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Trends in publications in fluvial geomorphology over two decades: A truly new era in the discipline owing to recent technological revolution?

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ABSTRACT

Trends in the field of fluvial geomorphology have been reviewed by a number of authors, who have emphasized the dramatic change occuring in the field in the last two decades of the twentieth century, largely as a result of technological advances. Nevertheless, no prior authors have systematically compiled data on publications in fluvial geomorphology over a long period and statistically analyzed the resulting data set. In this contribution we present a quantitative analysis of fluvial geomorphology papers published in the twenty-two-year period 1987–2009 in five journals of the discipline with a more specific focus on *Geomorphology* and *Earth Surface Processes and Landforms* (*ESPL*), identifying authorships, geographic origin of authors, and spatial and temporal scales covered. We also documented the tools employed, demonstrating the transformation of the field with the emergence of new tools over this period, and conducted a cluster to highlight links between tools and a set of factors (country of author's origin, journals, time, and spatial and temporal scales). Of the 1717 papers published in the five journals during this period, the results showed an increased diversity in the nationality of the first author, mainly when dealing with present time scale, and channel feature. Our data show a significant change in methods used in the field as a result of the increase in data availability and new sources of information from remote sensing (ground, airborne and, satellite). Clearly, a new era in knowledge production is observed since 2000, showing the emergence of a second period of active quantification and an internationalization of the fields.

1. Introduction

Because of its position at the intersection of geology, geography, and river engineering, fluvial geomorphic research is published in a wide range of journals, including not only geomorphically-oriented standards such as *Geomorphology*, *Earth Surface Processes and Landforms* (*ESPL*), and *Zeitschrift für Geomorphologie* (*ZfG*), but also journals as diverse as *Géographie Physique et Quaternaire* (*GpQ*), *Catena*, *Water Resources Research*, *Annals of the American Association of Geographers*, and the *Bulletin of the Geological Society of America*.

These publications provide a rich source of information to determine trends in the field and a number of prior authors have already reviewed portions of this publication record to characterize research in the field and identify trends. Costa and Graf (1984) reviewed papers in geomorphology (not only fluvial) published from 1976 to 1980 and documented that the greatest concentration was in *ESPL*, *ZfG*, and *Catena*, with smaller numbers occurring in other outlets. This was before the launch of the journal *Geomorphology* in 1988. Noting that U.S. geomorphologists were drawn from geography and geology backgrounds, they observed that those affiliated with geography tended to publish more in the sampled journals. Geomorphologists were concentrated in parts of the U.S. with important universities and government research centers, which implied that certain regions were likely better studied than others. In reviewing the current state of fluvial geomorphology and its lack of leadership, Smith (1993) encountered only two published papers addressing the future of the field and its priorities. He noted the increasing importance for fluvial geomorphologists to collaborate with scientists from other disciplines. Neither of these papers discussed methodological issues in depth.

The journal *Progress in Physical Geography* has published a number of excellent reviews of research in the field of fluvial geomorphology. We can cite the reviews by Richards (1986) and Rhoads (1992, 1994), and continuing with Dollar (2000, 2002, 2004), Hardy (2006), and Stott (2010, 2011). These reviews emphasized the role of new applications of geomorphology to inform river management and restoration. They highlighted the increasingly interdisciplinary context within which geomorphology is practiced and advances in technologies and methods, which have greatly expanded the scope of what fluvial geomorphology can accomplish. For example, Dollar's (2004) review of papers

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published 2001–2003 focused mostly on thematic trends. However, he also noted that many "(innovative techniques have also been developed to aid in the understanding of river behavior…)" which allow us to "(address geomorphic questions that have not been addressed before)". He included a table of "(recent techniques applied to understand fluvial system behavior)", which listed 73 citations under 20 categories of techniques. Hardy's (2006) review of papers published in 2004–2005 noted "(an increasing sophistication in the methodological techniques applied which has led to an improved insight into classical fluvial geomorphological problems)". He also stated that "(…in addition to these classical fluvial geomorphology studies, research has extended into more interdisciplinary fields such as river ecosystem problems)" (Hardy, 2006, p.553). While the review was mostly thematic, Hardy devoted two pages to methodological advances. He highlighted measurements of current velocity with 'acoustic Doppler current profilers' (ADCPs) and electromagnetic current meters (ECMs), new methods to measure microtopography and grain size in river beds, and increased use of bedload traps.

Stott (2010, 2011) reviewed fluvial geomorphology papers in *ESPL* and *Geomorphology* for 2006–2007 and 2008–2009, respectively, and classified 44% of the 2006–2007 papers and 38% of the 2008–2009 papers as concerning fluvial geomorphology. However, he included papers on landslides and debris flows as 'fluvial geomorphology', but pointed out that they could be excluded. Stott's (2011) review compared results between the two study periods, organized according to research themes, one of which was, "(Advances in methodology in fluvial geomorphology)". This section (two pages) highlighted use of hydroacoustics and high-resolution video cameras to monitor bedload transport, magnetic finger-printing of soils, a new bed material sampler, applications of LiDAR and DEMs, a boat-based, mobile mapping system with a laser scanner, and close-range terrestrial laser scanning for sedimentological applications.

Other reviews, outside the context of the periodic reviews in *Progress in Physical Geography*, have reached similar conclusions. James and Marcus (2006, p.152) noted that "(…river research [is] now driven to a greater degree by institutional needs, environmental regulations, and aquatic restoration. New techniques include a host of dating, spatial imaging, and ground measurement methods that can be coupled with analytical functions and digital models. These new methods have led to a greater understanding of channel change, variations across multiple temporal and spatial scales, and integrated watershed perspectives)". In their review of current status and methods in fluvial geomorphology, Thorndycraft et al. (2008, p.4) emphasized the role of "(innovative research methods and techniques)", noting that "(recent advances of fluvial geomorphology…are partly the result of new applications developed in response to progress in computing science and new techniques related to computational fluid dynamics, remote sensing, radiometric and isotopic methods for numerical dating, geophysical data acquisition and analysis, among others)". They discussed the importance of new methods such as optically stimulated luminescence, U-series dating of calcrete formed within alluvial terrace deposits, LiDAR, geoelectrical methods such as two-dimensional ground penetrating radar, and the greatly expanded opportunities for computational fluid dynamics as desktop computers have become sufficiently powerful to run large and complex simulations.

In sweeping reviews of the development of geomorphology, Church (2010, 2013) traced the evolution of the field from its emphasis on historical interpretation of landscapes (nineteenth through mid-twentieth centuries) to the quest to understand and measure geomorphic processes, and emphasized the dramatic transformation of the field in the last 1–2 decades of the twentieth century with the emergence of "(improved technologies for remote sensing and surveying of Earth's surface, the advent of personal computation and of large-scale computation, and important developments of absolute dating techniques)" (Church, 2010, p.265). As observed by Church (2010, p.269), the bases for these profound changes in the field have been "(largely technical)". Church (2013) also stated that "(field work moved from being the single domain of activity of geomorphologists to one leg of tripartite routine involving field work, remote sensing, and data analysis)". More recently, Wohl (2014) reviewed advances in the field over almost 50 years, considering scientific publications, geomorphic specialty groups, and textbooks, underlining the broadening in the questions posed, a more integrative perspective, and a greater diversity of river types and bioclimatic contexts.

These reviews provided insights into thematic developments and innovations in the field and recognized the importance of changing technologies in the evolution of the field of fluvial geomorphology. The tools used in fluvial geomorphological research are of interest in part because the field draws upon a wider range of methods and techniques than in most fields. As fluvial geomorphology is at the intersection of several disciplines, the choice of tools is large and reflects the diverse disciplinary training of the investigators and the fundamental and practical questions posed. The field is becoming more interdisciplinary, with disciplines focusing on integration and complex system understanding, using approaches ranging from pure physics to space-time landscape perspectives and considering historical changes and spatial variability of forms and processes. Not only does fluvial geomorphology borrow tools from geology, geography, hydrology, chemistry, physics, ecology, and human and natural history, but increasingly fluvial geomorphologic concepts and methods are adopted or modified by nongeomorphologists in their work. Geomorphology is becoming crucial for ecologists who need to understand how habitats are organized in space, how species respond to fluvial processes; and how they are sensitive to change (Vaughan et al., 2009; Elosegi et al., 2010; Meitzen et al., 2013).

Focusing on tools used in the field, Kondolf and Piégay (2003) conducted a quantitative analysis of fluvial geomorphology papers published in the 11-year period 1987–1997 in the journals *Geomorphology*, *ESPL*, *GpQ*, *ZfG*, and *Catena*, also examining papers published in *Water Resources Research*, *Geological Society of America Bulletin*, and, for 1996–1999, *Géomorphologie* (published by the *Groupe Français de Géomorphologie*). These five principal journals (which had the most fluvial geomorphic papers from a reconnaissance review of many journals) summarized trends in total number of papers published in fluvial geomorphology, country of first authorship, temporal and spatial scales of each paper, and then analyzed in detail the tools utilized in each paper.

In light of the profound changes in the field since 1997, we sought to identify geographic and temporal trends between 1987 and 2009 and to document the tools employed in published research in the field, for the latter question focussing on the first two journals (*Geomorphology* and *ESPL*), in which the majority of the papers in fluvial geomorphology have appeared.

2. Methods

We first identified papers dealing with fluvial geomorphology in the five principal journals (*Geomorphology*, *ESPL*, *GpQ*, *ZfG*, and *Catena*) between 1987 and 2009, documenting the number of papers published in fluvial geomorphology as a percentage of all papers published in the field. We defined fluvial geomorphology papers as those that concerned river and catchment processes and landforms, including sediment transport, landscape denudation, alluvial stratigraphy, hydraulic modeling of river processes, and related topics. We did not include papers that concerned only debris flows and landslides without reference to more classical fluvial processes and landforms. For each fluvial geomorphology paper identified in the five journals, we notably noted year of publication, authors' country, time scale, and spatial scale (Table 1).

We classified the papers according to the temporal and spatial scales studied, using seven temporal and six spatial categories, which reflected our attempt to reduce a large number of potential categories to a manageable number that covered the spread of the data and in a way that