Oeconomia
Copernicana

Volume 11 Issue 3 September 2020

p-ISSN 2083-1277, e-ISSN 2353-1827
www.oeconomia.pl

ORIGINAL ARTICLE

Citation: Kuc-Czarnecka, M. (2020). COVID-19 and digital deprivation in Poland. *Oeconomia Copernicana*, *11*(3), 415–431. doi: 10.24136/oc.2020.017

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Received: 3.07.2020; Revised: 21.08.2020; Accepted: 5.09.2020; Published online: 17.09.2020

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COVID-19 and digital deprivation in Poland

JEL Classification: *A10; I24; O18*

Keywords: *COVID-19; digital deprivation; e-exclusion; GIS methods*

Abstract

Research background: The problem of digital deprivation is already known, but the COVID-19 pandemic has highlighted its negative consequences. A global change in the way of life, work and socialisation resulting from the epidemic has indicated that a basic level of digital integration is becoming necessary. During the lockdown, people were forced to use ICTs to adapt to a rapidly changing reality. Current experience with coronavirus pandemic shows that the transition to these extraordinary circumstances is not smooth. The inability to rapid conversion to the online world (due to a lack of skills or technical capabilities) significantly reduces professional mobility, hinders access to public services, and in the case of children, exposes them to the risk of remaining outside the remote education system.
Purpose of the article: This research paper is addressing new issues of the impact of the COVID-19 pandemic on deepening and increasing the severity of e-exclusion. The goal of the paper is to indicate territorial areas in Poland which are particularly vulnerable to digital deprivation due to infrastructural deficiencies.
Methods: Raster data regarding landform, combined with vector data regarding population density and type of buildings as well as the location of BTS stations are used in so-called modelling overland paths (GIS method) to indicate areas vulnerable to the infrastructural digital divide.
Findings & Value added: The research showed that 4% of Poles remain out-side the Internet coverage, and additional ten percent of them are out of the reach of the Internet, allowing efficient remote work or learning. The research indicated that digital 'accessibility gap' is underestimated. E-exclusion has become a pressing issue and requires urgent system solutions, in case of future lockdowns.

Introduction

The digital divide, both the first- and second-order, has been the subject of scientists' interest for a long time, being perceived as one of the factors of social exclusion and an impediment to sustainable development. However, due to the outbreak of the COVID-19 pandemic, digital exclusion has become more pronounced than ever before. Just a year ago, no one could have foreseen that societies will be living in times of controlled movement of residents, closure of schools and public institutions or limited business activity. Unexpectedly, people had to learn to live in a new, restrictive reality, as most governments around the world have temporarily enforced lockdowns to stem the spread of the coronavirus (Alfano & Ercolano, 2020).

For many, information and communication technologies (ICTs) turned out to be a blessing, allowing them to work from home or to participate in the remote education system. On the other hand, some could not take advantage of this opportunity due to the lack of digital skills, equipment deficiency or insufficient infrastructure. While essential digital skills could be acquired relatively quickly, hardware and infrastructure constraints proved to be more challenging to overcome. The latter is particularly severe, as due to the stay-at-home orders, people were not allowed to move to places with potentially better internet coverage. Cutting off from both, the real and virtual world, apart from psychological consequences, often resulted in the inability to perform job duties, or in the case of children — deepened educational backwardness.

This study aims to identify and quantify areas that are highly exposed to digital exclusion due to infrastructural reasons. The obtained surface data are then combined with demographic information, allowing to estimate the scale of infrastructural e-exclusion in Poland. Awareness of the depth and distribution of digital deprivation is vital; besides gained knowledge can be implemented in post-COVID infrastructure and social policy planning.

Methods derived from geographic information systems (GIS), in particular modelling overland paths, are used to identify areas that are beyond Internet coverage. This approach is based on the spatial analysis of Digital Elevation Model (DEM) data and combining them with vector data, such as information about land coverage, base transceiver stations (BTS) location and population density data.

This paper is organised as follows. The literature review section describes the framework of digital deprivation and tries to place it in the context of COVID-19 pandemic. In the research methodology section, the overland flow and pathway analysis of Internet coverage are described. The next section presents the results of an empirical study for Polish regions in 2020. Finally, the last part of the paper concludes research findings.

Literature review

The digital deprivation is a socio-economic phenomenon describing the gap in both the access and usage of information and communication technologies (ICTs) among individuals, households or geographic areas (OECD, 2001; Venkatesh & Sykes, 2013, pp. 239–260). This concept has evolved over recent years and is being currently considered in three categories: binary Internet access (first-order digital divide), digital skills (second-order digital divide), and as the outcomes of Internet use (third-order digital divide) (Scheeder *et al*., 2017, pp. 1607–1624; Gladkova & Ragnedda, 2020, pp. 767–787). It is, therefore, an interdisciplinary and multilevel phenomenon with its foremost causes considered as the lack of digital literacy (Vasilescu *et al*., 2020, pp. 1–39), age (Huxhold *et al*., 2020, pp. 1–10; Walker *et al*., 2020, pp. 603–613), poverty (Witte & Mannon, 2010; Goedhart *et al*., 2019, pp. 2347–2365) or insufficient infrastructure (Tranos *et al*., 2014, pp. 409–428; Balcerzak, 2017, pp. 49–57 Balcerzak & Pietrzak, 2017a, pp. 5–18; 2017b, pp. 21–28). Regardless of the exclusion reason, researchers agree that it has negative consequences, not only for the individuals but also for entire societies (Robinson *et al*., 2015, pp. 569–582; Loktieva, 2016, pp. 148–157; Helsper, 2017, pp. 223–242; Seda *et al*., 2018, pp. 147–160). Academics are pointing out that the digital deprivation might be the source of economic, social, cultural and political marginalisation (Polat, 2012, pp. 589–596; Wamuyu, 2017, pp. 1709–1720).

In recent years, e-exclusion has been gaining popularity among researchers (Bruno *et al*., 2010, pp. 16–28; van Deursen & van Dijk, 2011, pp. 893–911; Son *et al*., 2019, pp. 13–15; Wilson & Hopkins, 2019, pp. 563–583; Budziewicz-Guźlecka & Drab-Kurowska, 2020, pp. 1–18; Johansson *et al*., 2020; Ye & Yang, 2020, pp. 1–16). In contrast, a wider audience has enlarged interest in it with the outbreak of COVID-19, as pandemic showed a new face of this phenomenon. In addition to already mentioned negative consequences of digital exclusion, pandemic exposed its other dark side — hindering access to public services, limiting the ability to work and deepening educational exclusion. For many, the pandemic itself was a source of stress and anxiety (Elhai *et al*., 2020, pp. 576–582; Rehman *et al*., 2020) resulting from a change in habits and routines (de Hass *et al*., 2020, pp. 1–11; Dubey *et al*., 2020, pp. 779–788). The additional worries associated with staying outside both the real and virtual world have only worsened those feelings. People who didn't have sufficient access to the Internet at home have suffered noticeable educational and economic harms (Hidalgo *et al*., 2020, pp. 1–7).

Since the beginning of 2020, an accelerated process of transition towards the digital economy (Liu, 2017, pp. 111–133; Ozscan, 2018, pp. 93–113; Bilan *et al*., 2019, pp. 70–93; Rymarczyk, 2020, pp. 185–198; Pietrzak & Ziemkiewicz, 2018a, pp. 422–427, 2018b, pp. 1431–1439, 2018c, pp. 283–290) can be observed in many countries. Governments decided to limit physical meetings and implemented procedures allowing for e-learning and e-working. The social distancing regulations resulted in many education systems and business having to close their facilities and provide all activities online. Thus, remote work and telecommuting have become an obvious solution for many professions (notably, so-called white-collar workers) (Dingel & Neiman, 2020; Korzeba & Niedziółka, 2020, pp. 205–234; Reuschke & Felstead, 2020, pp. 208–212). As a consequence, long hours of online live meetings have become a new daily routine for many citizens. It turns out that computer possession or being the smartphone-internet user is not sufficient to fully participate in home-based learning or working for the reason that a household must meet a digital threshold to enable smooth online professional activities. What was previously just enough to use the Internet for entertainment purposes, does not entirely reflect the technical requirements of remote work or education. Therefore, lockdown not only highlighted existing digital exclusion, but also excluded those who used the Internet occasionally or outside their household. Pandemic showed that the assumption made by policymakers and entrepreneurs that everyone has at home decent equipment and broadband internet connection to participate smoothly and efficiently in webinars, online meetings and conferences, was entirely erroneous. The percentage of citizens being digitally excluded due to the lockdown is unknown, and this paper aims to fill this research gap.

The post-COVID-19 world is still hard to predict (Kufel, 2020, pp. 181–204), but the increasing prominence of digital technology is more than certain. Therefore, it is crucial to identify the size and depth of the digital exclusion in every dimension. Having this knowledge, it will be possible to ensure sufficient ICTs infrastructure to all citizens. As in most cases, market forces alone are not strong enough to do so, thus probably governmental legislation and recommendations will be needed. Another argument for comprehensive planning of society's digitisation is the theory of demographic and epidemiological transition. Already in 1998, Olshansky's team research paper was published (Olshanksy *et al*., 1998, pp. 207–217) suggesting that we could soon face the fifth epidemiological transition phase — the developing return of infectious diseases. The legitimacy of this vision confirms the ageing of the population, global warming, antibiotic resistance, increased people mobility and the fact that existing endemic diseases are reaching worldwide coverage. Perhaps COVID-19 is just the beginning of a series of infectious diseases that we will have to face.

Research methodology

The increasing availability of GIS data is allowing to utilize geospatial methods for distance estimation, not only for biology, ecology or epidemiology, but also for social sciences. In this research, modelling overland paths method will be used to mapping internet coverage. Finding areas without decent access to the Internet is essential to explain and estimate the size of infrastructural digital deprivation faced by Polish citizens due to the COVID-19 outbreak. Previous studies have not taken into account the quality of the internet connection, because the world has never been so digital before, and internet usage measurement was rather binary, regardless of the stability and speed of data transfer. Therefore, it is assumed that the problem of infrastructural digital deprivation is underestimated. This hypothesis will be verified in this study.

The starting point in this analysis is vector data on the location of base transceiver stations (BTS). BTS is an auxiliary signal generator being used for cellular purposes as an essential element of digital data exchange process. The terrain and spatial data are of great importance for smooth communication of data through BTS (Nizamuddin *et al.*, 2020, pp. 1–7). Usually, the main factor deciding to locate BTS in a specific place is the possibility of using its full potential, in other words obtaining maximum internet penetration. Therefore, there will be usually more BTSs in highly populated areas, which potentially allows operators to increase profits by reaching more consumers.

One has to remember that the terrain affects the range and strength of data transmission. The signal will transfer differently on a flat surface, separately in the mountains and different in the forest. Also, the geographical terrain is modified by urban buildings (Fry, 2010). All these factors will affect the performance of a particular BTS. Therefore, in this study, data on digital elevation model (DEM) and land cover were also included (Cai 2002, pp. 35–63). It may turn out that a given household is theoretically within the range of operation of a given BTS, but still geographical conditions and the urbanisation will not allow Internet usage for professional purposes. As already mentioned in the previous section, to work and/or distance learning — it's not enough to have a computer or the Internet on a mobile phone to fully participate in these activities. Depending on the type of digital activity, the following bandwidth is recommended:

- email and basic computer programs: 3-4 megabits-per-second (Mbps),
- Skype, Zoom, MSteams group video calls with screen sharing: 10+ Mbps,
- large file transfers: 40+ Mbps,
- 4K video streaming: 150+ Mbps.

The Internet speed declared on the contract is one thing, but the number of users and terrain slope may significantly reduce the actual signal strength. Therefore, it was assumed in this study that all households in an area below 10 Mbps would be considered as digital excluded, as inhabitants living there were unable to attend online lessons or business meetings efficiently.

One of the applications of terrain modelling is an investigation of the spread of phenomena under consideration. In this study, the greater distance from BTS, the weaker the signal, and thus less stable internet connection. The analysis is based on raster data (DEM, land cover) to which vector information is attached (BTS distribution, population density).

The procedure for determining areas which are particularly vulnerable to digital deprivation due to infrastructural deficiencies is presented below (Kennedy, 2009):

1. gathering raster data from and vector data from,
2. rasterisation of the vector map,
3. problem specification,
4. cost, direction and barriers identification,
5. defining the cost raster – three cost rasters were prepared: referring to the distance from BTS, the slope of the terrain and population density,
6. calculating the distance based on the path distance method (Gonçalves, 2010, pp. 983–996),
7. calculating vertical factors based on the vertical relative moving angle,
8. mapping infrastructural digital deprivation,
9. combining surface results with demographic data to estimate the size of digital exclusion.

All calculations have been done in ArcGIS Pro 2.5 version, using such tools as reclassify, cost distance, path distance and corridor.

Modelling overland path, unlike ordinary buffering, allows for more accurate results by taking into account the physical characteristics of the environment. The disadvantage of this approach is the lack of differentiation between BTS types. But, this is the fault of the obtained data, not the method itself. Since the larger area is a subject of interest, not one specific point, the results of the analysis should not be biased.

Results

In the empirical analysis, the following data were used:

- DEM data retrieved from Copernicus Land Monitoring Service,
- location of BTS transmitters retrieved from Office of Electronic Communications,
- CORINE Land Cover (CLC 2018) retrieved from Chief Inspectorate of Environmental Protection,
- demographic data (population density, population size, population by age) from Statistics Poland Local Data Bank. Data from 2019 were used as an approximation of the demographic situation in 2020.

In the research information about 142134 base transceiver stations have been used, their location is shown in Figure 1–3.

A high density of BTS network can be observed in Figure 1. In Poland, in June 2020 there was on average 0.45 transmitter per km^2 of area. However, looking at Figures 2 and 3, it can be seen that their distribution is not even and depends on the population density and landform. It is assumed that under laboratory conditions one station has a radius of 15 km. Of course, in reality, the range is much smaller due to obstacles in the form of buildings or terrain. Visualisation of such ideal conditions for one randomly selected BTS (BTS's ID ZBK3108) is presented in Figure 4. In this approach, it is assumed that the internet signal does not encounter any physical obstacles and spreads evenly over the entire surface.

The BTS's range, including buildings and terrain, is shown in Figure 5. It was assumed that the signal strength would decrease with each kilometre moving away from the transmitter. It was also expected that in highly urbanised areas, the signal strength would be lower than in the case of low-rise buildings. Lower signal strength was assumed in the forest than in the case of agricultural areas.

Comparing Figures 4 and 5, one can see differences in the transmitter coverage. Figure 5 more accurately reflects the actual spread of the internet signal in space. For this particular broadcast station, the difference in the covered area is $348.1km^2$. The difference size between 'ideal' and the real area coverage by 1 BTS depends in no small extent on the terrain. Therefore, it will be lower in lowlands, while higher in mountainous areas.

An identical analysis was performed for each of the BTSs. The study showed that 4% of Poles are within reach of at most one BTS station. Moreover, in the case of 14% of inhabitants, the internet signal strength enables active participation in teleconferences, so it is an indispensable factor enabling involvement in remote work or education in the case of a lockdown.

By applying demographic information to these areas, it turns out that they are inhabited by approx. — 2.5 million people, of whom around 630000 in working age and 350000 in school age. The conducted analysis provides a unique view of Poland's infrastructural digital exclusion.

Discussion

To the best of author's knowledge, no other studies on digital 'accessibility gap' in Poland associated with COVID-19 lockdown have been published so far. However, the problem of uneven availability to sufficient Internet connection appeared in the literature. The results obtained in the current research are consistent with Moroz (2017, pp. 175–190), who revealed the relatively weak development of the digital economy and ICT impact on society in Poland. Szarek-Iwaniuk and Senetra (2020, pp. 1–21) indicated significant differences in access to high-speed Internet among Polish voivodeships, which may contribute to delaying the process of evolution towards e-society. Tomczyk *et al.* (2019, pp. 159–190) among others, are dealing with the problem of insufficient availability of high-speed Internet in schools, which should be 'solved within next several dozen months', as the result of the implementation of National Educational Network by Council of Ministers. Some researchers pointed out that weak digital literacy of human capital causes a low level of digitisation amongst Polish SMEs (Śedziewska & Włoch, 2018, pp. 415–421) and the country as a whole (Czaja & Urbaniec, 2019, pp. 324–336).

On the other hand, these shortcomings in accessibility do not prevent Poles from having one of the fastest developing e-commerce market (Rokicki, 2016, pp. 563–572) or extensively use social media in travel decision-making processes (Werenowska & Rzepka, 2020, pp. 1–14).

This article is part of the discussion on the problems of digitisation in Poland, showing that some issues have still not been solved.

Conclusions

This article focuses on the scale of the infrastructural digital exclusion in Poland associated with COVID-19 lockdown. The intention was to estimate what percentage of residents could not fully participate in remote professional or educational life due to the insufficient Internet connection. The modelling process did not distinguish between the type of BTS transmitter and the transmission band, assuming the average speed of data transmission. However, this simplification should not affect the size of the analysed phenomenon.

According to Statistics Poland in 2019 (GUS, 2019):

- 83.1 percent of households have access to a computer;
- 72.8 percent of Polish citizens were regular computer users;
- 86.7 percent o of households have access to the Internet at home.

At first glance, that data would suggest relatively good situation; nonetheless, the conducted analysis showed that around 2.5 million of Polish inhabitants were not able to participate in e-work or e-learning during the COVID-19 lockdown. This exclusion resulted from infrastructural deficiencies, proving that the scale of the problem turns out to be significant.

Therefore, steps should be taken to mitigate the immediate impact of potential future lockdowns. Moreover, the danger of digital competition and polarisation is increasing. We still do not fully understand the social and economic implications of a post-COVID-19 reality. However, global digitalisation is almost inevitable. Thus, there is a need for complex cooperation to close the existing digital gap and reduce the harms of potential incoming social isolation. As mentioned earlier, system solutions will be needed, as the market alone is not able to deal with this problem.

It should be emphasised that the study did not examine digital exclusion resulting from poverty or lack of digital literacy. Its inclusion is planned in further studies based on survey data from Eurofound's European Quality of Life Survey (EQLS). It is assumed that the digital deprivation rate will be higher than just the one measuring 'accessibility gap'. It is essential to realise the negative implications of permanently transferring many activities to the online world. As this study shows, the assumption that everyone can smoothly participate in e-education or e-work is misleading. Furthermore, the vision of growing digital gap due to insufficient revenues seems real. It may turn out that due to job cuts and redundancies, some people will be forced to resing for Internet access because of their financial situation. And this can lead to a vicious circle of socio-economic-digital exclusion.

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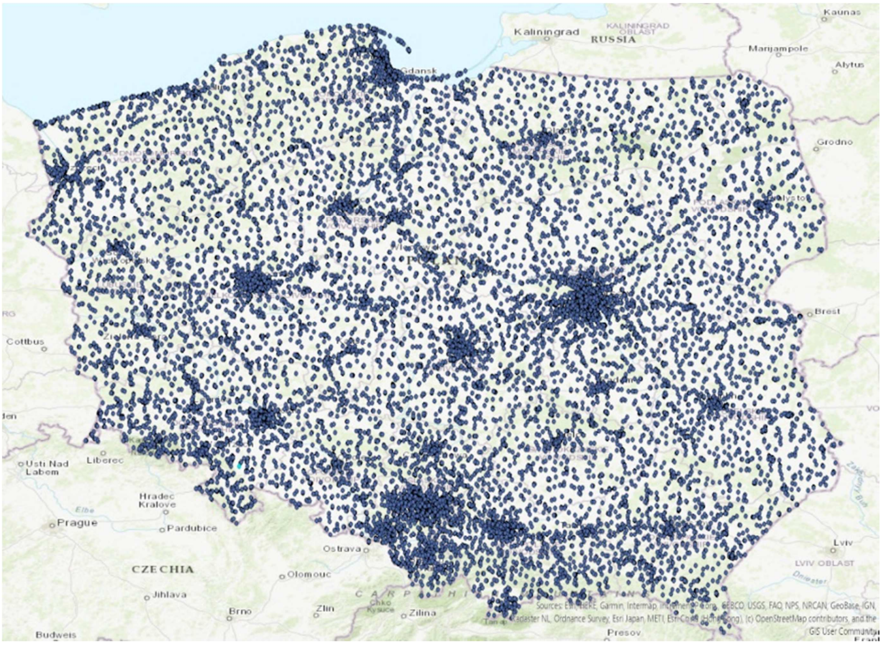
Annex

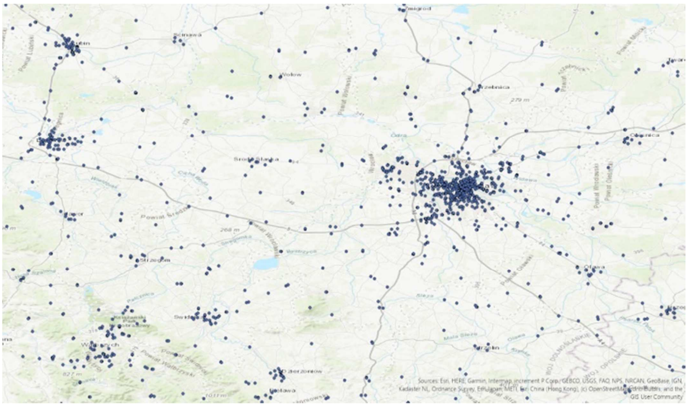
Figure 1. Base transceiver stations location in Poland in June 2020



Note: Visualisation prepared in the ArcGIS Pro software.

Source: own study based on data taken from the Office of Electronic Communications.

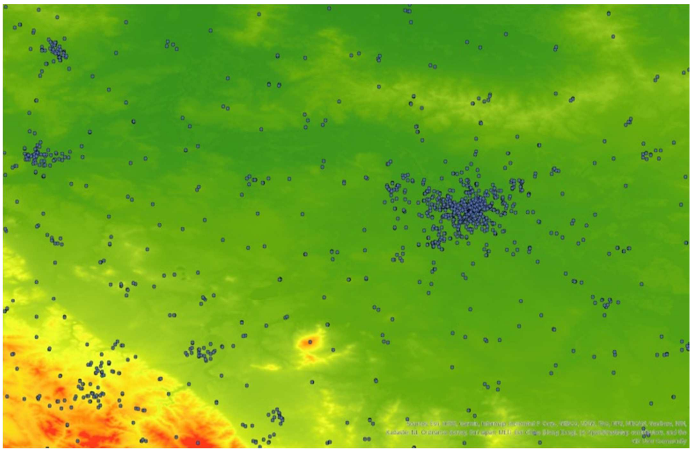
Figure 2. Zoom on selected* base transceiver stations in part of the Lower Silesian Voivodeship in June 2020



Note: *The largest cluster of points is created by Wrocław.
Visualisation prepared in the ArcGIS Pro software.

Source: own study based on data taken from the Office of Electronic Communications.

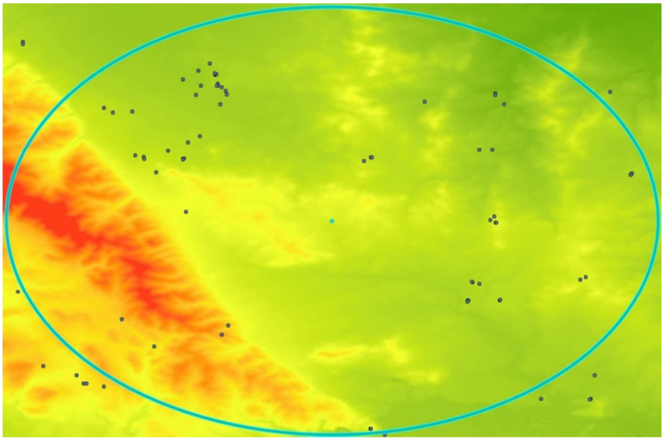
Figure 3. Zoom on selected* base transceiver stations in part of the Lower Silesian Voivodeship in June 2020 including digital elevation model data



Note: *The largest cluster of points is created by Wrocław.
Visualisation prepared in the ArcGIS Pro software.

Source: own study based on data taken from the Office of Electronic Communications and Copernicus Land Monitoring Service.

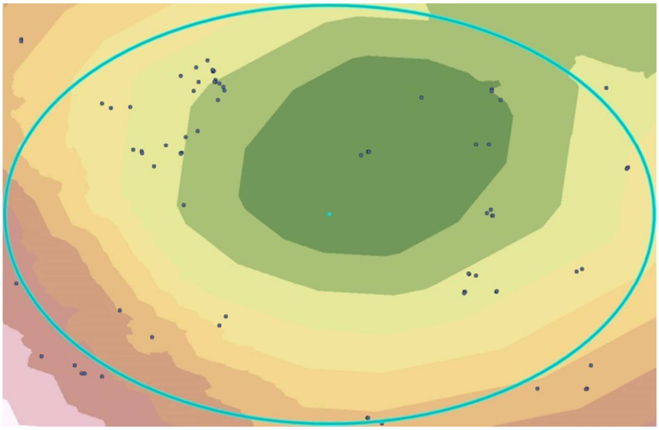
Figure 4. Selected BTS ZBK3108 (50°38'33"N, 16°43'24"E, Przedborowa 45) range in ideal conditions



Note: Visualisation prepared in the ArcGIS Pro software.

Source: own study based on data taken from the Office of Electronic Communications.

Figure 5. Selected BTS ZBK3108 (50°38'33"N, 16°43'24"E, Przedborowa 45) range in real conditions including land cover and terrain



Note: Visualisation prepared in the ArcGIS Pro software.

Source: own study based on data taken from the Office of Electronic Communications and Copernicus Land Monitoring Service.