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The development of the journal Spatial Statistics: The first 10 years

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A B S T R A C T

This paper presents an overview of the journal Spatial Statistics. It describes how it was initiated, how it developed and it highlights key moments from its young history. Starting in 2012, the journal has progressed in conjunction with the series of conferences in different countries over five continents. An important moment occurred when the journal received an impact factor in 2014. After a decline in the IF during the first years, the paper shows how the journal has now developed towards a more mature status, and is becoming a major scientific journal with a clearly defined niche. The paper describes in the end possible ways to move forward.

1. Introduction

Spatial statistics as a scientific domain has developed since the nineteen sixties. Its natural root is in statistics, while there are strong relations with probability theory, stochastic processes, time series analysis mathematics and computer science. The main motivation came from problems in society and the environment, i.e. the outside world. Without being too selective, we may recognize key contributions at an early stage as the documents from Matérn (1960), Matheron (1971) and Besag (1974), much of which was contained in books from Cliff and Ord (1981), Ripley (1981) and Cressie (1991). In fact, the distinction of spatial statistics into geostatistical data, lattice data and spatial patterns made in Cressie (1991) is still relevant and leading, also for the journal, while we realize that many cross links exist between these categories. The highlighted books were preceded as so often with scientific papers in the international literature. In addition,

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seminal work was done by Adrian Baddeley, resulting in the software package Spatstat (Baddeley et al., 2015). The development in spatial statistics can also not been seen separately from the developments in computer hard- and software, with the increasing computing power and the visualization and analysis opportunities in Geographical Information Systems. Of a special value has been the development of the R-package, which allowed open source code to be developed and used. Moreover, the domains that generate the data and the processes are critical throughout and the range of applications has been growing rapidly. It started with applications in mining, and was quickly followed by applications in soils, air quality and hydrology, which in turn was accompanied by applications in climate, ecology, agriculture, forestry, the wider environment, and social applications like in house prices, and econometric studies. Several journals were set up to deal with the increasing attention on spatial data. The – what we may call – top tier traditional statistical journals like Biometrics, JASA, Biometrika and the JRSS offered opportunities to publish the latest in the field, where the spatial studies were standing out in terms of their wonderful graphics, there transparent notations and their immediate appeal on visualization.

In the early years of the 21st century, a much clearer picture emerged that there was a need to focus more in particular on spatial statistics itself, and journals like Environmetrics and Environmental and Ecological Statistics started. A range of good and high quality papers were published, when around 2010 it became clear that spatial statistics was no longer a separate branch of statistics, nor solely a pillar in ecological studies, but became a discipline on its own. There was a clear need to bind the developments in geostatistical data, point patterns and lattice data as representing different angles on dealing with spatial data. The only albeit essential aspect was that the statistics were based upon data with coordinates. Hence on data that are – to some degree – characterized by the distance between observations and usually not replicates can be considered. In that sense, similarities with time series became apparent, while a major difference with spatial studies is the absence of directional aspect that one has in time. Hence, it was time for a new journal, the journal being Spatial Statistics. And the publisher became Elsevier Science.

It was not so hard to convince Elsevier of the need of the journal. In their environmental domain there was attention to spatial data with the advances in satellite images, spatial data collected and questions to be resolved with spatial interpolation. At that stage, however, Elsevier felt a limited momentum to start new journals at all, and hence the fair request became relevant to organize a conference first to investigate the potential of launching a new journal. That was done in 2011 in Enschede, where some 350 scientists from all over the world convened. Together with Gerard Heuvelink and Edzer Pebesma, we organized the meeting with as a title Spatial Statistics for Mapping the Environment, and we were able to attract high quality researchers to present their latest developments in the field. With this success we received the green light from Elsevier to start the journal.

From the start onwards the conference and the journal developed simultaneously and with clear links. We were happy with that combination, and the chicken-or-egg problem was easy to solve: the conference was first. The three of us served as the editors-in-chief of the new journal and a team of highly qualified spatial statisticians was willing to serve on the editorial board.

Fig. 1 shows the number of publications over the years in the journal. And three initial years, the number of publications stabilized at slightly less than 60 publications per year. There was a drop in 2019, which could be due to the single special issue we had that year. We also note that the number of cites of articles from the journal kept on increasing — the slightly lower number of 2021 may be due to the fact that the year is not yet completed.

2. The impact factor

After a few years of its existence, it became apparent that a journal needs an impact factor to attract the best papers in the domain. We considered the impact factor as critical in the development of the journal, also allowing us and others to compare it with other journals. After serious efforts by top scientists in our field, we received the impact factor in 2014 and we were proud on receiving a high value equal to 1.605, which put the journal immediately in the Q1 of the statistics journals. We did not realize then that this was largely due to a single paper that was heavily cited, and which
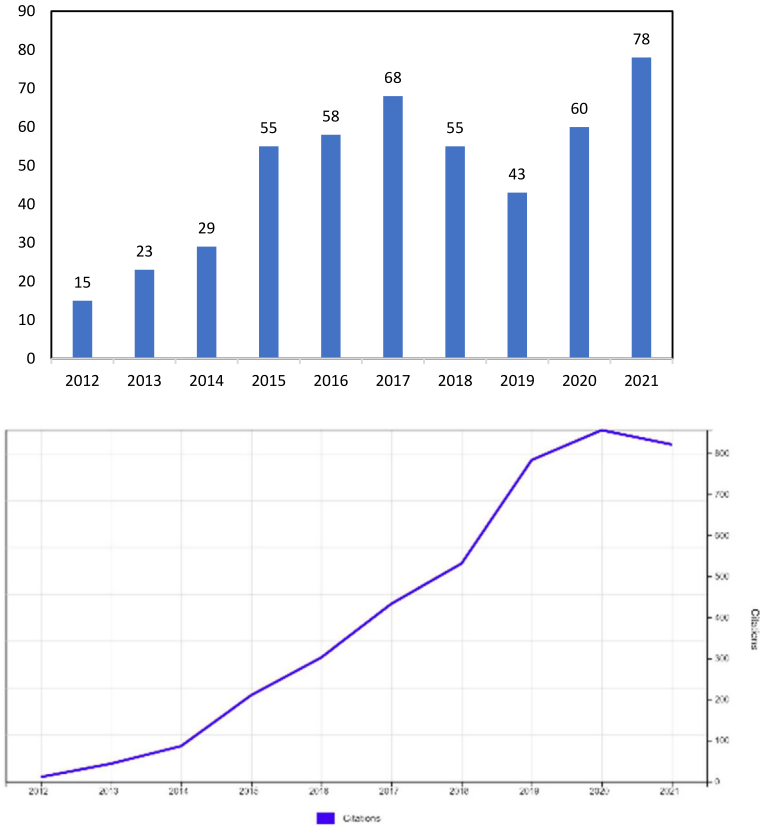
Fig. 1. The number of manuscripts published (top) and the number of downloads (bottom). After the initiation stage, the number of manuscripts stabilized to approximately 60 manuscripts/year, while the number of downloads is steadily increasing.

effect was damping in the years that followed (Fig. 2). At its lowest level, back in 2017, the impact factor was barely above 1.0, but with all the efforts that we put into it as the associate editors and the editors and with successful conferences in 2015, 2017 and 2019 the impact factor started to increase. At the moment (2021) it is above 2.0, and thus higher than at the start. With that IF it is in the Q2 of statistics journals. We aim of course to a further increase of the impact factor and bring it back to the Q1 in the statistics journals.

3. Background of the papers: international spread

For a journal, the impact factor is important, but possibly more important is its international spread. The 16 contributions in the first two issues in 2012 originated from 9 different countries, all from the western hemisphere except for one contribution from China. The USA was most prominent with three papers, followed by France, The Netherlands and the UK with each 2 contributions. That has changed. In later years we were able to attract contributions from countries in the other continents as well. Papers from Australia of course, while solid scientific contributions from sub-Saharan Africa and Latin America were submitted and published as well. Hence we are proud that
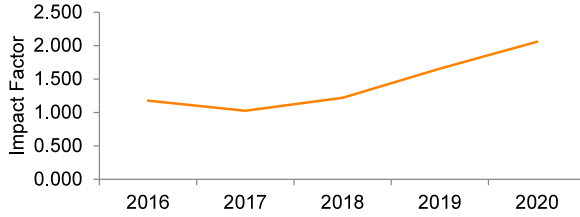
Fig. 2. The development of the impact factor since 2016. At present (2020), the impact factor equals 2.016.
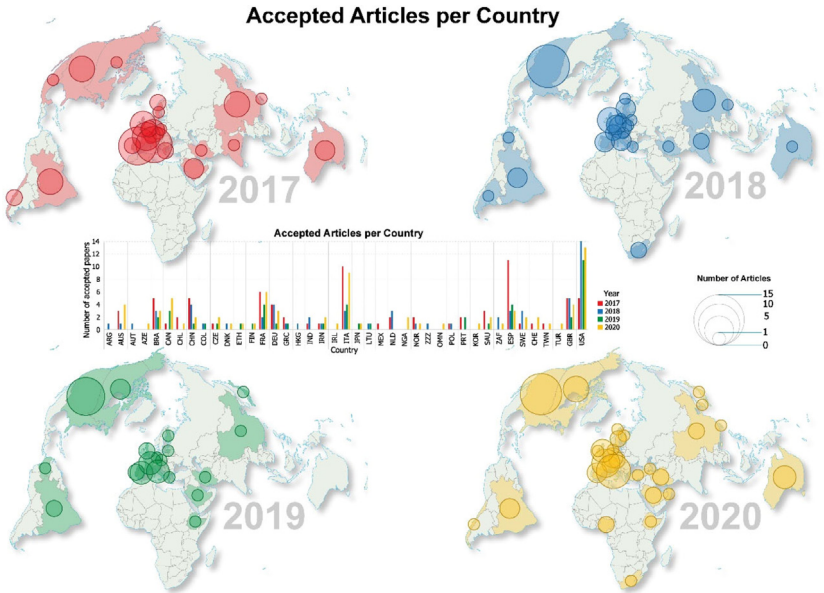

Fig. 3. The regional spread of the papers received during the last four years. We notice a stable influx of manuscripts from the Western world, and clear and steady increase in manuscripts from Africa.

the spread of the papers is now much more even throughout the globe, although until now they are and remain concentrated in the Western world (see Fig. 3).

4. Niche of the journal in the web of science

In the web of science, we explored the origin of the manuscripts in terms of their different domains, and we looked for papers which have as a keyword 'spatial statistics'. We realize that in this overview there are many more papers than what is published solely in Spatial Statistics; however, it positions the niche that we aim to fill. From the search we excluded papers from Clinical Neurology, Neurosciences, Neuroimaging, Meteorology Atmospheric Sciences, Engineering Electrical Electronic, Radiology Nuclear Medicine Medical Imagery and Psychiatry. Apparently, these domains also contribute with manuscripts on spatial statistics, but we are not in touch with the scientists from those areas. This left us with 4273 papers in the database. The background of the papers is displayed in Fig. 4.

Most of the manuscripts in the web of science comes from the Statistics and Probability domain, approximately 28%, followed by Multidisciplinary Geosciences (18%) and Interdisciplinary Mathematics (16%). Typical application domains are Remote Sensing (16%), Environmental Studies
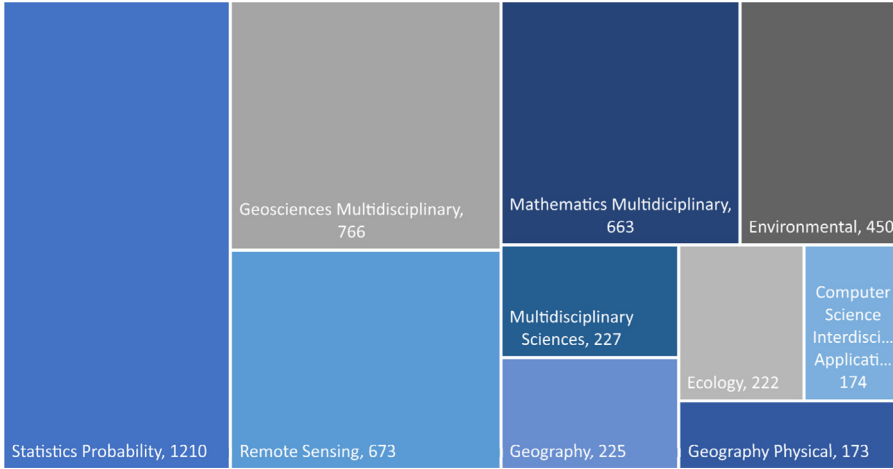
Fig. 4. The background of the manuscripts after a search in Web of Science with as search term 'spatial statistics' and excluding manuscripts from domains where the journal has no interactions.

(10%), Geographical Studies (6%), Multidisciplinary Science Studies (5%) and Ecological Studies (5%). This points us to the following for the journal. It is clearly rooted in the statistical, probabilistic and mathematical domain, with visible links towards computer science studies. The application domains are largely focusing on the natural environment, where remote sensing studies – more than we expected – are prominent. We trust that most of the thematic ambient studies like spatial statistics in soil science, hydrology, air, weather and climate fall under the geographical and multidisciplinary studies. So far we did not receive manuscripts from the medical sciences and there is a clear niche for a further progress into that direction, possibly with creating a new special issue.

5. The most cited papers, a critical analysis

Most importantly in any journal are the papers that are cited and hence have a scientific impact. Table 1 shows the most cited articles, until 2021. There is a clear and obvious effect of the year of publication: the older the paper the more often it is likely to be cited. Clearly, Goodchild and Li (2012) is by far the most frequently cited paper. The issue that it addresses, GIS and spatial statistics, is timely and relevant for a wide group of scientists in geography: the manuscript fills a need. There has been quite a history in related publications in other journals, like in the International Journal of GIS, as well as in various books, but the manuscript of 2012 was bringing the latest, overviewing the previous literature, it was published in a journal focusing on spatial statistics and it was written by outstanding scientists. In all these aspects, the paper was the right paper at the right moment. The next paper, not surprisingly, was the first paper published in Spatial Statistics on Covid. The manuscript had a clear applied context, and use of the spatial panel data model was filling a need. The third paper was providing an overview of a more theoretical basis for spatial sampling. The distinction between model- and design-based sampling was formalized and the manuscript in this sense was also bridging a gap. The other papers in the list showed by times clear theoretical advances, like Michael Stein's paper on covariance matrices and Huser et al.'s paper on spatial extremes, while a manuscript like Rodriguez Alvarez et al. was most appealing for the wide group of ecological scientists. This may have reached a different audience in the citations than the theoretical ones. As is a common mechanism, we note that papers that bridge a gap, or that provide an overview are most popular, while theoretical papers are of the greatest interest if an important and timely limitation is being addressed in a deep and novel way.

The list changes when we focus on the single year (2021), but the identified pattern comes back. We see that the first and the third paper have disappeared from the list, while the more timely

Table 1
The ten most cited papers from 2012 until 2021.

Citations	Citations (lifetime)	Article title	Authors	Publication year
Most cited articles, 2021 YTD (Published all time)				
30	459	Assuring the quality of volunteered geographical information	Goodchild M.F., Li L.	2012
21	36	Determining the spatial effects of COVID using the spatial panel data model	Guliyev H.	2020
18	180	A review of spatial sampling	Wang J-F., Stein A., Gao BB, Ge Y.	2012
17	73	Evaluating machine learning approaches for the interpolation of monthly air temperature at Mt. Kilimanjaro, Tanzania	Appelhaus T., Mwangomo E., Hardy D.R., Hemp A., Nauss T.	2015
16	131	Limitations on low rank approximations for covariance matrices of spatial data	Stein M.L.	2014
15	62	Correcting for spatial heterogeneity in plant breeding experiments with splines	Rodriguez-Alvarez M.X., More M.P., van Eeuwijk, F.A., Eilers P.H.C.	2018
13	61	Bridging asymptotic independence and dependence in spatial extremes using Gaussian scale mixtures	Huser, R., Opitz T., Thibaud E.	2017
12	38	Spatiotemporal point process statistics: a review	Gonzalez J.A., Rodriguez-Cortes, F.J., Cronie O., Mateu J.	2016
10	86	Scaling intrinsic Gaussian Markov random field priors in spatial modelling	Sorbye S.H., Rue H.	2014
10	61	Spatial econometric panel data model specification: A Bayesian approach	LeSage J.P.	2014

paper on Covid is – obviously – standing out. Further, the manuscripts that are wide and address important theoretical challenges are well cited like Krivoruchko and Gribov (2020) and Bakka et al. (2020), as are papers that are relevant for a wide group of applicants, like Naimi et al. (2020).

6. The most downloaded papers

If we consider the most downloaded papers, a different pattern emerges. Most importantly, the recent papers are mainly downloaded, indicating that despite that we like to write scientific papers *for eternity*, there is a timely component to each and every scientific contribution. Further, the number of downloads is much larger than the number of citations, indicating that downloading is largely done by those that are not always equally interested to publish themselves but feel the need to read and study the science. It could be scientists, students, – highly skilled – policy makers, and those that are curious on other than purely spatial statistical grounds in a paper. The top downloaded paper in 2021 was the paper of Dambon et al. which is of a clear interest to those interested in spatial statistics for economic purposes. This coincides with the high number of downloads for the special issues on regional economic (see below). There is apparently a large group of economists interested in spatial studies like in spatial econometrics. We further see that a focus on a specific country, be it Germany, Tanzania or Nigeria helps to increase the number of downloads: our downloaders have a clear preference for sharply delineated geographical indications. And as for the most downloaded papers, the manuscript on Covid by Guliyev is once more the list: Covid will reach the headlines for Spatial Statistics in the years to come, as it will do in other branches of science (see Table 2).

Table 2
The ten most cited papers in 2021.

Citations	Citations (lifetime)	Article title	Authors
21	36	Determining the spatial effects of COVID-19 using the spatial panel data model	Guliyev H.
10	17	Evaluation of empirical Bayesian kriging	Krivoruchko K., Gribov A.
10	29	Non-stationary Gaussian models with physical barriers	Bakka H., Vanhatalo J., Illian J.B., Simpson D., Rue H.
8	11	ELSA: Entropy-based local indicator of spatial association	Naimi B., Hamm N.A.S., Groen T.A., Skidmore A.K., Toxopeus A.G., Alibakhshi S.
7	13	BWM-ARAS: A new hybrid MCDM method for Cu prospectivity mapping in the Abhar area, NW Iran	Bahrami Y., Hassani H., Maghsoudi A.
6	9	Stochastic investigation of long-term persistence in two-dimensional images of rocks	Dimitriadis P., Tzouka K., Koutsoyiannis D., Tyralis H., Kalamioti A., Lerias E., Voudouris P.
6	14	Fuzzy clustering with spatial–temporal information	D'Urso P., De Giovanni L., Disegna M., Massari R.
5	7	Point-process based Bayesian modeling of space–time structures of forest fire occurrences in Mediterranean France	Opitz T., Bonneu F., Gabriel E.
4	8	Isotropy, symmetry, separability and strict positive definiteness for covariance functions: A critical review	De Iaco S., Posa D., Cappello C., Maggio S.
4	7	A spatio-temporal Bayesian Network approach for deforestation prediction in an Amazon rainforest expansion frontier	Silva A.C.O., Fonseca L.M.G., Korting T.S., Escada M.I.S.

7. The editorial flow

Spatial Statistics started after the conference in 2011 with three editors: Edzer Pebesma (Univ. of Munster), Gerard Heuvelink (Wageningen University) and myself at the University of Twente. When Edzer and Gerard stepped back, they were replaced and two members were added as associate editors. The core team of the journal consists at present of Sujit Sahu (University of Southampton), Christien Thiart (University of Cape Town), Alan Gelfand (Duke University) and Jinfeng Wang (LREIS - CAS, Beijing). Also the team of editors changed and increased over the years. Starting with some 40 editors, we are currently an international team of some 50 editors, all dedicated to the domain of spatial statistics. They take care of some of the review work, contribute with their own papers, organize special issues and most recently are becoming more active in the whole review process itself as well.

Any document will first fall upon the desk of the editor-in-chief, i.e. my desk. My primary task for each and every document is to assess whether it fits into the journal, i.e. whether it extends the domain of spatial statistics. That is sometimes difficult to see. A paper can be a theoretical advance, but it can be too mathematical or include too much probability theory to serve as a real extension of the domain. Valuable manuscripts could also be an interesting case study that encourages others to proceed in the domain. Such case studies should be sufficiently novel as well. We have seen a large range of good and motivating examples, in particular on air quality, house prices and sea ice. Finally, the paper should be written in sufficiently good English, so that it can be well understood by a dedicated reviewer. Other issues to check are the timeliness of the references, the degree of plagiarism (which almost never can be 0%) and the format and length of the paper. If all is answered to the positive (which happens in 50%–60% of all submitted manuscripts, see Fig. 5), the paper is moved forward to the review process. I myself, an associate editor or recently also an editor takes up the paper, reads it carefully and sends it to reviewers. This part of the review process is properly streamed these days through the submission system, called Editorial Manager. It is a convenient system and a step forward as compared to previous manuscript handling systems like EES and Evise.
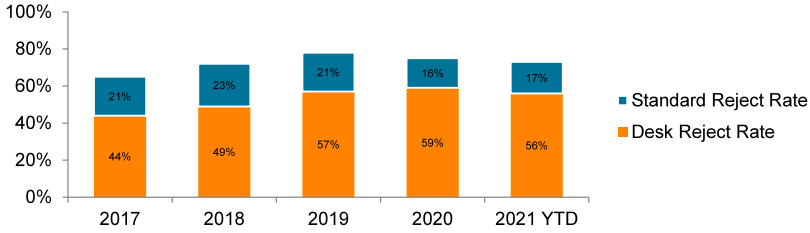
Fig. 5. The rejection rate of manuscripts submitted to Spatial Statistics, separated into desk reject rate and reject rate after review.
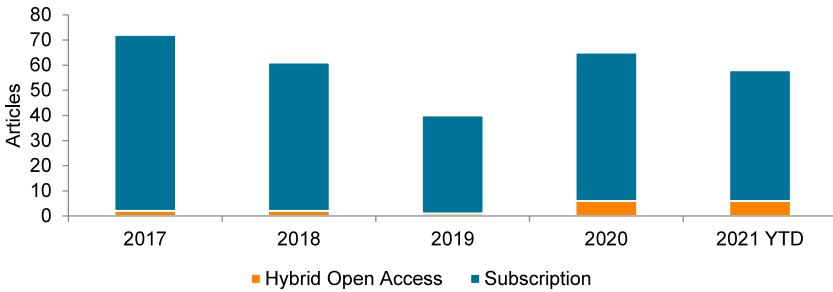

Fig. 6. Manuscripts published as hybrid open access (orange) and as subscription paper (blue). The number of hybrid open access is still a tiny fraction of the total number of published papers. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

8. Open science

Open science is these days an important characteristic of any scientific journal. In this aspect, Spatial Statistics follows the policy of the publisher, Elsevier Science. The policy of Elsevier is moving from subscription papers towards offering more opportunities for open science. In this sense, the journal is not fully open yet. The fraction of open papers as compared to subscription papers is shown in Fig. 6. We feel that the fraction of open papers must increase in the near future, but we also realize that papers can be published 'open access' if requested by the author, who then has to pay a price for it. So far, only limited use has been made of this facility, either because the price is high, although not deviating much from the prices of other journals, or because the need to make it openly available is felt to a limited degree. The reason may be that all scientific institutes have facilities to make the publications available for their scientific and academic staff. In addition, the journal offers opportunities to publish the data and the scientific code. Publication of those is critical, as making the data open enables the possibility that the research can be reproduced. We are confident that in the nearby future the policy will change and adjust itself to novel conditions.

9. The special issues

Since its inception, Spatial Statistics has published a range of special issues. Special issues are important, as they highlight the key topics in a discipline at a specific moment in time. The special issues that were published so far are provided in Table 4, while their distribution in time is shown in Fig. 7. Moreover, special issues are usually well cited and hence increase the visibility of the journal. Finally, it helps to attract scientists from other fields towards the domain of spatial statistics.

Most, but not all, special issues are related to conferences. Of particular interest in the above overview is the high number of citations of issue 21PB: it is the SI entitled 'Regional Economic', or more completely Regional Economy and Development: A Viewpoint and Application of Spatial
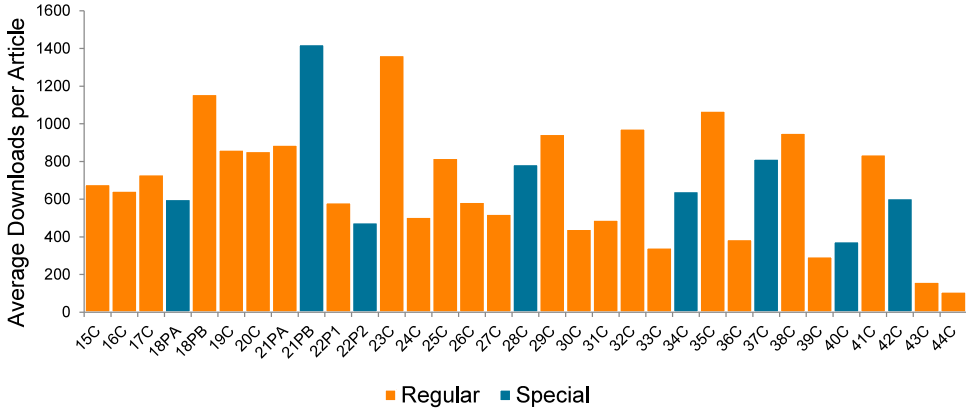
Fig. 7. The number of downloads per article for all issues between 2017 and 2020. Special issues are in dark blue, regular issues are in orange. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Statistics, with as guest editors Yong Ge and Xi Zhao. Although it contains 'only' 9 scientific contributions and an editorial, the manuscripts are frequently downloaded (see Table 3).

There are two issues upcoming at the moment: the special issue on Covid, edited by Sahu, D'Urso and myself, and of course the current special issue. If we investigate the list of special issues, we note that the emphasis is regularly on space–time aspects, as well as on natural and environmental processes. With the title of the journal remaining Spatial Statistics, we realize that statistical patterns are dynamic and reflect the processes behind them.

10. Outlook

The outlook of the journal is positive and challenging. The world has recently seen the outbreak of a major pandemic, which will be food for spatial statistical studies in the years to come. The main uncertainties, at present the erratic behaviour of the virus in relation with vaccination campaigns and the large differences between and even within single countries will lead to a large need of spatial statistical studies. As a different, but possibly related, focal area, we note that prediction of weather and climate has large uncertainties. A third focal area can be summarized by ecological processes that require details and interactions at an increasingly fine level of detail. Further, the scarcity of natural resources, energy transition, econometric prospects all have spatial components and interactions. These will require an increasing attention from disciplinary scientists as well as from the adjustment of existing spatial statistical methods.

The domain itself is growing rapidly as well. Aspects of big data are only partly addressed and solved, Bayesian methods are generally available but their applications are restricted as much of the methodology requires a good insight into sometimes challenging probability theory, while the interactions in space and time are notoriously hard to solve. For practitioners this can be a challenge to incorporate and communicate to other scientists and to society.

Internationally, we still see a focus on the developed world, while many problems in the majority world require solutions that can be supported and provided by spatial statistics. Alleviating poverty, feeding the population, dealing with scarce resources are critical aspects in everyday society, where we know that spatial statistical solutions could be used to identify and highlight the problem, while they can support local and national governments to reach sustainable solutions.

In all these aspects: the theory, the inspirations from applications, the solution of problems the journal have played a role, and will play a role in the years to come. Spatial Statistics serves as an outlet for smart thinking from the best of our scientists, inspired by a wide set of problems from science and society that will hopefully lead to world where the sustainable development goals are in place throughout.

Table 3

The ten most downloaded papers between 2012 and 2021.

Downloads	Downloads (lifetime)	Article title	Authors	Publication year
1,379	2,065	Maximum likelihood estimation of spatially varying coefficient models for large data with an application to real estate price prediction	Dambon J.A., Sigrist F. and Furrer R.	2021
1,303	2,270	Population-weighted exposure to air pollution and COVID-19 incidence in Germany	Huang G. and Brown P.E.	2021
1,273	13,343	Evaluating machine learning approaches for the interpolation of monthly air temperature at Mt. Kilimanjaro, Tanzania	Appelhans T., Mwangomo E., Hardy D.R., Hemp A. and Nauss T.	2015
1,161	1,318	Demography and Crime: A Spatial analysis of geographical patterns and risk factors of Crimes in Nigeria	Adeyemi R.A., Mayaki J. Zewotir T.T. and Ramroop S.	2021
848	848	Testing for complete spatial randomness on three dimensional bounded convex shapes	Ward S., Cohen E.A.K. and Adams N.	2021
821	7,784	Determining the spatial effects of COVID-19 using the spatial panel data model	Guliyev H.	2020
801	1,798	Accounting for spatial varying sampling effort due to accessibility in Citizen Science data: A case study of moose in Norway	Sicacha-Parada J., Steinsland I., Cretois B. and Borgelt J.	2020
801	801	Scalable Bayesian modelling for smoothing disease risks in large spatial data sets using INLA	Orozco-Acosta E., Adin A. and Ugarte M.D.	2021
752	5,083	Spatial mapping with Gaussian processes and nonstationary Fourier features	Ton J.-F., Flaxman S., Sejdinovic D. and Bhatt S.	2018
703	2,127	Using multiple linear regression and random forests to identify spatial poverty determinants in rural China	Liu M., Hu S., Ge Y., Heuvelink G.B.M., Ren Z. and Huang X.	2021

Table 4

The special issues published by Spatial Statistics.

Articles	Special item group name	Year	Editors
22	SI: Spatial Data Science	2021	Mateu and Stein
11	SI: Metma	2020	Bel, Toulemonde and Opitz
11	SI: SpatialResearchFrontiers	2020	Gelfand
7	SI: Spatio-temporal analysis	2019	Varouchakis, Hristopulos, Heuvelink and Corzo Perez
23	SI: One world, One health	2018	Atkinson and Stein
16	SI: STmethods in Env-Biometry_METMA	2017	22P2
10	SI: Regional economic	2017	Yong and Xi
32	SI: Emerging Patterns	2016	Allard and Stein
15	SI: DailyMeteo	2015	Hengl, Pebesma and Hijmans
13	SI: ST Intricacies	2014	Griffith, Stehman and Stein
9	SI: Spatial Statistics Miami	2014	Guan
7	SI: GeoENV2012	2013	Gómez-Hernández, Horta and Jeanée
15	Spatial Statistics for Mapping the Environment[a]	2013	Heuvelink, Pebesma and Stein

[a]Published as Volume 22 of the International Journal of Applied Earth Observation and Geoinformation.

Acknowledgment

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