AIP Conference Proceedings

Remote sensing and GIS technologies in land reclamation and landscape planning processes on post-mining areas in the Polish and world literature

Cite as: AIP Conference Proceedings **2209**, 040002 (2020); https://doi.org/10.1063/5.0000009
Published Online: 25 March 2020

Anna Buczyńska

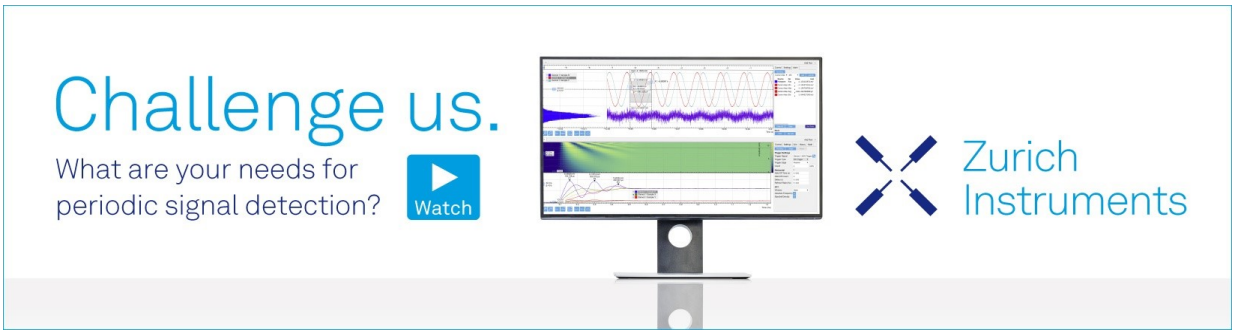
View Online
Export Citation

ARTICLES YOU MAY BE INTERESTED IN

Analysis of the speed of change of the Werenskiold glacier front for the period 2015-2018
AIP Conference Proceedings **2209**, 040003 (2020); https://doi.org/10.1063/5.0000007

Ground surface deformation monitoring of an active volcano using the DInSAR technique in comparison with GPS data: Case study of Okmok Volcano, Alaska
AIP Conference Proceedings **2209**, 040004 (2020); https://doi.org/10.1063/5.0000008

Identification and statistical analysis of impulse-like patterns of carbon monoxide variation in deep underground mine
AIP Conference Proceedings **2209**, 020005 (2020); https://doi.org/10.1063/5.0000230



© 2020 Author(s).

Remote Sensing And GIS Technologies In Land Reclamation And Landscape Planning Processes On Post-Mining Areas In The Polish And World Literature

Anna Buczyńska

Wrocław University of Science and Technology, Faculty of Geoengineering, Mining and Geology, Geodesy and Geoinformatics Division, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław

Corresponding address: anna.buczyńska@pwr.edu.pl

Abstract. All stages of mining activities, starting with the exploration phase up to the end of the extraction works lead to significant natural landscape alteration and formation of new, anthropogenic surface features. In order to mitigate the effects caused by mining, both in Poland and in the world, a number of legal regulations have been developed, which oblige mainly the mining entrepreneurs to restore use values of degraded or devastated lands. This process called reclamation is a long-term, complex operation and covers large areas. Therefore, the academic society publishes more and more papers concerning monitoring reclamation status, as well as supporting landscape planning processes using different technologies and measurement methods. It should be emphasized that scientific publications are not only limited to the mentioned subject fields. The main purpose of this paper is to exemplify issues connected with reclamation process, which have been investigated by means of remote sensing and GIS technologies. As a part of this publication 25 scientific papers written by Polish and foreign academics have been studied. The results of a conducted analysis provide a comprehensive summary in terms of quantity and quality concerning scientific materials published so far on the subject of reclamation process, remote sensing and GIS technologies.

INTRODUCTION

Mining activity may lead to significant environmental transformations. The examples of these changes might be as follows: change of water conditions, topographical relief modification (development of deep mine workings and hills of a big true height as a consequence of overburden tipping), formation of the so-called soilless land caused by soil layer removal during the process of mine preparation, indigenous vegetation degradation or toxification of atmosphere, water and ground. Therefore, at each stage of mining operations people should aim for a degraded environment renewal, which afterwards will allow the reuse of these lands (Fig. 1).

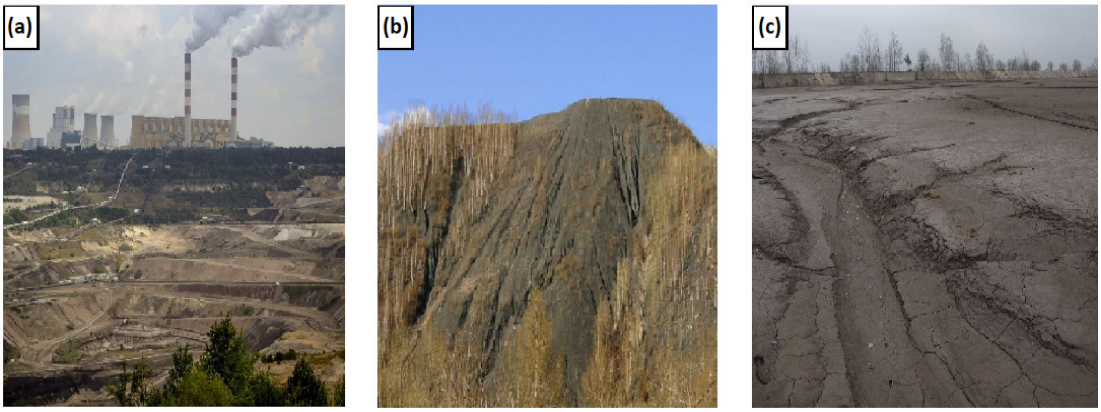


FIGURE 1. Effects of conducting mining activities: (a) Bełchatów lignite open-cast; (b) tailing of the coal mine "Nowa Ruda" pole Piast; (c) dry surface of Wartowice flotation tailings reservoir with a developed present drainage system [1]

XIXth Conference of PhD Students and Young Scientists
AIP Conf. Proc. 2209, 040002-1–040002-10; https://doi.org/10.1063/5.0000009
Published by AIP Publishing. 978-0-7354-1960-5/$30.00

One of the oldest, written regulations by polish law determining the compensation of damage caused by mining industry is the Ordunek Gorny of 1528. Next legal acts concerning pointed issue appeared in later periods, but only the Decree of May 6th, 1953 Mining Law brought the term of reclamation into force for the first time [2]. Currently on the grounds of the legal act of February 3rd, 1995 concerning agricultural and forest lands protection by land reclamation one understands granting or restoring use/natural values of degraded or devastated lands through relevant land forming, physical and chemical properties improvement, adjustment of water conditions, soil restoration, reinforcement of slopes and reconstruction or construction of necessary roads. The same legal act defines landscape planning as agricultural, forest or any other usage of reclaimed lands [3].

Other legal polish acts related to the problem of reclamation and landscape planning include the following ones:

- act of April 27th, 2001 Environmental protection law [Journal of Laws 2001 no. 62 item 627],
- act of April 13th, 2007 in the matter of environmental loss prevention and its compensation [Journal of Laws 2007 no. 75 item 493],
- act of June 9th, 2011 Geological and mining law [Journal of Laws 2011 no. 163 item 981],
- regulation by Economy Minister of April 8th, 2013 about specific requirements connected with open-cut movement of mining works [Journal of Laws 2013 item 1008].

Based on data collected by Central Statistical Office since 1975 one can state that rapid growth of reclamation and landscape planning processes in Poland began in the early ’80s., whereas since 2010 the surface of reclaimed and developed lands remains constant. There are 500 to 700 ha being reclaimed and 200 to 300 ha being developed per year. Figure 2 presents a comparison of lands under mining activities, reclaimed lands and developed lands between 2000 and 2017 [4].

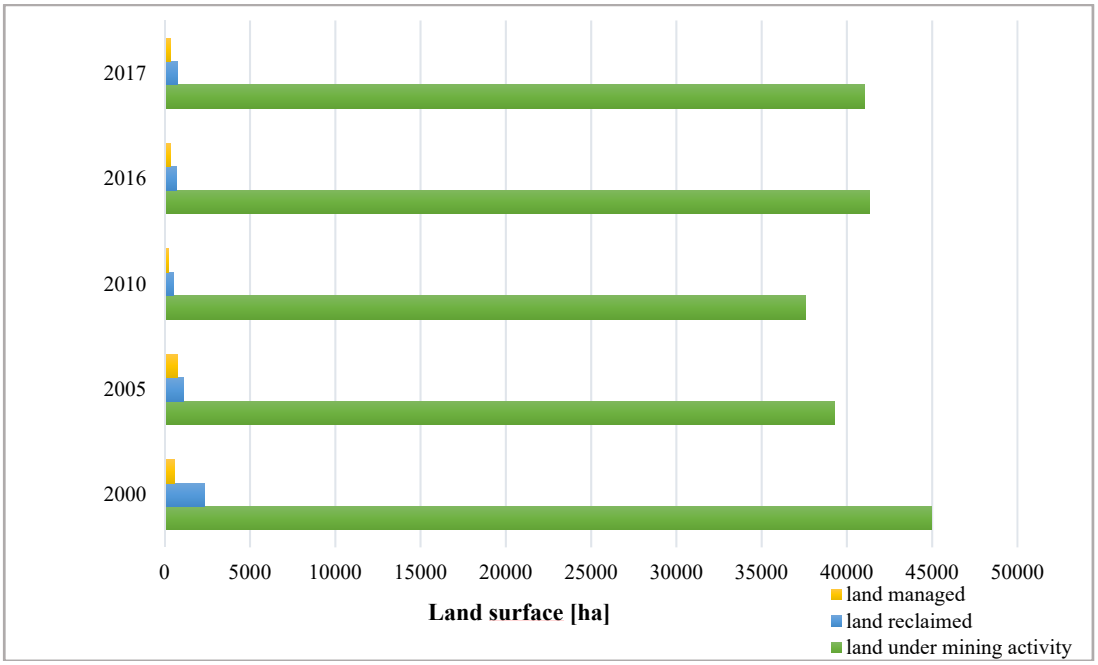


FIGURE 2. Lands under mining activities, reclaimed lands and developed lands between 2000 and 2017 [4]

Despite the fact that people pay more and more attention to the issues of environment protection and land reclamation, there are still a lot of post-mining areas left degraded. Furthermore, in defiance of laws about periodic environmental monitoring of reclaimed lands, this duty is often not done properly. According to the report of Government Inspectorate of April 2019 district heads and mayors of the cities with district rights did not keep records concerning annual changes in reclamation status on the areas of overburden tipping being under control and decisions about courses of actions, methods as well as due dates were made without the expert’s opinion [5]. There are many reasons explaining presented conjuncture. Mainly legal, social and financial aspects should be enumerated among them. Table 1. summarizes major obstacles in land reclamation and landscape planning process on post-mining areas.

TABLE 1. Obstacles in land reclamation and landscape planning process [6]

Legal	Social	Financial
Lack of relevant legal acts until the ’60s	Cultural and social factors override in land reclamation and landscape planning process	Insufficient funds for monitoring the reclamation process
Plurality of records concerning land reclamation and landscape planning in many legal acts		Not encouraging the investors to support post-mining areas reclamation process
Restricting reclamation and landscape planning processes in legal acts to agricultural and forest directions		
Separation of reclamation and landscape planning processes in the eyes of the law		
Outstanding ownership issues		
Shortage of local development plans		

Given the extent of areas degraded by mining activities and the amount of environmental parameters, which should be assessed, the employment of satellite remote sensing seems to be the effective and economical solution to indicated problems. It is closely associated with the definition of remote sensing itself, which one understands as a remote acquisition of data about phenomena and object on the ground. On the other hand, GIS technologies enable the establishment of database gathering environmental data, the analysis with the use of various tools as well as the development of reclamation and landscape planning possible ways on degraded areas. The aim of this research is to exemplify issues connected with reclamation process, which have been investigated by means of remote sensing and GIS technologies. As a part of this publication many scientific papers written by Polish and foreign academics have been studied. To that end the Scopus database and keywords („reclamation”, „mining”, „GIS” and „remote sensing”) have been searched. 25 out of 229 items have been chosen to a further research. Articles were selected in order to show the most popular subject raised by the scholars as well as the extent of problems, which could be examined with the aid of relevant tools. The results of a conducted analysis provide a comprehensive summary in terms of quantity and quality concerning scientific materials published so far on the subject of reclamation process, remote sensing and GIS technologies.

QUALITATIVE ANALYSIS OF PUBLICATIONS

Qualitative analysis of collected references confirmed the existence of great number of issues related to reclamation and landscape planning processes, which have been studied by the use of remote sensing and GIS technologies. Figure 3 presents the subject of analyzed publications along with a number of articles about the given problem.

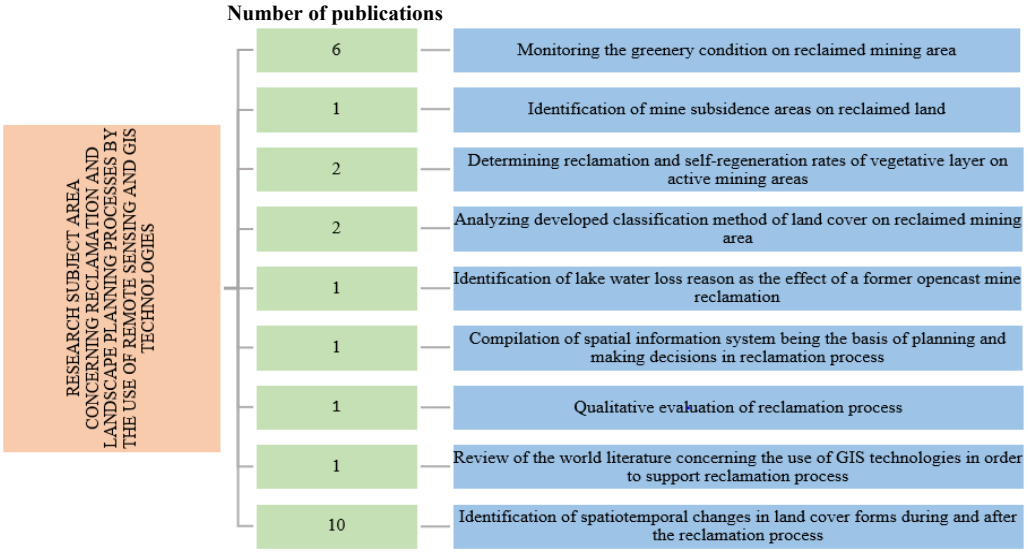


FIGURE 3. Research problems discussed in publications concerning reclamation and landscape planning processes, where paramount tools were remote sensing and GIS technologies

Identification of spatio-temporal changes in land cover forms is mostly raised question for analyzed scientific documents, both during and after the reclamation process. Singh and others [7] used images of IRS satellite missions (IRS-P6/LISS-IV and IRS-1D) and ArcGIS program to prepare the maps showing current status of reclamation process. Processed data was supposed to introduce the extent of operative mining activity, vegetation, surface waters, landfill sites and farmlands within 50 open-cast mines in India at 3 and 5 years intervals. In turn, Szostak and others [8] examined the possibility of using open-access geodata to devise the maps of landcover and land use for reclaimed grounds. Former areas of sulfur extraction were chosen as a field of research, namely tailing of Machów mine and reclaimed Jeziórko mine. Images acquired by the Landsat 7 and 8 satellites as well as the data of Corine Land Cover program were used in the study. Presented article features identified land covers, which are the result of classification of remote sensing, that is to say: extraction area, inland waters, deciduous forests, coniferous forests, shrubbery, road and railway networks, wetlands, arable lands and pastures. The above-mentioned issue was also discussed by Matejicek i Kopackova [9]. In the context of food safety the authors examined changes within range of farmlands, which had been influenced by lignite mining. On the grounds of Landsat 6 and 7 satellite images, that constituted the basis of NDVI indicators, changes in designated land cover forms between 1985 and 2009 have been analyzed. The publication emphasized the importance of seasonal vegetation changes and meteorological conditions impacting the homogeneity of Landsat database used for spatial analyses. The employment of Unmanned Aerial System (UAS) for the sake of land cover forms identification during 20 years of reclamation process was introduced by Padró and others [10]. The study contained the data collected by Parrot Sequoia sensor for the whole area of operative sandstone quarry in Catalonia. The authors used plenty of vegetation indexes to achieve the intended goal, including: NDVI, MSAVI2, NDVI1 and SAVI. After the application of k-nearest neighbor algorithm 6 land cover forms have been revealed and their modifications were the subject of further research. Within the confines of a conducted analysis scientists investigated the usefulness of images depending on the season and collection time. Based on gained results it was stated that the best accuracy and quality can be drawn from spring and summer images, during the highest solar activity. UAS images are also the data applied in Tong and others' work [11]. In this instance images were acquired due to the use of ISAR-II sensor of 15 cm spatial resolution. The authors defined 9 grades of land use thanks to vegetation index they invented themselves. This paper indicated UAV restrictions concerning the identification of land cover forms on the areas of reclaimed open-cast mines, which include as follows: instruments of small capacity that require sensors of low mass, the necessity of carrying out the photogrammetric survey by reason of a battery lifespan, difficulty with pointing the characteristic features. Finally, it is worth underlining that discussed issues are raised all across the world. The identification of changes in land cover forms in terms of reclamation and landscape planning processes with the aid of remote sensing and GIS technologies have been used for Pine Point zinc and lead mine in Canada [12], Wise County coal mine in the USA [13], sulfur mine on Milos island [14], the area of copper extraction in Bulgaria [15] as well as ion mine in China [16].

Second, equally popular subject area is monitoring of vegetation condition on reclaimed and developed lands. The example of such a publication is the article by Karan and others [17], who assessed health state of vegetation considering NDVI, NDMI, EVI and RVI indicators that had been delivered by Landsat 5 and 8 satellite images. Furthermore, within the framework of pursuing a goal they wanted to reach correlations between the indexes have been studied. The outcome confirmed a strong relationship between NDMI and EVI as well as NDVI and NDMI. Publications about this issue appeared in polish scientific community, too. Szostak and others [18] examined the possibility of Sentinel-2 mission images integration with the data collected by airborne laser scanning in the ISOK project, which was concerned with the former area of sulfur extraction. Research results allowed to define spatio-temporal vegetation changes between 2000 and 2016 as well as to present its parameters, such as tree crown density. On the other hand, Raval and others [19] attempted to estimate biomass production in reclaimed open-cast coal mine Wise County. To that end, they have applied Landsat 5 satellite images of 2008 to 2012. The analysis of the present problem were also a subject area of other scientists' works: Wężyk and others [20], Zhang and others [21] Yao and Zhou [22].

Remote sensing and GIS technologies were also used to identify the side effects on already reclaimed and developed lands. On the basis of short-term landscape changes and the evaluation of vegetation productivity Padmanaban and others [23] in the paper of 2017 determined mine subsidence areas on reclaimed sites of coalmining Kirchhellen Heide. The authors applied Landsat 7 ETM+ images, which served as the development of SMA and NDVI indexes. The result of a conducted analysis was indicating the places with degraded vegetation and increasing the surface of wetlands due to water table modifications.

Supporting reclamation process by the use of GIS tools was dissertated in Suh and others' publication [24]. The article describes the range of opportunities, which technology offers to mold and measure soil, water and forests affected by mining activity. It also discusses the research with the aid of various tools, for instance:

- determining soil contamination levels in the neighborhood of non-operational mine,
- fixing soil erosion level on the area of tailing,
- setting boundaries of mine flooding danger zones,

- monitoring the deforestation process in connection with mineral extraction.

Geographic Information System was the main research instrument in Neustupa and others' work [25]. Their aim was to develop a system, which will provide the information to plan and make decisions in reclamation process, including the alternatives of its future advancement. A coal mine Lazy has been selected as the field of research. In task accomplishment a lot of data was used, namely: tectonic and geological structure of the area, mandatory legal provisions, ecological factors, economic indicators, topographic data, buildings and communication lines placement et cetera.

A vital issue, oft-repeated among the academia, is raising precision of satellite images classification on post-mining areas by devising new methods. Chen and others [26] in their paper analyzed the accuracy of impartial Random Forest classification using GF-1 satellite images. Research results justified that devised method is more detailed and effective in comparison to pixel classifications, that is Support Vector Machine (SVM) and Artificial Neural Network (ANN). Similar analysis was conducted by Zhang and others [27]. Technique they invented is the combination of SVM method and object-oriented classification. It was applied to identify land cover forms on the area of coal mining Pingshuo based on RapidEye and SPOT7 satellite images.

Except for enumerated research problems, associated with reclamation and landscape planning processes in terms of remote sensing and GIS technologies, there are also scientific papers, where pointed tools served to determine the effects of incorrectly carried out works on post-mining areas. Penaz and others [28] examined changes in water level of Lake Lost, which had emerged as a consequence of flooding the former lignite open-cast mine. Water loss caused by insufficiently sealed working was being monitored with Sentinel-1 and Cosmo satellite images. In addition, studied matters also involved fixing reclamation and self-regeneration rates of vegetation cover on the areas of operative mining activity [29], [30]. Last but not least, another issue raised in gathered references was an appraisal of landscape functionality made by Bodlák and others [31]. On the grounds of Landsat satellite images the authors defined surface temperature and humidity index, that are the basic parameters for the established goal. The bottom line of the investigation is quality assessment of reclamation relevant to tailing on the area of lignite mine in northwestern Czech Republic.

QUANTITATIVE ANALYSIS OF PUBLICATIONS

Publications with their description mentioned above were also studied in terms of quantity. As a result of a conducted analysis the information about the following problems has been gathered:

- number of publications over a span of several years (2010-2017),
- the most popular remote sensing satellite missions, which images were taken into consideration,
- countries that most frequently raised indicated question in scientific research,
- software types used to process remote sensing images and for presenting research results,
- types of minerals extracted on the fields of research.

Figure 4 presents the number of articles published between 2010 and 2019. On its basis it may be stated that since 2015 one can observe growing interest in GIS technologies and remote sensing in the context of reclamation and landscape planning. The largest amount of articles was issued in 2017. Among collected papers only one was published in the current year, but this number is definitely bigger and it will increase within the next 6 months.

Figure 5 shows the conclusion of remote sensing satellite missions applied in the undertaken research. In more than a half of these articles images of Landsat satellite missions have been used. Surely it stems from the fact that this is a program of remote images of outer space with the longest lifespan. On this score it enables analyzing the matters, which took place even 30 years ago. It is worth underlining that more and more publications describe research conducted with the use of European Space Agency – Sentinel missions.

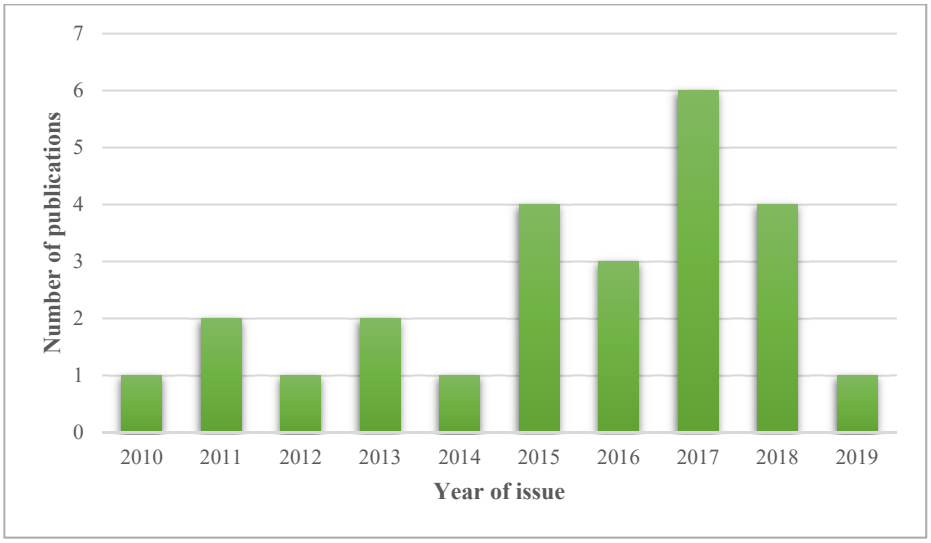


FIGURE 4. Number of articles published between 2010 and 2019

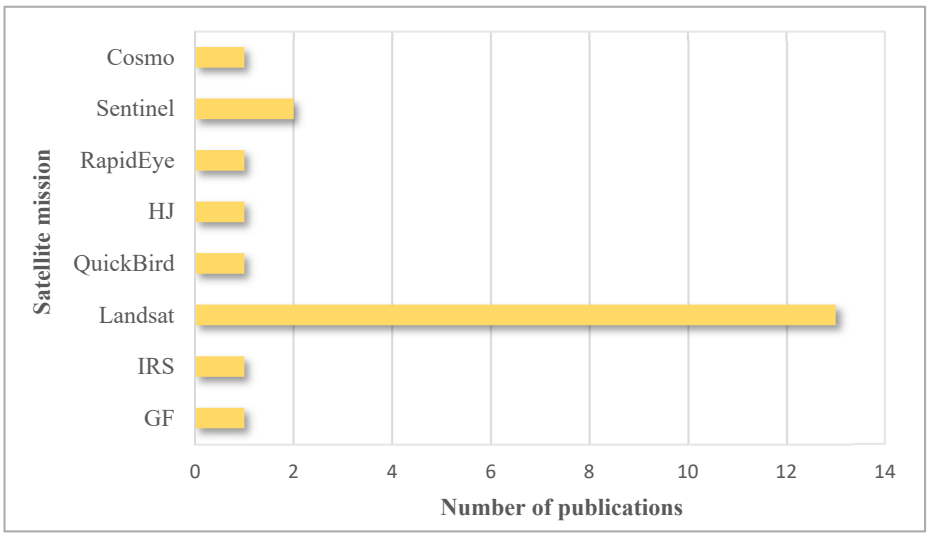


FIGURE 5. Remote sensing satellite missions, which images were used in analyzed publications

The subsequent important quantitative analysis was defining the countries that most frequently raised indicated question. Without a doubt the discussed research was carried out mainly in the People's Republic of China. Almost 25% of analyzed papers come exactly from this country. Germans are also among the nations, which often relate to this issue. Between 2010 and 2019 there were 3 articles published and their authors are Polish scholars. The detailed information about the examined problem was depicted on Figure 6.

The last two analyses present software types, which application allowed to process the remote sensing images and to present the results as well as the types of minerals extracted in the field of research. The outcome was displayed on Figures 7 and 8 respectively. As it turns out software that was employed can be divided into 4 groups reflecting their intended use:

- processing and visualization of point cloud,
- edition and display of both raster and vector data,
- analysis and presentation of spatial data,
- processing satellite remote sensing images.

Based on the figure it can be concluded that there is a wide range of software on the market, which application enables accomplish the objectives described in the aforesaid chapter.
The analysis of these fields of research demonstrates that mostly chosen places are coal mining sites. More than 60% of the articles were related to reclamation and landscape planning on the areas of this very mineral extraction.

The authors selected also sulfur mines as their fields of research. The other areas of mineral extraction, such as iron ores, zinc and lead, phosphates, copper and sandstone constituted merely 4% of all the publications.

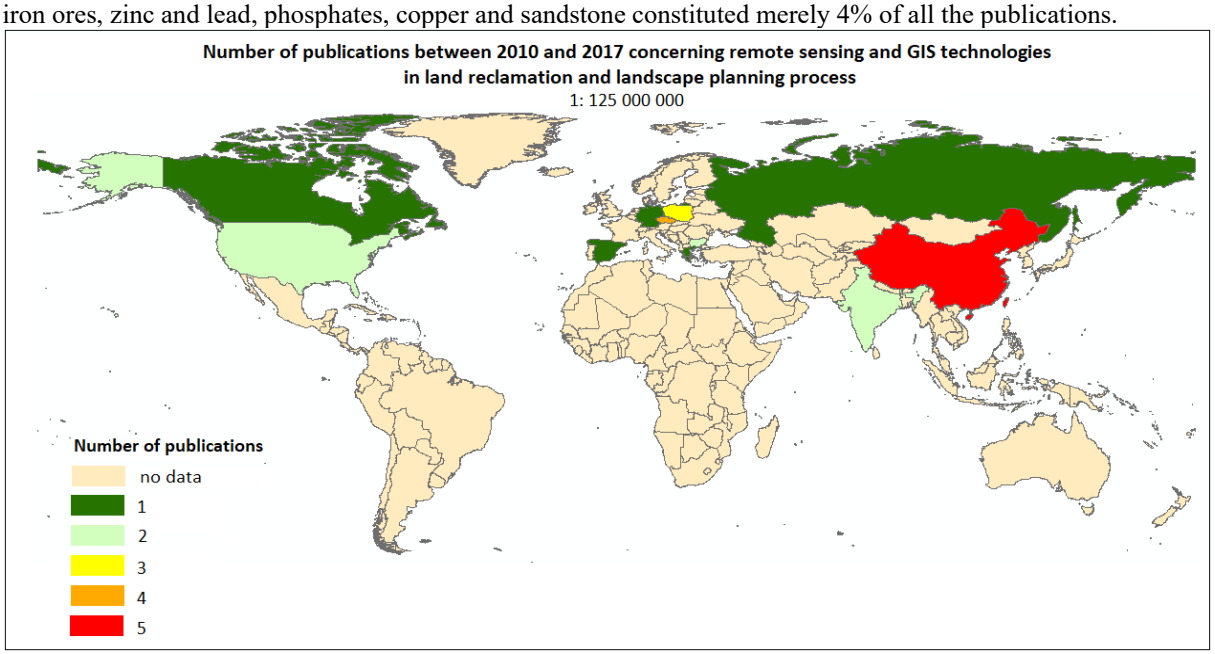


FIGURE 6. Number of publications between 2010 and 2019 concerning the use of remote sensing and GIS technologies in reclamation as well as landscape planning processes

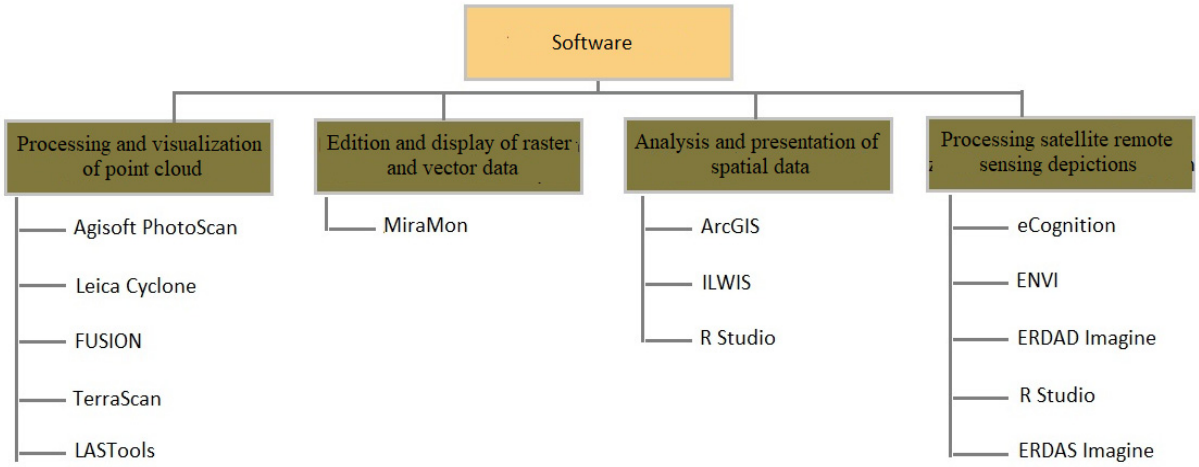


FIGURE 7. Software types used to process remote sensing images and for presenting research results

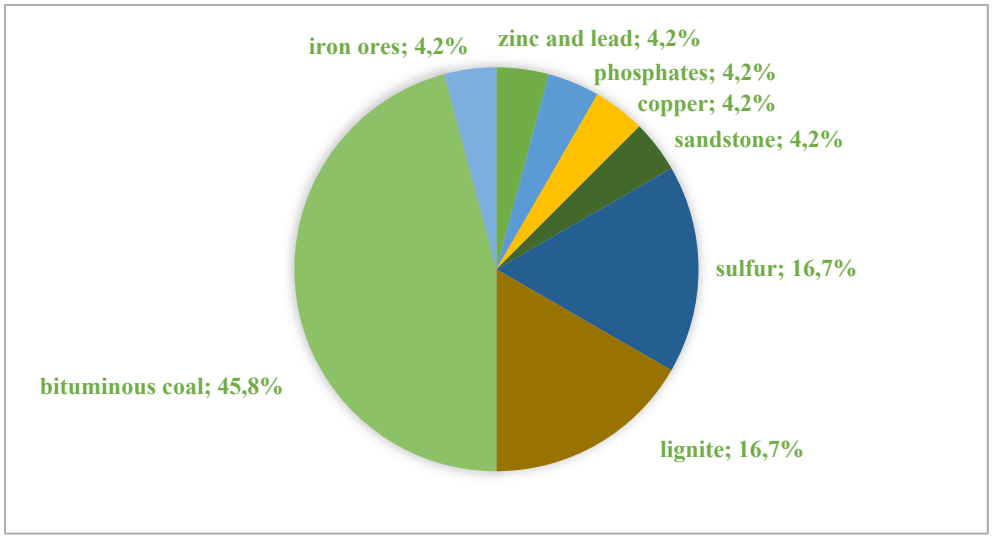


FIGURE 8. Types of minerals extracted on the fields of research in studied publications

SUMMARY

Presented article should be considered as a review and a synthesis of the research references published both in Poland and worldwide, where remote sensing and GIS technologies have been used to examine reclamation, as well as landscape planning. Selected publications enforce a wide range of issues that the authors raised. Satellite images and GIS software were used not only to monitor the above processes by visualization of changes in land cover and land use over the years, but also to identify the side effects on already reclaimed areas and to present the results of incorrectly executed reclamation and landscape planning processes. Papers analyzed newly established classification methods of satellite images aimed for the identification of land cover forms on post-mining areas. Additionally, they described studies related to monitoring of vegetation condition, which modifications caused by mining activity were levelled during reclamation process.

Publication contains the quantitative data pertinent to chosen articles, too. Ergo, one can state growing interest in GIS technologies and remote sensing that are employed for the sake of reclamation and landscape planning. Since 2015 the number of publications remains stable, at a high level. Among the countries that most willingly raise this question one ought to enumerate the People's Republic of China and Germany. The analysis of used remote sensing images provided the information about the most popular satellite missions. Research results show a preponderance of Landsat missions over the other programs of remote monitoring the Earth from the outer space. However, it should be noted that more and more publications take advantage of European Space Agency called Sentinel. Considering the type of minerals extracted on the fields of research it is easy to notice that more than 60% of characterized sites are the areas of coal mining. The second major mineral in discussed study is sulfur. Finally, the article concludes software types applied to process satellite images as well as to present its outcome. Studies define a significant amount of commercially available tools, which might be used depending on images parameters or research purpose.

Research results achieved so far by scientific community as well as the insights into images processing methods and GIS technologies will help to write a doctoral dissertation, which aim is to develop a spatial information system making it possible to enable monitoring changes in reclaimed areas, to identify undesirable modifications and to take necessary steps preventing from damages to natural environment. It is worth emphasizing that discussed references are the author's personal touch and in the course of writing a thesis the bibliography will be upgraded to new items. The mission of present publication is to introduce the issue of remote sensing and GIS technologies in terms of reclamation and landscape planning processes, but it does not describe all the published research comprehensively.

REFERENCE LIST

1. Poland on photography https://polska-org.pl/ Access 7 June 2019 (2018)
2. Z. Kasztelewicz, *Reclamation of post-mining areas in the Polish open pit mines* (Science and Mining Traditions Foundation, Kraków, 2010), pp. 14 [in Polish]
3. Act of February 3rd, 1995 on agricultural and forest lands protection [Journal of Laws 1995 no. 16 item 78] [in Polish]

4. Central Statistical Office, *Environment protection 2018* https://stat.gov.pl Access 9 June 2019 (2018) [in Polish]
5. Supreme Chamber of Control, *Protection and management of post-mining spoil tips* https://www.nik.gov.pl Access 10 June 2019 [in Polish]
6. A. Ostręga and R. Uberman *Formal-legal problems of post-industrial areas revitalisation, including post-mining areas* Mining and Geoengineering **29**, 115-127 (2005) [in Polish]
7. N.P. Singh, V.K. Gupta and A.K. Singh *Geospatial technology for land reclamation monitoring of opencast coal mines in India* 34th International Symposium on Remote Sensing of Environment - The GEOSS Era: Towards Operational Environmental Monitoring (Surveying and Spatial Sciences Institute, Sydney, Australia, 2011)
8. M. Szostak, P. Wężyk, P. Hawryło and et al. *The analysis of spatial and temporal changes of land cover and land use in the reclaimed areas with the application of airborne orthophotomaps and LANDSAT images* Geodesy and Cartography **64**, 75-86 (2015)
9. L. Matejicek and V. Kopackova *Changes in croplands as a result of large scale mining and the associated impact on food security studied using time-series Landsat images* Remote Sensing **2**, 1463-1480 (2010)
10. J.C. Padró, V. Carabassa. J. Balagué et al. *Monitoring opencast mine restorations using Unmanned Aerial System (UAS) imagery* Science of The Total Environment **657**, 1602-1614 (2019)
11. X. Tong, X. Liu, P. Chen et al. *Integration of UAV-based photogrammetry and terrestrial laser scanning for the three-dimensional mapping and monitoring of open-pit mine areas* Remote Sensing **7**, 6635-6662 (2015)
12. E. LeClerc and Y.F. Wiersma *Assessing post-industrial land cover change at the Pine Point Mine, NWT, Canada using multi-temporal Landsat analysis and landscape metrics* Environmental Monitoring and Assessment **189**, (2017)
13. J. Li, C.E. Zipper, S. Li et al. *Character analysis of mining disturbance and reclamation trajectory in surface coal-mine area by times-series NDVI* Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering **31**, 251-257 (2015)
14. G.P. Petropoulos, P. Partsinevolos and Z. Mitraka *Change detection of surface mining activity and reclamation based on a machine learning approach of multi-temporal Landsat TM imagery* Geocarto International **28**, 323-342 (2013)
15. D. Borisova, H. Nikolov and D. Petkov *Multitemporal satellite data in mine waste monitoring of Medet copper deposit* Proceedings of SPIE - The International Society for Optical Engineering 8538, (Edinburgh, United Kingdom, 2012)
16. H. Li, J. Lei and J. Wu *Analysis of land damage and recovery process in rare earth mining area based on multi-source sequential NDVI* Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering **34**, 232-240 (2018)
17. S.K. Karan, S.R. Samadder and S.K. Maiti *Assessment of the capability of remote sensing and GIS techniques for monitoring reclamation success in coal mine degraded land* Journal of Environmental Management **182**, 272-283 (2016)
18. M. Szostak, K. Knapik, P. Wężyk et al. *Fusing Sentinel-2 Imagery and ALS Point Clouds for defining LULC changes on reclaimed areas by afforestation* Sustainability **11**, (2019)
19. S. Raval, E. Sarver, A. Shamsoddini et al. *Satellite remote sensing-based: Estimates of biomass production on reclaimed coal mines* Mining Engineering **66**, 76-82 (2014)
20. P. Wężyk, M. Szostak and W. Krzaklewski *Landscape monitoring of post-industrial areas using LiDAR and GIS technology* Geodesy and Cartography **64**, 125-137 (2015)
21. S. Zhang, H. Ning, D. Xu et al. *Analysis of spatio-temporal evolution and driving factors of vegetation fraction for opencast coal mine in grassland area* Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering **32**, 233-241 (2016)
22. Z. Yao and W. Zhou *Correlation analysis between vegetation fraction and vegetation indices in reclaimed forest: A case study in Pingshuo mining area* 4th International Workshop on Earth Observation and Remote Sensing Applications, (Guangzhou, Chiny, 2016)
23. R. Padmanaban, A.K. Bhowmik and P. Cabral *A remote sensing approach to environmental monitoring in a reclaimed mine area* ISPRS International Journal of Geo-Information **6**, (2017)
24. J. Suh, K. Sung-Min, H. Yi et al. *An overview of GIS-based modelling and assessment of mining-induced hazards: soil, water and forest.* International Journal of Environmental Research and Public Health **14**, (2017)
25. Z. Neustupa, B. Stalmachová and R. Danel *Information systems for regeneration of landscape affected by mining* 11th International Multidisciplinary Scientific GeoConference and EXPO (Bułgaria, 2011)
26. Y. Chen, M. Luo, L. Xu et al. *Object-based Random Forest classification of land cover from remotely sensed imagery for industrial and mining reclamation* International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences **42**, 199-206 (2018)

27. M. Zhang, W. Zhou and Y. Li *The analysis of object-based change detection in mining area: a case study with Pingshuo coal mine* International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences **42**, 1017-1023 (2017)
28. T. Penaz and M. Lazecky *Land and soil moisture change analysis in the lake most surroundings from the Sentinel-1 and Cosmo images (Czech Republic)* 38th Asian Conference on Remote Sensing - Space Applications: Touching Human Lives (Delhi, Indie, 2017)
29. I.V. Zen'Kov, I.A. Ganieva and A.S. Morin *Space technologies in assessing the production of mining operations and the ecological state of disturbed lands by coal mines in the Kemerovo Region* Ecology and Industry of Russia **22**, 28-33 (2018)
30. V. Zenkov, I.A. Ganieva, M.Y. Lukichev et al. *Information support for remote monitoring of disturbed lands by coal mines on the territory of the Northern and Southern Kuzbass* Ecology and Industry of Russia **22**, 34-39 (2018)
31. L. Bodlák, K. Křováková and V. Nedbal *Assessment of landscape functionality changes as one aspect of reclamation quality – the case of Velká podkrušnohorská dump, Czech Republic* Ecological Engineering **43**, 19-25 (2012)