acceptability, and accommodation (Caspi et al., 2012; Penchansky & Thomas, 1981).

Increasing accessibility to fast food outlets can increase consumption of fast food, which is associated with higher BMI (Fraser et al., 2012). In industrialized countries, adequate accessibility to and availability of supermarkets may improve diet among urban residents, as they can offer diverse healthy and affordable foods (Dubowitz et al., 2015). This is less the case in Latin America, where fresh and varied fruit and vegetables at affordable prices are traditionally obtained in open markets. Supermarket chains, although offering fresh produce, are also the main providers of ultra-processed foods, to the detriment of traditional ways of obtaining, cooking and consuming food (Freire et al., 2014; Monteiro et al., 2018). Although food environments are not the only influences on BMI, better access to high-quality foods can improve weight outcomes of urban residents (Gordon-Larsen, 2014). Environments offering opportunities for recreational physical activity can modulate the effects of the obesity drivers on a population's BMI (Swinburn et al., 2011), and regular physical activity can reduce the likelihood of excess weight (Swinburn et al., 2004).

Healthy habits such as doing physical activity contribute to quality of life, while the opposite happens with non-healthy habits such as tobacco consumption. The obesity epidemic has been compared to the tobacco epidemic. Smoking and obesity have a common link: both epidemics are related to the activities of global corporations that resist attempts made by public health organizations to change practices of tobacco and fast food consumption (Chopra & Darnton-Hill, 2004; Courtney, 2006). Previous studies have related BMI and tobacco consumption as health determinants of populations, including urban residents (Aguilar-Salinas et al., 2001; Dare et al., 2015). Among school students, those aware of obesity were found to be more likely to be active smokers and regularly eat fast food (Alasmari et al., 2017).

Availability and geographical accessibility of food outlets are suitable for analysis using geospatial GIS approaches. 'Availability' refers to the number and types of food outlets from which a person can choose, while 'accessibility' reflects the geographical distance between the person and the food outlets: availability and accessibility may refer to the Euclidean distance between the person and the nearest outlet. Most of the research on food environments using GIS has measured distances to food outlets, and the density of these outlets (Charreire et al., 2010).

Methods supported by GIS have also considered socio-economic status and ethnicity variables as independent factors (Apparicio, Cloutier, & Shearmur, 2007; Charreire et al., 2010; Moore et al., 2008; Zenk et al., 2005). Spatial autocorrelation analysis is a useful geographical technique to identify clusters. However, there is limited research applying spatial autocorrelation to food environments (Pineda & Mindell, 2016). Additional geographical techniques such as geographically weighted regressions have been applied in an attempt to understand social-ecological influences on body weight status (Chalkias et al., 2013; Chi et al., 2013; Fraser et al., 2012).

The literature referred to above indicates the existence of associations between weight and physical activity, weight and obesity, and weight and accessibility of food outlets. However, it is limited in the extent to which it studies weight as the effect variable of the covariates physical activity, smoking and access to food outlets through the application of multivariate regression models. Hence our work addressed two research questions. (1) In order to study spatial autocorrelations of the weight health outcomes, we asked 'Do hotspots of BMI/obesity exist in the study area?'. (2) In order to examine associations of weight health outcomes (BMI/obesity) with individual health-related variables (physical activity, smoking) and food environments (distances to food outlets), we asked 'To what extent is variation in BMI and obesity spatially associated with variation in physical activity, smoking and distances to food outlets?'. To answer these questions, we performed an explorative geospatial analysis of data from the Metropolitan District of Quito (MDQ), Ecuador.

2 Methods

The MDQ is and urban–rural administrative area that includes the city of Quito, the capital of the Republic of Ecuador. The city of Quito comprises 32 urban parishes. The Ecuadorean National Institute of Statistics and Census (2019) reports a population of 2.7 million people living in the MDQ.

For this study, three types of spatial analysis were used. The Getis Ord-Gi* index of spatial autocorrelation was applied to identify clusters of BMI/obesity. Global regressions and geographically weighted regressions were applied to identify potential associations of physical activity, smoking and distances to food outlets with BMI/obesity. The Moran's I measure of spatial autocorrelation was applied to assess the ability of the regression models to explain variation in BMI/obesity.

We used data obtained from a cross-sectional survey of a random sample population in the urban and rural areas of the MDQ, in the context of the Ekomer project. This project was funded by the International Development Research Centre of Canada (IDRC) and launched in 2016. The questionnaire comprised diverse questions relating to individual health and food-related behaviour (Paredes et al., in progress). Random survey sectors were generated, and in each sector interviewers visited randomly selected households, obtaining information from each head of household after informed consent was given. Each survey took between 20 and 45 minutes and was carried out between August and December 2017. We obtained 769 responses.

Supermarkets and organic markets are important determinants of the food environment, and access to these food outlets has been associated with health-related factors (Dubowitz et al., 2015; Jilcott Pitts et al., 2013). Within the context of the Ekomer project, we identified 77 supermarkets by searching the website of the Internal Revenue Service of Ecuador, as well as the websites of the main supermarket chains present in Quito. We also ran a survey of all agroecological markets (which include organic markets), identifying 24 in the study area. Figure 1 shows the locations of the supermarkets, agroecological markets and the individuals interviewed.

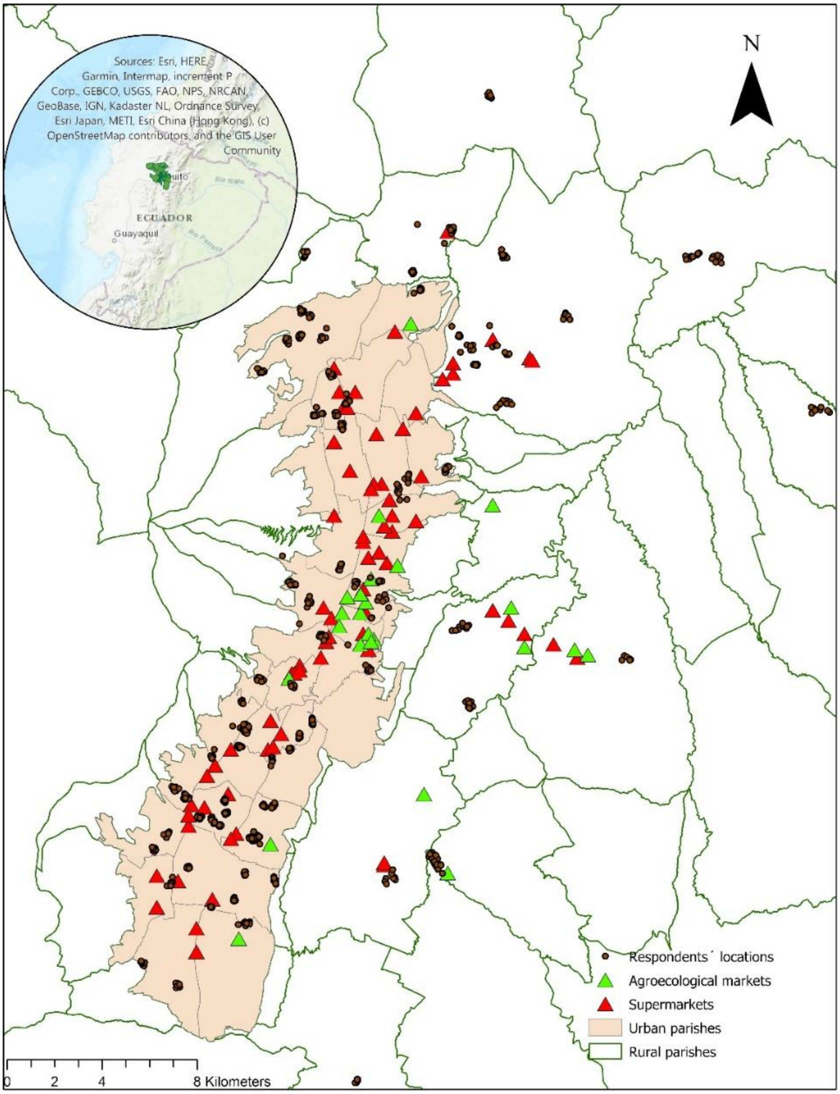


Figure 1: Study Area: The Metropolitan District of Quito. Interviews in rural parishes were taken in populated centres of the parishes.

Based on the conceptual framework presented in the Introduction, we chose the following variables from the questionnaire relaing to individual-level health: smoking and physical activity; direct anthropometric measures of weight and height, from which we calculated BMI. The smoking and physical activity variables were dichotomic, obtained by asking the following questions: 'Have you smoked in the last 30 days?' and 'Do you carry out activities that demand a slight increase of heart and respiratory rates for at least 10 minutes?'.

Additionally, the study considered a food environment-related measure: access to food outlets, which was obtained through GIS analysis. Respondents' locations and the locations of agroecological markets were geo-referenced in the field. Supermarket locations were obtained from websites. The Euclidean distances (in meters) from each respondent's location to the nearest supermarket and agroecological market were calculated. Euclidean distance has been demonstrated to be a useful proxy of real distances and travel times (Jones et al., 2010; Phibbs & Luft, 1995).

The calculated distances were added to the dataset comprising the other variables. Data cleaning was conducted on the dataset: null responses for health variables were removed. After this filtering, 707 respondents were retained for regression analyses. To answer our first research question, 'Do hotspots of BMI/obesity exist in the study area?', an optimized cluster analysis was calculated for all BMI and obesity values (BMI > 30) by applying the Getis-Ord Gi* statistic. This statistic facilitates the identification of clusters of high and low values for BMI and obesity. ArcGIS software was used to calculate Euclidean distances and the spatial autocorrelation indices.

To answer our second research question, 'To what extent is variation in BMI and obesity associated with variation in physical activity, smoking and distances to food outlets?', we calculated global regressions (GR) and geographically weighted regressions (GWR). We applied the regressions to assess the relationships between body weigh status (BMI/obesity – the dependent variables) and tobacco consumption, physical activity, distance to supermarkets, and distance to agroecological markets (the independent variables). GWR4 software was used to perform the GR and GWR. GR is a multivariate linear regression based on the ordinary least squares method; GWR considers the spatial locations of all the variables and performs an explanatory analysis to identify possible non-stationarity of independent variables in relation to the dependent variable.

For regressions considering BMI as a dependent variable, 157 sets of data were considered, corresponding to the 157 respondents identified as obese (BMI > 30). An adaptive Gaussian kernel was used to calculate the GWR in order to mitigate the risk of there being no data within a kernel. To evaluate stationarity, we considered standard errors of the GR, and the quartiles of the local estimates of the GWR. There is non-stationarity if the interquartile range of the GWR's local estimates are more than double the standard errors of the GR estimates (Fraser et al., 2012). The Moran's I statistic was applied for the residuals of the GWRs, in order to identify inconsistencies in the regression model.

3 Results

We found that 22 % of the interviewees were obese; 15% of respondents smoked, and the same percentage conducted vigorous activity for at least 10 minutes. The average distance to supermarkets was 1674 ± 1994 meters, while the average distance to agroecological markets was 3324 ± 2541 m.

Significant hotspots for high BMI were identified in the rural parishes located to the east of the city of Quito (Figure 2).

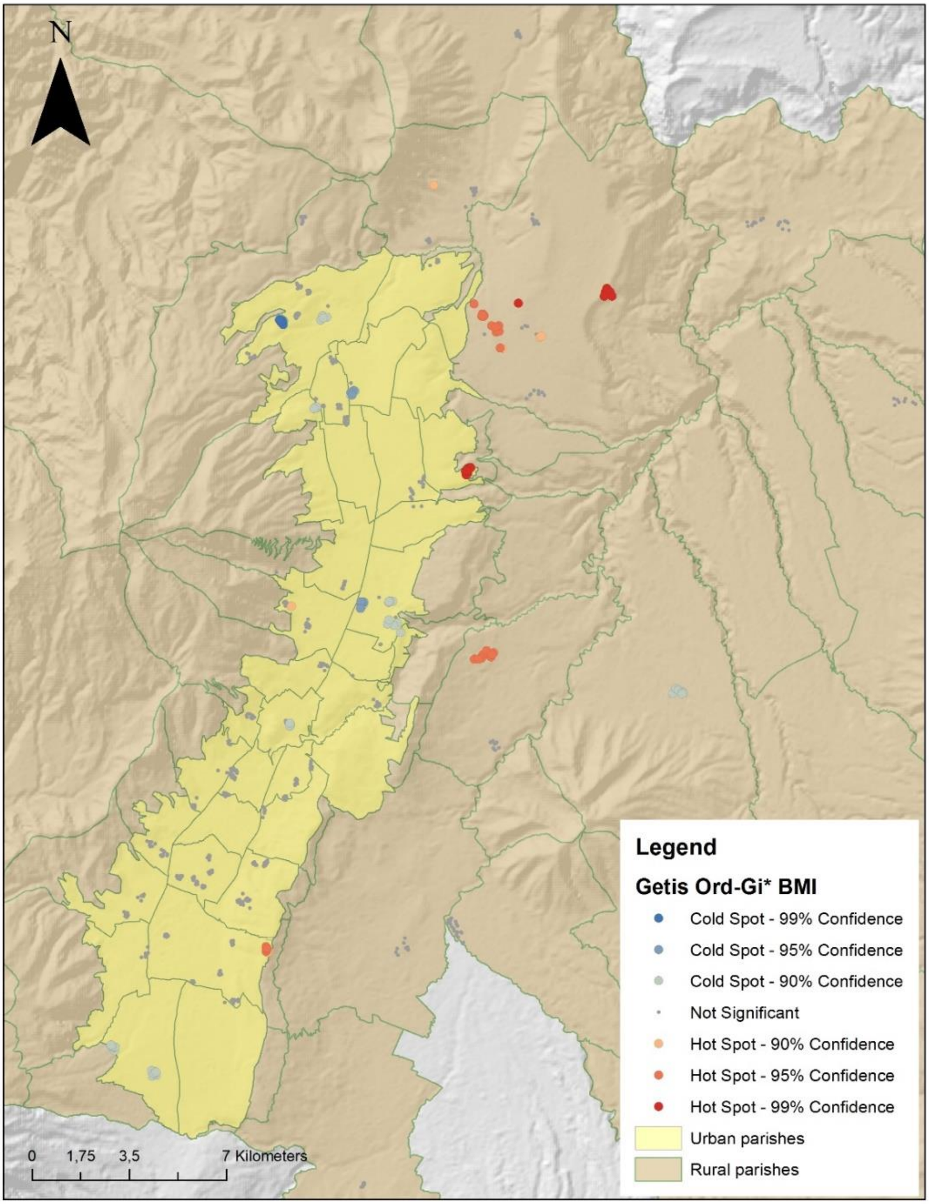


Figure 2: Getis Ord-Gi* for all the BMI values

Highly significant BMI coldspots were found in one northern urban parish, and other significant coldspots throughout some of the urban parishes. In the case of the Getis Ord-Gi*for BMI values > 30, it is striking how clusters of very obese individuals are concentrated in the northern urban parishes (Figure 3).

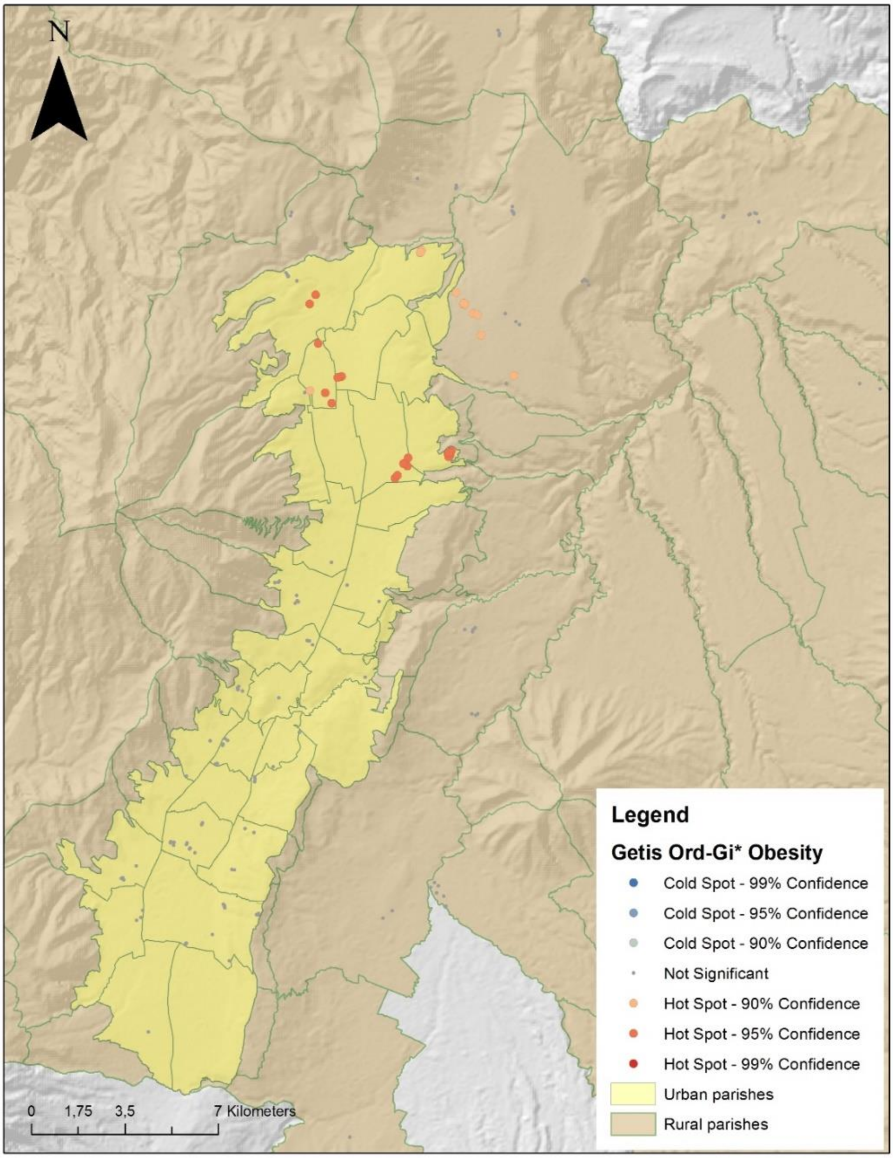


Figure 3: Getis Ord-Gi* for BMI values > 30

When BMI (all values) was considered as a dependent variable (Table 1), smoking was found to be significant (99% confidence) with a negative coefficient, indicating that if people smoked they were less likely to have high BMI. Physical activity, distance to supermarkets and distance to agroecological markets were not found to be significant in the regression analysis.

Table 1: Results of the GR for all BMI

	Estimate	p-value
Intercept	27.598	0.000
Smoking	-1.309	0.005
Physical activity	-0.232	0.495
Distance to supermarkets	-0.000	0.585
Distance to agroecological markets	-0.000	0.411
Adjusted R2	0.006	
AICc*	4104.085	

*AICc: Akaike Information Criterion corrected

For the GR considering obesity (BMI > 30) as a dependent variable (Table 2), smoking was found to be significant. Distance to supermarkets was significant (significance level of 0.10) when considered in a one-tailed hypothesis, with greater distances to supermarkets being associated with lower obesity (Table 2). Distance to agroecological markets was not found to be significantly associated with obesity. Intercepts of the two GRs (the value of the dependent variable when all independent variables are equal to zero) were also found to be significant.

Table 2: Results of the GR for obesity (BMI > 30)

	Estimate	p-value
Intercept	33.796	0.000
Smoking	-1.795	0.067
Physical activity	0.439	0.445
Distance to supermarkets	-0.0003	0.064*
Distance to agroecological markets	-0.0002	0.347
Adjusted R2	0.006	
AICc	850.394	

*one-tailed hypothesis

If we look at the GWR for BMI as a dependent variable, an improvement of fit over the GR model can be seen: the Akaike Information Criterion corrected (AICc) is lower in the GWR model (Table 3). In the GWR models, no extreme variations of local estimates were obtained (low SD). However, evidence of non-stationarity was found for all the independent variables of the GWR with BMI as a dependent variable (Table 3) – that is, the relationships between each independent variable and the dependent variable differ among themselves and vary across the space. The results from the stationarity evaluation in the GWR model with the dependent variable 'obesity' show that the associations of obesity with smoking and with distances to markets vary across space.

Table 3: Results of the GWR for all BMI

	Min	Max	Mean	SD	Stationarity
Intercept	27.621	27.691	27.652	0.017	Stationary
Smoking	-1.559	-1.151	-1.409	0.163	Nonstationary
Physical activity	-0.293	-0.188	-0.249	0.041	Nonstationary
Distance to supermarkets	-0.000	0.000	-0.000	0.000	Nonstationary
Distance to agroecological markets	0.000	0.000	0.000	0.000	Nonstationary
Adjusted R2	0.007				
AICc	4103.386				

When the GWR considered obesity as a dependent variable, there was no improvement compared with the GR model (Table 4).

Table 4: Results of the GWR for obesity (BMI > 30)

	Min	Max	Mean	SD	Stationarity
Intercept	32.717	33.891	33.796	0.068	Stationary
Smoking	-1.938	-1.758	-1.862	0.061	Nonstationary
Physical activity	0.429	0.485	0.452	0.012	Stationary
Distance to supermarkets	-0.0003	-0.0003	-0.0003	0.000	Nonstationary
Distance to agroecological markets	0.0001	0.0001	0.0002	0.000	Nonstationary
Adjusted R2	0.005				
AICc	850.744				

Table 5 shows a random pattern for residuals of the GWR. This means that the regression models are well defined, and the independent variables used are useful for predicting BMI and obesity.

Table 5: Moran´s I for residuals of the GWR

	BMI (all)	Obesity
Moran's Index	0.014	0.025
z-Score	0.286	0.417
p-Value	0.774	0.676

4 Discussion

Our study identified spatial variations of BMI and obesity, and spatial variations between these dependent variables and the independent variables 'smoking' and 'distance to food outlets'. We also identified BMI hotspots in rural parishes. In general, urban areas tend to offer better spatial access to food stores than rural areas (Apparicio et al., 2007; Dai & Wang, 2011). The urban parishes in the study area are in the city of Quito, where the majority of the supermarkets are concentrated. Most of the agroecological markets are located in central areas of the city.

Results of the Getis Ord-Gi* show that there are hotspots of obese people in the north of the city. In the center of this area, there is a concentration of supermarkets and agroecological markets, and some significant BMI coldspots (90-95 % confidence). The reason might be that this is where most universities are located, where people suffer no or very little socio-economic deprivation (Cabrera-Barona, Blaschke, & Gaona, 2017; Cabrera-Barona et al., 2015). People here have greater access to education and financial resources, a situation that probably contributes to their decisions for a healthier diet. The first agroecological markets in Quito were found in this area as a result of people's interest in fresh produce and in purchasing direct from farmers. In these central urban parishes, accessibility to healthy food outlets is adequate, and a higher proportion of people are not overweight. However, further research in the study area is needed to explore relationships between weight, education and other socio-economic indicators.

Less affluent urban parishes, such as those located in the south of the study area, have poor availability of agroecological markets. Although supermarkets are present in these parishes, these are not the cheapest food outlets for fresh fruit and vegetables, and processed foods occupy greater areas than those dedicated to fresh food. As stated by Freire et al. (2014) and Monteiro et al. (2018), in Latin America supermarkets are the main providers of highly processed foods. Moreover, in the MDQ, supermarket corporations are able to locate cheaper stores in less affluent neighbourhoods. Food deserts are urban zones where cheap and nutritious food is unobtainable (Macintyre, 2007). To identify potential food deserts in less affluent parishes, future research should focus on the spatial distribution of greengrocers (*fruterías*) and markets, as well as the prices of these markets compared to those of supermarkets.

As Cummins & Macintyre (2002) state, the term 'food desert' may be misleading, and a lack of clear information about this issue may cause flawed health policy. There is evidence that low-income households do not necessarily have poorer access to healthy food (Cummins & Macintyre, 2002; Macintyre, 2007). Dubowitz et al. (2015) found that urban residents could do most of their food shopping outside their neighbourhood. However, we need to be careful of oversimplifications for our study area. In less affluent Ecuadorean neighbourhoods, there is generally at least one corner shop, but these shops do not necessarily sell healthy foods, and the food corporations often use them to advertise and promote processed foods. In our study area, populations of urban residents among whom obesity was less prevalent had to travel longer distances to get to a supermarket. These residents possibly also look for healthier sources of food such as markets and greengrocers. The latter have become very common in residential and business centers in Quito. However, further investigation is needed to establish any link between lower obesity levels and greater distances from supermarkets.

The results obtained from the GWR can be considered reliable thanks to the sample size and the Moran's I statistics, which suggest that the models are using relevant explanatory variables. These conditions minimize false-positives in the regressions (Fraser et al., 2012). Using BMI as the dependent variable, the GWR model represented an improvement over the GR model. The most striking results of the GWR and GR models was the inverse relationship between smoking and BMI and obesity, confirming the findings of Dare et al. (2015): smokers had a lower risk of obesity than non-smokers, while former smokers had the same risk of obesity as people who had never smoked. However, they also identified heavy smokers as more likely to be obese than people who had never smoked. Dare et al. concluded that steps to manage weight are needed when people are helped to quit smoking. Global food corporations control much of the food we eat, and to tackle obesity similar strategies are needed to those used against the tobacco industry (Chopra & Darnton-Hill, 2004).

Physical activity was not found to be a significant factor in either GR. However, we also found that physical activity levels vary across space when BMI is used as a dependent variable, suggesting that in some areas of the MDQ people may be doing more exercise. In general, people with better access to green spaces are less likely to be overweight (Coombes, Jones, & Hillsdon, 2010). The areas where average BMI is lowest are close to the city's biggest park: good access to this green space may be attracting local residents to exercise. Availability of green spaces is not always related to weight, but in neighbourhoods with better access to green areas, physical activity tends to be higher (Richardson, Pearce, Mitchell, & Kingham, 2013). We therefore think that access to green spaces is a factor to be explored in future research in Ecuador.

Although Euclidean distance is useful to assess distances, spatial accessibility could be measured by other means, such as density analysis, travel-time modelling, or gravity-based accessibility (Cabrera-Barona et al., 2017; Charreire et al., 2010). Investigations addressing the problematics of the food environment and food deserts need to apply diverse geospatial methods, and we consider it important that future research should compare different approaches to evaluate spatial accessibility to food outlets.

We are agree with Turner et al. (2018) that food environment research should take into account differences between high income countries (HICs) and low and medium-income countries (LMICs). One of the biggest differences is the stability of prices and the types of food available in supermarkets in the HICs, as opposed to the LMICs where supermarkets are relatively new introductions. A related question is the importance of area-level socio-economic deprivation as an influence on BMI and obesity. For this, multilevel models can be applied that use a finer-grained scale, for example measures of deprivation at census-tract level.

5 Conclusion and Outlook

Our investigation contributes to the public health and food environment literatures by employing spatial autocorrelation, and GR and GWR to uncover influences on BMI/obesity of individual-level health variables and context-level food environment variables. Further analyses should incorporate contextual and individual-level variables that can be associated with food environments, such as neighbourhood socio-economic status, and consumers' food preferences and behaviours.

This paper contributes to an understanding of weight factors and of spatial patterns of weight and obesity in a Latin American context. The study identified highly significant BMI hotspots in rural parishes, and significant obesity hotspots in northern urban parishes of the MDQ. Smoking was found to be inversely associated with BMI, whereas smoking and distance to supermarkets were found to be associated with obesity. We identified spatial variations in the relationships between the weight outcomes and most of the independent variables considered. The spatial heterogeneity of local associations of the health-related variables used suggests that weight may be influenced by additional local factors, which require further investigation.

Including spatial methodologies at local scales can contribute to a better understanding of inequalities in health related to food environments, and to informing public health strategies that encourage people to move away from buying processed and more energy-dense foods in small stores and supermarkets, to purchasing fresher foods from markets and greengrocers.

Findings presented in this research are important for improving knowledge of the ecology of weight as a key health outcome. Finally, the research provides important insights for health policy and may support decision-makers in the Municipality of Quito to tackle the problematics of obesity in the MDQ.

References

Aguilar-Salinas, C. A., Vázquez-Chávez, C., Gamboa-Marrufo, R., García-Soto, N., de Jesús Ríos-González, J., Holguı□n, R., … Mayagoitia, S. (2001). Obesity, Diabetes, Hypertension, and Tobacco Consumption in an Urban Adult Mexican Population. *Archives of Medical Research*, *32*(5), 446–453. https://doi.org/10.1016/S0188-4409(01)00300-9

Alasmari, H. D., Al-Shehri, A. D., Aljuaid, T. A., Alzaidi, B. A., & Alswat, K. A. (2017). Relationship Between Body Mass Index and Obesity Awareness in School Students. *Journal of Clinical Medicine Research*, *9*(6), 520–524. https://doi.org/10.14740/jocmr2987w

Apparicio, P., Cloutier, M. S., & Shearmur, R. (2007). The case of Montréal's missing food deserts: Evaluation of accessibility to food supermarkets. *International Journal of Health Geographics*, *6*(4), 1–13. https://doi.org/10.1186/1476-072X-6-4

Cabrera-Barona, P., Blaschke, T., & Gaona, G. (2017). Deprivation, Healthcare Accessibility and Satisfaction: Geographical Context and Scale Implications. *Applied Spatial Analysis and Policy*, 1–20. https://doi.org/10.1007/s12061-017-9221

Cabrera-Barona, P., Murphy, T., Kienberger, S., & Blaschke, T. (2015). A multi-criteria spatial deprivation index to support health inequality analyses. *International Journal of Health Geographics*, *14*(11). Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4376370&tool=pmcentrez&rendertype=abstract

Caspi, C. E., Sorensen, G., Subramanian, S. V., & Kawachi, I. (2012). The local food environment and diet: A systematic review. *Health & Place*, *18*(5), 1172–1187. https://doi.org/10.1016/J.HEALTHPLACE.2012.05.006

Chalkias, C., Papadopoulos, A. G., Kalogeropoulos, K., Tambalis, K., Psarra, G., & Sidossis, L. (2013). Geographical heterogeneity of the relationship between childhood obesity and socio-environmental status: Empirical evidence from Athens, Greece. *Applied Geography*, *37*, 34–43. https://doi.org/https://doi.org/10.1016/j.apgeog.2012.10.007

Charreire, H., Casey, R., Salze, P., Simon, C., Chaix, B., Banos, A., … Oppert, J.-M. (2010). Measuring the food environment using geographical information systems: a methodological review. *Public Health Nutrition*, *13*(11), 1773–1785. https://doi.org/DOI: 10.1017/S1368980010000753

Chi, S.-H., Grigsby-Toussaint, D. S., Bradford, N., & Choi, J. (2013). Can Geographically Weighted Regression improve our contextual understanding of obesity in the US? Findings from the USDA Food Atlas. *Applied Geography*, *44*, 134–142. https://doi.org/https://doi.org/10.1016/j.apgeog.2013.07.017

Chopra, M., & Darnton-Hill, I. (2004). Tobacco and obesity epidemics: not so different after all? *BMJ*, *328*(7455), 1558–1560. https://doi.org/10.1136/bmj.328.7455.1558

Coombes, E., Jones, A. P., & Hillsdon, M. (2010). The relationship of physical activity and overweight to objectively measured green space accessibility and use. *Social Science & Medicine*, *70*(6), 816–822. https://doi.org/10.1016/J.SOCSCIMED.2009.11.020

Courtney, B. (2006). Is Obesity Reallythe Next Tobacco? Lessons Learned from Tobacco for Obesity Litigation. *Annals of Health Law*, *15*(1), 61–106.

Cummins, S., & Macintyre, S. (2002). 'Food deserts' – evidence and assumption in health policy making. *BMJ*, *325*(7361), 436–438. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/12193363

Dai, D., & Wang, F. (2011). Geographic Disparities in Accessibility to Food Stores in Southwest Mississippi. *Environment and Planning B: Planning and Design*, *38*(4), 659–677. https://doi.org/10.1068/b36149

Dare, S., Mackay, D. F., & Pell, J. P. (2015). Relationship between Smoking and Obesity: A Cross-Sectional Study of 499,504 Middle-Aged Adults in the UK General Population. *PLOS ONE*, *10*(4), e0123579-. Retrieved from https://doi.org/10.1371/journal.pone.0123579

Dubowitz, T., Zenk, S. N., Ghosh-Dastidar, B., Cohen, D. A., Beckman, R., Hunter, G., … Collins, R. L. (2015). Healthy food access for urban food desert residents: examination of the food environment, food purchasing practices, diet and BMI. *Public Health Nutrition*, *18*(12), 2220–2230. https://doi.org/DOI: 10.1017/S1368980014002742

Fraser, L. K., Clarke, G. P., Cade, J. E., & Edwards, K. L. (2012). Fast Food and Obesity: A Spatial Analysis in a Large United Kingdom Population of Children Aged 13–15. *American Journal of Preventive Medicine*, *42*(5), e77–e85. https://doi.org/https://doi.org/10.1016/j.amepre.2012.02.007

Freire, W. B., Ramirez-Luzuriaga, M. J., Belmont, P., Mendieta, M. J., Silva-Jaramillo, K. M., Romero, N., … Monge, R. (2014). *Resumen Ejecutivo. Tomo I: Encuesta Nacional de Salud y Nutricio□ n de la poblacio□ n ecuatoriana de cero a 59 an□ os. ENSANUT-ECU 2012*. Quito.

Gordon-Larsen, P. (2014). Food Availability/Convenience and Obesity. *Advances in Nutrition*, *5*(6), 809–817. Retrieved from http://dx.doi.org/10.3945/an.114.007070

Jilcott Pitts, S. B., Wu, Q., McGuirt, J. T., Crawford, T. W., Keyserling, T. C., & Ammerman, A. S. (2013). Associations between access to farmers' markets and supermarkets, shopping patterns, fruit and vegetable consumption and health indicators among women of reproductive age in eastern North Carolina, U.S.A. *Public Health Nutrition*, *16*(11), 1944–1952. https://doi.org/10.1017/S1368980013001389

Jones, S. G., Ashby, A. J., Momin, S. R., & Naidoo, A. (2010). Spatial implications associated with using euclidean distance measurements and geographic centroid imputation in health care research. *Health Services Research*, *45*(1), 316–327. https://doi.org/10.1111/j.1475-6773.2009.01044.x

Lytle, L. A., & Sokol, R. L. (2017). Measures of the food environment: A systematic review of the field, 2007–2015. *Health & Place*, *44*, 18–34. https://doi.org/10.1016/J.HEALTHPLACE.2016.12.007

Macintyre, S. (2007). Deprivation amplification revisited; or, is it always true that poorer places have poorer access to resources for healthy diets and physical activity? *International Journal of Behavioral Nutrition and Physical Activity* , *4*(32), 1–7.

McKinnon, R. A., Reedy, J., Morrissette, M. A., Lytle, L. A., & Yaroch, A. L. (2009). Measures of the Food Environment: A Compilation of the Literature, 1990–2007. *American Journal of Preventive Medicine*, *36*(4), S124–S133. https://doi.org/10.1016/J.AMEPRE.2009.01.012

Monteiro, C. A., Cannon, G., Moubarac, J.-C., Levy, R. B., Louzada, M. L. C., & Jaime, P. C. (2018). The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutrition*, *21*(1), 5–17. https://doi.org/DOI: 10.1017/S1368980017000234

Moore, L. V, Diez Roux, A. V, & Brines, S. (2008). Comparing Perception-Based and Geographic Information System (GIS)-based characterizations of the local food environment. *Journal of Urban Health : Bulletin of the New York Academy of Medicine*, *85*(2), 206–216. https://doi.org/10.1007/s11524-008-9259-x

Morland, K., Diez Roux, A. V., & Wing, S. (2006). Supermarkets, Other Food Stores, and Obesity: The Atherosclerosis Risk in Communities Study. *American Journal of Preventive Medicine*, *30*(4), 333–339. https://doi.org/10.1016/J.AMEPRE.2005.11.003

Müller, O., & Krawinkel, M. (2005). Malnutrition and health in developing countries. *CMAJ : Canadian Medical Association Journal = Journal de l'Association Medicale Canadienne*, *173*(3), 279–286. https://doi.org/10.1503/cmaj.050342

Niemeier, H. M., Raynor, H. A., Lloyd-Richardson, E. E., Rogers, M. L., & Wing, R. R. (2006). Fast Food Consumption and Breakfast Skipping: Predictors of Weight Gain from Adolescence to Adulthood in a Nationally Representative Sample. *Journal of Adolescent Health*, *39*(6), 842–849. https://doi.org/10.1016/j.jadohealth.2006.07.001

Paredes, M., Cole, D., Muñoz, F., April-Lalonde, G., Bert, P., Valero, Y., … Ekomer project team. (n.d.). *Assessing responsible food consumption in three Ecuadorian city-regions*.

Penchansky, R., & Thomas, J. W. (1981). The Concept of Access: Definition and Relationship to Consumer Satisfaction. *Medical Care*, *19*(2), 127–140.

Phibbs, C. S., & Luft, H. S. (1995). Correlation of travel time on roads versus straight line distance. *Medical Care Research and Review*, *52*(4), 532–542.

Pineda, E., & Mindell, J. (2016). Association of the food environment with obesity: a systematic review of geographical and statistical methods. *The Lancet*, *388*, S89. https://doi.org/10.1016/S0140-6736(16)32325-X

Poobalan, A., & Aucott, L. (2016). Obesity Among Young Adults in Developing Countries: A Systematic Overview. *Current Obesity Reports*, *5*(1), 2–13. https://doi.org/10.1007/s13679-016-0187-x

Richardson, E. A., Pearce, J., Mitchell, R., & Kingham, S. (2013). Role of physical activity in the relationship between urban green space and health. *Public Health*. https://doi.org/10.1016/j.puhe.2013.01.004

Swinburn, B. A., Caterson, I., Seidell, J. C., & James, W. P. T. (2004). Diet, nutrition and the prevention of excess weight gain and obesity. *Public Health Nutrition*, *7*(1a), 123–146. https://doi.org/DOI: 10.1079/PHN2003585

Swinburn, B. A., Sacks, G., Hall, K. D., McPherson, K., Finegood, D. T., Moodie, M. L., & Gortmaker, S. L. (2011). The global obesity pandemic: shaped by global drivers and local environments. *The Lancet*, *378*, 804–814.

Turner, C., Aggarwal, A., Walls, H., Herforth, A., Drewnowski, A., Coates, J., … Kadiyala, S. (2018). Concepts and critical perspectives for food environment research: A global framework with implications for action in low- and middle-income countries. *Global Food Security*, *18*, 93–101. https://doi.org/10.1016/J.GFS.2018.08.003

Zenk, S. N., Schulz, A. J., Israel, B. A., James, S. A., Bao, S., & Wilson, M. L. (2005). Neighborhood Racial Composition, Neighborhood Poverty, and the Spatial Accessibility of Supermarkets in Metropolitan Detroit. *American Journal of Public Health*, *95*(4), 660–667. https://doi.org/10.2105/AJPH.2004.042150

Sustainability Objectives of Non-Profit Sharing-Economy Activities: Assessing Achievement. A Case Study of the Mundraub Food-Sharing Poject

GI_Forum 2019, Issue 2
Page: 24 - 33
Short Paper
Corresponding Author:
sabine.hennig@sbg.ac.at
DOI: 10.1553/giscience2019_02_s24

Sabine Hennig
Salzburg University, Austria

Abstract

Web-based participation has received growing interest over recent years. Such participation includes both profit- and non-profit-oriented sharing-economy initiatives. Not-for-profit sharing-economy initiatives focus less on economic aspects and more on awareness-raising in society regarding sustainability objectives (e.g. sustainable production and consumption of goods). In the current discussions around climate change and sustainable lifestyles, awareness-raising is important and new ways of reaching the public are attracting more interest. The question now is not simply to what extent non-profit sharing-initiatives achieve their goals, but how to assess any achievement as, due to the nature of these projects, little information on the participants' background, perspectives and behaviour is available.

These questions are discussed with reference to the Mundraub project, which allows people to share information on plants (e.g. fruit and nut trees, berry bushes and herbs) in public urban spaces (primarily German cities) so that others can harvest the plants for free. To learn about how sustainability objectives are achieved, data for the sites where the plants that have been mapped to Mundraub are located were analysed statistically. The results indicate that the people who are reached by the Mundraub project are mostly those who are already interested and aware of sustainability-related topics. The assessment approach used is a first attempt towards a better understanding of the extent to which the sustainability objectives of non-profit sharing-economy activities have been reached and towards identifying how the achievement of objectives might be improved on.

Keywords:

sharing economy, non-profit sharing-activities, sustainability, participation, food

1 Introduction and Research Questions

The rapid advance of Information and Communication Technologies (ICT), the rise of the Internet, the emergence of social media, and the growth in Internet user numbers have triggered new modes of participation. These include the 'sharing economy', in which consumers grant each other temporary access to under-utilized physical assets, possibly for money, enabled by web-based platforms. As it allows any kind of goods and services to be shared, the sharing economy covers sectors such as transportation, accommodation, the labor market and education, but also food (Frenken & Schor, 2017; Ganapati & Reddick, 2017). A distinction is made between sharing-economy activities run by companies to make a profit (e.g., Uber, Airbnb), and non-profit, voluntary projects (IICOM, n.d.).

Various objectives of the sharing economy are highlighted in the literature: reducing negative environmental impacts through decreasing the amount of goods to be produced and transported, lowering costs for consumers, and accelerating sustainable production. Moreover, non-profit sharing-economy initiatives in particular stress objectives such as raising people's awareness about sustainability, and changing their behaviour towards greater sustainability (Berchem, 2016; IICOM, n.d.; Rudenko, 2013). In what follows, these objectives are summarized under the umbrella term 'sustainability objectives'. Due to current discussions around climate change and movements promoting sustainable lifestyles, sustainability objectives are attracting increasing attention. In this context, the literature outlines that by involving people in different ways and at different levels, participatory approaches contribute significantly to increasing people's awareness and their positive attitudes toward environmental and public concerns (Bonney et al., 2009; Cohn, 2008; Newman, 2012).

Understanding to what extent non-profit sharing-economy initiatives actually reach the public and their own sustainability objectives is of interest but difficult to assess. This is because – as common in participatory projects and particularly non-profit sharing-economy activities – there is little data available on who participates. To register, for instance, users usually only have to provide a username and/or email in order to access the information being shared (see, e.g., Klein et al., 2019; Vogler et al., 2017). When data such as socio-demographic categories or land use is available on a site that makes available information about a resource to be shared, this information can help to characterize participants. The question is how useful this approach is to gain insights into the extent to which sustainability objectives are being met. This is discussed through the example of the not-for-profit sharing-economy project Mundraub (Box 1), which was chosen because food-related topics such as food sustainability and sovereignty, local and global food movements, and food-sharing activities are attracting more and more attention.

Box 1: The Mundraub project (Berchem, 2016; Keppler & Faust, 2017; Klein et al., 2019; Mundraub, n.d.)

Key data	The Mundraub project (initiated 2009; https://mundraub.org) is a food-sharing initiative with the aim of having the public share their knowledge on fruit and nut trees, berry bushes and herbs in the public spaces so that others can harvest them. Focus is on plants located in the urban environment in Germany. Similar projects are falling fruit (http://fallingfruit.org/) or na ovoce (https://na-ovoce.cz/web/) and initiatives like foodsharing (https://foodsharing.de/).
Providing and using information	Information on plants is provided by adding plants to an interactive online map embedded in the Mundraub platform and a mobile app. Information includes the location of the plant, the species, and taste rating. The plants are grouped into four categories: fruit (9 species) and nut trees (4 species), berry bushes (13 species), and herbs (7 species). Using the Mundraub map, others can access the information on plants, and thus find and harvest them. While the mapping of plants requires users to register, searching the map for plants can be done without registration. As with other non-profit participatory, sharing-economy initiatives, only limited personal data is required when registering on Mundraub: username, password and email.
Pecularities	To attract people's interest, local Mundraub groups exist and organize activities (harvest camps, sharing traditional recipes, etc.) which allow for personal, face-to-face contact of the people involved or interested in the project. City and/or community administrations are invited to add data to the Mundraub database (e.g. tree data available by tree cadastres).
Aims and Objectives	The Mundraub project has several non-profit aims and objectives which are particularly relevant to society: to have people discover and use edible landscapes, to connect people with nature, to raise their awareness of topics such as resources and their use, regionality and seasonality of food, food sovereignty and local food movements. Moreover, the project may trigger people to change their behaviour towards a more sustainable lifestyle and to increase their identification with the local environment. The project also serves as a channel for collaboration and participation, and to foster social interaction and partnership.

2 Workflow and methods

The approach used comprises four steps (Figure 1): (1) accessing Mundraub data; (2) identifying and accessing data for sites where plants that have been mapped to Mundraub are located (e.g. sociodemographic and land-use data, referred to from now on as 'explanatory data'); (3) preprocessing, and (4) analysing the Mundraub and explanatory data together.

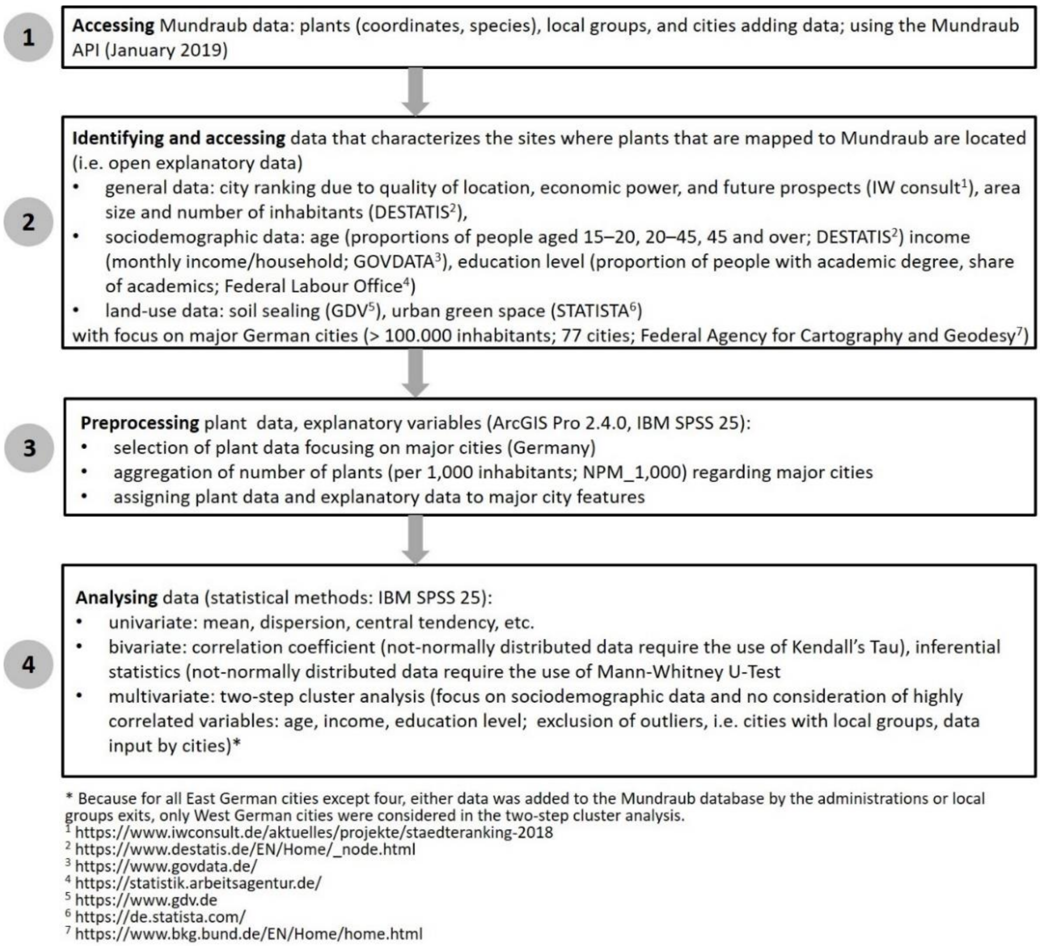


Figure 1: Workflow steps with data and tools, and methods used

The Mundraub project provides an Application Programing Interface (API) that allows accessing data from the Mundraub database. When HTTP requests are made to the Mundraub API, the data on plants (coordinates, species) and local groups (coordinates) are delivered in JSON format (status: January 2019).

Various aspects of the explanatory data were identified. Although a wide range of data for German cities and communities exists, explanatory data is not available to the same extent for all cities and their sub-districts. Consequently, focus was on major German cities (> 100,000 inhabitants; 77 cities) for which explanatory data was available as open data and/or free, and each city was considered as a whole.

The Mundraub data was aggregated at city level as number of plants and local groups per city. To improve readability and handling, the number of plants per city is referred to as number per 1,000 inhabitants (NPM_1,000; see, e.g., Klein et al., 2019).

The Mundraub data and the explanatory data were assigned to the corresponding city features. The data was analysed by applying uni-, bi- and multivariate statistical methods. The results from uni- and bivariate statistical analyses allowed decisions to be made on appropriate bivariate and multivariate statistical methods, as well as on which data it was appropriate to take into account.

3 Analysis results

The Mundraub database holds data on 47,519 plants, 98% of which (46,533) are located in Germany (Figure 2). 65% of the plants (31,084) have been mapped in German major cities. Of the 163 local Mundraub groups, 63 are located in 35 of these cities. The Mundraub data includes information provided by the public and data contributed by several city administrations. The city administrations of Berlin, Hamburg, Frankfurt/ Main, Leipzig, Bonn and Osnabruck have contributed data on trees located in their areas.

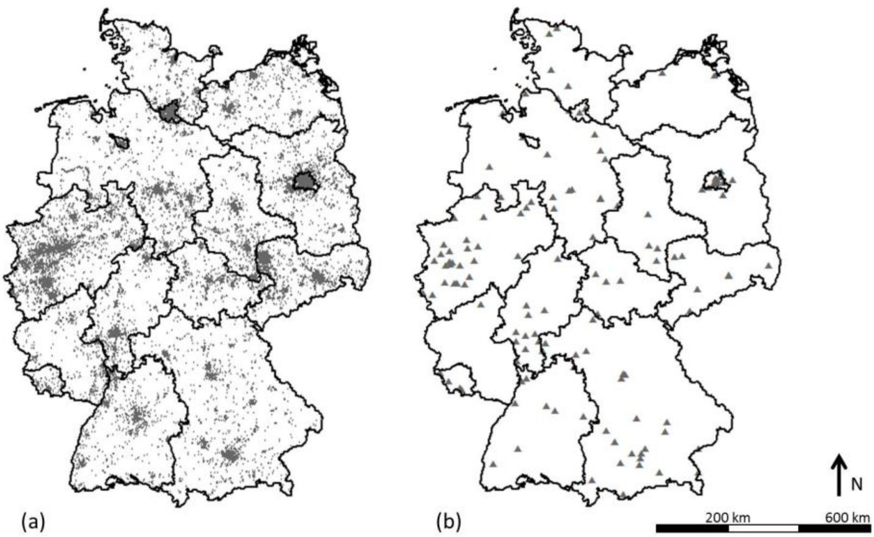


Figure 2: Mundraub data (Germany): (a) plants mapped; (b) local groups

With respect to NPM_1,000, the statistical results indicate differences between: (1) cities where city administrations contributed data on trees to the Mundraub database or not; (2) East and West German cities[1]; (3) cities with and without local groups. The significance of the

[1] There are notable differences between East and West German cities in terms of tree density, due to the different political and economic trajectories followed by the two German states after the Second World War. In West Germany, the rapid economic recovery after the war allowed people to buy fruit cheaply throughout the year. In East Germany, fruit trees were still being planted in housing estates in the 1990s, while in West Germany they had been replaced by ornamentals. These differences resulted in far-reaching consequences for green development in West and East German cities, which is also reflected in the Mundraub database (Larondelle & Strohbach, 2016).

differences between these cities (East/West German city; city data input/no city data input; city with/without local groups) was confirmed by inferential statistical tests (Mann-Whitney U-Test): the null hypothesis (no differences between the samples) was rejected for each group (Table 1). In a nutshell, East German cities, cities where the administration added data to the Mundraub database, and cities with local Mundraub groups have higher NPM_1,000 than West German cities, cities where the administration did not add data to the database, and cities without local Mundraub groups.

Table 1: Inferential statistical tests (Mann-Whitney U-Test) for different groups of cities

Groups of cities	Asymp. Sig. (2-tailed)	Sample size
City data input/no city data input	P=0.00 ($p < 0.05$)	Data input 6; no data input = 71
West/East Germany	P=0.00 ($p < 0.05$)	East Germany = 10; West Germany = 67
City with/without local groups	P=0.02 ($p < 0.05$)	Local group =34; no local group = 43

Running correlation analysis (Kendall's Tau) and two-step cluster analysis delivered additional information. Kendall's Tau results revealed relationships between the age-related demographics of a city and education level on the one hand, and NPM_1,000 on the other (Table 2):

- the smaller the proportion of people aged over 45, the higher the NPM_1,000
- the smaller the proportion of people aged 15–20, the higher the NPM_1,000
- the higher the proportion of people aged 20–45, the higher the NPM_1,000
- the higher the proportion of people with academic degree, the higher the NPM_1,000.

Table 2: Correlation analysis results (Kendall's Tau): sociodemographic/land-use data and NPM_1,000 (data sources: DESTATIS, Federal Labor Office, GDV, Govdata, IW consult, STATISTA; see Figure 1)

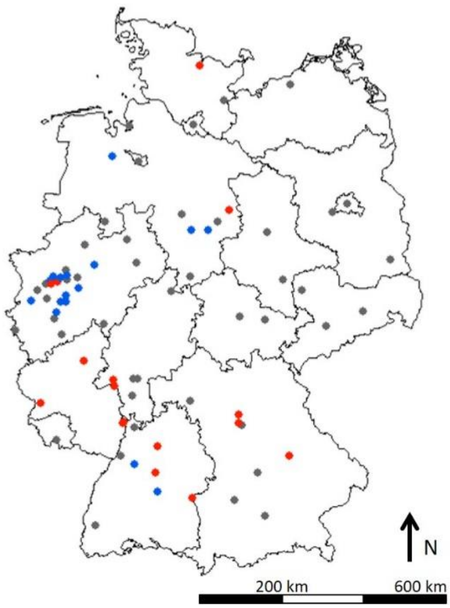
Variables	Correlation coefficient	Sample size
number of inhabitants (1,000)	0.141*	77
area (km²)	0.185*	77
aged 15-20 (share)	**-0.371**(2)**	70
aged 20-45 (share)	**0.293 (1)**	70
Aged over 45 (share)	**-0.205* (1)**	70
Income per household (1,000 €)	-0.118	72
academics (percentage)	**0.287** (1)**	73
city level ranking	-0.192*	71
soil sealing (percentage)	-0.043	50
urban green space (percentage)	-0.033	14

* significant, alpha = 0,05 (2-tailed); ** significant, alpha = 0,01 (2-tailed);
(1) weak relationship; (2) medium-strong relationship

The two-step cluster analysis identified two clusters (good cluster model quality; Figure 3):

- Cluster 1: cities with a smaller share of older (> 45 years) and younger people (15–20 years), higher monthly income per household, and higher share of academics have a higher NPM_1,000
- Cluster 2: cities with a higher share of older (> 45 years) and younger people (15–20 years), lower monthly income per household, and smaller share of academics have a lower NPM_1,000

The Mann-Whitney U Test (N = 32; p <=0,046 asymp. sig. 2-tailed) confirmed that there is a significant difference between the two clusters regarding NPM_1,000.



Variable	Cluster 1 Mean Std. Deviation	Cluster 2 Mean Std. Deviation
age older 45 (share)	51 2.08	46.03 3.34
age 15–20 (share)	5.18 0.2	4.68 0.25
income/house hold (1.000 €)	20,235 2,172	23,298 3,555
academics (share)	12 3.02	20.52 5.50
NPM_1.000	0.2527 0.29	0.33 0.24

Figure 3: Cluster analysis results (data sources: DESTATIS, Federal Labor Office, Federal Agency for Cartography and Geodesy, Govdata; see Figure 1)

4 Discussion

At first glance, the number of plants (47,519) available in the Mundraub database seems high, but if we focus on the cities, a different picture emerges: in general, the individual cities are characterized by a small number of plants mapped (i.e. NPM_1,000). This also applies to cities where data on trees has been added by the city administrations – even though for these cities NPM_1,000 is higher in comparison to cities where no data on trees has been added by the city administrations (Table 3).

Table 3: Number of plants available in the Mundraub database (German major cities)

City	number of plants	NPM_1,000	number of (fruit/nut) trees per 1,000 inhabitants	number of herbs/shrubs per 1,000 inhabitants
Berlin	9,488	2.6	2.34	0.29
Hamburg	4,110	2.2	2.02	0.22
Frankfurt/ Main	2,564	3.4	3.18	0.25
Leipzig	2,456	4.2	3.42	0.81
Bonn	1,424	4.4	4.11	0.26
Osnabruck	346	2.1	1.86	0.25
Other cities (N = 71): median, min. - max.	*100, 0-766*	*0.45, 0-2.2*	*0.22, 0-1.86*	*0.19, 0-0.96*

In addition to the quantity of data, the number of people actively participating in a community related to a project is key for the achievement of participatory project objectives. Projects are often challenged by a low number of people contributing to, or interested in, the initiative (Hennig, 2019). Hakley (2013) notes that, generally, just a small share of committed users add the vast majority of data to an initiative. Thus, it can be assumed that of the 71,000 registered users, only a small number of individuals are actively contributing to and engaged in the Mundraub project. Here, it should be noted that a large but active community (e.g. including members who act as disseminators and role models; Hennig, 2019) would attract more people; this also has an impact on the number of people actually reached by a project and the extent to which objectives will be met.

Although participatory projects aim to involve people from a wide variety of backgrounds, participants often come from certain backgrounds only and/or belong to particular segments of society (King & Brown, 2007; Vogler et al., 2017). Regarding the Mundraub project, the analysis results show that cities with certain sociodemographic characteristics have a higher number of plants mapped (Figure 3): i.e. cities characterized by a higher monthly income per household, higher education levels (more academics), and fewer people aged over 45 or aged 15–20. This is in line with other studies outlining that people with higher educational levels and income are often among those engaged in plant foraging (Arrington et al., 2017; Synk et al., 2017). Generally speaking, these are also the people who are interested in sustainability and environmental topics (see, e.g., BMU & BfN, 2017). This suggests that not everyone in society is equally attracted by and aware of the Mundraub project: the project seems to reach mainly people who are already interested in, and aware of, sustainability objectives.

To improve the extent to which sustainability objectives are achieved, the results allow the following recommendations to be made:

- increasing synergies between the Mundraub project and other initiatives and organizations (e.g. other participatory initiatives such as OpenStreetMap; urban gardening initiatives) in order to increase, on the one hand, the amount of data available in the Mundraub database and, on the other hand, project publicity

- facilitating contacts between people involved and interested in the Mundraub project (e.g. through local groups and events)
- addressing those segments of society which so far have been reached scarcely or not at all; to promote the project and its aims, group-specific motivational factors and communication channels should be taken into account.

5 Conclusion and Outlook

The sharing economy is drawing growing interest, including in the form of non-profit initiatives such as the food-sharing project Mundraub. The project's objectives refer in particular to issues like awareness raising and changing people's behaviour with respect to sustainability. However, the extent to which these objectives are being achieved is difficult to ascertain since little data is available on participants (i.e. individuals who share data, or who use the shared data). Analysing the Mundraub data together with explanatory data (i.e. data characterizing the sites where plants have been mapped, with a focus on German major cities) shows that the project (including its objectives) seems to reach only a relatively small number of people – primarily individuals who are already interested in sustainability.

Using explanatory data and focusing on German major cities has certain limitations, due to considering the cities as wholes, and the use of just a few variables. The results give only an idea of the general situation (e.g. the sociodemographic characteristics of those interested). However, the results are in line with the results other studies and allow us to draw some initial conclusions regarding the extent to which sustainability objectives are being achieved, and to gain a better understanding of the situation. The approach could therefore be useful for other participatory and non-profit sharing-economy projects. Nevertheless, it needs to be improved: it would be useful to have access to data at the level of individual city neighbourhoods, and not only for major cities in Germany.

References

Arrington, A. B., Diemont, S. A., Phillips, G. T., & Welty, E. Z. (2017). Demographic and landscape-level urban foraging trends in the USA derived from web and mobile app usage. *Journal of Urban Ecology*, 1–9. doi:10.1093/jue/jux006.

Berchem, M. (2016). *Changing Consumption Patterns*. Retrieved from http://www.futuresdiamond.com/casi2020/blog/posts/changing-consumption-patterns/

BMU & BfN, (2017). Naturbewusstsein 2017. Bevölkerungsumfrage zu Natur und biologischer Vielfalt

Bonney R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J. & Wilderman. C. (2009). *Public participation in scientific research: defining the field and assessing its potential for informal science education*. A CAISE inquiry group report. CAISE, Washington, DC.

Cohn, J. P. 2008. Citizen science: Can volunteers do real research? *Bioscience*, 58 (3): 192–197. doi:10.1641/B580303.

Frenken, K. & Schor, J. (2017). Putting the sharing econonomy into perspective. *Environmental Innovations and Societal Transitions*, 23, 3-10.

Ganapati, S. & Reddick, C. (2017). Prospects and challenges of sharing economy for the public sector. *Government Information Quarterly*, 35(1), 77-87.

Haklay, M. (2013). Citizen Science and Volunteered Geographic Information – overview and typology of participation. In: D. Z. Sui, S. Elwood & M.F. Goodchild (Eds.), *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice*, 105-122. Berlin: Springer.

Hennig, S. (2018). Motivation und webbasierte Geopartizipation. *AGIT Journal für Angewandter Geoinformatik* 1-2018, 282-291.

Hennig, S. (2019). Motivation and its consideration in participatory spatial data contribution. *The Professional Geographer*. DOI/MS ID: 10.1080/00330124.2019.1676799 /

IICOM International Institute of Communications (n.d.) Impact of the sharing econonomy. Retrieved from http://www.iicom.org/themes/item/impact-of-the-sharing-economy-2

Keck, H. Faust, M. Fink, Gaedke. M. & Reeh, T. (Eds*), Transformationsräume: Lokale Initiativen des sozial-ökologischen Wandels*, Göttinger Schriften zu Landschaftsinterpretation u. Tourismus 9, 95-122.

Keppler, B. & Faust, H. (2017). Alternative urbane Nahrungsmittelnetzwerke – Eine vergleichende Analyse mit einer vertiefenden Betrachtung des Projekts 'Mundraub'. In: M. King, S., & P. Brown. 2007. Fix my street or else: Using the Internet to voice local public service concerns. Paper presented at the ICEGOV2007, Macao, December 10-13.

Klein, T., Gildhorn, K. & Jurasinski, G. (2019). Der 'mundraub'-Datensatz; Stand und Potenzial für Naturschutz und Forschung. *AGIT – Journal für Angewandter Geoinformatik* 5-2019, 246-260.

Larondelle, N. & Strohbach, M. (2016). A murmur in the trees to note: Urban legacy effects on fruit trees in Berlin, Germany. *Urban Forestry & Urban Gardening* 17, 11-15.

Mundraub (n.d.). Zahlen, Fakten, Obst. Retrieved from https://mundraub.org/

Newman, G., A. Wiggins, A. Crall, E, Graham, S. Newman, and K. Crowston. 2012. The future of citizen science: Emerging technologies and shifting paradigms. *Frontiers in Ecology and the Environment* 10: 298-304. doi:10.1890/110294.

Rudenko, A. (2013). *The collaborative consumption on the rise: why shared economy is winning over the 'capitalism of me'.* Retrieved from http://popsop.com/2013/08/the-collaborative-consumption-sharing-wins-over-ownership/

Synk, C. M., Kim, B. F., Davis et al. (2017). Garthering Baltimore's bounty: Characterizing behaviours, motivations, and barriers of foragers in an urban ecosystem. *Urban Forestry & Urban Greening*, 28, 91–102. doi:http://dx.doi.org/10.1016/j.ufug.2017.10.007.

Vogler, R., Hennig, S. & Ferber, N. (2017). Redressing the Exclusiveness. Challenges which Prevent New Users from Contributing to OSM. *GI_Forum* 2017(1), 294-299.

GI_Forum 2019, Issue 2
Page: 34 - 46
Full Paper
Corresponding Author:
sven-schmuderer@uni-passau.de
DOI: 10.1553/giscience2019_02_s34

Citizen Participation via Digital Maps: A Comparison of Current Applications

Sven Schmuderer[1, 2], Roland Zink[2] and Werner Gamerith[1]
[1]University of Passau, Germany
[2]Deggendorf Institute of Technology, Germany

Abstract

The effects of digitization on social coexistence have been a subject of controversy not only since the increased use of social media for political campaigns. Digital platforms are also being developed which, from the perspective of spatial planning and geography, enhance communication between administrations and citizens at the local municipal level. These applications are being developed in relation to three areas: (1) the everyday experiences and competences of citizens in dealing with geomedia, especially the use of smartphones; (2) the individual process design for a particular participatory case; (3) the desired societal or local political benefit. This paper deals with these three aspects and discusses five selected examples of how digital participation platforms can be designed to include the use of geomedia. Based on experiences with the proprietary development of the web application PUBinPLAN in particular and on its comparison with other platforms, insights can be derived with regard to success factors as well as to opportunities and risks.

Keywords:

geomedia, participation, digitization, success factors

1 Geomedia in everyday life

According to Döring & Thielmann (2009, p. 19) and emphasizing the spatial aspect, geomedia in this article are defined as 'media in which spatial coordinates and/or physical localization are necessary conditions for their functioning'. The continuing rapid technological progress in mobile technologies (notebooks, smartphones), digital map services (Google Maps, OpenStreetMap etc.), and localization systems (GNSS, GSM, WiFi, RFID etc.) is propelling the use of geomedia. Together, these technologies are prerequisites for geolocalization (Genevois & Delorme, 2010, p. 41), which in turn forms the basis of numerous services. Examples for this are geocoded tweets, restaurant ratings that give georeferences, navigation apps or pedometers: geomedia have long been an integral part of digital and connected everyday life.

While initially services focused on providing information to one's individual position (location-based services) or route suggestions, the current trend is towards Web 2.0 applications, where the user him/herself becomes the data supplier (Thielmann, 2014, p. 26). This trend is increasingly affecting social networks by geotagging tweets or by leveraging features like 'my position' on Google. Social networks benefit from this trend, first because all these services are Internet-based and require an application connection and, second, because of the openness of many citizens to providing a wealth of personal data (partially) publicly. Examples are pulse rate or oxygen saturation recorded and shared via fitness apps using hardware such as wearables. New visualization techniques, such as augmented reality, which display real-time interactive environmental information (Goudarznia et al., 2017, p. 250), will enable new features, for example virtual sports competitions, which will further promote the connection between social media and geomedia.

Taking these developments together in combination with the possibility of capturing not only measurable sensor data but also citizens' individual wishes, sensitivities and opinions in a geo-based manner, geomedia allow innovative approaches in citizen participation. In this paper, we define citizen participation, after the upper levels of the 'Ladder Of Citizen Participation' of Arnstein (1969, pp. 217, 221-223), as an honest partnership between citizens and authorities, in which event-based decision-making powers are shared and citizen engagement is strengthened. Nevertheless, there is a need for critical scientific underpinning, which is why this article deals with two main questions: What are the potential uses of geomedia in the field of digital participation in collaborating with municipal institutions? And what prerequisites should be met?

Section 2 will look at the state of the art. Sections 3 and 4 will then discuss the relevance of geomedia for participation and compare five examples of digital participation that use geomedia. The analysis focuses on the application context and the accessibility of the services. The findings are then assessed in Section 5, critically questioned, and finally used to answer the research questions presented above.

2 State of the Art

Inviting people to comment on and add to the virtual world of maps presented publicly via the Internet, as exemplified by Google or OpenStreetMap (Boeckler, 2014, p. 4), is often used in the literature in conjunction with the term 'neogeography' (Turner, 2006, p. 3). Current approaches in this field are concerned with the integration of real-time data into maps (Steiger et al., 2016), the development of geographic online platforms for the public sector (Pietsch et al., 2016), or the quality assurance of user-generated content (Aden & Kirchner, 2016).

Geomedia are also discussed as scientific tools, data sources or research topics per se in the literature. Groß & Zeile (2016, pp. 273-278) describe how geo-referenced vital signs (pulse rate, temperature etc.) are recorded by means of body sensors, which allow conclusions about the psycho-physiological status of humans and thus provide information about stress levels and the level of (perceived) danger in situations like road traffic, for example. There are also novel possibilities of location-based research using geomedia, such as the study of emotions associated with earthquakes or responses to global events – especially from social media, like Twitter (see e.g. Fearnley & Fyfe, 2018, pp. 97-98).

Concepts such as the 'Ladder Of Citizen Participation' (Arnstein, 1969) or the 'Public participation ladder' (Wiedemann & Femers, 1993, p. 357) classify citizen participation in levels, from manipulating via consulting up to public partnership and even citizen control. Today, digital maps, geoinformation and geomedia also play an increasingly important role (Zink et al., 2016, pp. 489–490), as has been seen for quite some time in approaches such as Public Participation Geographic Information Systems (PPGIS), as discussed in Carver (2001), Weiner et al. (2002) or Sieber (2006); Volunteered Geographic Information (VGI) (Goodchild (2007)); Crowdsourced Maps as presented in Neis et al. (2012); Participatory Sensing (Goldman et al., 2009); Urban Sensing (Campbell et al., 2008); Citizen Sensing (Sheth, 2009), and the Geospatial Web (Atzmanstorfer & Blaschke, 2013).

3 Relevance of geomedia for participation

Geomedia of various forms play an important part in the everyday lives of many people, both technically and socially. Due to their everyday significance, geomedia can also be highly relevant for participation in social/civic contexts. This results in a triad comprising previous experiences with geomedia, instruction to participation and the social benefits of geomedia (see Figure 1), which will be discussed below.

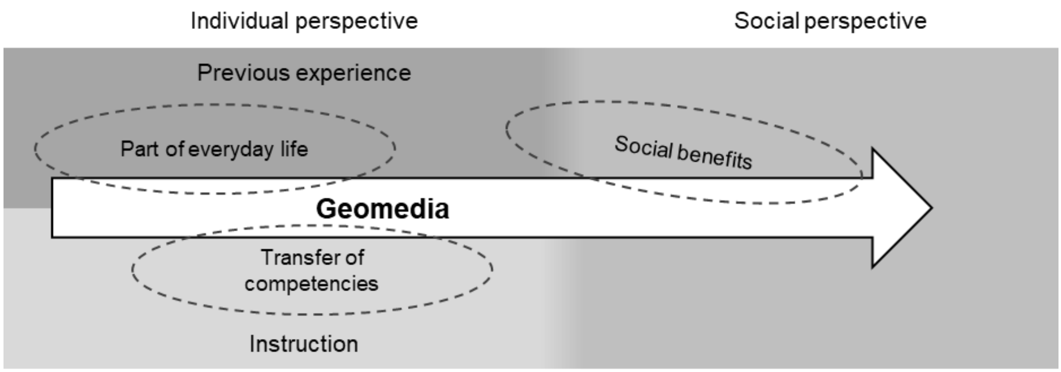


Figure 1: Relevance of geomedia for participation

3.1 Geomedia as a part of everyday life and as a starting point for participation

Since Google Earth in particular came on the scene, digital maps have been present in people's everyday lives, in a form that people can actively help to shape (Manovich & Thielmann, 2009, pp. 383, 389). In the meantime, the maps are interwoven with personal information, friendships and other content that is important to individuals (Gordon, 2009, p. 398). This everyday presence also has an age-related aspect. In discussions connected with participation, decision-makers at municipal level (mostly mayors) often express the hope of using digital methods to address new and, above all, younger citizens – the so-called digital natives.

This results in playful approaches that have the potential to increase both the attractiveness of geomedia and participation by young people in particular. Computer games such as Minecraft or Cities:Skylines, in which buildings, streets or infrastructure can be planned and visualized in an interactive virtual world, allow an initial approach to topics of spatial planning, making the subject more accessible and easier to understand for many people (Andorfer et al., 2016, pp. 534-535, 538). The game environment promotes a better understanding and offers novel participatory and collaborative possibilities (virtual tours, building work, changing or expanding planning etc.) combined with a motivating effect.

Both the everyday and the gaming experiences of citizens offer numerous starting points for digital citizen participation. As a central component, geomedia create added value for participatory processes by making citizens' high regional and spatial knowledge and competence usable for the planning process in an innovative and often ludic manner (Zink et al., 2016, p. 488). However, an institutional and technical framework that sets out both the process of participation and the functionalities of digital participation remains essential. Accordingly, users require training and need to learn how to handle geomedia.

3.2 Transfer of competences as a prerequisite for civil use of geomedia

The ability to interpret and critically interrogate maps and other spatial representations, to communicate through maps, and to express location-based opinions through the use of geomedia is helpful for engaging in societal developments and projects (Gryl et al., 2010, p. 7). Although learning how to use geomedia does not need to be institutionalized, especially as digital natives use most applications intuitively, support at different levels can be helpful: on the one hand, the creation of basic skills over the longer term and, on the other, short-term and project-related instruction.

For the former, Hoffmann (2018, pp. 7, 9) argues for a stronger orientation towards problem solving and the future in geography lessons, in order to broaden how the complexity and current challenges of the modern world are dealt with. According to Harris (2018, p. 17), students should learn to deal with geographical data and facts, because factualness is seen as an effective antidote to misinformation and suggestibility.

Project-related guidance refers to a specific case. Digital citizen participation should not take place in a manner that is detached from social processes, but rather be embedded as a complementary tool. This embedding requires the adaptation of the digital participatory process to the task at hand (for example, long-term urban development, or short-term infrastructure measures), with a corresponding definition of the process, participation functions and co-determination rights (e.g. voting, commenting or moderating). It is the responsibility of instructors to deliver the relevant information and training, which must take into account previous individual experiences and competences of citizens, as well as to moderate the facilitation.

3.3 Social use of geomedia as a participatory instrument

Because of the high costs and lack of clarity about the supposed benefits of public works, it is important to involve citizens already during the design and planning process (Bitsch et al., 2016, p. 353). This is important for successfully developing target-group-oriented solutions. If citizens are able to submit their opinions and suggestions for improvement spatially by using geomedia, these can be included much more effectively (Herbst et al., 2016, p. 271).

Combining advantages of social media with Web-GIS applications, innovative and practical tools for participatory processes can emerge. Better provision of information to citizens, more flexible handling of the individual steps in the participation process, avoidance of media discontinuities, greater clarity about spatial interconnections in planning, purposeful facilitation, as well as clear orientation in the complexity-reduced procedure are all objectives of participation that can be helped by the use of geomedia (Helbig et al., 2016, pp. 509-517). Especially helpful in achieving results is the visualization of projects in 2D or 3D. Both support more efficient communication throughout a project, to the public as well as to experts (Schaller et al., 2017, p. 110).

The aim of geo-based digital participation platforms should be to provide interfaces for citizens as well as for experts (planning offices, construction companies, technicians, legal advisers etc.). This ensures that information can be retrieved centrally and the process can be stringent. Managing the participation process centrally enables a temporary allocation of active and passive roles to individual groups. If actors work periodically but purposefully on individual project steps, a productive way of working with a high degree of acceptance on the part of citizens is guaranteed (Küspert & Zink, 2017, pp. 138-139).

Scheffer (2018, p. 46) also mentions disadvantages of using geomedia. Dangers for politics and society must not be overlooked, notably if people as individuals or as part of a group use filters and other functions to focus increasingly on things which affect their own interests. Participatory processes – analogue and digital – should strengthen social discourse and allow a multifaceted opinion to emerge. Table 1 summarizes opportunities and risks that may result from the use of geomedia in general, and participatory geomedia in particular.

Table 1: Opportunities and risks resulting from geomedia

Advantages / Opportunities	Disadvantages / Dangers
▪ Improved orientation / visualization. ▪ Social networking / community. ▪ Making contributions that are useful to other people (personal expertise). ▪ Benefits for science and research. ▪ Contributing to the formation of public will. ▪ Motivation for a stronger (active) social commitment. ▪ Assisting in and contributing to decision-making. ▪ Modernizing geography lessons. ▪ Improving (working) relationship between citizens and state/municipalities/authorities.	▪ Untrue entries (fake messages). ▪ Abuse by hackers, bots etc. ▪ Inappropriate comments, hate speech etc. ▪ Privacy issues. ▪ Traceability of personal opinions, wishes, movements, etc. ▪ Unwitting data transmission to third parties. ▪ Lack of knowledge regarding how data is used. ▪ Concerns about monitoring / control. ▪ Being unwittingly manipulated by other users or by technology (filter functions, algorithms etc.). ▪ Use with bad intentions.

4 Examples of participation using geomedia

The following examples show the use of geomedia in connection with participation in space-related planning, with a focus on accessibility and functionality. After describing some functionalities of the in-house development PUBinPLAN, the platforms Betri Reykjavik, Frankfurt gestalten, Mängelmelder and Sag's doch are shown, in particular to illustrate different ways of accessing platforms. They can be seen as examples for the variety of platforms.

PUBinPLAN (https://pubinplan.th-deg.de) is a browser-based application which aims to integrate citizens affected by a project into spatial planning processes right from the start. The range of applications includes village, urban and regional development as well as school projects. PUBinPLAN combines project management approaches with geomedia and participation functionalities.

Frankfurt-gestalten (https://www.frankfurt-gestalten.de) is a platform with three functions. First, an information service covering ten years of local politics in the city of Frankfurt. Second, the platform aims to facilitate exchanges between citizens. Third, citizens can become actively involved by posting their ideas on the website. Regionally, the platform focuses on the city of Frankfurt and addresses the whole spectrum of city administration and urban development.

In contrast to Frankfurt-gestalten, which expresses its regional focus in its name, Mängelmelder (https://www.mängelmelder.de) focuses on a very specific topic. The platform allows everyone to report local problems of all kinds. Photos and text can be added. One version of Mängelmelder is operated by the city of Jena (https://maengelmelder.jena.de/de/report). Depending on the category selected (trees, streets, etc.), an e-mail is sent to the relevant city authority (JENA TV, 2018). Although the reports can be made anonymously, this has not resulted in particularly significant levels of misuse: of the 300 or so concerns that were sent to the city of Jena within the first month, only a few were ambiguous in intent (JEZT AKTUELL, 2018).

Sag's doch (https://sags-doch.de) is similar to Mängelmelder. It allows problems to be posted on the platform, but ideas can also be introduced. Together with citizens, the city of Friedrichshafen and the District Office of Bodenseekreis want to develop realistic but also creative solutions to local political issues.

Using Betri Reykjavik (https://betrireykjavik.is/domain/1), an example from Iceland, citizens can express ideas on issues regarding services and operations in the city of Reykjavik and discuss proposals that have been made. Top-rated ideas are processed by standing committees. Lesser-rated ideas are noted by representatives and city administrators.

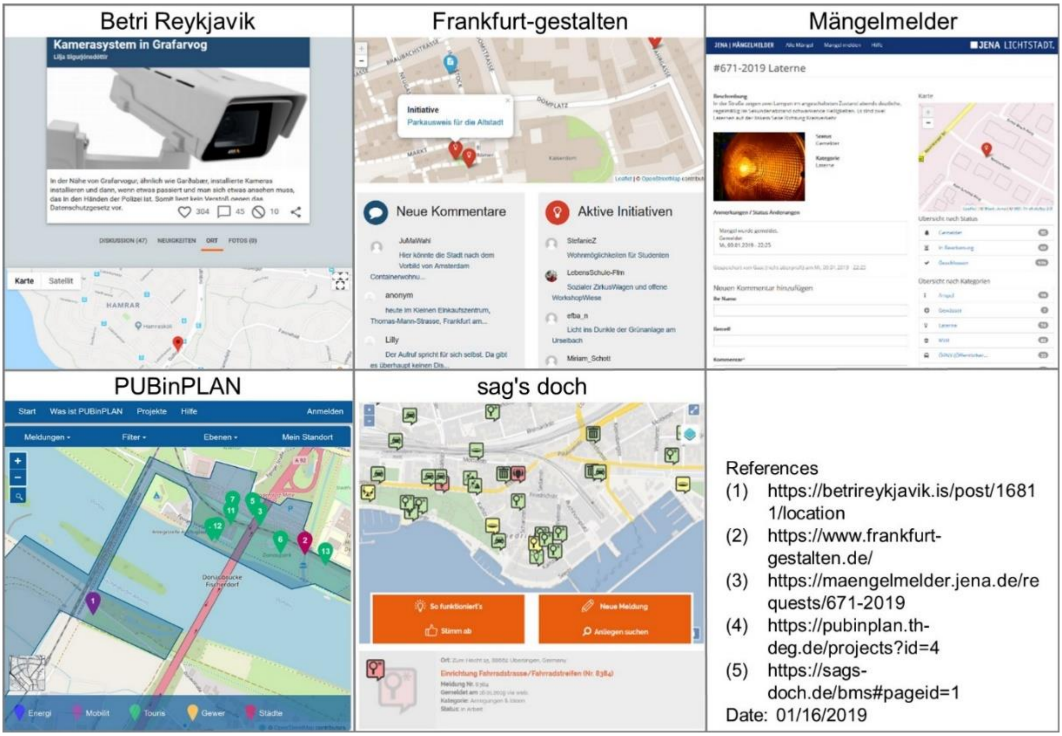


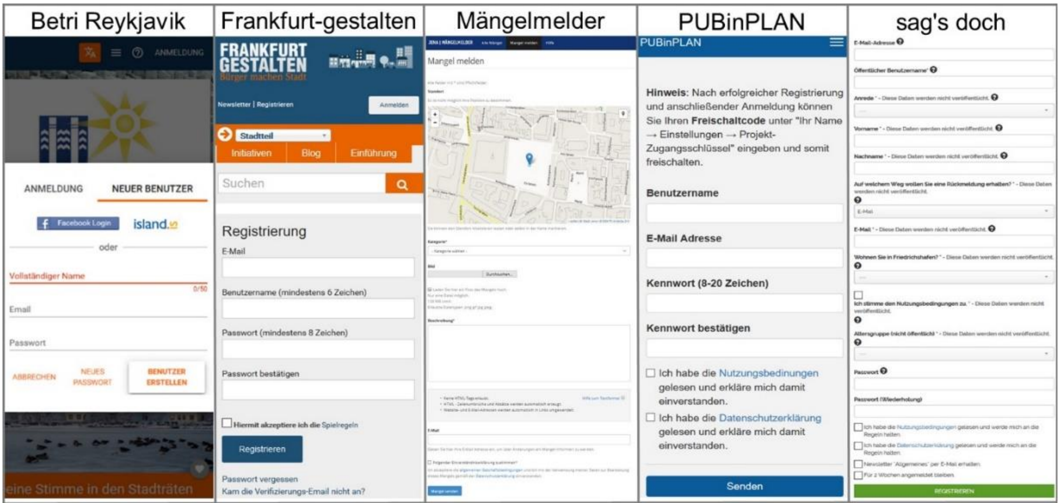
Figure 2: Excerpts from chosen participatory geomedia

The use of interactive maps is common to all platforms (see Figure 2). The maps are intended for orientation as well as for presentation of content provided by users or those who manage the platforms. They are intuitive to use, which was tested on devices with different screen sizes (notebook and smartphone). The preparation of data, simple presentation, as well as intuitive comprehensibility and operability are important factors for the success of participatory geomedia (Mueller et al., 2016, p. 500). An uncomplicated subscription and participation option – all examples can be reached via a URL – is also generally considered to be attractive for smartphone or online services (Scheffer, 2018, p. 44). Table 2 compares the platforms for selected criteria.

Table 2: Comparison of selected participatory geomedia

Examples / Criteria	Betri Reykjavik	Frankfurt-gestalten	Mängelmelder city of Jena	PUBinPLAN	Sag's doch
Costs for citizens	None	None	None	None	None
Registration process	Registration	Registration	No registration needed	Registration and activation for non-public projects	Registration
Required user data	Name and e-mail address	Name and e-mail address	None	E-mail address	Name, age, e-mail address, place of residence, communication path
Process of participation	Find Log In Capture message correctly	Find Log In Capture message correctly	Find Report a problem	Find Log In Capture message correctly	Find Log In Capture message correctly
Focus	Submitting ideas and discussion	Submitting applications	Reporting defects	Shaping policy and projects	Reporting ideas and defects
Level of participation according to Arnstein (1969)	Partnership	Placation	Consultation	Partnership	Partnership
Level of participation according to Wiedemann & Femers (1993)	Defining interests and determining the agenda	Informing the public	Right to object	Recommending solutions	Recommending solutions
Number of initiatives since start (as at 06/09/2019)	8,895 since 2010	169 since 2010	1,557 since 2018	1,303 since 2017	8,946 since 2014

The registration process and the user data that may be required already constitute important criteria for participation. If registration is required, information provided by the user will be linked to the corresponding account (clear name or pseudonym), whereas in the case of there being no registration obligation, contributions may be provided anonymously. At the same time, however, hurdles to participation increase when login processes are more complex or if user data are required. Here, Mängelmelder presents the fewest hurdles, as participation can start immediately after opening the homepage. Figure 3 shows excerpts from the examples' registration processes.



References: (1) https://betrireykjavik.is/domain/1 (2) https://www.frankfurt-gestalten.de/users/sign_up
(3) https://maengelmelder.jena.de/de/report (4) https://pubinplan.th-deg.de/users/signup
(5) https://sags-doch.de/login?referer=https%3A%2F%2Fsags-doch.de%2F, Date: 01/16/2019

Figure 3 : Comparison of the examples with regard to the registration process

Personal reference and/or project reference (see PUBinPLAN) allows the digital participation process to be customized. First, one can moderate the discourse to avoid hate posts or insults and establish productive communication. Second, user groups can be defined and given appropriate rights of participation (e.g. voting, commenting or moderating). Third, concrete projects are placed at the centre, which in particular supports 'shaping'. Finally, the level of citizen empowerment is probably the key criterion for participation. Among the chosen examples, PUBinPLAN, Sag's doch and Betri Reykjavik offer higher levels of citizen empowerment than Mängelmelder or Frankfurt-gestalten. It is interesting that this also seems to reflect the number of initiatives handled by the platforms.

5 Conclusions for participation using geomedia

The examples examined show that geomedia have their legitimacy within digital participatory processes, and should even be regarded as core to them. Here, then, is a summary of the uses of geomedia in municipal spatial planning:

- Citizen information: Using modern/contemporary digital tools to inform citizens.
- Citizen interest: Awakening/strengthening interest in local politics and municipal projects.
- Citizen dialogue: Creating a strong and innovative dialogue with and between citizens.
- Citizen communication: Considering citizens' wishes, sensitivities and knowledge.
- Transparency: Creating a better understanding (visualization) and a higher acceptance of a project through greatest possible transparency throughout the project's duration, by presenting background, alternatives, explanations, justifications etc.

- Acceleration and scope: Generating economic benefits through fast and effective communication between all stakeholders.
- Savings by consensus: Achieving compromises while reducing avoidable costs by including a variety of perspectives and expertise in all phases of the planning and implementation of public projects.
- Marketing: Improving the image of public administration as a modern service provider.

The second research question – what the prerequisites are for a successful use of geomedia in the field of participation – will be answered by experiences gained from using the platform PUBinPLAN. The ease of use of social media should be seen as a role model for digital participation platforms. The easier the access, the clearer the information and the more intuitive the participation, the greater the chance that citizens will participate actively. At the same time, civil dialogue requires balancing personalization with the lowest possible registration effort on the one hand, and ensuring privacy without making participation arbitrary and non-binding on the other.

A marketing strategy is also required which ensures that citizens know the digital participation offer and motivates them to use it actively. Availability of hardware or network coverage is not usually a barrier, especially in urban areas. However, in addition to participation via geomedia, conventional instruments such as community meetings, citizen surveys, workshops etc. are also needed to involve citizens who are more attached to these events. Digital instruments do not replace traditional ones; they complement them. To control this interplay of analogue and digital participation instruments, flexible project and process management is required that is geared to the specific project or individual municipality.

When this focus is on a particular municipality (spatially) or project (thematically), the appreciation by citizens that their participation is valued will also increase. This affects their motivation and thus whether they actively participate in municipal projects at all. On the one side, possible solutions focus on quality of life and topics of concern in the citizen's own region. On the other, there is the potential to transfer a fascination with new digital media and one's own individual experiences (for example with social media or computer games) to the topic of participation.

6 Geomedia as new potential for active citizens

The article highlights current efforts to transfer the booming geomedia sector to the socio-politically important field of public participation. The examples show opportunities and risks, but also make clear that municipalities and municipal administrations in particular, as well as social communication and the democratic order in general, cannot and must not shy away from the trends of digitization. At the same time, however, manifold technological possibilities appear to be devoid of social benefits.

Consequently, in addition to technical development, further scientific analyses are required. In future studies, municipal projects in which geomedia (as well as other instruments) are used for citizen participation need to be explored to answer the following research questions: What are the project- and context-related strengths and weaknesses of different forms of digital and analogue participation events? How can these forms of participation (events) be optimally connected? Are there typical user groups? Questions remain open as to when and with what kind of functionality digital participation provides most added value for projects, and how success or failure in digital participation can actually be assessed or measured. Possible studies could be carried out in parallel to municipal projects. Existing project partners (citizens, responsible persons, experts) might then be won as participants in novel participatory events (e.g. as citizen sensors using geomedia) or as interviewees. A take-up rate of about 20 participants per event seems sufficient for the mainly qualitative orientation of such research.

Acknowledgements

The project Smart Landscapes is funded by the Bayerisches Staatsministerium für Bildung und Kultus, Wissenschaft und Kunst. The duration of the project is 30 months from October 2017. For further information, visit https://pubinplan.th-deg.de/.

References

References

Aden, C., & Kirchner, A. C. (2016). GoINSPIRED - Kontrolle und Transformation von Artendaten aus Citizen-Science-Projekten für INSPIRE. In J. Strobl, B. Zagel, G. Griesebner, & T. Blaschke (Eds.), *AGIT 2-2016: Journal für Angewandte Geoinformatik* (1st ed., pp. 590–599). Berlin: Wichmann, H; Wichmann Verlag.

Andorfer, M., Vockner, B., Spitzer, W., & Mittlböck, M. (2016). Partizipative Raumplanungsansätze mit 3D-Informationsbeständen. In J. Strobl, B. Zagel, G. Griesebner, & T. Blaschke (Eds.), *AGIT 2-2016: Journal für Angewandte Geoinformatik* (1st ed., pp. 534–539). Berlin: Wichmann, H; Wichmann Verlag.

Arnstein, S. R. (1969). A Ladder Of Citizen Participation. *Journal of the American Institute of Planners*, *35*(4), 216–224. https://doi.org/10.1080/01944366908977225

Atzmanstorfer, K., & Blaschke, T. (2013). The Geospatial Web: A Tool to Support the Empowerment of Citizens through E-Participation? In C. N. Silva (Ed.), *Advances in Electronic Government, Digital Divide, and Regional Development. Citizen E-Participation in Urban Governance: Crowdsourcing and Collaborative Creativity* (Vol. 178, pp. 144–171). Hershey, PA: Information Science Reference. https://doi.org/10.4018/978-1-4666-4169-3.ch009

Bitsch, J., Jonietz, D., & Timpf, S. (2016). Eine agentenbasierte Fußgängersimulation zur Bewertung der Bewegungs- und Nutzungsmuster eines städtischen Platzes. In J. Strobl, B. Zagel, G. Griesebner, & T. Blaschke (Eds.), *AGIT 2-2016: Journal für Angewandte Geoinformatik* (1st ed., pp. 353–363). Berlin: Wichmann, H; Wichmann Verlag.

Boeckler, M. (2014). Neogeographie, Ortsmedien und der Ort der Geographie im digitalen Zeitalter. *Geographische Rundschau*. (6), 4–11.

Campbell, A. T., Eisenman, S. B., Lane, N. D., Miluzzo, E., Peterson, R. A., Lu, H., . . . Ahn, G. S. (2008). The Rise of People-Centric Sensing. In *IEEE Internet Computing 12(4)* (pp. 12–21).

Carver, S. (2001). Participation and Geographical Information: a position paper. Retrieved from https://www.google.de/search?q=steve+carver+participation+and+geographical+information&ie=utf-8&oe=utf-8&gws_rd=cr&ei=r_6dVuOAFsflUZSegdAD

Döring, J., & Thielmann, T. (2009). Mediengeographie: Für eine Geomedienwissenschaft. In J. Döring & T. Thielmann (Eds.), *Medienumbrüche: Vol. 26. Mediengeographie: Theorie - Analyse - Diskussion.* Bielefeld: transcript-Verl.

Fearnley, F., & Fyfe, R. (2018). Twitter: an emerging source for geographical study. *Geography - An international Journal.* (103/Summer), 97–101.

Genevois, S., & Delorme, L. (2010). Playing with Location-based and Augmented Reality Games - What Spatial Competences for What Citizenship? In T. Jekel, A. Koller, K. Donert, & R. Vogler (Eds.), *Learning with Geoinformation V* (pp. 41–50). Berlin/Offenbach: Wichmann Verlag.

Goldman, J., Shilton, K., Burke, J., Estrin, D., Hansen, M., Ramanathan, N., . . . West, R. (2009). Participatory Sensing: A citizen-powered approach to illuminating the patterns that shape our world. Retrieved from https://www.wilsoncenter.org/sites/default/files/participatory_sensing.pdf

Goodchild, M. (2007). Citizens as sensors: The world of volunteered geography. *GeoJournal*, *69*(4), 211–221. https://doi.org/10.1007/s10708-007-9111-y

Gordon, E. (2009). The Metageography of the Internet: Mapping from Web 1.0 to 2.0. In J. Döring & T. Thielmann (Eds.), *Medienumbrüche: Vol. 26. Mediengeographie: Theorie - Analyse - Diskussion* (pp. 397–412). Bielefeld: transcript-Verl.

Goudarznia, T., Pietsch, M., & Krug, R. (2017). Testing the Effectiveness of Augmented Reality in the Public Participation Process: A Case Study in the City of Bernburg. In E. Buhmann, S. Ervin, S. Hehl-Lange, & J. Palmer (Eds.), *JoDLA: Journal of Digital Landscape Architecture, 2-2017* (pp. 244–251). Berlin/Offenbach: Herbert Wichmann Verlag.

Groß, D., & Zeile, P. (2016). EmoCyclingConcept - Potenziale der emotionalen Stadtkartierung. In J. Strobl, B. Zagel, G. Griesebner, & T. Blaschke (Eds.), *AGIT 2-2016: Journal für Angewandte Geoinformatik* (1st ed., pp. 273–278). Berlin: Wichmann, H; Wichmann Verlag.

Gryl, I., Jekel, T., & Donert, K. (2010). Gi and Spatial Citizenship. In T. Jekel, A. Koller, K. Donert, & R. Vogler (Eds.), *Learning with Geoinformation V* (pp. 2–11). Berlin/Offenbach: Wichmann Verlag.

Harris, R. (2018). From data to knowledge: teaching data skills in geography. *Geography - An international Journal.* (103/Spring), 12–18.

Helbig, D., Pietsch, M., Schütz, L., Bade, K., Richter, A., & Nürnberger, A. (2016). Online-Beteiligung in Entscheidungs- und Planungsprozessen - Anforderungen aus der Praxis. In J. Strobl, B. Zagel, G. Griesebner, & T. Blaschke (Eds.), *AGIT 2-2016: Journal für Angewandte Geoinformatik* (1st ed., pp. 508–517). Berlin: Wichmann, H; Wichmann Verlag.

Herbst, S., Prinz, T., & Castellazzi, B. (2016). MobilityOptimizer - bedarfsorientierte ÖV-Angebotsplanung mit NutzerInnen-Feedback. In J. Strobl, B. Zagel, G. Griesebner, & T. Blaschke (Eds.), *AGIT 2-2016: Journal für Angewandte Geoinformatik* (1st ed., pp. 268–272). Berlin: Wichmann, H; Wichmann Verlag.

Hoffmann, T. (2018). Gerüstet für die Zukunft: Aufgaben des Geographieunterrichts. *Praxis Geographie.* (1), 4–9.

JENA TV (2018, September 18). Jenaer Mängelmelder ist online. Retrieved from https://www.jenatv.de/mediathek/47042/Jenaer_Maengelmelder_ist_online.html

JEZT AKTUELL (2018, October 17). Ein voller Erfolg: Der vor einem Monat eingeführte Mängelmelder der Stadt Jena wird rege genutzt. Retrieved from http://www.jezt.de/2018/10/17/ein-voller-erfolg-der-vor-einem-monat-eingefuehrte-maengelmelder-der-stadt-jena-wird-rege-genutzt/

Küspert, S., & Zink, R. (2017). Concept of a Digital Communication Platform to Increase the Citizens' Interest in Spatial Planning. In E. Buhmann, S. Ervin, S. Hehl-Lange, & J. Palmer (Eds.), *JoDLA: Journal of Digital Landscape Architecture, 2-2017* (pp. 136–143). Berlin/Offenbach: Herbert Wichmann Verlag.

Manovich, L., & Thielmann, T. (2009). Geomedien: Raum als neue Medien-Plattform?: Ein Interview mit Lev Manovich. In J. Döring & T. Thielmann (Eds.), *Medienumbrüche: Vol. 26. Mediengeographie: Theorie - Analyse - Diskussion* (pp. 383–396). Bielefeld: transcript-Verl.

Mueller, C., Klein, U., & Hof, A. (2016). Automatisierte Integration heterogener Geodaten für ganzheitliche Raumplanung. In J. Strobl, B. Zagel, G. Griesebner, & T. Blaschke (Eds.), *AGIT 2-2016: Journal für Angewandte Geoinformatik* (1st ed., pp. 498–507). Berlin: Wichmann, H; Wichmann Verlag.

Neis, P., Zielstra, D., & Zipf, A. (2012). The Street Network Evolution of Crowdsourced Maps: OpenStreetMap in Germany 2007–2011. *Future Internet*, *4*(4), 1–21. https://doi.org/10.3390/fi4010001

Pietsch, M., Richter, A., & Henning, M. (2016). Aufbau von Geoportalen sowie Entwicklung spezifischer Geo-Webapplikationen unter Verwendung des Standards XPlanung. In J. Strobl, B. Zagel, G. Griesebner, & T. Blaschke (Eds.), *AGIT 2-2016: Journal für Angewandte Geoinformatik* (1st ed., pp. 528–533). Berlin: Wichmann, H; Wichmann Verlag.

Schaller, J., Gnaedinger, J., Reith, L., Freller, S., & Mattos, C. (2017). Geodesign: Concept for Integration of BIM and GIS in Landscape Planning. In E. Buhmann, S. Ervin, S. Hehl-Lange, & J. Palmer (Eds.), *JoDLA: Journal of Digital Landscape Architecture, 2-2017* (pp. 102–112). Berlin/Offenbach: Herbert Wichmann Verlag.

Scheffer, J. (2018). Räume als Spiegel: Neue Befähigungen und Beschränkungen im digitalisierten Alltag. *Geographische Rundschau*. (10), 42–47.

Sheth, A. (2009). Citizen Sensing, Social Signals, and Enriching Human Experience. *IEEE Internet Computing*, *13*(4), 87–92. https://doi.org/10.1109/MIC.2009.77

Sieber, R. (2006). Public Participation Geographic Information Systems: A Literature Review and Framework. *Annals of the Association of American Geographers*, *96*(3), 491–507. https://doi.org/10.1111/j.1467-8306.2006.00702.x

Steiger, E., Rylov, M., & Zipf, A. (2016). Echtzeitverkehrslage basierend auf OSM-Daten im OpenRouteService. In J. Strobl, B. Zagel, G. Griesebner, & T. Blaschke (Eds.), *AGIT 2-2016: Journal für Angewandte Geoinformatik* (1st ed., pp. 264–267). Berlin: Wichmann, H; Wichmann Verlag.

Thielmann, T. (2014). Wegbereiter: Mobile Geomedien im Einsatz. *Geographische Rundschau*. (6), 26–33.

Turner, A. (2006). *Introduction to Neogeography*. *O'Reilly short cuts*. Sebastopol, Calif.: O'Reilly. Retrieved from http://site.ebrary.com/lib/alltitles/docDetail.action?docID=10762047

Weiner, D., Harris, T. M., & Craig, W. J. (2002). *Community Participation and Geographic Information Systems*. London.

Wiedemann, P. M., & Femers, S. (1993). Public participation in waste management decision making: Analysis and management of conflicts. *Journal of Hazardous Materials*, *33*(3), 355–368. https://doi.org/10.1016/0304-3894(93)85085-S

Zink, R., Küspert, S., Haselberger, J., Marquardt, A., & Schröck, S. (2016). Interaktives GIS-Framework für partizipative Raumplanungsverfahren. In J. Strobl, B. Zagel, G. Griesebner, & T. Blaschke (Eds.), *AGIT 2-2016: Journal für Angewandte Geoinformatik* (1st ed., pp. 488–497). Berlin: Wichmann, H; Wichmann Verlag.

GI_Forum 2019, Issue 2
Page: 47 - 59
Short Paper
Corresponding Author:
stefan.reder@hnee.de
DOI: 10.1553/giscience2019_02_s47

UAV-based Tree Height Estimation in Dense Tropical Rainforest Areas in Ecuador and Brazil

Stefan Reder, Lilli Waßermann and Jan-Peter Mund
Eberswalde University for Sustainable Development, Germany

Abstract

The aim of this study was to develop an easily applicable, cost-efficient workflow for tree height estimation in remote, inaccessible rainforest areas in Ecuador and Brazil. Structure from Motion (SfM) was combined with a digital terrain model (DTM) from the Shuttle Radar Topography Mission (SRTM) to complement relief information from photogrammetric point clouds (PPC) which represent the upper canopy layers. Based on ground points extracted from a 3D model, a vertical shift of the model was applied to adjust the ellipsoid level of the PPC. Digital surface models (DSM) of 22 research plots were normalized to canopy height models (CHM) to allow the estimation of relative tree heights in all research plots without using ground control points (GCP). The calculated tree height values indicate the applicability of the proposed workflow even in tropical rainforests with dense canopies. This approach allows the classification of canopy structures for identifying forest succession and other ecological forest monitoring purposes. The results highlight the potential of 3D models for tree height estimation derived from PPCs based on unmanned aerial vehicle (UAV) imagery in rainforest research.

Keywords:

unmanned aerial vehicle (UAV), rainforest, canopy height model (CHM), structure from motion (SfM), forest structure

Abbreviations used in the text:

AGL *Altitude Above Ground Level*
ASL *Altitude Above Sea Level*
CHM *Canopy Height Model*
DTM *Digital Terrain Model*
ECP *Elevation Correction Point*
GCP *Ground Control Point*
GSD *Ground Sampling Distance*
LIDAR *Light Detection and Ranging*
PPC *Photogrammetric Point Cloud*
SfM *Structure from Motion*
SRTM *Shuttle Radar Topography Mission*
UAV *Unmanned Aerial Vehicle*
USGS *United States Geological Survey*

1 Introduction

There is a vast range of applications in tropical rainforest research, where the estimation of tree heights and the modelling of canopy structures and its surface are urgent. The canopy height is an important factor for estimating biomass (Hunter, Keller, Victoria, & Morton, 2013). Tree heights serve as an indicator for the state of succession and condition of the forest ecosystem, as the average tree height in primary forests is higher than in secondary forests (Richards & Walsh, 1996). Additionally, the height variations along the canopy surface increase constantly and are greater in the later stages of succession (Birnbaum, 2001). Furthermore, a canopy height model (CHM) can be used for spatial analyses of forest dynamics, such as gap formations and regrowth (Birnbaum, 2001). Canopy models are used to investigate the light regime, which regulates seedling regeneration (Montgomery & Chazdon, 2001). Moreover, height variations along the canopy can be used to calculate a vegetation roughness index for the creation of atmosphere–land interaction models (Raupach, 1994). The structural diversity of the canopy can also be used as an indicator for biodiversity (Lindenmayer, Margules, & Botkin, 2000).

In accessible forests and forest plantations, tree height measurements are typically made from the ground using ultrasound or hand-held laser measurement tools (Thünen – Institute of Forest Ecosystems, 2017). This manual technique has at best an accuracy of 0.2 m (Vasilescu, 2013). A terrestrial laser scanner provides good results, but has a tendency towards underestimation (Olofsson, Holmgren, & Olsson, 2014). But for the application of these tools, the forest needs to be accessible. Light detection and ranging (LIDAR) provides another sophisticated, but expensive, technological alternative for measuring exact tree heights and is frequently applied in temperate forests. Technically, this is a reasonable solution which produces precise results with a mean elevation error of less than 0.2 m, but it is only cost-efficient for large areas (Cao et al., 2019; Leitold, Keller, Morton, Cook, & Shimabukuro, 2015).

Consumer cameras mounted on unmanned aerial vehicles (UAV) equipped with autonomous flight management software can produce very high resolution imagery with a ground resolution of less than 0.5 cm and a high image overlap that allows the calculation of 3D point cloud models using structure from motion (SfM) (Krause, Sanders, Mund, & Greve, 2019). In combination with ground control points (GCPs), canopy heights and even individual tree heights can be extracted easily from 3D point clouds with an accuracy similar to LIDAR measurements (Krause et al., 2019; Torres-Sánchez, López-Granados, Serrano, Arquero, & Peña, 2015).

2 Motivation, Aim and Scope of the Study

In this paper, we present a robust and easily applicable solution for tropical tree height estimation in dense and remote, or even inaccessible, rainforest areas, where using GCPs or additional ground truth surveys is expensive, dangerous or even impossible (see section 3). The aim of the study was to find ways to extract relative individual tree heights and structural differences in the canopy and crown surface which can be used to characterize and/or classify forest succession under various conditions. Another aim was to evaluate options for rainforest monitoring, using UAV imagery, in order to facilitate protection management. The workflow has the advantage of being usable by NGOs or volunteers without access to sophisticated survey and image processing equipment.

3 Material and Methods

The data for this study was collected on 22 investigation plots in the evergreen rainforest along the foothills of the Ecuadorian Andes (9 plots), and the evergreen Atlantic Mountain Rainforest in Brazil (13 plots). In order to get access to such remote, dense, tropical forest plots, we cooperated with two NGOs, the *Asociación Lisan Yacu Iloculín* (Centro de Educación Ambiental en el Ecosistema Amazónico) in Ecuador, and the *Entidade Ambientalista Onda Verde* in Brazil. As we intended to develop a workfow that can also be applied by NGOs and volunteers, which typically have less funding, the research was restricted to a low-budget investigation.

From October 2017 to March 2018, we conducted an applied-science research project, aiming for a structural analysis of the canopies of selected small-sized tropical-rainforest plots in Ecuador and Brazil. The location of these areas can be seen in Figure 1.

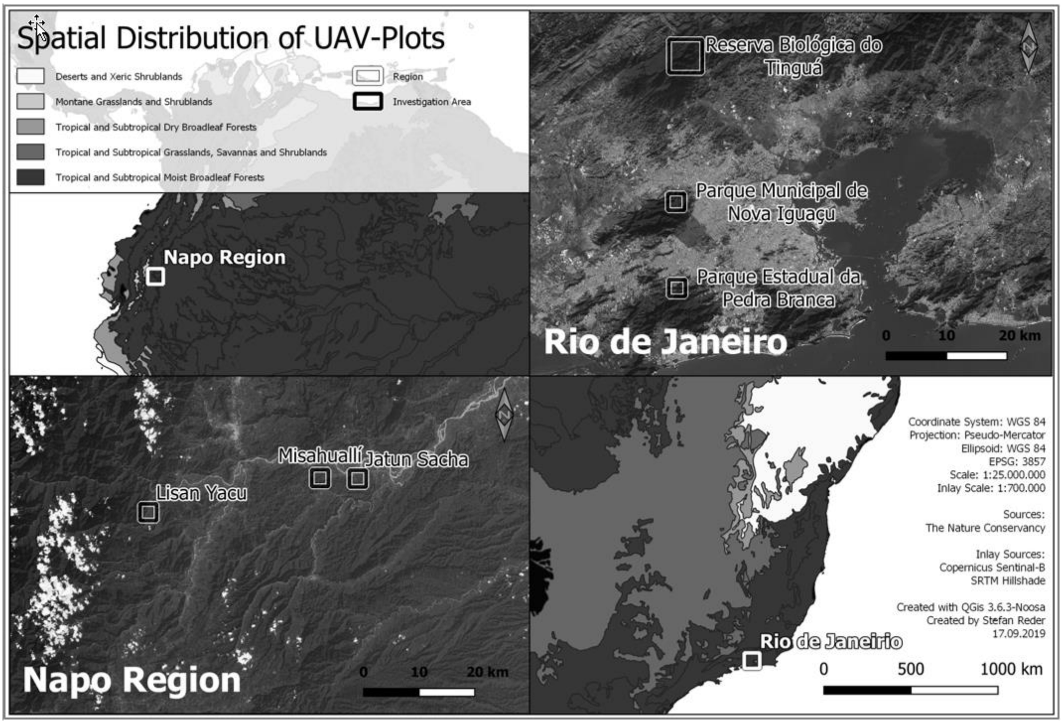


Figure 1: Maps of the investigation sites in Ecuador (left) and Brazil (right), and a map of the ecoregions of Latin America (background)

In Ecuador, the investigation areas were chosen in the Napo region, 20 km south-east of the regional capital Tena, close to the River Napo in the foothills of the Andes. The ecosystem in this area is classified as Amazon lowland evergreen rainforest and is a biodiversity hotspot (Sierra, Campos, & Chamberlin, 2002). In Brazil, the plots were in the state of Rio de Janeiro, in three natural reserves. These reserves are all found in the Mata Atlântica, a coastal tropical forest classified as Floresta Ombrófila (IBAMA, 2006) which contains many hotspots of endemic species and is in great danger of being deforested (Crouzeilles, Feltran-Barbieri, Ferreira, & Strassburg, 2017). The plots were chosen for the state of succession they manifested since the last large-scale disturbance occurred (e.g. clear cutting or storm clearing), namely early succession (< 50 years), late succession (> 50 years), and climax/old growth (> 100 years). Information about the plots' histories was obtained from oral and/or other evidence.

The data collection was restricted by the limited accessibility and dense structure of the rainforest and thus had to be adapted to the conditions. Reaching the primary forest by car with large and sophisticated equipment was not always possible as roads do not exist in most of the areas investigated. Often, access can be gained only on foot over long distances through difficult terrain, requiring all technical equipment and several days' worth of food and other provisions to be carried into the forest. Untouched or intact dense rainforest remains are often found only on steeper slopes or in other remote areas. They are thus difficult and dangerous or even impossible to access (Porembski & Barthlott, 2000). The majority of the research plots were not accessible on foot but could be reached by UAV automatic image acquisition flights.

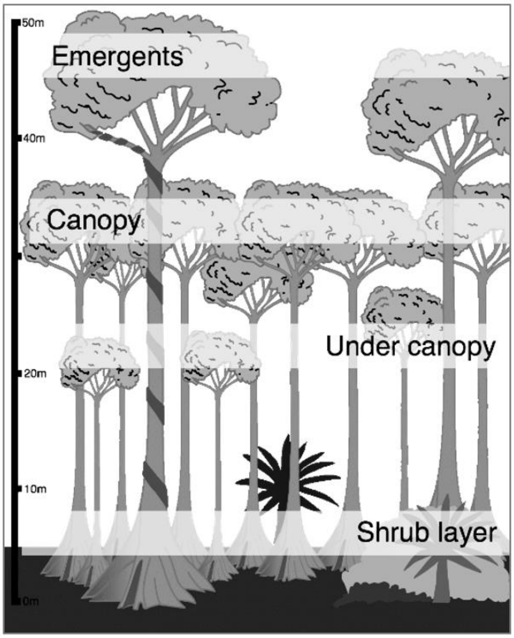


Figure 2:
Canopy structure of dense rainforests Source: https://www.internetgeography.net/topics/what-is-the-structure-of-the-tropical-rainforest/

In general, tropical rainforests have very dense canopy and under-canopy layers, as illustrated in Figure 2. Only 1% to 2% of the canopy is opened by treefalls each year (Brokaw, 1985), and as the competition for light is very strong, small gaps close in 3 to 6 years. Even in cases of larger openings (> 300m²), a new closed canopy layer with a height of 10m generally takes just 5–10 years to become established (van der Meer, 1995). Therefore, in such dense and multi-layered canopies it is rare to find openings or canopy gaps which reach to the ground and are large enough to install GCPs and calculate differential GNSS-positions, as the vegetation strongly influences the signal. Furthermore, it is impossible to extract the requisite number of ground points from the 3D model to calculate a digital terrain model (DTM) (Wallace, Lucieer, Malenovský, Turner, & Vopěnka, 2016). Using traditional forest mensuration equipment such as mobile laser or a Vertex under this type of canopy structure leads to uncertainty in tree height measurements from the ground, because generally speaking the treetops are not visible (Larjavaara & Muller-Landau, 2013).

Taking all these restrictions and limitations into account, then, traditional, common or very sophisticated surveying methods for tree height measurements were excluded from this research. We therefore decided to develop a simple but still state-of-the-art and repeatable approach for tree height estimations in dense rainforests. This approach is based on UAV imagery and photogrammetric point clouds, and it works without surveyed GCPs. This aims to estimate relative tree and canopy heights and to describe relative changes in canopy structure in order to distinguish categories such as degraded, secondary or primary rainforest types. Thus, the principal aim is the estimation of stand heights or the mean heights of the upper and/or different canopy layers, rather than the precise measurement of the exact height of individual trees. This method is not intended for application in high-precision forestry or tree measurements for economic timber calculations.

3.1 UAV-based data collection

A DJI Mavic Pro commercial drone was used to capture images for the calculation of 3D point cloud models. The inbuilt camera has a 1/2.3” CMOS sensor and captures Red Green Blue (RGB) pictures in 4k resolution (4,000 x 3,000 pixels) (DJI, 2017).

For each investigation plot, an area of 75 m x 75 m was demarcated on the flight plan; three automatic flight plans (Pix4D Capture App Version 3.8) per plot were carried out to capture the canopy structure. The flight plan settings are shown in Table 1. After an initial investigative flight to identify the tallest tree within each research plot, the flight altitude was set to 30 m above the canopy. All three flights per plot were then flown at the same height, which, depending on the canopy height, resulted in an altitude above ground level (AGL) of 60 m to 100 m and an average ground sampling distance (GSD) of 2 cm. The camera was fixed at a different angle for each of the three flights per plot. The views from different camera incident angles on the canopy and its gaps and openings allow a detailed reproduction of the canopy structure in a later data fusion stage. This also allows the visualization of parts of the under-canopy layers, the ground vegetation and the ground surface which are not visible in nadir flights. The first flight was a single nadir flight, with 95% image overlap. The second and third flights were both cross flight plans, with 85% image overlap and oblique camera angles of 60° and 30°. Through iterative testing, this combination of camera angles proved to give valuable results. The data collection workflow was tested and assessed beforehand in mixed forest stands with various canopy structures in Brandenburg, where exact tree heights are available for comparison (Krause et al., 2019).

Table 1: Automated flight plan settings applied for each of the 22 research plots in Ecuador and Brazil

Plot size	Flight plan	Camera angle	Image overlap	Flight speed	Height above canopy	GSD average
75 m x 75 m	1 x nadir	90°	95 %	~2m/s	30 m	2 cm
	1 x cross oblique	60°	85 %	~4m/s	30 m	2 cm
	1 x cross oblique	30°	85 %	~4m/s	30 m	2 cm

3.2 Data processing

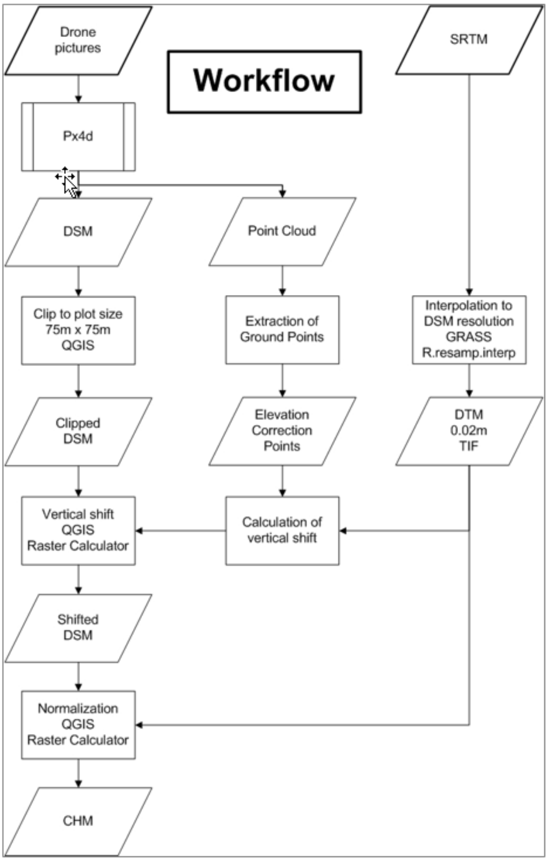


Figure 3: Workflow diagram for the calculation of a CHM from UAV images and an external DTM

In this section, the image- and data-processing workflow is described (and illustrated in Figure 3). We decided to use the Pix4D Desktop App Version 4.1.25 for calculating the 3D point cloud model. Even though the cost of professional proprietary software is high, the technical and application advantages are better than those of open source packages such as OpenDroneMap (Alidoost & Arefi, 2017).

In order to generate ground points, especially beyond tree crowns and in narrow canopy openings, the pictures from the three individual flights were processed together. For this scenario, the standard settings of the template for 3D models had to be adapted. To improve the calculation of the camera positions, *Triangulation of Image Geolocation* was used for *Matching* in *the Initial Processing* stage. The *Relative Distance Between Consecutive Images* was increased to eight to force the algorithm to search for matching points in eight neighbouring images in each direction. This increases the calculation time but enables the program to find matching points between nadir and oblique flights.

In addition, the *Geometrically Verified Matching* was activated for more precise matching in a relatively homogeneous colour spectrum, as found in green forests (Pix4D, 2018). The outputs are a photogrammetric point cloud (PPC), an Orthophoto and the digital surface model (DSM). The DSM shows the altitudes above sea level (ASL) of the canopy surface.

As the PPCs did not provide sufficient ground points to generate a DTM, the information about the ground surface structure had to be supplemented from an external source. To meet typical NGO constraints such as lack of expert knowledge and need for a low-budget workflow, the ASL of each research plot was taken from the Shuttle Radar Topography Mission (SRTM), which is provided free of charge by the United States Geological Survey (USGS). It has a sampling distance of 1 arc sec, which corresponds to approximately 30 m per pixel (Kautz, 2017). As preparation for the normalization, it had to be interpolated to the resolution of the DSM.

Several technical and surveying problems had to be solved in the course of this process.

In dense forest areas, radar techniques, such as those used by the SRTM, are known to represent the surface of the vegetation layer rather than the bare ground (Gesch, J. Oimoen, & A. Evans, 2014). The above-ground height information stored in the Exchangeable Image File Format header (Exif) of UAV images is given as ASL, as the *GPSAltitudeRef* flag indicates (Camera & Imaging Products Association, 2010). Thus, UAV altitudes refer to the WGS84-ellipsoid, while altitudes calculated in the SRTM refer to the EGM96-geoid (Kautz, 2017), which requires a 3D re-projection to adjust the z-level accordingly.

To remove this difference between the geodic and ellipsoid heights and the vertical error from the SRTM, a vertical shift of the z-coordinate was applied. Therefore, at least 3 ground points in each PPC, referred to from now on as ECPs (elevation correction points), were manually identified as ground references.

Subsequently, the differences between the elevation of each ECP and the elevation of the corresponding x/y-coordinate in the DTM were calculated as follows. The mean of the differences equals the vertical shift.

$$vertical\ shift = \frac{\sum(z(SRTM) - z(PPC))}{n}$$; with z = elevation, n = number of ECPs

In the following step, the DSM was vertically shifted with the Raster Calculator in the QGIS program as follows:

$$DSM_{shifted} = DSM + verical\ shift$$

The shifted DSM was then normalized using the QGIS Raster Calculator. The result is a CHM, which shows the elevation of the canopy surface above forest ground.

$$CHM = DSM_{shifted} - DTM$$

The intermediate outputs and the result of the workflow are visualized in Figure 4.

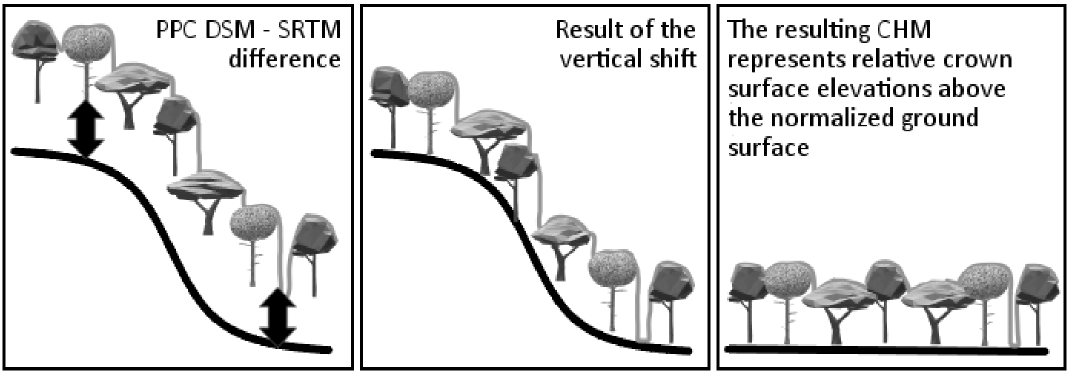


Figure 4: Conceptual illustration of workflow results; left: the DSM, generated in Pix4D, showing ungrounded vegetation layer; middle: after the application of the vertical shift, all trees are grounded to the surface; right: the normalization generates the CHM, which represents the relative elevation of the crown surface above the ground surface

4 Results

4.1 Example Pedra Branca 0301 Plot 3

The research plot Pedra Branca 0301 Plot 3 is located in Brazil, south-west of Rio de Janeiro city, in the Mata Atlântica, on a 25° slope. It will be used as an example of the analytical results for the 22 individual research plots.

The original DSM derived from the PPC showed height values of 850 m to 910 m and was levelled completely under the surface of the SRTM. ECP 50 and ECP 52 were visible in canopy gaps below the crown surface and could only be detected in the PPC due to matching points derived from pictures taken during oblique camera flights.

The mean height difference between the three ECPs and the SRTM resulted in a relative vertical shift of +23 m. The shifted DSM and the DTM are shown at the top of Figure 5.

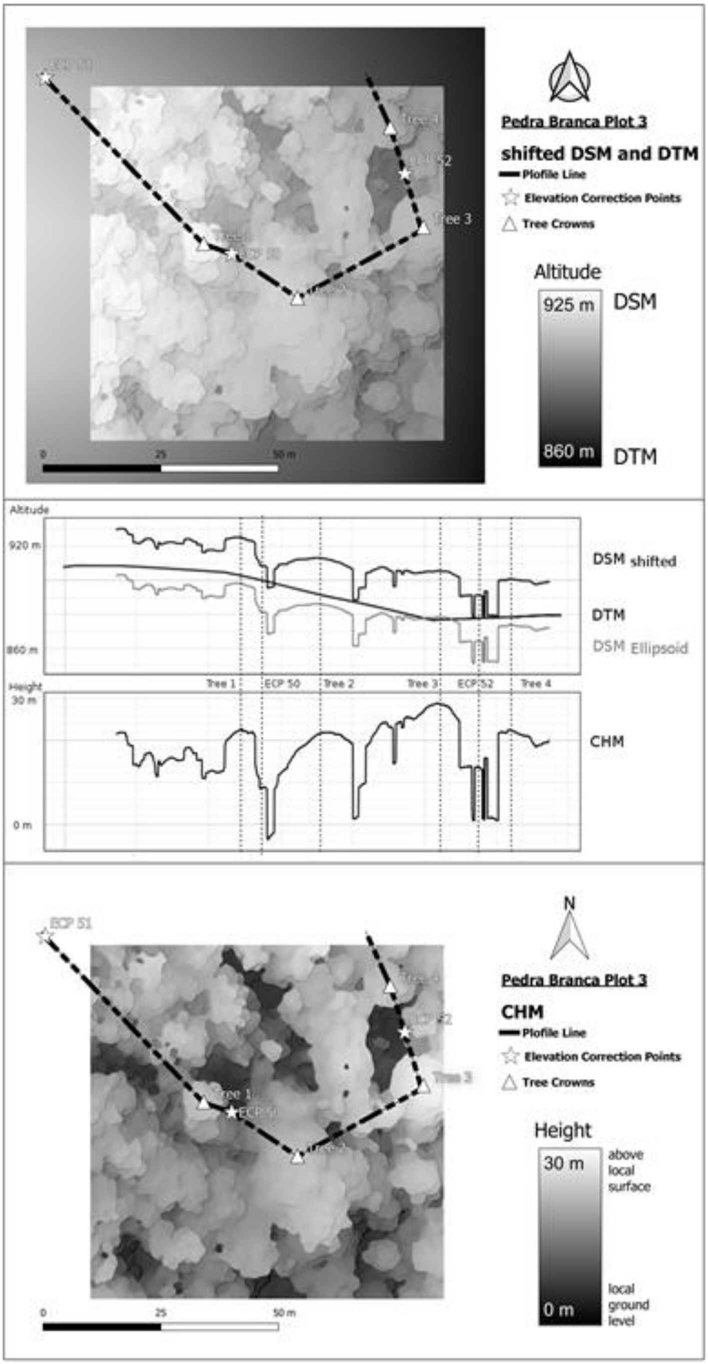


Figure 5: Results of Pedra Branca Plot 3; top: Visualization of the shifted DSM, the DTM and the transect for the profile view that follows the ECPs and selected treetops; middle: Profile view of the DSM before and after the shift with the resulting normalized CHM; bottom: Visualization of the CHM with the derived crown surface height.

A profile view was calculated that followed the dashed black line connecting the tallest treetops and the ECPs (Figure 5, middle). This profile shows that the lowest PPC points of the shifted surface model are located close to the terrain model. The highest treetop along the cutline is estimated to be 29 m, while the height of most trees in the upper canopy of this 75 m x 75 m plot is estimated to be 25 m AGL.

As a result of the normalization, the CHM (Figure 5, bottom) shows only a few areas with a negative value. The analysis of the CHM revealed a mean value of 15.7 m with a standard deviation of 6.8 m, while the highest point of the canopy is 29.7 m above and the lowest point 4.8 m below the interpolated surface. This tree height estimation based on DTM, DSM and a normalized CHM was applied identically to all the other 21 research plots. The results of the statistical analysis are presented in section 4.2.

4.2 Statistical Analyses

Grouping all observed plots by their state of succession, the maximum values of the CHM indicate taller trees in a later state of succession (Figure 6). The median of the plots of the forest climax group is, at 39 m, much higher than the median of the secondary forest plots in early or late succession (33 m and 31 m respectively). Degraded plots show significantly lower estimated tree heights, with a median height of 14 m. While there is little difference between the median heights in early and late-secondary succession plots, the ranges of the height values of the plot groups show a clear tendency towards taller trees in the later successional stage.

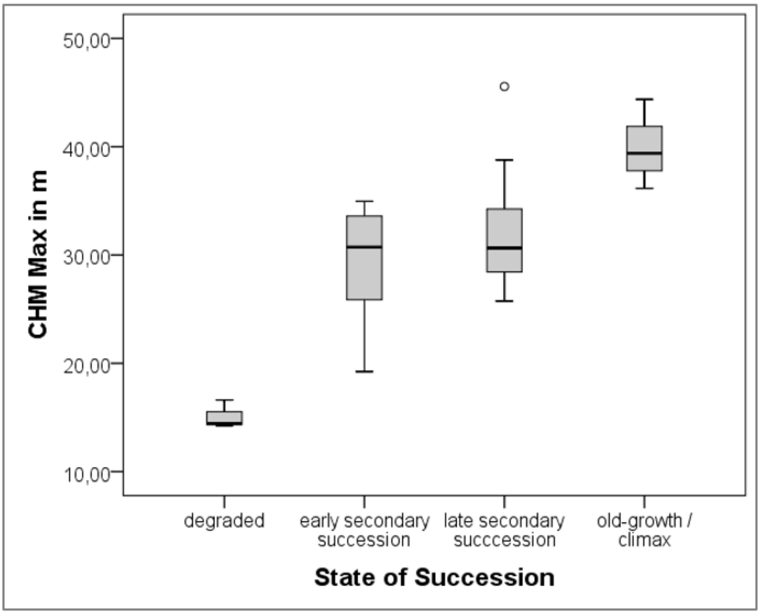


Figure 6: The boxplots show the maximum values of the CHM grouped by the state of succession. (Early succession < 50 y; late succession 50 – 100 y; old-growth / climax > 100 y)

5 Discussion and conclusion

This study demonstrates the feasibility of estimating tree height values for dense as well as degraded rainforest plots from UAV imagery, without using GCPs as further ground level reference. A combination of nadir and oblique flight plans with differing incident camera angles offer insights, even for very dense multi-layered forest areas, into the derived PPCs for the extraction of ECPs. The increased density of matching points, as a result of combining pictures from all three flights (oblique flights of 60°, 30° and nadir), allowed the 3D matching and visualization of forest structures which are not visible in simple nadir DSM or CHM. Furthermore, the statistical evaluation indicates that the succession states can be distinguished from the estimated heights. With these results, our approach helps to close a gap in rainforest canopy research. Until now, there have been no satisfactory means for low-cost and remote succession analyses, as freely available satellite data does not provide sufficient resolution (Chazdon, 2014), while other approaches rely on LIDAR and ground surveys (Almeida et al., 2019) which are unaffordable for local NGOs (see section 2). Nonetheless, the model makes several assumptions which must be tested and verified before reliable statements about the accuracy of the 3D point cloud data can be drawn. First, the 3D PPC model itself is coherent internally, but we cannot guarantee its accuracy: we worked without GCPs, and therefore scaling problems with modelled pixel sizes and their exact location in the 3D point cloud remain. Second, the ECPs used to correct the CHM were chosen manually from the PPC. In this manual workflow, the correct selection of the lowest relative height detected for the representation of the local ground level is not guaranteed. Dense ground vegetation such as the herbal or shrub layer could be misidentified as ground level, which might result in an underestimation of local tree heights.

The study serves as proof of concept for the proposed UAV-based PPC workflow under typical NGO conditions and for other applied-science research with limited budget and access to sophisticated survey equipment. Although we were not able to verify the exact measurements of absolute tree heights on the plots, the methodology for analysing canopy reconstruction and estimating tree heights can be used in research into the ecological and successional status of other rainforest plots.

References

Alidoost, F., & Arefi, H. (2017). Comparison of UAS-Based Photogrammetry Software for 3D Point Cloud Generation: A Survey Over a Historical Site. *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences*, *IV-4/W4*, 55–61. https://doi.org/10.5194/isprs-annals-IV-4-W4-55-2017

Almeida, D.R.A., Stark, S. C., Chazdon, R. [R.], Nelson, B. W., Cesar, R. G., Meli, P., Brancalion, P.H.S. (2019). The effectiveness of lidar remote sensing for monitoring forest cover attributes and landscape restoration. *Forest Ecology and Management*, *438*, 34–43. https://doi.org/10.1016/j.foreco.2019.02.002

Birnbaum, P. (2001). Canopy surface topography in a French Guiana forest and the folded forest theory. *Plant Ecology*, *153*(1/2), 293–300. https://doi.org/10.1023/A:1017563809252

Brokaw, N. V.L. (1985). Treefalls, Regrowth, and Community Structure in Tropical Forests. In S. T. Pickett & P. S. White (Eds.), *The ecology of natural disturbance and patch dynamics* (pp. 53–69). Orlando, Florida: Academic Press. https://doi.org/10.1016/B978-0-08-050495-7.50009-0

Camera & Imaging Products Association (2010). CIPA DC-008-2012: Exchangeable image file format for digital still cameras: Exif Version 2.3 (English). Retrieved from http://www.cipa.jp/std/documents/j/DC-008-2012_J.pdf

Cao, L., Liu, H., Fu, X., Zhang, Z., Shen, X., & Ruan, H. (2019). Comparison of UAV LiDAR and Digital Aerial Photogrammetry Point Clouds for Estimating Forest Structural Attributes in Subtropical Planted Forests. *Forests*, *10*(2), 145. https://doi.org/10.3390/f10020145

Chazdon, R. L. [Robin L.]. (2014). *Second Growth: The Promise of Tropical Forest Regeneration in an Age of Deforestation*. Chicago: University of Chicago Press. Retrieved from http://gbv.eblib.com/patron/FullRecord.aspx?p=1676710

Crouzeilles, R., Feltran-Barbieri, R., Ferreira, M. S., & Strassburg, B. B. N. (2017). Hard times for the Brazilian environment. *Nature Ecology & Evolution*, *1*(9), 1213. https://doi.org/10.1038/s41559-017-0303-7

DJI (2017). Mavic Pro user manual 1.4. Retrieved from https://dl.djicdn.com/downloads/mavic/20170301/UserManual/Mavic_Pro_User_Manual_en_v1.4.pdf

Gesch, D., J. Oimoen, M., & A. Evans, G. (2014). Accuracy Assessment of the U.S. Geological Survey National Elevation Dataset, and Comparison with Other Large-Area Elevation Datasets—SRTM and ASTER. Retrieved from https://pubs.er.usgs.gov/publication/ofr20141008

Hunter, M. O., Keller, M., Victoria, D., & Morton, D. C. (2013). Tree height and tropical forest biomass estimation, *10*, 8385–8399. Retrieved from www.biogeosciences.net/10/8385/2013/

IBAMA (2006). Plano de Manejo Rebio do Tinguá. Retrieved from www.icmbio.gov.br/portal/images/stories/imgs-unidades-coservacao/rebio_tingua.pdf

Kautz, Sheila (2017). *Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global.* https://doi.org/10.5066/F7PR7TFT

Krause, S., Sanders, T. G.M., Mund, J.-P., & Greve, K. (2019). UAV-Based Photogrammetric Tree Height Measurement for Intensive Forest Monitoring. *Remote Sensing*, *11*(7), 758. https://doi.org/10.3390/rs11070758

Larjavaara, M., & Muller-Landau, H. C. (2013). Measuring tree height: a quantitative comparison of two common field methods in a moist tropical forest. (4), 793–801.

Leitold, V., Keller, M. [Michael], Morton, D. C. [Douglas], Cook, B. D., & Shimabukuro, Y. E. (2015). Airborne lidar-based estimates of tropical forest structure in complex terrain: Opportunities and trade-offs for REDD+. *Carbon Balance and Management*, *10*(1), 3. https://doi.org/10.1186/s13021-015-0013-x

Lindenmayer, D. B., Margules, C. R., & Botkin, D. B. (2000). Indicators of Biodiversity for Ecologically Sustainable Forest Management. *Conservation Biology*, *14*(4), 941–950. https://doi.org/10.1046/j.1523-1739.2000.98533.x

Montgomery, R. A., & Chazdon, R. L. (2001). Forest structure, canopy architecture, and light transmittance in tropical wet forests. *Ecology*, *82*(10), 2707–2718.

Olofsson, K., Holmgren, J., & Olsson, H. (2014). Tree Stem and Height Measurements using Terrestrial Laser Scanning and the RANSAC Algorithm. *Remote Sensing*, *6*(5), 4323–4344. https://doi.org/10.3390/rs6054323

Pix4D (2018). Pix4dmapper 4.1 User Manual. Retrieved from https://support.pix4d.com/hc/en-us/articles/205433155-Menu-Process-Processing-Options-1-Initial-Processing-Matching

Porembski, S., & Barthlott, W. (2000). *Inselbergs. Biotic Diversity of Isolated Rock Outcrops in Tropical and Temperate Regions* (Vol. 146). https://doi.org/10.1007/978-3-642-59773-2

Raupach, M. R. (1994). Simplified expressions for vegetation roughness length and zero-plane displacement as functions of canopy height and area index. *Boundary-Layer Meteorology*, *71*(1-2), 211–216. https://doi.org/10.1007/BF00709229

Richards, P. W., & Walsh, R. P. D. (1996). *The tropical rain forest: An ecological study* (2. ed.). Cambridge

Sierra, R., Campos, F., & Chamberlin, J. (2002). Assessing biodiversity conservation priorities: ecosystem risk and representativeness in continental Ecuador. *Landscape and Urban Planning*, *59*(2), 95–110. https://doi.org/10.1016/S0169-2046(02)00006-3

Thünen - Institute of Forest Ecosystems. (2017). *Die dritte Bundeswaldinventur BWI 2012: Inventur- und Auswertungsmethoden*. Eberswalde: Bundesministerium für Ernährung und Landwirtschaft (BMEL).

Torres-Sánchez, J., López-Granados, F., Serrano, N., Arquero, O., & Peña, J. M. (2015). High-Throughput 3-D Monitoring of Agricultural-Tree Plantations with Unmanned Aerial Vehicle (UAV) Technology. *PloS One*, *10*(6), e0130479. https://doi.org/10.1371/journal.pone.0130479

Van der Meer, P. J. (1995). *Canopy dynamics of a tropical rain forest in French Guiana*. @wageningen, Landbouwuniv., Diss., 1995. S.l.

Vasilescu, M. M. (2013). Standard error of tree height using Vertex III. *Bulletin of the Transilvania University of Brașov*, *6(55)*(2).

Wallace, L., Lucieer, A., Malenovský, Z., Turner, D., & Vopěnka, P. (2016). Assessment of Forest Structure Using Two UAV Techniques: A Comparison of Airborne Laser Scanning and Structure from Motion (SfM) Point Clouds. *Forests*, *7*(12), 62. https://doi.org/10.3390/f7030062

GI_Forum 2019, Issue 2
Page: 60 - 72
Shortl Paper
Corresponding Author:
stuart.krause@thuenen.de
DOI: 10.1553/giscience2019_02_s60

Aerial and Terrestrial Photogrammetric Point Cloud Fusion for Intensive Forest Monitoring

Stuart Krause[1,2,3]

[1]Thünen Institute of Forest Ecosystems, Germany
[2]Eberswalde University of Sustainable Development, Germany
[3]University of Bonn, Germany

Abstract

Remote sensing methods for forest monitoring are evolving rapidly thanks to recent advances in Unmanned Aerial Vehicle technology and digital photogrammetry. Photogrammetric point clouds allow the non-destructive derivation of individual tree parameters at a low cost. The fusion of aerial and terrestrial photogrammetry for creating full-tree point clouds is of utility for forest research, as tree volume could be assessed more economically and efficiently than by traditional methods. However, this is challenging to implement due to difficulties with co-registration and issues of occlusion. This study explores the possibility of using spherical targets typically used for Terrestrial Laser Scanning to accomplish the co-registration of UAV-based and terrestrial photogrammetric datasets. Results show a full-tree point cloud derived from UAV oblique imagery in combination with terrestrial imagery. Despite issues of noise produced from the sky in terrestrial imagery, the methodology is promising for aerial and terrestrial point cloud fusion.

Keywords:

point cloud fusion, UAV, terrestrial imagery, photogrammetry

1 Introduction

Recent technological developments in remote sensing and photogrammetry have opened up new possibilities for forest monitoring. Thanks to recent developments with consumer-grade sensors, civilian Unmanned Aerial Vehicles (UAVs) and Structure from Motion (SfM) processing software, the acquisition of high-quality spatial and temporal digital information of forests has become possible as well as affordable (Grenzdörffer, Engel, & Teichert, 2008). UAV-based photogrammetric point clouds have proven successful in estimating various tree parameters such as height and crown diameter (Panagiotidis, Abdollahnejad, Surový, & Chiteculo, 2016; St-Onge, Audet, & Bégin, 2015), at the stand and individual tree levels. Terrestrial photogrammetry has also shown success in the extraction of the diameter at breast height (DBH) of individual trees (Piermattei et al., 2019). The empirical derivation of full-tree volumes, however, would require the capture of imagery of the full-tree stem as well as tree crowns. Such image-based point clouds encompassing full trees would require the fusion of aerial and terrestrial point clouds. The creation of full-tree point clouds of forest stands has to the authors knowledge only been accomplished using Light Detection and Ranging (LiDAR) technology (Paris, Kelbe, van Aardt, & Bruzzone, 2017). Although one study did successfully accomplish the fusion of aerial and terrestrial photogrammetry in a forested area, only the lower portion of tree stems and upper canopy were able to be fused (Mikita, Janata, & Surový, 2016). Due to matters of occlusion and co-registration, the fusion of aerial and terrestrial photogrammetric point clouds of forested areas depicting full trees has up until now been a challenge.

In this study, the possibility of fusing aerial and terrestrial image-based point clouds of an intensive-monitoring forest stand will be explored. An experiment involving spherical 3D targets (Brazeal, 2013) to co-register low oblique UAV-based imagery with terrestrial imagery will be presented. The results are subjected to a quantitative analysis of the horizontal accuracy of extracted tree positions as well as a qualitative analysis of the merged point cloud.

2 Materials and Methods

2.1 Study Area

The study area is located at the Britz Research Station, approximately 50 km north-east of Berlin, Germany, near the village of Britz. The plot chosen for the study was a 0.24 ha monoculture stand of Scots Pine (*Pinus sylvestris*) established in the mid-1970s. The stand consisted of 286 trees which had an average height of 17.5 m. The understorey is comprised of young European Beech (*Fagus sylvatica*) and Sessile Oak (*Quercus petraea*) sparsely dispersed throughout the stand. More information about the Britz research station can be found in Krause, Sanders, Mund, & Greve, 2019; and Krause, Strer, Mund, & Sanders, 2019.

2.2 Spherical Ground Control Points

The aims of spherical ground control points (SGCPs) are to enable the georeferencing of terrestrial imagery as well as to provide a basis for merging terrestrial and aerial imagery. For this experiment, the SGCPs were created by painting a pattern similar to the one that is typically implemented on a 2D Ground Control Point (GCP) on to low-cost Styrofoam spheres mounted on poles. Five target points (North, South, East, West and 'top') were measured and painted on the spheres using black acrylic paint. Terrestrial imagery makes use of the four azimuth directions; the 'top' target would be visible in aerial nadir and oblique imagery, depending on gaps in the forest canopy.

The GCPs and tree positions were measured using a Total Station (Sokkia ® Set 510) (TS) from a known absolute position and marked permanently with the installation of PVC pipes buried vertically into the ground. During the field campaign, the poles with the mounted SGCPs were placed inside the PVC pipes, which were positioned perpendicular to the ground using a spirit level (see Figure 1a, 1b). The height from the ground GCP to the base of the sphere was measured (approx. 1.6 m) and the targets lined up to magnetic north with a compass. Aerial and terrestrial imagery was acquired on the same day to enable the same SGCP positioning for both acquisitions.

Figure 1: (a) PVC Piping installed at each ground control point; (b) the spherical ground control point after levelling

In order to calculate the geolocations of the four azimuths, the middle of the sphere was calculated by adding the radius of the sphere to the base height. From the middle of the sphere, the four targets were calculated using the radius (0.153 m) and each cardinal direction angle. The 'top' target of the sphere is the same as the ground GCP in terms of X and Y coordinates; the Z-value is calculated simply by adding 2r to the base value. The calculation of the sphere's azimuth target points are as follows:

$$SGCP_x = \sin(a\frac{\pi}{180})r + GCP_x$$

$$SGCP_y = \cos(a\frac{\pi}{180})r + GCP_y$$

where a = 0, 90, 180 or 270°, and r = 0.153 m.

2.3 Aerial Image Acquisition

The aerial oblique imagery was acquired with a Sony ® A7r fixed-lens camera (35 mm *Zeiss Sonnar* 2.8) mounted on an OctoXL 6S12 Octocopter from Mikrokopter ® (HiSystems GmbH). The camera was triggered using an intervalometer, set at an angle of 70°, and flown over four separate flight plan grids to ensure 3D coverage (see Figure 2). The flight plans were calculated using the principle of a trapezoid-shaped image ground footprint, where the distance from the bottom of the image footprint to the ground position of the sensor at nadir (Grenzdörffer, Guretzki, & Friedlander, 2008) is estimated in order to ensure adequate coverage of the forest stand while reducing extraneous imagery outside of the area of interest. Two flight missions were carried out at the end of August 2017 (near solar noon), each mission carrying out two flight plans at a time.

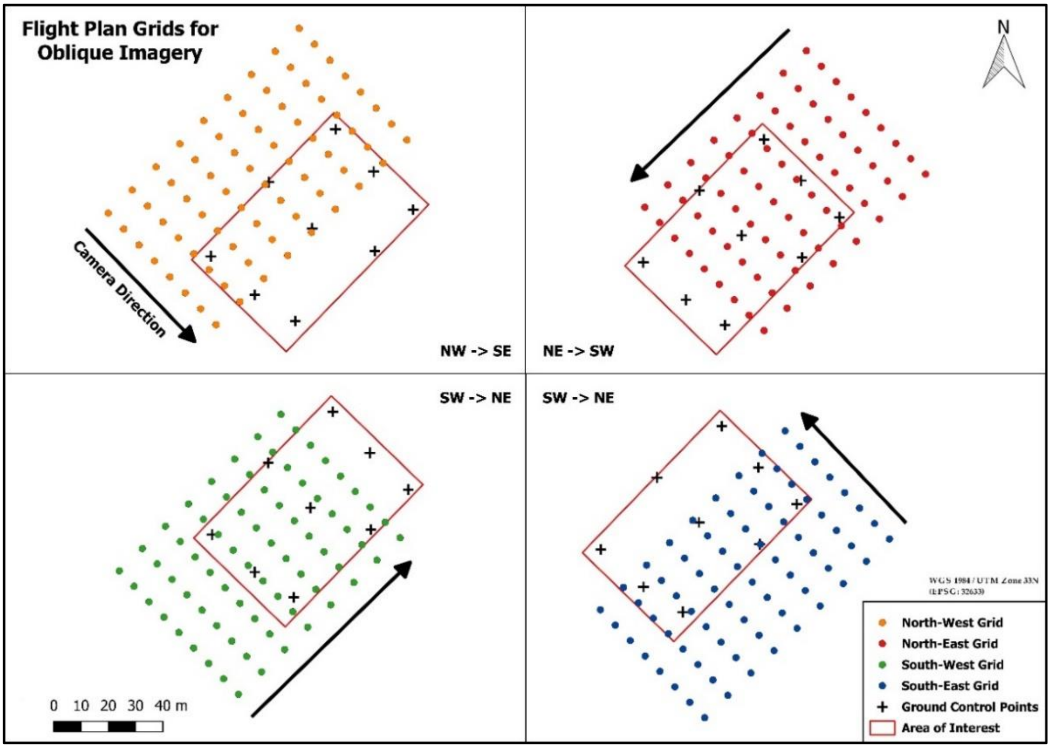


Figure 2: The four flight plan grids used for the acquisition of oblique imagery

2.4 Terrestrial Image Acquisition

The terrestrial images were acquired using the same fixed-lens camera as in the UAV campaign. Three images were taken at each camera station in a horizontal fashion, moving from bottom to top. As shown in Figure 3, an outer path surrounding the rectangular forest stand was taken, as well as a path going through the middle of the stand always facing inwards. Additionally, a circle from the centre of the stand facing outwards was carried out at 360°. An attempt was made to take three images at each camera station such that every image contained at least one SGCP (see Figures 4a, 4b, 4c). Ideally, multiple SGCPs were visible within a single image. The terrestrial campaign was carried out directly after the UAV campaign in order to reduce the effects of varying solar illumination.

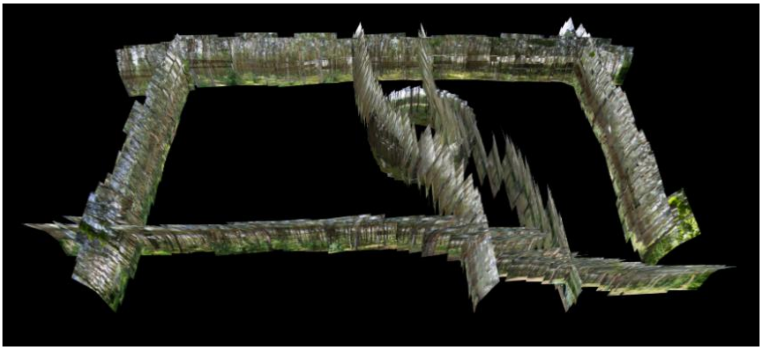
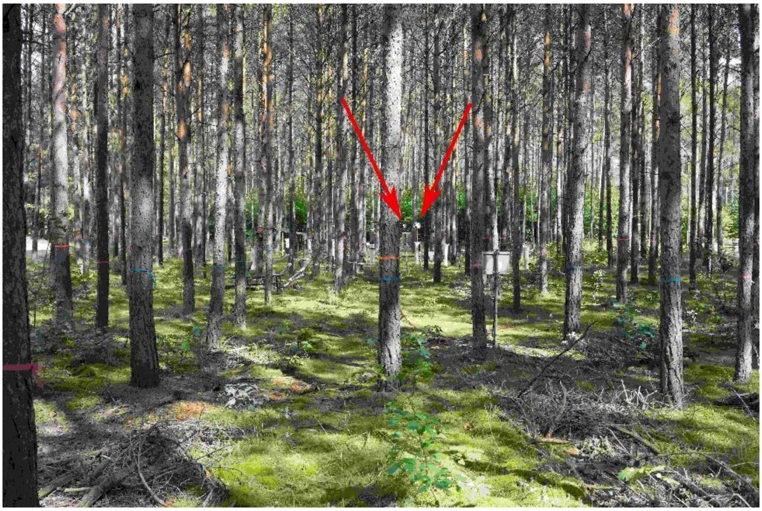
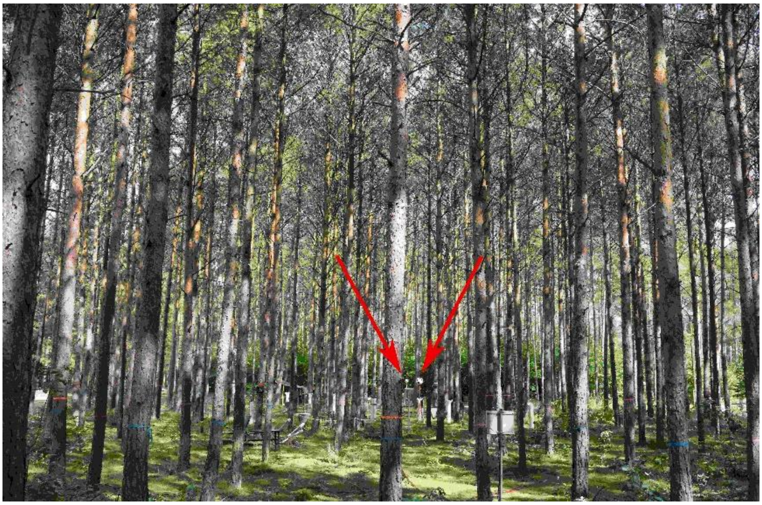


Figure 3: Terrestrial image acquisition path



(a)



(b)

(c)

Figure 4: Terrestrial imagery: (a) first image with 60% ground; (b) second image with 20% ground; (c) third image with 0% ground. Red arrows point to the position of the same spherical target in all three images (a, b and c)

2.5 Processing

Images from both campaigns were adjusted for exposure and converted to 8-bit TIFF. The terrestrial and aerial image datasets were processed in separate Pix4Dmapper ® (Version 4.1.24, 2018) projects until the calibration stages. The projects were then merged into one larger project where the full point cloud was processed. Further point cloud editing and analysis were carried out in CloudCompare ® (Version 2.9, 2018), as well as lidR (Roussel & Auty, 2018) and TreeLS (de Conto, 2019) packages in R (R Core Team, 2016). The processing workflow and acquisition of the image datasets and field data are shown in Figure 5.

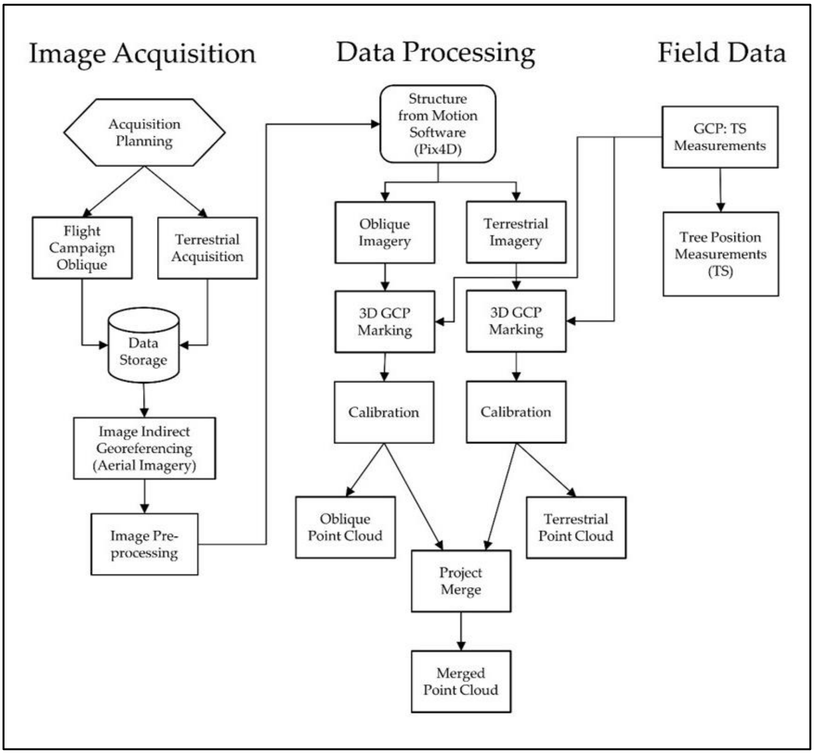


Figure 5: Flowchart showing the image acquisition and processing workflow

2.6 Statistical Analysis

The root-mean-square-error (RMSE) established within the Pix4D photogrammetry software gives an estimate of the systematic error (X, Y and Z) within the photogrammetric block with reference to the marked SGCPs.

The estimated tree positions were extracted as the centroid at the base of each stem and validated for horizontal accuracy (X, Y) against the TS tree position measurements. A quantification of the horizontal error at 95% confidence level was calculated as follows (McGlone & Lee, 2013):

$$Horizontal\ Accuracy = 2.4477 * 0.5 * (RMSE_X + RMSE_Y)$$

3 Results

3.1 Accuracy Assessment

The final point cloud was derived from almost 1,000 images and comprised over 85 million points. The reported (Pix4D) RMSE of the merged project was estimated at 0.063 m; 29 SGCPs were utilized throughout the whole photogrammetric block. Table 1 gives an overview of the results of the photogrammetric processing. The level of error in the terrestrial dataset (RMSE = 0.073 m) in comparison to the aerial dataset could be due to the increased number of SGCPs implemented.

Table 1: Results of the photogrammetric processing

Project	Images	RMSE (m)	SGCPs	Point Count	Point Density (m^3)
UAV-based	378	0.014	9	-	-
Terrestrial	614	0.073	20	-	-
Merged	992	0.063	29	85,219,047	6,898.16

In terms of horizontal error, the extracted tree positions (n = 270) were estimated at 0.69 m when validated against the TS tree position measurements at a 95% confidence level. In other words, 95% of the 270 photogrammetrically derived tree-stem positions will have an error equal to or less than 0.69 m with respect to the TS measurements. Figure 6 shows the extracted tree positions from the fused point cloud in relation to the TS measured tree positions. From the 286 actual trees, 16 trees remained undetected – a detection rate of 94.41%. Increased horizontal accuracy as well as detection rate are evident in the central part of the area of interest (see Figure 6).

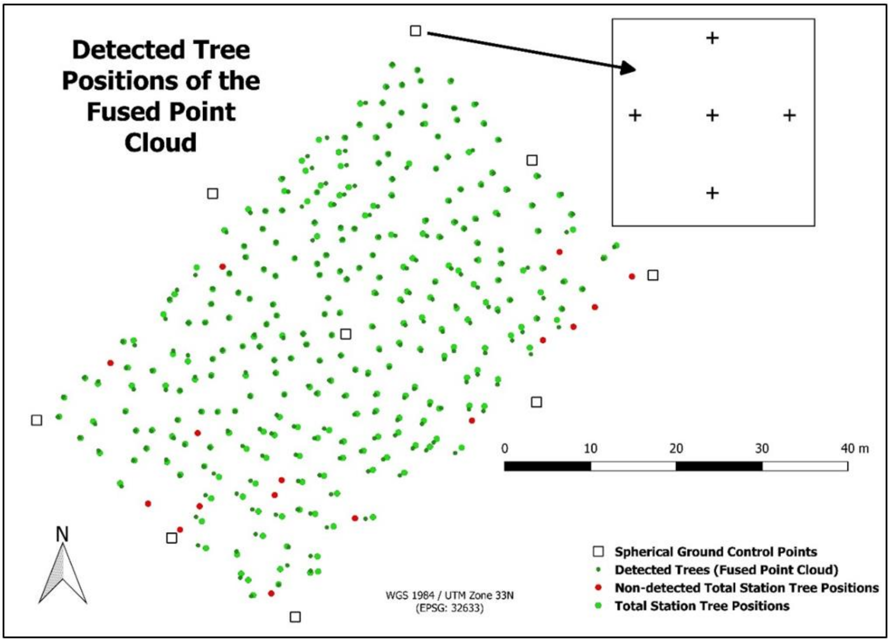


Figure 6: Detected tree positions in the point cloud shown in comparison to the Total Station tree position measurements. The crosshairs shown in the box in the upper right-hand corner represent the 4 cardinal directions and the top (centre) of a spherical target.

3.2 Qualitative Analysis of the Resulting Point Cloud

For visualization purposes, point clouds were also processed for the oblique and terrestrial datasets separately. Figure 7 shows the variation in coverage for both datasets. A large proportion of the upper and lower tree crowns were reconstructed using the oblique imagery (Figure 7a). The terrestrial imagery was responsible for the reconstruction of the tree stems with added noise due to sky within images (Figure 7b). From the ground view perspective of the RGB point cloud shown in Figure 8, each tree stem is for the most part intact, and artefacts or noise are minimal in the lower parts of the tree stems. In the upper canopy however, noise due to sky in the terrestrial imagery is also evident in the form of white points (see Figure 9).

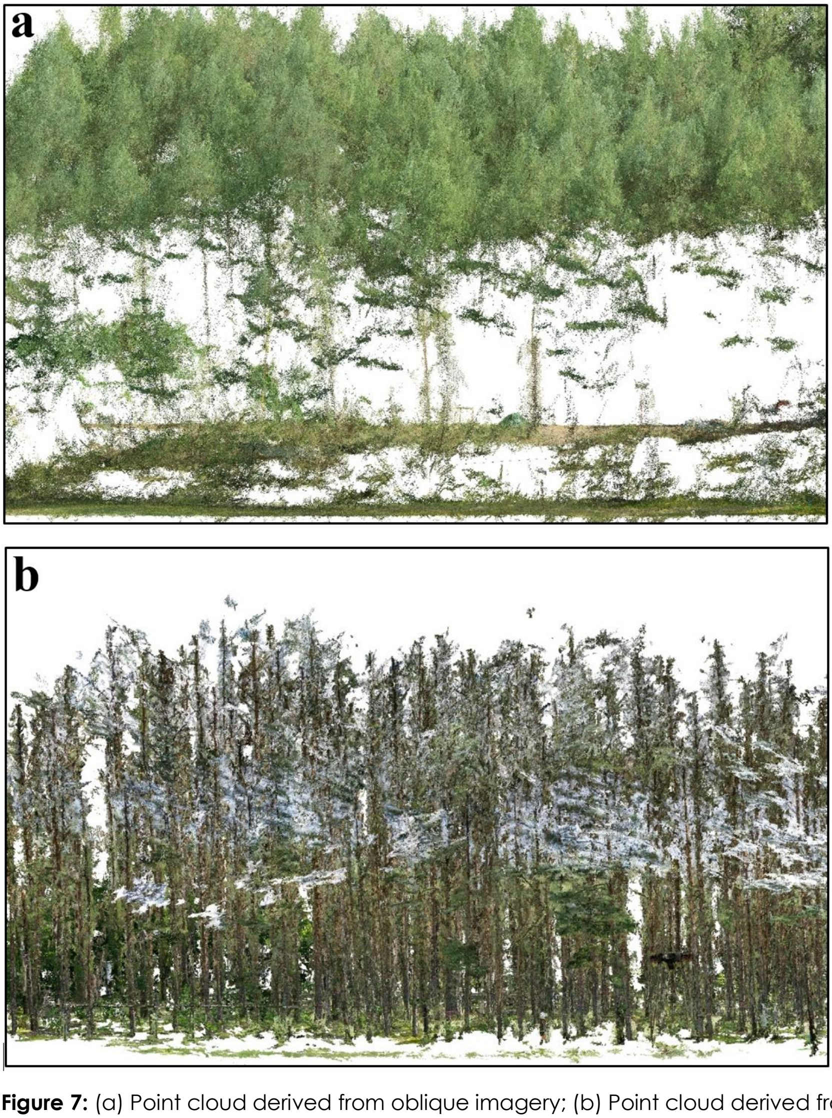


Figure 7: (a) Point cloud derived from oblique imagery; (b) Point cloud derived from terrestrial imagery

Figure 8: View within the resulting merged point cloud from the ground perspective

Figure 9: Oblique aerial view of the resulting merged point cloud. White points in the upper canopy are due to noise propagated from sky in the terrestrial imagery

A random tree was chosen and segmented from the point cloud for further analysis. Segmenting the stem within the point cloud at the typical diameter at breast height (DBH) of

1.3 m (see Figure 10, left) shows that it is possible to measure the diameter using, for example, stem-modelling algorithms (de Conto, Olofsson, Görgens, Rodriguez, & Almeida, 2017). As height increases however, noise in the point cloud becomes more prominent, which could result in stem diameter estimation inaccuracies (see Figure 10, right). The full tree depicted in Figure 10 (right) illustrates the potential to carry out detailed tree crown measurements, despite noise issues. Figure 11 displays the possibility to denoise a segmented saw log by the manual removal of extraneous points, potentially enabling more precise digital measurements.

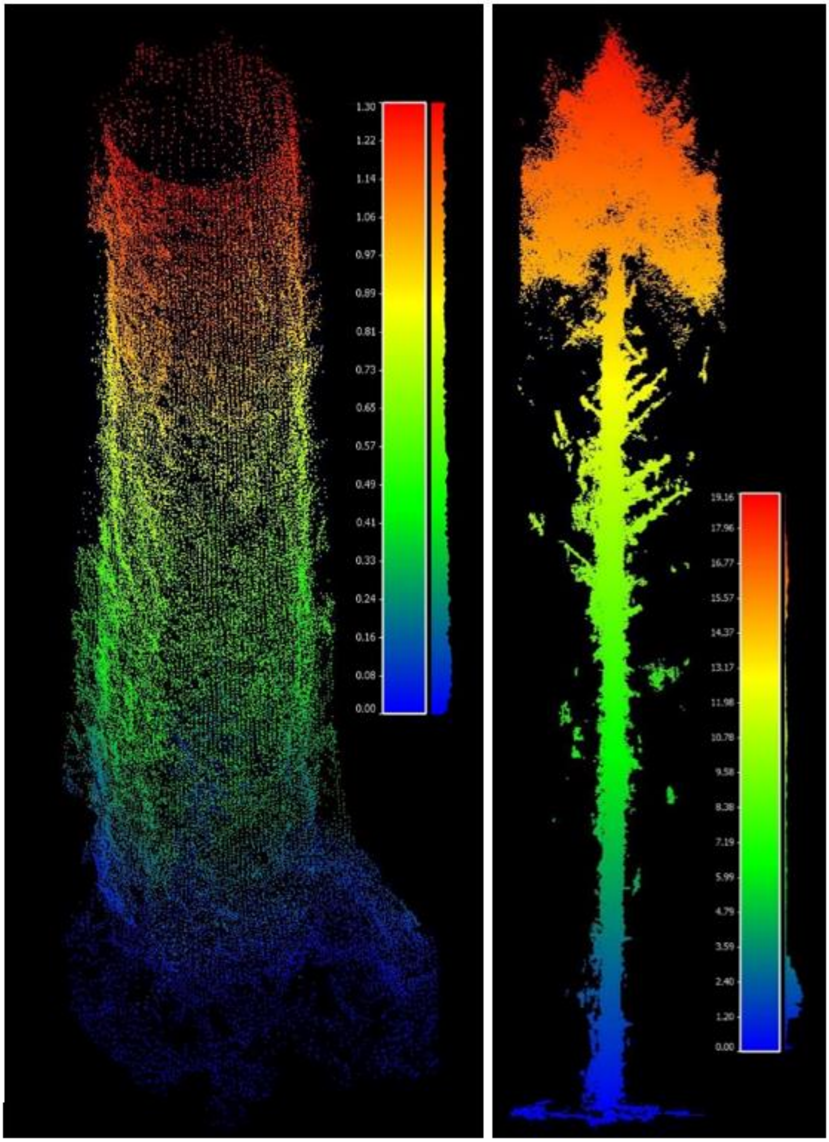


Figure 10: (left) Tree stem segmented at the DBH (1.3 m); (right) Full tree with intact stem and crown. The amount of noise increases with height. Values are shown in metres

Figure 11: Tree stem (RGB) segmented at 4 m with the manual removal of extraneous points

4 Discussion and Future Work

The approach presented in this study represents a successful attempt at fusing aerial and terrestrial image datasets. Tree positions extracted from the point cloud resulted in a higher horizontal accuracy and detection rate within the central parts of the area of interest (see Figure 6). This shows that when planning the acquisition of terrestrial imagery, a buffer zone outside an area of interest could potentially improve the horizontal accuracy and detection of tree stems near the inner parts of the area of interest. Also evident in Figure 6 is the radial systematic error, which could be due to inaccurate northing of the spherical targets.

Full point clouds of forest stands can be used to derive various forest parameters and could be deemed multi-purpose in terms of their utility, especially if they are acquired at frequent intervals. Despite increased noise in the upper canopy, this methodology could prove competitive to Terrestrial and Airborne Laser Scanning (TLS, ALS) at a lower cost when a permanent GCP installation is available. The benefit of permanent GCPs at intensive-monitoring plots is that they have the potential to be measured with a Total Station, which in turn eliminates the problem typical of mobile field campaigns in terms of RTK GNSS multipath effects under a dense forest canopy. The question remains as to whether it is possible to remove the noise from the point clouds using automatic methods in order to enable reliable diameter measurements to be made throughout entire tree stems.

Further development of the method using spherical targets to co-register aerial and terrestrial imagery as described in this study is merited. Spherical targets manufactured using weatherproof materials conducive to geometric integrity could improve overall accuracy of the photogrammetric block. The next step is to develop automatic methods to denoise artefacts within the photogrammetric point cloud. This would enable more precise stem diameter measurements throughout the whole tree stem. Furthermore, such stem diameter measurements require validation through destructive methods.

Acknowledgements

This research would not have been possible without the support of Dr. Tanja Sanders and the team at the Britz research station (Thünen Institute of Forest Ecosystems), or Prof. Dr. Jan-

Peter Mund (Eberswalde University of Sustainable Development) and Prof. Dr. Klaus Greve (University of Bonn).

References

Brazeal, R. (2013). Low Cost Spherical Registration Targets for Terrestrial Laser Scanning. https://doi.org/10.13140/2.1.4091.0724

de Conto, T. (2019). TreeLS: Terrestrial Point Cloud Processing of Forest Data (Version 1.0). Retrieved from https://CRAN.R-project.org/package=TreeLS

de Conto, T., Olofsson, K., Görgens, E. B., Rodriguez, L. C. E., & Almeida, G. (2017). Performance of stem denoising and stem modelling algorithms on single tree point clouds from terrestrial laser scanning. *Computers and Electronics in Agriculture*, *143*, 165–176. https://doi.org/10.1016/j.compag.2017.10.019

Grenzdörffer, G. J., Engel, A., & Teichert, B. (2008). The photogrammetric potential of low-cost UAVs in forestry and agriculture. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *31*(B3), 1207–1214.

Grenzdörffer, G. J., Guretzki, M., & Friedlander, I. (2008). Photogrammetric image acquisition and image analysis of oblique imagery. *The Photogrammetric Record*, *23*(124), 372–386.

Krause, S., Sanders, T. G. M., Mund, J.-P., & Greve, K. (2019). UAV-Based Photogrammetric Tree Height Measurement for Intensive Forest Monitoring. *Remote Sensing*, *11*(7), 758-. https://doi.org/10.3390/rs11070758

Krause, S., Strer, M., Mund, J.-P., & Sanders, T. G. (2019). UAV Remote Sensing Data Handling: A Transition from Testing to Long-Term Data Acquisition for Intensive Forest Monitoring. *Dreiländertagung Der OVG, DGPF Und SGPF Photogrammetrie - Fernerkundung - Geoinformation - 2019*, *28*, 8. Vienna, Austria: 39. Wissenschaftlich-Technische Jahrestagung der DGPF e.V.

McGlone, J. C., & Lee, G. Y. G. (2013). *Manual of photogrammetry* (6th ed.). Retrieved from http://www.worldcat.org/oclc/856568615

Mikita, T., Janata, P., & Surový, P. (2016). Forest Stand Inventory Based on Combined Aerial and Terrestrial Close-Range Photogrammetry. *Forests*, *7*(8), 165. https://doi.org/10.3390/f7080165

Panagiotidis, D., Abdollahnejad, A., Surový, P., & Chiteculo, V. (2016). Determining tree height and crown diameter from high-resolution UAV imagery. *International Journal of Remote Sensing*, 1–19. https://doi.org/10.1080/01431161.2016.1264028

Paris, C., Kelbe, D., van Aardt, J., & Bruzzone, L. (2017). A Novel Automatic Method for the Fusion of ALS and TLS LiDAR Data for Robust Assessment of Tree Crown Structure. *IEEE Transactions on Geoscience and Remote Sensing*, *55*, 3679–3693. https://doi.org/10.1109/TGRS.2017.2675963

Piermattei, L., Karel, W., Wang, D., Wieser, M., Mokroš, M., Surový, P., … Hollaus, M. (2019). Terrestrial Structure from Motion Photogrammetry for Deriving Forest Inventory Data. *Remote Sensing*, *11*(8), 950. https://doi.org/10.3390/rs11080950

R Core Team. (2016). *R: A language and environment for statistical computing*. Retrieved from http://www.R-project.org/

Roussel, J.-R., & Auty, D. (2018). LidR: Airborne LiDAR Data Manipulation and Visualization for Forestry Applications (Version R package version 1.4.1). Retrieved from https://CRAN.R-project.org/package=lidR

St-Onge, B., Audet, F.-A., & Bégin, J. (2015). Characterizing the Height Structure and Composition of a Boreal Forest Using an Individual Tree Crown Approach Applied to Photogrammetric Point Clouds. *Forests*, *6*(11), 3899–3922. https://doi.org/10.3390/f6113899

GI_Forum 2019, Issue 2
Page: 73 - 80
Short Paper
Corresponding Author:
christoph.giger@landplan.ch
DOI: 10.1553/giscience2019_02_s73

Assessing Shrub and Tree Encroachment in Alpine Pastures from Airborne Laser Scanning Data

Christoph Giger
landplan AG Bern, Switzerland

Abstract

The forest area in alpine regions is increasing. Agricultural land is abandoned; shrub and tree encroachment and reforestation are the consequences, with negative impacts on agriculture, biodiversity and tourism.

Assessing encroachment on agricultural land from Airborne Laser Scanning (ALS) data was tested in three study areas in Switzerland. The results of the data evaluation were compared with those for manually collected data from the interpretation of orthophotos. The evaluation indicated that when a higher point density was available, the detection rate for areas with shrub and tree encroachment was also higher. The workflow using the Vertical Complexity Index (VCI) turned out to be robust for both large areas and large datasets. The accuracy levels achieved in this study for the encroachment index may provide a solid basis for prioritizing certain areas for projects that aim to limit the process of reforestation.

Keywords:

airborne laser scanning ALS, secondary succession, shrub and tree encroachment, change detection

1 Introduction

As in all mountain areas in Europe, the total wooded area in Switzerland is increasing due to agricultural land abandonment. In the alpine pasture and meadow region in Switzerland, forest increases by 2,400 ha per year (Lauber et al., 2013, Brändli et al., 2014). This process is viewed negatively by various actors from the agriculture, nature conservation and tourism sectors. Experts and laypersons in Switzerland oppose reforestation strongly for a variety of reasons, especially in alpine pastures, which are an outstanding element of the cultural landscape of Switzerland (Baur et al., 2007, Brändli et al., 2014). Various projects aim to make such areas suitable for agriculture again. Adapted grazing, other livestock interventions, tree-felling or rooting out bushes help to keep the pasture land open in the long term. The canton of Valais, for example, has developed guidelines to assist *communes* (municipalities) in projects to work against the process of reforestation (Canton Valais, 2011).

Observing the encroachment process can be done easily in the field over small areas, but monitoring large areas using remote sensing is challenging. Changes in land cover often concern just small patches, and discrimination between land uses can be difficult (Kolecka et al., 2015). In much research, the forest is in the foreground. Van Ewijk, Treitz and Scott (2011) used Light Detection and Ranging (LiDAR) indices to distinguish four stages of forest succession, but not to identify the reforestation stage. Multispectral or colour infrared aerial imagery in combination with Airborne Laser Scanning (ALS) data is widely used, with good results, for forest change detection by means of Object Based Image Analysis (OBIA) (Waser et al., 2008, Szostak, Wężyk and Tompalski, 2014, Blaschke, 2010).

In this paper, a practical approach for the detection of shrub and tree encroachment in agricultural land is presented, based on the author's Master's dissertation (Giger, 2018). The objectives of the thesis were (1) to verify whether it is possible or not to detect shrub and tree encroachment from ALS data using open source tools and standard available data; (2) to assess the minimum point density of ALS data required to obtain a reasonable detection rate.

2 Data

The study areas were selected based on recent land-use changes and availability of ALS data. Recent land-use changes were taken from the Swiss Land Use Statistics (Federal Statistical Office, 2014). Areas which changed land-use classes between 1992–97 and 2004–09 from 'agricultural area' to 'wooded area' were quantified and overlaid with the boundaries of summer pastures (these had not changed over the period in question). As most of the changes in the area statistics for the canton of Bern concerned Saxeten and Grandval, these two *communes* were selected for the study (Figure 1). The third test area, in Maienfeld, in the canton of Grisons (Figure 2), was chosen because of the comparatively high point density of the ALS dataset from the year 2002, as Maienfeld was probably scanned for test purposes using a density of more than 4 points/m2. The extent of the area in Maienfeld corresponds exactly to an orthophoto tile from Swisstopo (the Swiss Federal Office of Topography).

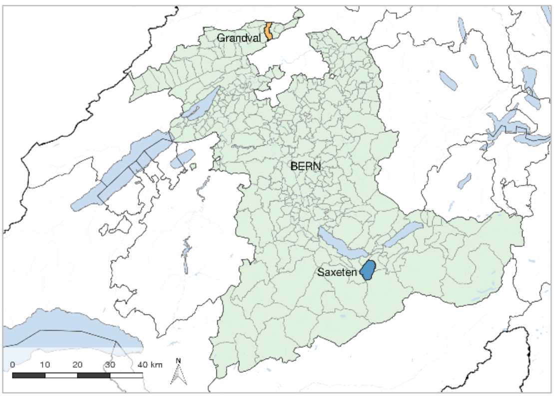


Figure 1: *Communes* Grandval and Saxeten in Bern canton

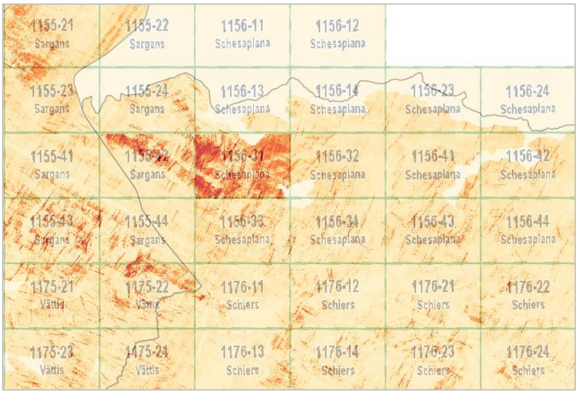


Figure 2: Study area Maienfeld in Grisons canton, recognizable by the dark red colour, which represents the high point density (tile number 1156-31).

In order to identify shrub and tree encroachment from ALS data, two datasets from different years are required. For study areas Saxeten and Grandval, ALS data from Swisstopo (Federal Office of Topography Swisstopo, 2019) collected in 2001was used as the first dataset. The second dataset was collected by the canton of Bern (Amt für Wald des Kantons Bern, 2013). For the Maienfeld study area, a dataset from 2002 provided by Swisstopo and one collected by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in 2015 were analysed (overview in Table 1).

To assess the accuracy of our results, orthophotos corresponding as closely as possible to the year of the ALS data collection were used. The orthophotos have a ground pixel size of 0.25 or 0.5 m and were provided by Swisstopo (Table 1).

Table 1: ALS data and orthophotos used in the three study areas

	Saxeten		Grandval		Maienfeld	
year of ALS data	2001	2012	2001	2011	2002	2015
mean point density (points/m²)	1.5	18.9	1.2	9.8	4.2	21.7
year of orthophotos	2004	2012	2004	2012	2002	2014

3 Methods

The Vertical Complexity Index (VCI) based on the Shannon Index (Shannon, 1948) was used to identify shrub and tree structures in agricultural areas. The index can be used to determine the diversity or the uniformity of the height distribution of ALS points.

In order to calculate the VCI, a normalised ALS point cloud was divided into a number of height bins (HB). The number of LiDAR returns per height bin as a proportion of the total number of LiDAR returns was used to define p_i.

$$VCI = (-\sum_{i=1}^{HB}[(p_i) \cdot \ln(p_i)])/\ln(HB)$$

A VCI value close to 1 indicates that most height bins have equal numbers of points. As the distribution of points per height bin becomes more uneven, VCI decreases (van Ewijk et al., 2011). Van Ewijk et al. used the VCI to differentiate the succession stages of forest stands from ALS data, but not to differentiate between bare ground or pastures and the initiation stage. For the stem exclusion stage, the same authors measured a mean VCI of 0.63; for the understorey re-initiation stage, a mean VCI of 0.75, and for the old growth stage, a mean VCI of 0.80. The analysis of the results obtained from the encroachment indicator calculation showed that for shrub and tree encroachment a VCI of less than 0.63 could be expected. Therefore, a threshold of 0.61 was chosen in order to distinguish between areas with encroachment and an understorey re-initiation stage. In addition, the maximum Z-value was calculated and included in order to reduce unidentified individual trees. Grid cells with a maximum Z-value of more than 3.5m were excluded. The spatial resolution was set at 3 x 3m, as a compromise between accuracy and computational cost. The differences between the resulting VCIs from the old (t1) and the new (t2) ALS data show potential areas of encroachment (Figure 3).

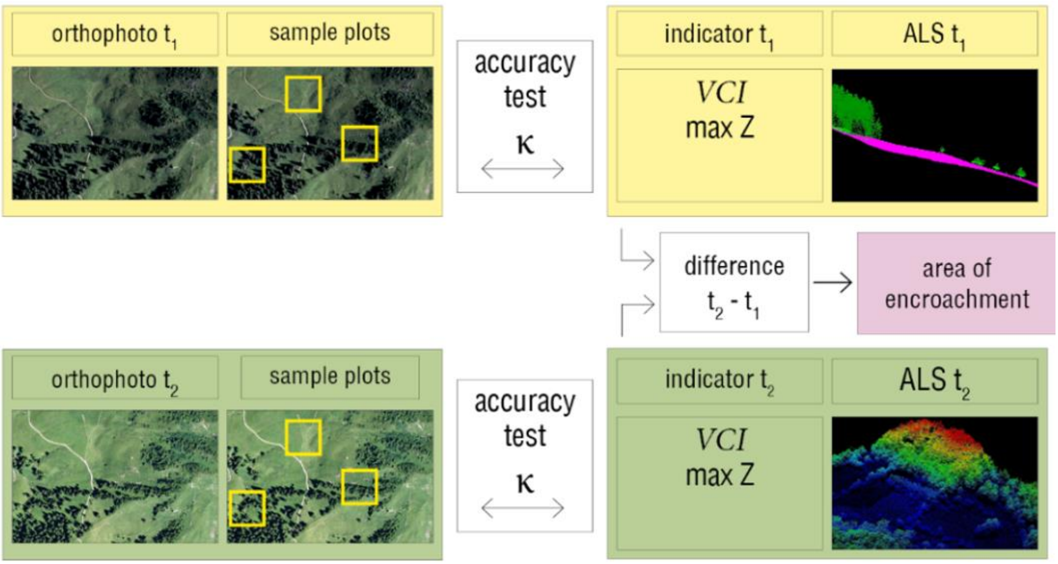


Figure 3: Workflow of data analysis: orthophoto interpretation on the left, VCI calculation on the right

Figure 3 shows the workflow for analysing the old and new orthophotos and the ALS data, which was carried out for each study area. The accuracy of the VCI calculated combined with a maximum Z-value is verified by comparing it with manually digitized information from orthophotos. For each study area, 450 sample plots were classified as plots with shrub and trees, or plots without. The area of shrub and tree encroachment was obtained from the difference between the indicators calculated from old and new ALS data.

The raw data were filtered and normalized with PDAL (Point Data Abstraction Library, Version 1.5); VCI and the maximum Z-value were calculated using the lidR package (version 1.2.0) in R; the results were stored in a PostgreSQL database. There, the POSTGIS extension was used to combine the VCI and the maximum Z-value, to calculate the changes between the old and the new datasets, and from these to determine the areas with an increase in shrub and tree structures (Figure 4).

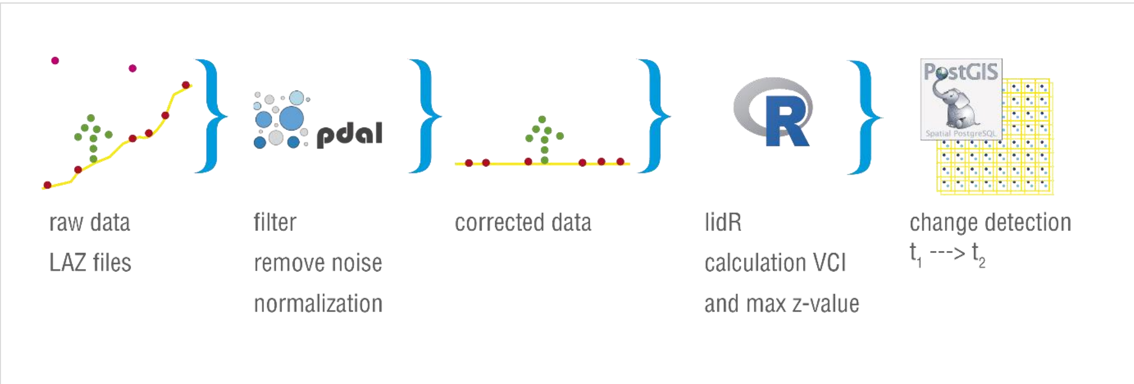


Figure 4: Workflow for processing ALS data and extracting areas of encroachment

To assess the accuracy of the ALS data interpretation, 450 plots (12 x 12m) per study area were evaluated using orthophotos from the year in which the ALS data was collected (+/- 3 years). The plots were categorized as plots with shrubs and trees, and plots without. Figure 5 shows a sample plot classified as a plot with shrubs and trees, Figure 6 a plot without shrubs and trees, and Figure 7 a plot which is not classified due to shadows. Forested areas or areas with large trees were assigned to 'unclassified', as were plots affected by shadow (e.g. of large trees or the topography). The threshold for the category 'shrubs and trees' is 25% coverage of the plot area.

For comparison with the orthophoto interpretation, the grid cells (3 x 3m) classified as 'shrubs and trees' based on ALS data were aggregated to the size of a sample plot (12 x 12m). If at least 4 cells in a plot were classified as 'shrub and trees', the plot as a whole was assigned to the category 'shrubs and trees'.

Figure 5: control area, classified as *shrubs and trees*

Figure 6: control area without shrubs and trees, classified as *other*

Figure 7: due to shadows, assigned to *unclassified*

4 Results

Table 2 shows the results of the orthophoto interpretation for each classification category. In all areas, the percentage of 'shrubs and trees' increased between the old and the new datasets. While 'unclassified' plots decreased in the Saxeten and Maienfeld study areas, for Grandval there was an increase.

Table 2: Comparison of orthophoto interpretation

	Saxeten		Grandval		Maienfeld	
year of orthophoto	2004 (t_1)	2012 (t_2)	2004 (t_1)	2012 (t_2)	2002 (t_1)	2014 (t_2)
shrubs and trees [%]	17.1	20.7	1.8	7.3	6.7	12
other [%]	70.8	68.4	85.8	80.9	91.6	87.3
unclassified [%]	12.1	11	8.6	11.8	1.8	0.7
plots classified [n]	400	405	394	397	442	447

Data derived from orthophoto interpretation were used as reference data for the accuracy assessment. The number of sample plots correctly classified by the ALS data calculation is of primary interest and represented by the producer's accuracy (PA) for the category 'shrubs and trees'.

As shown in Table 3, the PA for category 'other' ranges from 83 to 98%, for both the old and the new ALS datasets. For the category 'shrubs and tree', we obtained accuracies between 34 and 74% for the old dataset and between 57 and 79% for the new dataset.

Table 3: Comparison of Producer's accuracy (PA) and User's accuracy (UA) in the three study areas

Study area	Point density ALS data [p/m²]	Old data (t_1), category *other* [%]		Old data (t_1), category *shrubs and trees* [%]		Point density ALS data [p/m²]	New data (t_2), category *other* [%]		New data (t_2), category *shrubs and trees* [%]	
		PA	UA	PA	UA		PA	UA	PA	UA
Saxeten	1.5	83	93	34	25	18.9	90	86	58	67
Grandval	1.2	97	98	43	35	9.8	98	95	57	79
Maienfeld	4.2	96	99	74	47	21.7	94	98	79	57

5 Conclusion

The study shows that it is possible to quantify shrub and tree encroachment in alpine pastures in Switzerland using ALS data with medium to high point density. By extending the VCI with a maximum Z-value, a reliable shrub and tree encroachment indicator for alpine regions was calculated. In Maienfeld, for both the old and new ALS datasets, data with middle to high point density was available. This good data quality led to the following results: for the category 'shrubs and trees', a producer's accuracy of 74% (ALS data 2002, 4.2 points/m2) and 79% (ALS data 2015, 21.7 points/m2) was achieved.

While point density has an influence on the accuracy, it is not possible to derive from the results the minimum point density of ALS data required to obtain a reasonable detection rate. Study-area-specific difficulties and various sources of error may have more impact than the point density. The two lowest producer's accuracies were obtained from ALS data with low point density – of 1.2 and 1.5 points/m2.

The study shows that the VCI, implemented in the R-package lidR, in combination with the maximum Z-value is suitable for the workflow presented here. If new ALS data become available in the future, it will be possible to carry out the analysis to identify areas with shrubs and tree encroachment. A larger-scale analysis could serve as the basis for funding decisions for projects that limit the process of reforestation in Switzerland.

References

Amt für Wald des Kantons Bern. (2013). LIDAR-Daten Kanton Bern. Retrieved from http://files.be.ch/bve/agi/geoportal/geo/lpi/LDOM50CM_2012_01_LANG_DE.pdf

Baur, P., Müller, P. & Herzog, F. (2007). Alpweiden im Wandel. *Agrarforschung*, 14, 254-259.

Blaschke, T. (2010). Object based image analysis for remote sensing. *ISPRS Journal of Photogrammetry and Remote Sensing*, 65, 2-16.

Brändli, U., Cioldi, F., Fischer, C., Herold-Bonardi, A., Keller, H. & Meile, R. (2014). Viertes Schweizerisches Landesforstinventar-Ergebnistabellen und Karten im Internet zum LFI 2009-2013 (LFI4b). Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft WSL, Birmensdorf.

Canton Valais. (2011). Leitfaden zum Vorgehen für Gemeinden mit Waldeinwuchs im Wallis. Retrieved from https://www.vs.ch/web/sfcep/extension-des-forets

Federal Office of Topography Swisstopo. (2019). LiDAR Data Aquistion. Retrieved from https://www.swisstopo.admin.ch/en/knowledge-facts/geoinformation/lidar-data.html

Federal Statistical Office FSO. (2014). Arealstatistik Bodenbedeckung nach Nomenklatur 2004 - Metainformation zu Geodaten. Retrieved from https://www.bfs.admin.ch/bfs/de/home/statistiken/raum-umwelt/nomenklaturen/arealstatistik/nolc2004.assetdetail.313706.html

Giger, C. (2018). Assessing Shrub and Tree Encroachment in Alpine Pastures from Airborne Laser Scanning Data. http://unigis.sbg.ac.at/files/Mastertheses/Full/104172.pdf

Kolecka, N., Kozak, J., Kaim, D., Dobosz, M., Ginzler, C. & Psomas, A. (2015). Mapping secondary forest succession on abandoned agricultural land with LiDAR point clouds and terrestrial photography. *Remote Sensing*, 7, 8300-8322.

Lauber, S., Herzog, F., Seidl, I., Böni, R., Bürgi, M., Gmür, P., Hofer, G., Mann, S., Raaflaub, M. & Schick, M. (2013). Zukunft der Schweizer Alpwirtschaft. Fakten, Analysen und Denkanstösse aus dem Forschungsprogramm AlpFUTUR. Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft WSL, Birmensdorf.

Shannon, C. E. (1948). The mathematical theory of communication. *Bell System Technical Journal*, 27, 379-423 and 623-656.

Szostak, M., Wężyk, P., & Tompalski, P. (2014). Aerial orthophoto and airborne laser scanning as monitoring tools for land cover dynamics: A case study from the Milicz Forest District (Poland). *Pure and Applied Geophysic*, 171(6), 857-866. doi:10.1007/s00024-013-0668-8

Van Ewijk, K. Y., Treitz, P. M. & Scott, N. A. (2011). Characterizing forest succession in Central Ontario using LiDAR-derived indices. *Photogrammetric Engineering & Remote Sensing*, 77, 261-269.

Waser, L.T., Baltsavias, E., Ecker K., Eisenbeiss, H., Feldmeyer-Christe, E., Ginzler, C., Küchler, M., Zhang, L. (2008). Assessing changes of forest area and shrub encroachment in a mire ecosystem using digital surface models and CIR aerial images. *Remote Sensing of Environment*, 112 (5), 1956-1968.

GI_Forum 2019, Issue 2
Page: 81 - 97
Full Paper
Corresponding Author:
jihyes@student.unimelb.edu.au
DOI: 10.1553/giscience2019_02_s81

A Conceptual Framework for Unified 3D Digital Management of Urban Land and Property Information

Abbas Rajabirad, Jihye Shin, Behnam Atazadeh and Mohsen Kalantari
University of Melbourne, Australia

Abstract

Over recent years, unprecedented urbanization has fostered the rapid development of multi-storey buildings and infrastructure facilities, resulting in spatial and functional complexities in cities. Land and property information plays a vital role in a wide range of applications in land administration in rapidly growing cities. However, the current fragmented practice relying on 2D representation does not provide a reliable and accurate legal description of underground and aboveground properties as a foundation for evidence-based decisions in support of economic prosperity, human activities and public safety in urban areas. We propose a conceptual framework for 3D digital management of urban land and property information. The framework provides a foundation to federate various 3D models, validate their integrity, and analyse them for land administration. Using a case study of a multi-owned building located in the state of Victoria, Australia, this paper explores the practicality of the framework to support decision-making in building subdivision.

Keywords:

land and property information, map base, 3D SDI, 3D digital data, 3D data validation

1 Introduction

Rapid urbanization and population growth have led to high pressure on vertical development and land use in urban areas around the world, resulting in spatial complexities associated with the legal ownership of properties. Urban land and property information refers to the legal ownership of all properties on the Earth's surface or of underground facilities/infrastructures. This information specifies the legal entitlements to carry out activities within an urban community at the individual, group and public levels. It plays an important role in managing our rapidly growing cities to accommodate the increasing population, as well as in supporting a wide range of applications in land administration, such as positioning, navigation, transportation and urban planning.

Most governments provide map bases as an enabling infrastructure for decision-making at various levels across government, businesses and communities. Map bases are the authoritative graphical representations of land parcels. In general, their 2D representation omits an array of physical property objects that are vertically located, such as apartment blocks, tunnels, and underground utility networks. The current silo-based approach for managing and planning urban information is inadequate for reliable and accurate legal descriptions of underground and aboveground properties (Tsiliakou, Labropoulos, & Dimopoulou, 2013), and for supporting decision-making in managing vertical living environments and planning other aspects of urban settings.

A 3D digital data framework for urban land and property will be fundamental for evidence-based decisions concerning economic prosperity, human activities and public safety in cities (Stoter et al., 2011). Such a framework can support urban planning and the management of infrastructure assets, as well as such things as drilling for oil and forecasting the impacts of a flood. The benefits derived from moving to a 3D digital approach have been noted at government, society and industry levels as follows: (1) improving the authority's ability to make decisions in urban planning and development; (2) reducing disputes within multi-owned buildings (MOB) through facilitating a clear understanding of the 3D extent of ownership; and (3) enhancing productivity by exchanging 3D data for asset management with high interoperability (Acil Allen Consulting, 2017). The estimates indicate that a 3D data infrastructure will provide 2.1 billion Australian dollars of economic benefit for Australia over the next 20 years (Acil Allen Consulting, 2017).

Some jurisdictions have implemented a 3D digital data framework for urban land and property for specific purposes. However, a knowledge base to establish the framework for modernizing land administration practices is generally lacking (Stoter et al., 2011). This research aims to explicate critical components for implementing a 3D data framework to facilitate the integrated management of land and property in urban areas. Because the legal foundation for managing land and property information varies between countries, this paper focuses on a specific jurisdiction – the state of Victoria, Australia. The case study of an MOB located in Victoria was conducted to demonstrate the practicality of the suggested framework to support decision-making in building subdivision.

2 Management of Urban Land and Property Information

2.1 Challenges

Land administration practices refer to the information and processes required for supporting the subdivision, registration and ongoing management of rights, restrictions, and responsibilities (RRRs) associated with land and vertically arranged properties (Ho, Rajabifard, & Kalantari, 2015). Although practices differ between jurisdictions, 2D map bases are typically used to describe the spatial extent of land and properties (see Figure 1). Most countries, including Australia, now give ownership titles for properties within MOBs using the same 2D-based methods developed for traditional broadacre development on vacant land. Moreover, the spatial dimensions of urban land and properties located above and below the earth's surface are not represented in the property map bases of most jurisdictions around the globe.

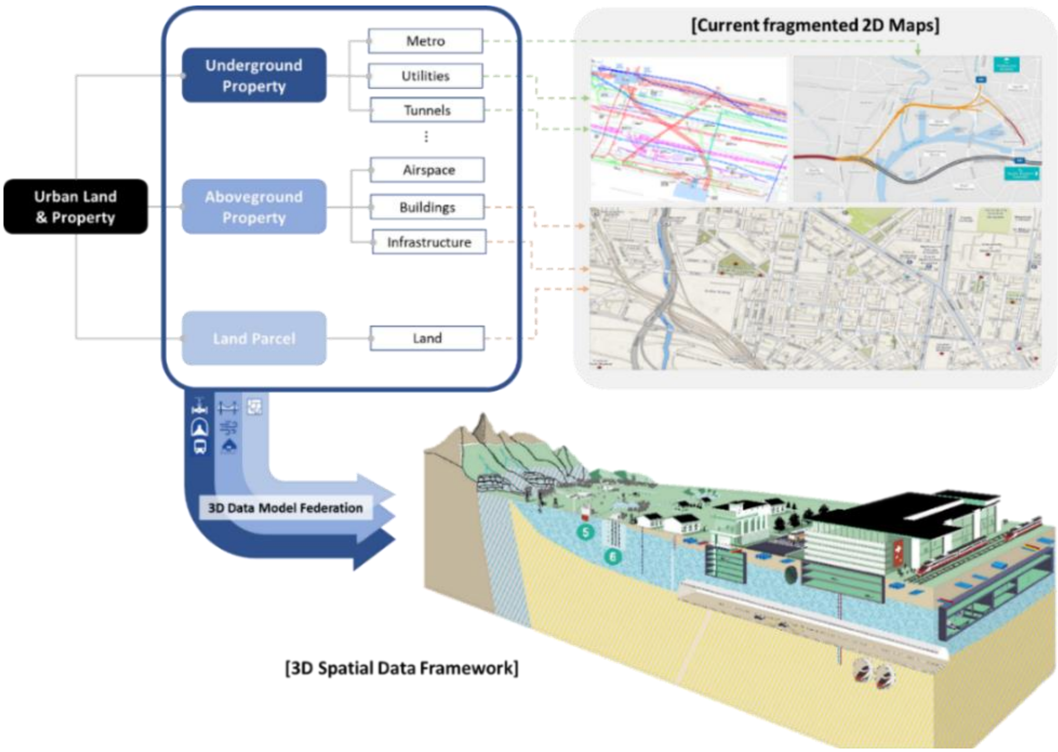


Figure 1: A diagrammatic representation of the complexity of urban land and property

The 2D map base of the state of Victoria provides only the name of a multi-owned property located on a land parcel. The *plan of subdivision* (the cadastral plan in Victoria) describes the 3D spatial extent of ownership RRRs of multiple properties within one parcel using 2D projection (floor plan and cross-section diagrams). This plan cannot sufficiently delineate the complicated arrangement of multi-layered 3D legal spaces and their ownership RRRs in structurally complex multi-owned properties. According to earlier research, a 40-storey building in Melbourne requires a plan running to 60 pages to show the 3D spatial extent of ownership RRRs (Rajabifard et al., 2014). It is highly unlikely that anyone from outside the surveying profession would be able to interpret the land and property information in the plans correctly by knitting all plan drawings together.

To overcome the challenges in managing land and property information using a 2D-based practice, communicating information about urban environments is no longer limited to 2D maps (Atazadeh, Rajabifard, Kalantari, & Shin, 2018). However, international initiatives to develop a 3D-based cadastre mainly address 3D visualization and 3D data models for specific aspects of land administration. Little attention has been paid to creating a more comprehensive and holistic approach to support the variety of decision-making in land administration in the 3D data environment.

2.2 3D Data Models in the Land Administration Domain

Several jurisdictions, including Sweden, Norway and the Australian states of Victoria and Queensland, have examined and implemented prototype 3D cadastres as systems for the comprehensive documentation of land and property information (Shojaei et al., 2017). In the trend towards 3D cadastres, there has been an effort to establish 3D digital models that provide comprehensive representations of complex built structures located vertically, both above and below the ground (Zhu, Hu, Zhang, & Du, 2009). Rajabifard, Atazadeh and Kalantari (2018) categorize 3D data models in the land and property development domain into three types: purely legal, purely physical, and integrated models.

Purely legal 3D models focus solely on legal spaces to manage land and property information in a 3D digital environment. LADM at an international level and ePlan in Australia are two of just a handful of legal models that are able to support 3D legal objects. Legal models are adequate for registering ownership RRRs of land and properties, but they have limitations in communicating the legal ownership allocated within the complicated physical structures of multi-owned properties.

Purely physical models focus mainly on the 3D physical representation of built assets with limitations in managing legal information. There are three dominant physical models: CityGML and IndoorGML for the geospatial industry, and IFC for the building sector. Although those models are adapted for managing existing physical aspects of urban built environments, they can be extended to incorporate further information for managing urban land and property. For example, the potential of IFC, a standard data structure for building information models (BIM), to be extended to accommodate the legal information has been explored in several studies (Atazadeh, Rajabifard, & Kalantari, 2017; Rönsdorff, Wilson, & Stoter, 2014).

Integrated information models have recently emerged due to the need to link the legal and physical dimensions of properties that have multiple owners such as MOBs. Different integrations of physical and legal models have been considered at a conceptual level, such as the integration of CityGML and LADM (Rönsdorff et al., 2014). The 3D data models all show very limited legal aspects of land and property (such as boundary location and type). 3D models are yet to be developed that support land and property management practices fully.

2.3 3D Spatial Data Integrity and Validation for Urban Land and Property

Decision-making in land administration relies on a wide variety of legal objects, from 2D entities like land parcels to complex 3D objects for MOBs. To guarantee the quality of the results of the decisions, the diverse data associated with legal spatial objects must be trustworthy and contain the required detail (Thompson & Van Oosterom, 2012). This implies the need to develop 3D spatial data validation rules to ensure the spatial integrity of volumetric legal spaces in urban environments. Validation is the process of checking whether consistency, integrity, correctness and completeness of data can be guaranteed before the data is processed or entered into the system (Karki, Thompson, & McDougall, 2010). Despite the existence of a wide range of (2D) validation rules, the complete manual validation of 3D cadastral data is an almost impossible task (Drobež, Fras, Ferlan, & Lisec, 2017). Moreover, the current 2D validation rules are not fully capable of ensuring an unambiguous and definitive spatial and legal definition of 3D property parcels.

Research into the validation of 3D data has been concerned mainly with spatial aspects, such as six types of 3D validation for geometry (Karki et al., 2010), geometric validity axioms for LADM (Thompson & Van Oosterom, 2012), and a set of validation rules for the complete set of 3D geometric primitives (Kazar, Kothuri, Van Oosterom, & Ravada, 2008). This research has centred primarily on providing a general mathematical definition of validation checks for 3D objects. Although some fundamental concepts have been identified, synthesizing the research in line with a cadastral system is essential to ensure that 3D cadastral data can be guaranteed through a set of validation rules and a valid examination process.

3 Framework for 3D Digital Management of Urban Land and Property Information

Building a 3D digital data infrastructure for urban land and property information is achieved by applying a four-stage conceptual framework: modelling, federation, validation and analytics (see Figure 2).

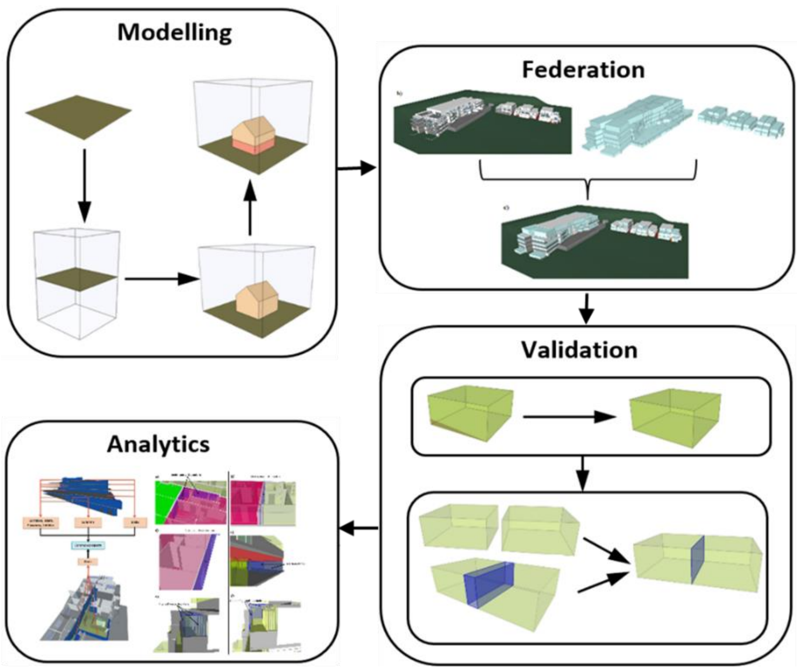


Figure 2: A conceptual framework for 3D urban land and property management

3.1 Modelling

Modelling urban land and property in a 3D digital environment requires different levels of detail for various parts of cities. The legal boundaries of land parcels (horizontal extent of ownership of land parcels) and their height and depth ownership extent (vertical extent of ownership of land parcels) are adequate in suburban areas where one land parcel belongs to one person. On the other hand, in city areas, a detailed model showing the complex ownership arrangements both indoors and outdoors of multi-owned properties is required. Three levels of complexity for urban land and properties are suggested: (1) land parcels without any built property; (2) land parcels with their height and depth extents; and (3) land parcels with individually owned under- and above-ground properties (see Figure 3). The individually owned properties located above ground and underground include single-owned properties as well as multi-owned properties. 3D models of land and property can be sourced from the standard data models referred to in section 2.2. Connecting two physical models, for buildings (IFC) and for a city as a whole (CityGML), provides highly detailed physical information about urban built environments (Zhu et al., 2009). As explained above, unless they are extended these physical models are unable to accommodate the legal ownership of private, communal and public properties within urban areas. Therefore, another innovative aspect of this project is to identify a good mechanism for extending these data models to incorporate the legal ownership information.

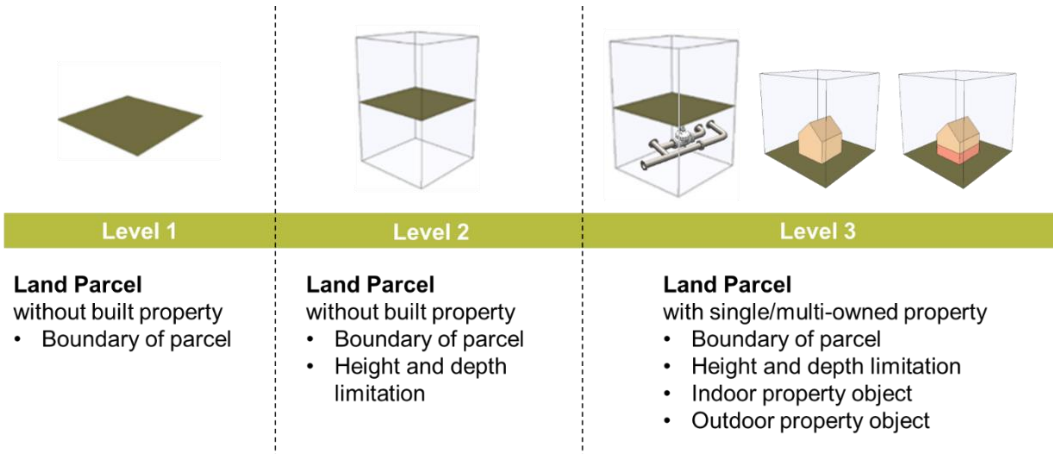


Figure 3: Three complexity levels of land and properties

As noted by Volk, Stengel and Schultmann (2014), physical aspects of the 3D model can be captured in two ways, as represented in Figure 4. For newly built properties, expanded physical models for the legal aspect are typically defined by 3D data authoring tools. The critical components in the management of legal information of multi-owned properties, such as type and location of legal boundaries, or spatial arrangements of legal interest, can be presented well in the IFC model (Atazadeh, Kalantari, Rajabifard, Ho, & Champion, 2017). In the case of existing urban properties, a reverse-engineering approach for generating 3D models needs to be adopted to create the as-built reality of the properties. This semi-automatic approach generates the 3D geometry of a property according to the points-to-BIM transformation process, which consists of data capture, data processing and BIM creation. Within the process, point clouds captured by laser scanners are coordinated and integrated as one. This integrated point cloud can then be used to guide the generation of geometry in BIM authoring tools. This corresponds to the expanded IFC data schema. During the BIM creation phase, the legal information for a property is defined and overlaid with physical elements (spaces and building elements) of the IFC model.

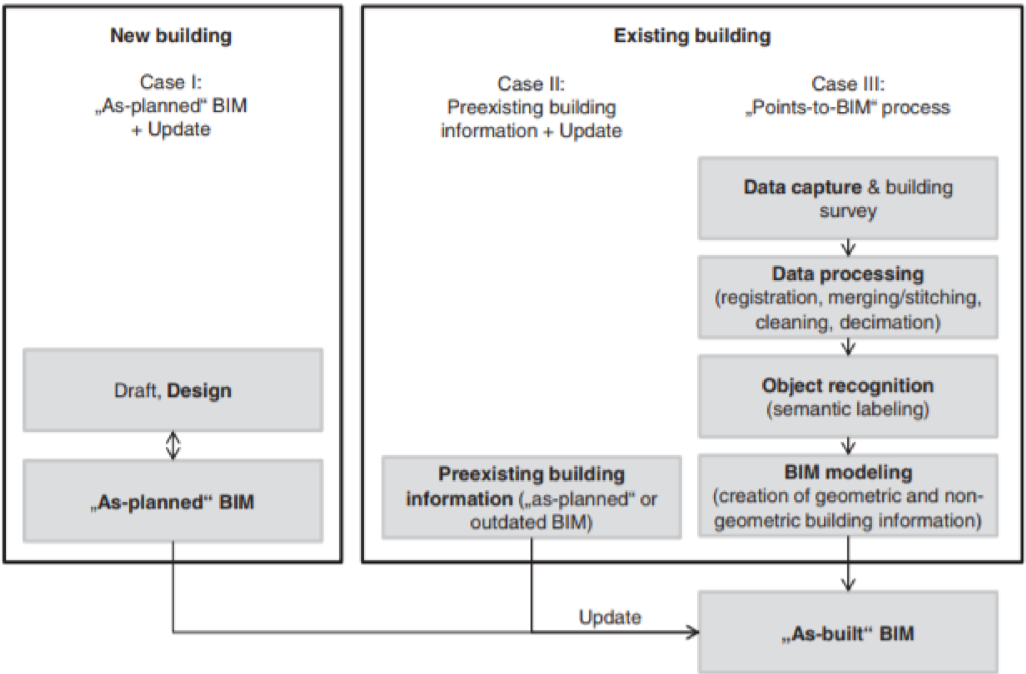


Figure 4: The BIM-centred process for generating a 3D physical model (adapted from Volk et al., 2014)

3.2 Federation

As discussed in section 3.1, not every part of a city needs the same level of detail in a 3D land and property model. In line with this, different mechanisms for federating 3D models are needed to combine the information at the appropriate level of detail. This research proposes the following four-stage process for 3D data federation: stage 1: legal space definition for all land parcels giving height and depth limits; stage 2: physical information and 3D legal spaces in multi-owned properties; stage 3: 3D outdoor legal spaces and 3D utility networks; stage 4: 3D digital visualization (see Figure 5).

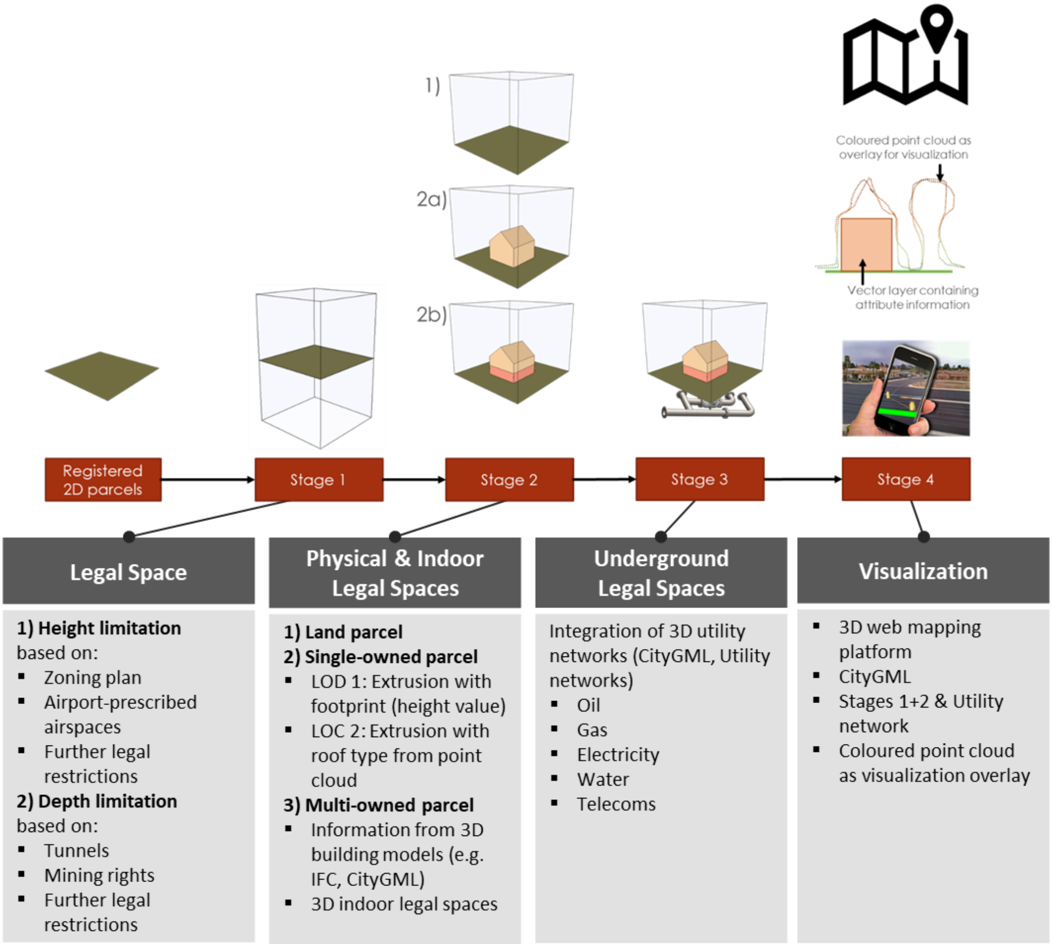


Figure 5: The suggested process for federating various 3D digital models

The federation of 3D digital models requires the integration of indoor and outdoor property objects. These comprise both physical elements and legal spaces. The physical components in the integrated model can be obtained from IFC and CityGML (Rajabifard et al., 2018). Physical elements inside buildings can be defined based on IFC, since this 3D digital model allows the modelling of architectural, structural and utility elements within buildings. CityGML entities can be used for modelling other urban structures, such as tunnels, bridges and roads. The legal elements of the federated model can be defined in the IFC model by extending its data structure. Finally, the federated 3D model is implemented in a platform-independent 3D digital environment to facilitate visual communication of complex arrangements of urban land and property.

3.3 Validation

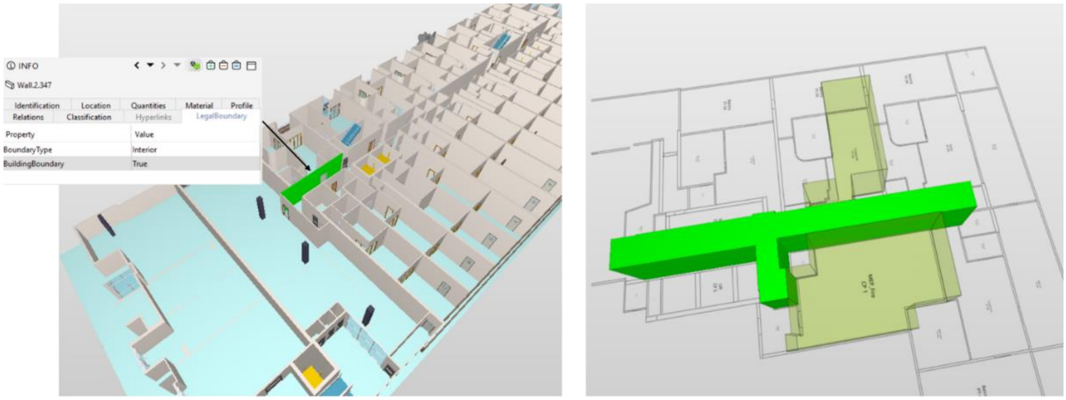
Trustworthy 3D data is fundamental for any decision related to land and property management. Therefore, 3D data for urban land and property should be validated in order to create meaningful 3D legal objects. In the jurisdiction area of Victoria, 128 validation rules (112 non-spatial and 18 spatial rules) were applied to evaluate the data quality of 2D-based ePlan models for the land registry system (Shojaei et al., 2017) (see Table 1). The non-spatial rules are essential to check textual administrative information. Among the spatial rules, geometric rules are used to examine depth and height boundaries of legal space (lot, common property and easement). In addition, spatial connectivity ensures the intrinsic connectivity within legal property objects, as well as extrinsic connectivity of one object with others. Intrinsic rules help to produce valid geometries of individual objects, while extrinsic rules ensure that there is no gap or overlap between any two objects across the whole urban area.

Table 1: Extract from 2D ePlan validation rules (adapted from Shojaei et al., 2017)

Semantic Rule		Geometrical Rule	
No.	Rule	No.	Rule
VR005	Easement Purpose Exists	VR063	Parcel Area
VR006	Owners Corporation Limitation Exists	VR069	Parcel Geometry Closure
VR008	Road Parcel Description Exists	VR072	Title Boundary Consistency
VR019	Title Reference	VR073	Title Connection
VR034	Depth Limitation Manual Check	VR074	Survey Marks Connection
VR047	Easement Benefit	VR084	Restriction Fixing
VR062	Existing Crown Parcels	VR106	Easement Width
VR104	Building Boundary Description	VR117	Overlapping Parcels

Like ePlan rules, the 2D validation rules based on the relevant legislation can be leveraged to develop 3D validation rules for land and property information. According to the specific land-administration purposes, a variety of 3D validation rules can be developed to examine the quality of 3D data for land and property. In this section, 2D ePlan validation rules, which are the typical checking-rules for the urban land and property information in practice, are used to exemplify the transformation to 3D rules.

The non-spatial rules for the ePlan model can be directly translated into checking-rules for the IFC model in order to examine its semantic information regarding legal ownership. However, spatial rules need to be revised based on the 3D volumetric shape of legal objects. Two ePlan rules, *VR104 – Building Boundary Description* and *VR117 – Overlapping Parcels*, serve as examples in this section to explain how validation rules examine the expanded IFC model of an MOB (see Figure 6). VR104 for examining whether each legal boundary within a building is described can be applied to IFC models. This rule checks the building boundary types of the building elements, representing the location of boundaries in an IFC model. In addition, VR063, which relates to checking whether parcels overlap, can be implemented for IFC models by checking whether the 3D extent of a legal space touches the surface of any other space.



(a) Validation of an IFC model on Rule VR104-Building Boundary Description

(b) Validation of an IFC model on Rule VR117-Overlapping Parcels

Figure 6: Application of ePlan validation rules to a 3D data model

3.4 Analytics

Informed decision-making regarding land and property management needs to draw on a broad analysis base in the architecture, urban planning and land administration domains. Currently, the generation of 3D analysis models with different levels and types of information for each of these areas is a time-consuming and error-prone manual process and a key barrier to conducting 3D data analytics. 3D data query potentially supports the automatic generation of an input data model for each analysis from one federated model, as represented in Figure 7. The federated model of indoor, outdoor, physical and legal data for land and property functions as a central repository of land and property information.

3D land and property analytics have new implications for decision-making in complex urban built environments (Rajabifard et al., 2018), enabling property information to be leveraged for new urban applications, such as estimating the density of occupancy in 3D indoor spaces. In addition, volumetric computation of urban land and legal property spaces will be possible for the valuation of individual properties within complex developments. Another 3D analytics capability will be performing a 3D buffer analysis to identify under- and above-ground properties affected by new urban development. Therefore, 3D spatial data analytics will add valuable knowledge for making decisions associated with the legal ownership of land and property in complex densified urban areas.

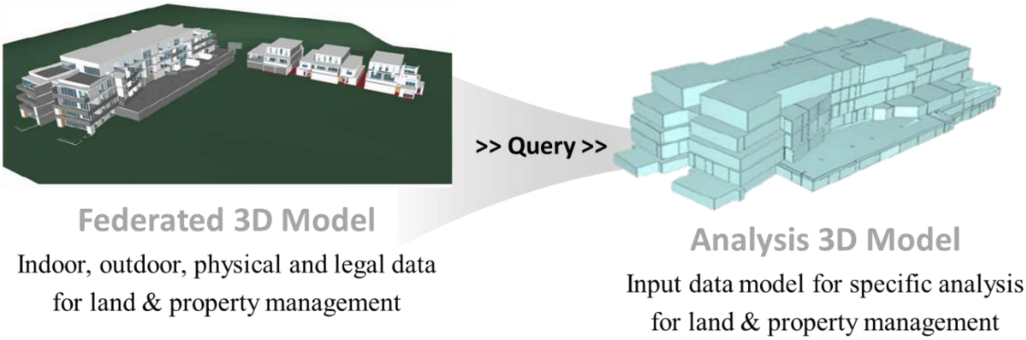


Figure 7: Automatic generation of a 3D input model from the federated 3D model for use in land and property management (adapted from (Atazadeh, Rajabifard, et al., 2017)

4 Application of the Proposed Framework to Case Study

In this section, the practicality of the suggested conceptual framework is discussed in relation to a particular scenario – examination of ownership allocation within an MOB. A crucial practice in land administration, unreasonable partitioning of legal ownership extent in MOBs has generated increasing numbers of disputes over the use and management of properties (Shin, Rajabifard, Kalantari, & Atazadeh, 2019). The framework is applied to a case study building, a 24-storey MOB located in Melbourne. Autodesk Revit 2016 was utilised to generate an IFC model of the property. The federation, validation and analytics were conducted using Solibri Model Checker (SMC), an IFC rules-based model-checking tool.

Firstly, the IFC data structure was extended to accommodate the legal aspect of the MOB described in the plan of subdivision. The five building structures (wall, floor, ceiling, window and door), which are referred to as building boundaries in subdivision plans, are matched to sub-entities of 'IfcBuildingElement' (see Figure 8). To accommodate additional information regarding legal information, the data schema for each entity is extended using IfcPropertySet. In this extended data structure, IFC entities representing the five building structures used as building boundaries include two further attributes (BuildingBoundary and BoundaryType) as attributes newly defined by users.

Based on the IFC extension, the physical aspect (arrangement of building elements with boundary-type information) and legal aspect (layout of legal spaces and location of building boundaries) of the two storeys of the MOB are generated in Revit and exported individually as IFC data.

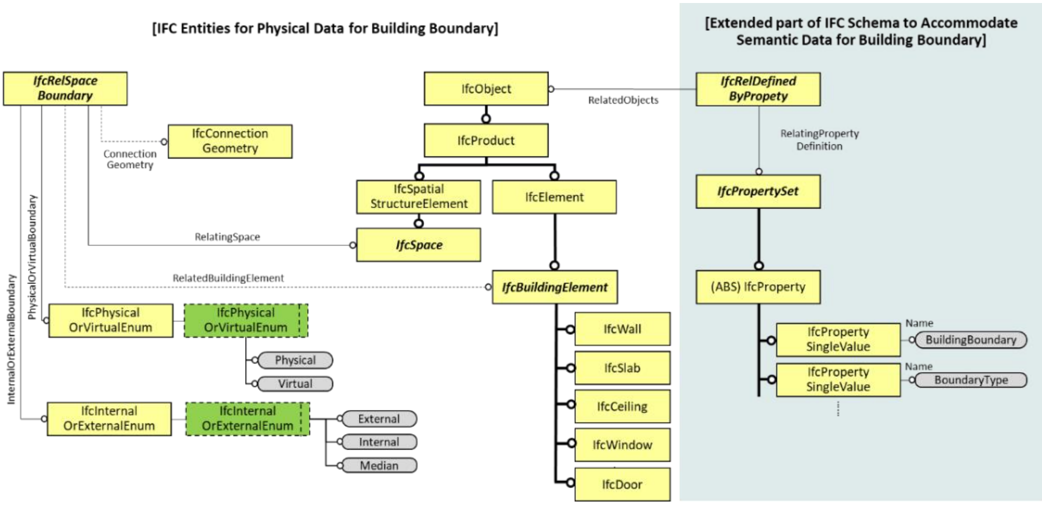


Figure 8: The Extended Part of the IFC Data Structure, allowing the Legal Information for the Scenario – Examination of Ownership Allocation within an MOB – to be accommodated

Using SMC, the two IFC models are federated into one. Figure 9 illustrates part of the federated IFC model – a green-coloured legal space representing a corridor (a part of common property) overlapped with building elements, including a boundary wall, which has two extended properties (i.e. BuildingBoundary and BoundaryType). The following ePlan validation rules that should be checked before analytics for the scenario were translated into an SMC rule-set: *VR072 – Title Boundary Consistency, VR100 – Building Boundary Annotation* and *VR104 – Building Boundary Description*. Using the template rule 'Property Rule Template with Component Filters Rule', three SMC rules to check the semantic information related to ePlan rules were defined. In the SMC rule for VR104, for instance, a building boundary description is examined by checking the 'BoundaryType' properties for five types of building boundary structure that have a 'True' 'BuildingBoundary' property (see Figure 9).

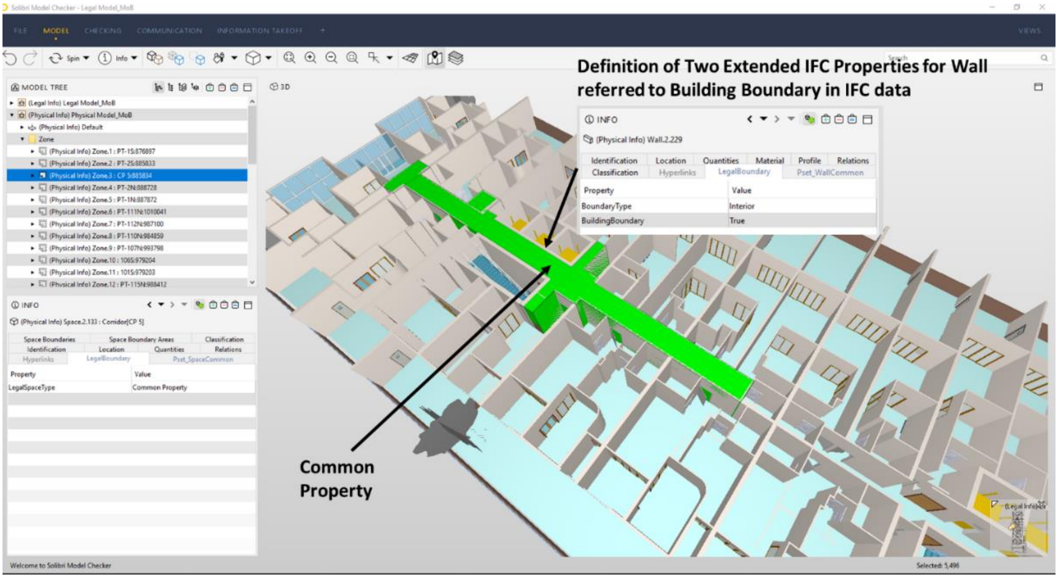


Figure 9: The Two Federated IFC Models of the Case Study MOB (Physical and Legal IFC models).

In building subdivision practice, two principles for good ownership allocation are (1) defining 'median' building boundaries between two lots, and (2) defining 'interior' building boundaries between lot and common property. For VR072, the consistency of the ownership partitioning can be analysed according to the same principles as those which can be translated into the SMC rules. In the same manner as for validation, the template rule 'Comparison Between Property Values' was used to translate two principles into SMC rules (see Figure 10). For example, the compliance of an IFC model with principle (2) is determined by filtering the building elements for interior 'BoundaryType' and checking that these components touch the surface of two spaces defined as lot and common property. Within SMC, the data query for analytics was well executed by setting the data filter, and the analytics for the scenario was conducted successfully using two rules. As illustrated in Figure 11, the results showed that the tested IFC model was compliant with the two principles.

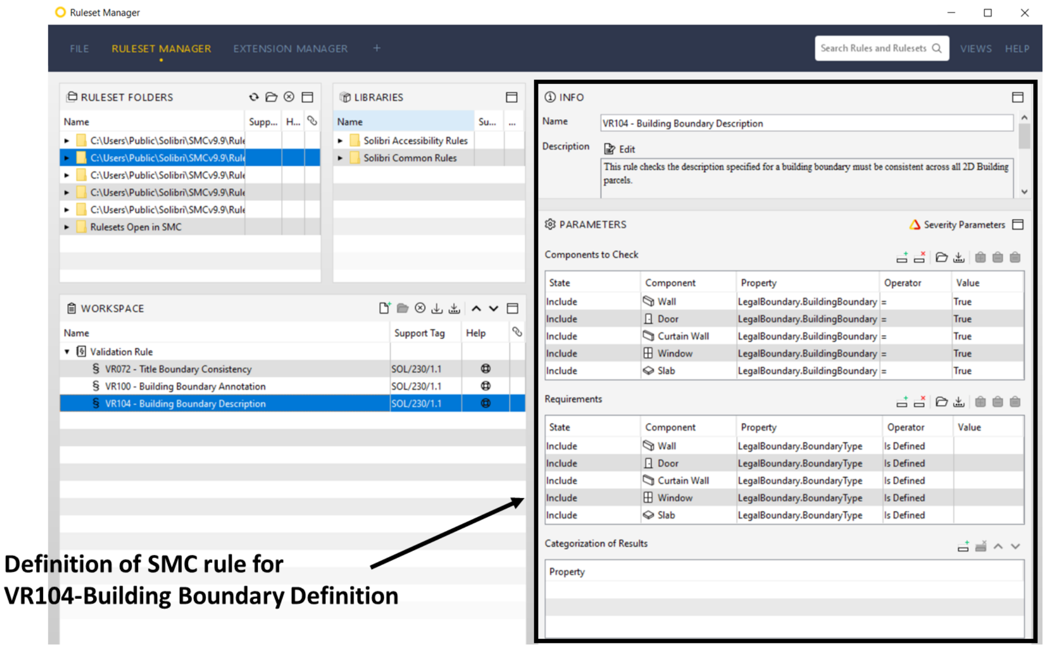


Figure 10: The Defined SMC Rule for ePlan Validation – *VR104-Building Boundary Definition*

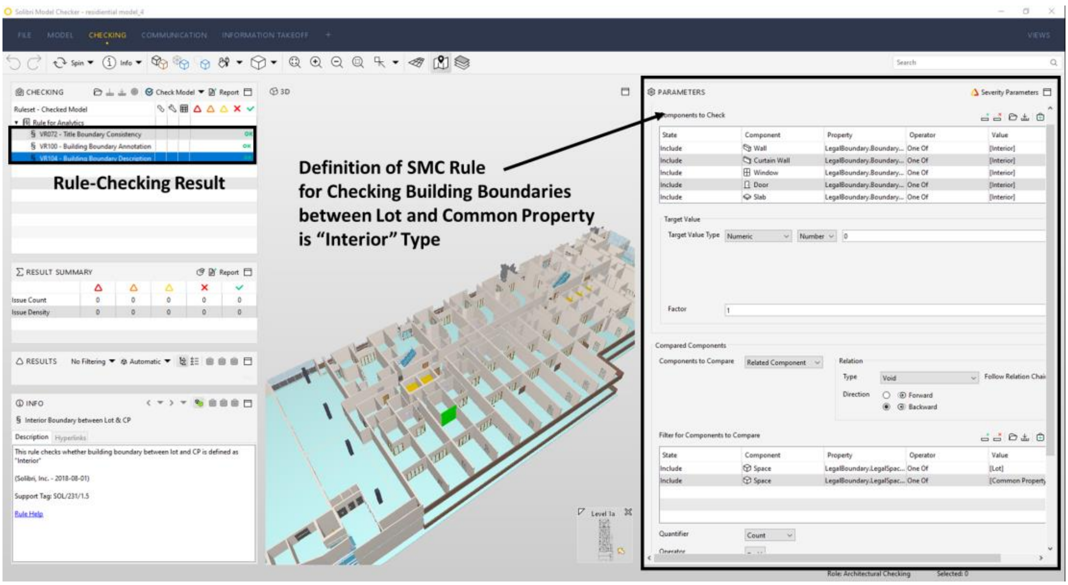


Figure 11: The Result of Validating the IFC Model based on Three SMC Rules – VR072, VR100 and VR104

5 Discussion

Current 2D-based practice in land administration is based on the fragmented approach for recording, sharing and using information on urban land and property. This results in challenges for effective decision-making related to management and operation of urban environments. Moving towards a 3D-based approach, this paper has suggested a conceptual framework for 3D digital management of land and property information in urban areas. In this framework, information required for specific analyses in planning and managing cities can be acquired from the federated 3D digital data models for land and property information. The federated model has high integrity, achieved through validation using spatial queries. As a basis for informed decision-making, the framework can facilitate the visual communication of the full extent of legal and physical indoor and outdoor properties to various stakeholders (e.g., owners, city councils, utility companies and land registries).

In the case study, two IFC models for physical and legal aspects of an MOB were created and federated into a single model. In addition, validation and analysis of the integrated IFC model for ownership allocation within an MOB were executed based on the 3D data validation rules, IFC data query, and analysis methods in SMC. The case study shows the potential of the framework presented here to support decision-making in land administration by supporting the creation, exchange, utilization and management of urban land and property information systematically. Our results show that adopting IFC, an international open standard, provides high interoperability throughout the whole framework, from modelling to analytics.

The framework focuses mainly on the state of Victoria, especially in the modelling and validation parts. However, by adjusting it to take account of specific features of land administration, the framework can be applied to other jurisdictions to support the management of land and property information in other urban areas. For example, the IFC schema could be extended to include the required information for legal title systems by country. In addition, 3D data validation rules should respond to the land registry service of a country. The implementation of the framework needs to take national legislation into consideration in order to achieve cross-national collaboration and spatial information interoperability at federal, state and local government levels.

From a technical perspective, this framework shows limitations in its practical implementation. Firstly, the extension or the integration of 3D data schemas needs to be discussed in order to accommodate the physical, legal, indoor and outdoor information of land and property required for analysis purposes in specific jurisdictions. In addition, generic and jurisdiction-specific validation rules for 3D information of land and property should be established. The rule management system needs to be flexible enough to perform the validation rule-checking for a variety of analytical purposes. Lastly, an open platform based on open standards for 3D data models needs to be developed to support the federation, validation and analytics of the framework. The validation management system should be connected to this platform. Future work will focus on the limitations of this research as outlined here.

6 Conclusion

Land and property information associated with the legal ownership of properties in urban built environments cannot currently be captured appropriately and utilized as a source of knowledge to support land and property decision-making at government, business and community levels. The development of a 3D spatial data framework has high potential to alleviate the traditional fragmented communication and management of the legal extent of urban land and property. However, this movement towards a 3D data environment reveals the lack of a comprehensive, holistic approach, and a limited knowledge base to establish a 3D digital data infrastructure for modernizing land and property practices. Here, we have proposed a 3D spatial data framework, explored its main components, and highlighted its potential for creating better and more effective urban planning and management. A 3D digital land and property infrastructure will support collaboration and coordination in sustainable urban development and reduce costs associated with data duplication, potentially saving millions of dollars per annum.

References

Acil Allen Consulting. (2017). *3D QLD Road Map Preliminary Findings – Interim Report Addressing Part A*.

Atazadeh, B., Kalantari, M., Rajabifard, A., Ho, S., & Champion, T. (2017). Extending a BIM-based data model to support 3D digital management of complex ownership spaces. *International Journal of Geographical Information Science*, *31*(3), 499–522.

Atazadeh, B., Rajabifard, A., & Kalantari, M. (2017). Assessing performance of three BIM-based views of buildings for communication and management of vertically stratified legal interests. *ISPRS International Journal of Geo-Information*, *6*(7), 198.

Atazadeh, B., Rajabifard, A., Kalantari, M., & Shin, J. (2018). A BIM-Driven Approach to Managing Common Properties within MultiOwned Developments. In *6th International FIG 3D Cadastre Workshop 2-4 October 2018, Delft, The Netherlands*.

Drobež, P., Fras, M. K., Ferlan, M., & Lisec, A. (2017). Transition from 2D to 3D real property cadastre: The case of the Slovenian cadastre. *Computers, Environment and Urban Systems*, *62*, 125–135.

Ho, S., Rajabifard, A., & Kalantari, M. (2015). Invisible'constraints on 3D innovation in land administration: A case study on the city of Melbourne. *Land Use Policy*, *42*, 412–425.

Karki, S., Thompson, R., & McDougall, K. (2010). Data validation in 3D cadastre. In *Developments in 3D geo-information sciences* (pp. 92–122). Springer.

Kazar, M., Kothuri, R., Van Oosterom, P., & Ravada, S. (2008). On valid and invalid three-dimensional geometries. In *Advances in 3D geoinformation systems* (pp. 19–46). Springer.

Rajabifard, A., Atazadeh, B., & Kalantari, M. (2018). A critical evaluation of 3D spatial information models for managing legal arrangements of multi-owned developments in Victoria, Australia. *International Journal of Geographical Information Science*, *32*(10), 2098–2122.

Rajabifard, A., Williamson, I., Marwick, B., Kalantari, M., Ho, S., Shojaei, D., Atazadeh, B., Amirebrahimi, S., & Jamshidi, A. (2014). 3D-cadastre, a multifaceted challenge. In *FIG Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014* (pp. 1-17).

Rönsdorff, C., Wilson, D., & Stoter, J. E. (2014). Integration of land administration domain model with CityGML for 3D Cadastre. In *Proceedings 4th International FIG Workshop on 3D Cadastres, 9-11 November 2014, Dubai, United Arab Emirates* (pp. 313-322).

Shin, J., Rajabifard, A., Kalantari, M., & Atazadeh, B. (2019). BIM-based Approach for Preaction Resolution of Disputes over Common Property Management in Multi-owned Developments. In *International Congress and Conferences on Computational Design and Engineering* (pp. 330–337).

Shojaei, D., Olfat, H., Faundez, Q., Kalantari, M., Rajabifard, A., & Briffa, M. (2017). Geometrical data validation in 3D digital cadastre − A case study for Victoria, Australia. *Land Use Policy*, *68*, 638–648.

Stoter, J., Vosselman, G., Goos, J., Zlatanova, S., Verbree, E., Klooster, R., & Reuvers, M. (2011). Towards a national 3D spatial data infrastructure: case of the Netherlands. *Photogrammetrie-Fernerkundung-Geoinformation*, *2011*(6), 405–420.

Thompson, J., & Van Oosterom, M. (2012). Validity of mixed 2D and 3D cadastral parcels in the land administration domain model. In *3rd International FIG Workshop on 3D Cadastres: Developments and practices, Shenzhen, China, 25-26 October 2012* (pp. 325-344).

Tsiliakou, E., Labropoulos, T., & Dimopoulou, E. (2013). Transforming 2D cadastral data into a dynamic smart 3D model. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences(ISPRS) 8th 3D GeoInfo conference and WG II/2 workshop, Istanbul, Turkey, 27 – 29 November 2013* (pp. 105-111).

Volk, R., Stengel, J., & Schultmann, F. (2014). Building Information Modeling (BIM) for existing buildings – Literature review and future needs. *Automation in Construction*, *38*, 109–127.

Zhu, Q., Hu, M., Zhang, Y., & Du, Z. (2009). Research and practice in three-dimensional city modeling. *Geo-Spatial Information Science*, *12*(1), 18–24.

GI_Forum 2019, Issue 2
Page: 98 - 112
Full Paper
Corresponding Author:
metemu@itu.edu.tr
DOI: 10.1553/giscience2019_02_s98

Creation of Nominal Asset Value-Based Maps using GIS: A Case Study of Istanbul Beyoglu and Gaziosmanpasa Districts

Muhammed Oguzhan Mete and Tahsin Yomralioglu
İstanbul Technical University, Turkey

Abstract

Estimating the value of real estate has applications in fields as diverse as taxation, buying and renting properties, expropriation and urban regeneration. Determining the most objective, accurate and acceptable value for real estate by considering spatial criteria is therefore important. One stochastic method used to determine real estate values is 'nominal valuation'. In this approach, criteria that may affect land value are subjected to various spatial analyses, and pixel-based value maps can be produced using GIS. Land value maps are in raster data format and need to be compared with the actual market values. Pixel-resolution analyses are required that depend on the selected grid dimensions. First of all, nominal value maps were produced using a nominal valuation model, using criteria for proximity, visibility and terrain. These were weighted in order to produce a nominal asset value-based map according to the 'Best Worst Method'. Changes in the unit land values were examined for maps at various resolutions; a resolution of 10 metres emerged as the ideal pixel size for valuation maps.

Keywords:

GIS, real estate valuation, land valuation, nominal valuation

1 Introduction

Owning a property is important to humans in terms of financial security because real estate has a value. In order to calculate property values, parametric land values of the real estate are determined by using nominal valuation. This method provides mass valuation of real estate according to the properties' spatial characteristics. The sub-unit can be cadastral parcels or the cells (pixels, grids) used to divide the study area to determine the value. It is possible to produce a pixel-based land value map using GIS techniques (Yomralioglu, 1993; Nisanci, 2005). Pagourtzi, Assimakopoulos, Hatzichristos and French (2003) reviewed real estate valuation methods, including spatial analysis ones. Yomralioglu and Nisanci (2004) suggested a nominal valuation method based on spatial factors of real estate which can be analysed using GIS software. Pagourtzi, Nikolopoulos and Assimakopoulos (2006) proposed GIS-based real estate valuation using fuzzy theory and spatial analysis. Yomralioglu, Nisanci and Yildirim (2007) applied a nominal valuation method in land readjustment applications for planning purposes. Liu, Zhe and Wang (2011) proposed a real estate appraisal system based on GIS and a back propagation neural network. Bostancı, Demir, and Karaağaç (2015) created a nominal value map using the Fuzzy Analytic Hierarchy Process (AHP) and Multi-Criteria Decision Making (MCDM) to calculate weight factors. Demetriou (2016) suggested a land valuation framework for land consolidation processes using Multiple Regression Analysis (MRA) and Geographically Weighted Regression (GWR) within GIS. Bencure, Tripathi, Miyazaki, Ninsawat and Kim (2019) developed a land valuation model for mass appraisal applications using AHP in GIS.

Determining the criteria that may affect real estate value is the most important step in the valuation process. The effects of the factors can vary in terms of influence level. In order to reflect the varying influence of each criterion on the value, weight coefficients were determined using the 'Best Worst Method', a Multi-Criteria Decision-Making (MCDM) method.

The aims of this study were to create a dynamic real estate valuation model and to produce nominal value maps using GIS. The resolution of raster-based value maps should be defined in the model as a parameter, and overlay analysis should be used to calculate the land value of the parcels. Before calculating the parcel values, the Modifiable Areal Unit Problem (MAUP) needs to be dealt with in order to estimate appropriate scales of aggregation. In this context, maps with different pixel sizes are produced and the effect of the resolution on the values is examined to decide the ideal pixel size.

Subjectivity is a major problem in valuing real estate (Demetriou, 2016). Since the valuation process is based on the experience and judgement of appraisers, inflated values may arise in the market (Pagourtzi et al., 2003): human beings do not concentrate on scientific parameters that affect the value of a property. However, scientific and mathematical approaches are gaining importance, with the use of information systems and statistics in real estate valuation processes. In this GIS-based study, nominal values are generated as a result of proximity, terrain and visibility analyses for the creation of a land value map. Property-owners or buyers will know or want to know, for example, whether the property has an appealing view (Visibility criterion) or is on flat terrain (Terrain criterion), and how far amenities such as public transport or shopping centres are from the property (Proximity criterion).

2 Nominal Valuation

There are various methods for real estate valuation appropriate for different objectives and needs. Most are based on the market value. Classical methods include sales and market comparisons, the income capitalization method, and the replacement cost method. In addition to these there are stochastic methods based on statistical approaches. One such method is nominal valuation, which provides calculated parametric scores of weighted criteria which affect real estate values (Yomralioglu et al., 2007). This method does not require the market value and provides a distribution of land values as parametric quantities by using scientific approaches (Mete, 2019). Furthermore, using this method (as presented in Yomralioglu, 1993), it is possible easily to convert nominal coefficients into market price. In the present study, the method is used to create pixel-based nominal land value maps in order to achieve standardization in the real estate market, avoiding overpricing due to subjective judgements, inadequate knowledge and lack of data. However, criteria that affect property values vary and change constantly, based on location. In the method presented here, coefficients are calculated by determining the minimum and maximum values for the criteria in order to express the values of properties relative to each other.

3 The Nominal Asset value-based approach

3.1 Methodology

In order to calculate land values, all the criteria that affect the land value, and their relative weights, should be determined. With the help of GIS, it is possible to identify each criterion's effects on real estate values, and the total nominal land value can be expressed using the following formula:

$$V_i = S_i * \sum_{j=1}^{k} (f_{ji} * w_j) \tag{1}$$

where,

***V**: Total nominal value,*
***S**: Parcel or pixel area,*
***f**: Criterion value,*
***w:** Criterion weight,*
***k**: Total number of factors.*

In the context of this study, pixel-based land value maps with resolutions of 1, 10, 50 and 100 metres were produced. As raster data format provides some advantages over vector format for storing and presenting huge datasets, nominal land value maps were created in raster format. Pixel values that indicate nominal values can be added as an attribute in vector-based parcel data using basic GIS operations

3.2 Determination of criteria and weights

In order to produce a nominal value map, we identified 23 criteria affecting land values. These criteria were categorized into three main groups: proximity, visibility and terrain aspects. In order to determine the weight coefficients of each criterion, the Best Worst Method was used: by comparing, pair-wise, each criterion with all the others, the decision-maker's preferences lead to the identification of both the best criterion and the worst in comparison to the others, and weights can be determined (Rezaei, 2016).

A Likert scale of 1 to 9 is used in the comparisons between the criteria to determine the levels of preference. The decision-making process according to this method can be summarized as follows.

1. A set of decision-making criteria is determined. In the case of a house purchase, for example, the criteria may be classed as physical, spatial, legal or economic.

2. The best and the worst of these criteria are identified.

3. The degree to which the best criterion is preferred over the other criteria is determined. Using a scale of 1 to 9, 1 point is given to a criterion with equal importance to the best criterion, and 9 points are given if the best criterion is more important than the other criterion.

4. The pair-wise comparisons are completed by determining the degree of preference of the worst criterion according to other criteria. (In this, we followed a survey by Nisanci (2005) regarding criteria and weights.)

3.3 Choice of best and worst criteria

The metro is the most comfortable form of rail transport within İstanbul, and 16% of all public transport journeys in the city are by metro (İETT, 2018). Consequently, for this study proximity to a metro station was chosen as the best criterion. Proximity to a police station was chosen as the worst, and the two criteria were compared to other criteria to calculate the weights. The weights and consistency ratio (ξ^L) are calculated using the following equation (Rezai, 2016):

$$\begin{aligned}
&\min \xi^L \text{ such that} \\
&\left|w_B - a_{Bj} w_j\right| \le \xi^L, \text{ for all j} \\
&\left|w_j - a_{jW} w_W\right| \le \xi^L, \text{ for all j} \\
&\sum_j w_j = 1 \\
&w_j \ge 0, \text{ for all j}
\end{aligned} \tag{2}$$

where,

a_{Bj} : *preference for the best criterion over criterion j*

a_{jW} : *preference for criterion j over the worst criterion.*

The consistency ratio in decision making can be between 0 (complete consistency) and 1 (very inconsistent). For high consistency, the value is expected to be ≤ 0.25 (Rezai, 2016). The consistency ratio for the 23 criteria was calculated as 0.024, and was thus very high.

The criteria determined for the nominal real estate valuation model and their weights are shown in Table 1.

Table 1: Criteria Affecting Real Estate Values and Weight Coefficients

Criterion	Weights	Criterion	Weights
Proximity to Main Road	0.04440	Proximity to Educational Institutions	0.02664
Proximity to Highway Junctions	0.03330	Proximity to Universities	0.03330
Accessibility to Street	0.06660	Proximity to Health Institutions	0.02664
Proximity to Railways	0.10942	Proximity to Hospitals	0.03330
Proximity to rapid-transit bus (BRT) Stations	0.10942	Proximity to Fire Station	0.00951
Proximity to Bus Stations	0.04440	Proximity to Police Station	0.00951
Proximity to Quays	0.02664	Proximity to Parking Lots	0.03330
Proximity to Shopping Centres	0.03330	Proximity to Historical Places	0.03330
Proximity to Green Spaces	0.02664	Proximity to Hazardous Areas	0.02664
Proximity to City Centre	0.04440	Sea View	0.06660
Bosphorus View	0.10942	Slope	0.02664
Aspect	0.02664		

3.4 Modelling and analysing using GIS

To produce nominal land value maps from the proximity, visibility and terrain analyses that are included in the model, the weighted sum tool is used. The process of creating a nominal asset value-based map from raster data is shown in Figure 1.

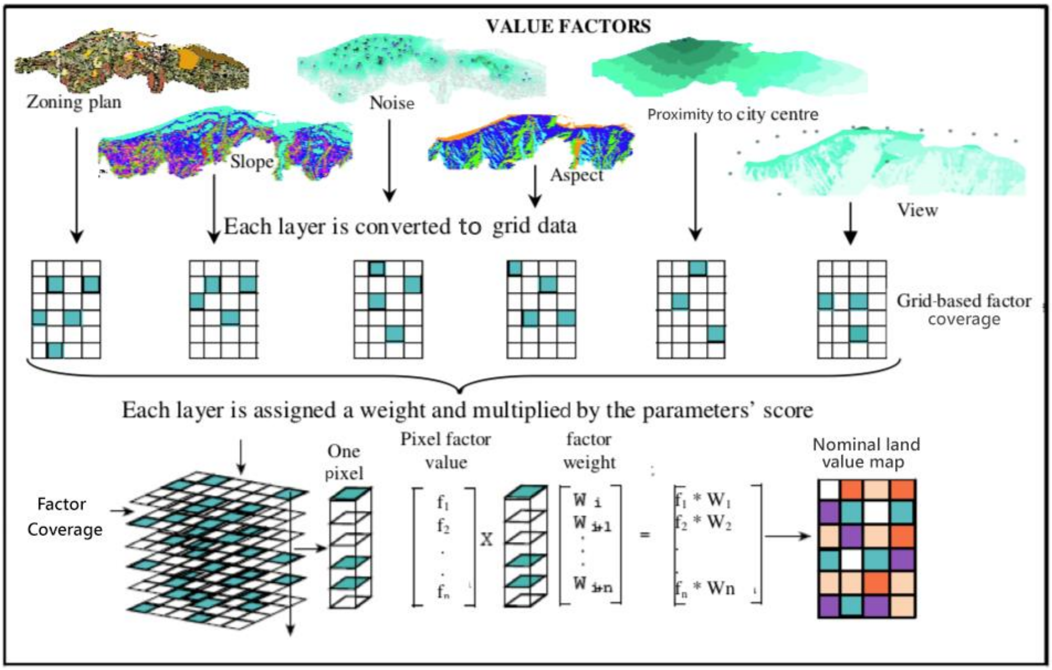


Figure 1: Process of creating nominal asset value-based map (Yomralioglu et al., 2007)

The Euclidean Distance tool is used in the proximity analysis sub-model. The values of the raster maps are generated from the proximity analyses, rated from 0 to 100 using the 'reclassify' tool according to the walking or driving distances. For example, railway stations which can be reached by walking 0–100 metres are given the value 100; distances between 100 and 250 metres are rated 90.

On the other hand, main roads which can be accessed by driving 0 to 1 kilometre are given the value 100; distances between 1 and 2 kilometres are rated 80. The maximum distance that can affect the land value is 5 kilometres for proximity to the main roads, since distances of more than 5 kilometres are not considered reasonable access in the real estate valuation process (Mete, 2019).

It is mandatory for zoning parcels to have access to roads. However, there may in practice be some cadastral parcels that do not satisfy this requirement. To evaluate this, access from the parcel to the road network is analysed using GIS software which checks whether any segment of the parcel's boundaries coincides with a road. If the condition is satisfied, relevant parcels are rated 100; otherwise, they score 0.

Slope and aspect analyses are conducted in the terrain sub-model. For height data, ALOS World 3D Digital Surface Model (DSM) produced by the Japan Aerospace Research Agency (JAXA) was used. ALOS has 30-metre spatial resolution. In the slope analysis, the effect of 0 to 1% slope on the value is classified as 100; a slope of more than 12% results in a classification of 0. In the aspect analysis, south-facing slopes are given a value of 100. For this purpose, the values between 135° and 225° (i.e. facing southeast, east or southwest) are classified as 100 and the remaining values as 0. The visibility sub-model identifies places which have a view of an island, the Bosphorus or the sea. Vector data of the sea, the Bosphorus and islands are created and visibility analysis is performed. Areas which have a clear view are given a value of 100; places that have no view score 0. Figure 2 shows the nominal land valuation model.

Figure 2: Nominal Land Valuation Model

Some criteria have a negative effect on the land value, like steep slope or proximity to hazardous areas. To ensure that such negative effects are reflected accurately in the land's value, the pixel values of those criteria are inversed in a reclassification phase. For instance, places which are next to hazardous areas are given a value of 100 in this analysis. After reclassification in the output raster, values of 100 are inversed – as having a nominal land value, in the relevant analysis, of 0.

4 Case Study

4.1 Description of study areas: Beyoğlu and Gaziosmanpaşa Districts, Istanbul

Istanbul is the most densely populated city in Turkey. The city's Beyoğlu and Gaziosmanpaşa districts were selected as study areas for the creation of a nominal asset-based land value map, as shown in Figure 3. According to the 'Address Based Census Registration System' (Turkish

Statistical Institute (TUIK)), in 2019 the populations of Beyoğlu and Gaziosmanpaşa were 230,526 and 487,046 respectively. Beyoğlu covers 8.96 km² and Gaziosmanpaşa 11.67 km². Both districts are densely populated and located close to the city centre. These districts have recently become desirable places to live due to urban regeneration projects, and real estate transactions here have increased significantly. Consequently, land values in the areas have also changed. For these reasons, we aimed to create nominal asset-based land value maps for the two districts in order to compare the nominal values of various locations that have different characteristics.

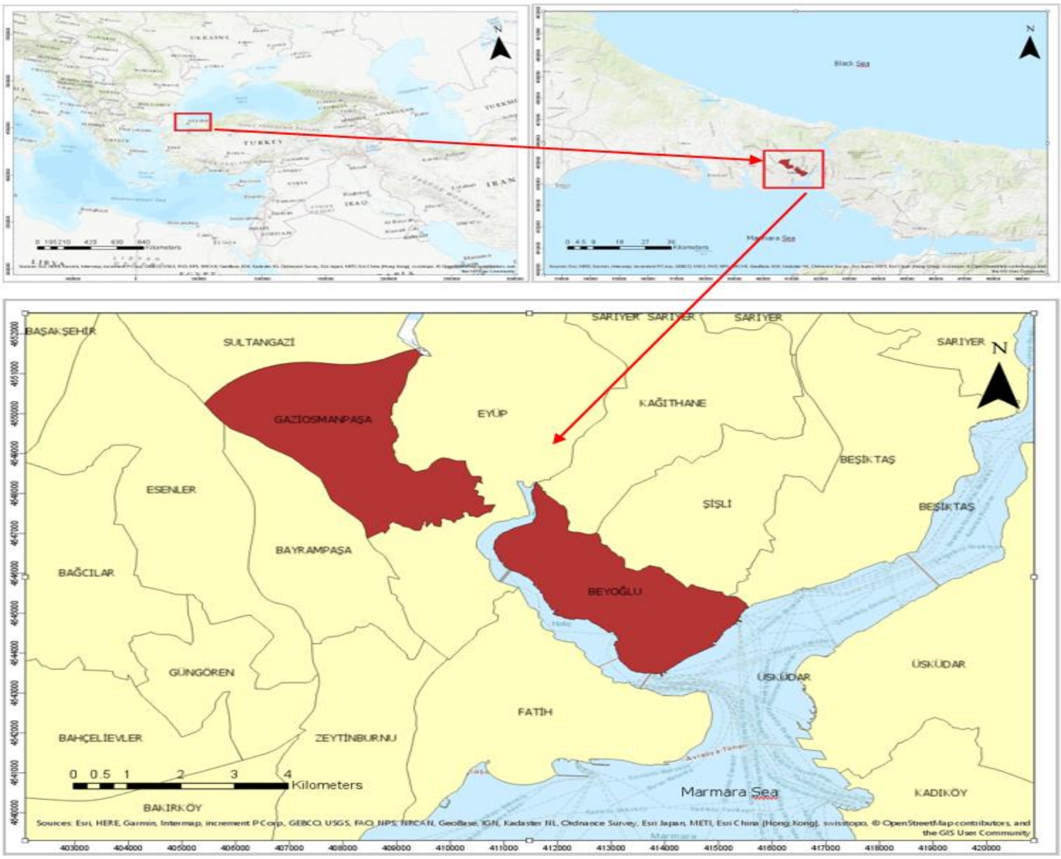


Figure 3: Study Areas: Beyoğlu and Gaziosmanpaşa Districts of Istanbul, Turkey

4.2 Production of nominal land value maps

To produce a land value map using the nominal valuation model, the pixel size must be defined as a model parameter. The nominal land value maps of Beyoğlu and Gaziosmanpaşa districts were produced separately, at 1-, 10-, 50- and 100-metre resolutions. Examining the effect of the resolution on the land values determined the best pixel size to be used (Figure 4).

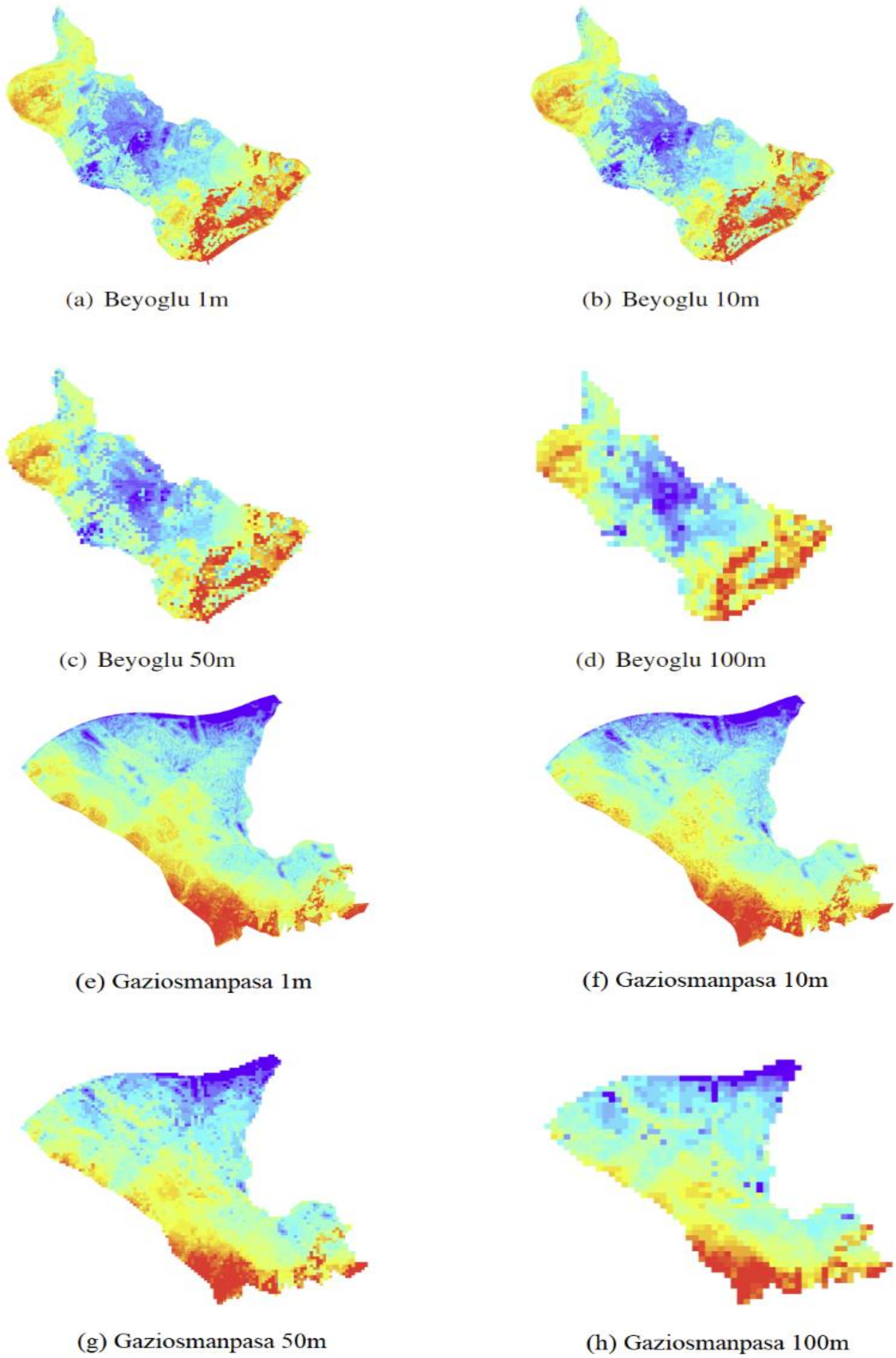


Figure 4: Land Value Maps of Two Districts using Different Pixel Sizes. Values range from dark blue (lowest) to red (highest).

In Beyoğlu, the highest land values are seen in the eastern strip of İstiklal Street, one of the city's most famous streets, and the Marmara Sea in the south. Places with high nominal value are distributed along the shoreline of the Golden Horn and the Sea of Marmara (Figure 5).

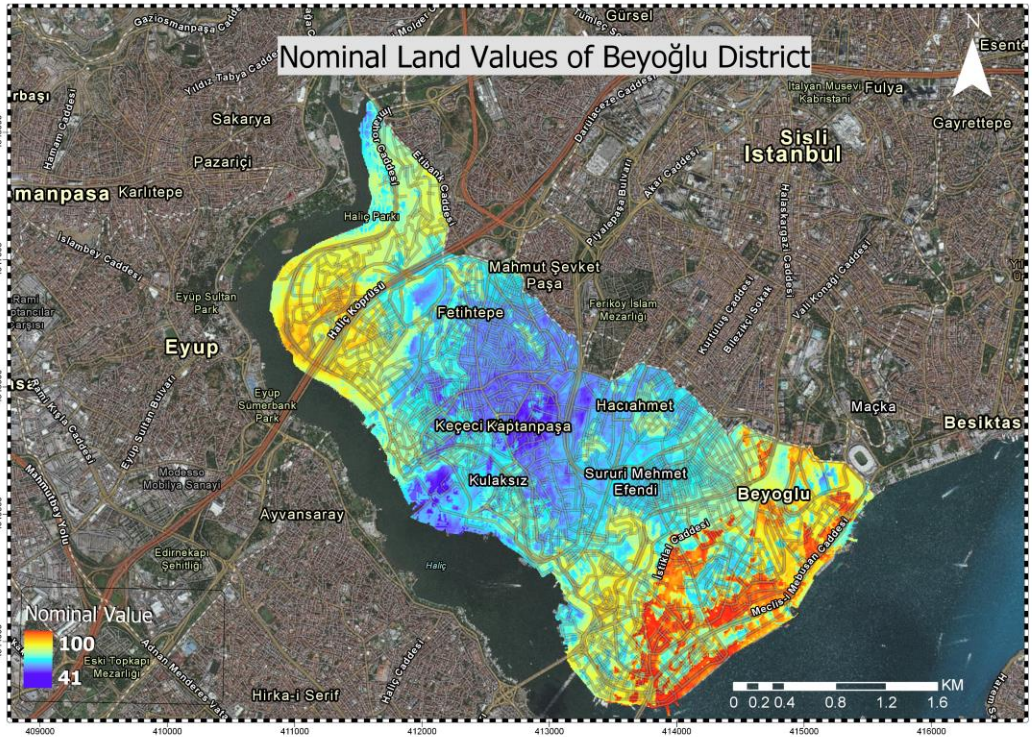


Figure 5: Nominal Land Value Map of Istanbul Beyoğlu District

Regions with higher nominal values in Gaziosmanpaşa centre on the Merkez Neighbourhood, and on the borders with Bayrampaşa and Eyüpsultan districts to the south. There are many public buildings in Merkez, such as the District Office, Asya Hospital and Duygu Hospital, and public gardens; the neighbourhood has good access to highways (1.5 to 2 kilometres away) (Figure 6).

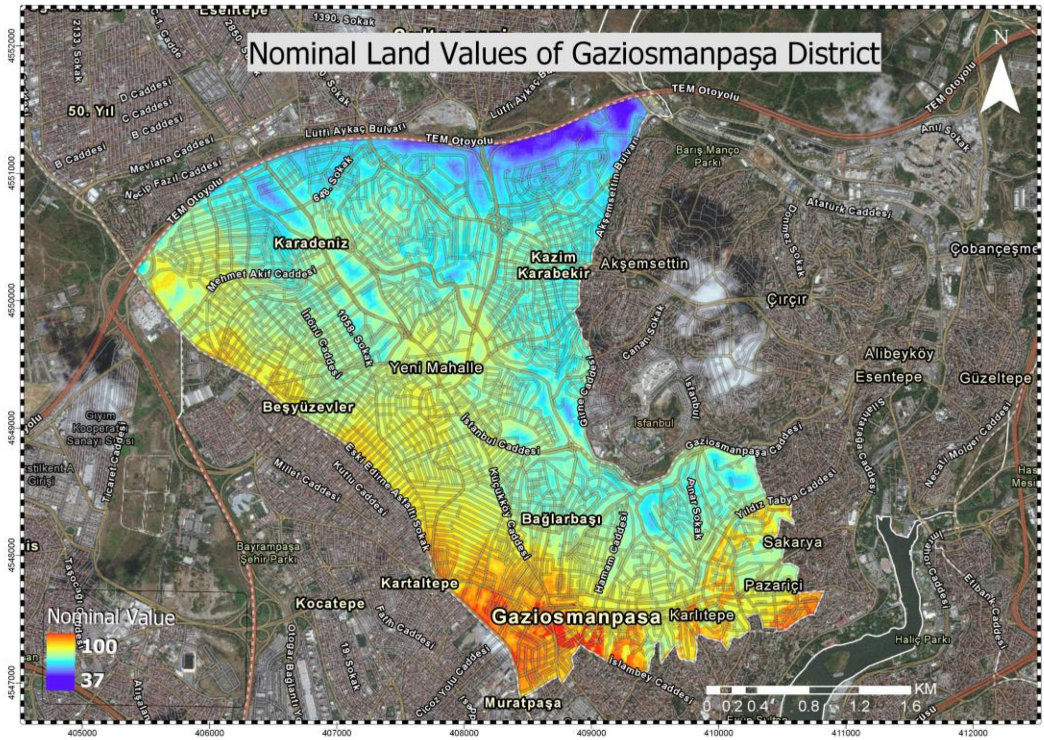


Figure 6: Nominal Land Value Map of Istanbul's Gaziosmanpaşa District

4.3 Examination of the effects of resolution differences on the nominal values

After creating nominal land value maps of Beyoğlu and Gaziosmanpaşa at resolutions of 1, 10, 50 and 100 metres, parcel values were added as an attribute in the parcel layers to examine the effect of the resolution changes. The pixel-based nominal land value maps were then converted to vector format, and vector pixel grids containing the nominal values were created. The generated vector-based nominal value layer is intersected with the parcel layer by using overlay analysis. The total nominal value of each parcel is obtained by multiplying the values of the respective pixels and the areas of the intersections.

Finally, all the nominal values within the parcels were added as an attribute in the parcel layer by performing a spatial join between the intersection vector and the parcel layer, so that all polygons which intersect with the nominal value pixels are included in the calculation.

A vectorized pixel that intersects with a parcel affects the nominal value in proportion to the area of the intersection. For example, if only half of a pixel falls inside a parcel boundary, the nominal value of the parcel will be affected by half of this pixel area.

After the same operation has been carried out for maps with different resolutions, the average relative errors for all the nominal land values of parcels are calculated with reference to 1-

metre resolution map values (Table 2). Thus, the effect of the resolution change on the nominal value can be expressed as a percentage. The average relative error for 22,481 parcels in Beyoğlu district is 2.40% at 10-metre resolution, 5.50% for 50-metre resolution, and 8.35% at 100-metre resolution. Because of the large number of parcels, standard deviations provide useful information regarding error distribution for the values. The standard deviation for 10-metre resolution values is 5.36%, for 50-metre resolution it is 8.39%, and for 100-metre resolution it is 13.44%. The average parcel size in Beyoğlu is 284.36 m².

The average relative error for the 23,776 parcels in Gaziosmanpaşa is 7.64% at 10 metres, 11.00% at 50 metres, and 13.11% at 100 metres. The standard deviation of the 10-metre resolution values is 2.40%; for 50-metre resolution it is 4.51%, and for 100-metre resolution it is 8.40%. The average parcel size in Gaziosmanpaşa is 346.37 m².

Table 2: Average Relative Errors of Parcels for Different Resolutions

RESOLUTION (m)	BEYOĞLU (22,481 parcels)		GAZİOSMANPAŞA (23,776 parcels)	
	RELATIVE ERROR (%)	STANDARD DEVIATION (%)	RELATIVE ERROR (%)	STANDARD DEVIATION (%)
10	2.40	5.36	7.64	2.40
50	5.50	8.39	11.00	4.51
100	8.35	13.44	13.11	8.40

Various streets in Beyoğlu and Gaziosmanpaşa were chosen for the investigation of nominal land value changes according to resolution: Müeyyetzade Neighbourhood and Yüksek Kaldırım Street in Beyoğlu; Barbaros Hayrettin Paşa Neighbourhood and 1103rd Street in Gaziosmanpaşa. Figure 7 shows a graph of the change of the unit m² values of the parcels according to the resolution.

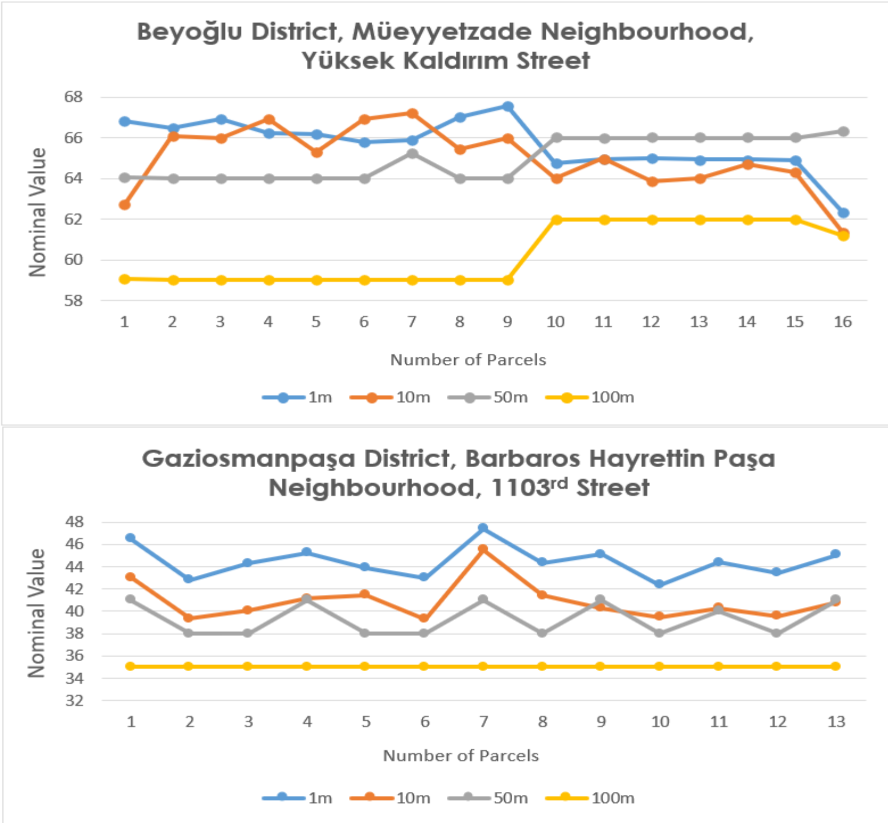


Figure 7: Variation of Nominal Values as Unit m2 for the Different Resolutions

To investigate the effects of pixel size on nominal land values in the parcel layers, average unit values of the parcels within the chosen streets were calculated for different resolutions. The market values of reference parcels on Yüksek Kaldırım Street and 1103rd Street were collected from a real estate valuation company in order to allow indexing 1-metre pixel nominal values to the market values. After calculation of the market values of the parcels within the streets, average unit values were calculated for resolutions of 10, 50 and 100 metres taking into consideration the average relative error values as shown in Table 2. The effect of 10-metre resolution on unit values is calculated as 142 Turkish Lira (TL)/m^2 in Beyoğlu Yüksek Kaldırım Street; for 50-metre resolution it is 325 TL/m^2; and for 100-metre resolution it is 494 TL/m^2. On the other hand, for 1103rd Street in Gaziosmanpaşa the effect of the 10-metres resolution on unit values was 257 TL/m^2; for the 50-metre resolution it was 370 TL/m^2; for 100-metre resolution it was 441 TL/m^2. The effect of resolution change on average unit values is always downwards as can be seen in Figure 7.

Additionally, to verify the selection of the appropriate grid resolution, a statistical concept was used for representing the smallest and the narrowest objects in a raster, the formula for which was:

$$p \le \begin{cases} \dfrac{\sqrt{\alpha_{MLD}}}{4} & \text{if S < 3} \\ \dfrac{\sqrt{\omega_{MLD}}}{2} & \text{if S > 3} \end{cases} \qquad (3)$$

where,

p is pixel size, α_{MLD} is the area of the smallest object, ω_{MLD} is the width of the narrowest object, and S is the shape complexity index derived as the perimeter to boundary ratio:

$$S = \frac{P}{2 \cdot r \cdot \pi}, \quad r = \sqrt{\frac{\alpha}{\pi}} \qquad (4)$$

where,

P is the perimeter of a polygon, α is the area of the polygon, and r is the radius of the circle with the same surface area (Hengl, 2006).

The smallest polygon is 49 m^2, and the largest is 40,125 m^2; the average size of the polygons is 284.36 m^2, with a standard deviation of 324.78 m^2. Using formula **(3)**, pixel size should be between 1.75 m (S=1.29) and 50.08 m (S=1.31). We recommend that the output raster map of the study area should be produced with a pixel size of between 2 and 50 metres.

5 Results and Discussion

In traditional valuation methods for real estate based on comparisons, the acceptable difference between the mean value and the comparable values is 15%. In our study, in order to examine the effect of resolution differences on value, relative error and standard deviation values were calculated for all parcels in two districts. According to our results, resolutions of 10 and 50 metres gave values that are within the acceptable range of values.

In addition, using this method the production of nominal land value maps with GIS at larger levels, such as region and country, could be fast and efficient for spatial resolutions up to 50 metres. On the other hand, it is not possible to produce a land value map at 100-metre resolution with the desired accuracy, since the average absolute relative error and standard deviation are high in comparison with the 1-metre resolution map (Table 2). The square-metre unit values for resolutions of 1 and 10 metres result in very similar graphs for the selected streets in both districts (Figure 7). Therefore, rather than 1-metre resolution, 10-metre resolution can be used for value maps of large areas.

In the form of the value map produced within this study, a model has been created that is based on uninflated, scientific findings from which buyers and sellers of properties can benefit in their transactions. With further development of the model, users will be able to see the values of real estate based on property information in the land registry by using Web GIS and Cloud GIS. Thus, this model could contribute to the national economy by helping to realize state-level valuation studies through a pioneering use of GIS.

Acknowledgements

This work was supported by the Scientific Research Projects Coordination Unit of İstanbul Technical University. Project Number: MYL-2018-41706.

References

ALOS Global Digital Surface Model. Available online: ttps://www.eorc.jaxa.jp/ALOS/en/aw3d30/index.htm (accessed on 31 January 2019).

Bencure, J. C., Tripathi, N. K., Miyazaki, H., Ninsawat, S., & Kim, S. M. (2019). Development of an Innovative Land Valuation Model (iLVM) for Mass Appraisal Application in Sub-Urban Areas Using AHP: An Integration of Theoretical and Practical Approaches. *Sustainability, 11*(13), 3731.

Bostancı, B., Demir, H., & Karaağaç, A. (2015). Determination of Nominal Value by Fuzzy Analytic Hierarchic Process Weights, *Proceedings of World Cadastre Summit 2015*, pp. 876-884.

Demetriou, D. (2016). The assessment of land valuation in land consolidation schemes: The need for a new land valuation framework. *Land Use Policy, 54*, 487-498.

Hengl, T. (2006). Finding the right pixel size. *Computers & geosciences*, 32(9), 1283-1298.

İstanbul Electric, Tram and Tunnel (İETT), (2018), İstanbul'da Toplu Taşıma [Public transportation in İstanbul], Available online: https://www.iett.istanbul/tr/main/pages/istanbulda-toplu-ulasim/95 (accessed on 31 January 2019).

Liu, X. S., Zhe, D. E. N. G., & Wang, T. L. (2011). Real estate appraisal system based on GIS and BP neural network. *Transactions of Nonferrous Metals Society of China, 21*, s626-s630.

Mete, M. O. (2019). Coğrafi bilgi sistemleri ile İstanbul ili nominal taşınmaz değer haritasının oluşturulması [Creation of nominal asset value-based map using Geographic Information Systems in İstanbul city] (Master's dissertation, İstanbul Technical University Institute of Science and Technology). Retrieved from https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=Mir2lXQK1dkmQ9Ige3PZbu1Yx9Cc VR0iMMy8sXZw9pkxXd-x3C3BRPToxuQ54z52

Nisanci, R., 2005, Coğrafi Bilgi Sistemleri ile Nominal Değerleme Yöntemine Dayalı Piksel Tabanlı Kentsel Taşınmaz Değer Haritalarının Üretilmesi [The Production of Pixel Based Urban Land Value Maps with Nominal Valuation Method Using GIS] (Doctoral thesis, Karadeniz Technical University Institute of Science and Technology, Trabzon).

Pagourtzi, E., Assimakopoulos, V., Hatzichristos, T., & French, N. (2003). Real estate appraisal: a review of valuation methods. *Journal of Property Investment & Finance, 21*(4), 383-401.

Pagourtzi, E., Nikolopoulos, K. and Assimakopoulos, V. (2006). Architecture for a real estate analysis information system using GIS techniques integrated with fuzzy theory, *Journal of Property Investment & Finance*, 24(1), pp. 68-78. https://doi.org/10.1108/14635780610642971

Rezaei, J. (2016). Best-worst multi-criteria decision-making method: Some properties and a linear model, *Omega*, 64, pp. 126-130.

Turkish Statistical Institute (TUIK). Available online: ttps://biruni.tuik.gov.tr/medas/?kn=95&locale=tr (accessed on 31 January 2019).

Yomralioglu, T. (1993). A Nominal Asset Value-based Approach for Land Readjustment and Its Implementation Using Geographical Information Systems (Doctoral thesis, University of Newcastle upon Tyne).

Yomralioglu, T., & Nisanci, R. (2004). Nominal asset land valuation technique by GIS, *Proceedings of FIG Working Week, Athens, Greece, May 22-27, 2004*.

Yomralioglu, T., Nisanci, R. & Yildirim, V. (2007). An Implementation of Nominal Asset Based Land Readjustment, *Proceedings of FIG Working Week, Hong Kong SAR, China, 13-17 May 2007*.

Blended Learning and Automated Evaluation in GIS Education

GI_Forum 2019, Issue 2
Page: 113 - 128
Full Paper
Corresponding Author:
florian.puehringer@tuwien.ac.at t
DOI: 10.1553/giscience2019_02_s113

Alexander Czech, Robert Kalasek and Florian Pühringer
TU Wien, Austria

Abstract

For many years, GIS has been a flexible tool for a wide range of spatial tasks in the spatial planning curriculum of at TU Wien. The steadily increasing number of students, the rising number of participants struggling with solving analytical problems, as well as suboptimal evaluation strategies initiated a total redesign of the course. We have rebuilt the didactic concept to better support the learning process and strengthen the understanding of learned skills, and have automated large parts of the evaluation, which allows for a more thorough assessment of quantitative results.

Keywords:

GIS education, blended learning, automated evaluation, spatial analytics

1 Introduction

When ESRI launched their first version of ArcView GIS 2.0 in October 1995, we seized the opportunity to implement a basic GIS course for the students of spatial planning. The course was designed as mandatory within the first section of a two-stage diploma curriculum (TU Wien, 2011). Within this curriculum, the courses were part of the analytical modules that have a clear focus on methodological approaches. Providing students with critical spatial-thinking skills, abilities and knowledge is essential not just for geography students (see Bearman et al., 2016) but also for aspiring spatial planners. According to Kedron et al. (2016), introductory courses frequently fail to address fundamental GIS concepts and theories. As a result, the objective of our original GIS course was to introduce the principles of spatial data acquisition and data handling and, in particular, to impart basic methods of spatial analysis. These objectives remain almost unchanged in the new, revised, course: we still aim to teach the skills needed to use GIS software in a professional setting, based on a hands-on approach.

Given that the initial number of students was about 30 to 40 per year and that our didactical as well as our GIS-specific expertise at the time lacked grounding in real-world applications, we started with a very conventional concept: classroom-style teaching via a data projector, short exercises to do at home, and an extensive final project that students worked on in pairs.

As the number of students increased significantly to more than 200 in 2010 (TISS, 2019), this original concept was in need of adaptation. The great variation in individuals' GIS-skills showed unsatisfactory developments: the quality of individual outputs was decreasing slightly but steadily, and we were observing an increasingly collaborative way of organizing work, with a tendency to share tasks according to personal preferences and capabilities. The necessary knowledge and expertise to solve more demanding tasks were held by just a handful of highly dedicated students, while others consequently reduced their inputs.

We noticed that a growing number of students were unable to carry out analytical tasks successfully on their own and subsequently transform their findings into meaningful GIS-based cartographic outputs. We also noticed students using various vector graphics applications instead of GIS-based tools to tackle basic tasks like calculating simple buffer features. Finally, we had to recognize that an increasing number of students did not apply GIS methods within subsequent higher-level courses, even if these methods would have been the most appropriate for the specific tasks. At the same time, students complained about the excessive workload and the overall intensity of our introductory GIS-course.

This summary may sound like a common complaint from disillusioned academic instructors. But we quickly decided to take these facts as a challenging opportunity to re-design our didactic approach and address criticisms by both lecturers and participants. As a result, we launched a complete overhaul of the structure of the course and of substantial elements of its content. The new focus was on encouraging basic expertise in handling spatial data, developing and implementing analytical mapping, and applying spatial analysis techniques. The redesign process specifically aimed to achieve a high level of practical relevance, support for different learning styles, a clear and consistent sequence of lesson-specific content, and the elimination of excess material. Thus, classroom-style teaching, where participants simply replicate the lecturers' activities, did not seem appropriate. The new paradigm is to guide students through an efficient process of skill-building.

The following guiding principles emerged during the redesign process, which was reflective:

- being able to verify quantitative analytical results
- evaluation of students individually, as a measure to counter the problem of 'free-riders'
- establishing a scalable course design

- encouraging students' personal curiosity as a means of encouraging them to solve tasks individually.

Implementing these principles resulted in a number of components that are linked within a formal conceptual framework. At the core, a step-by-step manual and a corresponding video-based series of web-lectures are complemented in the classroom by a competent academic team of supervisors and tutors.

While this new approach turned out to be promising in principle, the way the results were assessed continued to be an object of discontent and discussion. The evaluation of the exercises was still partly based on the subjective judgement of cartographic outputs and was thus in stark contrast to the initial intention of introducing basic objective methods of spatial analysis. The skill-building process implements a loop-style structure, where instructive and reflective elements feed into each other.

2 Didactic Concept

Stop teaching GIS - Teach how to learn GIS instead. (DiBiase, 2018)

2.1 General Considerations

The relaunched didactic concept offers a application-oriented learning process. Students work out the contents independently, either on their own or in pairs. They learn to develop their own creative approaches to spatial tasks. Students' individual performance is then evaluated in exams.

The course is organized as blended learning, with both online elements and face-to-face contact, as our experience echoes that of Ooms et al. (2015): social interactions between lecturers and students are an important part of the learning process, complementing digitally offered learning materials.

An E-Learning platform is used to organize the course. Such platforms have been widely used in Austrian universities for many years (Bratengeyer et al., 2016). In addition, they have the advantage of offering a scalable solution, irrespective of student numbers (Painho et al., 2002, p.3). Although our course design is software agnostic, we use ArcMap 10.6.

The development of the course content went hand in hand with discussion of the course's scope and sequence, which has already been discussed in connection with GIS by Foote (2012). His considerations are based on the experimental learning cycle developed by Kolb (1984), an idea from constructivist learning theories:

Rather than viewing learning as the transmission of knowledge from teacher to learner, or as a purely behaviourist process, constructivism considers how learners 'construct' or build their understanding of new experiences, phenomena and processes based upon their existing knowledge, motivations and preconceptions. Constructivism positions the teacher as a facilitator of learning, as a guide who develops activities or realistic problems which promote student exploration and discovery. (Foote, 2014, p.86)

The main point is that students should learn from their own experiences. Indeed, it is the central theme of the new concept. As Foote (2014, p. 87) also notes, it is not enough to just move from session to session: it is important that individual activities and tasks are well inter-connected, to give students the opportunity for personal active experiences – e.g. troubleshooting when they find errors – and to reflect.

2.2 Course Structure

The course comprises several didactic components, which are iterated six times throughout the semester. We call this the Didactic Loop (see Figure 1). Tests are held after the third and sixth loops. Each cycle starts with a Skill Building Week, where students acquire basic knowledge for the Exercises which follow. The Exercises, the new skills are consolidated and refined in preparation for the tests. They give students active hands-on experience and a chance to reflect on the contents of the Skill Building Week. Each Exercise comprises two tasks: an analytical task where geo-related methods are in focus, and a cartographic one in which the geo-processed results are mapped. This two-fold structure is reflected in the Exercise Evaluation. Students need to reach a minimum number of points in both subtasks throughout the course.

The individual results are presented on the E-learning platform after each Exercise Evaluation. Students can view their current scores there anytime. After the Feedback Element, a new loop starts.

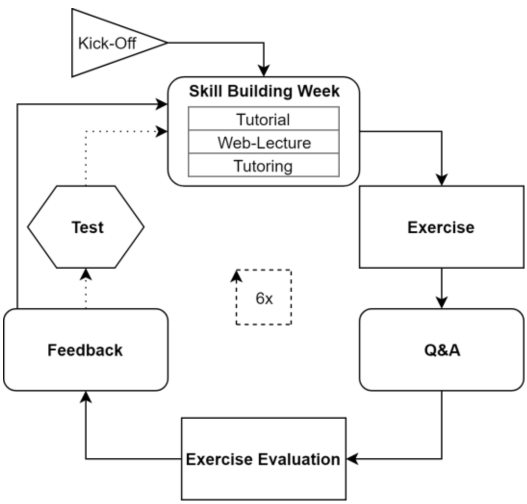


Figure 1: The Didactic Loop

2.3 Skill Building Week

Goal: The aim of the Skill Building Week is to learn how to use new tools, concepts and methods in preparation for the Exercise. In addition, the previously learned skills are repeated and consolidated.

Format: Based on written tutorials and web-lectures (in the form of videos), students are introduced to the content of the unit (the Didactic Loop) using practical examples. As Painho et al. (2002) note, GIS lectures have to deal with both the theoretical background and its practical implementation. The tutorials follow a how-to style, with substantial amounts of background information, and are complemented by web-lectures. Students can watch the video at their own pace and as often as they wish. The use of videos gives lecturers more time for supervising and supporting. Students can learn anytime and anywhere, following their own study rhythm (Painho et al., 2002, p.3). They do, however, need to be encouraged to watch the web-lecture, which requires additional study discipline (Ooms et al., 2015).

Simultaneously, we offer a supervised tutoring session in the faculty computer lab, where students can take advantage of additional support from experienced senior students in 3-hour blocks. We thus combine complementary learning elements that enable knowledge acquisition in different formats.

2.4 Exercise

Goal: The aim of the Exercise is to reflect on the tools and concepts learned in the previous Skill Building Week and to actively apply them independently. This involves students recombining the knowledge acquired to date and structuring their own workflows. The Exercise is designed in part so that students gain experience in order subsequently to be able to self-solve new GIS tasks. Students should be able to transfer what they have practised to similar problems, or to solve new problems they have not been exposed to before.

Format: Our Exercises cover a wide range of GIS applications - from calculating weighted population density, data acquisition via open-data portals, to basic raster calculations. All these spatial applications are accompanied by cartographic visualization tasks and thus follow Jakab et al. (2017), who note three key aspects in GIS lectures: data collection, data manipulation and data dissemination.

To better understand the scope and format of an Exercise, we present an example from the course: Exercise 3 (of 6) focuses on a site search for recreational areas based on the following characteristics (see also Figure 2):

Forest areas (as defined by Corine Land Cover classes) that are:

- close to urban areas (urban buffer) and
- free of traffic noise (noise range depends on road type, or presence of street buffer)

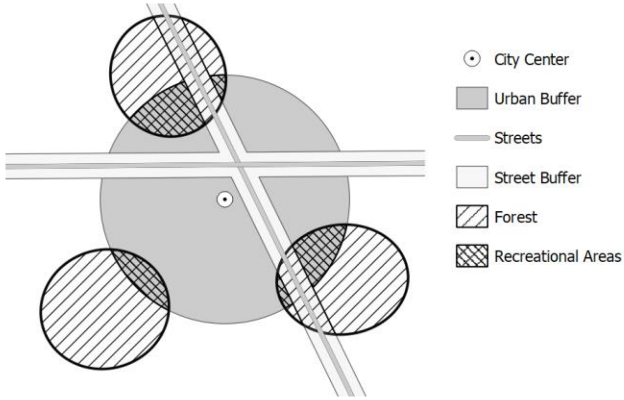


Figure 2: Schematic illustration of Exercise 3. The aim is to calculate and visualize the recreational areas.

To obtain the correct result, individually students have to use geoprocessing tools (such as Buffer, Dissolve, Intersect, Spatial Join and Clip) and common space-related methods taught in the Skill Building Week, elaborating the workflow on their own. The result (here, the combined sizes of the recreational areas in hectares) has to be calculated for each municipality of the region and stored in a dBase table. As part of the exercise, students receive an e-mail containing a tip in the form of the result for one spatial entity. For Exercise 3, this is the size of the recreational area of one municipality. Using this clue, they can check whether their own calculations are correct. (See also section 3.2)

In addition, students must create an aesthetic and user-friendly map, conforming to cartographic guidelines, on which the results are visualized.

The Exercises are released only after the Skill Building Week. During the Exercise elements, students are provided with assistance in multiple ways:

- Forum within the E-Learning-Platform: students can ask questions that are answered by other students, tutors or lecturers.
- Tutorial Appendix: here, further tools are introduced briefly; they are not used in the tutorial itself, but help with the Exercise.
- A Q&A (discussed in 2.5 below).

In addition, students are asked to look for other sources of support. The use of specialized forums such as StackExchange is encouraged as part of the Exercise.

2.5 Q&A

Goal: The Q&A aims to help students deal with difficult aspects of the Exercise. In addition, the search for a solution demonstrates how GIS troubleshooting and task-solving works.

Format: Students have the opportunity to ask questions about the Exercise within the framework of the Q&A session. They are advised to come up with questions they want to ask before the class begins. Solutions for these questions are worked out in groups (approx. 15 students + 1 lecturer). When working on a particular issue, an individual student's screen is shared on a data-projector and other students are encouraged to weigh in on the problem. The issues are solved by other students (based on their solutions to the same problems) or by the lecturer. The value for the students is that they get an answer to an Exercise-related question and see how GIS problems are solved by experienced GIS users. The Q&A is over when students have no more questions, or when the time is up.

2.6 Exercise Submission & Evaluation

The completed Exercise task is submitted to the E-learning platform. The students upload a zip-archive containing the results from the subtasks Cartography (.png-image) and Spatial analytics (dBase-table). How these are handled is discussed in Section 3 (Evaluation) below.

2.7 Feedback

Goal: The students receive cartographic feedback on the Exercise. In addition, general and organizational information about the course is given. Because attendance at Feedback sessions is mandatory (in contrast to all other elements), we can reach all students directly at the same time.

Format: After each Exercise, a Feedback session with all participants takes place. For the cartographic Feedback, anonymized maps are projected for all to see and to be discussed by students. Lecturers then give feedback and advice. Our aim is to encourage students to have a critical perspective on their own work. This format allows constructive feedback that can be implemented in subsequent Exercises. In this way, students learn that the evaluation of maps is often influenced by subjective factors. The discussion is complemented by the use of interactive tools, such as a poll-app, where students can evaluate the maps by smartphone using a scale of points. The result is then projected in a real-time poll.
The Feedback session completes the Didactic Loop, and a new Loop then starts.

2.8 Test

Although other studies (Bowlick et al., 2016; DiBiase, 2018; Harvey & Kotting, 2011) show that GIS skills can be successfully measured by evaluating projects, we decided to organize individual assessments (or Tests). With the current framework conditions - notably the high student counts - we can only check individual performance on the basis of individual tests, as group work may lead to a free-rider phenomenon (Joyce, 1999). We still observe a large discrepancy between group work ratings and individual test results. (See Figure 6 in Section 4.)

For the in-class Test, a short spatial task (similar in scope to a single Exercise) has to be solved individually in the computer lab. The Test comprises several analytical subtasks and cartographic representation of the results. As in the Exercise, we supply check-values (hints) at sub-task level and thus provide students with the means to verify their intermediate results.

Students who have solved the Exercises on their own should be able to master the Test as well: the intention of the Test is to determine whether group members have understood the Exercises.

Quantitative results are checked manually. The map is evaluated in two stages:

- Required map elements: Are all required map elements present?
- Jury evaluation: Each lecturer evaluates maps individually on the basis of a checklist. The average of the lecturers' scores is calculated. If the deviation between them is high, the lecturers consult with each other again. The aim is to counteract the criticism of subjectivity.

The course includes two Tests. Students are allowed to repeat one of them in the case of a negative grade.

3 Evaluation of quantitative results

To enable a large-scale evaluation of quantitative GIS results, which was one of our main goals, and to limit the amount of work required to run the course, many repetitive elements from evaluation to communication need to be automated. During the semester, the students hand in 6 datasets of calculations with 6 corresponding maps for evaluation; the last time we ran the course, we evaluated a total of 355 submissions. The Evaluations take place between the Q&A and Feedback elements.

3.1 Specifications for an automated evaluation tool

To be of value for the course, the evaluation, even though automated, should be flexible enough to allow for the assessment of both single students and groups. Furthermore, it should allow for a flexible Exercise structure that supports the evaluation of varying spatial entities – as in the Exercise described in section 2.4 above, for which students need to calculate the total recreational areas within municipalities.

A further useful aspect of automation lies in communication with students: the tool needs both to produce feedback and to communicate results and mistakes to students.

In order to provide a transparent overview of the whole evaluation process and the student's personal rating as it evolves with each didactic loop, we use a collaborative spreadsheet platform where individual results are documented for each Exercise.

Lastly, feedback and evaluations need to be aggregated and uploaded back to the E-learning platform.

3.2 Data Preparation

We created a student-to-data relation model to allow for flexibility in assigning students to groups and ultimately to the data for which they are tasked to produce results (see Figure 3).

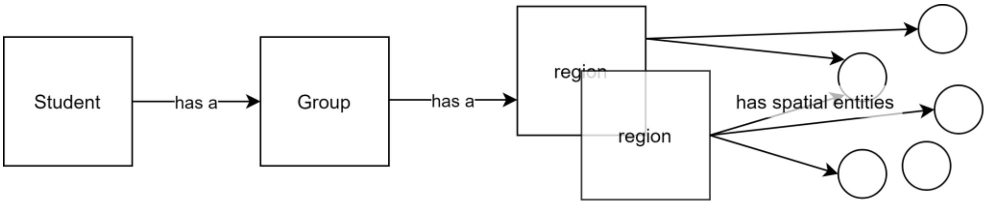


Figure 3: Relation Diagram

Students are assigned to groups, and groups consist of at least one student; a student cannot be part of multiple groups. Each group is assigned one region, which can vary from Exercise to Exercise. Each region covers the geographical entities for which students have to calculate results. Regions can overlap, and multiple groups can be assigned to the same region. Students are not aware of the regions: they are just presented with the geodata.

For reasons of convenience, we designed the evaluation tool so that it evaluates only one set of spatial entities within an Exercise (for example one set of shapes, points or lines). While results can stem from multiple calculations for each Exercise, all results need to be spatially aggregated to the same spatial entity type. This approach reduces the complexity of the evaluation tool.

The process of assigning districts to regions as well as preparing the corresponding sets of geodata within these regions is done within the class lectures. The first region-building step is done manually, with the aim of creating similar levels of complexity between regions. The second step – preparing the dataset for each region – is automated where possible.

3.3 Reference Results

We check the students' numerical results against reference results that we have produced beforehand. An important part of producing the reference results is to calculate them on a by-region basis, because the results for a region vary depending on which other spatial entities are included or excluded in the calculation. To differentiate between multiple results for the same spatial entity belonging to different regions, each result and entity combination is assigned a separate ID. This allows linking each student to the IDs of the spatial entities for which they have to produce results, as depicted in Figure 3

3.4 Automated Evaluation

When the students have completed an Exercise, they upload an archive (which contains a dBase file that includes the results and a map file) to the E-learning platform, from where it is fetched and fed into the assessment tool. Figure 4 shows the evaluation process.

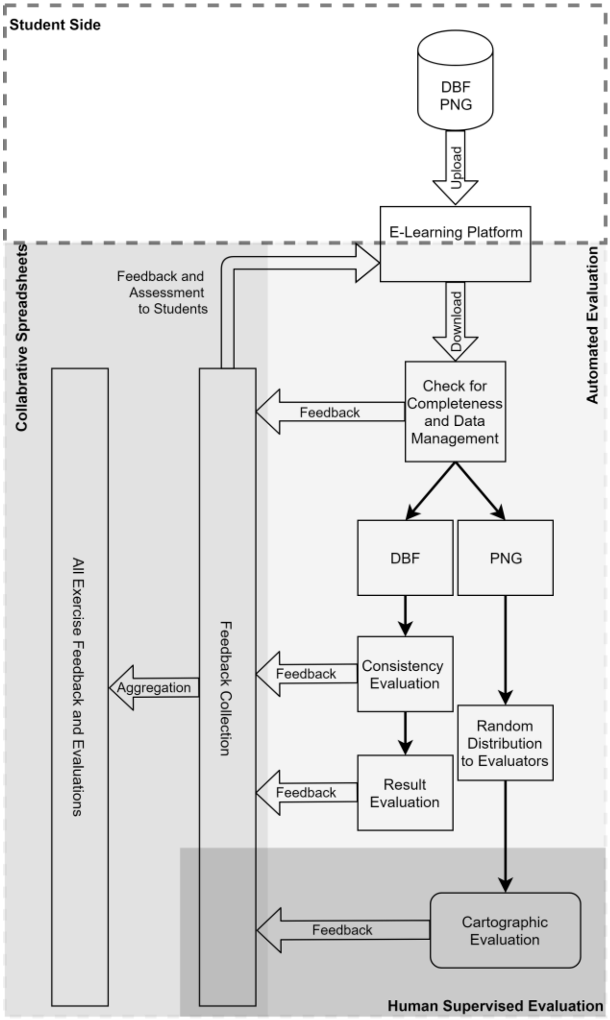


Figure 4: Evaluation Process.

The data archives submitted by students are downloaded and checked for completeness, in our case for a PNG file and a dBase file. The files are then sorted for further processing. All map files are distributed randomly to human evaluators. Since we aim for consistency and fairness when assessing the results, we set up a formal scheme. A 'scorecard' provides a multi-level framework for evaluating the cartographic products.

For the numerical results, the dBase files are read into the evaluation script using dbfread1. Internally, they are then represented as pandas2 DataFrames. The data is checked for consistency, for example for whether all required fields are present in the dataset and are of the required type. If there are any issues, feedback is generated.

The required results for a given student group are fetched from the reference results and joined to the results handed in by the students. The two sets of results are then compared with each other. Lastly, either positive feedback is generated if the dataset meets all expectations, or discrepancies are recorded.

All feedback and evaluation results produced by the tool are outputted to the collaborative spreadsheets. They are combined with the map evaluations, and points for each Exercise are then calculated. The point score plus the feedback are prepared for uploading to the E-learning platform.

The tool is also used to issue students with hints for every Exercise. The hint usually consists of the expected result or results for one randomly chosen spatial entity (a check value) to which the students are assigned. This can be problematic when students think they have solved a GIS problem because the check values line up with theirs but in fact their solution contains errors. To mitigate this problem, we plan to introduce a second check value that is the sum of all correct values. All check values are sent to the students automatically via email.

3.5 Exceptions

When processing the student submissions, a small number of problems arise from inconsistencies within the data; these exceptions need to be dealt with. Figure 5 shows some common data errors we have observed in the past and which we try to correct in the data consistency phase.

One common problem is incomplete submissions, where the map file and/or the dBase file is missing. The omission may be deliberate, because the group was not able to solve the task, or the wrong files may have been submitted. For map files, it is common for students to submit a file in the wrong format; more troublesome is the submission of the wrong dBase file. There are two factors involved here that compound each other: Windows hiding the file extension for known files from the

[1] https://github.com/olemb/dbfread

[2] https://pandas.pydata.org/

user as a default setting, and ArcGIS generating metadata for dBase files. This results in a file named my_dbase.dbf.xml (clearly an xml file), but since Windows hides the xml extension, the user sees 'my_dbase.dbf' displayed in their Windows file-manager app. This is highly misleading, sometimes even for experienced users. As a consequence, several students submitted this xml file instead of the dBase file required.

Other common errors are easy to handle, for example, capitalization mistakes, where all column names (in the reference results and student results) simply get changed to lowercase. Others are more problematic, like data-type mismatches. Some of these mismatches are correctable. For example, a frequent mistake in Exercise 2 was to hand in files with a float ID field, while an integer field was required. Other mismatches are more problematic. In Exercise 3, a string-type ID field that contains letters and numbers is used. If we receive a file where the ID field-type is changed to an integer, it is not possible to reconstruct the correct ID because the string information is lost. In this case, a group would fail the Exercise. In one instance, during the two runs of this class, a group handed in a corrupted dBase file which contained a string value in an integer field.

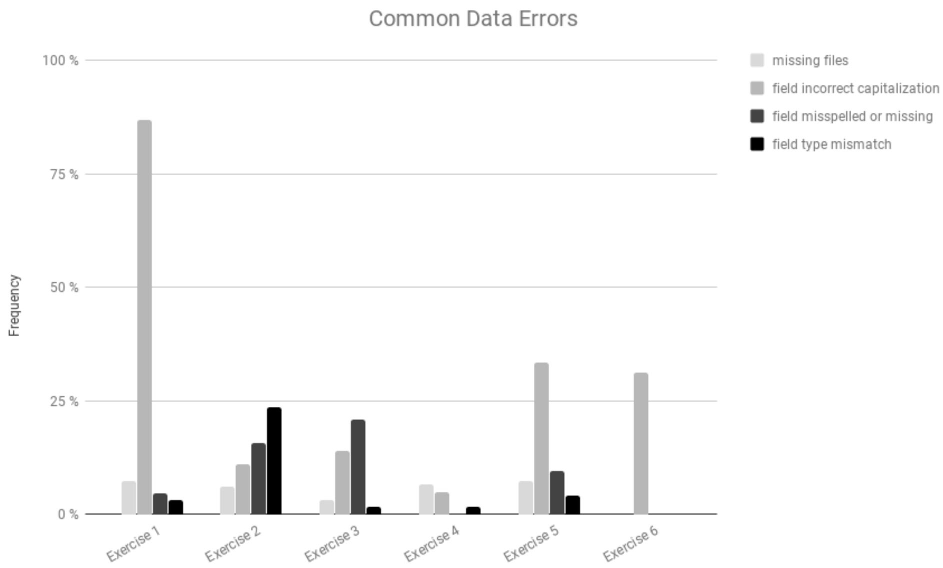


Figure 5: Common data errors in the 2018 course.

A further complication is the inconsistent way ArcGIS handles geoprocessing methods, which leads to problems when student results are checked against reference results. We calculated discrepancies of up to .4%.

4 Findings, Student Feedback and Future Work

If a course uses a highly automated process, this process needs to be well attuned with the concept of the course. Both have hard and soft limitations that can be worked around. For example, an automated evaluation process can produce basic feedback, but the feedback needs to be supplemented. On the other hand, Exercises need to be designed so that valid reference results are feasible to produce, meaningful and unambiguous.

4.1 Results

Comparing grades obtained during the redesigned course with grades from before 2017 is not really possible, because grading has become stricter. In the lecturers' opinion, the following goals have been achieved:

- We are now able to limit the number of 'free-riders' by implementing GIS examinations in front of a PC where each student needs to demonstrate GIS problem-solving skills.
- The automated evaluation enables the quantitative evaluation of exercises that are handed in by student groups. This is possible with little or no extra work and an improvement compared with guessing (by inspecting map documents) where students might have made mistakes in their results.
- The course has not only become more scalable by including automation, but also, by modulating the teaching group sizes, now fits the needs of the students and the setting (see: Feedback, Q&A and Skill Building Week group sizes).
- Cartographic evaluation of Exercises is now more streamlined and based on transparent criteria.
- Instead of classes in which students are told to 'just follow the instructions', they are now challenged to solve GIS problems on their own, and they receive the necessary support to do so.
- We provide the students with more feedback.
- Looking into the future, it will be easier to maintain the structure and quality of the course because of the better scalability.
- In our opinion, students who pass the redesigned course are more capable GIS-users than those who followed courses pre-2017.

Figure 6 is a scatterplot comparing the individual assessments in the tests (70 points in total) to the exercises (30 points in total) during the last semester. The plot highlights the problem of students who try to 'free-ride' (i.e. let their group or partner do the work). We are working on adapting the course without lowering requirements, so that more students are able to pass. The preliminary results from the 2019 course are encouraging.

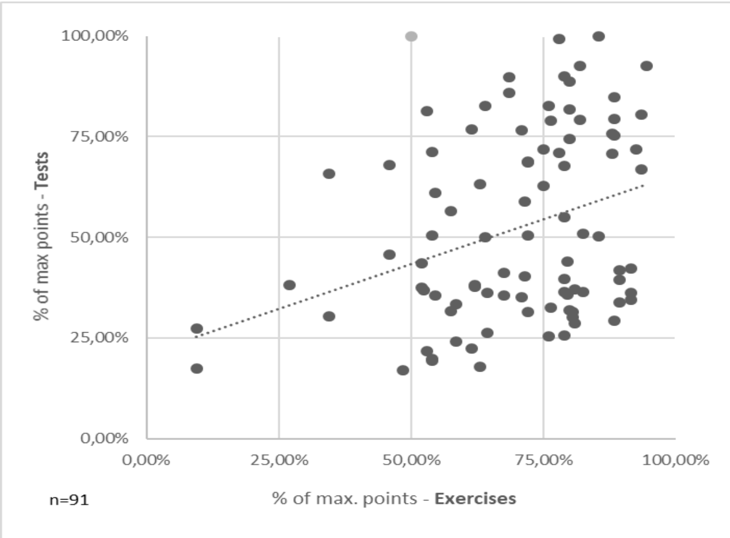


Figure 6: Test result percentage vs. Exercise result percentage.

4.2 Student Feedback

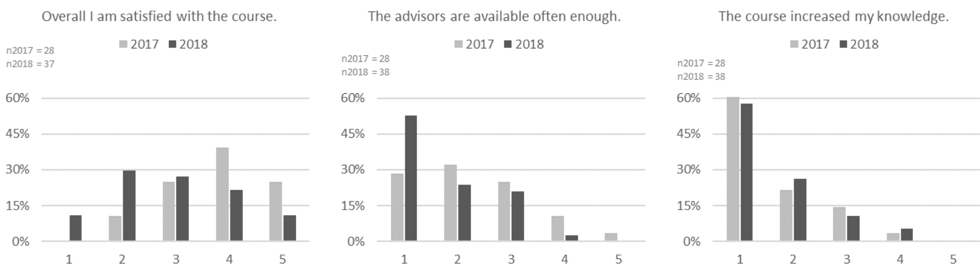


Figure 7: Student Feedback. (1 = Yes, 5 = No).

The course evaluation by students is important for lecturers. Feedback at the end of every semester is provided anonymously and in digital form using a standardized questionnaire with approximately 25 questions.

The results show that changes in the course between 2017 (the year in which we first applied the new concept) and 2018 resulted in greater participant satisfaction, although there is potential for further improvement. The level of automation allowed improvements to the level of individual support received from lecturers. Small adaptations in the concept were made from 2017 to 2018, which are also reflected in the results. Students consistently rate their increase in knowledge as high.

4.3 Further Improvements

The conception of courses requires constant adaptation. Our aim is to integrate our experience gained during the last semester into the concept, in order to increase students' positive responses and improve the success rate.

The following points are currently being worked on:

- Second tip for Exercises: a second check value in the form of the sum of all results in order to further minimize uncertainties in solutions.
- Pretest: The Pretest will be similar in scope and level of difficulty to the actual test.
- Spatial Analytics within Feedback: this aims to demonstrate the most important methodical steps of the Exercise
- Tutorials: greater precision of the texts and cutting unnecessary parts.

References

Bearman, N., Jones, N., André, I., Cachinho, H. A., & DeMers, M. (2016). The future role of GIS education in creating critical spatial thinkers. *Journal of Geography in Higher Education*, 40(3), 394-408.

Bowlick, F. J., Bednarz, S. W., & Goldberg, D. W. (2016). Student Learning in an Introductory GIS Course: Using a Project-Based Approach. *Transactions in GIS*, 20(2), 182-202.

Bratengeyer, E., Steinbacher, H. P., Friesenbichler, M., Neuböck, K., Kopp, M., Gröblinger, O., & Ebner, M. (2016). Die österreichische Hochschul-E-Learning-Landschaft: Studie zur Erfassung des Status quo der E-Learning-Landschaft im tertiären Bildungsbereich hinsichtlich Strategie, Ressourcen, Organisation und Erfahrungen. *BoD–Books on Demand.*

DiBiase, David. (2018). Stop Teaching GIS. *American Association of Geographers Website. http://news.aag.org/2018/04/stop-teaching-gis/ (last accessed 2019-01-30)*

Foote, K. E. (2012). Scope and sequence in GIS&T education: learning theory, learning cycles and spiral curricula. *Teaching geographic information science and technology in higher education, 81-95.*

Harvey, F., & Kotting, J. (2011). Teaching mapping for digital natives: New pedagogical ideas for undergraduate cartography education. *Cartography and Geographic Information Science*, 38(3), 269-277.

Jakab, I., Ševcík, M., & Grežo, H. (2017). Model of Higher GIS Education. *Electronic Journal of e-Learning*, 15(3), 220-234.

Joyce, W. B. (1999). On the free-rider problem in cooperative learning. *Journal of Education for Business*, 74(5), 271-274.

Kedron, P., Frazier, A., Greene, C., & Mitchell, D. (2016). Curriculum Design for Upper- and Advanced-level GIS Classes: Are New Skills being Taught and Integrated? *GI_Forum 2016*, 4, 324-335.

Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development.* Englewood Cliffs, NJ: Prentice-Hall.

Ooms, K., De Maeyer, P., De Wit, B., Maddens, R., Nuttens, T., Van De Weghe, N., & Vervust, S. (2015). Design and use of web lectures to enhance GIS teaching and learning strategies: the students' opinions. *Cartography and Geographic Information Science*, 42(3), 271-282.

Painho, M., Cabral, P., Peixoto, M., & Pires, P. (2002). E-teaching and GIS: ISEGI-UNL learning experience. In *Third European GIS Education Seminar EUGISES*.

TISS – Campusinformationssystem der TU Wien. (2019): Inskriptionsstatistik. *https://tiss.tuwien.ac.at/statistik/public_lehre?locale=en (last seen 2019-07-16)*

TU Wien, (2011): Studienplan für das Bachelorstudium Rauplanung und Raumordnung. *https://www.tuwien.at/studium/studienangebot/bachelorstudien/raumplanung-und-raumordnung/uebersicht/ (last seen 2019-07-16)*

Augmented Reality and Mobile GIS as Tools for Teaching Data-collection in the Context of Forest Inventories

GI_Forum 2019, Issue 2
Page: 129 - 143
Full Paper
Corresponding Author:
jan-peter.mund@hnee.de
DOI: 10.1553/giscience2019_02_s129

Jan-Peter Mund[1] and Susanne Müller[2]

[1]Eberswalde University for Sustainable Development, Germany
[2]Freelance author

Abstract

Innovative and disruptive technological innovations trigger educational advances. Novel sensor-based distance and height measurement tools or wearable augmented realty (AR) devices and cameras have recently been introduced into several University curricula focusing on the environmental sector. Consumer gadgets and mobile GIS support students during self-organized fieldwork by displaying collected data in an immersive AR.

This paper summarizes the authors' experiences in implementing a module re-design integrating a new didactical approach to teaching empirical data collection for forest inventories with the use of AR tools and mobile data-collection methods. The new module combines blended and mobile learning and state-of-the-art IT in order to address future professional needs of the forestry sector. The piloting of the module from 2016 to 2018 demonstrated the potential for the forestry sector of mobile learning that uses geospatial information and AR technologies.

Keywords:

GIS, Forest inventories, Augmented Reality, Mobile Learning

1 Introduction

During the last decade, geo-information techniques, location-based services (LBS) and augmented reality (AR) have advanced from experimental science-based innovations to accepted ready-made consumer electronics products (Rathmell, 2018). Thanks to novel geospatial, surveying and environmental assessment techniques, scientists are increasingly able to record the dynamics of the environment using modern, mobile digital surveying and data collection equipment (MaKinster et al. 2014).

Teaching the skills required for monitoring environmental parameters using geospatial aspects of LBS and AR has become essential in higher education curricula in the fields of forestry and ecosystem management (Morgenroth & Visser, 2013). Teaching empirical data collection for the purposes of forest inventories specifically offers an intrinsically complex topic for several reasons: the sector sees less innovation due to long forestry production cycles and lasting product characteristics; empirical data in forestry is often still generated manually (Aufnahmeanweisung Bundeswaldinventur, Riedel et al., 2017); attitudes towards digital working methods and devices differ among forestry students (Adams et al., 2013).

This paper presents the design and piloting of a new higher education module that integrates mobile geo-information and computing techniques, features of AR, and various learning approaches to enhance students' understanding of the principles of database management and the learning of up-to-date environmental data-collection methods in a realistic forest inventory application.

2 The new module: content and sequence

The higher education module discussed here teaches principles of empirical data collection and GIS for forest inventories and environmental monitoring. It targets BSc students who are either studying for a forestry degree or are on an ecosystem management programme. The main objective of this second-semester module is 'to enable students to independently carry out data collection, data management, analysis and visualization of forest inventory related spatial data in individual GIS projects' (HNEE, IFEM Curriculum; effective from WS 2015/16).

The motivation for re-designing the module was to increase students' operational autonomy and responsibility for the collection of empirical environmental and GIS data in forest stands by enabling mobile, in-context learning in inventory plots. The new approach introduces up-to-date spatial data collection methods for a realistic forest inventory, merging mobile geo-information techniques with features of AR and other e-learning methods. The module is aligned with typical industry job requirements and settings, creating significant added value for students, preparing them for careers connected to geo-spatial analysis.

The two course modules taught at the Eberswalde University for sustainable Development regularly draw a heterogeneous set of students, some with a strong interest in computer science and GIS, others with a strong dislike for technology. Students come from international or German federal state backgrounds. Their digital literacies levels vary widely. Here, digital literacy is understood in a very broad sense, as a capacity to continuously adjust, comprehend and utilize innovations in information technology (Koltay, 2011).

In order to be able to apply individually the data collection methods taught in the module, students need to master geo-spatial concepts, including spatial location, 2D and 3D data hierarchy, buffer and clipping tools, as well as raster and vector principles. They also need to understand how to combine forest mensuration techniques with spatial data acquisition and GIS tools for the creation of forest inventories, as well as how to solve problems using geo-spatial analytics and GIS software.

The learning process of the new module is sequenced in three phases, which include e-learning and elements of self-directed learning: 1. Information and Transfer; 2. Application; 3. Securing results. (See Figure 1.)

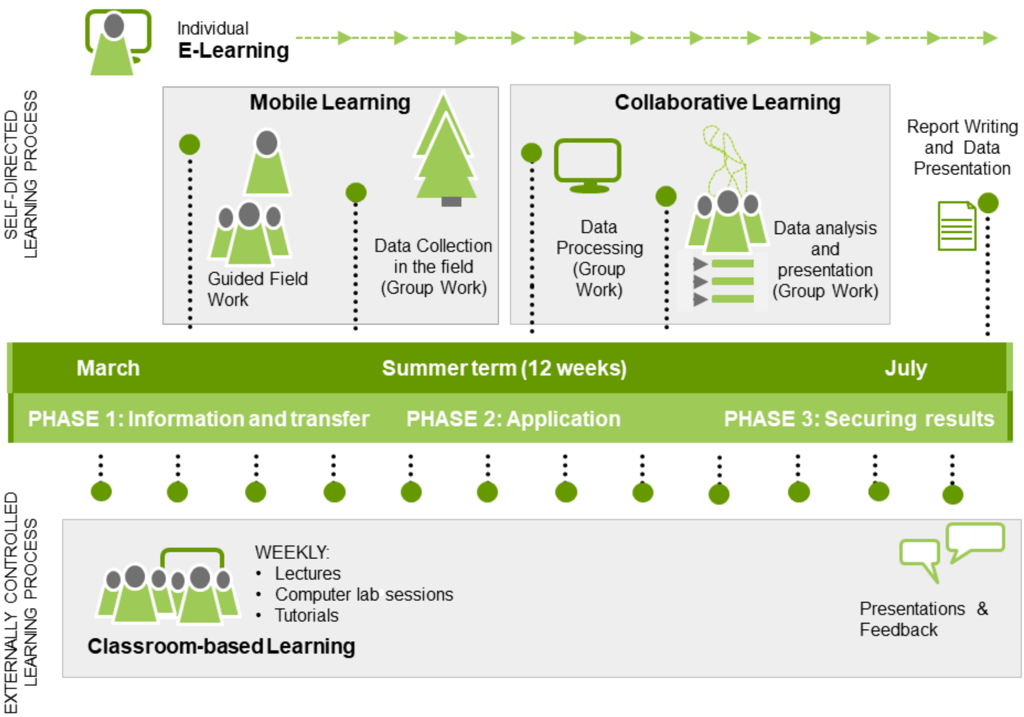


Figure 1: Sequence of the learning architecture

2.1 Phase One: Information and Transfer

During the introductory phase, short lectures and on-site presentations provide necessary theoretical information and methodological expertise.

Across 12 weeks of the summer term, the learning sessions deal with typical GIS principles of vector- and raster-based geospatial information, coordinate and reference systems, the combination of raster- and vector-based geospatial information, topical attribute data, calculating and converting polar to world coordinates, visualization and thematic cartography. The lecture topics are connected to an e-learning portfolio in order to facilitate flipped classroom methods and preparatory learning tasks. In addition, reading material and digital exercises enable self-directed learning.

All resources and learning materials can be accessed by the students at any time in an e-learning classroom linked to the university's network. The e-learning materials point to further online training opportunities, recommending particular internet tutorials and online video resources. Each lecture is followed by a practical computer lab session where students process geospatial data recently collected for their individual inventory into an ESRI online database which is part of the HNEE ESRI online repository. Students who prefer personal guidance rather than self-guided online tutorials have the opportunity to work with the lecturer or tutor to learn how to use GIS for spatial analysis to solve a problem similar to the ones they will encounter on their individual research plots. In the lab sessions, students are also able to discuss questions that arise in the self-directed learning phases.

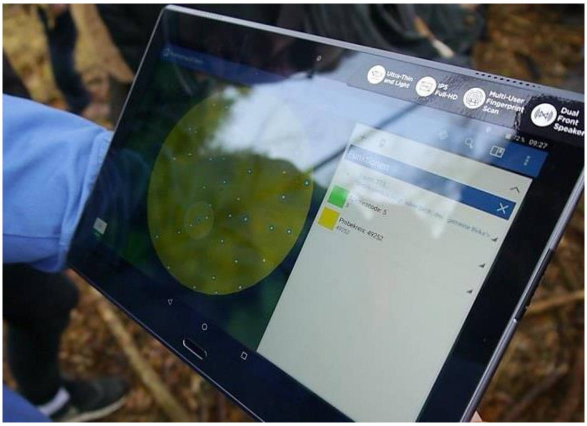


Figure 2: Mobile computing and real-time entry of forest inventory data during student fieldwork with ESRI ARC GIS Collector App

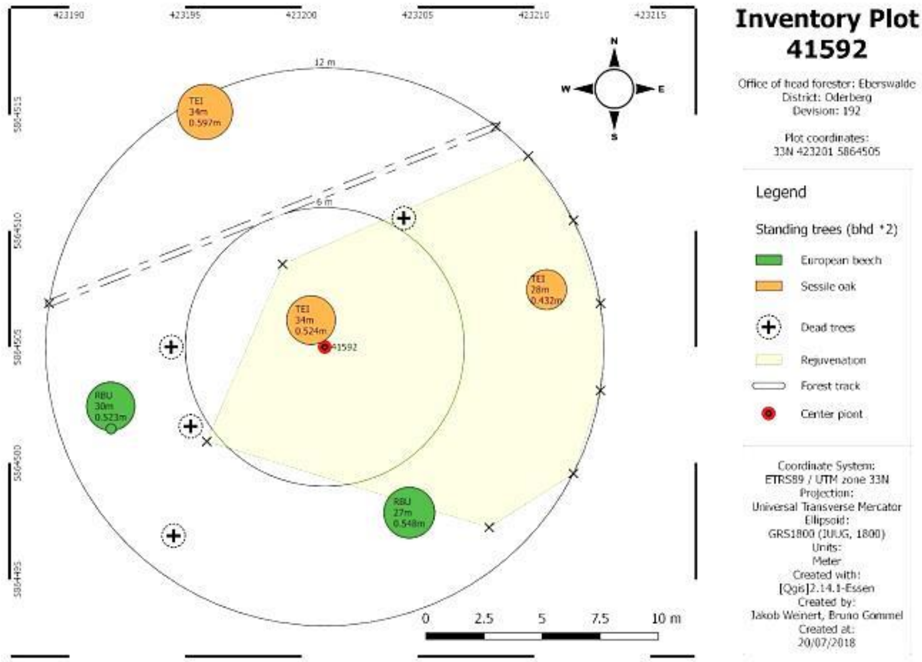


Figure 3: Example of a circular forest inventory plot in the Eberswalde region, Germany, using a projected geo-reference system with auxiliary spatial and attribute information

Equipped with prior knowledge, students more easily comprehend particular forest inventory concepts and increase their GIS application competence (Clark et al. 2007).

2.2 Phase Two: Application

In phase two, students apply the methods they have learnt in an actual forest plot. The authors intentionally chose an inverted classroom setting, 'swapping phases of knowledge acquisition and application' (Lambach et al., 2017, p. 554). During the first half of the 2nd term, in parallel to the classroom sessions, students form working groups for field data collection exercises, and guided practical fields days introduce students to their assignment. In groups of four, students work together on two circular forest inventory plots (r=12m) to collect empirical data (see Figure 3) following the principles of the federal state forest inventory guidelines. They need to navigate solo to the inventory plots and survey the assigned area. Additionally, students assess typical biological parameters such as species names, soil type and climatic conditions in their forest stands. They also differentiate between growth and yield functions in order to predict productivity (number of cubic metres harvested) and enter all collected data into a forest inventory training database, including inventory descriptions, stratification and auxiliary data.

During their fieldwork, immersive information or AR (Figure 4) provides students with digital spatial data attribute information and metadata for individual trees (e.g. physiological tree parameters) and other auxiliary information. The immersive information in the AR places the existing datasets in their original contexts. Multiple datasets can be presented and analysed simultaneously. Thus the AR supports mobile learning on the plot. Additionally, real-time AR data presentation and standardized data entry forms reduce individual data-entry errors as students compare their data live in the field.

Figure 4: Screenshot of the immersive information (AR) displayed offline at each inventory plot.

The learning process for data management continues with a comprehensive data quality assessment, followed by modification or correction of attributes if necessary. Updated spatial forest inventory information is now ready for further analysis of forest growth parameters, for being superimposed on background information for presentation (Figure 3), or for designing meaningful thematic maps.

2.3 Phase Three: Securing results

At the end of the learning process, the processed data is saved in the inventory database where it updates the existing attribute dataset with new data, thus expanding the existing AR for future use. The final examination part of the module consists of a presentation of the group assignment. Student groups need to discuss and present the analysis and visualization of the self-collected data to their peers, processing the collected data, producing overview maps, and comparing current data to previous datasets. A written report and a digital file with the collected and processed data need to be handed in for students to be credited for the module.

3 The learning architecture of the module

This new module employs parallel blended learning settings, where blended learning is understood as the linking of online and offline learning and teaching resources (Kopp et al. 2016). The module comprises:

- Classroom-based lectures and computer lab seminars
- Online e-learning, flipped classroom and video tutorials
- Individual and guided practical fieldwork at students' research plots.

The blended learning design combines classroom formats with online self-learning phases; mobile learning and independently organized project work in groups (see Figure 2). Mobile learning here is understood as an extension of e-learning (cf. de Witt and Sieber, 2013, p. 14). In contrast to e-learning, mobile learning is not necessarily online, but refers to learning processes that use mobile devices such as tablets on location. The introduction of mobile learning allows in-context learning on the forestry inventory plots and establishes a direct link between abstract learning and both concrete use cases and the relevant physical environments (Seipold, 2013).

Mobile and e-learning options serve as supports to compensate for differing or limited prior knowledge and divergent working methods in heterogeneous student groups. In this case, e-learning ensures familiarization with, and practical use of, software and digital measuring devices before classroom teaching. By sequencing the materials and offering different learning methods, the module reaches out to a diverse set of learners and their needs. By combining face-to-face formats, digital self-study and self-organized group work, very different approaches were integrated to foster students' responsibility and reliability. Collaborative procedures and production processes for data collection and analysis strengthened students' logical thinking and collaboration between them. Further benefits for students included the promotion of transfer and decision-making skills. Mobile learning opened up a wider scope of action for students and gave them control in the learning context, including deciding when and where to study. The mixture of online and off-line teaching allows individualized, adaptive learning, with the ability to tailor learning speed and intensity to individual needs. Linking different learning approaches and teaching formats encourages and motivates students through activating learning and independent working methods (Goldstein & Alibrandi, 2013).

The student assignment is designed according to problem-based learning (PBL) principles. The authors understand PBL in Moallem et al.'s (2019) sense, as offering an instructional method that focuses on problems as drivers of the learning process. PBL is considered an effective format and is popular for introducing geospatial applications and methods in particular (Howarth and Sinton, 2011). In their online work, students independently develop a digital data model for the acquisition of typical forest inventory and geospatial data. This approach enables students to independently recognize the need for a structured and organized data model which they then implement independently into their own learning environment. Dealing with the attribute parameters, digital processing, technical limitations and dangers of geospatial data is learnt using real examples, so that the students can transfer this experience into their future professions. Mobile visualization such as AR simulates collected data in the context of their occurrence (Veas et al., 2013). The idea of including an AR layer as learning material was triggered by research which found that using AR technology increases students' level of interest and/or engagement (Goff et al., 2018; Balog and Pribeanu, 2010; Dunleavy and Dede, 2014).

4 Skills and intended learning outcomes

The focus of the module rests more on linking the practical application of digital methodological skills with theoretical foundations of spatial data than on imparting subject-specific and theoretical knowledge. The module has four general learning objectives (illustrated in Figure 5): to transfer factual and conceptual knowledge about various technologies and their functions; to build the capability of using and troubleshooting selected technology; to enhance critical thinking and decision making; to foster problem-solving skills, and soft skills such as group work and conflict resolution.

The intended learning outcomes that relate specifically to geospatial technologies are:

- Students are able to capture and organize spatial data using GIS and software.
- Students use AR and existing data infrastructures to compare spatial and attribute data.
- Students master basic GIS operations, including simple 2D mapping tasks, and become acquainted with selected software types (see Figure 4).
- Students independently carry out data collection, and perform simple spatial analysis and visualization of spatial data using ARC-GIS or Q-GIS.
- Students understand map projections and are able to use cartographic and analytical methods.
- Students relate environmental attribute data to geospatial data of individual trees and visualize them using digital presentation methods (see Figure 3).

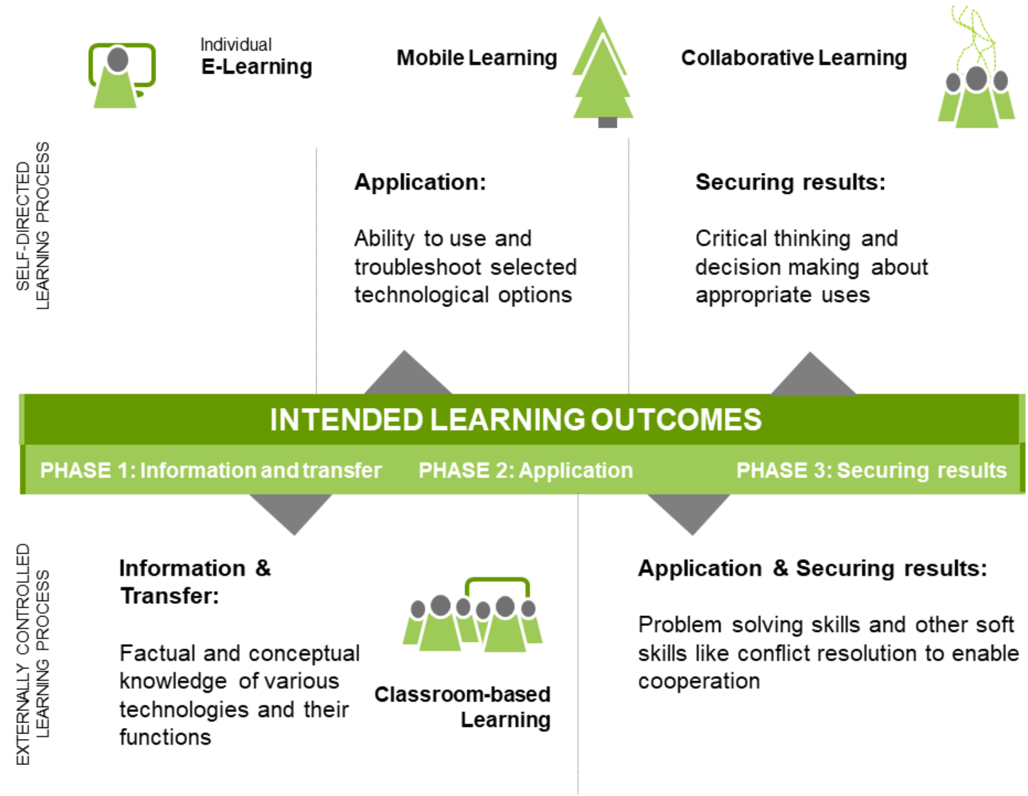


Figure 5: Intended Learning outcomes according to the sequence of the module

5 Technical pre-conditions

During practical field days, students make use of consumer tablets, mobile GIS applications, and AR software that visualizes data collected previously in the inventory plots. As the federal state forest administration in Brandenburg does not use a comprehensive forestry-oriented geo-data model, a database had to be introduced. This is similar to topographical data models like ATKIS (general topographical cadastral information system) or 'city gml' (Open Geospatial Consortium, ISO TC211). In 2012, a joint forest inventory training database was set up by the federal state forest service (LFE-LFB Brandenburg) and Eberswalde University for Sustainable Development that consists of approximately 160 separate inventory plots with ancillary attribute data for each inventoried tree (see Figures 2 and 6). Since then, all plots have been registered in an ESRI ArcGIS geospatial database and inventoried twice, by different student groups. Structured and parametrized attribute data for each plot are available (as seen in Figure 4) and support the permanent monitoring of environmental changes or yield growth of timber stock (ESRI Canada 2017).

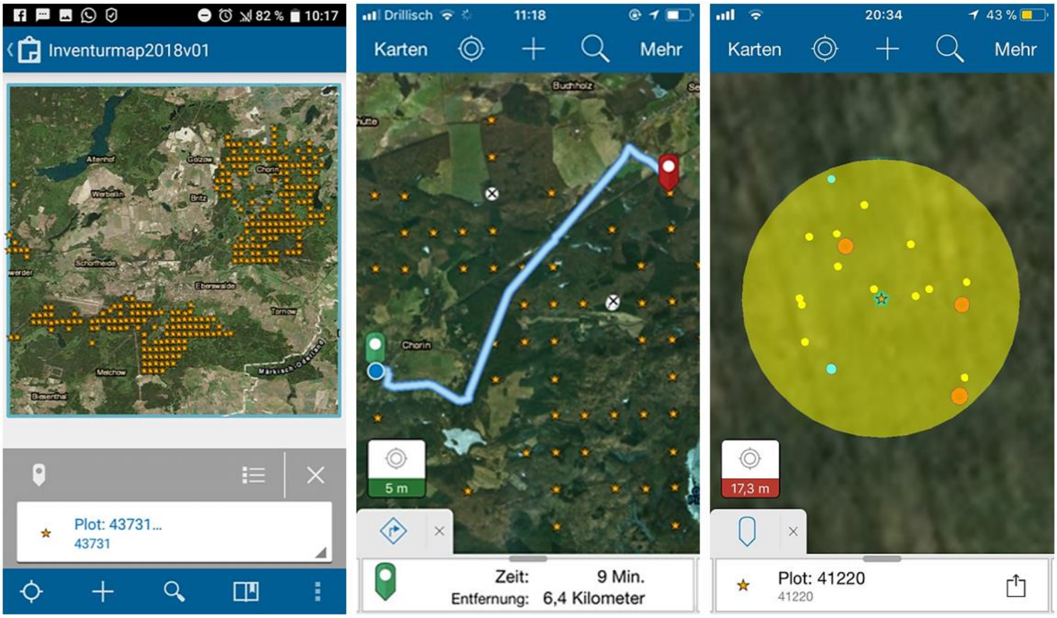


Figure 6: ESRI ArcGIS Online collector app screenshots of student fieldwork.
From left to right: Inventory plot overview map, navigation map, and individual plot map with approximate GNSS assisted real-time geolocation of the handheld computer

Applying mobile geospatial technology and using geo-information software in the field such as LBS in a partially self-organized learning environment, both on- and offline, also requires the manipulation of data through analysis and synthesis of datasets (Trautmann et al., 2010; Hall-Wallace and McAuliffe, 2002).

Since mobile networks still offer only weak to fair coverage and narrow bandwidth in rural or remote areas like forests, an off-line mobile application such as the ArcGIS mobile collector app is essential for supported mobile data collection.

6 Monitoring and Evaluation

Learning is decoupled from the lecture hall and put into a work-related context that uses digital media, in order to increase students' motivation and relevance from their future careers. Professional, conceptually methodical and correctly presented results are a strong indicator of students' successful learning. The educational forest inventory datasets produced in the students' fieldwork form part of the evaluation of their learning progress. The degree of digital and methodological innovation in their project work also indicates the students' ability to transfer knowledge and skills.

Reviewing the results obtained over the course of two years, the data and project reports presented reveal that a number of students have benefitted to an exceptional extent from this module (Figures 7 and 8). Their reports and data surpass expectations in terms of display and accuracy, and the level of reflection. For most students, the report indicates that their understanding of geospatial information and forest inventory has increased. However, reviewing the results does not pinpoint why understanding increased. Here a gap exists between module design, didactics and indications of learning progress. Other reports with less qualitative results indicate a digital divide among the students. The assumption that LBS and AR would engage the majority did not turn out to be true.

In order to gather empirical evidence, a survey was designed to investigate students' level of content uptake and to identify obstacles to applying digital data collection independently in the field. In 2018, an online questionnaire was sent to participants on six data-collection courses. Questions related to when the students used the mobile data collection app, with what effect, and any benefits for their GIS project work. Despite efforts on our part, the response rate remained low, at 25 % (n= 54). The majority of those who responded were second-term students who were under 25 years old. Surprisingly, as their age group can be categorized as digital natives, many stated that they had no previous experience of digital learning and geospatial data. 36% answered that working with the ArcGIS Collector and AR tools speeded up their work.

Figures 7 and 8 display empirical results of the student survey.

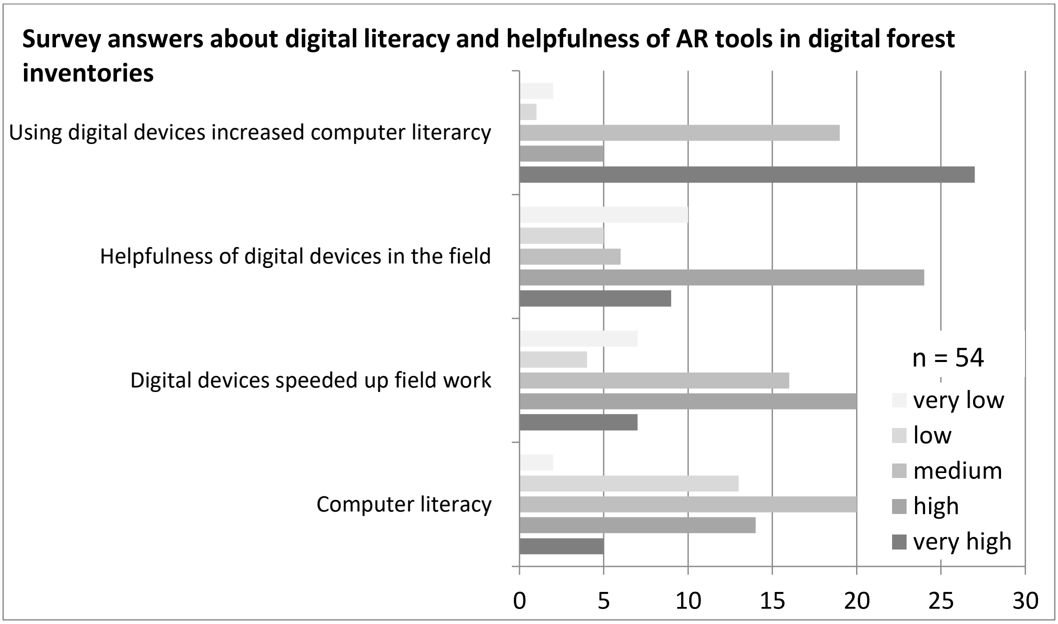


Figure 7: Answers to online student survey in 2019 about computer literacy and helpfulness of AR tools in digital forest inventories

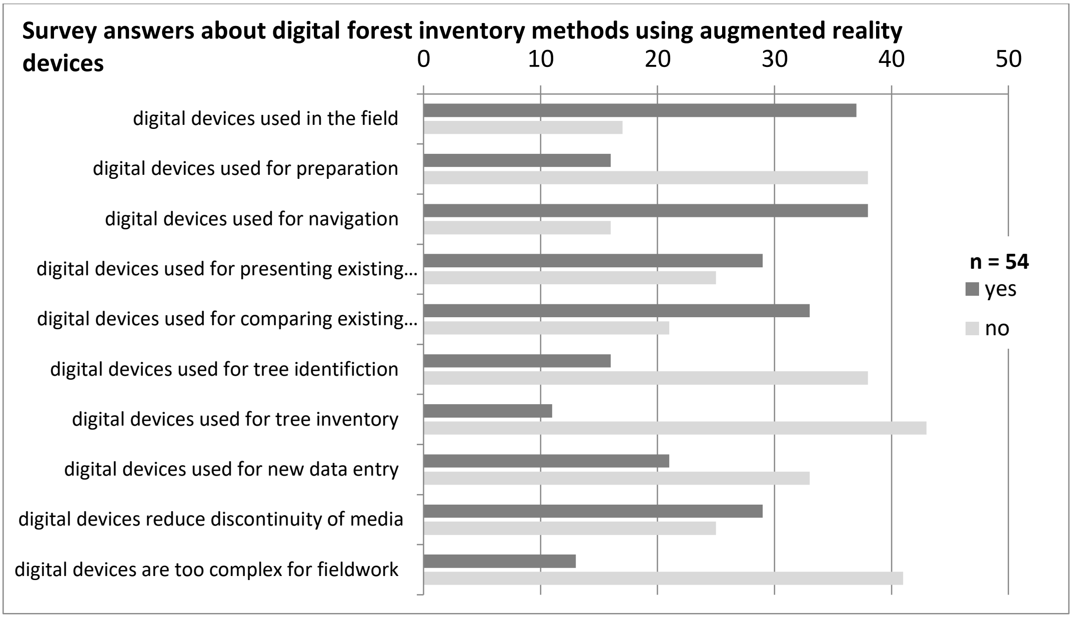


Figure 8: Answers to online student survey in 2019 about digital forest inventory methods using AR devices in 2017–2019.

The integration of the ESRI ArcGIS online Collector app and AR assists students on their particular forest inventory plot by providing previously collected data and other contextual information as 'visual methods of instruction […] to facilitate schema acquisition by novices', as Howarth and Sinton (2011) summarize. A large majority confirmed this, stating that the ArcGIS Collector App was helpful for their fieldwork assignment.

Asked what obstacles they encountered working with the ArcGIS Collector App, respondents gave four types of reason:

1. External reasons like poor mobile reception, insufficient storage or server crashes.
2. Inadequate content-related understanding, e.g. of the parameters to be collected.
3. App-related reasons, e.g. 'App is insufficient in the terrain', or 'App is not intuitive enough'.
4. Individual reasons: insufficient knowledge to use and understand the software. Others said that they were 'not technophile' or 'computer freaks'.

These statements reinforce the impression of a digital divide among the students (see Figures 7 and 8). Questioned on the comparison of recent and past datasets, respondents criticized the quality of the data collected by previous student groups. This pinpoints good and accurate results and inaccurate results at the same time, which impacts on the quality of the AR. Given the low number of respondents (n=54), the survey results cannot be interpreted as providing representative answers or directions for curriculum re-design. The opinions gathered can only indicate trends, and voices to be taken into account in future revisions. Finally, because of the qualitative limitations of the survey questions, it is not possible to draw any conclusion as to whether students' digital literacy improved thanks to the positive learning experiences gained from the innovative method.

In regular university evaluations, many students have stated that self-organized learning structures contribute positively to their learning results and increase their motivation to try out e-learning approaches. Reactions of students during the term indicate that the ongoing flipped classroom approach, the fine-tuned learning progress, and the continuous preparation for the examination projects were well received. However, bias due to lecturer–student interactions cannot be ruled out.

7 Discussion and Conclusion

This paper has provided a snapshot of the re-design of a blended learning module that merges topical content with various largely technology-based methods to enhance learning of environmental data collection procedures in a realistic forest inventory context.

Forest inventory and mensuration methods have a strong spatial dimension in stratified plot sampling, geospatial location and attribute data collection of specific forest and ecological parameters (see Figures 1 and 4). GIS is therefore frequently found in forestry curricula (see e.g. Scholz et al., 2018; Arevalo et al., 2010), but a didactical combination of AR and GI-Science tools and methods with forest inventory and mensuration techniques is not widely implemented in higher education curricula, although using virtual reality in technical training is becoming more and more popular (Cochrane, 2016), for example as instruction for operating chainsaws, in flight simulations or in medical school training. However, to the best of our knowledge, only a few studies (e.g. Priestnall et al., 2009; Sommerauer & Müller, 2014 and Antonioli et al., 2014) discuss the use of AR in teaching geo-science or environmental monitoring, or forest inventories specifically, and reason that AR has not yet become mainstream because its implementation requires specific technical and other conditions. Curtis sums up a number of barriers for the use of geo-spatial technology in school education: 'prohibitive costs; limited availability of hardware and software; inconsistent access to computers; limited availability of pre-processed data; little or no technical support; lack of training, teacher collaboration, and lesson planning time; disproportionate demands on teachers' time; limited instructional support; and lack of pedagogy' (Curtis, 2015, p. 25). Most of these limitations equally apply to the use of AR in any curriculum. The authors agree with Curtis that the introduction of AR and mobile learning tools poses a challenge to universities and their teaching staff.

The implementation process delivered several lessons for the authors. Next to the technical and conceptual design challenges, the biggest structural challenge is to integrate such a complex module successfully into the standard lecture plan of a BSc curriculum, because the implementation of such fine-tuned, multi-level blended learning requires support structures at faculty and university level as well as flexibility from all teachers involved. Further, the switch from analogue to digital methods involved different departments at the university, and coordination between technical support, tutors and lecturers is time-consuming. Shared motivation of all staff to implement the blended learning scenario is needed. A joint kick-off workshop or other awareness-raising activities are needed to explain the advantages and demands of the approach as well as the barriers to it.

This blended learning requires strict time management by teachers and students, and challenges students to remain engaged throughout the learning process. At the same time, students who independently choose a different learning pace state the advantages of e-learning materials and self-structured and organized learning environments. The self-organisable learning sequence presented here can be adapted to various student learning-style preferences and learning experiences. Solutions for those students who are lagging behind or who are 'not technophiles' are to intensify support for the group work, or to introduce stronger facilitation of peer-to-peer learning sessions.

The implementation phase identified problems working with the mobile devices. Tablets and software for data collection need more set-up time than paper and pencil. The availability and number of mobile devices are critical to learning outcomes – old devices with little memory or old operating systems hamper data collection. As rugged tablets are relatively expensive and not available everywhere, the principle „bring you own device' might solve problems in the future. As the innovation cycles of IT gadgets are short, future generations of students will probably not encounter the same problems as the students during the last two years.

An interesting side-effect of this innovation is the continuous re-inventory of data at the same inventory points: this module continually validates and improves the empirical inventory data quality. The errors encountered in the database facilitate a debate around data quality, and in the long run they will serve to improve data quality.

Comprehensive spatial and attribute data processing of forest inventory parameters with geospatial references to discrete inventory points enables students to model and simulate certain forest growth, yield and stand management scenarios. The processing also allows them to use spatial data analysis methods such as geostatistical interpolation. The continuous re-collection of data over the years allows change detection analysis at inventory plots, for example as the topic of a research degree.

The integration of several learning approaches enhanced with mobile computing techniques remains a challenging exercise. However, given the relevance to the sector and the future employability of graduates, implementing further improvements to the module will be a worthwhile exercise.

Acknowledgements

The development and implementation of this module was an intensive, iterative design process supported by Ms. Mirella Zeidler, geospatial data manager at HNEE. Ms. Gnilke, Mr. Lindenberg and Mr. Krause, graduates from the HNEE, supported the development and implementation of the ESRI-online inventory database.

Mr. Kindermann and Dr. Körner from the LFE-LFB provided the original forest inventory plot database and supported the initial data collection.

Piloting the new approach was supported under an Innovative Teaching Fund of the HNEE (ILL 15-18), and by funding from the federal state government of Brandenburg.

References

Adams, Anne; FitzGerald, Elizabeth and Priestnall, Gary (2013). Of catwalk technologies and boundary creatures. *ACM Transactions on Computer-Human Interaction* (*TOCHI*), 20(3), p.1-16. Retrieved from: http://oro.open.ac.uk/35323/1/TOCHI%20submission2.pdf. 11.07.2019

Antonioli, M., Blake, C., & Sparks, K. (2014). Augmented reality applications in education. *Journal Of Technology Studies, 40*(2), 96-107.

Arevalo, Javier, et al. (2010). Market-relevant competencies for professional foresters in European graduate education, *International Forestry Review* 12(3).

Balog, A. & Pribeanu, C. (2010). The role of perceived Enjoyment in the students' acceptance of an augmented reality teaching platform: A structural equation modelling approach. *Studies in Informatics and Control*, 19(3), 319–330.

Clark, A.M. et al. GIS (2007). Pedagogy, Web-based Learning and Student Achievement. *Journal of Geography in Higher Education*, Vol. 31, No. 2, 225–239

Cochrane, T. (2016) Mobile VR in Education: From the Fringe to the Mainstream. International Journal of Mobile and Blended Learning 8(4).

Curtis, Mary D. (2015). 'Analyzing the diffusion of geospatial technologies as instructional tools in high school geography education'. PhD dissertation Texas State University, Retrieved from: https://pdfs.semanticscholar.org/b6ee/28fb513ddab88170b3a018d950a94afb18d5.pdf 11.07.2019

De Witt, C.& Sieber, A. (Eds.) (2013). Mobile Learning. Potenziale, Einsatzszenarien und Perspektiven des Lernens mit mobilen Endgeräten. Wiesbaden: Springer DOI 10.1007/978-3-531-19484-4.

Dunleavy, M. & Dede, C. (2014). Augmented reality teaching and learning. In: Spector, M., Merrill, D., Elen, J. & Bishop, M. J. (Eds.), *Handbook of research on educational communications and technology* (pp. 735–745). New York: Springer.

ESRI CANADA (2017). Smart Digital Strategies for Sustainable Forest Management, 2017: https://resources.esri.ca/ann-stories/smart-digital-strategies-for-sustainable-forest-management

Goff, E.E., et al. (2018). Applications of Augmented Reality in Informal Science Learning Sites: a Review. *Journal of Science Education and Technology* 27: 433. https://doi.org/10.1007/s10956-018-9734-4.

Goldstein, D. & Alibrandi, M. (2013). Integrating GIS in the Middle School Curriculum: Impacts on Diverse Students' Standardized Test Scores, *Journal of Geography*, 112(2). doi: 10.1080/00221341.2012.692703

Hall-Wallace, M. K. & McAuliffe, C. M. (2002). Design, implementation, and evaluation of GIS-based learning materials in an introductory geoscience course. *Journal of Geoscience Education, 50*, 5–14.

Howarth, J. T. & Sinton, D. (2011). Sequencing spatial concepts in problem-based GIS instruction: Procedia Social and Behavioral Sciences 21, 253–259.

Koltay, Tibor (2011). The media and the literacies: media literacy, information literacy, digital literacy. Media, Culture & Society 33 (2) 211–221. https://DOI: 10.1177/0163443710393382.

Kopp, M.; et al (2016). Entwicklung von 'eDidactics': Ein Fortbildungsprogramm für den Einsatz von Technologien in der Hochschullehre. Springer Wiesbaden 2016. Doi: 10.1007/978-3-658-13738-0_16.

Kumar, P. et al. (2019). Applications and Challenges of Geospatial Technology. Potential and Future Trends. Springer. DOI: https://doi.org/10.1007/978-3-319-99882-4.

Lambach, D. et.al. (2017). Inverting the large lecture class: active learning in an introductory international relations course. *European Political Science*16: 553. https://doi.org/10.1057/s41304-016-0078-3

MaKinster, J.; Trautmann, N.; Barnett, M.: (2014). Teaching Science and Investigating Environmental Issues with Geospatial Technology, https://doi.org/10.1007/978-90-481-3931-6

Moallem, M., et.al. (eds). (2019). The Wiley Handbook of Problem Based Learning. John Wiley & Sons, Inc.https://doi.org/10.1002/9781119173243.ch11

Morgenroth, J.& Visser, R. (2013). Uptake and barriers to the use of geospatial technologies in forest management. *New Zealand Journal of Forestry Science*. 43:16. Retrieved from: http://www.nzjforestryscience.com/content/43/1/16 11.07.2019.

Priestnall, Gary et al: (2009. A student-led comparison of techniques for augmenting the field experience. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.372.3026&rep=rep1&type=pdf 11.7.2019

Rathmell, L. (2018).). Augmented reality app launches for landscape designers, 2018. Lawn & landscape Market Leadership. https://www.lawnandlandscape.com/article/ll-032718-augmented-reality-App-for-landscape-design-build-yard/.

Riedel T., Hennig P., Kroiher F., Polley H., et al. (2017). Die dritte Bundeswaldinventur (BWI 2012). Inventur- und Auswertemethoden, 124 S

Rychen, D.S., Salganik, L.H. (2003). A holistic model of competence. In: Rychen & Salganik (eds) Key competencies for a successful life and a well-functioning society. Göttingen: Hogrefe & Huber.

Scholz, J. et al. (2018). Digital Technologies for Forest Supply Chain Optimization: Existing Solutions and Future Trends. *Environmental Management* 62:1108–1133. https://doi.org/10.1007/s00267-018-1095-5

Seipold, J. (2013). Mobiles Lernen – Systematik, Theorien und Praxis eines noch jungen Forschungsfeldes. In: De Witt, C.& Sieber, A. (Eds.).). Mobile Learning. Potenziale, Einsatzszenarien und Perspektiven des Lernens mit mobilen Endgeräten. Wiesbaden: Springer. DOI 10.1007/978-3-531-19484-4. P. 28 -54.

Sommerauer. P. & Müller, O. (2014). Augmented reality in informal learning environments: A field experiment in a mathematics exhibition. In: *Computers & Education*, doi:10.1016/j.compedu.2014.07.013.

Trautmann, N.M. & MaKinster, J.G. (2010). Flexibly Adaptive Professional Development in Support of Teaching Science with Geospatial Technology. *Journal of Science Teacher Education* 21: 351-370. https://doi.org/10.1007/s10972-009-9181-4.

Veas, E., Grasset, R., Ferencik, I. et al. (2013). Mobile augmented reality for environmental monitoring Personal and Ubiquitous Computing (2013) 17:1515–1531, https://doi.org/10.1007/s00779-012-0597-z.

GI_Forum 2019, Issue 2
Page: 144 - 152
Short Paper
Corresponding Author:
friedrich.barnikel@awg.musin.de
DOI: 10.1553/giscience2019_02_s144

Describe! Analyse! Act! Geomedia and Sustainability: Results from a European School Project

Friedrich Barnikel[1], Floris Willems[2] and Robert Plötz[3]

[1]Landeshauptstadt München, Germany
[2]OLVP Sint-Niklaas, Belgium
[3]Städt. Adolf-Weber-Gymnasium München, Germany

Abstract

Digital geomedia empower students not only to describe features of their environment but also to help change it. Geoscience education may therefore help students claim their rights as citizens for a more sustainable future. This paper shows results from a European project financed through the Erasmus+ funding scheme. It is not designed to contribute to the scientific development within spatial education. Rather, it is meant to serve as a best practice example for teachers in Europe for how to connect different school subject areas within one project, in order to describe, analyse and help promote spatial citizenship, largely through the use of geomedia.

Keywords:

GIS, Geography, digital maps, sustainability, spatial citizenship

1 The European dimension of Erasmus+

Erasmus+ was designed as a funding scheme to support activities in the fields of education, training, youth and sport in Europe (https://eacea.ec.europa.eu/erasmus-plus_en). Schools applying for financial support are encouraged to cooperate with schools from other European countries.

In the project discussed here, for the Erasmus+ call for 2016–2018, the German Municipal Adolf-Weber-Gymnasium in Munich (AWG) sought cooperation with schools in Oulu, Finland (Oulun Lyseo), Sint-Niklaas, Belgium (OLVP), Loulé, Portugal (Escola Secundária de Loulé), and the First Language School in Varna, Bulgaria. The underlying idea was to cover the topic 'Living in a smart environment 2030 – Chances and challenges' ('LiSE') with schools from different parts of Europe: our partners were from the northeast (Finland), southeast (Bulgaria), southwest (Portugal), and centre (Belgium and Germany) of Europe. Our main objective was to cover the topic 'smart future', mainly by using geomedia applications, with the support and participation of many different school departments (art, languages etc.), having learned from the results of our previous European project (see Barnikel & Plötz 2015).

2 Our project 'Living in a smart environment 2030 – Chances and challenges'

One crucial product were to be digital maps, the use of which we had already practised in earlier projects and courses (e.g. Plötz & Barnikel 2015). Goodchild's famous call for a fourth 'R' (2006), following the quip on Reading, Writing and Arithmetic, was to be a central demand within our work with students (the fourth 'R' being Spatial Literacy). Even though the challenges for schools in general when implementing modern cartography are well known (see Donert 2009 or Heiken & Peyke 2007), many positive results from school projects in different disciplines have already been published (e.g. Plötz 2015 or Ellbrunner, Barnikel & Vetter 2014).

The description of the situation in a given area (e.g. around a school or in a particular neighbourhood) can easily be made using GI systems and simple mapping tools (like ArcGISs online or Google MyMaps). These maps can illustrate opportunities and problems in certain areas, but they can also be a starting point for participating in changing the environment. (For first results of this undertaking, see Barnikel, Anttila-Muilu & Pereira 2017.)

The 'smart city' is part of the 'smart environment', integral to which is addressing challenges for the future. Technocratic visions of the future (so-called 'smart' visions) tend to rule out the improvement of social connections (Olsen 2016), which needs, of course, to be addressed within education. But all in all, the biggest challenges for the future are going to be climate change (McCann 2017) and answering the almost romantic question: 'What is the smart city in which we want to live going to be like?' (see Vanolo 2014 after McCann 2017). This question was by and large the nucleus around which we started our work. We concentrated not only on the technological aspect of being 'smart', but also on fields like schools, public transport, living conditions, migration and inclusion, since we also wanted to contribute to changing our environment for the better.

3 ‘Going Green’ as the most important challenge for the future

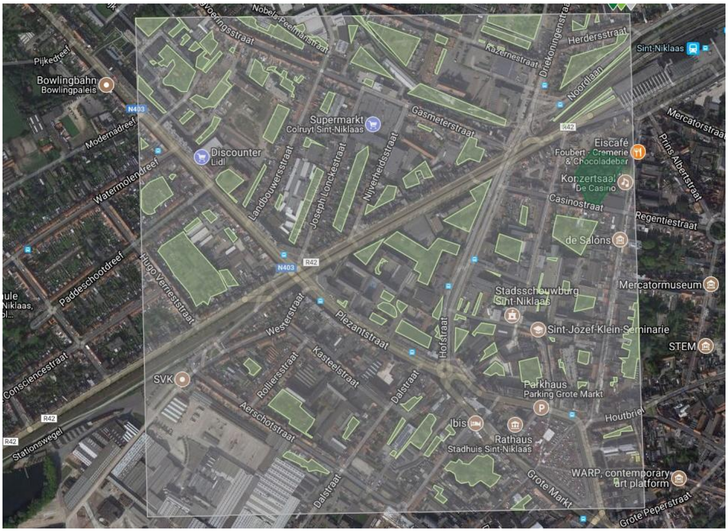


Figure 1: Early version of green spaces around the OLVP in Sint-Niklaas, Belgium (S. Berthels with Google MyMaps/Google Earth)

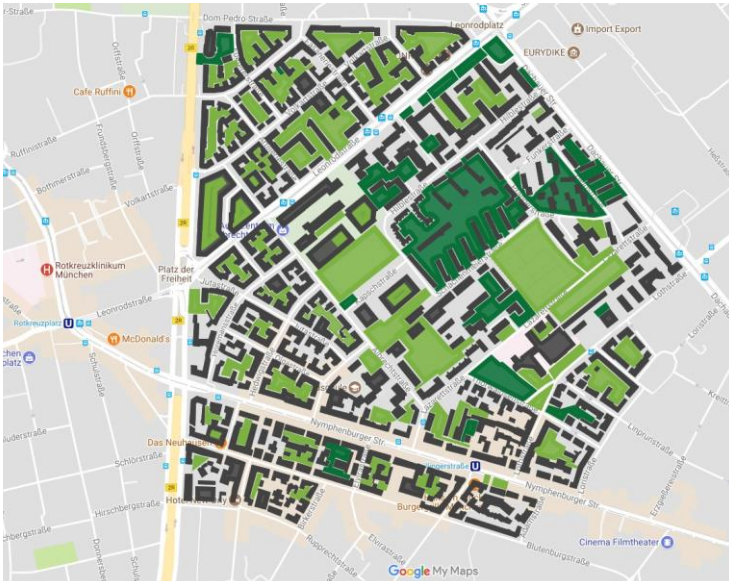


Figure 2: Green spaces around the AWG in Munich, Germany. (For colour coding, see text; compilation M. Kubitsch with Google MyMaps.)

Figures 1 and 2 show ‘green spaces’ around two of the participating schools. Dark green shows public green areas, to be used for recreation (parks, playgrounds etc.); light green is used for green spaces without recreational functions (e.g. flower beds, trees lining streets etc.); and grey is used for public or private ground without plants (houses, streets, paths etc.). The underlying idea was that green spaces contribute to the individual's well-being, help reduce pollution, and support us in our need to relax (see Blessi & al. 2015). The mapping was done by the students themselves (Analyse!) after some collective fieldwork (Describe!) which showed them the desirability of participation (Act!).

Green spaces generally have one of two origins: established by city councils, or the history of the area. After basic cartography had been carried out, citizen–government interaction would be the next step towards taking action in greening urban spaces (see also Tapia-McClung 2016). No matter whether this greening is done in an orderly fashion and as part of learning how to create a sustainable environment (Blanchard & Cmiel 2012), or applied freestyle as e.g. guerilla gardening (Hardman & al. 2018), creating green spaces is neither difficult nor limited to decision-makers anymore: 'The smart city is fundamentally about redefining and reconfiguring relations within and between people, their community, government and the urban environment' (Ho 2017, p. 3103).

4 Participation as a basic need

Zeile & Resch (2018) state that current urban planning is still dominated by the same group of decision-makers, even though the public appears to be more involved now than in the past: 'In many cases, urban planning processes take place in offices and behind desks. They do not meet the needs of citizens and do not take digital forms of participation into account' (Zeile & Resch 2018, p. 345, following thoughts of Brenner & al. 2012). Gryl & al. (2017, p. 6) take this thought even further:

The aim of Spatial Citizenship is to enable every citizen to maturely appropriate public spaces and participate in spatial formation processes with the help of (digital) geomedia technologies while taking part in public spatial decision-making processes. Maturity, here, refers to the ability to act autonomously, to reflect critically upon given (e.g. social, policital, economic) structures and processes; it also refers to being capable of self-determination and, if necessary, to being able to act in opposition to existing, anti-democratic tendencies.

Within the diversity of interests in the classroom (curriculum, subject, students' individual needs…), political education is not always a priority, and in some cases it is not accorded any class-time, especially in natural sciences, at all. In many cases, because of the constraints of the classrom context, working with geomedia cannot go beyond the odd basic exercise and is not intended to fulfil requests for theoretical approaches made by theoreticians (as in Gryl & Naumann 2016); the projects themselves remain in the classroom and are not taken 'outside' into any real-life context. But if the use of geomedia in the classroom does actually go some way towards fulfilling these requests, there is a basis for true participation and the project may result in higher levels of spatialawareness. (One example of a basic classroom-based exercise within our project would be the planning of a new city quarter in Munich for roughly 30,000 inhabitants, using 'smart homes'; see Figure 3).

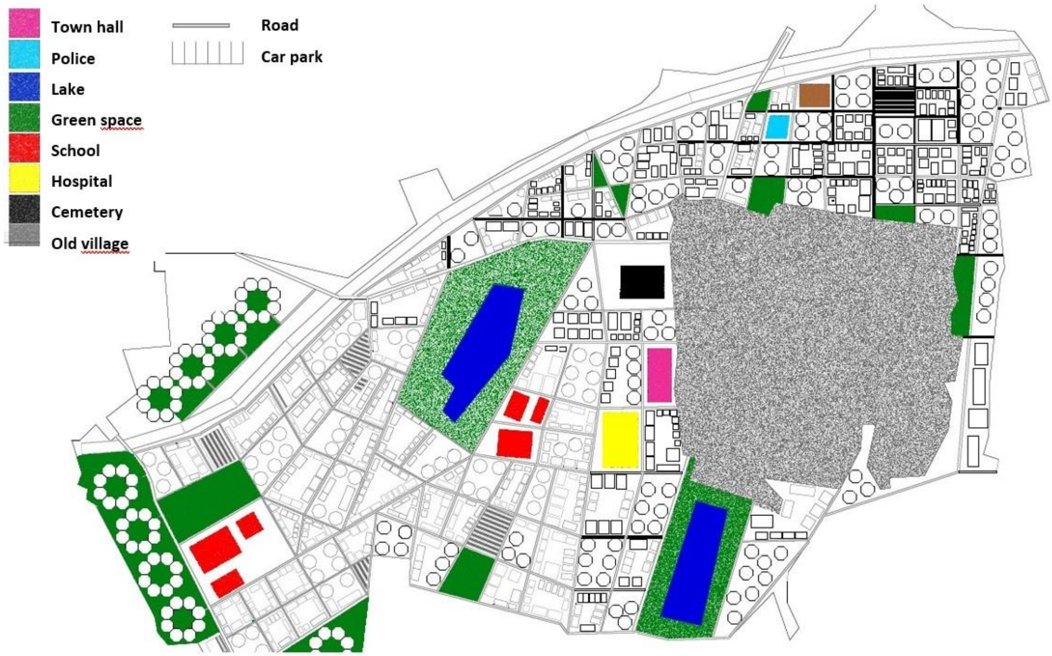


Figure 3: Plan for Feldmoching, a new city quarter in the north of Munich (P. Mayer using Vectorworks)

5 Participation within the LiSE project

Figure 4: Selfie with the Lord Mayor of Munich, Dieter Reiter, handing over the Charta of Varna (B. Mäder)

During the project meeting in Varna, Bulgaria, students designed workshops in which they discussed demands for the future, to be put forward to the mayors of their cities (Figure 4). These demands were grouped into six fields: 1) Social Equality; 2) Leisure, recreation and health; 3) Education; 4) Public transportation; 5) Energy and environment, and 6) Politics. The two-page list of demands was named (after Magna Charta) the 'Charta of Varna' (https://t1p.de/wib7). Further issues were discussed with a member of the European Parliament in Varna in 2017, and with five politicians from German parties during a panel discussion in Munich in 2018 in front of all senior classes of the AWG. In this way, by confronting decision-makers with their requests, the students took the vital step from description to participation in the political context as mature citizens. The students were also asked to officially participate in city planning on two occasions. First, they took part in a workshop on future means of public transportation, initiated by the City Council of Munich. They also took part in a city planning project from scratch: near the school, a large area is to be completely rebuilt, after the demolition of old barracks, and is to become a creative quarter for the City of Munich. In a network meeting, the new inhabitants and users of the area got to know each other and the AWG was invited. Our students were the only teenagers on the scene and the planners were very interested in their ideas (Figure 5). Both city-planning projects are on-going.

Figure 5: Planning a new city quarter where once barracks stood (R. Plötz)

6 Do-It-Yourself: Planting Trees

European cities keep on growing, and the physical and mental impacts on the health of citizens is obvious. The assertion that clean air and a natural environment are good for wellbeing can be regarded as common sense, and there is plenty of scientific evidence to back this up. The impact of stress on wellbeing and health as result of a non-natural environment needs no further explaining, and its impact is greater on those who are more vulnerable.

Growing awareness of the impact of air pollution is resulting in a wave of civil activism all over Europe. Belgium can serve as an example with 'De luchtzaak' (*the air affair*), which tries to raise awareness by focusing in particular on the air quality around schools. Results of a satellite survey show that Flanders is a highly polluted area in which schools are especially vulnerable because they are primarily located in areas with dense traffic. The scale of the problem became clearer when the results of the largest-ever crowdfunded survey on air pollution in Belgium were communicated in September 2018. (The survey was carried out by 20,000 civilians during the month of May 2018, https://curieuzeneuzen.be/). Also in 2018, Harald Welzer, a German social psychologist, wrote in the German edition of *National Geographic* that the only way to mitigate climate change thoroughly was to plant trees all over the globe (Welzer 2018). It is in this context of grassroots organizations, guerilla movements and the obvious that our students come in as current stakeholders and future decision makers.

A school's environmental and health policies can provide learning opportunities for students and chances for them to participate, helping the school to place its focus on young people's health and wellbeing. Student participation will most probably start on an observational level, or at the planning level (Describe!). Last but not least, student participation in environmental school policy can also be an essential part in democratic education, as long as it is firmly rooted in the curriculum (Act!). Such involvement fosters plenty of learning opportunities to help build and strengthen modern democracy, which by nature is not only political but also civic. In bypassing certain strict guidelines relating to the curriculum and educational policies, exchange programmes or international school projects like the Erasmus+ programme can contribute by offering a platform for unusual activities and thinking 'outside the box'.

As a result of the surveys about green spaces around the schools and the data presented by governments and non-governmental organisations on air pollution and climate change, the members of the LiSE project decided to take action and encourage students to plant trees in their respective environments, usually in the schools' surroundings (Figures 6 & 7). While the schools in Loulé and Munich have so far contributed just one tree to their respective school gardens, the schools in Oulu and Varna were able to plant several trees in their community, and the school in Sint-Niklaas managed to secure funding for 1,200 trees in the vicinity. As a follow-up of our project, the Portuguese students have helped plant 5,000 trees in the voluntary campaign 'Operação Montanha Verde/Green Mountain Operation' in Portugal.

Figure 6: Planting a LiSE tree in Loulé, Portugal (D. Fernandes)

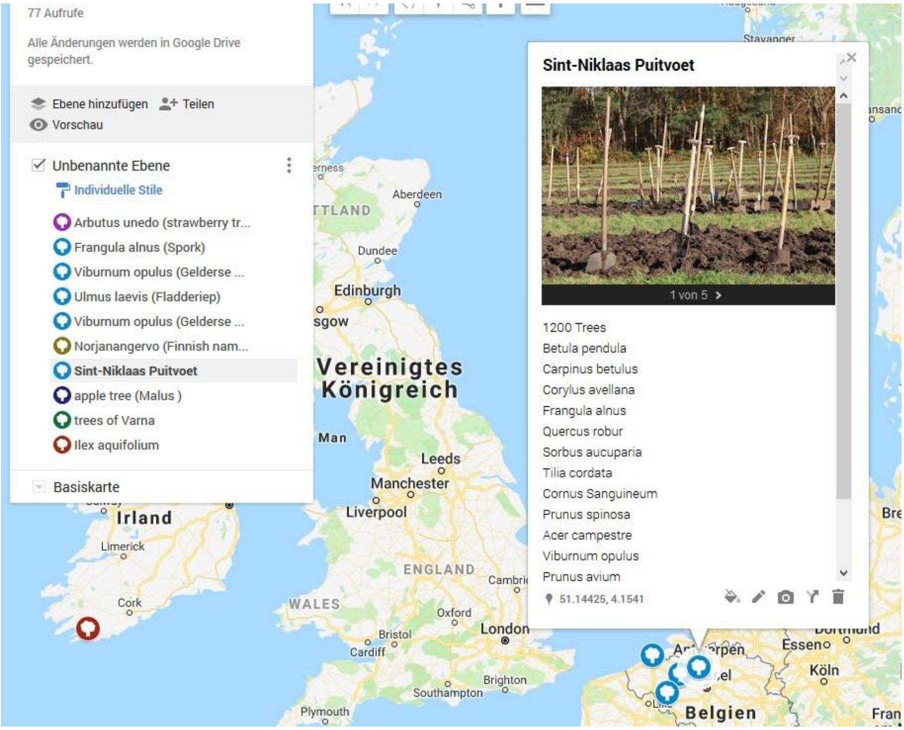


Figure 7: Tree Map as an ongoing project (compilation M. Kubitsch with Google MyMaps)

7 Conclusion

The project comprised various important aspects of geography education:

- Learning different digital mapping techniques (e.g. working with Google MyMaps and Vectorworks) while looking at green spaces around schools, food origin and waste, barrier-free public spaces in cities, origins of clothing, and designing new residential areas (Describe!)
- Learning spatial and sustainable thinking at different scales: these included green areas around schools, forests in each participating country and in Europe, accompanied by tree-planting, solar cooking, food and clothes awareness projects (Analyse!)
- Learning how to put geomedia to use when transforming analyses into political and societal action. (Act!)

However, the most important overall achievement of the project was to promote spatial and sustainable thinking among students and teachers in general. The project was surprisingly successful with, for example, the art and language teachers who took part in the project: they started to find 'hidden geographies' in their own subjects, too.

References

Barnikel, F., Anttila-Muilu, S. & Pereira, H. (2017). Urban Studies in Secondary Education – from Description to Participation. *Urban Design*, *1*(1), 12-22.

Barnikel, F. & Plötz, R. (2015). The Acquisition of Spatial Competence – Fast and Easy Multidisciplinary Learning with an Online GIS. *European Journal of Geography*, *6*(2), 6-14.

Blanchard, D. & Cmiel, B. (2012). The 'Greening' of Campuses in Higher Education and K-12 Schools: The Value of Experiential Learning for Sustainability. *Research in Geographic Education*, *1&2*, 55-76.

Blessi, G., Grossi, E., Pieretti, G., Ferilli, G. & Landi, A. (2015). Cities, the Urban Green Environment, and Individual Subjective Well-Being: The Case of Milan, Italy. *Urban Studies Research*. doi:10.1155/2015/137027.

Brenner, N., Marcuse, P., & Mayer, M. (Eds.) (2012). *Cities for people, not for profit: Critical urban theory and the right to the city*. London: Routledge.

Donert, K., (2009). Benchmarking GIS – a Charter for European Education. In T. Jekel, A. Koller & K. Donert (Eds.), *Learning with Geoinformation IV*, 2-11.

Ellbrunner, H., F. Barnikel & Vetter, M. (2014). 'Geocaching' as a method to improve not only spatial but also social skills – Results from a school project. In R. Vogler, A. Car, J. Strobl & G. Griesebner (Eds.) *GI_Forum 2014 – Geospatial Innovation for Society*, 348-351.

Goodchild, M. (2006). The Fourth R.? Rethinking GIS Education. *ArcNews Online, 28*(3).

Gryl, I., Könen, D. & Pokraka J. (2017). Limits of Freedom – Defining a Normative Background for Spatial Citizenship. *GI_Forum 2017, 2*, 3-12.

Gryl, I. & Naumann, J. (2016). Mündigkeit im Zeitalter des ökonomischen Selbst? Blinde Flecken des Geographielernens bildungstheoretisch durchdacht. *GW-Unterricht, 141*(1), 19-30.

Hardman, M., Chipungu, L., Magidimisha, H., Larkham, P., Scott, A., & Armitage, R. (2018). Guerilla gardening and green activism: Rethinking the informal urban growing movement. *Landscape and Urban Planning*, 6-14. doi:10.1016/j.landurbplan.2017.08.015.

Heiken, A. & G. Peyke 2007. Einsatzmöglichkeiten von Google Earth und einer GI- Teachware im Schulunterricht. In T. Jekel, A. Koller, & J. Strobl (Eds.) *Lernen mit Geoinformation II*, 127-136.

Ho, E. (2017). Smart Subjects for a Smart Nation? Governing (smart)mentalities in Singapore, *Urban Studies, 54*(13), 3101-3118. doi:10.1177/0042098016664305.

McCann, E. (2017). Governing urbanism: Urban governance studies 1.0, 2.0 and beyond. *Urban Studies, 54*(2), 312-326. doi:10.1177/00420980166570046.

Olsen, C.S. (2016). Performing Urban Archives – a starting point for exploration. *cultural geographies, 23*(3), 511-515. doi:10.1177/1474474016638048.

Plötz, R. (2015). Assessing History with Mathematical Tools: The Use of GI Systems in Social Sciences. *American Journal of Geophysics, Geochemistry and Geosystems, 1*(3), 100-104.

Plötz, R. & Barnikel, F. (2015). Erasmus+/Comenius-Cooperation of European Schools Using GIS Applications to Assess 'Life in Our Neighbourhood – Life in Our City'. In R. Vogler, A. Car, J. Strobl & G. Griesebner (Eds.) *GI_Forum 2015 – Geospatial Innovation for Society*, 320-323.

Tapia-McClung, R. (2016). Collective Mapping to Support Citizen-Government Interactions Using a Digital Platform. *GI_Forum – Journal for Geographic Information Science, 2*, 147-156. doi:10.1553/giscience2016_02_s147.

Vanolo, A. (2014). Smartmentality: The smart city as disciplinary strategy. *Urban Studies 51*(5), 883–898.

Welzer, H. (2018). Wald für die Welt. *National Geographic, 1*, 18-19.

Zeile, P. & Resch, B. (2018). Combining Biosensing Technology and Virtual Environments for Improved Urban Planning. *GI_Forum 2018, 1*, 344-357. doi:10.1553/giscience2018_01_s344.

GI_Forum 2019, Issue 2
Page: 153 - 162
Short Paper
Corresponding Author:
claudia.lindner@rub.de
DOI: 10.1553/giscience2019_02_s153

Expanding STEM Education in Secondary Schools: An Innovative Geography-Physics Course Focusing on Remote Sensing

Claudia Lindner, Christina Müller, Henryk Hodam, Carsten Jürgens, Annette Ortwein, Johannes Schultz, Fabian Selg and Andreas Rienow
Ruhr Universität Bochum, Germany

Abstract

A new elective school subject called 'Geography-Physics' was developed by the Universities of Bonn and Bochum in cooperation with a German high school. With a focus on remote sensing, the modules of this STEM subject convey information, and present methodology and applications. There are two main sections: the physics of remote sensing, including both mathematics and computer science, and the geographic applications. GIS is a major part of the exploitation of Earth Observation data, but the use of GIS and EO data is not feasible in school lessons due to financial and time constraints. Instead, small specialized GIS tools with embedded EO imagery are used. The tools were developed by two projects, FIS and Columbus Eye/KEPLER ISS, and evaluation and meetings with experts were conducted in close cooperation with the partner school. The first 2-year course of the new subject was completed in summer 2018. The teachers implementing the course have since re-evaluated their concept and revised the syllabus to enhance applicability in professional contexts, to reduce redundancies with other subjects, and to ensure that the overall content fits into the allotted number of teaching hours. The pupils also evaluated the materials and the subject.

Keywords:

education, remote sensing, learning environments, ISS, e-learning

1 Introduction

Germany is facing an increasing shortage of STEM professionals in all areas and at all education levels. In October 2018, there were 337,900 more job vacancies than available qualified personnel (German Economic Institute, 2018). The figures include a shortage of STEM teachers in most German schools. Other contributing causes are: pupils' lack of motivation, which has a major influence on their study and training choices; frequently inadequate school IT infrastructure, although IT skills are crucial for modern scientific and technical work; the fact that development of appropriate teaching concepts which would be beneficial to pupils is not yet complete. Schools compensate with optional classes and extracurricular participation in STEM competitions (German Economic Institute, 2018).

The Gymnasium Siegburg Alleestraße (GSA, a Gymnasium being an academically oriented secondary school) was awarded the title of 'STEM-friendly school' in 2018, thanks among other things to its introduction of the new STEM subject 'Geography-Physics' in 2015 and its cooperation with Bonn and Bochum universities, where the projects FIS (Fernerkundung in Schulen [Remote Sensing in Schools]) and KEPLER ISS (formerly Columbus Eye, CE) use satellite- and ISS-borne remote sensing and earth observation (EO) data relevant to all STEM subjects. These projects use analogue and digital learning materials that are designed to run on older school computers or pupils' smartphones. The main goal of the cooperation is closer exchanges between educational applications and university research that yield benefits for the projects, the school and especially the pupils. By using real data and image processing techniques, the lessons incorporate recent scientific findings and introduce the pupils to scientific processes.

2 Education portals on Remote Sensing

The FIS and KEPLER ISS projects provide extensive digital and analogue learning materials featuring remote sensing data and methods on their websites fis.rub.de and columbuseye.rub.de. The materials are interactive, interdisciplinary and intermedial, and apply a scientific-preparatory, medium-constructivist approach (Goetzke et al., 2013, Ortwein et al. 2017).

The FIS portal covers 12 topics in geography, 4 in biology, 3 in physics, 2 in mathematics, and 1 in computer science. Furthermore, research tools such as an encyclopaedia, an image gallery, and an interactive learning module about satellite systems can be accessed. Analysis tools with embedded EO imagery include a MeteoViewer, NDVI and image difference calculators, and an RGB classifier. Recently, some teaching units have been revised and updated to include data gained through the Copernicus programme and the Sentinel missions (Lindner et al., 2018).

The KEPLER ISS/CE portal offers 5 topics in geography, 3 in physics, the ISS live stream, and an archive of ISS videos, some of which have been enhanced and annotated. All materials come with tasks and information for pupils along with sample solutions and background information for teachers. The topics are selected from the curricula of the German Federal States, but since these are highly diverse, not all learning modules can be applied in all Federal States. Recently, augmented reality (AR) applications that merge regular worksheets with virtual data from satellites and ISS sensors have been implemented.

The new elective subject Geography-Physics at GSA uses a selection of modules and supporting materials from both sites, thus implementing Remote Sensing as a subject in terms both of theory and of its applications.

3 The Geography-Physics syllabus

The subject is currently taught in years 8 and 9 (ages 13–15), as an elective subject. The pupils have 3 hours of classes per week, which is more than they receive in physics (2h/week) or in geography in year 7 (2h/week; geography is not taught in years 8 and 9). The subject expands on the current state curricula for Geography and Physics as individual subjects (MNSFE NRW, 2007, MNSFE NRW, 2008). The syllabus was developed by the geography and physics teachers, who each teach one semester per year of Geography-Physics.

Most lessons are taught on computers, which is necessary for most of the learning modules. All semesters (4 in total) feature a visit to the class by an expert, and an excursion accompanied by an expert. These experts are the projects' scientists, who create the learning materials and have a background in geography and remote sensing. They provide an extended overview of recent research activities relevant to the topics covered in Geography-Physics and answer questions that might go beyond the teachers' knowledge, delving, for example, into astronomy, ESA and NASA missions, programming and work life. Further training sessions for teachers are conducted regularly.

3.1 Semester 8.1

This semester focuses on physical geography. Since geography in the regular syllabus is strongly focused on socio-economic topics and considered part of humanities education (MNSFE NRW, 2007), the elective subject starts with an overview of the wide variety of subject areas within geography and their methods. Among these is remote sensing, which is covered by the FIS materials.

Table 1: Syllabus for Semester 8.1 – Physical Geography

Topic	Modules	Module content
Research Areas in Geography and Geographic Methods	*No FIS or CE modules available for this topic.*	
Uses of Remote Sensing	FIS: analysis tool and encyclopaedia	Methods, application examples, electromagnetic radiation, sensors, types of resolution, image processing, analysis, classification, change detection.
How to create maps from satellite images	FIS: From Satellite Images to Maps	Classification of satellite images using red, green, blue channels.
Geology basics and remote sensing applications of	CE: Archive videos	Various videos including volcanoes, in Kamtchatka, Guatemala, Sicily, Java, …

endogenic processes	FIS: Tsunami – when waves change everything	Classification of satellite images of Sumatra-Andaman tsunami by colour values. Discussion of earthquakes and tsunami generation. Effects on livelihoods.
	Volcano Excursion	Recent advances and local findings in volcano monitoring. Interferometry.

3.2 Semester 8.2

The focus of this semester is on the physics basics of remote sensing. Since there are regular physics lessons in Year 8, the elective subject needs to avoid redundancies and expand theoretical knowledge with applications and methodology, or to include topics outside the regular syllabus.

Table 2: Syllabus for Semester 8.2 – Physics

Topic	Modules	Module content
Electromagnetic Spectrum	FIS: Encyclopedia	Composition of light and colours, radiation interaction, active and passive remote sensing.
	FIS: Tracing the Invisible	Composition of light, infrared, digital experiment on reflection and absorption. Discussion of implications. Digital experiment on false-colour images.
	CE: Atmospheric Scattering	Rayleigh and Mie scattering in earth’s atmosphere. ISS video with and without atmospheric correction.
Remote Sensing Sensors	FIS: Encyclopaedia	Colour detection in Charge-Coupled Devices (CCD) vs. the human eye.
Satellite Orbits	FIS: Research tools: Satellite systems	Satellite orbits: benefits, drawbacks.
	CE: ISS	–”–
	Geocaching excursion	GPS and orbits.

3.3 Semester 9.1

Semester 1 of Year 9 again focuses on physics.

Table 3: Syllabus for Semester 9.1 – Physics

Topic	Modules	Module content
Digital Image processing	FIS: Contrast	Digital Experiment: raster resolution, radiometric resolution, image calculation, histogram stretch, image file formats, point vs. vector data, etc.
Thermodynamics	FIS: Summer in the City	High-resolution thermal images of Berlin in a heatwave; determine heat absorption in different surfaces; apply to everyday problems.
Atmospheric composition	FIS: Research Tools	Composition and stratification of the atmosphere; earth's energy budget.
Radiation budget	*No FIS or CE modules available for this topic.*	
Astrophysics	CE: Earth-Moon system (AR)	Gravitation in the Earth-Moon system; digital experiments on the effect of the Moon on tides.

3.4 Semester 9.2

The final semester of the course focuses on physical geography again.

Table 4: Syllabus for Semester 9.2 – Physical Geography

Topic	Modules	Module content
Weather and Climate	FIS: Analysis tools	Meteorological satellites, weather observation.
	FIS: Atmospheric Circulation	Meteosat 1-day video, cloud patterns, development and relations of cloud and wind systems, convection and advection, global exchange processes.
Exogenic natural disasters	CE: The eye of the Cyclone (AR),	Atmospheric pressure map animations, cross-sections, ISS video. Development and dangers of cyclones.
	FIS: Floods	Dangers of flood to infrastructure; location research using Sentinel-2 true colour, land use map and elevation model for a basic digital flood modelling experiment.
Climate Change	New this year: SNAP tutorial 'Alpine Glaciers'	Introduction to Sentinel Applications Platform, classification of glaciers, vegetation and soil; Change Detection.

The greatest natural disaster, climate change, is discussed in the final part of the course. Now that the pupils know more about physics, measurements and the analysis of atmospheric changes, they can discuss the differences between natural and anthropogenic climate change at a higher level and observe the effects of climate change themselves.

4 Evaluation

4.1 Method

The school is interested to know how pupils react to the new elective subject. The projects' team also need to know reactions to their materials and how to improve them. Thus, the evaluation is performed internally by the subject's teachers with external guidance by the projects' scientists (Schmidt & Perels, 2010). At the very beginning of the course, the pupils' background knowledge is determined, and they fill out a questionnaire at the end of each semester. The assessment is thus summative, but it has formative elements as the content of each semester is adapted in accordance with the results of the previous semester's evaluation. Thus the course content and teaching materials are constantly being improved (Schmidt & Perels, 2010). A partially standardized questionnaire was used because of its high practical relevance and good comparability (Kromley, 2009, Raab-Steiner & Benesch, 2012). Most of the questions are closed and use a rating scale of 1 to 6, which was chosen because of the pupils' familiarity with the German school rating system, which ranges from 1 (very good) to 6 (poor).

4.2 Results

The gender distribution started out with a strong imbalance towards male pupils in 2016. This was reversed in 2017 and has since evened out (see Table 5). Of the pupils who started the course in the years 2016–2018, only 37% had already worked with remote sensing methods. Half of these students were on the 2018 course. However, 58% of those who started the course in 2016–2018 had used satellite imagery at home, usually in the form of Google Maps/Earth or other navigation devices and apps (Lindner et al., 2018). Pupils' expectations included excursions, working with computers (which is rare at GSA), doing practical work applicable to real-life problems, and learning from real scientists about real science and work life.

Table 5: Gender distribution in Geography-Physics

Start Year	Girls	Boys
2016	8	17
2017	10	6
2018	13	10

For the remote-sensing part of the course, the pupils on the 2016–2018 course found the satellite imagery and videos from the ISS quite interesting, and particularly helpful in understanding the topics at hand (see Figure 1). They felt that their expectations had mostly been met (see Figure 2), which is important for an elective subject.

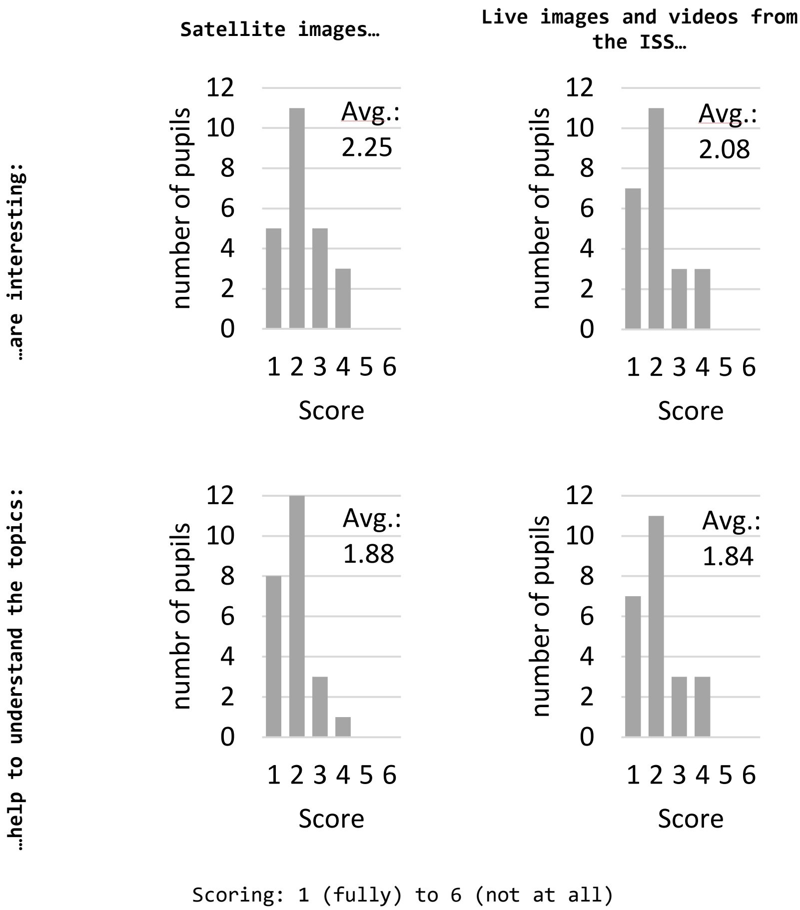


Figure 1: Evaluation of EO materials in school (total no. of pupils: 24, on course finishing in 2018)

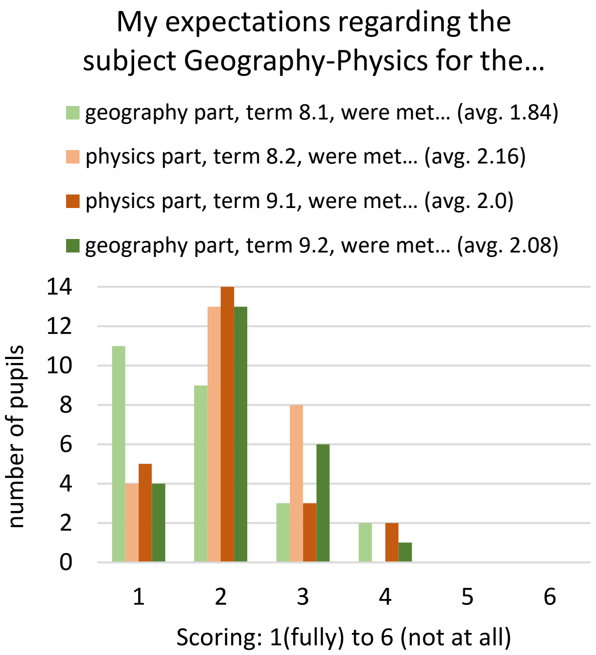


Figure 2: Met expectations of the first Geography-Physics course (total no. of pupils: 24, on course finishing in 2018)

4.3 Discussion

The gender distribution has evened out and gives no indication that pupils are discouraged from taking up the subject due to gender-related issues.

While satellite imagery is already used in everyday life, it is not sufficiently explained in regular classes and it is not much utilized, although pupils consider the images not only interesting but also particularly helpful in understanding complex topics. This indicates the images' usefulness beyond being 'pretty pictures' and suggests significant potential for the extended use of satellite images and quantitative analysis in regular classes.

The pupils accept Geography-Physics well, especially in the first semester. The evaluation of the individual modules shows that the pupils find the content interesting, comprehensible, and applicable (Lindner et al., 2018). This is important for the school to know in order to determine the sustainability of Geography-Physics as an elective subject.

5 Summary and Outlook

The FIS and KEPLER ISS/CE learning modules enrich STEM lessons with topics from physical geography and methodology, especially in remote sensing. They provide free-of-charge, easy-to-use digital experiments for pupils to learn relevant theory and look at applications in other STEM subjects. The modules also, with little preparation time required, allow teachers to integrate motivating real-world applications with otherwise theory-loaded topics.

The new subject Geography-Physics teaches extensively about STEM, combining the physical and methodological sides of geography with the physics, and consequently mathematics and computer science, necessary for remote sensing. The teachers have defined and revised a syllabus for a two-year course in which they continue to work closely with the scientists creating the learning modules, both to improve the materials and to provide pupils with access to recent research and impressions of real-world applications. The two teachers emphasize the additional educational value of this new interdisciplinary subject. The pupils appreciate the subject for its interesting, comprehensive and applicable content using satellite imagery and ISS videos, the excursions, and its expert inputs.

The pupils' evaluation questionnaire is currently being reworked to understand the long-term effects of the course. Furthermore, the bank of teaching resources of FIS and KEPLER ISS/CE continues to be extended by virtual reality materials and Mini-MOOCs to integrate the bird's eye view of satellites and astronauts in everyday STEM lessons.

Acknowledgements

This work was supported by the German Aerospace Center DLR under grants 50JR1701 and 50EE1703.

References

German Economic Institute. (2018). MINT-Herbstreport 2018. Retrieved from https://www.iwkoeln.de/fileadmin/user_upload/Studien/Gutachten/PDF/2018/MINT-Herbstreport-2018.pdf

Goetzke, R., Hodam, H., Rienow, A., & Voß, K.. (2013). Teaching materials, encyclopaedia, easy-to-use image processing - the FIS Learning Portal on remote sensing. In: EARSeL Proceedings, 12(2), 164-173.

Kromley, H.. (2009): *Empirische Sozialforschung (12th edition)*. Germany: Lucius & Lucius.

Lindner, C., Müller, C., Hodam, H., Jürgens, C., Ortwein, A., Schultz, J., Selg, F., Weppler, J., & Rienow, A.. (2018). From Earth to Moon and beyond – Immersive STEM education based on Remote Sensing Data. In: 69th Proceedings of the International Astronautical Congress (IAC), 1-5 October, Bremen, Germany.

MNSFE NRW: Ministry of School and Further Education in North Rhine-Westphalia. (2007). Kernlehrplan für das Gymnasium – Sekundarstufe I (G8) in Nordrhein-Westfalen. Erdkunde. Retrieved from https://www.schulentwicklung.nrw.de/lehrplaene/upload/lehrplaene_download/gymnasium_g8/gym8_erdkunde.pdf

MNSFE NRW: Ministry of School and Further Education in North Rhine-Westphalia. (2008). Kernlehrplan für das Gymnasium – Sekundarstufe I (G8) in Nordrhein-Westfalen. Physik. Retrieved from https://www.schulentwicklung.nrw.de/lehrplaene/upload/lehrplaene_download/gymnasium_g8/gym8_physik.pdf

Ortwein, A., Graw, V., Heinemann, S., Henning, T., Schultz, J., Selg, F., Staar, K., & Rienow, A. (2017). Earth Observation from the ISS in classrooms – from e-learning to m-learning. In: European Journal of Geography 8(3), 6-18.

Raab-Steiner, E. & Benesch, M. (2012). Der Fragebogen. Von der Forschungsidee zur SPSS-Auswertung. (3rd edition) Austria: Facultas.wuv.Universitätsverlag.

Schmitz, M., & Perels, F. (2010). *Der optimale Unterricht? Praxishandbuch Evaluation*. Germany: Vandenhoeck & Ruprecht

GI_Forum 2019, Issue 2
Page: 163 - 179
Full Paper
Corresponding Author:
marcel.vorage@phsalzburg.at
DOI: 10.1553/giscience2019_02_s163

Traffic Noise Education in Secondary Schools: From Basic Understanding to Active Engagement

Marcel Vorage
Salzburg University of Education Stefan Zweig, Austria

Abstract

Chronic exposure to loud noise has detrimental effects on health, subjective wellbeing and concentration levels of both adults and children. Over two million people in Austria reside in areas where traffic noise surpasses the legal threshold for action. Hundreds of schools are also affected. A similar situation is present throughout large parts of the European Union. Because traffic noise can be heard and measured relatively easily, awareness among the general population is high. Publicly funded data collection has taken place based on EU regulations, and reliable noise maps are available online.

This paper aims to provide teachers with multidisciplinary tools to improve their students' understanding of noise. It suggests project ideas for students to choose depending on their strengths and affinities. The ultimate goal is to enable and motivate students to engage in informed spatial citizenship, notably in taking action to help keep exposure to traffic noise at acceptable levels.

Keywords:

traffic noise, education, secondary school, spatial citizenship

1 Introduction

Noise surrounds many of us throughout our daily lives. Although we can get used to the presence of noise, negative health impacts occur if the noise is loud enough and exposure to it is chronic (Basner et al, 2011). In large geographical areas, traffic or transportation noise caused by roads, trains and aircraft is exactly that: chronic and loud. Unsurprisingly, traffic noise is related to non-auditory health effects such as annoyance, stress, unusual tiredness, sleep disturbance and cardiovascular disease (Öhrström et al, 1988; Miedema and Oudshoorn, 2001; Ouis, 2001; Muzet, 2007; Pirrera et al, 2010; Basner et al, 2011; Sørensen et al, 2012; van Kempen and Babisch, 2012). Because noise is registered by human senses and can be measured easily using apps, awareness of it is high compared to pollutants that are more difficult to detect. Most people are well aware of noise caused by traffic in the city where they live (Pődör & Borsföldi-Nagy, 2018).

On a daily basis, teachers in schools try to keep noise levels down to keep concentration levels up. With good reason, because noise can have detrimental effects on cognitive performance in children (Stansfeld and Matheson, 2003). Chronic traffic noise at home or at school is outside the teachers' control, but it causes stress in children and negatively affects their reading comprehension and test scores (e.g. Cohen et al., 1973; Lukas et al., 1981; Sanz et al., 1993; Evans et al., 1995; Haines et al., 2001a; Haines et al., 2001b; Shield & Dockrell, 2003; Clark et al., 2006; Shield & Dockrell, 2008).

As noise comes from a particular source, such as a running engine, and dissipates though the air, it has an inherent spatial component. Noise levels decrease with increasing distance from the noise source. In addition, the longitudinal waves that constitute sound allow it to be registered despite the presence of an obstacle between the source and the receiver. In practice, this implies that, for example, a car with its engine left running can be seen without being heard if the distance is great enough and the line of sight is free, or heard without being seen when the distance is small enough and the line of sight is blocked. These properties of sound create an opportunity for spatially enabled learning (Vogler et al., 2012) in the form of noise maps, an understanding of noise being fundamental for effective spatial citizenship (Gryl & Jekel, 2012) that aims for an acceptable long-term degree of exposure to traffic noise.

Noise is thus an interesting topic to discuss with students in secondary school. In addition, it can be approached from multidisciplinary perspectives, allows for different learning styles to be accommodated, and readily enables students to discover and improve their own environment. This paper includes some fundamental background knowledge on sound measurement and traffic noise before providing materials and ideas for use in class. The goal is to provide a basis from which further ideas can be developed by teachers and students alike.

2 Quantifying noise levels

When there is noise, sound waves are present. These waves are vibrations in solids, liquids or gases. The loudness of a sound, or the noise level, is determined by the amplitude of the wave (see Figure 1). The pitch of the sound (think of a low bass or a high soprano) is determined by the frequency of the wave. The frequency is given by the number of waves in a given period of time. The shorter every single wave is, or the shorter the wavelength, the higher the frequency and the higher the pitch of the sound. The recognition of a pitch with the human ear requires a sufficiently long sequence of sound waves of a similar length.

Displacement

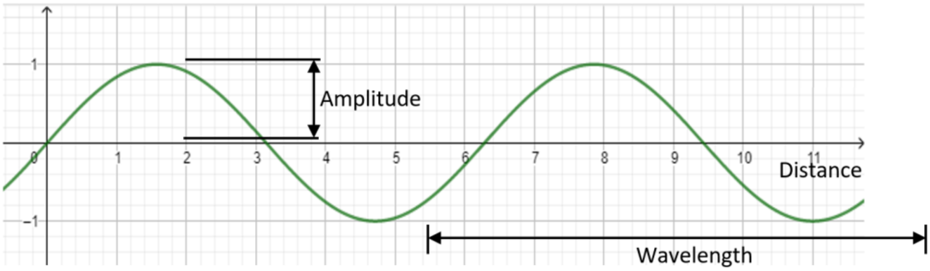


Figure 1: The amplitude and the wavelength of a soundwave

Noise levels are measured in decibels (dB), the scaling of which is based on the power produced by the sound in a non-linear fashion. To be more precise, differences in dB are based on logarithms to base 10 (ISO Standard 80000-3:2006). It is useful to consider an example at this point. Imagine two sounds, one with power x and one with power y. The difference in dB between these two sounds is given by $10 * log_{10}(^{y}/_{x}) = 10 * lg(^{y}/_{x})$. If sound y has ten times more power than sound x, then the difference between these sounds is $10 * lg10 = 10$dB. If sound y has a hundred times more power than sound x, the difference between these sounds is $10 * lg100 = 20$dB. The table gives an overview of some important power ratios and dB levels of sound y in comparison to the reference sound x.

Table 1: Power in watts per square metre and dB levels. The reference value at 0dB is one picowatt per square metre.

Power sound x	Power sound y	Power ratio $^{y}/_{x}$	dB difference	Sound y example
$1\ (^{pW}/_{m^2})$	$1\ (^{pW}/_{m^2})$	$1 = 10^0$	0	almost silent
$1\ (^{pW}/_{m^2})$	$2\ (^{pW}/_{m^2})$	$2 \approx 10^{0.3}$	3	very quiet
$1\ (^{pW}/_{m^2})$	$10\ (^{pW}/_{m^2})$	$10 = 10^1$	10	light breathing
$1\ (^{pW}/_{m^2})$	$100\ (^{pW}/_{m^2})$	$100 = 10^2$	20	rustling leaves
$1\ (^{pW}/_{m^2})$	$1\ (^{nW}/_{m^2})$	$1000 = 10^3$	30	whispering
$1\ (^{pW}/_{m^2})$	$1\ (^{\mu W}/_{m^2})$	10^6	60	conversational speech
$1\ (^{pW}/_{m^2})$	$1\ (^{mW}/_{m^2})$	10^9	90	petrol-powered lawn mower
$1\ (^{pW}/_{m^2})$	$1\ (^{W}/_{m^2})$	10^{12}	120	loud nightclub music

The frequency of a sound is measured in hertz (Hz), or the number of waves per second. The young human ear can register sounds from about 20Hz to about 20,000Hz, the range becoming narrower with age (Cutnell & Johnson, 2014). But to complicate matters, the human ear is more sensitive to some frequencies than others. As a result, a given level of sound (dB) has a different perceived loudness for different frequencies (Hz). Nevertheless, when quantifying the loudness of a sound within a limited range of frequencies, the dB is a good place to start.

3 Traffic as a source of noise

3.1 Types of noise

There are different types of noise source. Sources may be (1) natural or anthropogenic (occupational, social or environmental); (2) stationary or moving; (3) point, line or area sources; (4) making noise (more or less) constantly, intermittently or punctually. A single vehicle in operation represents an anthropogenic environmental moving point source that is making noise constantly. A busy road, railway track or airport, on the other hand, is an anthropogenic environmental stationary line source with more or less constant noise emission.

3.2 Frequency of the noise

Low frequency noise is known to have an especially great annoyance potential. Noise in the 20-200Hz range is closely associated with stress, headaches, unusual tiredness, reduced levels of concentration and irritation. A possible reason is the absence in nature of noises of this frequency range, apart from dangerous events such as volcanic eruptions, storms, thunder and earthquakes (Persson Waye, 2011). Anthropogenic sources such as road traffic, trains and aircraft emit noise in these lower frequency ranges. It is not surprising that road traffic noise, for example, has been associated with greater risk of hypertension, with the effect being strongest for noise with a frequency of 125Hz (Chang et al, 2014).

3.3 Level of the noise

Traffic can cause significant levels of noise. Noise levels above 75 dB are not unusual for noise generated by road, rail and air traffic in the EU including Austria (BMNT, 2018). Railway noise is caused mainly by wheels making track contact, whereas aircraft noise is generated mainly by the engines. In the case of average fossil-fuel passenger cars, engine noise dominates at speeds below 40 km/h, whereas tyre noise dominates at speeds above 60 km/h (Nijland & Dassen, 2002).

3.4 Presence of people

The number of people present in a given area, their vulnerability, the duration of their stay and the frequency of their visits to affected areas all influence the potential effects on health of a given level of noise pollution. Because traffic and industrial activity are so closely related to human activity itself, it is only natural that many people of all ages spend considerable amounts of time being exposed to the noise generated by these sources. Many Austrians are exposed to traffic noise at home and at school, both in denser population centres and in the countryside (see Table 2). On the 1st of January 2018, Austria was estimated to have 8,820,000 inhabitants and an average population density of about 106 people per km2 (Eurostat, 2018). As noise measurements are mandatory in the European Union (Directive 2002/49/EG), noise data is available for every EU country, although the publicly available information may be aggregated differently than in the Austrian example presented here.

Table 2: Number of people based on registered address data and schools affected by noise inside and outside population centres (cities with at least 100,000 inhabitants, or areas with a population density of over 1,000 people per km2) (BMNT, 2018)

A. Noise zones over 24h: Number of people and schools affected						
	Inside population centres			Outside population centres		
	Streets	Railways & tramways	Airports	Streets	Railways & tramways	Airports
55-60 dB	389,400	279,700	10,500	430,200	303,200	20,400
60-65 dB	602,600	207,100	1,500	174,700	132,100	1,800
65-70 dB	633,000	60,100	0	88,100	46,100	0
70-75 dB	357,800	22,800	0	26,200	15,100	0
> 75 dB	130,700	10,300	0	1,200	5,600	0
Total	2,122,600	580,000	12,000	720,400	502,000	22,200
Legal threshold*	60 dB	70 dB	65 dB	60 dB	70 Db	65 dB
Total above threshold	1,724,400	33,000	0	209,200	20,600	0
Schools > 55 dB	153	53	8	224	170	11
Schools > 65 dB	33	7	0	24	30	0
Schools > 75 dB	1	1	0	0	3	0

B. Noise zones at night (10 pm to 6 am): Number of people affected						
	Inside population centres			Outside of population centres		
	Streets	Railways & tramways	Airports	Streets	Railways	Airports
45-50 dB	370,200	no data	6,000	514,200	no data	12,200
50-55 dB	491,400	268,900	0	219,300	248,600	900
55-60 dB	754,800	109,600	0	102,400	99,700	200
60-65 dB	360,500	41,400	0	39,700	34,500	0
65-70 dB	219,600	17,000	0	4,400	10,400	0
> 70 dB	23,000	4,000	0	0	3,800	0
Total	2,219,600	219,900	6,000	880,100	397,000	13,300
Legal threshold*	50 dB	60 dB	55 dB	50 dB	60 dB	55 dB
Total above threshold	1.849.300	53.400	0	365.800	48.700	200

* If average noise levels exceed the legal threshold, governments are mandated by the EU to devise plans to mitigate noise at the affected locations.

3.5 Noise maps

Noise maps generated by the Austrian Ministry for Sustainability and Tourism show the average noise levels generated by traffic on main roads, main railway lines and commercial airports (as well as by larger industrial facilities). Measurements were undertaken by the provincial authorities and conducted at 4 metres above ground level. Digital maps are available for noise originating from provincial roads, highways, railway tracks and airports. Complete street coverage is available for the larger provincial capitals of Graz, Innsbruck, Linz, Salzburg and Vienna.

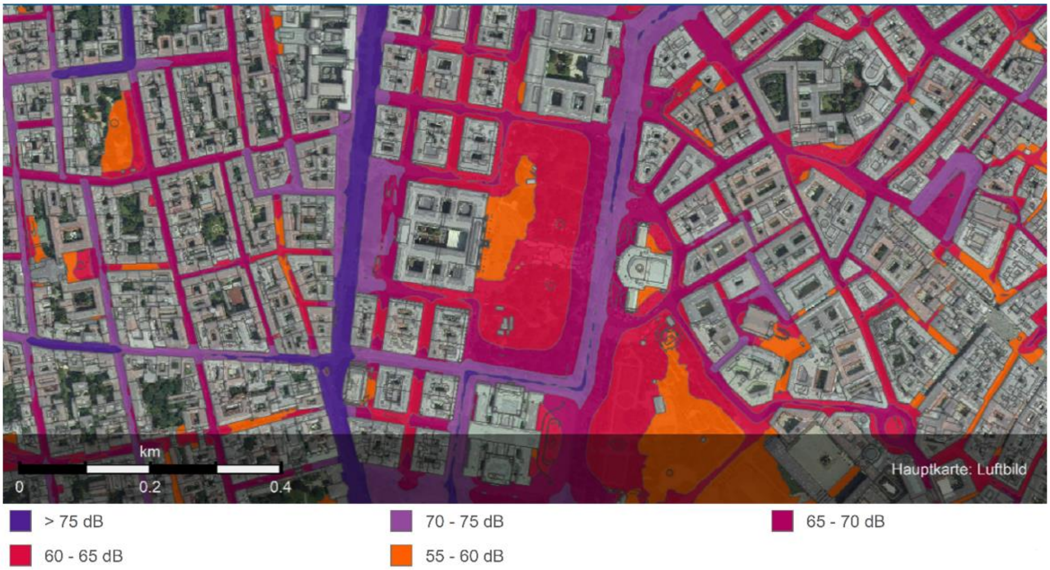


Figure 2: Exemplary map for average noise levels over 24h caused by road traffic, measured at 4 metres above ground, around the city hall in Vienna (Rathausplatz). Source: www.laerminfo.at (retrieved on 19.12.2018).

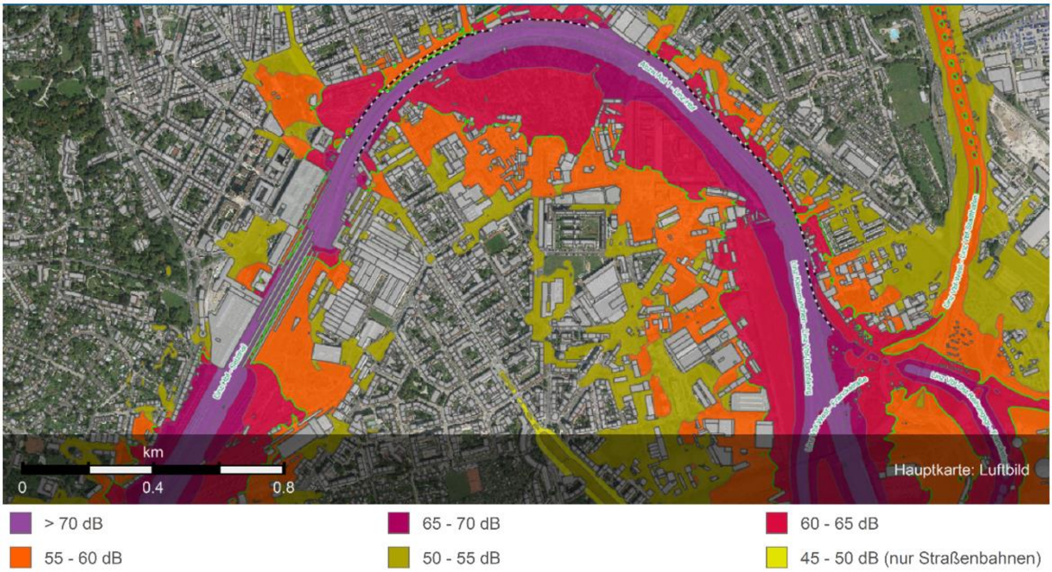


Figure 3: Exemplary map of average noise levels during the night caused by railway traffic, measured at 4 metres above ground level in an area including the central station in Linz (located above the linear scale of the map). Source: www.laerminfo.at (retrieved on 19.12.2018).

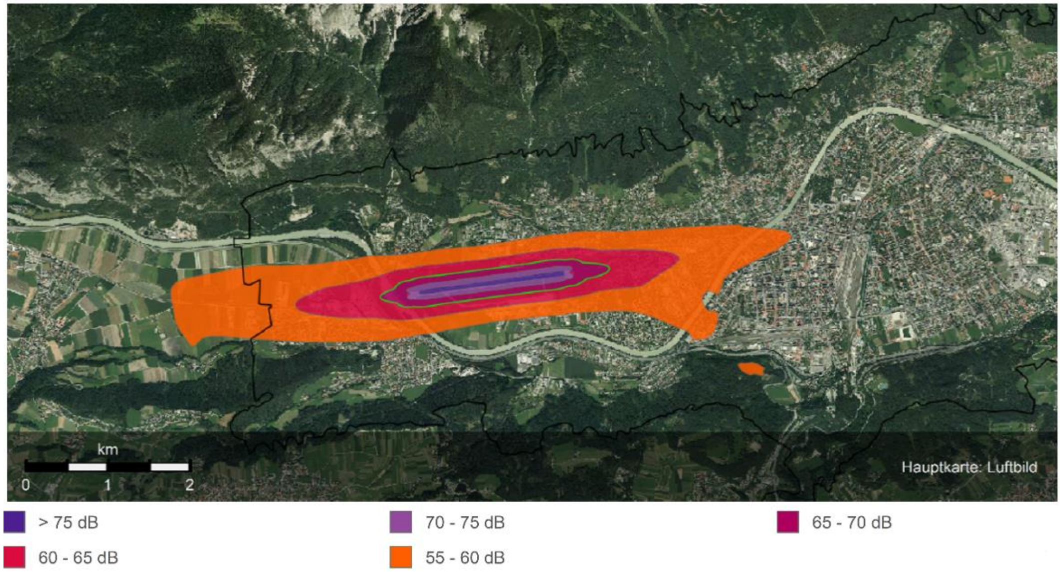


Figure 4: An exemplary map of noise levels over 24h caused by aircraft, measured at 4 metres above ground around the airport in Innsbruck. Source: www.laerminfo.at (retrieved on 19.12.2018).

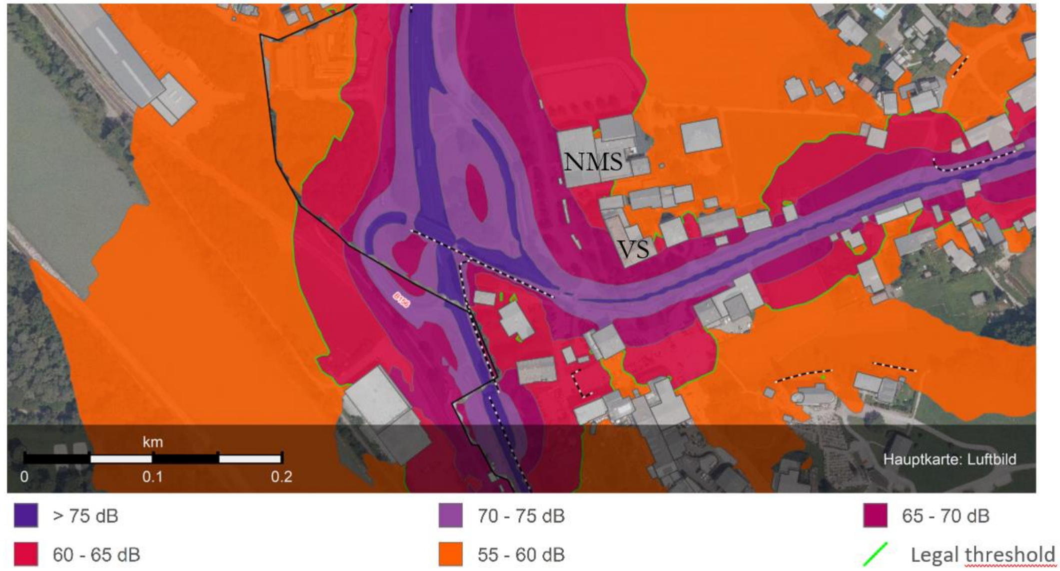


Figure 5: Exemplary map for average road noise levels over 24h, measured at 4 metres above ground around the primary school (VS=Volksschule) and secondary school (NMS=Neue Mittelschule) in Bergheim bei Salzburg. Source: www.laerminfo.at (retrieved on 03.01.2019).

4 Teaching materials

The teaching materials are meant to provide a minimum understanding of what sound is, how to measure sound using a smartphone, a heightened awareness of the sounds surrounding us and of how they can affect us physically and emotionally, as well as an introduction to traffic noise. The contents of the materials relate to multiple subjects: physics, musical education, biology and geography. The Table below summarises these subjects and suggests noise-related activities in other subject areas.

Table 3: Examples of sound and noise as multidisciplinary subjects

A. Included in teaching material	
Physics	The physical properties of sounds and how to quantify them
Music	Experiencing, describing, making and evaluating sounds and pitch
Biology	Using our ears to register sounds and the effects of noise on wellbeing
Geography	The geographical distribution of traffic noise (noise maps)
B. Further suggestions	
Languages	Discuss newspaper articles on traffic noise and write an opinion piece of your own
Mathematics	The functional forms of decibel and hertz, including graphical representations
History	Noise surrounding people in the past and today. What were the sources then?
Sports	Can sounds help me run faster? If so, what sounds are most effective?
Economics	Selling noise and quietness: car engine noise generated by the speaker system
Political Science	Decision making in relation to construction of noise barriers, flight times and routes, etc.
Art	Drawing sounds: depicting different types of sounds

Table 4: Multiple intelligences in the mini-projects

Intelligence description (Gardner, 1999)	Description in mini-projects
1. Visual-spatial	Picture smart
2. Logical-mathematical	Number smart
3. Verbal-linguistic	Word smart
4. Naturalistic	Nature smart
5. Musical-rhythmic and harmonic	Music smart
6. Bodily-kinaesthetic	Body smart
7. Intrapersonal	Me smart
8. Interpersonal	People smart
9. Existential	Soul smart

In addition to the teaching materials outlined in Table 3, nine mini-projects related to (traffic) noise are offered for students to choose from. Each exercise offers a relatively high degree of freedom and aims to fit one of the nine intelligences proposed by Gardner (Gardner, 1999). In general, students know where their strengths lie and will choose their tasks accordingly. If time permits, time can be spent on tests and self-assessments to determine which of the multiple intelligences are most developed in different students. For ease of understanding by students, the different intelligences have been given new names in the exercise sheet explaining the mini-projects, as described in Table 4.

The subject of traffic noise and the proposed materials also address a range of overarching goals, as codified in a number of legally binding educational policy documents in Austria, such as traffic and mobility education, health education, digital education and education for sustainable development. As was the case for the different subject areas, the materials are meant simply to provide a basis on which to build. For example, students' noise measurements can be mapped digitally (e.g. ArcGIS Online) and statistically and spatially analysed. Furthermore, students' personal interests and perceptions can be included explicitly.

The exercises presented in the teaching materials were trialled in class. As a result, the following advice can be offered. (1) Agree on a clear signal for students to be completely (!) quiet. Practise this signal from the front of the classroom at the start of every class. If the class has difficulties staying quiet, it may be helpful to start with the listening exercise with closed windows and closed doors. Asking students to really concentrate on listening and discovering sounds not heard before increases the likelihood of them remaining silent. (2) Take the time to download and install the app of your choice in class on the devices to be used and try the app (for example by shouting as loud as possible). Asking students to install the app at home only saves time if all students do so, which is highly unlikely in practice. (3) When using the tone generator, use a single speaker to generate the tone to avoid constructive and destructive interference. If possible, get students to stand in a semi-circle around this speaker so that they are all the same distance from it, with a data projector displaying the screen of the tone generator behind it. (4) Show a video, in slow motion, of a guitar string that has been plucked, and pluck the guitar string live in class. (5) Showing the propagation of transverse waves (e.g. light) next to that of longitudinal waves (e.g. sound) can increase understanding. (6) The noise maps presented here are Austrian. Similar data and maps should be available for all EU countries and can easily be used instead if desired. (7) The different types of intelligence and the mini-projects may require explanation.

Although no formal survey was carried out, a few words on the perceived learning effects may be of interest. Almost all students gained a very good understanding of the basic physical properties of sounds and how humans register just a limited range of sounds with their ears. Students gained insights into how to carry out experiments and the different ways in which observations can be made, recorded, structured and interpreted. Potential differences between making observations with human senses and using electrical measurement equipment such as a smartphone with an app became apparent. Moreover, using apps proved to be a very effective means to get to grips with the non-linearity of the dB scale. Some students continued measuring ambient sound levels on a daily basis for a number of weeks. During the mini-projects especially, self-motivated interdisciplinary work of admirable quality was achieved. Most importantly, however, students' awareness of the broad range of sounds, including traffic noise, that constitute an ever-present part of their daily lives has increased substantially.

5 Conclusion

Many us of are surrounded by noise throughout large parts of the day. Chronic exposure to noise above a certain volume negatively affects our health, ability to concentrate and feeling of wellbeing. A very important source of chronic ambient noise is traffic. This paper aims to provide teachers with background information and materials for multidisciplinary classes on traffic noise during the first years of secondary education. This multidisciplinarity allows students of different abilities and with varying interests to approach the subject and to embed new insights into existing thought processes. Methods and knowledge that students have acquired in different subject areas can be practised by applying these to traffic noise. Preliminary ideas for expansion beyond physics, geography, music and biology are presented. By catering for the different types of intelligence, interests and skills that students possess, the proposed mini-projects give students the opportunity to further develop themselves in an area of their choice.

The ultimate goal is to provide students with sufficient interest in and understanding of traffic noise, its consequences and potential solutions. The use of noise maps supports active engagement in public debate and spatial citizenship to achieve acceptable long-term levels of traffic noise exposure via targeted and effective action. The skills developed may thereafter be used to address other types of ambient pollutants that are more difficult to register with human senses, such as carbon dioxide, nitrogen oxides, ultrafine particles, radiation and so on.

Acknowledgement

The Federal Ministry of the Republic of Austria for Sustainability and Tourism generously granted permission to use the noise maps available on laerminfo.at for this paper.

Measuring sounds – ear and smartphone

Download and install an app on your smartphone to measure the volume of a sound (e.g. Sound Meter).

Open a tone generator on the internet.
(e.g. http://www.szynalski.com/tone-generator/)

You will have to be very quiet now.

Use the tone generator to play a tone at full volume. Adjust the speakers so that you get 50 dB on your teacher's smartphone. Calibrate your apps with that of your teacher.

Use the tone generator to play a tone at full volume. Adjust the speakers to 50 dB on your app.

Decrease the volume in the tone generator by half.

My app now measures a sound level of .... dB.

Decrease the volume in the tone generator by half.

My app now measures a sound level of .... dB.

Decrease the volume in the tone generator by half.

My app now measures a sound level of .... dB.

Every time I decrease the volume by half, the sound level is decreased by about ....dB.

Use the tone generator to play a tone with 110 Hz. Change the tone to 220 Hz. Complete the sentences:

The tone with ....Hz makes the higher sound.

The tone with ....Hz makes the lower sound.

What sounds can you hear? Beat the teacher!

Use the tone generator to play a tone with 30dB and 220 Hz. Keep decreasing the volume.

The quietest sound I can hear has ....dB.

My teacher can hear down to ....dB.

Start at 40 Hz. Keep decreasing to 10 Hz.

The lowest sound I can hear has ....Hz.

Start at 18,000 Hz. Slowly increase to 20,000 Hz.

The highest sound I can hear has ....Hz.

My teacher hears from ....Hz to ....Hz.

Everyone has different hearing. Some people can hear sounds that others can't. Your hearing gets worse when you are exposed to loud noises and as you get older.

Animals have different hearing from us. For example, dog whistles make a sound of about 54,000 Hz. Humans cannot hear such sounds, but dogs can!

Soundwaves are caused by vibration

Download and install an app (e.g. Spectroid) on your smartphone to measure the frequency of a sound.

<u>You will have to be very quiet now.</u>

Switch on your app. Play the second lowest string on a guitar. Your hear the concert pitch (a' 440Hz).

The note being played has ....Hz.

The musical note .... is being played.

Observe the string closely. How does it move? Sketch the moving string below.

● = fixed point, called a node

Measure the length of the same string on the guitar. Exactly in the middle create a new node by placing your finger on the string.

The note being played has ....Hz.

The musical note .... is being played.

Sketch the moving string below.

Sound is caused by a vibrating object, for example a guitar string that has been plucked. Such an object is a sound source.

You are also a sound source. Let's give it a go.

Switch on your app. Start a new measurement. You may have to reset the app to delete previous data. One after another, whistle as loud as you can.

I get up to ....dB and ....Hz.

Start a new measurement in your app. Whistle together as loud as you can.

Together, we get up to ....dB.

The noise has a clear level of Hz : □ yes □ no

The teacher's smartphone is going to play a song in the corridor. Measure the volume with your smart-phone. The volume in the classroom is similar when:

the door is completely open:	**□ yes**	**□ no**
the door is opened halfway:	**□ yes**	**□ no**
the door is left ajar:	**□ yes**	**□ no**
the door is completely shut:	**□ yes**	**□ no**

Switch on an alarm. Put it in a vacuum chamber. Pump out the air. Can you still hear the alarm?

Hearing sounds – Listen carefully

All windows and doors should be closed. Be quiet and listen carefully for one minute. Afterwards, depict the sources of the sounds on the map.

In front of me

To the left

To the right

Behind me

quiet	1	2	3	4	5	loud
pleasant	1	2	3	4	5	annoying

For this exercise, all windows should be opened. Again be quiet and listen carefully for one minute.

In front of me

To the left

To the right

Behind me

quiet	1	2	3	4	5	loud
pleasant	1	2	3	4	5	annoying

In pairs, measure each other's heartbeat for exactly one minute. Sit down facing each other and be as calm as possible. Rest one arm on your knee and get your partner to feel your pulse.

My heartbeat is beats/min.

You may now have heard traffic noise. If so, you are not alone. Many schools and homes in Austria suffer from traffic noise.

Listen to road traffic noise on the internet. Use your Apps to adjust the volume to an average of 60 dB. Be quiet and listen carefully for one minute.

quiet	1	2	3	4	5	loud
pleasant	1	2	3	4	5	annoying

Listen to the road traffic noise at 60 dB. Measure each other's heartbeat again for exactly one minute.

My heartbeat is beats/min.

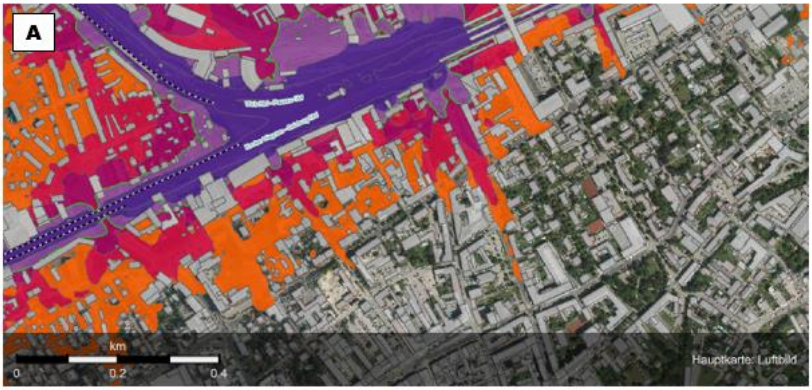
The legal limit beyond which action for road traffic noise should be taken is an average 60 dB over 24h. I think that is...

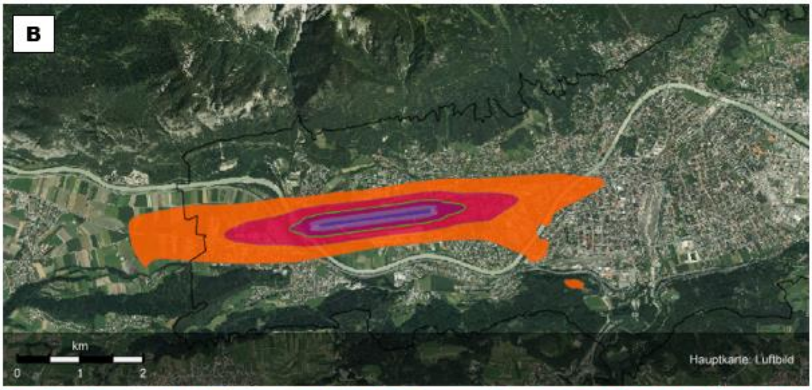
Mapping traffic noise

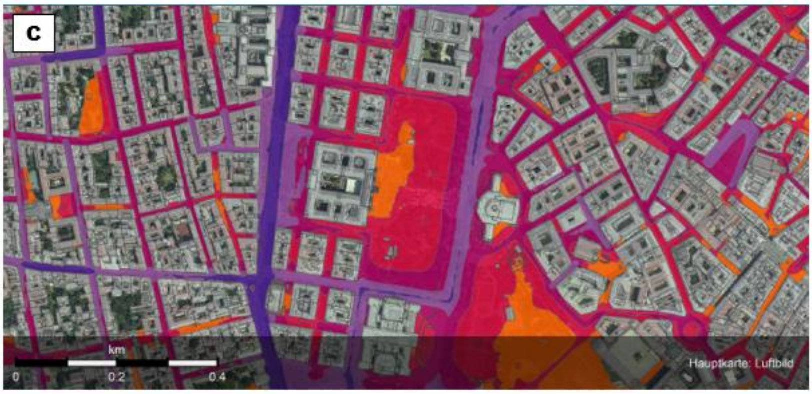
Sound can be mapped using contour lines with colour-coding for given levels of dB. Can you find out which type of traffic noise is shown on the three maps A, B and C?

Road noise in central Vienna **Railway noise in Wels** **Aircraft noise in Innsbruck**

- > 75 dB
- 60 - 65 dB
- 70 - 75 dB
- 55 - 60 dB
- 65 - 70 dB







Maps were downloaded from www.laerminfo.at (19.12.2018). The maps can be viewed online on computer and smartphone.

Traffic noise: projects to choose from

Complete at least ____ of the following projects by _______: ___________________

Picture smart	**Number smart**	**Word smart**
Draw a map of one floor of your home. Include the rooms and large pieces of furniture. Draw open or closed doors and windows. You may also include the garden or balcony. Listen to the sounds carefully. Where do they come from? Add the sources to your map using your imagination. Hand in: an A3 sheet of paper with your drawing	Print out the official (noise) map for your school and about 200 metres in every direction around it. Measure noise levels and frequencies at different outside locations using a smartphone. Write your dB measurements on the map. Compare your measurements with the official noise map. Hand in: an A3 sheet of paper with your findings	Write a letter to the mayor about the traffic noise at your school and in your town. Suggest how to improve the situation and try to convince the city council to take action. Post this letter. Tip: include an official noise map to help make your point. Hand in: a copy of the letter, envelope and possible reply
Nature smart	**Music smart**	**Body smart**
Find a ‘quiet’ place in nature completely without traffic noise. Record the sounds for a minute, without talking, using a smartphone. To the same recording, next add your verbal descriptions of all the sounds that can be heard. Hand in: sound recording with your comments	Make a song about traffic noise. You may use traffic noise recordings, your voice, musical instruments or any other sounds you make yourself. Video yourself performing (?) the music. Hand in: video clip of the song	Build a box with maximum sound-proofing. It should be big enough to hold your mobile phone. Test the box by playing the same loud music or ringtone outside and inside the box. Compare the volume of the sound. If you wish, you can use a second mobile phone to measure dB levels. Hand in: your box, a short explanation and test recording.
Me smart	**People smart**	**Soul smart**
Choose eight sounds and listen carefully to them with your eyes closed. Make a list of these sounds. Describe them and explain what you feel when listening to each of them. Some of the sounds should relate to traffic. Think of cars, bikes, boats, planes, etc. Hand in: list with sounds, feelings and explanations	Prepare a list of at least five questions about traffic noise and how this is perceived. Interview five people using your questions. Then form your own opinion. Tip: you may record the interviews and then write down the answers. Hand in: questions with answers and own opinion	Create a quiet zone in class or in school. Come up with an idea to reduce noise and create space for daydreaming and peaceful thinking. Try to make the idea easy to carry out. Write a short explanation of the idea and explain how it is supposed to work. If helpful, you can also draw a sketch of the idea. Hand in: description of the idea. Can be tried in class!

References

Basner, M., Müller, U. & Elmenhorst, E. (2011). Single and combined effects of air, road, and rail traffic noise on sleep and recuperation. *Sleep, 34*, 11–23.

BMNT (2018). Umgebungslärm-Aktionsplan - Österreich 2018 – Allgemeiner Teil – Zusammenfassenden Betroffenenauswertung. BMNT-UW.1.4.12/0012-I/5/2018.

Chang, T.-Y., Beelen, R., Li, S.-F. , Chen, T.-I, Lin, Y.-J., Bao, B.-Y. & Liu, C.-S. (2014). Road traffic noise frequency and prevalent hypertension in Taichung, Taiwan: A cross-sectional study. *Environmental Health, 13*(37), 1-9.

Clark, C., Martin, R., van Kempen, E., Alfred, T., Head, J., Davies, H., Haines, M., Lopez Barrio, Matheson, M. & Stansfeld, S. (2006). Exposure-Effect Relations between Aircraft and Road Traffic Noise Exposure at School and Reading Comprehension: The RANCH Project. *American Journal of Epidemiology, 163*(1), 27–37.

Cohen, S., Glass, D.C. & Singer, J.E. (1973). Apartment noise, auditory discrimination, and reading ability in children. *Journal of Experimental Social Psychology, 9*, 407–422.

Cutnell, J. & Johnson K. (2014). *Physics. 10th ed.* New York: Wiley

Eurostat (2018). Usually resident population on 1 January - Last update: 02-10-2018. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_urespop&lang=en (accessed on 02-01-2019)

Evans, G., Hygge, S. & Bullinger, M. (1995). Chronic noise and psychological stress. *Psychological Science, 6*, 333–338.

Evans G. & Maxwell L. (1997). Chronic noise exposure and reading deficits: the mediating effect of language acquisition. *Environment and Behavior, 29*, 638–656.

Gardner, H. (1999). *Intelligence Reframed: Multiple Intelligences for the 21st Century*. New York: Basic Books.

Gryl, I., & Jekel, T. (2012). Re-centring Geoinformation in Secondary Education: Toward a Spatial Citizenship Approach. *Cartographica: The International Journal for Geographic Information and Geovisualization, 47*(1), 18-28.

Haines, M., Stansfeld, S., Job, R., Berglund, B. & Head, J. (2001a). Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. *Psychological Medicine, 31*, 265–277.

Haines M., Stansfeld S., Job R., Berglund B. & Head, J. (2001b). A follow-up study of effects of chronic aircraft noise exposure on child stress responses and cognition. *International Journal of Epidemiology, 30*(4:1), 839–845.

Lukas J., DuPree R. & Swing J. (1981). *Report of a study on the effects of freeway noise on academic achievement of elementary school children*. Sacramento, CA: California Department of Health Services.

Miedema H. & Oudshoorn C. (2001). Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals. *Environmental Health Perspectives, 109*, 409–416.

Muzet A. (2007). Environmental noise, sleep and health. *Sleep Medicine Reviews, 11*, 135–142.

Nijland, H. & Dassen A. (2002). *Verkeerslawaai in Europa (Traffic noise in Europe)*. Bilthoven: RIVM rapport 715120009/2002.

Öhrström E., Rylander R. & Björkman M. (1988). Effects of night time road traffic noise—an overview of laboratory and field studies on noise dose and subjective noise sensitivity. *Journal of Sound and Vibration, 127*(3), 441-448.

Ouis P. (2001). Annoyance from road traffic: a review. *Journal of Environmental Psychology, 21*(1), 101-120.

Persson Waye, K. (2011). Noise and Health - Effects of Low Frequency Noise and Vibrations: Environmental and Occupational Perspectives. *Encyclopedia of Environmental Health, 2,* 240-253.

Pirrera S., De Valck E. & Cluydts R. (2010). Nocturnal road traffic noise: A review on its assessment and consequences on sleep and health. *Environment International, 36*(5), 492-498.

Pődör A. & Borsföldi-Nagy, D. (2018), Citizens' Perceptions of Environmental Noise – A Case Study. *GI_Forum – Journal for Geographic Information Science, 6*(1), 126-134.

Sanz, S.A., García, A.M. & García, A. (1993) Road traffic noise around schools: a risk for pupil's performance? *International Archives of Occupational and Environmental Health, 65*, 205-207.

Shield, B. & Dockrell, J. (2003). The Effects of Noise on Children at School: A Review. *Building Acoustics, 10*(2), 97–116.

Shield, B. & Dockrell J. (2008). The effects of noise on the attainments and cognitive performance of primary school children. *The Journal of the Acoustical Society of America,* 123-133.

Sørensen, M., Andersen, Z., Nordsborg, R., Jensen, S., Lillelund, K., Beelen, R., Schmidt, E., Tjønneland, A., Overvad, K. & Raaschou-Nielsen, O. (2012). Road traffic noise and incident myocardial infarction: a prospective cohort study. *PLoS One, 7*(6), 1-7.

Stansfeld, S. & Matheson, M. (2003). Noise pollution: non-auditory effects on health. *British Medical Bulletin, 68*, 243–57.

van Kempen, E. & Babisch, W. (2012). The quantitative relationship between road traffic noise and hypertension: a meta-analysis. *Journal of Hypertension, 30*, 1075–1086.

Vogler, R., Hennig, S., Jekel, T., & Donert, K. (2012). Towards a Concept of 'Spatially Enabled Learning'. *GI_Forum – Journal for Geographic Information Science*, *2012*(1), 204-211.

GI_Forum 2019, Issue 2
Page: 180 - 193
Full Paper
Corresponding Author:
claudia.scharf@uni-due.de
DOI: 10.1553/giscience2019_02_s180

Fostering Valuable Participation in Shaping Spaces and Societies: Towards Creating an Ethical Meta Level in the Model Design for Innovativeness

Claudia Scharf and Inga Gryl
Universität Duisburg-Essen, Germany

Abstract

The approach of an education for innovativeness aims to enable pupils to participate in shaping societies in a mature manner, which includes the appropriation and designing of spaces. This approach is useful for educational and practical concepts such as Spatial Citizenship, which promotes the use of digital geomedia for individual and collective appropriation and re-shaping of spaces. However, encouraging innovativeness may also seem to foster participation in questionable inventing processes with trivial – or even harmful – intentions. Including an ethical meta level in the model design for innovativeness would generate reflection on the purpose of the novelty. In this paper, we look first at theories that address the term 'problem', social innovations and applied ethics, in order then to develop a first attempt at creating an ethical meta level in the model design for innovativeness.

Keywords:

innovativeness, participation, applied ethics, social innovation, appropriation of space

1 Introduction

In the manifold social and human–environment relations, problems arise as outcomes of complex systems. These problems in turn result in the need for reaction and action, and for new solutions, namely innovations. Innovations emerge and take their place in everyday lives, framing and reframing the opportunities and barriers to action. Being innovative saves humans from simply being victims of changing conditions; thus, society and policy call for people's participation in innovation processes so that changes are controlled collectively.

At the same time, a neoliberal (educational) system instrumentalizes this demand with individualization and self-regulation (e.g. Krautz, 2007): educational policy is characterized by calls for efficiency, competitiveness and focus on (ever better) results (Hakala & Uusikylä, 2015). Such practices are also relevant in spatial planning. While several projects exist that seek to involve lay people in planning processes as those who will use the spaces afterwards, some of these are not real forms of participation, and some fail to produce innovative spaces that really address the users' (diverse) needs (e.g. Millei & Imre, 2015). Some practices of appropriation of spaces are illegalized (regarding street art, for example, see e.g. Scharf et al., 2018). Thus, spatial planning is deeply embedded in normalized models of the appropriation of space, only seldom taking into account the much wider potential of changing spaces that opens up in relational concepts of space. Such neoliberal perspectives only encourage 'nonparticipation' and not 'genuine participation' (Hart, 1992, p. 9, 11), as it makes it harder for people to act democratically (see e.g. Žižek, 2012).[1]

In order to support humanistic claims without falling into the trap of particular market interests, an education is needed that fosters maturity (Adorno, 1971). Like geography- and geomedia-based approaches such as Spatial Citizenship (or 'SPACIT') (Gryl & Jekel, 2012), an education for innovativeness (e.g. Weis et al., 2017) also aims to foster the appropriation of spaces through the use of mainly digital geomedia. Going beyond SPACIT, the model design for innovativeness may foster understanding of an innovative appropriation of spaces, utilizing appropriate tools such as counter-mapping and neogeography, thus using the participatory potential that current geomedia provide.

As a potential basis for participatory spatial planning processes, this paper will outline the more general model design for innovativeness as developed so far, and will also address an eminent problem: in general, new creations and their distribution can also be ethically questionable. Some may be harmful to certain groups, for example through the re-location of people due to mining or the spatial claims of right-wing groups. In order to counter the attribution of 'innovativeness' to unethical creations, an ethical meta level is necessary, involving a discussion of the term 'problem', social innovations, negative side-effects and the power of interpretation (i.e. who has the power to decide what is innovative) (Scharf et al., 2019).

2 The Approach of an Education for Innovativeness: State of the Art

Participation in the shaping and appropriation of spaces has been a subject within geography education and applied geography for a long time, e.g. 'Public Participation GIS' (Ramasubramanian, 2010), 'SPACIT' (Gryl & Jekel, 2012), and 'participatory mapping' (Elwood & Mitchell, 2013). However, several participatory planning projects have resulted in rather traditional outcomes (Vogler et al., 2010; Plötz et al., 2014) which clearly lack attention to the essence of changing and innovating spaces. The approach of an education for innovativeness therefore seems to be promising.

The model design defines innovativeness as 'the ability to participate in innovation processes' (Scharf et al., 2018, p. 159; Weis et al., 2017) in order to be able to shape the world in a mature (Adorno, 1971) manner (see e.g. Weis et al., 2017). It differentiates between components which are relevant for being innovative, the innovation process itself, and its possible outcomes.

Reflexivity, creativity and implementivity are described as the central components of innovativeness. Reflexivity is the ability to critically engage with what exists and to identify problem areas (Gryl, 2013; Jekel et al., 2015). According to Gryl (2013), it includes not only

[1] For a more in-depth description of the neoliberal education system in the context of innovativeness, see e.g. Scharf et al. (2019).

external phenomena, but also one's own thinking (Schneider, 2013) and acting (Luhmann, 1998). This makes reflexivity a necessary prerequisite for creativity (Dewey n/d., cited in Joas, 1992), which is defined as the ability to develop ideas for the solving of identified problems (e.g. Gryl, 2013); it comprises, based on Popitz (2000), imagination and fantasy (Scharf et al., 2019). The ability to convince others by way of argumentation of the existence of problems and/or ideas for solutions is referred to as implementivity (Gryl, 2013; Jekel et al., 2015; Weis et al., 2017). Only through its implementation, through its diffusion, does an idea become an innovation (see e.g. Gryl, 2013).

Reflexivity, creativity and implementivity are important in every single phase of an innovation process (Weis et al., 2017). Such a process is circular and dynamic, and consists of the identification of problem areas, the development of solutions, and their implementation (ibid.). According to Hartmann and Meyer-Wölfing (2003), participation in innovation processes can be both active and reactive (Scharf et al., 2016), which also means that innovation processes are characterized by constant feedback loops and are thus always collaborative (Scharf et al., 2018). Thus reflexivity, for example, is necessary not only in the problem identification phase, but also in the critical questioning of an idea for a solution and/or its implementation strategy (Scharf et al., 2019).

The need for reflexive and communication skills as well as argumentation capabilities to be innovative links innovativeness closely with SPACIT, which partly includes these components, but lacks a more detailed explanation of the nature of spatial innovation. Therefore, the approach of an education for innovativeness fits nicely as a valuable complement.

From an anti-authoritarian perspective, Scharf et al. (2019) (based on remarks by Bröckling (2004) and Joas (1992)) aim at limiting innovativeness to the political ability to participate in the development of society,[2] e.g. by taking a position against social circumstances that are perceived as problematic, as illustrated in Golser et al. (2019) (see Figure 1). This would exclude participating in processes that create something new but trivial, e.g. a crispier brand of potato chips, and would include e.g. influencing social processes through the use of geomedia.[3] However, by limiting innovativeness to a political ability, the approach could allow the creation of, or participation in, something harmful, e.g. the Ku Klux Klan. In order to avoid such an attribution to innovativeness, and to buttress Scharf et al.'s (2019) ideas theoretically, an ethical meta level is necessary.

[2] Here, the term 'political' is to be understood in a broad, citizenship education manner (e.g. SPACIT, Gryl & Jekel, 2012).

[3] Geomedia may also be like catalysts, as they provide new insights into spatial problems (e.g. visual analytics, hypothesis generation (see MacEachren, 1992), and may work as innovation tools as suggested by SPACIT.

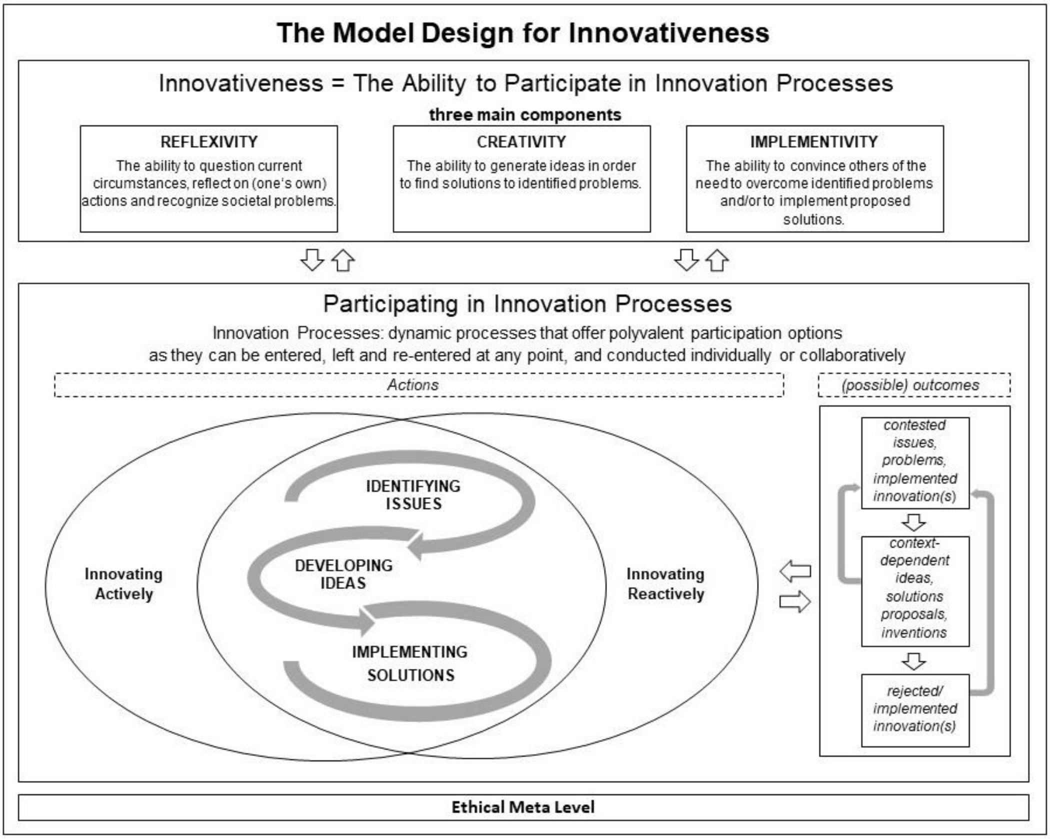


Figure 1: The model design for innovativeness (translation based on Golser et al., 2019, p. 64, itself adapted from Weis et al., 2017, p. 386-5), complemented with an ethical meta level.4

3 Towards Creating an Ethical Meta Level

If we take a closer look at the model design for innovativeness, some questions arise: What exactly is a problem? Is focusing on social innovations the way to fulfil the aspiration of being aligned with the aim of limiting innovativeness to a political theory? Assuming that social innovations aim at solving social problems, who is in charge of determining that a problem has been 'solved', especially if there are conflicting interests? How should unintended side effects be dealt with?

3.1 The Term 'Problem'

Attempting to address problems in innovation processes is always challenging because the perception of a problem is limited to certain individuals or groups, and complex situations

[4] The ethical meta level itself is described in Figure 2.

never involve only disadvantages for all. For instance, the global market involves inequalities in income and human rights imbalances, with serious consequences for employees in poorer countries but a better standard of living in richer ones and greater profits for international companies. The 'right to the city' movement, based on Lefebvre (1996), illustrates that public spatial planning is also confronted by divergent interests. Naturally, conflicting interests are one basis for the emergence of problems.

At the level of the description of the components of innovativeness, therefore, a critical examination of the concept of 'problem' needs to be included. The concept of the 'problem' is used in particular to define the component of reflexivity. If it is assumed that problems are identified in terms of reflexivity, then it is already anticipated that certain occurrences will be classified as problems in a positivist sense. Because of this, speaking of 'constructing' or 'inventing problems' could be preferable. However, such an approach involves the danger of euphemizing problems, whether strictly physical ones such as hunger, or socially embedded ones like racial discrimination.

Drawing on Jaeggi's (2014) explanations, we argue for using the term 'noticing' or 'recognizing problems' when talking about reflexivity. On the one hand, the practical philosopher describes problems as culturally specific and socially as well as historically formed. Hence, problems are 'normatively pre-defined tasks and conflicts' (ibid., p. 164, translated by the authors): issues become problematic with respect to an ethically pre-defined definition of what may (or may not) be problematic. Besides, problems have a history of attempts to solve them which influences their current interpretations as well as further attempts to find solutions (ibid). On the other hand, problems are also objective and real: 'We do not invent the problems, but react to them' (ibid., p. 172, translated by the authors).

We are thus dealing with an ambivalent situation: problems derive from the world, but the world is constructed by the people who live in it. This means that problems are both factual and constructed (Jaeggi, 2014). There needs to be an interpretation for recognizing something as a problem, since problems are – despite their normative pre-definition – not undeniably problems (ibid.). A problem appears when (planned) courses of action get stuck, or when things one believed in are becoming inconsistent or unintelligible (ibid.). A reason arises to remedy this imbalance (ibid.). Referring to Dewey (2002), Jaeggi states that without its perception as a problem, it is not a problem and therefore cannot be solved: the fragmentation of a situation, its opacity, its ambivalence are the critical elements that identify it as a problem. It is precisely this identification of the problem that is the first step to solving it, as it leads to searching for a more detailed definition of the problem itself and an appropriate direction for its solution (Jaeggi, 2014). This approach is a realization of the two aspects of reflexivity (engaging with what exists and identifying problematic areas) in terms of innovativeness.

3.2 Social Innovations

The approach of an education for innovativeness aims at fostering 'maturity', in Adorno's (1971) sense of the term. Thus, the approach must also be based on critical theory that points to contradictions within capitalist bourgeois society and suggests transformation, calling for political action that disrupts the status quo (Horkheimer, 1937; see also Schwandt, 2010). Thus, and in accordance with Scharf et al.'s (2019) remarks, the approach does not aim simply at enabling people to invent trivial novelties, which do not seek to change society. Moreover, inventions which intentionally harm others, particularly minorities, cannot be considered innovations either.

Following this argumentation, then, the approach of an education for innovativeness must enable people 'to liberate human beings from circumstances that enslave them' (Horkheimer, 1982, p. 244, cited in van Bouwell, 2009), advancing 'the abolition of social injustice' (Horkheimer, 1982, p. 242; see also van Bouwel, 2009). A focus on social innovations could be the answer, as these aim to solve social problems (Hochgerner, 2009), improve society (Gillwald, 2000), affect the direction of social change, and achieve societal objectives (Zapf, 1994). According to Gillwald (2000), social innovations may also aim to better the lot of minorities, whereas purely technical innovations aim to benefit those who are already better off. Following Rammert (2010, p. 43, translated by the authors), social innovations are 'new forms of participation and social integration, of balance of interests and solidarity'. Thus, they seem appropriate to respond to social challenges; and therefore they also fit the model design for innovativeness.

Social innovations are societal achievements, of a social, ecological, cultural or political nature, that improve on earlier solutions (Gillwald, 2000; see also Zapf, 1994). Fundamental characteristics of social innovations are their relative novelty in contrast to former practices, their diffusion, their stabilization, and their influence on the direction of social development (Gillwald, 2000). They are recognizable in different forms and in all social spheres as they can be organizational, structural/institutional or procedural (Merritt & Merritt, 1985), and can be aligned with those who are affected directly and those who are not (Ellwein, 1985). Social innovations can furthermore include technical innovations that have these same aims, and the two may in fact be mutually dependent on each other. For instance, the Reformation would not have happened without letterpress printing (Eisenstein, 1983). '[T]echnical innovations are [concrete] devices and social innovations [are abstract] acts of social change' (Gillwald, 2000, p. 36, translated by the authors).

However, definitions of 'social innovation' vary a little (referring, for example, to solving social problems or improving society) and are fairly vague. It is unclear how to distinguish social innovations from other social changes (Gillwald, 2000), and most importantly to determine the essence of social benefit (Howaldt & Jacobsen, 2010; Rammert, 2010): the complexity of the consequences of changes makes it difficult to judge the improvement itself as there are differing interpretations of problems and of their solutions, and there are always negative side effects. Consequently – if there is to be a focus on social innovations within the innovativeness approach – the approach should itself include an adequate definition of social innovation derived from the research on social innovations.

3.3 Negative Side-Effects and the Power of Interpretation

In a bid to find a clear definition of 'social innovation', attempts were made to list what have been considered social innovations. The first list, by Ogburn (1933), included a great range of things from laws (e.g. minimum wages) or practices (e.g. quotas), to hate groups like the Ku Klux Klan (Gillwald, 2000). Such very harmful examples aside, there are novelties which represent both an improvement for one group and a worsening for another (ibid.), since people have different interests (Deutsch, 1985). For example, whereas video surveillance in public spaces is used as a tool to protect people from thieving and muggings, people are put under general suspicion. Identifying a solution to a problem as the right, appropriate, one is dependent on perspectives and interpretation, especially when we assume the normative pre-definition of a problem (Jaeggi, 2014). Here, we are pointing to the ambivalent character of a problem as both constructed and real: reacting to unemployment by the creation of new jobs or introducing a statutory minimum wage are acts that depend on how we see the world (ibid.). Labelling 'Fridays for Future' as truancy or as mature and genuine participation is similarly dependent on our perspective.

Social innovations also have unintended side effects. The contraceptive pill, for instance, enabled women to pursue gainful employment and therefore independence, but at the same time it fostered their oppression because of pay inequalities with men, and because there seems to be very little interest in developing contraceptives for men: those male contraceptives that have been developed have negative side effects and have therefore not made it on to the market, though side effects are generally accepted in contraceptives for women (see e.g. Klemm, 2017). Wind turbines as an energy solution to help mitigate climate change also cause bird- and batstrikes (e.g. Traxler et al., 2004).[5] Moreover, the prohibition of exploitative child labour aimed at protecting children's rights led companies to use child labour in areas (rural ones, for example) where child-protection laws were less vigorously enforced (see e.g. Küppers, 2012).

To sum up, when attempts are made to solve social problems, new problems arise, which can be classified into two types: (1) the negative side-effects that arise from solving problems through (social) innovations[6] (e.g. Heidbrink, 2010); and (2) questions of power: who will benefit from the innovation and who will lose out? Can 'harmful and uneconomic solutions' (Rogers & Kim, 1985, p. 88) be numbered among social innovations (see also Gillwald, 2000)? Introducing an ethical meta level should help, if not to solve then at least to discuss these problems.

Handling Negative Side-Effects

Often, due to the pragmatic pressure to act and the scarcity of resources (e.g. Heidbrink, 2010), solving problems may cause new ones (see e.g. Gillwald, 2000). Sometimes, those side-effects can be anticipated, but often they are unpredictable because of the complexity of social causal relations (ibid.). The possibility of predicting unintended side-effects depends on the nature of people's lack of knowledge (*Unwissen*) (Heidbrink, 2010). Using Wehling's typology of a 'sociology of ignorance' (Wehling, 2006, pp. 109–46), for Heidbrink (2010) it is not a question of whether people lack knowledge, but of whether they are able to recognize this lack and influence it – in other words, whether they are able to turn ignorance (*Nichtwissen*) into uncertainty (*Ungewissheit*).

[5] This example also highlights the charged relationship between social and technical innovations, i.e. the difficulty of defining them separately.

[6] The emergence of these negative side-effects gives rise to the question of responsibility (Heidbrink, 2010).

Following Heidbrink (2010), uncertainty means knowledge which is uncertain but knowable (*ungewiss*), whereas ignorance is a blind spot (*unsicher*). Ignorance has three dimensions: (a) knowledge of ignorance, (b) intention of ignorance, and (c) temporary stability. (a) Knowledge of ignorance means that one is able to identify what it is that one does not know ('specified ignorance'; Grove-White, 2001, pp. 470–71), or the ignorance goes totally unrecognized ('unknown unknowns'; ibid.) (Heidbrink, 2010). In this context, the Lacanian term 'unknown knowns' (Žižek, 2006, p. 52) also got to be taken into account as the 'things we don't know that we know' – which are precisely 'the Freudian unconscious […], the disavowed beliefs and suppositions we are not even aware of adhering to ourselves, but which nonetheless determine our acts and feelings' (ibid.). Following Heidbrink's (2010) argumentation again, (b) ignorance can be involuntary, but it can also be intentional, for example by asserting the right not to know, maintaining taboos, or deliberately misinforming or misguiding others. (c) Ignorance can be temporary and therefore turned into an uncertainty ('reducible ignorance'; Faber & Proops (1994), pp. 116–17), or it can last indefinitely ('irreducible ignorance'; ibid., pp. 118–19).

As a component of innovativeness, turning one's ignorance into uncertainty is part of reflexivity since it involves (re)thinking critically. Intended ignorance, therefore, is incommensurate with this ability, since reflexivity denies the possibility of maintaining one's ignorance: a person cannot be considered innovative if they act despite their knowledge of their ignorance. Therefore, an education for innovativeness needs to include enabling people to change their ignorance into uncertainty (by innovating actively), and/or not intentionally to misinform others (by innovating reactively).

Since the model design for innovativeness also names not-innovations as possible outcomes of an innovation process (Weis et al., 2017), it allows for the reworking of ideas and/or implementing strategies, which is also in accordance with Gillwald's (2000) remarks. In the approach of an education for innovativeness, one cannot be responsible for side-effects due to their unknown unknowns. However, the approach can allow reworking novelties (innovating actively) or at least suggesting rework on novelties (innovating reactively). This also highlights the general social component of innovation processes. Thus, it seems possible to minimize the probability of unintended side-effects, or at least to fix them in the aftermath, and consequently to act as responsibly as possible when innovating. However, we still have to ask the question of the power of interpretation – i.e. who is in charge of determining which knowledge needs to be known? How can the benefits of a novelty be determined when group interests conflict with each other?

The Power of Interpretation

Following Heibrink (2010) and Jaeggi (2014), it is not interests and power but norms that should determine the value of a solution. This can be done with the use of normative criteria (Thurnherr, 2000). For this, applied ethics may be useful, as they address practical problems in depth (see e.g. Fenner, 2010). Social ethics, which are part of applied ethics, develop overall principles or criteria in order to assess concrete actions or to question and possibly correct accepted norms, not at the level of an individual actor but on an institutional one (ibid.).

Nevertheless, the approaches of applied ethics are full of pitfalls. Gillwald (2000) suggests that a benefit to more than 50% of members of society should be the benchmark for referring to a social novelty as a social innovation. This, however, is a circular argument, because determining just what the threshold should be is itself determined by power. Moreover, such a suggestion again gives rise to the basic utilitarian basic problem that minorities can be harmed for the benefit of the majority (Rawls, 1972). Another approach is the systematization of moral dilemmas (Horster, 2013) in order to reduce complexity. In the end, one needs to examine which group's interest should be focused on and whose expertise should be seen as appropriate; but these do not answer the question of the power of interpretation. Such inductive bottom-up (practice-based) approaches do not seem fruitful, but neither do deductive top-down (theory-based) ones because of an over-hierarchization of theory which ignores the specificity of individual cases (Fenner, 2010). However, the need for a theoretical basis for acting ethically still exists. In order to evaluate the suitability of various theories of ethics for such a basis, Ott (1996) developed a list of criteria, namely: (i) simplicity, (ii) clarity, (iii) consistency, (iv) relevance in as many areas of practice as possible, (v) accordance with fundamental scientific and moral convictions[7], and (vi) evidently reasoning (see also Fenner, 2010).

According to Ott (1996), discourse ethics, originated by Habermas and Apel, meet his criteria and therefore are the theory of choice for him (see also Fenner, 2010).[8] In this approach, a norm is legitimate when it is or can be accepted by all parties concerned. This will be negotiated in a real communication community. In order to find consensus, all parties concerned must participate in the discourse equally, without social coercion, as all must question their own arguments and stances critically and defer to the better argument. Those who are not able to speak for themselves (non-human sentient beings or those in a persistent vegetative state, for example) will be given a voice by others in the form of a representing discourse (Apel, 1973; Habermas, 1999; see also Fenner, 2010).

At first glance, this approach sounds fruitful, but if we take a closer look at power relations, it does not seem possible to free oneself from social coercion and power interests in communication processes (Heidbrink, 2010), including when speaking for minorities who cannot speak for themselves (Fenner, 2010). Not everybody upholds the rules of discourse outlined above. And even if they do, it is not always possible to find a consensus, since there are no established criteria for assessing the accuracy of arguments (Habermas, 1999).

Consequently, discourse ethics need additional theories in order to deal with heterogeneous groups and conflicting arguments (see e.g. Habermas, 1999). Ott (2001) therefore adopts argumentation theory, according to which valid arguments could be, for example, consequentialist (determining the value of an action according to the value of its consequences), or deontological (describing actions as good or bad despite their consequences, by the use of laws, prohibitions and overall principles, such as autonomy, human dignity or

---

[7] However, assigning a normative value to a theory of ethics (i.e. because of normative convictions) seems to be a circular argument as well.

[8] Ott's (1996) criteria do nonetheless refer to discourse ethics, from which it is evident that these criteria fit the discourse ethics approach. Therefore, and due to Ott's questionable remarks on sea rescue (Hoang, 2018), his approach should be used with critical distance.

the categorical imperative (e.g. Fenner, 2010)). Nevertheless, deontological arguments risk disregarding the particular contexts of actions (ibid.), which would also not be in accordance with reflexivity. Therefore, deontological arguments should not be absolute, but relative (Fenner, 2008, cited in Fenner, 2010).

Following Fenner (2010), the 'theory of justice' (Rawls, 1972) also needs to be added as the highest moral principle.[9] To determine which aspects of equality are relevant when rating (in)equality, justice became typologized: (a) arithmetic/egalitarian equality means that everybody has the same rights; (b) geometric/recipient-distributed equality describes, for example, performance-related pay[10]; and (c) protective equality, which requires that weaker members of society are protected (ibid.). Utilitarian arguments (being part of consequentialist ones (Fenner, 2010)), cannot be in accordance with such an ethical meta level. Thus, and due to the deontological argument of the constitution as well as the basis of the critical theory, hate groups like the Ku Klux Klan cannot be a social innovation.

While Wehling's (2006) 'sociology of ignorance' seems to be an appropriate basis for handling unintended side effects, discourse ethics, extended with argumentation theory and the 'theory of justice', may be a way to deal with the question of the power of interpretation. Hence, these theories may be of use in an initial attempt to develop an ethical meta level in the model design for innovativeness (Figure 2). However, we need to dig deeper into both the theories named so far and others, as we have only scratched the surface.

---

[9] While Fenner (2010) describes the theory of justice as a theoretical addition to discourse ethics, along with argumentation theory, we would rather interpret the maxims of the theory of justice as deontological arguments themselves (see also Figure 2).

[10] This, too, involves a question of the power of interpretation, since jobs typically done by women, for example, are often considered to be worth less than jobs typically done by men.

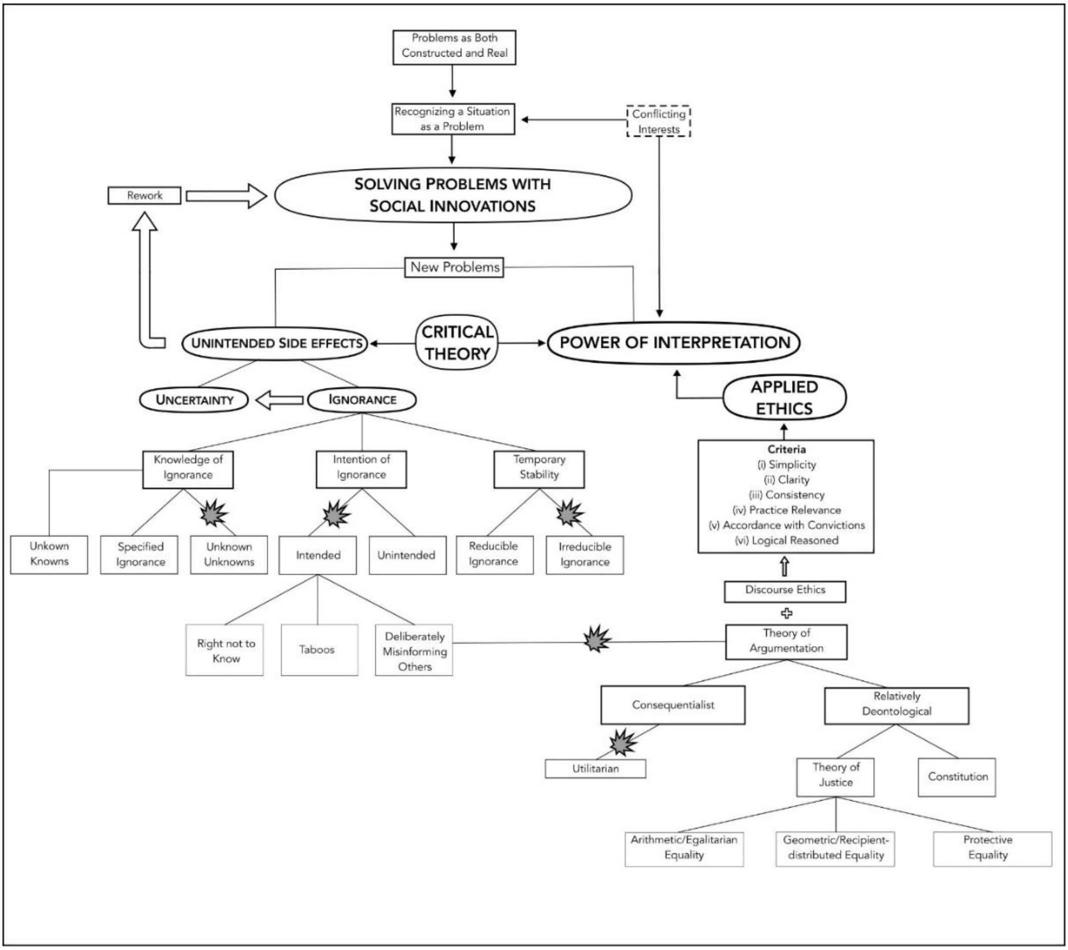


Figure 2: An ethical meta level for the innovativeness model design (own research, based mainly on Jaeggi (2014), Heidbrink (2010), and Fenner (2010)) (draft).

4 Summary

The approach of an education for innovativeness aims to foster participation but does not limit the kind of participation (except for limiting it to being genuine). With this, ethical questions arise: how to deal with divergent definitions of a 'problem', and with negative side effects of innovations; how to define and control improvements brought about by innovations, taking into account the complexity of interests.

This paper has sought to develop an ethical meta level of the innovativeness approach in order to address these issues. In doing so, a range of theories were discussed. Using Jaeggi's (2014) argumentation, the term 'problem' was defined as both constructed and real. Consequently, in the innovativeness approach reflexivity should include the 'identification of problems' and not their 'construction'. Mainly with the help of Gillwald's (2000) remarks, we touched on whether a focus on social innovations could help to meet the requirements of the critical theory, and therefore whether focusing on social innovations could limit the definition of problems to social ones. However, using Jaeggi's (2014) definition of a problem, a focus on social innovations still leaves unanswered the questions of the negative side effects and the power of interpretation. Therefore, Heidbrink's remarks on uncertainty and ignorance (Heidbrink 2010, based on Wehling, 2006) were used to handle negative side effects and responsibility for them. Fenner's (2010) explanatory notes on applied ethics, referring mainly to Ott's (2001) criteria catalogue for discourse ethics by Habermas (1999) and Apel (1973), with additional argumentation theory and Rawl's (1972) 'theory of justice', were taken as a starting point for a possible basis for handling the question of the power of interpretation.

The innovativeness approach in general, and within this paper specifically, supports the aims of geomedia-based SPACIT. While SPACIT fosters the innovative potential of spatial participation using geomedia, this paper has deepened the understanding of reflexivity concerning spaces and the deconstruction of geomedia by providing a closer perspective on the term 'problem', for example as a starting point for counter-mapping. Furthermore, this paper has raised ethical issues that are of interest for those participating in spatial innovation processes. SPACIT aims mainly at enabling people to participate based on their own interests (e.g. by convincing others), though with a basis in fundamental human rights and basic democratic principles. However, the closer perspective on relevance, awareness of others' situations and harmful side effects discussed in this paper may constitute a complement for SPACIT. Practical applications might prove to what extent these theoretical insights could help in public participation processes, such as shaping cities innovatively to make them good places to live for all inhabitants.

References

Adorno, T. (1971). *Erziehung zur Mündigkeit*. Frankfurt a.M.: Suhrkamp.

Apel, K.-O. (1973). *Transformationen in der Philosophie II*. Frankfurt a.M.: Suhrkamp.

Bröckling, U. (2004). Über Kreativität. In ibid., A. Paul, S. Kaufmann (Eds.), *Vernunft – Entwicklung – Leben*. München: Wilhelm Fink, 235–244.

Deutsch, K. (1985). In Theory and Research in Innovation. In: R. & A. Merritt (Eds.), *Innovation in the Public Sector*. Beverly Hills etc.: Sage, 17-35.

Dewey, J. (2002). *Logik*. Frankfurt: Suhrkamp.

Eisenstein, E. (1983). *The Printing Revolution in Early Modern Europe*. Cambridge: Cambridge University Press.

Ellwein, T. (1985). Innovation in West Germany's Public Sector. In: R. & A. Merrit (Eds.), *Innovation in the Public Sector*. Beverly Hills etc.: Sage, 111-142.

Elwood, S., Mitchell, K. (2013). Another politics is possible. *Cartographica*, 48 (4), 275-292.

Faber, M., Proops, John (1994). *Evolution, Time, Production and the Environment*. Berlin: Springer.

Fenner, D. (2010). *Einführung in die Angewandte Ethik*. Tübingen: UTB.

Gillwald, K. (2000). *Konzepte sozialer Innovation*. WZB Discussion Paper, No. P 00-519, Berlin: WZB.

Golser, K., Scharf, C., Jekel, T. (2019). Schüler*innen als Innovator*innen? *OpenSpaces*, 1, 60-70.

Grove-White, R. (2001). New Wine, Old Bottles? *Political Quarterly*, 72, 466-472.

Gryl, I. (2013). Alles neu? *GW-Unterricht*, 131, 16-27.

Gryl, I., Jekel, T. (2012). Re-centering geoinformation in secondary education. *Cartographica*, 47 (1), 18-28.

Habermas, J. (1999). *Moralbewußtsein und kommunikatives Handeln.* Frankfurt a.M.: Suhrkamp.
Hakala, J. & Uusikylä, K. (2015). Neoliberalism, curriculum development and manifestations of 'creativity'. *Improving Schools*, 18 (3), 250-262.
Hart, R. (1992). *Children's participation*. UNICEF Innocenti Essays, 4, Florence: International Child Development Centre of UNICEF.
Hartmann, T., & Meyer-Wölfing, E. (2003). *Nutzung von Innovationspotentialen in außerbetrieblichen Handlungs- und Lernfeldern*. *QUEM-Report* 83, 3-127.
Heidbrink, L. (2010). *Nichtwissen und Verantwortung*. Working Papers CRR, Nr. 8.
Hoang, K. S. (2018). *Philosoph über Schiffe im Mittelmeer*. https://www.derstandard.de/story/2000090527126/ngos-sollen-nicht-moralisch-ueberheblich-werden.
Hochgerner, J. (2009). *Soziale Innovationen finden, erfinden und realisieren* https://www.zsi.at/object/publication/1423/attach/SozialeInnovationenfinden-erfinden-realisieren_Hochgerner.pdf.
Horkheimer, M. (1937). *Traditionelle und kritische Theorie*. Vol. 4. Frankfurt a.M.: Fischer.
Horkheimer, M. (1982). *Critical Theory*. New York: Continuum.
Horster, D. (2013). *Angewandte Ethik*. Stuttgart: Reclam.
Howaldt, J., Jacobsen, H. (2010). Soziale Innovation. In J. Howaldt, H. Jacobsen (Eds.), *Soziale Innovation*. Wiesbaden: VS, 9-18.
Jaeggi, R. (2014). *Kritik von Lebensformen*. Berlin: Suhrkamp.
Jekel, T., Ferber, N., & Stuppacher, K. (2015). Innovation vs. innovativeness. *GI-Forum*, 373-381.
Joas, H. (1992). *Die Kreativität des Handelns*. Frankfurt a.M.: Suhrkamp.
Klemm, M. (2017). Overshadowed by the Pill. *Sexuologie*, 24 (1-2), 11-18.
Krautz, J. (2007). *Ware Bildung*. Kreuzlingen/München: Hugendubel.
Küppers, B. (2012). Plädoyer für den Kinderrechtlichen Ansatz. *APuZ*, 62 (3), 23-28.
Lefebvre, H. (1996). *Writings on Cities*. Oxford: Blackwell.
Luhmann, N. (1998). *Die Wissenschaft der Gesellschaft*. Frankfurt a.M.: Suhrkamp.
MacEachren, A. M. (1992). Visualization. In: R. F. Abler et al. (Eds.), *Geography's Inner Wolrds*. New Brunswick: Rutgers University Press, 99-137.
Merrit, R., Merrit, A. (Eds.) (1985). *Innovation in the Public Sector*. Beverly Hills etc.: Sage.
Millei, Z., Imre, R. (2015). 'Down the Toilet'. *Life Reference work entry*, 7, 1-14.
Ogburn, W. (1933). The Influence of Invention and Discovery. In: H. Hoover (Ed.), *Recent Social Trends in the United States*. New York: McGraw, 122-166.Ohl, U. (2009). 'Spielraumerweiterung. Institutionelle Rahmenbedingungen und Akteursstrategien in der großstädtischen Stadtteilentwicklung unter Einbezug von Kindern und Jugendlichen'. PhD Dissertation. Pädagogische Hochschule Heidelberg.
Ott, K. (1996). *Vom Begründen zum Handeln*. Tübingen: Attempto.
Ott, K. (2001). Moralbegründungen zur Einführung. Hamburg: Junius.
Plötz, R., Pinzek, K., Barnikel, F. (2014). Urban planning with a GIS at school. *GI_Forum*, 295-298.
Popitz, H. (2000). Wege der Kreativität, Tübingen: J.C.B. Mohr.
Ramasubramanian, L. (2010). *Geographic Information Science and Public Participation*. Berlin: Springer.
Rammert, W. (2010). Die Innovation der Gesellschaft. In J. Howaldt, H. Jacobsen (Eds.), *Soziale Innovation*. Wiesbaden: VS, 21-52.
Rawls, J. (1972). A Theory of Justice. Oxford: Clarendon.
Rogers, E., Kim, J (1985). Diffusion of Innovations in Public Organizations. In R. Merrit, A. Merrit (Eds.), *Innovations in the Public Sector*. Beverly Hills etc.: Sage, 85-107.
Scharf, C., Gryl, I., Gamper, M., Weis, S. (2018). Collaborative. *GI_Forum* 2, 156-167.
Scharf, C., Gryl, I., Weis, S., Rott, B. (2019). Kreativität zur Partizipationsförderung. In K. Kannler, V. Klug, K. Petzold, F. Schaaf (Eds.), *Kritische Kreativität*. Bielefeld: Transkript, 205-220.
Scharf, C., Schmitz, S., Gryl, I. (2016). Innovativeness as fresh ground. *GI-Forum*, 1, 250-261.

Schneider, A. (2013). *Geographiedidaktische Reflexivitat*. Berlin: LIT.
Schwandt, M. (2010). *Kritische Theorie*. Stuttgart: Schmetterling.
Solem, M., Cheung, I., Schlemper, M. B. (2008). Skills in Professional Geography. *The Professional Geographer*, 60 (3), 356-373.
Thurnherr, U. (2000). *Angewandte Ethik*. Hamburg: Junius.
Traxler, A., Wegleitner S., Jaklitsch, H. (2004). Vogelschlag, Meideverhalten & Habitatnutzung an bestehenden Windkraftanlagen. Gerasdorf: BIOME.
Van Bouwel, J. (2009). Where the Epistemic and the Political Meet. In ibid. (Eds), *The Social Sciences and Democracy*. London: Palgrave Macmillan, 1-13.
Vogler, R., Ahamer, G., Jekel, T. (2010). GeoKom-PEP. In T. Jekel, A. Koller, K. Donert, R. Vogler (Eds.), *Learning with Geoinformation V*. Heidelberg: Wichmann, 51-60.
Wehling, P. (2006). *Im Schatten des Wissens?* Konstanz: UVK.
Weis, S., Scharf, C., Greifzu, L., & Gryl, I. (2017). Stimulating by simulating. *International Conference on Education: Conference Proceedings*, 386/1-386/11.
Zapf, W. (1994). Über soziale Innovationen. In ibid. (Eds.), *Modernisierung, Wohlfahrtsentwicklung und Transformation*. Berlin: WZB, 23-40
Žižek, S. (2006). *How to read Lacan*. London: Granta.
Žižek, S. (2012). Living in the time of monsters. In M. Nikolakaki (Ed.), *Critical Pedagogy in the New Dark Ages*. New York: Peter Lang, S. 32–44.

GI_Forum 2019, Issue 2
Page: 194 - 205
Full Paper
Corresponding Author:
michael.lehner@uni-due.de
DOI: 10.1553/giscience2019_02_s194

From 'The Map' to an Internalized Concept. Developing a Method of Deconstruction as Practice for Reflexive Cartography

Michael Lehner, Jana Pokraka and Inga Gryl
University of Duisburg-Essen, Germany

Abstract

John Brian Harley's canonical paper 'Deconstructing the map' (1989) has been one of the main bases of Critical Cartography, Critical GIScience, and reflexive approaches to working with maps and geomedia in geography education. However, reducing deconstruction mainly to reading the map's margins is only part of the potential that deconstruction offers. In this paper, following Derrida's approach of deconstruction more closely, we build on the discussion of Harley's paper and try to develop a deconstructive practice for reflexive cartography in educational contexts.

Keywords:

deconstruction, maturity, education, spatial citizenship, map-reading, poststructuralism, critical cartography

1 Introduction and background

In their literature review on cartography, Gryl and Kanwischer (2011) identify a gap concerning reflexive map work (pp. 190–191) – that is, most of the literature examined offers methods for a better understanding of 'the map', but only partly provides techniques for a better understanding of the map-makers' intentions. However, reflexive map work tries to go beyond an intention-oriented demand and critically asks for the margins of the author's intention and, more importantly, for the margins of the socially perceived norm, to be made explicit.

This gap was tackled by the reflexive map education approach (Gryl 2009, Gryl 2012) and the Spatial Citizenship approach alike (Gryl & Jekel, 2012; Jekel, Gryl, & Oberrauch, 2015). Both approaches are rooted in critical cartography, while the Spatial Citizenship approach focuses on spatial-societal participation through the reflexive use of geomedia, such as (digital) maps. One central source of inspiration for both approaches was Harley's (1989) canonical paper 'Deconstructing the Map', with its influential idea that maps could be treated as 'texts'. Harley's paper opened the way for the so-called linguistic turn in the cartographic debate, as well as for post-structuralist arguments.

Lehner et al. (2018) focused on a re-reading of Harley's paper, contrasting his perspective on the deconstructing of maps, which is *partly* based on Derrida, with their own approach to deconstruction, which was based *mainly* on Derrida. To show the epistemic differences between the two authors, Lehner et al. (ibid.) focused on a comparison between the structuralist approach of Saussure (Hoffmann, 2010, pp. 39–57; Saussure, 1931) and the post-structuralist approach of Derrida, emphasizing that Harley uses Derridean terminology (Lehner et al., 2018, pp. 148–150). Lehner et al. suggest a practice of deconstructing the map which tends towards hermeneutics/structuralism, rather than deconstruction. Thus, Harley's interpretation of Derrida can be taken further and the approach of critical cartography extended, to a methodological approach that goes beyond existing work in reflexive map education and Spatial Citizenship.

A central argument put forward by Lehner et al. (2018) is that Harley's approach preserves 'the map' as an object of reflection and does not treat it consistently as 'text' in a Derridean, post-structuralist manner. Based on this discussion that contrasts Harley and Derrida, the paper highlighted specific potentials and limitations of Harley's approach, as illustrated in Table 1, and drew attention to earlier critics who focused on Harley's eclecticism (Belyea, 1992).

Table 1: potentials and limits of Harley's approach (Lehner et al., 2018, p.153)

Potentials	Limits
Potential to question the influence of e.g. institutions on 'the map'…	but not the institutions as such;
Potential to understand 'the map' as an instrument of power…	but power-relations are treated as means to an end, to…
question and uncover implied ideologies of 'the map'…	but not power-relations as such.
With the focus on the creation and the impact of 'the map', Harley's approach enables a critical interpretation of 'the map'… …	but its critical potential is focused on the specific map itself.

A Derridean-style deconstruction shifts the focus from reflecting on 'the map' within its power relations to a specific kind of self-reflection. This kind of self-reflection is based on Derrida's perspective on reading, which he sees as an 'interpretation that takes us outside of the writing toward a psychobiographical signified' (Derrida, 1997, p. 159). Lüdemann describes this way of reading as the production of a new text, which is closely linked to the text that we read but which at the same time has a specific character due to the reader's own particularities and experiences (Lüdemann, 2013, p. 78). Summarized, this specific kind of self-reflection would be a reflection of the 'text' that is produced through the reading. This perspective on reading should offer the potential to take the reader 'outside of the writing [or map]' (Derrida, 1997, p. 159) and could help to question institutions or power relations more directly. These considerations are coherent with the theoretically (Schneider 2010) and empirically validated differentiation between reflection, as externalized map critics, and reflexivity, as questioning thinking and acting with a map, in Gryl (2012). Furthermore, the Spatial Citizenship approach is also aware that map-reading involves the production of hypotheses (MacEachren 1995) and strongly suggests reflexivity in the production of one's own hypotheses ('text production' in a Derridean sense) (Gryl & Jekel 2012). Nevertheless, this reflexivity was still deeply rooted in Harley-inspired critical cartography. This paper, however, will suggest a method that is based more on Derrida's deconstruction, and so bring out the full potential of Harley's pioneering idea.

This approach will be fruitful, as we are convinced that a Derridean practice of map-reading offers great potential for educational contexts, notably to foster what Adorno (1971) calls 'maturity' ('Mündigkeit'). Adorno describes the struggle for maturity as a tension between internalization1 on the one hand, and resistance or dissent on the other. A Derridean deconstructive practice offers the potential to uncover what has been internalized, or internalized concepts2, and to become self-aware, which we regard as an important basis in the permanent process of becoming mature.

Before providing a methodological framework for a potential practice for deconstructive map-reading, we would like to summarize the insights (based on Lehner et al. 2018) that might function as guidelines for the essentials of a method of deconstruction:

- principle A: The specific kind of self-reflection enabled by deconstructive map-reading helps to uncover and identify map-readers' internalized concepts.
- principle B: Deconstructive map-reading helps to perceive these internalized concepts as constructed and historically grown, and makes them discussable.
- principle C: Deconstructive map-reading shows the map as a medium that is discussable and part of power dynamics.
- principle D: Deconstructive map-reading turns the normalization or internalization effect of the communicated map upside-down.

2 Method, Design and Results

2.1 Method and Design

Driven by these reflections on deconstruction (Derrida, 1997) and 'Deconstructing the Map' (Harley 1989), we tried to develop a deconstructive practice for reflexive map-reading in educational contexts that could be evaluated according to the principles outlined above. Inspired by Schmied-Kowarzik's (2008) discussion about dialectics of theory and practice in pedagogics, we developed a guided worksheet for a deconstructive map-reading that should

[1] We see 'internalization' as being rooted in socialization and education (Berger, & Luckmann, 2012, p. 139; Habermas, 1972; Hurrelmann, 2008).

[2] We use 'concept' for terms that structure perception (e.g. 'power', 'ethnicity') and are precursors to constructions while being constructions themselves (see Kuckartz, 2018, p. 36; Schnell, Hill, & Esser, 2008, pp. 128–129). We see the combination of these two strands, 'internalization' and 'concept', as a single but complex element of the socially constructed 'norm' and 'abnormal'.

help (1) to put our thoughts on deconstruction into practice, and (2) to revise the method used to deconstruct the map in the light of experience gained from our practice.

To initiate the process of deconstruction, we had the opportunity to implement our thoughts on deconstruction during a 'Society and Space' course for student teachers in primary social and science education at the University of Duisburg-Essen, in the winter semester of 2018/19. With a group of eleven students, we tested and discussed the first draft of our worksheet. The students applied the tasks given on the worksheet to a political map of Europe. Afterwards, they shared their comments on every step of the worksheet with us and the group.

In section 2.2 below, we present each step of the worksheet to suggest a practice of deconstructive map-reading that remains close to Derrida's theories while also being suitable for use in the classroom. We explain our ideas concerning the method's design. Following this, we present the results of the students' deconstructive map-reading as a basis for a later evaluation of the worksheet, where we compare the results with our principles from section 1. The presentation and evaluation of the results is based on qualitative content analysis (Bohnsack, 2014; Kelle & Kluge, 2010; Kuckartz, 2007, 2018; Mayring, 2015). We decided to discuss the worksheet's design and to present its results in the same section (section 3, 'Discussion and Reflection') in order to illustrate the circular character of the method, where theory and praxis feed into each other.

2.2 Theory and Practice of a deconstructive map-reading

Deconstructive map-reading should include four aspects (see Figure 1), which the worksheet divides into 8 tasks or steps, described in detail in what follows.

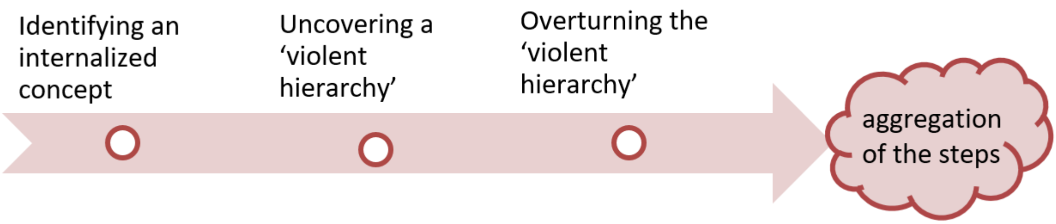


Figure 1: The four major aspects of a practice for a deconstructive map-reading (authors' own design)

Aspect 1: Identifying an internalized concept

Step 1 helps to record what Derrida calls the 'psychobiographical signified' (Derrida, 1997, p. 159) – a 'text' that is produced through the reading (of the map), as discussed above (see section 1). Following Adorno's (1971) argumentation, we think that this new 'text' produced through subjective reading has the potential to represent *internalized concepts*. Therefore, we developed two further steps (*Steps 2* and *3*) which create the foundation for self-reflection that derives from a deconstructive practice.

In *Step 2*, we simply ask students to note down what they recognize on the map (in our case, a map of Europe). We then ask them to go over what they have written to enrich it with just one term that seems particularly meaningful – that is, a specific term corresponding to an *internalized concept* (Adorno, 1971).

Table 2: Identifying an internalized concept

Step 2	Describe what you recognize on the map.
Step 3	Go over your text from Step 2 and choose or add one term that seems particularly meaningful to you.

The students' confrontation with the political map of Europe evoked two categories of concepts.3 The first comprises variations of the concept of border, which we grouped using the 'code' *content-oriented concepts*. This category is fairly dominant, and nine of the eleven students aggregated their map-reading with the term 'border' (4 students) or terms linked to it, like 'boundary', 'demarcation', 'belonging', 'European countries' and 'countries' (1 student each). The second category of concepts we identified is more abstract and focuses on aspects of the map's design. We coded these as *design-oriented concepts* and included the terms 'colourful' and 'centre' (1 case each) in this category.

While we think that reflecting *on content-oriented concepts* offers great potential to foster maturity, we did not at first glance really expect the category *design-oriented concepts* and reflecting on it to imply great potential for fostering the political subject. The new 'text' produced through subjective reading is still closely linked to the 'text' (map) that has been read, as Lüdemann (2013, p. 78) claims. This relation between the two hints at the more abstract *design-oriented concepts* reflection on which does not seem to be too promising in fostering the political subject. Nevertheless, these more abstract concepts do have the potential to turn the normalizing effect of the communicated map upside-down, as we will try to show below.

Aspect 2: Uncovering a 'violent hierarchy'

Although internalized concepts (such as 'country' or 'border') were uncovered and identified by the reading of the map, we cannot assume that the subjective meaning ('signified') of the term itself (the 'signifier') chosen in *Step 3* was uncovered at this stage. We follow Saussure (1931), who argues that meaning ('signified') derives from differences between 'signifiers'. For example, the meaning of 'active' derives from the difference from 'passive'. Thus, mediated by the concept of a system of differences, Saussure breaks with the idea that language represents the world: rather, he sees language as a system that produces meaning and reality (*world x language <-> subject*). Thus, to clarify the meaning of the internalized concept in *Step 3*, in *Step 4* we ask for its opposite in order to construct an awareness of differences.

Derrida partly follows Saussure but diverges from the structuralist argumentation with his alternative concept of 'différance'. With this, he criticizes the idea implicit in the structuralists' argumentation of a natural connection between meaning ('signified') and speaker. He sees 'différance' – a constant process of producing and reproducing metaphors of (hidden) meaning ('signifier of the signifier') –*before* conscious articulation. With the concept of 'différance',

[3] We follow Kuckartz (2018, p. 35) in our terminology and use 'category' and 'code' as synonyms.

Derrida decentres the subject (*world x language x subject*). But more importantly, 'Différance' also involves the idea that 'in a classical philosophical opposition we are not dealing with a peaceful coexistence of a vis-à-vis, but rather with a violent hierarchy' (Derrida, 2004, p. 39). This becomes clear if we apply the concept of a 'violent hierarchy' to binary oppositions such as 'homo'/'hetero', 'woman'/'man', etc.

Inspired by these Derridean thoughts, in *Step 5* we ask students to arrange the opposites from *Step 4* according to a subjectively perceived hierarchy. In *Step 6*, we then ask them to describe this hierarchy in order to uncover more clearly the 'violent hierarchy' that is implied in language (from a Derridean perspective), and to open up the potential for a better intersubjective comprehensibility.

Table 3: Uncovering a 'violent hierarchy'

Step 4	Find an opposite to that term, thus creating a pair of opposites. Term A: ______ vs. Term B: ______
Step 5	Arrange the 2 terms according to how you perceive their hierarchy. ________ ↓ ________
Step 6	Describe the relationship between the terms given in Step 5. Where, from your point of view, does the hierarchy come from?

The students chose the following opposites and arranged them hierarchically as shown:

- 'border' → 'freedom' (2 students)
- 'border' → 'openness'
- 'border' → 'borderless'
- 'boundary' → 'borderless'
- 'demarcation' → 'connectedness'
- 'exclusion' → 'belonging'
- 'European countries' → 'European community'
- 'waters' → 'countries'
- 'colourful' → 'monochrome'
- 'periphery' → 'centre'

Aspect 3: Overturning the 'violent hierarchy'

So far, this approach for a deconstructive practice should have helped to uncover an internalized concept and show its embeddedness in a 'violent hierarchy'. However, deconstruction tries to go further. It aims to defer that hierarchy, and with that the meaning of specific 'terms' or concepts (see Derrida, 2009, pp. 64–68). But how? As an example, in *Gender Trouble* (1990), Judith Butler deconstructs 'The compulsory order of sex/gender/desire' in just two pages (pp. 9-11). Butler also starts her deconstruction with a pair of opposites: 'sexed body' and 'gendered subject'. After describing the hierarchy of these 'terms', Butler focuses on their interrelations, and with that she 'overturns' their 'violent hierarchy':

If the immutable character of sex is contested, perhaps this construct called 'sex' is as culturally constructed as gender; indeed, perhaps it was always already gender, with the consequence that the distinction between sex and gender turns out to be no distinction at all. (pp. 10-11)

With this description of the interrelation between 'sex' and 'gender', Butler 'overturns' the hierarchy and presents the seemingly natural (or 'prediscursive') category 'sex' as having a discursive, or a historical/genealogical, character. Based on Butler's practical example of deconstruction, in the next two steps we ask students to describe the interrelations between their chosen terms, and to display them graphically for further clarification:

Table 4: Overturning the 'violent hierarchy'

Step 7	Describe the terms' mutual dependencies. Term B relies on term A, because: ______________________ Term A relies on term B, because: ______________________
Step 8	Create a graph to illustrate the terms' hierarchy and the mutual dependencies from Step 7.

To analyse the students' results, we created three 'codes'. We called the first one *dialectical thinking* and applied it to every case where we were able to identify the search for the interrelationship of the pairs of opposites. Due to the framing of *Step 7*, it was not surprising that the code was applicable to every student answer except one, where the answer was simply too short to clearly apply the code. We could see the production of variations of the terms' meanings in the students' notes. We interpret this production of variations as being, potentially, indicative of movement. Although we do not know whether the internalized concepts like 'border' identified by the students were prediscursive or perceived as natural before, with this step we show that they are now perceived as discursive.

While we expected to apply the 'code' *dialectical thinking* to almost every case, we tried to analyse the terms' variations and movement more deeply, and so created the codes *synthesis* and *open movement*. To operationalize these codes, we applied the code *synthesis* to identify a pair of opposites that had been merged in a new term incorporating them both. We applied the code *open movement* in cases where we did not see any such merger.4 The results of this analysis are shown in Table 5.

[4] The coding process is inspired by 'consensual coding' (Hopf & Schmidt, 1993): we applied the coding as a group of seven people and discussed our differences.

Table 5: Analysis of dialectical movement

field of tension	*'open movement'*	*'synthesis'*
'border' <-> 'freedom'		'borderless'
'border' <-> 'freedom'	x	
'border' <-> 'openness'	x	
'border' <-> 'borderless'	too little information to apply a code	
'boundary' <-> 'borderless'		'border transgression'
'demarcation' <-> 'connectedness'	x	
'exclusion' <-> 'belonging'	x	
'European countries' <-> 'European community'	x	
'waters' <-> 'countries'	x	
'colourful' <-> 'monochrome'	x	
'periphery' <-> 'centre'	x	

As this table shows, we applied the code *open movement* for most cases. We would argue that the code *dialectical thinking* could be applied to these cases as well, which means that in these cases the internalized concepts are open to discussion. At the same time, we think that the cases where we applied the code *synthesis* need further discussion. Derrida argued that deconstruction fosters the potential for a new 'term' to emerge which it would not be possible simply to extrapolate from the previous classification system (Derrida, 2009, pp. 66–67). These 'terms' or concepts that we emphasized with our code *synthesis*, such as 'borderless' and 'border transgression', are not *new* in Derrida's sense of '*new term*', which tries to overcome metaphysical thinking. Nevertheless, we think these concepts are very interesting. Remember: we started with a political map of Europe, where we see the idea of the nation-state represented quite prominently, but some students came up with concepts like 'borderless' and 'border transgression' in their process of (critical) reflexive map-reading.

One final aspect we would like to emphasize here is the link between the 'text' that is produced through reading and the 'text' (map) that has been read, mentioned in section 3.2.1. If we take a closer look at more abstract *design-oriented concepts* like 'colourful' and 'centre', reflection on which does not seem particularly promising in fostering the political subject, it shows up quite clearly in *Step 7* that these concepts are still linked to the 'text' that has been read (i.e. the map). For example, the student who came up with the field of tension 'colourful' vs 'monochrome' discussed the focus on Europe which appears 'colourful' in contrast to other continents, which are 'monochrome':

The Continent is displayed in different colours. In order to differentiate the continent, the countries are coloured differently. Continents outside the [map's] focus are displayed as monochrome and not differentiated. (Student's note; own translation.)

While we couldn't find a *synthesis* such as 'eurocentrism' in the students notes, this suggests that the student identified a tension between the emphasis of Europe and the devaluation of other continents.

Aspect 4: Aggregation of Steps 1–8

Up to this point, the different parts of the procedure do not seem to mesh, and therefore we tried to design a final step to aggregate the 8 steps. We experimented with different tasks. For example, we asked students to link the mutual dependencies from *Step 7* to concrete representations on the map which are subjectively apparent to the students. In another task, we asked for a comparison of *Step 5* ('Arrange the two terms according to how you perceive their hierarchy') and *Step 7* (mutual dependencies) and hoped for an explicit description of the 'overturn' of the 'violent hierarchy'. Due to redundancy and the attempt to keep the procedure as simple as possible, we skipped these steps in its latest version. We simply ask in the 9th and final step for new pairs of opposites based on the 'text' of *Steps 7* and *8*.

Table 6: Aggregation

Step 9	Try to identify new pairs of opposites based on ***Steps 7*** and ***8***.

We think this last task offers a good balance between consolidating the work done in the previous steps on the one hand, and an openness that avoids a new rigid re-construction on the other. We illustrate the results of this step in Table 7 by giving answers by a student who started with a *content-oriented concept* ('border') and those of a student who started with an *design-oriented concept* ('colourful').

Table 7: Aggregation results

content-oriented concept	***design-oriented concept***
universal – individual	Continents which aren't being focused on / continents which are being focused on
individual – state	not differentiated – differentiated
orientation – disorientation	starting point – endpoint
self-determination – common good	
satisfaction – dissatisfaction	

We think these examples provide a hint as to the potential of this approach. We started with a political map of Europe, and here we have a cloud of words that is full of tensions (e.g. 'individual – state') which can serve as a basis for discussions that reach beyond looking at maps critically – concepts that are oriented towards hermeneutics and understanding, and reflecting on one's own involvement in political discourses.

3 Discussion and Reflection

The potential of this approach goes far beyond deconstructing map-reading, but we are also aware that deconstructive map-reading is not about a fixed result, which would simply impose another rigid (re-)construction. We think the strength of this approach lies in the process of deconstruction itself, one central part of it (laid out in Steps 1 and 2) being to encourage the uncovering of internalized concepts (principle A)).

As discussed in section "Aspect 1: Identifying an internalized concept", we think that *content-oriented concepts* such as 'border' and its variations represent an internalized concept more directly than do *design-oriented concepts*, such as 'colourful' and 'centre'. In section 2, we defined the internalized concept as a jigsaw piece of the socially-constructed norm, or of what is considered abnormal. We think that the *content-oriented concepts* meet the requirements of this definition: for example, the concept 'border' can be seen as a precursory concept (a jigsaw piece) of the construction of the 'nation-state' as a norm.5 The exclusionary differences derived from the socially-constructed norm or (ab)normal linked to this construction (such as the differentiation between citizens and non-citizens of nation-states) contrasts with the universalism of human rights (Habermas, 2011, p. 31),6 or the anti-essentialist attempt of deconstruction (Engelmann, 2009, pp. 17–19).

While we think that *content-oriented concepts* represent internalized concepts more directly than the *design-oriented concepts*, we believe that the latter offer a specific quality of reflection. With their focus on design-based decisions in map-creation, such concepts facilitated discussion of questions such as 'What is colourful/monochrome?' or 'What is displayed in the centre/periphery?'. Based on the link between the 'text' produced through reading and the 'text' (map) that has been read, students identified a tension between, for example, those continents on which there was a focus and those which did not appear in detail. In design-oriented concepts, we recognize decisions made during map-creation as discursive elements and as a part of power dynamics (principle D).

In section "Aspect 3: Overturning the 'violent hierarchy'", we argued that the *content-oriented concepts* and *design-oriented concepts* located within 'violent hierarchies' are discussable (principle B), because of the interrelations between the terms in each pair of opposites. This perception of concepts as being open to discussion implies principle C.

To sum up: the shift in focus from a critical understanding of the map (see Table 1) to the 'text' that is produced through reading the map is the core idea of this approach. The approach should foster a specific kind of reflection and should make it possible to turn the normalization or internalization effect of the communicated map upside-down (principle D).

[5] For a detailed discussion of the history of the idea of the nation and the nation-state, see e.g. Anderson (1988) and Hobsbawm (2005). For a discussion of nationalism and racism within the discipline of geography based on the example of the Department of Geography at the University of Vienna around 1938, see Svatek (2018).

[6] For a discussion of the contradiction between civil rights that are linked to citizenship and human rights, see e.g. Denninger (2009).

While these insights seem promising, to evaluate the potential of our approach for geography education in a school-based context we are aware that further empirical research is required with primary or secondary school students. An adaption might be considered crucial, especially as the final step (*aggregation*) necessarily leaves students with open ends. This final step could, however, serve as a starting point for addressing the power relations in their own classes as perceived subjectively by the students themselves.

References

Adorno, T. W., & Becker, H. (1971). *Erziehung zur Mündigkeit Vorträge und Gespräche mit Hellmut Becker 1959 - 1969* (25.). Frankfurt: Suhrkamp.

Anderson, B. (1988). *Die Erfindung der Nation*. Frankfurt am Main: Campus-Verl.

Belyea, B. (1992): Images of power: Derrida, Foucault, Harley. In: *Cartographica (The International Journal for Geographic Information and Geovisualization)* 1992, no. 2, pp. 1-9.

Berger, P. L., & Luckmann, T. (2012). *Die gesellschaftliche Konstruktion der Wirklichkeit* (24th ed.). Frankfurt am Main: Fischer Taschenbuch.

Bohnsack, R. (2014). *Rekonstruktive Sozialforschung: Einführung in qualitative Methoden* (9., überarbeitete und erweiterte Auflage). Opladen Toronto: Verlag Barbara Budrich.

Butler, J. (1990). *Gender Trouble: Feminism and the Subversion of Identity*. New York: Routledge.

Crampton, J.W. (2010). *Mapping. A Critical Intro-duction to Cartography and GIS.* Malden

Denninger, E. (2009). 'Die Rechte der Anderen'. *Menschenrechte und Bürgerrechte im Widerstreit. Kritische Justiz, (3)*, 226–239.

Derrida, J. (1990). Die Struktur, das Zeichen und das Spiel im Diskurs der Wissenschaft vom Menschen. In P. Engelmann (Ed.), *Postmoderne und Dekonstruktion: Texte französischer Philosophen der Gegenwart* (pp. 114–139). Stuttgart: Reclam.

Derrida, J. (1997). *Of grammatology*. (G. C. Spivak, Trans.). Baltimore: Johns Hopkins University Press.

Derrida, J. (2004). *Positions*. (A. Bass, Trans.). Chicago: University of Chicago Press.

Derrida, J. (2006). *Die Schrift und die Differenz*. (R. Gasché & U. Köppen, Trans.) (12th ed.). Frankfurt am Main: Suhrkamp Verlag.

Derrida, J. (2009). *Positionen: Gespräche mit Henri Ronse, Julia Kristeva, Jean-Louis Houdebine, Guy Scarpetta*. (P. Engelmann, Ed., D. Schmidt & A. Wintersberger, Trans.) (2nd ed.). Wien: Passagen.

Engelmann, P. (2009). Positionen 2009. In *Positionen: Gespräche mit Henri Ronse, Julia Kristeva, Jean-Louis Houdebine, Guy Scarpetta* (2nd ed., pp. 11–21). Wien: Passagen.

Feustel, R. (2015). *Die Kunst des Verschiebens: Dekonstruktion für Einsteiger*. Verlag Wilhelm Fink.

Glasze, G. (2009). *Kritische Kartographie.* Geographische Zeitschrift, 181–191.

Gryl, I. (2009). *Kartenlesekompetenz. Ein Beitrag zum konstruktivistischen Geographie-unterricht* (= Materialien zur Didaktik der Geographie- und Wirtschaftskunde 22). Wien.

Gryl, I. (2012): Geographielehrende, Reflexivität und Geomedien. Zur Konstruktion einer empirische begründeten Typologie. In: *Geographie und ihre Didaktik (GuiD) 40, 4*, 161-182.

Gryl, I., & Jekel, T. (2012). Re-centring Geoinformation in Secondary Education: Toward a Spatial Citizenship Approach. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *47*, 18–28. https://doi.org/10.3138/carto.47.1.18

Gryl, I., & Kanwischer, D. (2011). Geomedien und Kompetenzentwicklung - ein Modell zur reflexiven Kartenarbeit im Unterricht. *Zeitschrift Für Didaktik Der Naturwissenschaften*, (17), 203–222.

Habermas, J. (1972). *Thesen zur Theorie der Sozialisation : Stichworte und Literatur zur Vorlesung im Sommer-Semester 1968*. Frankfurt am Main.

Habermas, J. (2011). *Zur Verfassung Europas: Ein Essay*. Suhrkamp Verlag.

Harley, J. B. (1989). Deconstructing the Map. *Cartographica*, *26*, 1–20. https://doi.org/10.3138/e635-7827-1757-9t53

Hobsbawm, E. J. (2005). *Nationen und Nationalismus Mythos und Realität seit 1780* (3rd ed.). Frankfurt, Main [u.a.]: Campus-Verl.

Hoffmann, L. (Ed.). (2010). *Sprachwissenschaft: ein Reader* (3., aktualisierte und erw. Aufl). Berlin ; New York: De Gruyter.

Hopf, C., & Schmidt, C. (Eds.). (1993). *Zum Verhältnis von innerfamilialen sozialen Erfahrungen, Persönlichkeitsentwicklung und politischen Orientierungen: Dokumentation und Erörterung des methodischen Vorgehens in einer Studie zu diesem Thema*. Hildesheim.

Hurrelmann, K. (Ed.). (2008). *Handbuch Sozialisationsforschung* (7., vollst. überarb. Aufl). Weinheim: Beltz.

Jekel, T., Gryl, I., & Oberrauch, A. (2015). Education for Spatial Citizenship: Versuch einer Einordnung. *GW-Unterricht*, *137*, 5–13.

Kelle, U., & Kluge, S. (2010). *Vom Einzelfall zum Typus: Fallvergleich und Fallkontrastierung in der qualitativen Sozialforschung* (2., überarb. Aufl). Wiesbaden: VS, Verl. für Sozialwiss.

Kuckartz, U. (2007). *Einführung in die computergestützte Analyse qualitativer Daten: Lehrbuch* (2., aktualisierte und erw. Aufl). Wiesbaden: VS, Verl. für Sozialwiss.

Kuckartz, U. (2018). *Qualitative Inhaltsanalyse: Methoden, Praxis, Computerunterstützung* (4. Auflage). Weinheim Basel: Beltz Juventa.

Lehner, M., Pokraka, J., Gryl, I., & Stuppacher, K. (2018). Re-Reading Spatial Citizenship and Re-Thinking Harley's Deconstructing the Map. *GI_Forum*, *1*, 143–155. https://doi.org/10.1553/giscience2018_02_s143

Lüdemann, S. (2013). *Jacques Derrida zur Einführung* (3rd ed.). Hamburg: Junius.

MacEachren, A. M. (1995): *How maps work. Representation, visualization, and design.* New York.

Mayring, P. (2015). *Qualitative Inhaltsanalyse: Grundlagen und Techniken* (12., überarbeitete Auflage). Weinheim Basel: Beltz.

Pickles, J. (Ed.). (1995). *Ground truth: The social implications of geographic information systems.* New York: Guilford Press.

Saussure, F. de. (1931). *Grundfragen der allgemeinen Sprachwissenschaft*. Berlin: de Gruyter.

Schmied-Kowarzik, W. (2008). *Das dialektische Verhältnis von Theorie und Praxis in der Pädagogik*. Kassel University Press.

Schneider, A. (2010): Der Zweite Blick in einer reflexiven Geographie und Didaktik. Dissertationsschrift. Jena.

Schnell, R., Hill, P. B., & Esser, E. (2008). *Methoden der empirischen Sozialforschung* (8., unveränd. Aufl). München: Oldenbourg.

Schuurman, N. (2000). Trouble in the heartland: GIS and its critics in the 1990s. *Progress in Human Geography, 24(4)*, 569–590. https://doi.org/10.1191/030913200100189111

Svatek, P. (2018). Kontinuität oder Wandlung? Stadt- und Landesplanung am Geographischen Institut der Universität Wien um 1938. *GW-Unterricht, 1*, 5–13. https://doi.org/10.1553/gw-unterricht152s5

Linguistic Landscaping at School - A Teaching Design

GI_Forum 2019, Issue 2
Page: 206 - 212
Short Paper
Corresponding Author:
s1013038@stud.sbg.ac.at
DOI: 10.1553/giscience2019_02_s206

Manuel Huyer
University of Salzburg, Austria

Abstract

In a Digital Humanities context, we give an overview of applications in the field of Linguistic Landscapes. Focusing on basic digital education, which is the first pillar of the digital competency model for 'School 4.0' in the *Masterplan Digitalisierung in der Schule*, a teaching model is currently being developed which focuses on the development and assessment of digital competences and uses various digital learning tools, allowing modern, innovative teaching. The model uses the advantages and possibilities of two subjects, Geography and German, in order to achieve the greatest possible educational value. The topic 'Linguistic Landscapes' represents just one of many intersections of the two subjects and, especially in the digital world, has potential for a wide range of applications. Because language takes place in space, it can be argued that language in its visible form in particular – for example on city streets – contributes to the shaping of the landscape. An advantage of this project is that improvements in teaching practices generally can be achieved through the digital humanities.

Keywords:

education, digital humanities, linguistic landscaping, lesson planning, digitalization in schools

1 The Linguistic Landscape

The landscape is a construct which has traditionally been associated with Geography as a scientific subject. Hard (1969) provides a broad overview of how the term 'landscape' (Landschaft) has developed since it first appeared in German literature in the early 1900s. According to Hard, the concept became known to the discipline of Geography shortly after the term was discovered by the Humanities.

Already in 1923, Hellpach writes that a landscape is a purely sensual overall impression that is awakened in us by a piece of the earth's surface and the associated section of the heavens (Hellpach, 1923). As can be seen in this definition, sensory impressions are strongly associated with the term. At the same time, Hettner states that the landscape includes earth, water, air, flora and fauna, as well as human beings and their works (Hettner, 1927, p. 231.) Through human activity, languages become visible in the form of written language. Gorter notes that a

‘Linguistic Landscape’ is an “all-encompassing view on written language in the public space, paying attention to all signs” (Gorter, 2012, p.1). Visually perceivable linguistic units (words, slogans, phrases …) are examined for the language(s) used, content, font style and size, frequency of occurrence, and the location where they can be seen. Gorter et al. believe that ‘linguistic landscaping’ „ examines [not only] the signs themselves, but also who initiates, creates, places and reads them” (Gorter, 2012, p.1). Examples of ‘signs’ include posters, stickers, graffiti, restaurant names, as well as street and traffic signs and so on.

According to Androutsopoulos, the linguistic landscape has two main functions – an informative function and a symbolic one. The informative function raises the question of what the linguistic landscape says about its inhabitants and users, and references the languages and ethnic composition present locally. The symbolic function reveals the presence or absence of a language and its vitality and strength (Androutsopoulos, 2008, p. 1).

2 Qualitative investigation of signs

The qualitative examination of signs deals in greater detail with the individual statement units. Clearly, this can be done in class only for a few selected examples if a fine-grained analysis is to be maintained.

The creator or person in charge: Is there a top-down (official) or a bottom-up (private commercial) structure in the sign under consideration? Androutsopoulos (2008, p.2) proposes a third category consisting of unauthorized signs, which are unlawfully affixed, and whose messages usually include mentions of rebellion or revolution. Unauthorized signs (such as tags) may also mark territorial claims.

Status of the languages involved: Are the languages used on the signs official languages, autochthonous or allochthonous minority languages, or international languages? How do they relate to one another?

Number of languages on the same sign: How is the semantic relationship between various languages made apparent? For instance, a sign may express the same meaning in several languages, employ verbatim translations, or one part may be in one language while another is in a different language. We can look at individual elements of a sign and identify the fonts and colours used, the sign's lay-out, and the font size, and how the various elements relate to each other. An example can be seen in Section 7 (Figure 3).

3 Quantitative investigation of signs

A sample area of investigation can be found on Google Maps using the hyperlink http://bit.ly/linguisticlandscapesalzburg (GOOGLE, n.d.). By left-clicking on one of the bubble icons, a window with the following picture will appear:

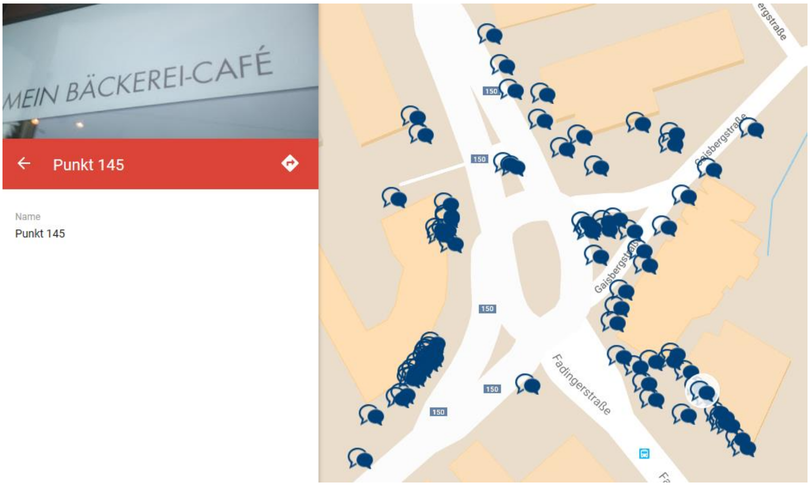


Figure 1: Illustration of one area from the map

Another click on the image allows a full-screen view. A button bottom-left allows the base map to be replaced by a satellite image or a simple street map. (All photos included in the Google-Map were taken by the author.)

4 General conditions - The question of when and where

Having trialled the course, and given the approach used, we would say that the Linguistic Landscaping course is suitable only for upper grades. The course requires ready access to smartphones and computers as the key platforms on which the lessons are taught. The *Masterplan Digitalisierung in der Bildung* mentions a revision of school curricula towards a comprehensive consideration of digital skills, pointing to a need for action in the development and acquisition of digital teaching and teaching materials for classes (BMBWF).

At least one laptop and a projector are required, and one smartphone per student. Student-owned devices may be used. Students may work in pairs or small groups if necessary. Open-air classes have also been planned. The curriculum of the 'Neue Oberstufe' for 'Geographie und Wirtschaftskunde' states that that geographic and economic information can be obtained, analysed and displayed in a target-group-oriented manner using computer-assisted procedures. Especially in upper secondary schools, students should be able to classify spatial information independently, as a basic competence. A didactic principle of geography teaching states that students should learn through practical work incorporated into certain course modules for every subject matter.

5 The course design

Given that most pupils have at the very least a basic understanding of maps, 'Linguistic Landscaping' should feature in lessons in tandem with digital maps (OSM, Google Maps, ESRI applications). In our project, it is important for pupils to be able to mark locations on digital maps, label them, and complement them with pictures. During German lessons, pupils should come to understand the meaning of 'signs', as well as become familiar with theory and the specific tools needed for conducting research. The course subject Geography first introduces pupils to digital maps. Students then carry out field work (best done in a city area) during which they collect data in the immediate vicinity of the school or elsewhere. This involves taking photos, with digital cameras or smartphones, of all sorts of written language that will later be evaluated in class. The use of central, app-based software is highly recommended, as this facilitates later processing considerably. For example, apps such as 'geo-editor' or 'geotag photos' allow photo locations to be added directly to a map. Another possibility is for smartphones to automatically add geotags to the photos when the GPS is turned on. The geotags can then be read out loud.

After collective or individual data collection, the photos are first mapped, then analysed, interpreted and discussed. The map example given in Figure 1 shows how such a map could look. Later, the photos are examined according to the quantitative and qualitative criteria described in Sections 2 and 3 above. While German lessons are particularly suited for qualitative investigations, as they can be used to interpret individual 'signs', Geography lessons lend themselves well to comparing quantitative results, for example the demographic data of different areas. Further examples of quantitative and qualitative evaluations can be found in the Sections 6 and 7.

5.1 Learning goals

This learning environment contributes to the ability to read and create digital maps, analyse and interpret digital data, and understand their implications. Furthermore, one of the goals for students is to explore and get to know the city or area around their school and to delve more deeply into the city's structure. A deeper understanding of space and landscape concepts should accordingly be achieved. The German courses may also include statistical data analysis, but we believe that the qualitative examination of signs offers many more creative possibilities.

5.2 Methods and Media

As the possibilities of digital media are enormous and ever-changing, an increasing number of opportunities present themselves. As educators, we must act in the knowledge that teachers live in a different digital world from the one their students inhabit. But neither group is homogeneous.

We can benefit from so-called 'sharing cultures', also known as the 'cloud'. This means that the knowledge and efforts of many individuals together create greater value. In our project's case, the collective efforts of students to collect photos are more efficient and better planned than would be possible if such tasks were performed individually. In addition, everyone has his/her own strengths and can incorporate them into the project. The students should appreciate the possibilities of cooperation and work cooperatively.

The end result should look something like the one that is linked in lesson planning (see Figure 1). To achieve this, upload all students' photos into either Dropbox or a folder on Google Drive, after which they will be marked in Google Maps. This requires a Google Account. By following the path Menu → My Places → Maps → Create Map, you can start a new project. Markers can be selected by using the marker symbol below the search bar; by left-clicking on the map, a marker can be set and later moved. You can give the marker a name, add a description, and most importantly, upload a photo. However, manually editing the map is very time-consuming, making it more efficient to use either a common Google Account which all students can log into, or a geotag-app, in which case the use of a common account remains the better option. Using a common Google account allows each student to create their own layer to better visualize the results. For example, the students could name their layer using their names. It also allows an efficient overview for the educator. In the second alternative, working with an app, the location on the map is identified automatically. Many possibilities are offered by the 'Geotag Photos' app, of which a free version exists for both Android and Apple. The routes covered can also be visualized in this app.

6 Example (Altstadt Salzburg) – Quantitative aspect

Only 2,497 main residences are registered in the Altstadt/Mülln district of Salzburg. One explanation is that many second homes are located here. 19- to 29-year-olds and 30- to 39-year-olds are the most represented age groups. Over-70s account for just over 10%. 63% of the people who live in the Altstadt are Austrian citizens.

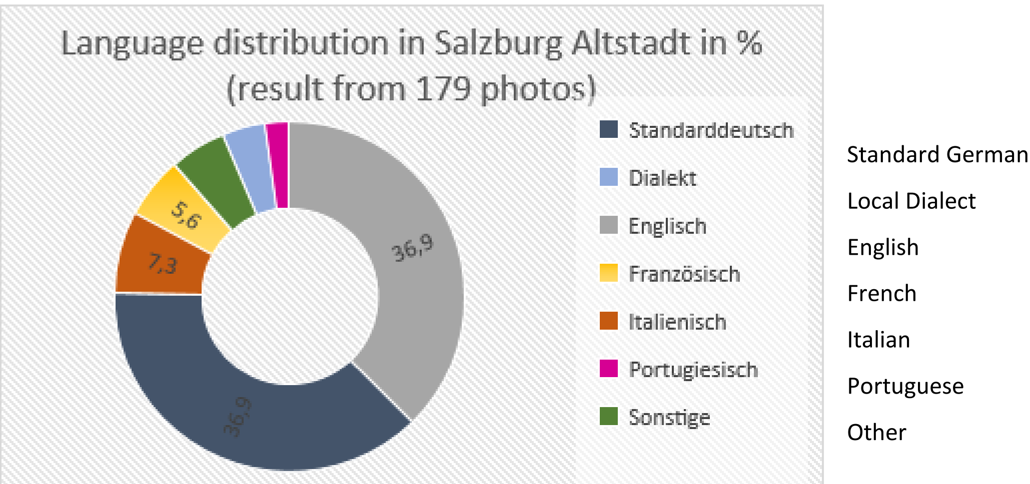


Figure 2: Language distribution in Altstadt/Mülln. Data source: own data collection.

German and English are represented equally in the Altstadt, on about 37% of the signs analysed for linguistic content. Together, they account for roughly three-quarters of all linguistic expressions. French and Italian occupy the third and fourth places. Boasting fifteen languages, linguistic diversity in the centre is very high: the city centre is clearly a tourist hub.

7 Example (a picture taken in Lehen) - Qualitative aspect

Figure 3: Syrian food (Lehen)

The photo is of a billboard outside a grocery store in Lehen which offers Syrian food. Beneath a large heading in German is a slightly smaller-sized text in Arabic. It is not an accurate translation, because 'سوبرماركت سوريا' means 'Syria supermarket'. These two expressions refer to the name of the business. Anything regarding organizational matters (shop opening times) is in German. Two languages are included – German as the official language and Arabic as the language of a minority. From the amount of text, its position and size, we can deduce that the Arabic language on this sign is subordinated to the German language. Although the font colour is uniform yellow, we can hardly compare the fonts because the languages use different scripts. We may deduce from the sign that its authors are probably the owners of the shop, and that they are Syrian or at least Arabic speakers: the heading appears to be an imperfect translation into German and should read 'Syrische Lebensmittel' or 'Lebensmittel aus Syrien' in idiomatic German. It is a private commercial signboard, which advertises the business to passers-by.

8 Conclusion

The importance of the linguistic landscape for schools is a given, especially in times of increasing migration which characterizes an intercultural society. This also applies to the school, where many different cultures interact.

As illustrated in Section 7, German is not the only language shaping the urban landscape. Many languages are visibly present. For students in school, this is a perfect way to get to know the city better and to understand how complex its appearance, structure and demographical composition can be. Using the methodology employed in the 'Linguistic Landscaping' course, which offers an excellent point of contact between German courses and Geography courses, students familiarize themselves with new techniques and interact intensively with language and space. In conclusion, this course appears to hold promise. Integrating it as part of the school curriculum is likely to offer strong educational value and increased awareness of society for participating pupils.

References

Androutsopoulos, J. (2008). ‚Linguistic landscapes: Visuelle Mehrsprachigkeitsforschung als Impuls an die Sprachpolitik'. Lecture at the international symposium „Städte-Sprachen-Kulturen" (September 17th -19th, 2008), Mannheim. p. 1-2.

BMBWF. ‚Masterplan Digitalisierung in der Bildung'. Lecture to the Council of Ministers (September 5th, 2018)

GOOGLE (n.d..: Linguistic Landscape Salzburg. Retrieved from: https://goo.gl/maps/1r6ygdQ25173BQbQ7.

Gorter, D. et al. (2012). *Studying Minority Languages in the Linguistic Landscape*. Basingstoke: Palgrave Macmillan. p. 1.

Hard, G. (1969). Die Diffusion der „Idee der Lanschaft". Primärlinien zu einer Geschichte der Landschaftsgeographie. In: *Erdkunde* 24(4), 249-264.

Hellpach, W. (1923). *Die geopsychischen Erscheinungen. Wetter und Klima, Boden und Landschaft in ihrem Einfluß auf das Seelenleben*. Leipzig: Wilhelm Engelmann.

Hettner, A. (1927). *Die Geographie, ihre Geschichte, ihr Wesen und ihre Methoden.* Breslau: Hirt. p. 231.

Stadtgemeinde Salzburg: Einwohner- und Bevölkerungsstatistik. *Statistische Zählbezirke und Zählsprengel.* https://www.stadt-salzburg.at/internet/bildung_kultur/salzburg_in_zahlen/einwohner_bevoelkeru_321402/statistische_zaehlbezirke_und_zaehlspren_251948.htm.