An introduction to advances in sediment science and management

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1 The role of scientists in providing the evidence-based warning of crises

For decades, scientists and others have expressed deep concern about the changes measured in the Earth's atmosphere, biosphere, cryosphere, hydrosphere and lithosphere. This concern and the associated attempt by scientists to inform society, in general, and policy developers, in particular, have intensified in recent years. Perhaps the most widely acknowledged and respected group of environmental scientists is the Intergovernmental Panel on Climate Change (IPCC) which was established by the United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO) in 1988. The IPCC has produced numerous reports which synthesize the best available scientific evidence on climate change and offer advice for how this may be addressed (see <https://www.ipcc.ch/>). Other scientific organizations have also provided reports and publications which provide “warnings” of the state of the planet and the consequences if humanity fails to act. For example, in 1992, the Union of Concerned Scientists (UCS) issued the “World scientists’ warning to humanity” (UCS 1992), which described the collision course between human beings and the natural world. These warnings have intensified in recent years with several publications by the Alliance of World Scientists and similar groups (e.g. Ripple et al. 2017, 2020; Cavicchioli et al. 2019; Albert et al. 2020; Jenny et al. 2020), as well as some initiatives which have built upon this at a national or regional level (e.g. Coogan et al. 2019). This science-based evidence has driven a wider recognition by society as a whole of the crisis that humanity and numerous other species appear to be facing from global

environmental change; here meant to incorporate global climate change. An example of this is the recent change in language from terms like “climate change” and “climate warming” to “climate crisis” by the media and others; some have argued that the magnitude and urgency of the problem were not made sufficiently clear by the former terms.

Perhaps the most important mechanism for communicating advances in scientific and other knowledge is academic journals. Until recently, communication via journals was mainly between discipline-specific scientists and researchers. However, developments associated with the world-wide web—especially academic search engines like Google Scholar, Scopus and Web of Science—have expanded the availability and access to journal articles and reports from organizations like IPCC. Thus, in theory, the general public and decision-makers should now be more informed of scientific developments.

In the 20th anniversary year of *Journal of Soils and Sediments* (JSS; Owens and Xu 2020), it seems appropriate to consider some of the advances in sediment science and management, and especially how the journal has contributed to this. This special issue contains papers that review some of these developments (e.g. Collins et al. 2020; Haynes et al. 2020; Owens 2020), while others provide a perspective on keys aspects and offer recommendations for how the discipline could progress (e.g. Heise et al. 2020; Spadaro and Rosenthal 2020; Vercruysse et al. 2020). Furthermore, Brils (2020) provides a summary of the role of SedNet in shaping how sediment fits into European environmental policy. Three of these papers (i.e. Collins et al. 2020; Haynes et al. 2020; Heise et al. 2020) provide some developments and perspectives—on sediment source fingerprinting, urban road-deposited sediment, and ecotoxicological testing of sediments and dredged material, respectively—since three of the most widely cited papers on sediment in JSS (i.e. Chapman and Hollert 2006; Taylor and Owens 2009a; Walling 2013). The following section gives a summary of each paper in this special issue with a focus on the relation with JSS.

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2 Some advances in sediment science and management

The paper by Owens (2020) provides some context for the themes covered in this special issue by reviewing how information on sediment dynamics and sediment composition has been used to understand how the planet has responded to the activities of humans. The paper focuses on changes since the middle of the twentieth century as this coincides with what may be the start of the Anthropocene Epoch (Syvitski et al. 2020). As the erosion of soil and other sediment sources is intimately linked to this, then information on soil erosion is also considered. It is apparent that such information has been, and will continue to be, crucial to our understanding of how the environment responds to natural and anthropogenic drivers. The paper then presents some of the main impacts of: (i) enhanced soil erosion and sediment delivery to water-courses and the atmosphere; and (ii) changes in sediment composition, especially contaminants. These include direct and indirect effects on the global climate and water (and food) security. While there is a vast literature on these issues, it is clear that many of the over 3000 papers published in JSS to date have contributed to this knowledge-base (see Owens and Xu 2011, 2020).

A fundamental requirement in sediment science and management is an understanding of how sediment travels through landscapes from headwater sources to the global ocean. This is required for improved conceptual and numerical modelling of landscape evolution, including biogeochemical fluxes, and for managing sediment. This necessitates an understanding of key processes which control sediment transport dynamics at a range of spatial and temporal scales. Numerous papers have been published in JSS which have investigated sediment transport dynamics (e.g. Onderka et al. 2012; Tena et al. 2014; Haddadchi and Hicks 2020), usually at a specific spatial (e.g. river reach or sub-watershed) or temporal (e.g. rain event or seasonal) scale. Few studies have explored how drivers affect sediment transport over multiple scales. To address this, Vercruysse et al. (2020) used samples of suspended sediment collected over nearly three decades, along with discharge records, for a river in the UK to develop a framework which considers sediment transport for event-based, intra- and inter-annual timescales. They describe how suspended sediment transport in rivers can be considered as a fractal system consisting of different timescales controlled by a set of interacting processes. As such, it should be possible to use this framework to improve predictive models and for developing targeted management strategies.

One of the areas where JSS has made a significant contribution to scientific development is in the area of sediment tracing and source fingerprinting, an area of research identified in a review by Owens and Xu (2011). Since then, several special issues of JSS have been dedicated to this research topic (i.e.

Gellis and Mukundan 2013; Smith et al. 2015; Laceby et al. 2019) and more than 50 papers have been published in JSS on soil and sediment tracing and source fingerprinting research. Collins et al. (2020) provide a comprehensive review of the developments made since the key paper in JSS by Walling (2013). Collins et al. (2020) identify that while progress continues to be made, there is a need to have consistency and standardization in how such studies are performed. They also identify key areas requiring further research that will enable the sediment source fingerprinting technique to reach its full potential as a tool for managing problematic sediment issues.

There is an increase in studies investigating urban environments reflecting the increase in the Earth's population and a trend towards a larger percentage of that population living in urban and peri-urban areas. Numerous studies have been published in JSS dealing with sediments in urban areas (e.g. Horowitz 2009; Dias-Ferreira et al. 2016; Silveira et al. 2016; Pun et al. 2019), including several special issues on urban soils and sediments (e.g. Taylor and Owens 2009b; Pereira et al. 2016; Siebe et al. 2018). Several papers (e.g. Irvine et al. 2009; Owens et al. 2011; Byrne et al. 2017) have focused on road-deposited sediment (RDS) given its relevance to both aquatic systems and air quality (e.g. PM_{2.5}). Haynes et al. (2020) provide a review of RDS that considers the following: (i) global patterns of RDS composition (mainly metals and metalloids); and (ii) the field sampling and analytical approaches used to assemble this information. They show how some contaminants in RDS, such as lead, have tended to decrease while others have either increased or are likely to become a problem in the future (e.g. polycyclic aromatic hydrocarbons (PAHs) and microplastics) given technological and societal developments. Haynes et al. (2020) also offer advice, via a “workflow”, for undertaking future studies on RDS.

An area touched-on by Haynes et al. (2020) is ways to determine if contaminated sediment is detrimental to human health and aquatic ecosystems. In RDS studies, this is often addressed via the use of pollution/contamination indices (such as sediment quality guidelines, enrichment ratio or geo-accumulation index) or chemical sequential extraction procedures. Approaches to assess sediment impacts on biota have been the focus of many papers in JSS, especially in the first decade of the journal (e.g. Ahlf et al. 2002, 2009; den Besten et al. 2003; Ahlf and Heise 2005; Heise and Ahlf 2005; Chapman and Hollert 2006). Heise et al. (2020) revisit this topic in terms of the potential advantages offered by ecotoxicological testing of sediment and dredged material over other approaches. They describe the reasons that such testing has met with resistance, especially in Europe, and explain that ecotoxicological testing offers opportunities “for sediment management decision-making that warrants more attention”.

As described by Owens and Xu (2020), there has been a strong connection between JSS and the European Sediment Network (SedNet). Many of the early articles from SedNet

were published in JSS (see Brils 2020) and several papers from the 11th SedNet conference in 2019 were published in a special issue (i.e. Obhodas et al. 2020), in part to coincide with the 20th anniversary of JSS. Brils (2020) reviews the development of SedNet since its initiation in 2000. The paper describes how SedNet has contributed to efforts to incorporate an understanding of sediment dynamics and composition within European environmental policy, such as the Water Framework Directive (WFD) and the River Basin Management Plans that are needed to fulfil the requirements of the WFD. The progress made by SedNet reinforces the value of science-based evidence, while illustrating that the ability of the scientific community to influence policy and decision-making is slow. Brils (2020) uses Kingdon's (1995) concept of "three-streams and windows-of-opportunities" to illustrate that progress in policy development often requires more than a solid understanding of environmental systems and the technology required for better management. In many cases, there is a requirement for a problem-stream—which is often driven by scientific investigations—to overlap with the timing of a policy- and/or political-stream, at which point there is a window of opportunity for substantial and lasting progress. This approach helps to explain why what appears to be unequivocal evidence is often ignored, and underlines the need to have science and other knowledge and evidence ready so that "windows of opportunity" can be maximized for the management of environmental systems.

The complexity of managing sediment and remediating contaminated sites is further illustrated by Spadaro and Rosenthal (2020), with a focus on developments in Europe and the USA. Spadaro and Rosenthal (2020) describe how the polluter-pays principal has not been as successful as initially anticipated in dealing with managing contaminated sediment and sites. They also explain why beneficial re-use of problematic sediment has generally failed to reach its potential, in part due to issues of perception and regulation, and thus by economic and social forces. They offer a new approach to the management of problematic sediment through a type of (punctuated) circular economy which is individual and project-based. However, as also illustrated by Brils (2020), progress is often slow and relies upon forces outside of the control of most scientists and stakeholders. This reinforces the need to be ready with the science-based understanding of environmental systems should the opportunity arise and to be adaptive to broader socio-economic and political situations.

3 Concluding comments

Journal of Soils and Sediments has tried to fill a gap in the journal market by contributing to the scientific understanding of the links between soil and sediment processes and environments—as soils are often the source of airborne,

aquatic and terrestrial sediment—and, in the case of sediment, by also addressing how scientific understanding can be used for the management of sediment. The papers in this special issue provide examples of recent developments in these areas via reviews, assessment procedures and conceptual frameworks. It is hoped that these papers encourage future work on sediment science and management so as to address some of the world's main environmental problems.

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