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Condition of young scientists of cartography in Poland: searching for a diagnosis (2016–2022)

Abstract. The article assesses the condition of cartographic research in the context of young scientists. Based on an analysis of the 469 academic achievements of 77 young Polish cartographers in the 2016–2022 period, the authors highlight challenges in defining contemporary cartography and difficulties in classifying research due to its interdisciplinary nature, overlap with GIS, and the use of cartographic methods in studies from other fields. The study also examines thematic trends, mobility constraints, and patterns of scientific collaboration. The findings emphasise the need to support young researchers and foster interinstitutional cooperation.

Keywords: cartography, young scientists, research directions, research funding, academic achievements, Poland

1. Introduction

In 2023, the first discussion panel of young cartographers "The future of Polish academic cartography – state and prospects – an attempt at diagnosis" ("Przyszłość polskiej kartografii akademickiej – stan i perspektywy – próba diagnozy") was held during the 45th National Cartographic Conference (XLV Ogólnopolska Konferencja Kartograficzna, 2023) in Lublin (Poland). The panel aimed to initiate discussions on the future of Polish academic cartography. The main topics were the impact of the research units on the study scope, the mobility of young scientists, and the perception of cartographers and their competences by collaborators.

For the panel, we collected publicly available data on the achievements of young scientists of cartography (hereinafter referred to also as: young cartographers or young researchers) in Poland in the 2016–2022 period and presented the results of preliminary analyses at the conference. Post-panel discussions allowed us to gather comments and observations and resulted in the idea of writing down our findings in a journal paper. Our aim in this paper is to discuss the state and potential directions of academic cartography in Poland, based on the scientific achievements of young scientists.

The initial challenge was to define the scope of cartographic studies. These attempts were previously undertaken inter alia in the Strategic Plan for the International Cartographic Association 2003–2011 (Ormeling et al., 2003), papers by Baranowski et al. (2018) or Lapaine et al. (2021), and the panel discussion "The Condition of Contemporary Cartography" during the 43rd National Cartographic Conference in Poland in 2021.[1] Due to the interdisciplinary nature of cartography, we define it here as the discipline dealing with the "art, science and technology of making and using maps" after Ormeling et al. (2003, p. 17).

[1] The discussion by Dariusz Gotlib, Beata Konopska, Zenon Kozieł, Beata Medyńska-Gulij, Wiesław Ostrowski and Wiesława Żyszkowska and moderated by Marek Baranowski was reported in written format in the "Polish Cartographical Review. Suplement w języku polskim" ("Dyskusja panelowa „Kondycja współczesnej kartografii" na XLIII Ogólnopolskiej Konferencji Kartograficznej 26 października 2021 r.", pp. 45–59).

2. Related studies

2.1. Existing methods for classifying research works

Assigning research papers, scientists, and grant applications to specific disciplines is challenging. This is mainly due to various classification systems serving different purposes: some for statistical and administrative use, others for bibliographic classification.

In Poland, the Regulation of the Minister of Science and Higher Education dated September 20, 2018, introduced a two-tier division into fields and disciplines. Initially, there were eight fields of science divided into 47 specific disciplines. The list was updated on October 11, 2022, comprising 10 fields and 54 disciplines (Rozporządzenie Ministra Edukacji i Nauki, 2022). The term "cartography" does not appear in any discipline name, creating a problem in categorising the research of young Polish cartographers. In some more detailed local classifications, cartography is given separate categories. For example, in the three-tier classification of research fields in Australia and New Zealand, "Cartography and digital mapping" is part of the "Geomatic Engineering" group (Australian Bureau of Statistics and Stats NZ, 2020). An even more detailed four-tier system exists in Canada, with a separate subclass for "Cartography" (Statistics Canada, 2020).

Many countries base their classifications on the Frascati Manual, an internationally recognised standard for collecting and using research and development statistics (OECD, 2015). Efforts are underway to standardise classification systems to facilitate the documentation and management of research activities. The concept of CRIS (Current Research Information Systems) is gradually being implemented in the European Union (Sivertsen, 2019). Although a common classification already exists for all projects funded by the ERC (ERC, 2020).

2.2. Keyword standardisation in research journals

Young scientists, regardless of their discipline, often limit their collaboration to colleagues within their own department or even lab (Ren et al., 2023; Yegros-Yegros et al., 2015). Reasons

include peer pressure, time constraints, and isolated research groups that exclude collaboration with researchers from other institutions. However, it is interdisciplinary research that drives scientific breakthroughs (Ren et al., 2023; Yegros-Yegros et al., 2015). Identifying researchers from different fields and disciplines with whom they could collaborate is already a challenge for young scientists. Standardised keywords assigned to publications, grant applications, and especially to researchers could help (Finelli et al., 2015; Vrkić, 2014). The lack of standardised keywords in scientific journals and funding institutions also hindered the identification of achievements by young cartographers, which was one of the objectives of this study.

2.3. Percentage of young scientists as primary investigators in funding reports

Among those applying for funding in National Science Centre (NSC, in Polish: Narodowe Centrum Nauki) competitions from 2016 to 2023, 47% of the total amount awarded by NSC, in both national and international agency competitions, was granted to young scientists, with the lowest 41% in 2017 and the highest 54% in 2022 (NSC, 2024b). These percentages include projects specifically aimed at young researchers, in which more experienced scientists cannot participate. When analysing only the NSC competitions in which scientists at various career stages can participate, the funding obtained by young scientists is lower than that obtained by more experienced researchers. For example, in 2023 NSC received 536 grant applications from young researchers, which translated into 40 million euros in funding. In contrast, 620 applications submitted by more experienced scientists resulted in a total of 187 million euros in funding (NSC, 2024b).

The NSC website (NSC, 2024a) also provides listings that include administrative divisions, types of competitions, as well as the academic and chronological age of the applicants. The latter shows a significant increase in applications submitted by early-career researchers (aged 26–28), most likely in the initial years of their doctoral studies.

The National Centre for Research and Development (NCRD, in Polish: Narodowe Centrum Badań i Rozwoju) primarily funds large implementation projects but offers one project specifically for young researchers – the Lider project. The average age of the laureates of the latest, 14th edition, is around 33 years. In the last five editions, none of the projects pertained to the field of cartography (NCRD, 2024).

The European Research Council (ERC) portfolio includes the Starting Grant project, which is open to individuals two to seven years after a PhD. ERC provides a platform summarising projects from various competitions – both applications and funded projects. Although there are no statistics on the age of project leaders, it is noteworthy that there is a zero success rate for applications from Poland in the panel relevant to cartography research, i.e. PE10 – Earth System Science. Of 14 applications from Poland for the Starting Grant project, none were accepted for funding, compared to an overall success rate of about 12% for this project (ERC, 2024).

2.4. Mobility of young scientists

The mobility of researchers plays a crucial role in many aspects of the academic world. Even a temporary change of affiliation positively impacts a career by broadening scientific horizons, building networks, exposing researchers to different cultures, and improving language skills (Ivancheva & Gourova, 2011; Franzoni et al., 2012). Institutions also benefit from increased recognition (Deville et al., 2014) and strengthened scientific standing of the represented country (Stephan & Levin, 2001). Researcher mobility also facilitates knowledge exchange (Ackers, 2005; Sugimoto et al., 2017). In some institutions, young researchers (usually during or immediately after a PhD) change their environment and complete an internship at another institution to prevent "inbreeding" (Schiermeier, 2011).

Previous research on the mobility of scientists primarily relied on survey results distributed to scientists (e.g. Auriol, 2010; Van Noorden, 2012). These surveys mainly targeted residents of developed countries and covered only recent years of scientists' activities. Today, online literature databases like Scopus and Web of Science enable analyses of scientists' mobility based on bibliographic data (Czaika & De Haas,

2018; Moed & Halevi, 2014). A study on geographers using Web of Science data noted that the percentage of mobile scientists – those who changed their affiliation at least once – increased from around 1% in 2000 to 3% by 2013. Despite the global increase in active scientists, this percentage has remained stable (Liu et al., 2024). The same study confirmed high mobility among young scientists, with the highest number of affiliation changes occurring in the third year after publishing their first article, coinciding with the completion of their PhD and subsequent post-doc programmes. Since 2020, the mobility of early-career researchers was limited due to the COVID pandemic (Ahmed et al., 2020).

Factors that motivate international mobility vary depending on the career stage of the scientist (FNP, 2019). Early career researchers (undergraduate, masters, and doctoral students) focus on linguistic and cultural aspects, while postdoctoral scientists are more concerned with family-related issues, such as childcare support or employment opportunities for their partners. Internationally, for researchers from countries like India and Mexico, better access to research infrastructure is crucial, while for those from South Africa, the USA and the UK, the political and economic situation of the destination country is significant.

In summary, popular international destinations for scientist migration include North America (mainly the USA and Canada), Europe (mainly the UK and Germany), and Oceania (Australia and New Zealand). In recent years, China has also gained importance. Factors motivating scientists' mobility include the spatial, cultural, and academic proximity of the target institution, its position in international rankings, and the economic development level of the host country. Barriers often include visa policies, language differences, and financial challenges.

2.5. Impact of affiliation on young scientists' research scope

Scientific research is largely funded by public resources, and funding principles are based on the evaluation of scientific institutions. This evaluation is increasingly based on researchers' publication achievements in leading, often international journals with high citation indices and significant rejection rates (Kulczycki, 2019).

Scientific productivity is influenced not only by abilities, knowledge, experience, and intrinsic motivation, but also significantly by institutional factors (Bukowska & Łopaciuk-Gonczaryk, 2013). The prestige of an institution or department and the presence of distinguished staff positively impact the productivity of other researchers, especially those at lower career stages (Abramo et al., 2011). This prestige is associated with adequate funding, enabling skill development through internships and providing appropriate logistic and technical infrastructure (Blume-Kohout & Adhikari, 2016). The size of the institution also matters, particularly at the lab or research group level. Larger research groups achieve better results by combining intellectual capital, and budgetary resources, and reducing administrative costs, while interactions among group members stimulate research ideas. Large teams have a higher chance of securing funding and attracting outstanding scientists (von Tunzelmann et al., 2003).

The literature emphasises that contemporary science is increasingly team-based and interdisciplinary (Cheruvelil et al., 2014; Kwiek, 2019). Analyses for Poland indicate that international collaboration positively impacts the number and quality of publications (Olechnicka & Płoszaj, 2008). Global studies show that publication success is largely dependent on interdisciplinary collaboration, especially between different research institutions, providing access to new resources and knowledge (Sá, 2008; Sigelman, 2009).

The institutional environment and the atmosphere within the scientific community significantly influence the quality of research institutions and, consequently, the researchers' achievements. Besides formal collaboration, scientists benefit from informal relationships with colleagues, which help avoiding errors and inspiring new ventures (Fox & Mohapatra, 2007). Collaboration in research projects also provides emotional support, enhancing motivation for research, and creating natural mechanisms of mutual control and responsibility (Laband & Tollison, 2000).

Another significant factor influencing scientists' productivity is their teaching load. Although focusing on research at the expense of teaching positively impacts the number of publications (Fox, 2005; Porter & Umbach, 2001), some

studies indicate the positive effects of simultaneous research and teaching activities. This not only enhances the quality of classes but also generates new research ideas and solutions through interactions with students (Fox & Mohapatra, 2007).

In summary, the research institution to which a scientist is affiliated primarily affects their productivity, which in turn influences the scope of their research. This impact is shaped by adequate financial and technical support, the ability to form large, interdisciplinary, and international teams, a conducive atmosphere, and a balanced distribution of teaching and research duties.

3. Materials

3.1. Data collection and study group selection

The query for eligible individuals was conducted from winter 2023 to spring 2024, using scientific databases and websites of institutions conducting cartographic research. We verified the data by corresponding with the heads of particular departments. To identify achievements, we used sources such as the Polish Science Database (Nauka Polska, 1999), ORCID data (ORCID, 2012), and the research units' websites. We used ArcGIS Survey123 (n.d.) and Excel (cloud) software to collect and analyse the data, working only with publicly available data.

The criteria for selecting the study group included meeting the legal definition of a young scientist and conducting research in the field of cartography. According to the current definition, "A young scientist shall be a person conducting a scientific activity, who: 1) is a doctoral student or an academic teacher – and does not hold a degree of doktor[2] or 2) holds a degree of doktor, obtained not more than 7 years ago, and is employed in an entity referred to in Art. 7 sec. 1" of the Law on Higher Education and Science (Ustawa, 2018). As we started gathering data at the beginning of 2023, we decided to analyse the previous seven years to include people who just crossed this limit. Thus, the chronological scope of the analyses is 2016–2022.

The selection of the study group could not be conducted based solely on discipline due to the interdisciplinary nature of cartography, whose boundaries are hard to define clearly. Many of the young researchers included in the analyses conducted such interdisciplinary research.

There are seven types of classifications used in the Polish Science Database (i.e. ERC; State Committee for Scientific Research; Ministry of Science and Higher Education (MSHE); NSC; Ontology of Scientific Journals; Organization for Economic Co-operation and Development; Dictionary of Scientific Fields and Disciplines). Searching by the keyword "cartography" provided results that included surveyors, remote sensing specialists, and various engineers. Some official profiles of people identified as young researchers still have a discipline attributed according to the revoked State Committee for Scientific Research, which classified cartography together with geodesy. The starting point for building a classification used currently by the MSHE is the OECD Fields of Science and Technology. As the classification does not include any specific discipline called cartography, most cartographers are classified within "social and economic geography and spatial management" (Social sciences) or "Earth and related environmental sciences" (Natural sciences).

We also considered obtaining the list of awarded PhDs (by institution) from the Polish Science Database. However, it turned out that some research units had incomplete data. Thus, the data were verified at the websites of the corresponding research units.

Achievements published under a maiden surname were registered with the current surname. As the data were not gathered in a direct survey and we used data available on the Internet, gender could only be estimated based on the person's name. We were unable to obtain data on the age of PhD completion for all individuals holding a doctoral degree. Additionally, we could not find keywords for all the identified achievements.

For thematic categories, we followed the classification from the "Polish Cartographical Review. Supplement w języku polskim" and adopted by Kozieł (2021). The original classification consists of 14 categories. We mapped recorded achievements to 10 of them (in italics):

[2] "Doktor" is the equivalent of the word "doctor" in English. The wording in the citation is according to the official translation available on the gov.pl website.

− Cartographic institutions and organisations, legal issues, cartographic profession;

− *General issues, cartographic theory and methodology, presentation methods, map editing, cartographic generalisation;*

− *Geographical nomenclature, toponomastics;*

− Globe and planetary cartography, "small cartography", maps on postcards and stamps, flags, coats of arms, monuments, coins, match labels, paramap representations;

− *History of cartography, bibliographies, catalogues, personal data, literature, cartographic collections;*

− *Map production and reproduction techniques, computer, web and mobile cartography, DEM, cartographic animation, augmented and virtual reality;*

− *Mathematical cartography, geodetic fundamentals, navigation systems, GPS;*

− *Perception and use of maps, cartographic and geomatic method to assist research;*

− Proceedings of multithreaded conferences and seminars;

− *Remote sensing and photogrammetry in cartography;*

− *School and university cartography, teaching of cartography and geoinformatics, typhlocartography;*

− *Spatial data infrastructure, spatial information systems;*

− *Thematic, atlas and ubiquitous cartography.*

Due to the interdisciplinary nature of some achievements, we have also introduced the category "Other".

We coded all achievements of the young researchers with their final affiliation in the analysed period (changes of research units are described in section 4.1. Study group). We mapped achievements to the thematic categories by analysing the available data (titles with keywords, abstracts, manuscripts, and descriptions of research grants). In identifying and classifying achievements, we referred to the adopted definition of cartography (see 1. Introduction) and our expertise. Inconclusive cases were resolved through discussions between co-authors.

Eventually, data on 91 people and over 600 scientific achievements were collected. Due to the method and period of data collection and the number of people collecting the data, the sets required harmonization.

First, individual cases of missing data in both tables were supplemented. In the table listing young cartographers, the affiliation was simplified from the full name of the unit to "acronym of the university name, full name of the faculty". To create a key for combining tables from pairs of cells titled "First name" and "Last name" and in some cases "First name" and "Maiden name", the cells "Abbreviation" and "Maiden name abbreviation" were created in the form "last name, first letter of first name or names with a dot". In the table with achievements of young cartographers, the following actions were taken:

− the description of affiliations for doctoral dissertations was simplified;

− discrepancies in the names of journals/books, publishers, and the description of the thematic scope of works were eliminated;

− the column with the list of authors was divided into separate columns for each author in a format analogous to the "Abbreviation" field from the person table;

− duplicates were removed in two approaches: more rigorous based on all table columns (2 records were removed), and less rigorous based on the columns "Type", "Title", "Name of journal/book", and "Year of publication";

− thematic categories were verified;

− papers and chapters from the conference materials were verified, as some turned out to be abstracts.

After thorough analysis, we decided not to include the achievements of 14 young researchers (with 138 achievements). The reason for that is that most of them were employed in a cartographic unit of a research institution, but their research was only slightly related to cartography. For example, they used GIS tools or geovisualisations in hydrology or geomorphology studies.

3.2. Data model

We recorded information about the study group in two tables. The first table was designed to collect background information about the young researchers (Table 1). The second table (Table 2) focused on three types of achievements: publications, research grants, and awarded PhDs. We coded publications as papers, chapters, or books (including book editing). All data were coded with the surname version as of the end of 2022.

Table 1. The structure of collected data in the table "Young cartographers"

Table "Young cartographers"
− name; − surname; − abbreviation used to code the person; − gender; − academic degree; − last known affiliation; − affiliation of PhD; − place where PhD was obtained; − year of obtaining PhD; − PhD supervisors (separate columns); − PhD reviewers (single column); − age of completing PhD; − maiden surname; − code for maiden surname; − ORCID; − second affiliation; − activity in the international/national environment; − varia.

Table 2. The structure of collected data in the table "Achievements"

Table "Achievements"
− authors (separate columns for all authors); − ORCID of the first author; − type of achievement; − title of achievement; − editor (of the book); − name of the journal; − publisher; − DOI; − link; − keywords (separate columns, up to 6); − language of publication; − year; − type of funding scheme;* − funding institution;* − grant affiliation;* − panel/discipline;* − PhD affiliation;** − thematic category; − varia. * only for grants ** only for PhDs

4. Results

4.1. Study group

The study group consisted of 77 young researchers in cartography as of December 2022. We gathered data about 33 women and 44 men (43% and 57% of the group). The study included 33 PhD holders: 18 with a Master of Science (MSc), and 15 with a Master of Arts (MA). The remaining group of 44 had not received their doctoral degree by the end of 2022, comprising 23 MAs and 21 MScs. The structure of academic degrees by gender is shown in Figure 1. There is a significant disproportion among PhD holders (13 women and 20 men). Interestingly, the number of researchers with an MA is almost identical to those with an MSc (38 and 39, respectively). At the end of 2022, the researchers were associated with 15 universities in Poland and four research institutes (Table 3). Four individuals ended their academic careers after obtaining their doctorate and did not work in academia at the end of 2022.

The number of young researchers in particular cities (without division into separate research units) is shown in Figure 2. We found that seven out of 33 PhDs changed their affiliation after obtaining their doctoral degrees (Table 4).

4.2. Achievements

The table of achievements consists of 469 entries (summary in Table 5). The majority are various forms of publications (426). We identified 333 papers, 71 chapters, 20 books, and two edited books. Between 2016 and 2022, 33 PhD degrees were awarded and 10 projects were

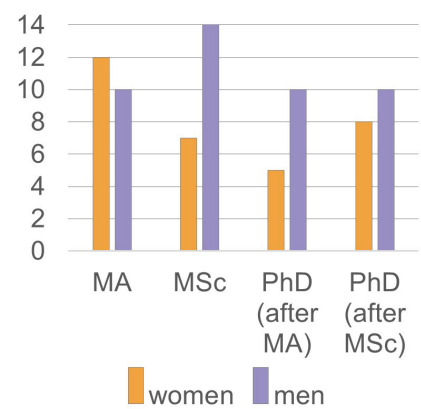

Figure 1. Structure of academic degrees by gender

Table 3. List of research units affiliating young researchers in cartography at the end of December 2022 (English names used in the paper are official translations provided by units)

No.	Research unit	Acronym	City
1.	Gdańsk University of Technology, Faculty of Civil and Environmental Engineering	GUT	Gdańsk
2.	Koszalin University of Technology, Faculty of Civil Engineering, Environmental and Geodetic Sciences	KUT	Koszalin
3.	AGH University of Krakow, Faculty of Geo-Data Science, Geodesy, and Environmental Engineering	AGH UST	Kraków
4.	AGH University of Krakow, Faculty of Geology, Geophysics, and Environmental Protection		
5.	Jagiellonian University, Faculty of Geography and Geology	JU	
6.	Jagiellonian University, Faculty of History		
7.	University of Agriculture in Krakow, Faculty of Environmental Engineering and Land Surveying	UA	
8.	Maria Curie-Skłodowska University, Faculty of Earth Sciences and Spatial Management	UMCS	Lublin
9.	University of Warmia and Mazury in Olsztyn, Faculty of Geoengineering	UWM	Olsztyn
10.	Adam Mickiewicz University, Poznań, Faculty of Geographical and Geological Sciences	AMU	Poznań
11.	Nicolaus Copernicus University in Toruń, Faculty of Earth Sciences and Spatial Management	NCU	Toruń
12.	Educational Research Institute	ERI	Warsaw
13.	Institute of Geodesy and Cartography	IGC	
14.	Stanisław Leszczycki Institute of Geography and Spatial Organization Polish Academy of Sciences	IGSO PAS	
15.	Military University of Technology, Faculty of Civil Engineering and Geodesy	MUT	
16.	Tadeusz Manteuffel Institute of History Polish Academy of Sciences	IH PAS	
17.	University of Warsaw, Faculty of Geography and Regional Studies	UW	
18.	Warsaw University of Technology, Faculty of Geodesy and Cartography	WUT	
19.	University of Wrocław, Faculty of Earth Sciences and Environmental Management	UWr	Wrocław
20.	Wrocław University of Science and Technology, Faculty of Geoengineering, Mining and Geology	WUST	
21.	Academy of Zamość, Institute of Social and Economic Sciences	AZ	Zamość

financed from external funds. Among the publications and PhD dissertations, 314 were written in English, 142 in Polish (including all PhD dissertations), two in German, and one in Russian.

4.2.1. Thematic categories and keywords

The most widely represented thematic category was “Map production and reproduction

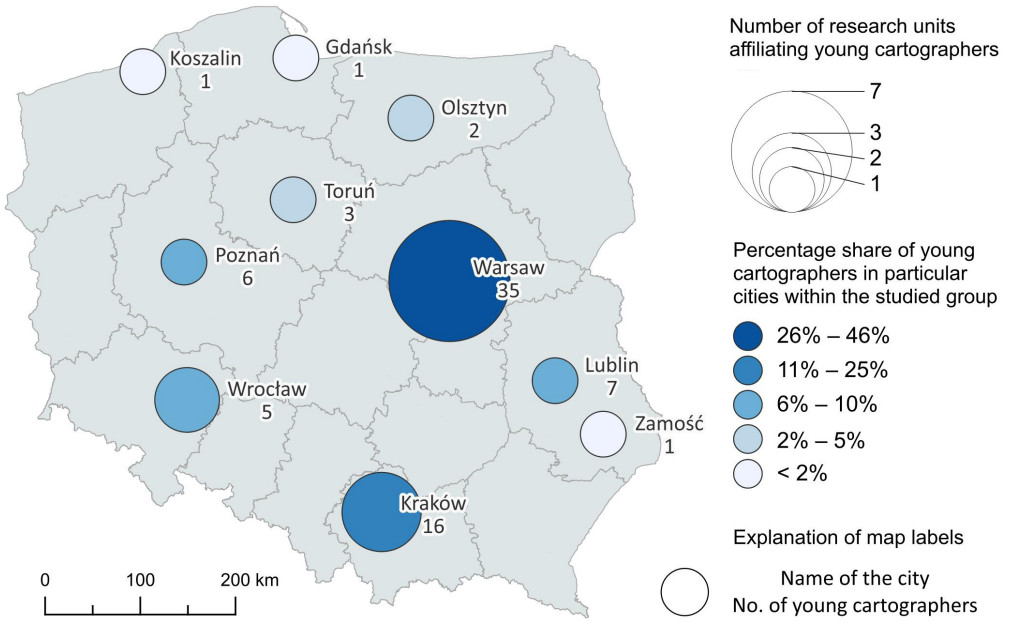

Figure 2. Distribution of young researchers in cartography in Poland at the end of 2022

Table 4. Professional mobility after obtaining doctoral degrees

Affiliation: doctoral degree	City	Affiliation: December 2022	City	No of occurrences
AGH UST	Kraków	GUT	Gdańsk	1
WUT	Warsaw	KUT	Koszalin	1
UW	Warsaw	IH PAS	Warsaw	2
UW	Warsaw	ERI	Warsaw	1
UW	Warsaw	IGC	Warsaw	1
UA	Kraków	AZ	Zamość	1

techniques…" (27.9%, 131 achievements, Table 5). The number of achievements mapped to the category "Other" may seem high (62), yet these entries constituted only 13.2% of all data. These achievements were related to the fields of spatial management, history, cultural heritage, tourism, environment protection, hydrology, demography, economy, physical geography, psychology, and rural studies. We noted a similar number of achievements in the category "Remote sensing and photogrammetry…". We recorded a balanced number of achievements in five other categories ("Perception and use of maps…", "Spatial data infrastructure…", "General issues, cartographic theory…", "Thematic and ubiquitous cartography", "History of cartography, bibliographies..."). The theme "Mathematical cartography, geodetic fundamentals…" was one of the less discussed by young researchers (22 records). The least popular categories were "School and university cartography…" and "Geographical nomenclature, toponomastics" (Table 5).

In most of the years analysed, the numbers of achievements are distributed fairly evenly and range from 10.4% (49) to 14.3% (67) per

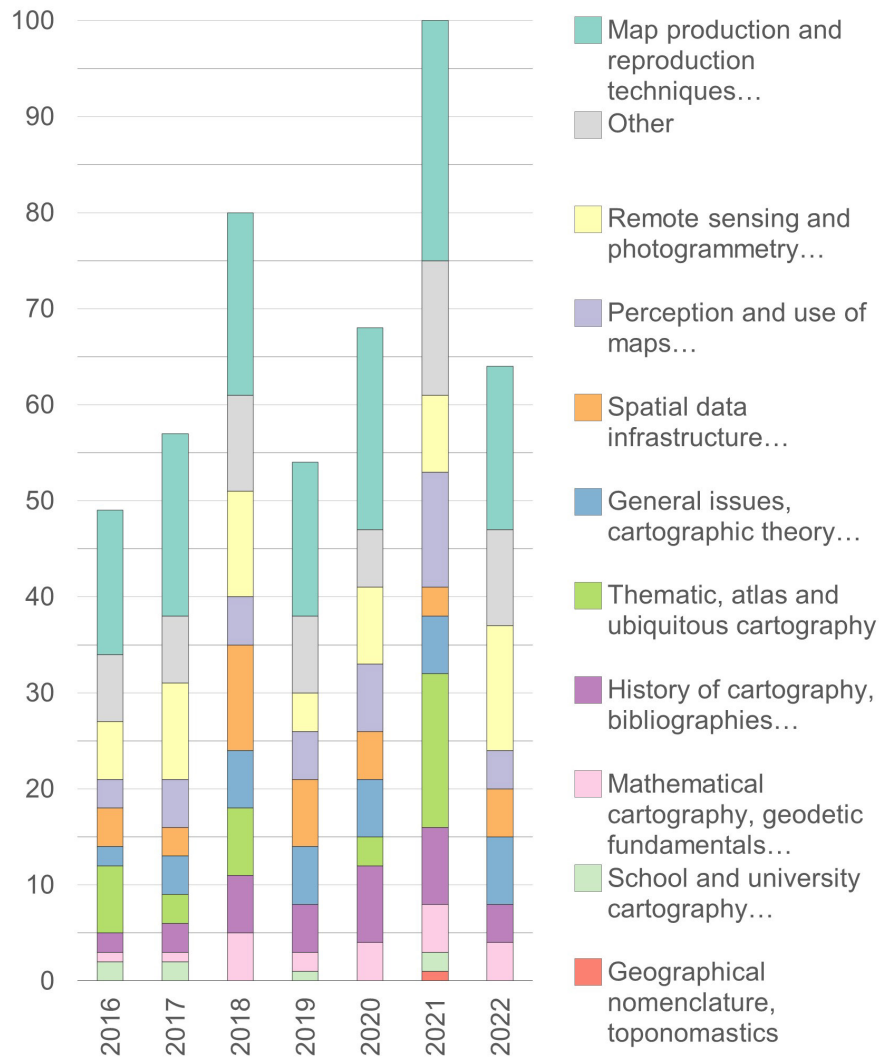

Figure 3. Number of achievements according to thematic categories between 2016 and 2022

year (Figure 3). Two years stand out: more than 20% of achievements date back to 2021, which was the last year of term the Polish research units evaluation (RAD-on, 2017), whereas about 16.8% of achievements were recorded for 2018. We recorded the highest number of achievements for six out of eleven categories in 2021. The peak is especially visible for the categories "Thematic, atlas and ubiquitous cartography" (16 entries, 44.4% of the total in this category in the analysed period) and "Perception and use of maps…" (12 entries, 29.3% of the total in this category). Additionally, 2021 is the only year with one achievement mapped to the category "Geographical nomenclature, toponomastics" (Figure 3).

We found keywords for 364 (77.6%) of 469 achievements. The identified keywords were in Polish and English. Many of the identified achievements lacked keywords: 39 chapters, 36 papers, 18 books, two edited books, five PhD dissertations, and six grants.

We identified 1,291 unique keywords. Keywords such as "GIS" or "UAV" appeared in

Table 5. Thematic categories: number of achievements of young cartographers per research unit (2016–2022)

	Thematic category	Research unit																			No. of achievements
		AGH UST	AMU	AZ	ERI	GUT	IGC	IGSO PAS	IH PAS	JU	KUT	MUT	NCU	UA	UMCS	UW	UWM	UWr	WUST	WUT	
1.	Map production and reproduction techniques…	13**	18			2			5	15	3	10	2	7	12	4**	1	1	1	39	131
2.	Other	1			4	1		21	5	1			5	8		1	5	6		4	62
3.	Remote sensing and photogrammetry…	9*	8			5	1			3		1	7	11	1*		1	9		4	59
4.	Perception and use of maps…	2	19		3		2	1	5			2		3	2	2					41
5.	Spatial data infrastructure…		1		1	1			1			1	1	15	2	1	1			13	38
6.	General issues, cartographic theory…	5				1	1	1	2	2	1	5		2		7	2			7	36
7.	Thematic, atlas and ubiquitous cartography		4					13	4			1	8	3		1	1	1			36
8.	History of cartography, bibliographies…	2		2					19	1			2		9	1					36
9.	Mathematical cartography, geodetic fundamentals…	1	1			2						3		8	2					5	22
10.	School and university cartography…								4	3											7
11.	Geographical nomenclature, toponomastics								1												1
No. of achievements		30	51	2	8	12	4	36	46	25	4	23	25	57	27	15	11	17	1	72	469
No. of young cartographers		4	6	1	1	1	1	1	3	7	1	3	3	5	7	11	2	4	1	15	77

* one achievement shared by researchers from AGH UST and UMCS

** two achievements shared by researchers from AGH UST and UW

publications in both: Polish and English, so we performed the analysis for the entire set together. We decided not to translate keywords, nor unify them (e.g. “HGIS” and “historical GIS”), as the goal was to analyse keywords in the form in which they can be searched in databases via search engines.

We took into account 84 keywords that occurred three times or more (Figure 4). We identified 1,064 keywords used once, and 144 keywords that appeared twice. The most popular keyword was “GIS” with 33 unique records. We also recorded six occurrences for “Geographic Information Systems”, four of “systemy informacji geograficznej” (GIS in Polish), two for “Geographic Information System”, and one for “Geographic Information Systems (GIS)” and “Geographical Information System”.

The next most common keywords were “cartography” with 19 records (with an additional five occurrences of “kartografia” – translation in Polish), and “Poland” (16, with an additional two occurrences of the equivalent in Polish, i.e. “Polska”). We identified 12 occurrences of the words “hGIS” and also seven occurrences of “historical GIS” and one of “GIS historyczny”.

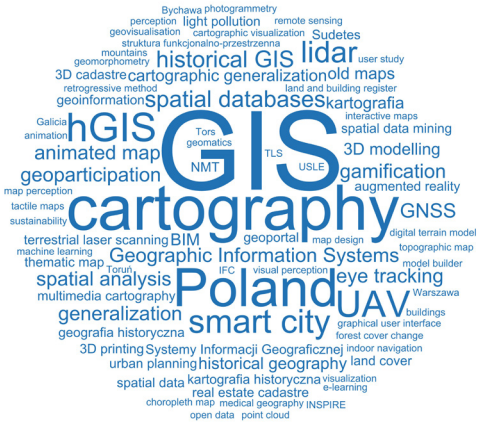

Figure 4. Word cloud presents 84 keywords that occurred at least three times. Generated using: https://www.wordclouds.com/

The keyword “UAV” was used 11 times (with an additional one occurrence of “unmanned aerial vehicle”) and the keyword “smart city” was used 10 times (additionally, one occurrence of: “smart cities and communities”, “smart city development”, “smart cities”).

Focusing on selected units allowed us to determine if research units specialise in specific areas. Figure 5 presents the most frequently identified keywords for four research units (WUT, UA, UAM, IH PAS) with the highest number of achievements (above the third quartile) and at least three young researchers (the median of the set of young researchers per research unit). “GIS” was the most common keyword in publications for both WUT and UA. Interestingly, it did not appear in the word cloud for UAM, where “cartography” was the most frequent keyword.

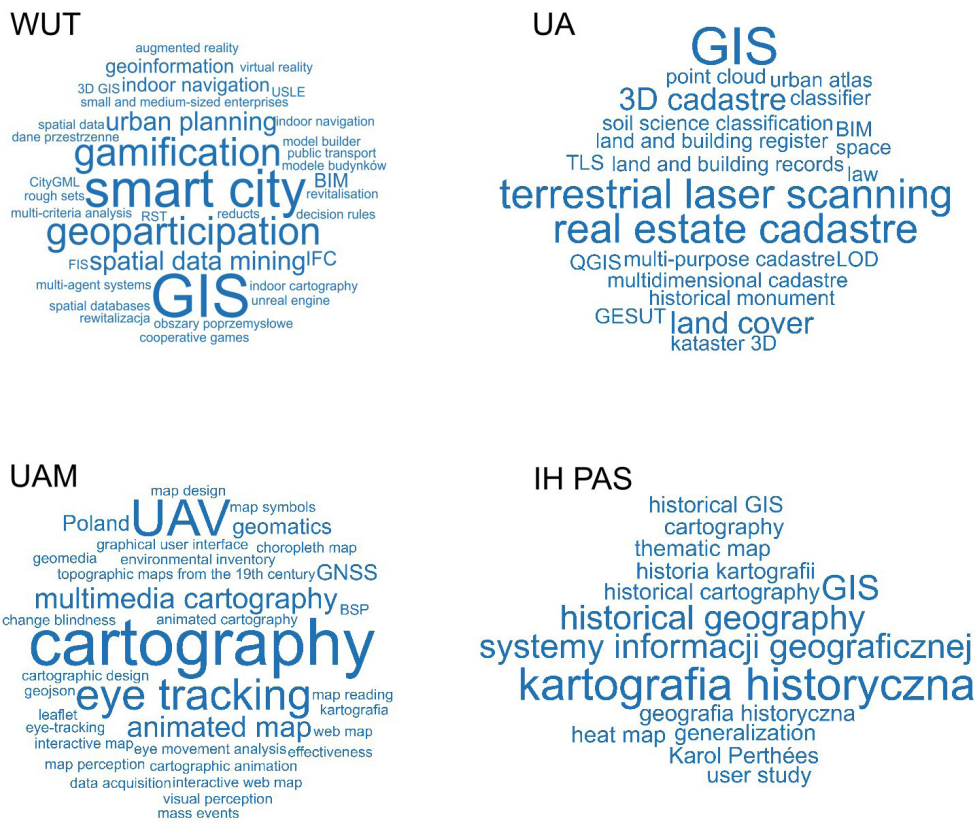

Figure 5. Word clouds present keywords that occurred at least twice per selected research unit. Generated using: https://www.wordclouds.com/

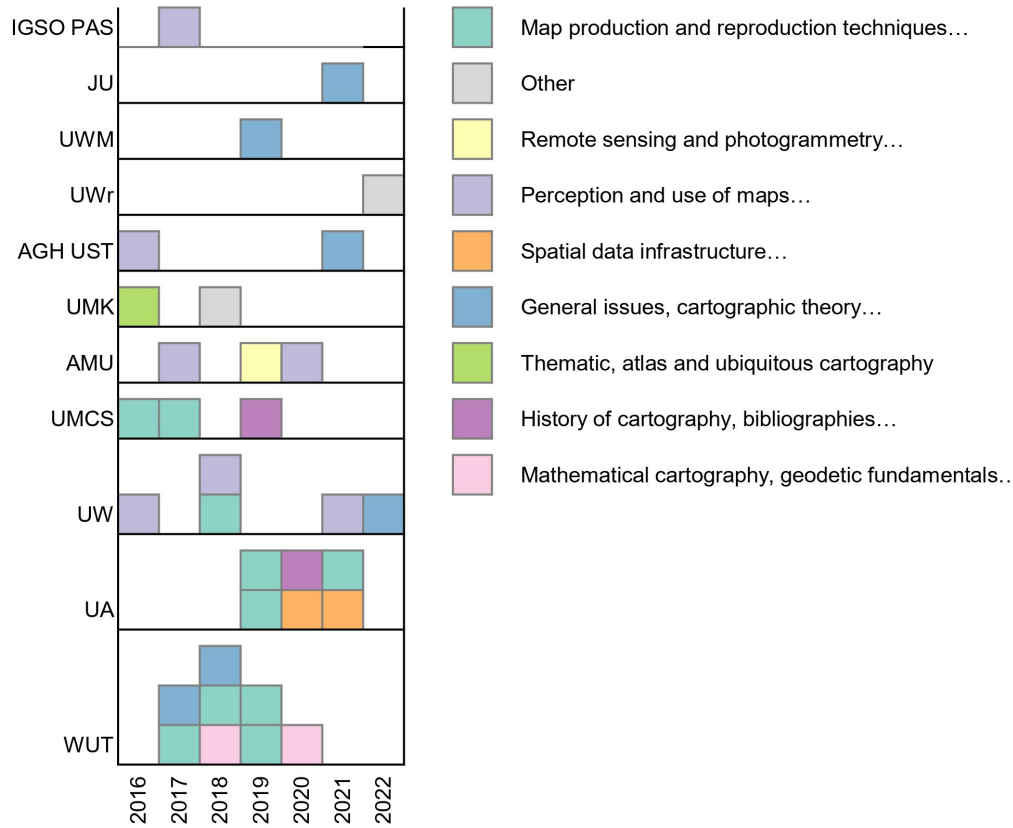

Figure 6. Number of PhDs per year per thematic category per research unit (affiliation at the time of the PhD defence)

Young researchers from WUT focused on the topic of smart cities and urban planning, using spatial data mining techniques. They were also interested in gamification and geoparticipation in cartography. Keywords frequently found in the achievements of young cartographers from UA indicate a focus on surveying topics, i.e. cadastre and terrestrial laser scanning. For UAM, the most frequent keywords (apart from "cartography") were related to studies on the perception of maps and map design (e.g. "eye tracking", "multimedia cartography", "animated maps"). Cartographers from UAM also studied applications of UAVs in spatial data collection. In turn, young cartographers from IH PAS focused on historical cartography and applications of GIS in historical geography.

4.2.2. Doctoral degrees

In the studied group, there were 33 individuals whose doctoral dissertations fit the broadly defined field of cartography (Figure 6). This number was initially higher. However, to create a set of unequivocally cartographic dissertations, it was necessary to remove certain theses from the database that were preliminary defined as cartographic. In some cases, this was because authors used cartographic or GIS methods in their research, rather than treating cartography as the main subject of study.

During the analysed period, the highest number of doctorates were defended at the WUT – eight, the UA – seven, and the UW – five. Based on the collected data, it can be concluded

that universities play a significant role in educating young researchers (66%), followed by technical universities (30% of doctorates), with research institutes accounting for only 3%.

When it comes to the number of defended doctoral dissertations, 2018 and 2019 stand out, with a total of 13 doctoral degrees defended (Figure 6). A significant decline was observed in 2022, with only 2 doctorates defended.

Thirty percent of the doctorates focused on "Map production and reproduction techniques…", 23% on "Perception and use of maps…" and 20% on "General issues, cartographic theory and methodology…" (Figure 6). The main research themes revolve around the core areas of cartography. It cannot be conclusively determined that any one scientific institution specialises exclusively in a single theme. However, specific research areas aligned with the unique characteristics of the institutions do emerge. Overall, the dominant theme is related to applied cartography, methods of map production, and their analysis (83.3%).

Beata Medyńska-Gulij, Dariusz Gotlib, and Wiesław Ostrowski each supervised three doctorates, making significant contributions to the development of young researchers. Zenon Kozieł reviewed the highest number of dissertations (5 of 33).

We also attempted to determine the age of the study group members at the point of receiving their doctoral degree. This task was challenging, as we were unable to obtain complete information. There are no official, publicly accessible databases that store such facts about researchers. We collected available information based on online repositories of PhD dissertations, personal conversations, websites dedicated to fostering professional and academic careers, social media, and other web sources. We collected data for 25 PhDs out of 33 (Figure 7).

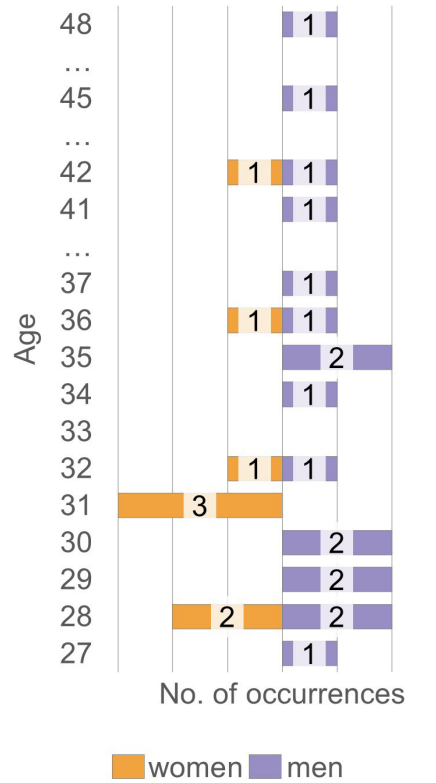

Figure 7. Number of men and women who obtained a PhD, ranked by their age at the time

4.2.3. Research grants

In our analyses, we also collected information about ten successfully acquired grants by young cartographers (Table 6). Three focused on the history of cartography, making it the most represented thematic area. The second most common was map production and reproduction techniques. The remaining projects covered various topics, including general cartographic issues, remote sensing and photogrammetry in cartography, the perception and use of maps, and the real estate market.

Three grants were awarded in 2016, and one in 2017. No project proposals were accepted by major funding agencies in the following three years. Three more grants were accepted in 2020, two in 2021 and one in 2022. Financial support for these projects primarily comes from national bodies, including the NSC and the MSHE.

Funding was distributed through various contests, targeting researchers at different career stages and specific project needs. Programs provided by the NSC, such as PRELUDIUM and SONATA, enable both PhD graduates and undergraduates to secure funding for their projects. Meanwhile, MINIATURA funds individual scientific activities that can be

Table 6. Number of grant projects categorised by funding sources and institutional affiliation

Funding	Research unit					No. of projects
	IH PAS	WUT	AMU	UMCS	UWM	
NSC	1		2	2		5
MSHE	2	2				4
University					1	1
No. of projects	3	2	2	2	1	10

expanded into broader projects. The MSHE provides support through competitions aimed at universities, research groups, or individual scientists. One of the projects received direct university funding.

We can highlight various research projects affiliated with several Polish universities present in Table 6. The IH PAS was notably involved in multiple funded projects, focusing on the history of cartography. The UMCS also focused on the history of cartography, blending historical analysis with contemporary data management. The AMU contributed to innovative research in map production and reproduction techniques and the perception and use of maps. This unit emphasised the integration of modern technology in geographical studies, such as computer vision and dynamic point symbols. The UWM applied geographical analysis to practical fields, including the real estate market. The WUT explored advanced cartographic methods as well as remote sensing and photogrammetry applications in cartography.

4.2.4. Publications

The distribution of publications, which constitute 90.8% of the identified achievements, corresponds to the values recorded in Figure 8. Young researchers from research units with the highest number of achievements published a similar number of papers in the analysed period. With high values ranging from 43 to 46, three research units: WUT, UA, and UAM stand out. When it comes to books, the unit with the highest number of achievements is IGSO PAS (11). The role of book editor was identified only for two representatives of IH PAS. In the analysed period, the largest number of book chapters were published by young cartographers from WUT and IGSO PAS.

4.2.4.1. Journal papers

Our dataset contains 333 unique research papers. 272 (81.7%) in English, 59 (17.7%) in Polish, and 2 (0.6%) in German. We distinguished journals with more than 10 publications. The most research papers were published by young cartographers in the following journals: 37 in “Polish Cartographical Review”, 29 in “ISPRS International Journal of Geo-Information”, 20 in “Geomatics, Landmanagement and Landscape”, 14 in “Annals of Geomatics” and 12 in “Remote Sensing”. The remaining 221 papers were published in 127 different journals. Analysis of publishing houses revealed that most papers were published in MDPI journals (67), De Gruyter (45), and Elsevier (29). A significant number of research papers was also published by Polish research units, research institutes, scientific societies, committees or commissions, with the most records for the Publishing House of the University of Agriculture in Krakow (25), Polish Association for Spatial Information (14) and Institute of History Polish Academy of Sciences (9).

The thematic structure of the analysed papers (percentage share) published by young cartographers is shown in Figure 9. The highest percentage share of papers (30.0% – 100 papers) was assigned to the category: “Map production and reproduction techniques…”. The next most common categories were “Remote sensing and photogrammetry…” with 13.2% (44 papers) and “Other” with 10.2% (34 papers). This distribution highlights the current trend in cartography research, being often paired with another research area, e.g. photogrammetry or hydrology. The least common thematic category was “School and university cartography…” with only 6 records, and no records were found for “Geographical nomenclature, toponomastics”.

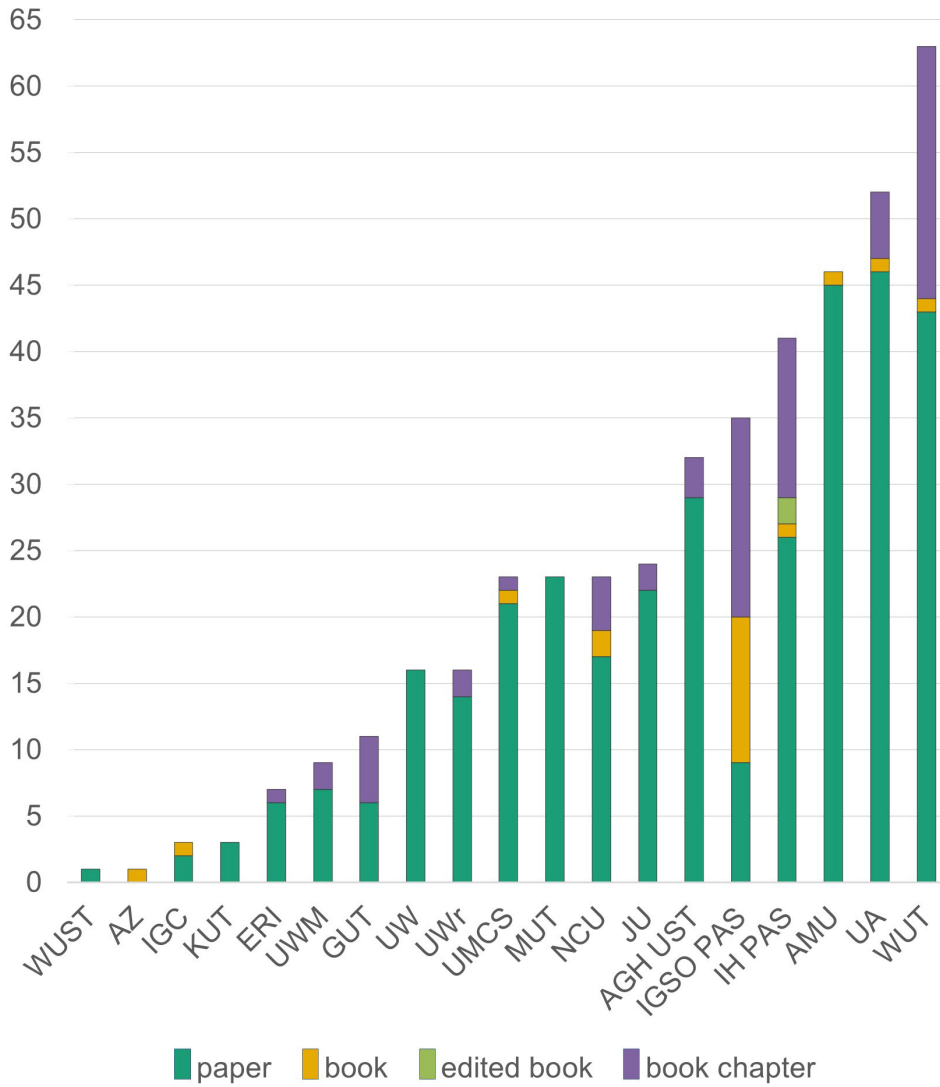

Figure 8. Publication types per research unit

Of the 333 articles published in scientific journals, 176 (52.8%) featured a young cartographer as the first author. In 27 publications, more than one young cartographer was involved. Most of these works were produced within a single institution, with only three papers resulting from collaboration between young researchers from different institutions. Young researchers from AGH UST co-authored two papers with young researchers from UW and one with colleagues from UMCS. The remaining 24 articles were co-authored by young cartographers affiliated with the same institution.

4.2.4.2. Books and edited books

In the analysed period, young cartographers in Poland published (or co-published) 20 books

and co-edited two books (Figure 10). Over 60% of all books were in Polish, and the remaining ones were in English. Only one book was published in the foreign publishing house. Ten of the 22 books were printed by publishing houses of research units or scientific societies. Half of the books could be identified as monographs, six as atlases, and five as reports. The predominant themes of the books were "Thematic, atlas and ubiquitous cartography" and "History of cartography, bibliographies…".

Most research units had representatives who (co-)authored only one book. A notable exception is IGSO PAS, with 11 books. In all these publications, the young cartographer was not the first author, and most books were on topics different from cartography. Five of the publications were European Observation Network for Territorial Development and Cohesion (ESPON) reports. Only two young scientists (UMCS, IH PAS) published single-authored books. Regarding book editing, this achievement was identified only for two researchers from IH PAS.

4.2.4.3. Book chapters

In the analysed period, young cartographers authored or co-authored 71 book chapters (Figure 10). Among these, 50.7% (36) were published in Polish, 47.9% (34) in English, and one in Russian. Of the 34 chapters published by international publishers, 10 were published by leading publishers, including Springer International Publishing (8 chapters) and Routledge, Taylor & Francis Group (2 chapters).

Many chapters (37%) appeared in conference proceedings, with 10 being part of the IEEE International Conference on Industrial Engineering and Engineering Management series. The next largest group included chapters in thematic monographs (31%), with most (62%) published in Polish.

A substantial portion of the publications comprised chapters in atlases (over 25%), included in several major atlas projects, such as the *Visegrad Atlas* (9 chapters), the *Historical Atlas of Poland* (6 chapters), the *Atlas of Rural Areas in Poland* (2 chapters), and the *Electoral Atlas of Poland* (1 chapter). All authors involved in these atlas publications were affiliated with institutes of the Polish Academy of Sciences, underscoring these institutes' contributions to atlas-oriented cartographic literature. The remaining chapters (7% – 5) were instructional publications and guides in the field of GIS and database solutions.

The most common thematic category for chapters was "Map production and reproduction techniques..." (over 25% – 18 chapters, Figure 10). The next largest category was "Other" (21.1% – 15 chapters), covering topics related to GIS applications in history, Earth sciences, and social sciences. The categories "Thematic, atlas and ubiquitous cartography" and "Remote sensing and photogrammetry…" included 13 entries each (18.3%). No publications were found in the categories "General issues, cartographic theory and methodology..." or "Perception and use of maps...".

Young cartographers frequently held leading authorship roles. In 41 chapters, a young researcher was the first author; in 19 – the second author, including two cases where both the first and second authors were young researchers

5. Discussion

This study aimed to compare the academic achievements of young cartographers in Poland and discuss the state of cartographic research and its prospects. Indirectly, it was an attempt to refer to the 43rd Polish National Cartographic Conference "The condition of contemporary cartography" discussion from 2021 (Gotlib et al., 2021b). One of the biggest challenges observed was defining cartography in relation to GIS studies. We encountered similar difficulties while classifying or defining achievements as cartographic. GIS tools are widely used, not only by geographers and cartographers. Many of those preliminary identified as "young cartographers" conducted work only slightly related or unrelated to cartography. Another problem was to unambiguously classify achievements into thematic categories. Sometimes, it was difficult to clearly define the primary goal of individual works. The inconsistency of keywords used by authors did not facilitate the process. Possibly, as suggested by Vrkić (2014), authors are unaware of the importance of keywords describing their works.

Regarding thematic categories of the achievements, we found a dominance of topics different from those discussed by Konopska (2021)

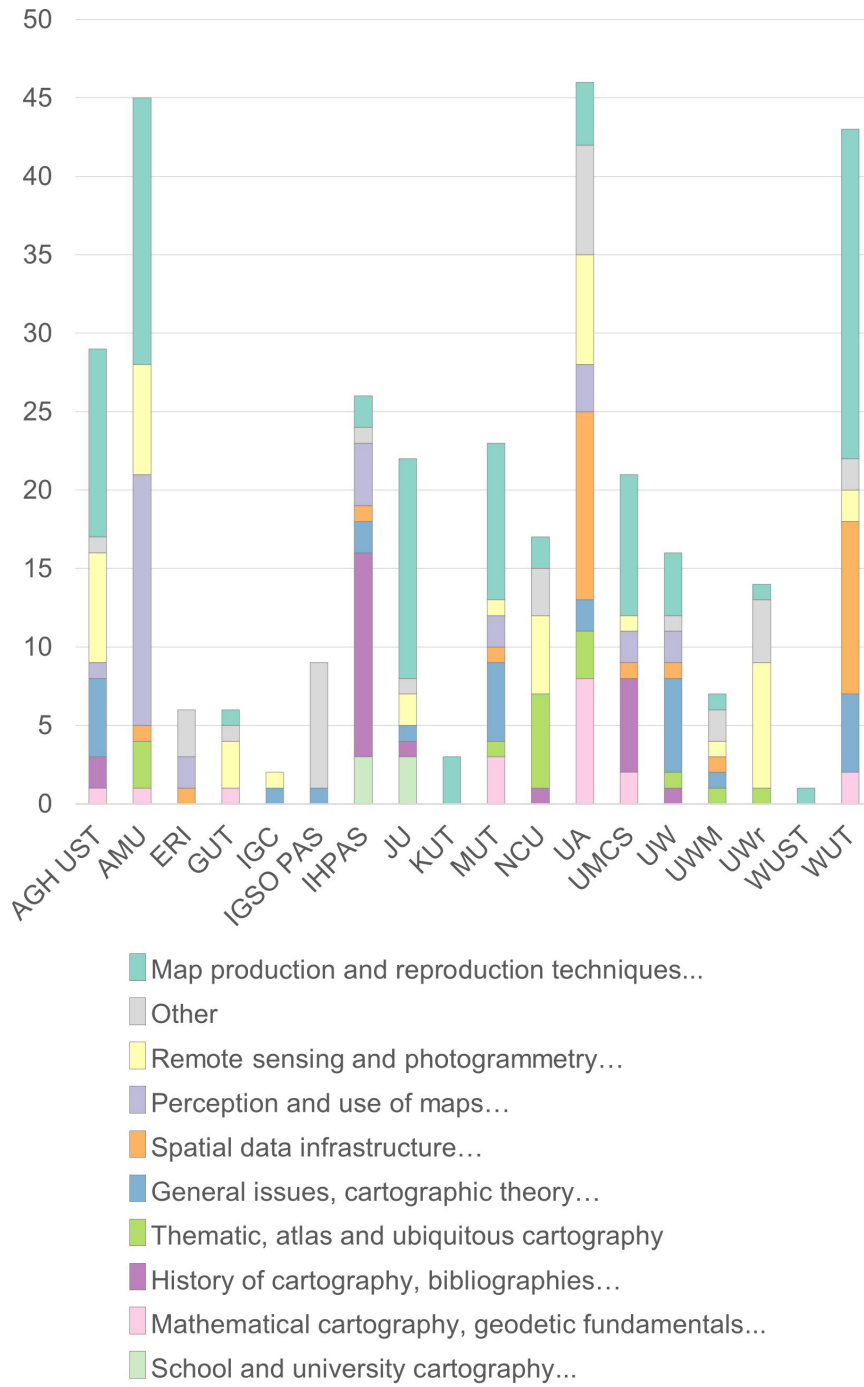

Figure 9. Number of papers per thematic category per research unit

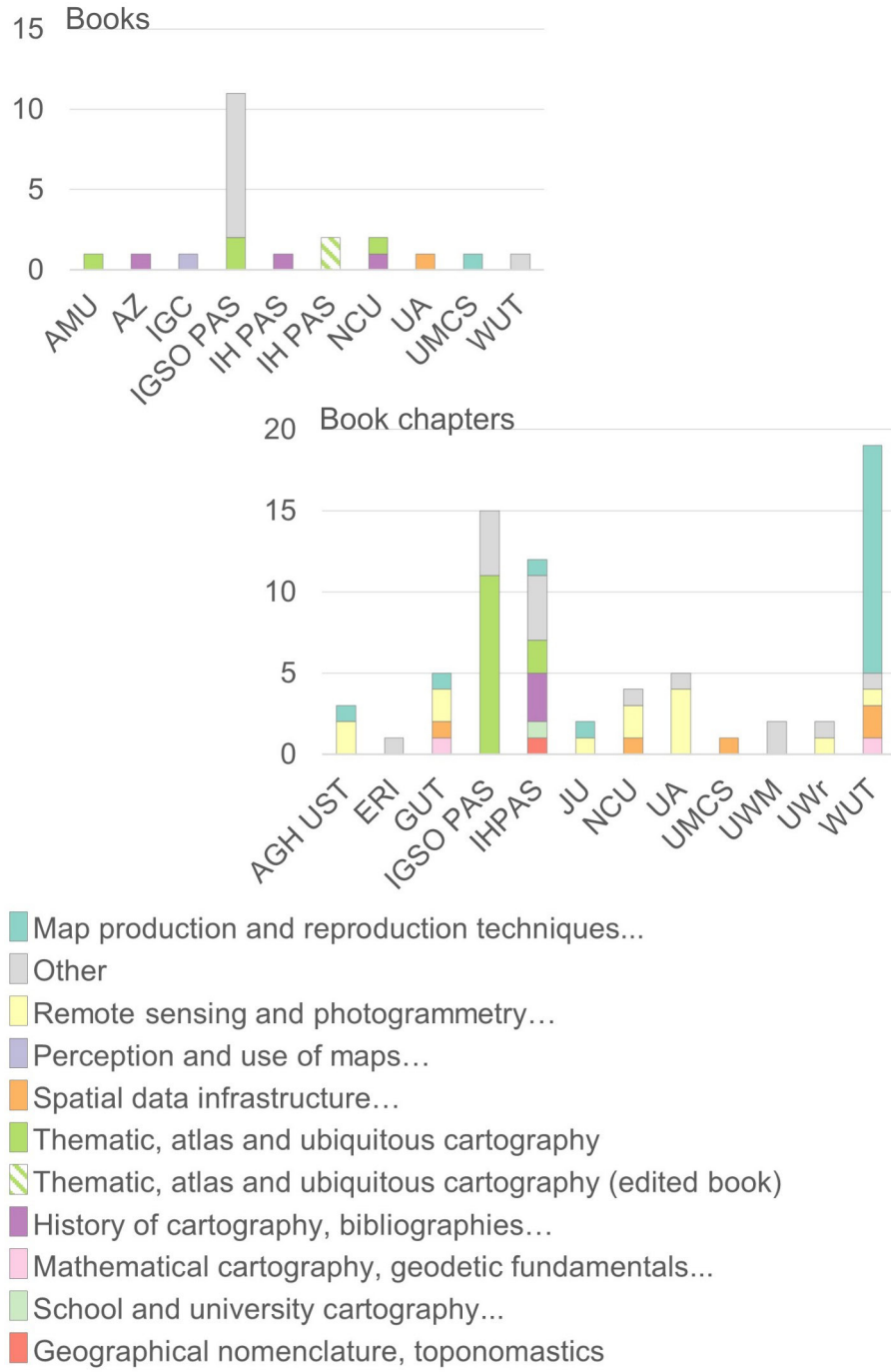

Figure 10. Number of books, edited books and book chapters per thematic category per research unit

in reference to the bibliography of Polish cartographic publications from 1968–2020 (Kozieł, 2021). The most popular thematic categories in this larger time range were the history of cartography, spatial data infrastructure, and thematic cartography. In turn, in the achievements of young cartographers from 2016–2022, we identified a dominance of map-making and reproduction techniques and issues related to remote sensing. The significant share of the "Other" category is promising as it might denote interdisciplinary research that, as suggested by Ren et al. (2023) and Yegros-Yegros et al. (2015), fosters scientific breakthroughs.

Research on doctoral dissertations in cartography identifies trends in the discipline's development and evaluates the academic institutions training future specialists. In the analysed group, 33 dissertations in cartography were identified. Initially, this number was higher, but some works were later excluded as they merely employed cartographic or GIS methods rather than focusing on cartography as the primary research area.

Determining the age of individuals obtaining their doctorate was challenging due to the lack of publicly available data. Information was gathered through interviews, accessible websites, and social media, allowing identification of age data for 25 of the 33 doctoral candidates. The incomplete data limited the ability to fully analyse age patterns, highlighting the need for more comprehensive databases to track researchers' careers.

Dissertations focus on key themes of applied cartography and map production methods: "Map production and reproduction techniques…", "Perception and map use…", "General issues, cartographic theory and methodology…". Together, these themes comprise 83.3% of the analysed dissertations, suggesting a strong emphasis on the practical applications of cartography. These trends appear to reflect the situation in academic cartography worldwide in the last two decades (Brewer & McMaster, 1999). Although none of the analysed institutions specialises exclusively in one topic, certain research areas align with the profiles of individual units.

Seven out of 33 young cartographers changed their affiliation after completing PhD. This number is relatively high (21%) compared to results by Liu et al. (2024). However, all these changes occurred at the national level; no international affiliation changes were registered. We identified only three movements between cities; other changes of affiliation happened within the same city. This outcome might be partly affected by the limited mobility during the COVID-19 pandemic. Eighteen out of 33 researchers defended their PhDs between 2019–2022 and might not have been able to participate in post-doc programs due to global restrictions or personal reasons, e.g. fear of leaving the country in such circumstances (Ahmed et al., 2020; Cahusac de Caux, 2022). An interesting issue concerning international mobility is short-term mobility, e.g. internships, study visits, and research collaboration travels. There is limited public availability of such data and we did not take it into account during our research, but it constitutes a possible direction for future studies.

Grants secured by young cartographers primarily focused on two areas: the history of cartography and map production techniques. The grant data reveals a noteworthy temporal trend: after a decline in successful grant applications between 2017 and 2019, there was a resurgence in 2020 and 2021. This resurgence may suggest the completion of previous projects, enabling new applications, typically from the same group of experienced researchers. National bodies, such as NSC and MSHE, have been instrumental in funding projects. Institutionally, grant projects reflect broad engagement across multiple research units, with notable contributions from IH PAS and UMCS (which focus on historical cartography), and the WUT, which specialises in advanced cartographic methods. This diversity reflects different research priorities within the field, demonstrating how institutional support and affiliation can shape the scope and focus of young researchers' work (Abramo et al., 2011).

When it comes to the achievements in the form of publications, a significant concentration of research efforts has been directed toward technical aspects of cartography, with the highest percentage of papers (30.0%) and chapters (25.4%) focusing on map production, reproduction techniques, computer-based cartography, and geospatial technologies such as digital elevation models and virtual reality. This trend reflects the interdisciplinary nature of cartography, merging with fields like photo-

grammetry and computer science. The dominance of these areas showcases the field's reliance on digital tools for mapping and spatial analysis, aligning with global shifts toward more technical and data-driven methods in cartography. For books, the most popular thematic categories were "Thematic, atlas and ubiquitous cartography" and "History of cartography, bibliographies…". On the other hand, certain topics appear to be underrepresented. For instance, research related to "School and university cartography" and "Geographic nomenclature" had very few publications, indicating that educational aspects may not be a priority for young researchers.

Authorship data indicates that in over half (52.8%) of the papers or book chapters (57.7%), young cartographers were the first authors, demonstrating their significant contribution to the academic discourse. However, in the case of the books, there were fewer achievements with a young cartographer as the first author (4 of 20).

Cross-institutional collaboration was limited, with only three papers co-authored by young researchers from different institutions. This pattern is consistent with studies showing that young scientists tend to collaborate mainly within their institution or lab (Ren et al., 2023; Yegros-Yegros et al., 2015). This lack of broader collaboration represents a potential area for development, where building networks across institutions, both nationally and internationally, could enhance research innovation and diversity.

6. Conclusions

To our knowledge, the presented study is the first attempt to assess the condition and perspectives of academic cartography in Poland based on scientific achievements. The analysis of the achievements of young cartographers in Poland indicates an inseparable relationship between cartography and GIScience. Moreover, cartographic tools and methods are used in many other fields, making it difficult to clearly classify the achievements and their authors. Interestingly, some researchers transferred to another discipline. We also identified people employed at cartographic research units but with achievements in other fields.

Considering the identified achievements, there is a noticeable emphasis on the practical aspects of cartography and its high interdisciplinarity, indicating a demand for specialists in this field, especially given the increasing use of GIS tools, including AI-based solutions. The conducted research provides valuable information on the current state of cartography as an academic discipline and can support shaping future academic policies, particularly in supporting young researchers and developing academic programs that address both research needs and market demands. The presented results can help those interested in studying cartography to make informed choices for a research unit. Another possible benefit of the study outcomes for the academic milieu would be the identification of thematic niches and research gaps.

The study's limitations include assigning works to the last affiliation, which may distort the researchers' career paths and prevailing themes for research units. Moreover, identifying people who went abroad was difficult; we identified only two persons who left Poland after completing their master's studies. Besides, we included only grants where people from the study group were principal investigators. Collecting data on grants in which these people were collaborators would enrich our knowledge about cooperation with other units or researchers from different disciplines.

Possible directions for future research include supplementing the database with further achievements and including new people, or repeating the study in, e.g. 10 years. It also seems important to analyse the applicability and commercialization of research results of young cartographers, or their cooperation with private companies and/or public institutions. Comparing the situation of cartographers with researchers in other fields can help identify specific challenges and opportunities. In this context, it seems essential to examine studies on how the emerging technologies, including AI solutions, will influence the role of cartography in the future.

It should be noted that one of the crucial elements of career development is international scientific exchange. It can be facilitated by i.e. active participation in scientific associations. In 2023, the Next Generation Cartographers Working Group (n.d.) was established by the International Cartographic Association. This initiative aims to support and provide mentor-

ship for early career cartographers within both academic and professional cartography (Meier et al., 2023).

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