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Geospatial Health: the first five years

Jürg Utzinger[1,2], Laura Rinaldi[3], John B. Malone[4], Stefanie J. Krauth[1,2], Thomas K. Kristensen[5,6], Giuseppe Cringoli[3], Robert Bergquist[7]

[1]Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute, P.O. Box, CH-4002 Basel, Switzerland; [2]University of Basel, P.O. Box, CH-4003 Basel, Switzerland; [3]Department of Pathology and Animal Health, Faculty of Veterinary Medicine, University of Naples Federico II, Naples, Italy; [4]Department of Pathobiological Sciences, School of Veterinary Medicine, Skip Bertman Drive, Louisiana State University, Baton Rouge, LA, USA; [5]DBL, Department of Veterinary Disease Biology, University of Copenhagen, Thorvaldsensvej 57, DK-1871 Frederiksberg C, Denmark; [6]School of Biological & Conservation Sciences, Faculty of Science and Agriculture, University of KwaZulu-Natal, South Africa; [7]Ingerod, Brastad, Sweden

Abstract. *Geospatial Health* is an international, peer-reviewed scientific journal produced by the Global Network for Geospatial Health (GnosisGIS). This network was founded in 2000 and the inaugural issue of its official journal was published in November 2006 with the aim to cover all aspects of geographical information system (GIS) applications, remote sensing and other spatial analytic tools focusing on human and veterinary health. The University of Naples Federico II is the publisher, producing two issues per year, both as hard copy and an open-access online version. The journal is referenced in major databases, including CABI, ISI Web of Knowledge and PubMed. In 2008, it was assigned its first impact factor (1.47), which has now reached 1.71. *Geospatial Health* is managed by an editor-in-chief and two associate editors, supported by five regional editors and a 23-member strong editorial board. This overview takes stock of the first five years of publishing: 133 contributions have been published so far, primarily original research (79.7%), followed by reviews (7.5%), announcements (6.0%), editorials and meeting reports (3.0% each) and a preface in the first issue. A content analysis of all the original research articles and reviews reveals that three quarters of the publications focus on human health with the remainder dealing with veterinary health. Two thirds of the papers come from Africa, Asia and Europe with similar numbers of contributions from each continent. Studies of more than 35 different diseases, injuries and risk factors have been presented. Malaria and schistosomiasis were identified as the two most important diseases (11.2% each). Almost half the contributions were based on GIS, one third on spatial analysis, often using advanced Bayesian geostatistics (13.8%), and one quarter on remote sensing. The 120 original research articles, reviews and editorials were produced by 505 authors based at institutions and universities in 52 countries. Importantly, a considerable proportion of the authors come from countries with a low or medium human development index (29.3%). In view of the increasing number of submissions, we are considering to publish more than two issues per year in the future. Finally, our vision is to open-up a new section predominantly based on visual presentations, including brief video clips, as discussed in a symposium at the 60th annual meeting of the American Society of Tropical Medicine and Hygiene in December 2011.

Keywords: bibliometric analysis, content analysis, geographical information system, *Geospatial Health*, human development index, remote sensing, spatial analysis, visualization.

Introduction

Ever since Snow's map rendition of the risk for cholera in London (Snow, 1855), geographical reconnaissance, mapping of disease occurrence and risk stratification have played important roles in the prevention and control of human and animal disease. For example, mapping the distribution of hookworm in Texas more than 100 years ago (Smith, 1903) was a crucial step to forge control efforts, which eventually led to the elimination of hookworm disease in the United States (Stiles, 1939). Risk mapping of malaria at small spatial scales was a key feature to guide multifaceted control approaches in Africa, Asia and the Americas shortly after the life cycle of this disease was fully elucidated (Watson, 1921, 1953; Maxcy, 1923).

The advent of aerial photography followed by Earth-observing satellites equipped with sensitive remote-sensing instruments opened up new opportunities for epidemiology and public health as foreseen by Cline when he was still a student (Cline, 1970). Since then, powerful satellite-based remote sensing and computer-based geographical information system (GIS), including advanced geostatistical analyses, have made great strives to further our understanding of the

Corresponding author:
Jürg Utzinger
Department of Epidemiology and Public Health
Swiss Tropical and Public Health Institute
P.O. Box CH-4002 Basel, Switzerland
Tel. +41 61 284-8129; Fax +41 61 284-8105
E-mail: juerg.utzinger@unibas.ch

epidemiology and control of human and veterinary diseases at different spatial and temporal scales. Indeed, reviews in leading medical journals have emphasized the strong potential of geospatial tools for health applications (Brooker and Michael, 2000; Hay et al., 2000; Brooker, 2002; Kistemann et al., 2002; Tanser and le Sueur, 2002; Cromley, 2003; Ceccato et al., 2005; Yang et al., 2005; Simoonga et al., 2009; Bergquist and Rinaldi, 2010; Bergquist, 2011; Khan et al., 2011). Additionally, special issues have been published in *Advances in Parasitology* (in 2000), *Acta Tropica* (in 2001) and *Parassitologia* (in 2005), discussing how the integration of GIS, remote sensing and spatial analysis can contribute to the establishment of early warning systems (EWS), risk mapping and prediction of epidemics due to diseases that are of major importance, both for public health and veterinary medicine. Moreover, two specialized journals are now available that are fully dedicated to all aspects of geospatial techniques for applications in health and healthcare, namely the *International Journal of Health Geographics* (published by BioMed Central since August 2002) and *Geospatial Health* (published by University of Naples for GnosisGIS since November 2006).

Here, we review the first five years of publication activities of *Geospatial Health*. Our overview begins with a historic account of the initial ideas and formation of the GnosisGIS network that was founded in 2000, and we then discuss briefly its main activities and evolution. The centre-piece of our review is an in-depth analysis of the 133 contributions published in the first 10 issues (November 2006-May 2011), including type of publication, authorship, authors' country, thematic and geographic focus of the research covered, and identification of the geospatial tool(s) employed. We conclude with the editors' vision of the journal's future, including a new "visualization" section based on animations and brief video clips, as discussed at this year's annual conference of the American Society of Tropical Medicine and Hygiene in Philadelphia.

GnosisGIS: once and forever

Team residency in Bellagio

GnosisGIS is the acronym for "GIS Network On Snail-borne Infections with special reference to Schistosomiasis" (emphasis added; http://www.GnosisGIS.org). The creation of this network took place at a team residency, held at the Bellagio Study and Conference Centre in Italy on April 10-14, 2000 (Bergquist et al., 2000; Malone et al., 2001). Sponsored by the Rockefeller Foundation, it brought together 10 scientists and human and veterinary health researchers from different institutions, universities and international organization:

- Mara E. Bavia (Federal University of Bahia; Salvador, Brazil);
- Robert Bergquist (then at the UNICEF/UNDP/World Bank/WHO Special Programme for Research & Training in Tropical Diseases (TDR); Geneva, Switzerland);
- Michele Bernardi (Food and Agriculture Organization; Rome, Italy);
- Mohamed M. El Bahy (Cairo University; Giza, Egypt);
- Màrius V. Fuentes (University of Valencia; Valencia, Spain);
- Oscar K. Huh (Louisiana State University; Baton Rouge, United States);
- Thomas K. Kristensen (DBL, University of Copenhagen; Copenhagen, Denmark);
- John B. Malone (Louisiana State University; Baton Rouge, United States);
- Jennifer C. McCarroll (Louisiana State University; Baton Rouge, United States); and
- Xiao-Nong Zhou (National Institute of Parasitic Diseases, Chinese Center for Disease Control and Prevention; Shanghai, People's Republic of China (P.R. China)).

The goal of this team residency was to develop and consolidate a network of collaborators dedicated to the development, validation and use of global computer-based models who had been informally discussing how to enhance the effectiveness of control programmes for schistosomiasis and other snail-borne diseases of medical and veterinary importance. The impetus came from previous successful applications of an integrated approach using GIS, remote sensing and spatial analysis to map the distribution of schistosomiasis and fascioliasis in different parts of the world (Cross and Bailey, 1984; Cross et al., 1984; Malone et al., 1992, 1994, 1998). Progress had already been made with these techniques for EWS, risk profiling of malaria, human African trypanosomiasis and other tropical diseases (Beck et al., 1994; Hay et al., 1996; Rogers et al., 1996).

The outcome of the Bellagio meeting was the agreement on a strategic plan and organizational structure to guide future development of a new scientific group devoted to GIS, remote sensing and spatial statistics. Expected outcomes were models based on datasets of the global climate, satellite sensors, disease prevalence rates, the distribution and abundance of snail intermediate hosts with the overarching aim of producing digital maps of key environmental factors that affect the development and propagation of snail-borne infectious agents. The Internet was chosen as the *modus operandi* for collaboration, data sharing and development of effective GIS models. It was envisaged that current and prospective disease investigations would be systematically and accurately placed in a broad geographical and ecological context using geospatial techniques.

The initial years

Work continued on the strategic plan outlined at Bellagio, and a special issue of *Acta Tropica* entitled "A global network on schistosomiasis information systems and control of snail-borne diseases" was published in 2001 that mainly included member research projects. A website was developed to foster communication and joint work on the specific objectives previously agreed by the group.

In the next four years, GIS resource datasets based on identified needs for current member research projects were produced in the form of minimum medical databases for the IGAD-Nile Region of Africa (2001), Asia (2003), West Africa (2004) and Latin America (2005). Based on these databases, a short-course training manual entitled "Starting up a medical GIS capability: a lessons manual and CD-Rom data resource" was developed as an introductory GIS course using ArcView and ArcGIS (i.e. the commercially available software products from ESRI headquartered at Redlands, United States). The manual was designed for use as step-by-step lesson modules for individual instruction and self-study or for short courses offered in conjunction with larger meetings to promote use of geospatial health applications. Short courses were held in different venues, usually in conjunction with various international scientific meetings: (i) the 1st meeting of the Regional Network of Asian Schistosomiasis, Wuxi, P.R. China, 2001; (ii) the 19th International Conference of the World Association for the Advancement of Veterinary Parasitology (WAAVP), New Orleans, United States, 2003; and (iii) a DBL – Health Research and Development Centre workshop, Lusaka, Zambia, 2004.

To achieve the results envisioned, however, turned out to be an uphill struggle, the lack of a sufficiently large critical mass of active scientists and regular meetings being mentioned as the main impediments. In an effort to remedy the situation, a workshop was convened in mid-2005 at the Sealodge Centre in Smögen, Sweden, to discuss and implement needed changes.

Jump-start

The goal of the Smögen workshop was to review accomplishments since the initial meeting in Bellagio and to define expanded objectives and purposes of the group, which in turn should lead to a more ambitious stage of development. While there was consensus that the original group members had assisted each other well with regard to the development of expert resource information and methods for use of GIS tools for snail-borne diseases, the need for new targets was clear. After considerable thinking, the aims of the network were expanded and consolidated as follows:

- enlarge the scope by encompassing a wider spectrum of target diseases of medical and veterinary importance;
- obtain a higher profile and impact via peer-reviewed publications, including the creation of a new open-access international journal;
- offer short courses and develop regional GIS centres for the provision of geospatial-related instruction and data;
- annual or biannual working group meetings; and
- prepare joint funding proposals supported by working group members.

The acronym GnosisGIS was kept, but the network was renamed the "Global Network for Geospatial Health". An executive committee was elected, including five members, supported by regional offices in Africa, Asia, Europe, Latin America and North America. In retrospect, the outcome of the Smögen workshop was a more focused, effective organization with members tasked to accomplish specific objectives. The greatest impact in promoting the purposes of GnosisGIS proved to be the establishment of annual meetings and the initiation of *Geospatial Health* as the official journal of the network.

Annual meetings

The Smögen workshop explicitly recommended annual meetings to be organized by GnosisGIS, ideally in conjunction with other national or international scientific conferences. The new activities gradually started to transform GnosisGIS into a different organization and, in retrospect, it has become clear that this recommendation was useful in achieving the set objectives. The 2005 Smögen workshop was designated the 1st annual GnosisGIS meeting, after which the group met every year as follows:

- 2nd annual GnosisGIS meeting, convened in July 2006 in Salina, Italy with a total of 20 members attending. The meeting was held back-to-back with the 19th Congress of the Italian Society of Parasitology (SOIPA), during which a symposium on geospatial health was offered by GnosisGIS.

- 3rd annual GnosisGIS meeting held in September 2007 in Lijiang, P.R. China, attended by 90 participants from 17 countries. This meeting was jointly organized with the Regional Network on Asian Schistosomiasis and Other Helminth Zoonoses (RNAS+). The local organizer, Prof. Xiao-Nong Zhou, opened the meeting and named it the "1st International Symposium on Geospatial Health". A summary report of this meeting was published in the open-access journal *Parasites & Vectors* (Zhou et al., 2009).
- 2nd International Symposium of Geospatial Health, held in December 2008 in New Orleans, United States, attended by 48 participants from 15 countries. This meeting was organized back-to-back with the 57th annual meeting of the American Society of Tropical Medicine and Hygiene, during which a symposium was organized by GnosisGIS.
- 3rd International Symposium of Geospatial Health with the theme "Climate change and geospatial health" was held in September 2009 in Vietri sul Mare, Italy. There were 50 participants from 15 countries. The meeting was held back-to-back with the 7th European Congress on Tropical Medicine and International Health that took place in Verona, Italy.
- In August 2010, the 4th International Symposium of Geospatial Health, built around the theme "A one health approach to geospatial health", was held as a satellite meeting of the 12th International Congress of Parasitology (ICOPA) in Melbourne, Australia. There were over 30 participants from 11 countries.
- 5th International Symposium of Geospatial Health held in September/October 2011 in Cartagena, Colombia. The theme was "Mapping and modelling neglected tropical diseases in Latin America and the Caribbean" and GnosisGIS sponsored a session on geospatial health applications at the Federation of Latin American Parasitologists meeting, held at the University of the Andes in Bogota prior to the Cartagena meeting.

Geospatial Health

Why was this journal launched?

The inaugural issue of *Geospatial Health* was published in November 2006 with an accompanying 1-page preface detailed its rationale, aims and vision. The journal was launched primarily to publish original research articles and reviews dealing with applications of global Earth observation systems (GEOS) tools to enhance human and animal health and wellbeing. Hence, since the beginning, it was suggested that *Geospatial Health* should become a source of vital information on the availability, application and integrated use of GIS, remote sensing and spatial analysis in human and veterinary medicine, to promote geospatial techniques for mapping, risk profiling, monitoring and surveillance, and to encourage studies of the potential, or real, impact of climate change.

As emphasized by the editor-in-chief in the setting-the-scene preface, "*GEOS has come into its own in this present age of information technology and can indeed provide the necessary data regarding the spatial and climatic parameters which determine the distribution limits of communicable (parasitic) diseases at various scales such as, for example, at the district, country or regional levels. Geospatial Health should aim to harness these advantages and to serve as a forum for discussion and publication of epidemiological data in a geographical context. It is evident that the tools are as complex as the disciplines studied, thus a high-level of expertise is essential, not only for the presentation and analysis of the various data but also for the technologies used for data collection*". Overall, it was felt that *Geospatial Health* would provide cross-fertilization between technical and health-oriented disciplines, covering the full spectrum from innovation to validation and application.

The editorial board

Geospatial Health is managed by an editor-in-chief and two associate editors, based in Europe. They do the bulk of day-to-day journal work, including e-mail exchange with authors and referees, final disposition of manuscript acceptance and specific requests for revisions, copy-editing of advanced manuscript drafts, proof setting and checking prior to sending galley proofs to authors. This core team is supported by five regional editors, based in Africa, Asia, Europe, Latin America and North America. The original editorial board consisted of 23 members, most of them European (n = 10) and North American (n = 8), whereas the remaining five are from Africa (n = 2), Asia (n = 2) and Latin America (n = 1).

After an initial term of five years, all editorial board members were invited to re-assess their interest, roles and responsibilities to act as editors on *Geospatial*

Health. Several board members took this opportunity to step down and let younger peers serve on the journal's editorial board. While recruiting new board members, efforts are made to seek for a regional editor and new board members from Oceania, as we are currently lacking representation from this area. Additionally, we aim to enhance gender balance, as our editorial board currently consists of considerably more males than females. Both these issues are important and inequities have been observed while scrutinizing the editorial board composition of leading journals of general medicine and tropical medicine (Keiser et al., 2003, 2004; Falagas et al., 2006).

Basic factors

Geospatial Health is published in English by the University of Naples Federico II and the contents can be accessed electronically, free of charge, at the journal website: http://www.geospatialhealth.unina.it/index.php. The journal is issued biannually both in print (ISSN 1827-1987) and online (ISSN 1970-7096). Its open-access policy means that readers can download all articles including illustrations in full length. It is indexed by major databases:

- CABI (Centre for Agriculture and Biosciences International, a not-for-profit organization providing information and databases in the life sciences; http://www.cabi.org/);
- PubMed and PubMed Central (free digital database of full-text scientific literature in the biomedical and life sciences, mainly based on the Medline. This database is maintained by the U.S. National Library of Medicine and the National Institutes of Health in the United States; http://www.ncbi.nlm.nih.gov); and
- ISI Web of Science (online academic citation index provided by Thomson Reuters; http://apps.webofknowledge.com).

In 2008, *Geospatial Health* was issued its first impact factor (i.e. 1.47), which has since gradually increased and is currently 1.71 (2010). In the ISI's Journal Citation Report (JCR), *Geospatial Health* is categorized under "Health Care Sciences & Services" (in 2010, it ranked at position 35 out of 72 indexed journals) and "Public, Environmental & Occupational Health" (ranking at position 64 out of 142 indexed journals).

Bibliometric analysis

As articulated in the aims and scope, the focus of *Geospatial Health* is on "*all aspects of the application of GIS, remote sensing and other spatial analysis tools in human and veterinary health*". Currently, five years into publication activities, we were motivated to conduct a detailed bibliometric analysis of all papers published so far. Hence, we examined the 133 contributions that are included in the first 10 issues of *Geospatial Health*. Emphasis is placed on publication type, number of authors per paper and country of contributing authors. For the latter analysis, we employed the 2011 human development index (HDI), which stratifies countries into: (i) very high, HDI rank 1 (Norway) to 47 (Barbados); (ii) high, HDI rank 48 (Uruguay) to 94 (Tunisia); (iii) medium, HDI rank 95 (Jordan) to 141 (Bhutan); and (iv) low, HDI rank 142 (Solomon Islands) to 187 (Democratic Republic of the Congo) (UNDP, 2011).

To get a holistic view of the origin, thematic focus and impact of articles accepted for publication, we performed a content analysis based on title, abstract and keywords of individual contributions. This analysis was restricted to original research articles and reviews (n = 116), whereas editorials were excluded, as they usually do not contain an abstract. In a first step, we determined whether articles had a focus on human or veterinary health. Next, we investigated the geographic (i.e. global, Africa, Asia, Europe, Latin America, North America and Oceania) and thematic foci. Research themes were grouped into disease (e.g. avian influenza, malaria, schistosomiasis, etc.), injury or risk factor (e.g. alcohol consumption). We also determined geospatial tools employed (e.g. GIS, remote sensing and spatial analysis) and did some further characterization (e.g. use of mathematical modelling, mapping, etc.).

Publication type

Our analysis of all the contributions (n = 133) covered in the first five volumes (10 issues) of *Geospatial Health* published between November 2006 and May 2011 revealed that original research accounted for four out of five publications (Fig. 1). The second most important publication type (n = 10, 7.5%) were the reviews (Fuentes, 2006; Rinaldi et al., 2006; Gazzinelli and Kloss, 2007; Leonardo et al., 2007; Martin et al., 2007; Bernardi, 2008; Marechal et al., 2008; Stensgaard et al., 2009; Ocaña-Riola, 2010; Machault et al., 2011). So far, four editorials have been published, two invited guest editorials in the inaugural issue (Cline, 2006; Crump, 2006), and two unsolicited editorials from journal board members (Brooker and Utzinger, 2007) and other contributors (Seifter et al., 2010). In addition, eight announcements, four meeting reports and a 1-page preface "setting-the-stage" piece (Bergquist, 2006) have been published, but these were not considered further in the subsequent analyses as they are usually put forth by the editors without external peer-review.

Who publishes in Geospatial Health?

The configuration of authors who utilized *Geospatial Health* as an outlet of their research has been determined by examining original research articles, reviews and editorials (n = 120). Fig. 2 shows a histogram, displaying the number of authors per publication, stratified by these three publication types. The distribution is slightly skewed with a peak of five authors per paper and a median of six. There are 10 single-authored pieces, half of them editorials and reviews (Cline, 2006; Crump, 2006; Fuentes, 2006; Bernardi, 2008; Ocaña-Riola, 2010), and the other half presenting original research (Aron, 2006; Lwasa, 2007; Murad, 2008; Estrada-Peña, 2009; Livingston, 2010). Eight papers, all of them original research, where co-authored by at least 10 and up to 15 individuals, interestingly often stemming from P.R. China (Chen et al., 2007; Steinmann et al., 2007; Dongus et al., 2009; Li et al., 2009; Masuoka et al., 2010; Yang et al., 2010; Peng et al., 2011; Suwannatrai et al., 2011).

Taken together, these 120 publications were written by 644 authors. However, some of the authors contributed to more than one article, as shown in Table 1. Indeed, the current champion is Dr. Penelope Vounatsou, a Bayesian disease mapping and modelling specialist based at the Swiss Tropical and Public Health Institute (Swiss TPH) in Basel, who contributed to 10 articles. Another 12 authors (five from Italy, two from France and one each from Brazil, Denmark, P.R. China, Switzerland and the United States) contributed to 63 articles. Overall, we identified 505 unique authors who are based in 52 different countries (very high HDI, n = 19; high HDI, n = 9; medium HDI, n = 10; low HDI, n = 14).

Table 2 summarizes the geographic distribution of authors, stratified by the latest available HDI. In our analysis, we distinguished by first and corresponding author (by default, 120 each), all authors (n = 644) and unique authors (n = 505). As expected, there was a predominance of authors from countries with a very high

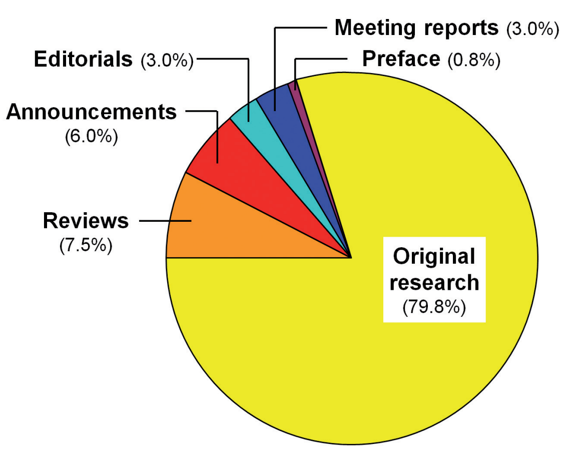

Fig. 1. Pie chart showing the percentage of publication types covered in the first five volumes of *Geospatial Health* (November 2006-May 2011).

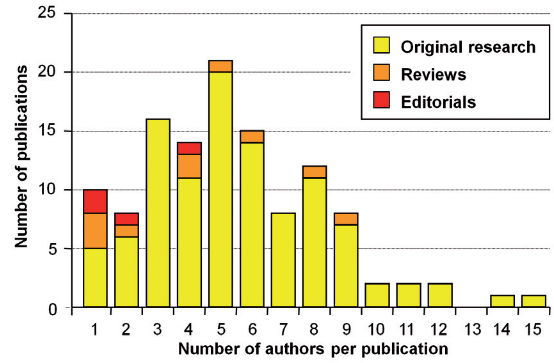

Fig. 2. Number of authors per paper in the 120 articles (original research, reviews and editorials), published in the first five volumes of *Geospatial Health* (November 2006-May 2011).

Table 1. Number of contributions by individual authors to the 120 publications (original research, reviews and editorials) published in the first five volumes of *Geospatial Health* (November 2006-May 2011).

Number of contribution(s)	Number of author(s)	Country of author (n)
10	1	Switzerland
9	1	Switzerland
6	4	Italy (3), P.R. China (1)
5	2	Italy (1), United States (1)
4	5	France (2), Brazil (1), Denmark (1), Italy (1)
3	14	United States (4), P.R. China (3), France (2), Switzerland (2), Italy (1), Spain (1), Sweden (1)
2	49	United States (14), Italy (8), India (4), Switzerland (3), Australia (2), Belgium (2), Denmark (2), France (2), P.R. China (2), Brazil (1), Germany (1), Malawi (1), Mali (1), Senegal (1), South Africa (1), Sweden (1), Uganda (1), United Kingdom (1), Zambia (1)
1	431	52 different countries

Table 2. Country origin of all contributing authors to the 120 publications (original research, reviews and editorials) published in the first five volumes of *Geospatial Health* (November 2006-May 2011).

Authorship	Number of authors	Number (%) of authors, stratified by human development index (HDI) in 2011[a]			
		Very high	High	Medium	Low
All authors	644	423.2 (65.7)	50 (7.8)	122.5 (19.0)	48.3 (7.5)
Unique authors	505	311.2 (61.6)	46 (9.1)	104.5 (20.7)	43.3 (8.6)
First author	120	87.7 (73.1)	9 (7.5)	18 (15.0)	5.3 (4.4)
Corresponding author	120	88.2 (73.5)	9 (7.5)	17.5 (14.6)	5.3 (4.4)

[a]Source: UNDP (2011)

or a high HDI, contributing to 70.7% (unique authors) and up to 81.0% of authorship (corresponding author). Nevertheless, almost one third of the unique authors are based in countries with low or medium HDI (29.3%), which is distinctively different from prior analyses focussing on the core tropical medicine literature (Glover and Bowen, 2004; Keiser et al., 2004; Keiser and Utzinger, 2005; Falagas et al., 2006). It is also noteworthy that 10 publications were uniquely written by authors from low HDI (Tanzania and Uganda) (Lwasa, 2007; Mboera et al., 2010) or medium HDI (India, P.R. China and Philippines) (Chen et al., 2007; Leonardo et al., 2007; Jayakumar et al., 2009; Bhunia et al., 2010; Chiang et al., 2010; Wen et al., 2010; Bhunia et al., 2011; Peng et al., 2011).

Table 3 gives a summary of the 15 countries with the largest share of authors having contributed to the 120 original research articles, reviews and editorials published in the first five volumes of *Geospatial Health*. Although the United States' share of scientific articles published in the peer-reviewed literature has declined over the last decades (Hill et al., 2007), this country emerged as the single most contributing nation; more than 100 out of the 505 unique authors are based in the United States (21.1%). Perhaps surprisingly, Italy and P.R. China followed at positions 2 and 3 in terms of country-specific contributions with shares of 11.3% and 10.4%, respectively, according to unique authorship contributions. Taken together, authors from the United States, Italy and P.R. China contributed more than 40% of all the publications in the first 10 issues of *Geospatial Health*.

Thematic and geographic focus

As shown in Fig. 3, three quarters of the original research articles and reviews published so far in *Geospatial Health* focussed on human health, whereas

Table 3. The 15 most contributing countries, as determined by authors' affiliations, in the 120 publications (original research, reviews and editorials) published in the first five volumes of *Geospatial Health* (November 2006-May 2011).

Country	HDI 2011 (HDI rank)[a]	Number (%) of authors			
		All	Unique	First	Corresponding
All		644 (100)	505 (100)	120 (100)	120 (100)
United States	4 (VH)	133.5 (20.7)	106.5 (21.1)	28.5 (23.8)	28.5 (23.8)
Italy	24 (VH)	90 (14.0)	57 (11.3)	17 (14.2)	17 (14.2)
P.R. China	101 (M)	65.5 (10.2)	52.5 (10.4)	9 (7.5)	8.5 (7.1)
Switzerland	11 (VH)	45.8 (7.1)	21.8 (4.3)	7.8 (6.5)	8.8 (7.4)
France	20 (VH)	35.5 (5.5)	24.5 (4.9)	7 (5.8)	6 (5.0)
Brazil	84 (H)	27 (4.2)	23 (4.6)	5 (4.2)	5 (4.2)
Thailand	103 (M)	20 (3.1)	20 (4.0)	2 (1.7)	2 (1.7)
India	134 (M)	17 (2.6)	13 (2.6)	3 (2.5)	3 (2.5)
Tanzania	152 (L)	14.8 (2.3)	14.8 (2.9)	1.3 (1.1)	1.3 (1.1)
Canada	6 (VH)	14 (2.2)	14 (2.8)	3 (2.5)	3 (2.5)
United Kingdom	28 (VH)	13.5 (2.1)	12.5 (2.5)	3 (2.5)	2 (1.7)
Australia	2 (VH)	13 (2.0)	10 (2.0)	5 (4.2)	5 (4.2)
Denmark	16 (VH)	13 (2.0)	8 (1.6)	2 (1.7)	2 (1.7)
Germany	9 (VH)	12.3 (1.9)	11.3 (2.2)	2.3 (1.9)	3.3 (2.8)
Belgium	18 (VH)	11.5 (1.8)	9.5 (1.9)	2 (1.7)	2 (1.7)
Remaining countries		117.5 (18.2)	106.5 (21.1)	22 (18.3)	22.5 (18.8)

[a]Data obtained from the 2011 Human Development Report (UNDP, 2011) (HDI, human development index; VH, very high (HDI rank 1-47); H, high (HDI rank 48-94); M, medium (HDI rank 95-141); L, low (HDI rank 142-187).

the remaining one quarter presented work related to veterinary health. We also identified six original research articles that pertained to both human and veterinary medicine (Stensgaard et al., 2006; Rossi et al., 2007; Wu et al., 2007; Infascelli et al., 2009; Sandes et al., 2009; Beugnet et al., 2011).

Fig. 4 reveals that the publication record in the first five volumes of *Geospatial Health* covers all parts of the world. We identified seven contributions (6.0%) that had a global focus, five of which were reviews (Rinaldi et al., 2006; Martin et al., 2007; Bernardi, 2008; Ocaña-Riola, 2010; Machault et al., 2011) and the remaining two original research articles (Si et al., 2009; Catelan and Biggeri, 2010). Approximately two thirds of the research published so far had a geographic focus on Africa, Asia and Europe, with similar shares for each of these three continents. Studies focussing on the Americas (North and Latin America) contributed one quarter, whereas only four publications (3.4%) had an explicit focus on Oceania (East et al., 2008a,b; Wang et al., 2009; Livingston, 2010).

Diseases, injuries and risk factors

Our content analysis revealed that not less than 36 different diseases, injuries and risk factors were in the focus of the 116 original research articles and reviews published in the first five volumes of *Geospatial Health*. Fig. 5 shows the nine most important diseases which together account for 55.1% of the research covered. Interestingly, the "big three", that is HIV/AIDS, tuberculosis and malaria, accounted for only 13.8%, whereas the neglected tropical diseases (NTDs), a cluster of mainly chronic, debilitating and poverty-related diseases (Hotez et al., 2007; Utzinger et al., 2009), contributed almost one third of the total published research. In the "big three" group, malaria was the predominant disease (11.2%) (Aron, 2006; Connor et al., 2006; Gosoniu et al., 2006; Kiang et al., 2006; Kazembe et al., 2007; Sogoba et al., 2007; Briët et al., 2008; Capinha et al., 2009; Dongus et al., 2009; Mboera et al., 2010; Wayant et al., 2010; Yang et al., 2010; Delgado-Petrocelli et al., 2011; Machault et al., 2011). On the other hand, HIV/AIDS and tuberculosis were discussed in only one and two studies, respectively (Zendejas-Martínez et al., 2008; Jacob et al., 2010; Peng et al., 2011).

Schistosomiasis was the predominant NTD (11.2%); we identified 15 papers, four of which covered also another disease (Kitron et al., 2006; Stensgaard et al., 2006, 2009; Yang et al., 2006; Chen et al., 2007; Gazzinelli and Kloss, 2007; Raso et al., 2007; Seto et al., 2007; Steinmann et al., 2007; Wu et al., 2007; Simoonga et al., 2008; Li et al., 2009; Standley et al., 2009; Filho et al., 2010; Yiannakoulias et al., 2010). The other NTDs, in descending order of importance, were leishmaniasis (6.9%) (Nieto et al., 2006; Carneiro et al., 2007; Rossi et al., 2007; Morosetti et al., 2009; Bhunia et al., 2010; Fischer et al., 2010; Salahi-Moghaddam et al., 2010; Bhunia et al., 2011), food-borne trematodiasis (3.7%) (Fuentes, 2006; Biggeri et al., 2007; Rinaldi et al., 2009; Suwannatrai et al., 2011), Chagas disease (3.0%) (Kitron et al., 2006; Bustamante et al., 2007; Lambert et al., 2008; Santana et al., 2011), soil-transmitted helminthiasis and other helminth infections (2.9%) (Biggeri et al., 2007; Raso et al., 2007; Knopp et al., 2008; Rinaldi et al., 2009; Standley et al., 2009;

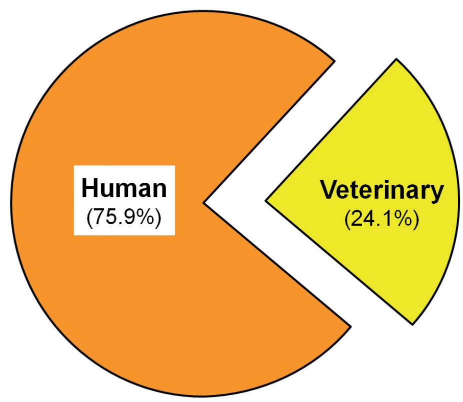

Fig. 3. Broad thematic focus (human and veterinary health) of the 116 original research articles and reviews published in the first five volumes of *Geospatial Health* (November 2006-May 2011).

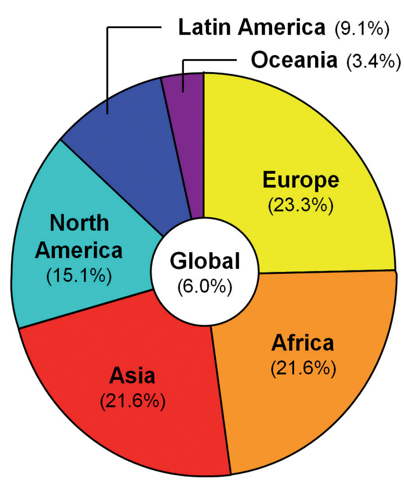

Fig. 4. Geographic focus of the 116 original research articles and reviews published in the first five volumes of *Geospatial Health* (November 2006-May 2011), stratified by continent.

Yiannakoulias et al., 2010), echinococcosis (0.9%) (Cringoli et al., 2007), rabies (0.9%) (Mulatti et al., 2011), leprosy (0.9%) (Argaw et al., 2006), brucellosis (0.9%) (Porphyre et al., 2010), and filariasis (0.9%) (Mortarino et al., 2008).

Research focussing on viral infectious diseases account for 9.5%, with a predominance of Rift Valley fever (5.2%) (Martin et al., 2007; Marechal et al., 2008; Tourre et al., 2008; Vignolles et al., 2009, 2010; Kakani et al., 2010), followed by West Nile virus (1.7%) (LaBeaud et al., 2008; Jacob et al., 2009), dengue (0.9%) (Tipayamongkholgul and Lisakulruk, 2011), Japanese encephalitis (0.9%) (Masuoka et al., 2010) and Hanta virus (0.9%) (Koch et al., 2007).

In as many as seven studies (6.0%), tick-borne diseases were the focus of interest (Estrada-Peña et al., 2007; Estrada-Peña and Venzal, 2007; Rizzoli et al., 2007; Stein et al., 2008; Beugnet et al., 2009; Estrada-Peña, 2009; Beugnet et al., 2011). The two most important animal diseases researched and published in *Geospatial Health* are avian influenza (H5N1), accounting for 5.2% (Cecchi et al., 2008; East et al., 2008a, b; Fiebig et al., 2009; Si et al., 2009; Williams et al., 2011), and bluetongue with a share of 1.7% (Ducheyne et al., 2007; Willgert et al., 2011). In one veterinary study, *Neospora caninum* in dairy cattle in Europe was investigated (Frössling et al., 2008).

Compared to the "big three" and the NTDs, only relatively few focussed on chronic diseases, such as cancer (3.5%) (Sturtz and Ickstadt, 2007; Catelan and Biggeri, 2008; Dreassi et al., 2008; Chiang et al., 2010; Hendryx et al., 2010), obesity (1.7%) (Wen et al., 2010; Duncan et al., 2011), heart disease (0.9%) (Sturtz and Ickstadt, 2007; Wang et al., 2009) and respiratory tract infection (0.9%) (Catelan and Biggeri, 2008; Wang et al., 2009). One study focussed on a sexually-transmitted infection other than HIV/AIDS, namely gonorrhoea (0.9%) (Theall et al., 2009). Two studies each discussed injury prevention (Cinnamon et al., 2009; Sandes et al., 2009) and (domestic) violence (Yu et al., 2008; Livingston, 2010); hence, accounting for 1.7% each.

The remaining studies discussed mental retardation in children (1.7%) (Zhen et al., 2008, 2009), influenza and pneumonia (1.7%) (Crighton et al., 2008; Tellman et al., 2010), child mortality (1.3%) (Kazembe et al., 2007; Sartorius et al., 2011), meningococcal disease (0.9%) (Maïnassara et al., 2010), conjunctive-uveal granuloma (0.9%) (Jayakumar et al., 2009), alcohol outlet density and alcohol consumption (0.9%) (Schonlau et al., 2008) and, finally, one descriptive epidemiological study with no clear disease or risk factor emphasis (Catelan and Biggeri, 2010).

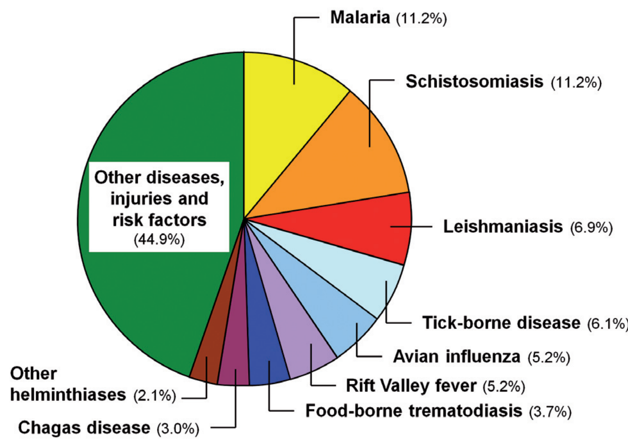

Fig. 5. Pie chart showing the nine most important diseases featured in the 116 original research articles and reviews published in the first five volumes of *Geospatial Health* (November 2006-May 2011).

Geospatial tools

Already 25 years ago, Burrough (1986) characterized GIS as "*a powerful set of tools for collecting, retrieving at will, transforming and displaying spatial data from the real world*". This still holds true although slightly different definitions of GIS can appear depending on the application (Brooker and Utzinger, 2007; Simoonga et al., 2008). As shown in Fig.6, almost half of the publications in the first five volumes of *Geospatial Health* used GIS. Some sort of spatial analysis was performed in one third of the studies, often using advanced Bayesian geostatistics. Remote sensing applications were evident in one quarter of the studies published thus far, whereas investigations involving global positioning system (GPS) instrumentation were described only in three original research articles (Seto et al., 2007; Tourre et al., 2008; Duncan et al., 2011).

Out of the 116 original research articles and reviews, modelling and mapping were evident in 35.3% and 34.5% of the contributions, respectively. It is worth adding that simultaneous visualization of various pieces of information, e.g. data related to health and data related to the environment is one of the exceptional capabilities of GIS. Yet, only five papers mentioned the term "visualization" in the title, abstract or keywords (Murad, 2008; Pfeiffer et al., 2008; Cinnamon et al., 2009; Stensgaard et al., 2009; Widgren and Frössling, 2010).

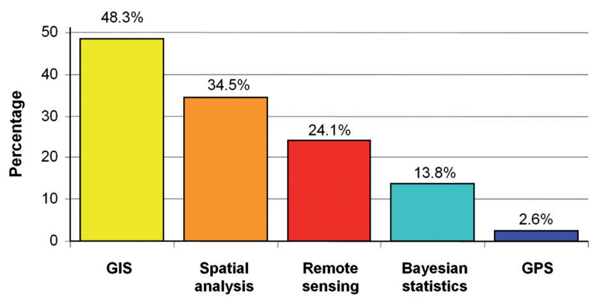

Fig. 6. Percentage of articles that made explicit mention of geospatial tools (in title, abstract and keywords) for analysing and displaying.

Impact

There are different metrics to measure the impact of scientific articles published in peer-reviewed journals, perhaps the most common of which is the ISI Web of Science-based impact factor. It takes at least two years until new journals are considered by the ISI Web of Science to receive an official impact factor. We were encouraged that our application to obtain an impact factor was granted by ISI Web of Sciences after the minimum time span of two years (first impact factor assigned in 2008). Recently, open-access journals published by the Public Library of Science (PLoS) and BioMed Central (BMC) have introduced an additional metric, namely how often a paper is accessed and downloaded. We like this concept and will explore to have this feature made available on the journal webpage.

Table 4 summarizes the characteristics and number of citations (total and stratified by year) of the 10 most highly cited papers published in the first five volumes of *Geospatial Health*. Interestingly, the most highly cited piece in our journal turned out to be a brief editorial, perhaps explained by the topical nature of the contribution, focussing on integrated mapping in a polyparasitic world, placing particular emphasis on malaria and NTDs (Brooker and Utzinger, 2007). Moreover, two reviews, both focussing on veterinary health issues have also been widely cited (Rinaldi et al., 2006; Martin et al., 2007). The other seven contributions that have been cited at least 10 times are original research covering a variety of diseases at different spatial scales.

Outlook: visualization of a new look

Visual and audible cues have always played a dominant role in human societies. This long perspective becomes perfectly clear when we behold the more than 35,000 years old rock carvings found in the caves of southwestern France. They may bear witness of early efforts of mass communication, but we do not know this for sure; they could just as well be ceremonial or religious. Whatever the reason, we can assume that they are the very first examples of visualization. Symbolically, the chapter can be said to have been closed on Christmas Eve in 1968 when the crew of Apollo 8 captured the first picture of planet Earth. The further development of the technology that made this possible was, however, far from closed. Much happened between these two events, but we should not to lose ourselves in endless pursuit of how the visual arts evolved. Let us instead focus on the last 50 years or so, and particularly the current situation.

Compared to classical epidemiological papers, the last decades have seen a spectacular development in the direction of much stronger visual content. This development started more than 70 years ago by the publication of the first concepts of landscape ecology, which was based on the use of aerial photography for the study of vegetation and its interactions with various types of the environment (Troll, 1939). While the modern implementation of GIS adds to visualization through maps showing disease distributions, infection risk and hotspots, Earth-observing satellites complemented this approach by data collection from the ground above which they pass. The particular attraction of satellite-based observation lays in the visible presentation of geographical structures (e.g. land cover, land use, water-bodies, elevations and manmade edifices). The merger of this information with information on the climate such as land surface temperature, normalized difference vegetation index, precipitation, etc., helped to promote the idea of infectious agents being part of the environment thereby integrating biophysical data collection and epidemiological approaches. This holistic perspective produced the notion of the landscape as a mosaic of heterogeneous areas characterized by interacting ecosystems, including emphasis on the relationship between distributions, patterns, process and scale. The flows between diverse ecological patches, relating landscape pattern analysis with landscape conservation and sustainability are the current key research topics in landscape ecology (Wu, 2006). It is encouraging to note, that four articles in *Geospatial Health* pertain to landscape ecology and further develop this concept into landscape epidemiology and genetics (Koch et al., 2007; Li et al., 2009; Filho et al., 2010; Delgado-Petrocelli et al., 2011).

Table 4. Characteristics and number of citations per year of the 10 most highly cited papers published in the first five volumes of *Geospatial Health* (November 2006-May 2011)[a]

Reference	Publication type	Human (H) or veterinary (V)	Disease(s) and risk factor	Geographic focus	No. of citations					
					2007	2008	2009	2010	2011	Total
Brooker and Utzinger (2007)	Editorial	H	Malaria and NTDs	Global	4	1	12	12	7	36
Rinaldi et al. (2006)	Review	V	Veterinary parasitology	Global	7	1	10	5	4	27
Gosoniu et al. (2006)	Original research	H	Malaria	Mali, Africa	2	5	4	5	9	25
Steinmann et al. (2007)	Original research	H	Schistosomiasis	P.R. China, Asia	0	2	2	10	1	15
Wu et al. (2007)	Original research	H and V	Schistosomiasis	P.R. China, Asia	0	2	4	7	0	14
Stensgaard et al. (2009)	Original research	H	Schistosomiasis (vector-borne diseases)	Africa	0	0	2	6	4	12
Si et al. (2009)	Original research	V	Avian influenza	Global	0	0	0	6	5	11
Schonlau et al. (2008)	Original research	H	Alcohol consumption	United States, North America	0	0	3	3	5	11
Martin et al. (2007)	Review	V	Rift Valley fever	Global	1	0	2	6	2	11
Kitron et al. (2006)	Original research	H	Chagas disease and schistosomiasis	Argentina, Latin America; Kenya, Africa	2	2	3	1	3	11

[a]Data obtained from ISI Web of Knowledge (http://apps.webofknowledge.com). Database accessed on December 17, 2011)

The spatial, temporal and spectral resolution of the sensor instruments onboard satellites rapidly drew attention to the utility of computer-based models of the Earth for epidemiological research. These technical advances have not only created unprecedented opportunities to investigate local geographic variations in disease distributions, but have also presented new complexity that can only be addressed by statistics, e.g. random components that may dominate in the estimation of disease rates across small areas. For example, although smooth estimates of disease risk can be produced with Bayesian statistics, the detection of high-risk areas is limited when the expected numbers of cases are small. Naturally, data errors can result in apparent local disease excess, while disease clustering can arise non-systematically. Thus, spatial statistics are playing an increasing role in relation to epidemiology and landscape ecology. In the future, developments leading to improved modelling of exposure, risk-mapping and new methods of surveillance of large health databases promise to improve our ability to better understand the relationships between environment and health.

Representation of health data (e.g. prevalence and intensity of infection and incidence) in the form of a map facilitates interpretation, synthesis and recognition of frequency and clusters of phenomena (Rinaldi et al., 2006). One of the most useful functions of GIS in epidemiology continues to be its utility in basic mapping. Usually, when data are collected either routinely or through purposely-designed surveys, they are presented in tabular forms, which can be exploited for analytical usage. However, the reading and interpretation of such data is often a laborious and time-consuming task and does not permit easy decision-making. On the other hand, seeing the data in the form of map facilitates interpretation, synthesis and recognition of patterns. The use of the map as provider of "first glance" information is obvious nowadays. However, changing the mentality of "traditional" epidemiologists has not been easy and convincing people has been an uphill struggle despite the usefulness of visualizing health in the form of maps and diagrams.

These aspects were discussed in a symposium entitled "A picture is worth a thousand words: visualization of health using geospatial tools", held in

Philadelphia on December 7, 2011 at the 60th annual meeting of the American Society of Tropical Medicine and Hygiene. After an initial overview of the importance of visual presentations, different ways of visualizing information were presented (Jürg Utzinger; Swiss TPH, Basel, Switzerland). In a second presentation, classical disease risk maps and predictive maps were discussed (Amadou Garba; Réseau International Schistosomoses, Environnement, Aménagement et Lutte, Niamey, Niger). Next, it was shown how a powerpoint presentation with highly "animated pictures" can not only captivate an audience, but also succeed in transferring a much stronger visual content in less time than a classical slide show (Mirko S. Winkler; Swiss TPH, Basel, Switzerland). The final presentation, delivered by Cassandra Kirk on behalf of Gary R. Krieger (NewFields, Boulder, United States), was a 9-min long video-clip visualizing the health risk for uranium contamination in a rural mine project in Kyrgyzstan, providing an insight how this new way of information as a means to imprint in our minds a lasting memory of the risks of mining dangerous materials, something which is not always the case when text, tables or figures alone are presented.

The discussion following these presentations was both long and animated showing that it could be useful to take the lead in showcasing this new format. Indeed, the reader can easily see the difference when consulting the illustrations of this article as they represent both sides of the coin, the tables on the one hand and the figures on the other. This is not the same as arguing that the tables upon which the visual displays (the figures) are based, can be done away with. Indeed, the illustrations lose much of their force without these table underpinnings.

The follow-up of the discussions in this symposium will appear in the next issue of *Geospatial Health*, in which we will attempt to publish one or more pilot articles of this kind. The basic idea is to publish a few lines explaining the background to, and the need for, visualization plus tables giving the mathematical foundations for what will be published in the format of visual presentations ("animated slides" and video clips). As we enter this new era, the old adage that a picture is worth more than thousand words rings truer than ever.

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