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Achieving cleaner water for UN sustainable development goal 6 with natural processes: Challenges and the future

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UN Sustainable Development Goal 6 aims to achieve clean water for all. Access to clean water is a basic human right but can be costly and challenging. Using natural processes to provide cleaner water for treatment is a cost effective, and often beneficial to other ecosystem services, method. Unfortunately, there are a number of barriers to the implementation of natural processes for cleaner water such as the difficulty of funding these nature-based solutions which is linked to the requirement of accurate valuation. Once funded, partnership with land practitioners is important to ensure that detrimental impacts are not experienced elsewhere and to ensure that these natural processes such as ponds and constructed wetlands are maintained and managed appropriately. The future in the United Kingdom and Europe, in general, is optimistic despite the large funding gap for nature-based solutions overall. Green finance, essentially a loan or investment to support environmentally-friendly activities, has been developed to funnel money towards sustainable investments with an environmental focus, and the percentage of world wealth spent on such investments has increased.

KEYWORDS
sustainability, water, nature-based, partnership, ecosystems

1 Introduction

Achieving the UN Sustainable Development Goals (SDGs) by 2030 requires adoption by various stakeholders and as such now underpins much activity in industry (e.g., Zimon et al., 2020), special interest groups (e.g., Delabre et al., 2020), government (e.g., Musekiwa and Mandiyanike, 2017), and educational institutions (Giangrande et al., 2019) across the world. In response to this challenge, the 4-yearly conference EUROSoil was convened online in August 2021 with sessions covering a wide base of topics developed around each UN SDG. This article is contained in a special issue of the output of the topic "Sustainable Management of Soil Functions as a Basis to Avoid, Halt, and Reverse Land Degradation" and contains the primary perspectives relating to the theme of UN SDG 6 which aims to achieve clean water and sanitation for all (UN, 2022). Water has always been paramount to civilization with settlements in early humanity focused on either coastal areas or where access to clean water was possible such as rivers and lakes. Estuaries with their access to clean freshwater and transport links *via* seas and oceans still harbor a number of the most influential cities across the world. Indeed, water could be thought of as the bloodstream of the natural world (Moss, 2018), providing hydration, nutrients, connection, waste management and income for those with access to substantial resources. Clean water therefore means different things to different people and we see a large disparity between the needs of clean water and sanitation in developing countries in contrast with those in developed.

Provision of safe and affordable drinking water for all is the first and probably the most basic target humanity faces. There have been some gains in this area with the proportion of people with access to clean and safe drinking water rising from 81% in 2000 to 89% in 2015 (UN, 2018). However, this still leaves 844 million people without access to basic water services and 2.1 billion people who live without clean water on their premises which is accessible and free from contamination (UN, 2018). Furthermore, the UN SDG 6 aims to provide access to sanitation and good hygiene, specifically removing the practice of open defecation. In 2015, 4.5 billion people lacked a safely managed sanitation system; where there may be a sanitation system in place but it is below the standard to ensure good hygiene and prevention of health problems (UN, 2018). Climate change adds a further pressure to these absent or poorly functioning systems, the consequences of such rather impactfully shown in the Oscar winning film "Parasite."

While water provision in developed countries is relatively well monitored, along with developing countries, maintaining (or improving) the quality of the water continues to be challenging (Brockwell et al., 2021). The loss of pristine sites due to emerging pollutants such as new pesticides and biocides (Cheng et al., 2021), pervasive invasive species disrupting the balance of these fragile ecosystems (Mooney and Cleland, 2001), loss of soil from land increasing turbidity (Sherriff et al., 2015), along with an increased frequency of extreme low flows exacerbating any water treatment failures (Shore et al., 2017) is a concerning and difficult challenge to manage and address. The final three objectives of UN SDG 6 relate to water quality and the protection and restoration of the ecosystems that rely on it. These final objectives presume that the original objectives of clean water and sanitation have been achieved and focus largely on the ecology of water bodies. Importantly, the SDG identifies an integrated approach to water management as a key objective and thus forms the basis of this perspectives paper. An integrated approach requires a contribution from all stakeholders to maximize the natural processes that lead to cleaner water, yet various barriers remain, preventing the success in achieving this SDG. Therefore, this article presents some perspectives on economical, social and behavioral barriers with consideration on how they may be overcome.

2 Natural processes for cleaner water

The long-standing challenges of addressing the pollution from point and diffuse sources have been the focus of many research articles and commentary (e.g., Albek, 2003; Dai, 2014; Grimvall and Stálnacke, 1996; Jarvie et al., 2010; Zinabu et al., 2018; and Wells et al., 2020). Both sources have their characteristics and methods of management and yet our pollution problems continue and the objectives of the Water Framework Directive (WFD) in the EU and national objectives in other countries have not been met in their entirety, receiving some criticism. For example, Bouleau and Pont (2015) identified challenges around nomenclature and ecological objectives of the WFD while Hüesker and Moss (2015) identified the complexities caused by different strategies by different stakeholders across scales. The criticism of the WFD has largely been levelled at the inconsistency of application (Bouleau and Pont, 2015) along with the divergent activities of different interested parties with their own interests (Hüesker and Moss, 2015) In recent times we have had the added challenge of emerging pollutants such as new (and existing) pesticides (De Castro-Catala et al., 2015) and micro (and macro) plastics (van Emmerik and Schwarz, 2020). No longer are water managers concerned solely with eutrophication of natural waters but also how to remove pollutants that are hazardous to human health such as metaldehyde, which are costly and require a variety of approaches (Rolph et al., 2019).

Loss of soil from land yields numerous water quality challenges from increased turbidity to increases in particulate and dissolved pollutants (heavy metals, POPs *etc.*) and nutrients. Natural processes that address these challenges and lead to cleaner water are not a new concept, neither is this article the first time that they have been championed, e.g., Beierkuhnlein (2021) and Bredemeier (2011), but what is clear is that for these processes to have an impact they need to be implemented across a landscape and be supported both technically and financially. The realized success of installed measures is also dependent on the quality of the influent water which is controlled by land management techniques upstream. The processes themselves can be relatively small and inexpensive, to include swales, trenches and drains that hold water for periods of time (alleviating flooding in some cases). Or they can be large such as ponds which have a higher processing power, or more engineered such as constructed wetlands with advanced water treatment the main objective. Controlling water flow, retaining water and allowing settlement contributes to the removal of particulate pollutants (Johannesson et al., 2011) and further reduces the opportunity of legacy impacts in the future (Jarvie et al., 2014).

The treatment of dissolved pollutants requires a more complex approach than simply settlement. For example, riparian zones may be used to process the nitrate rich groundwaters by allowing plant uptake and the anaerobic conversion to N_2 gas (Ranalli and Macalady, 2010). Therefore, it is not sufficient to install a water feature without also considering how different pollutants will be removed and importantly how these changes may be measured. In a small study located along a stretch of installed leaky debris dams, dissolved nutrients were found to be unaffected by the installed measures although, encouragingly, there was some accumulation of particulate pollutants (Crockford, L. 2020, anecdotal observation). Therefore, these measures should be considered along a continuum of water management across the catchment requiring planning and collaborative activities between stakeholders. The increase in frequency of a catchment-based approach to landscape management with Catchment Sensitive Farming in the United Kingdom (CaBA, 2022a) and Water Co-Governance in the EU (CaBA, 2022b) has led to varying success of addressing deteriorating water quality due to numerous challenges. While this perspective paper focuses largely on the United Kingdom and EU going forward, the obstacles this continent is facing is replicated worldwide to varying degrees.

3 The challenges

3.1 Valuation of natural processes

A continuing challenge across the United Kingdom, the EU and further afield is providing a valuation of these processes that provide cleaner water (Eric et al., 2022). Not only are the overt processes requiring valuation but general land management techniques that reduce water losses and soil movement such as no-till farming, contour farming and improving soil structure require recognition of the time, labour, and energy savings that they provide. The simple change from arable and pasture farming into agro-forestry can have impressive changes to water retention (Vaughan, 2019). Trees intercept and evaporate a significant proportion of rainfall, and as root depth increases soil structure improves, infiltration rates increase and overland flow decreases, so that surface runoff from up slopes can be captured, infiltrated and potentially treated. A small study across four land uses (arable, pasture, 1960 woodland, and 2010 woodland) investigated not only the change of land use to forestry but the longitudinal changes observed as the forest matures (Vaughan, 2019), which should be reflected in their value (Bredemeier, 2011). Consistently higher volumes of water were infiltrated in the woodlands with the slightly older woodland showing better water drainage than the younger. While initial drainage in the arable land use was high, it quickly reduced showing how soil wetting changes over time in relation to soil management (Vaughan, 2019).

The value of wetlands in the landscape continues to be explored with meta-analysis by Eric et al. (2022) showing that the existing income level of a country influences the level of provisioning and regulating of that ecosystem service, i.e., the existing wealth of a country determines whether the wetlands are protected and thus improving their ecosystem service. Additionally, the agricultural total factor productivity index (how efficient the farming systems are) had a positive influence on the regulating value of wetlands while negatively influencing the provisioning, which was the converse to that expected (Eric et al., 2022). There was a suggestion that the income level of the country may have affected the results where there was a large proportion of high-income countries in the regulating model compared to provisioning. This in itself shows that ecosystem services vary across income thresholds and provides another complexity to the valuation of these processes. Measures of wetlands' contribution to water quality improvement may also be measured abstractly by, for example, the improvement in fishing of downstream water bodies (Simonit and Perrings, 2011), increasing the disconnection between the process and required outcome. Figure 1 shows the various levels and components of such a model.

3.2 Funding changing behaviors

The Common Agricultural Policy provided income to farmers ensuring that the EU had a secure source of food (EC, 2022). As the impact of intensive farming resulted in reduced water quality there were many measures implemented to encourage farmers to reduce their nutrient losses from land, such as the Higher Level Stewardships in the United Kingdom. Many of these schemes received criticism (e.g., Hole, 2015) and as financial resources tighten, in the United Kingdom at least, there has been a shift from the "carrot approach," i.e., funding farmers to farm more environmentally friendly (sometimes with poor results e.g., Brambilla and Pedrini, 2013) to the "stick approach" where legislation requires farmers to farm with lower impacts but providing no funding for lost earnings. As Figure 2 shows, stewardship has many facets, not just funding, to be considered for it to be a success (Bennett et al., 2018). The fact remains though, with real valuation of a more sustainable farming approach, there is the opportunity to appropriately quantify the value of these natural processes and ultimately their improvement on water quality (and water retention). Numerous pilot schemes on farms have been used to provide these much-needed figures to provide confidence in more sustainable farming techniques. Indeed, the planning process in the United Kingdom now requires developers to consider the biodiversity net gain of their plans (DEFRA, 2019) opening the opportunity for funding of sustainable farming and integrated water management techniques.

3.3 Land ownership and security

While valuing these natural processes is important, appropriate land management and advisory of such is

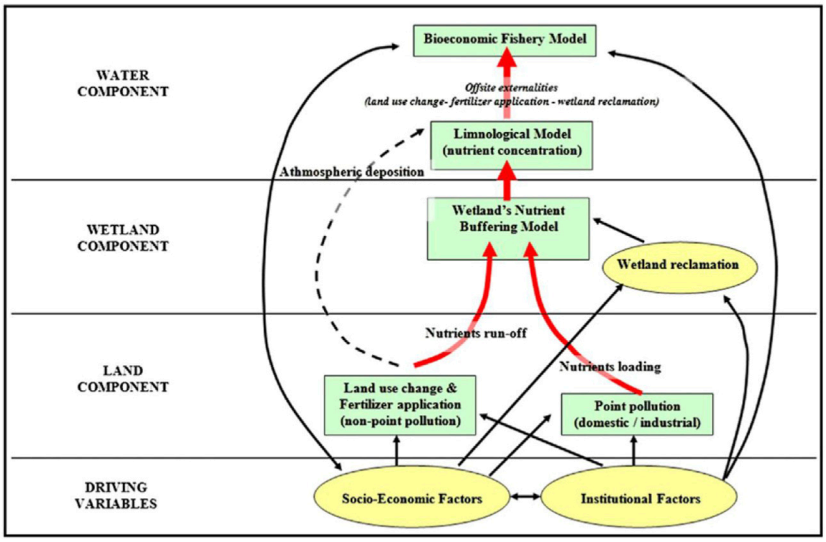

FIGURE 1
Logical framework of a valuation model, adapted from Simonit and Perrings (2011).

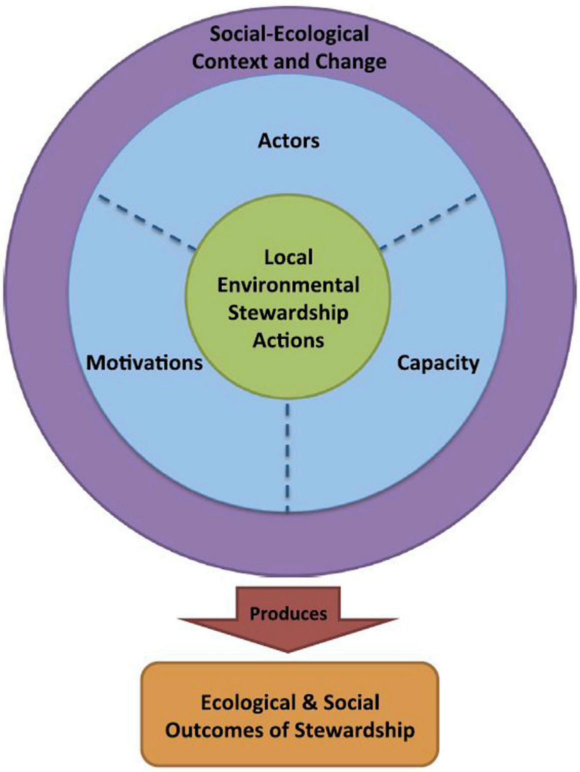

FIGURE 2
A conceptual framework for local environmental stewardship, adapted from Bennett et al. (2018).

required for integrated catchment management to be a success. However, land ownership can in some cases hinder the implementation of new techniques as the land may be rented rather than owned. Even land practitioners who are in a long-term rental agreement may have some hesitancy in changing behaviors firmly engrained in their practice or lack the capital to invest in new equipment/methods. In a small study of land practitioners, there was a belief that practitioners may either embrace environmentally friendly farming to ensure they continue to have a viable tenancy or reject these new measures because they require a longer-term investment (Exelby, 2019). The return on investment of conservation farming techniques, such as no-till, can take many years to yield (Pittelkow et al., 2015) and sometimes only if a holistic view of the technique is considered (e.g., reduced fertilizer and pesticide costs, reduced irrigation costs, decrease in labour, and reduced wear and tear on machinery). In fact, in the short term, conservation agriculture may prove deficit-inducing (Afshar et al., 2022) and require increased use of herbicide (Laukkanen and Nauges, 2011) as well as the capital investment. There can also be some variability on the improvement expected on the environment such as reduction in soil erosion (Malone and Polyakov, 2020). However, the measures embraced by conservation agriculture have been shown to have positive impacts on reducing soil erosion in the long term and have other important impacts such as reducing the losses of greenhouse gases which also need to be considered when striving to achieve the UN SDGs in their entirety (Lal, 2020).

4 The future

4.1 Funding

Funds flowing into nature-based solutions (NBSs) summed USD$133 billion globally in 2021 (UN, 2021) which is a large amount of money until it is compared to the world wealth of USD$431 trillion (Williams, 2021). The proportion of capital allocated to supporting measures to ultimately address a number of the UN SDGs is tiny but is improving. The use of Green Finance has seen an increase in sustainable investment bonds having an environmental focus with increases in funds dedicated to addressing climate change. Unfortunately, investment in NBS needs to increase triple fold by 2030 and four-fold by 2050 to meet the world targets on biodiversity, climate change and land degradation (UN, 2021). The question remains how can environmentalists get funders to care? By providing real valuation of the contribution that natural processes make to global society. This currently is in the form of natural capital where valuation of the benefits of these measures is developing as the links to wider improved environmental quality become stronger.

4.2 Partnership

One of the objectives of EUROSoil 2021 was to explore the importance of partnership between those in environmental research and those working the land. A special workshop aimed to investigate the methods that these two entities may work together going forward. What became clear was the success of the relationship between researchers and land practitioners is vital in our quest to meet the UN SDG 6 of cleaner water. The absence of practitioners in research was recently discussed by Bouma (2022), a long-standing researcher in the sector, and a call made for the serious involvement of farmers to achieve the UN SDGs. While researchers in soil are generally keen to work with the land practitioners, providing the opportunity for this collaborative work needs to come from the land sector themselves. Recent research in the Wupper sub-basin in Germany, by Hüesker and Moss (2015), identified very different motivations for engaging with the implementation of the measures to meet the Water Framework Directive. Agricultural stakeholders were found to be particularly powerful and lobbied successfully at national and local levels to ensure that farming's interests (primarily food production) were protected. While local interest groups felt their views were considered but really the direction of the planning in the sub-basin was controlled by those with more expertise such as agriculture and the water board (Hüesker and Moss, 2015). The roles that different stakeholders play and the methods to interact with them is an area worthy of further exploration to ensure that cleaning water passively through natural processes may be achieved.

The future is relatively hopeful however. The piece by Bouma (2022) extolled the value of real engagement with land practitioners and the need for real world data for which to base our decisions going forward. Thankfully there are encouraging activities across the United Kingdom and Europe with farmers groups now actively engaging with research and efforts made to trial new methods with supportive frameworks to reduce the initial outlay of changing equipment and governmental initiatives aimed at increasing no-till farming (e.g., Jones, 2021). Grassroot based networking and conference events are also becoming popular such as GroundsWell while established farmers networking are now acknowledging the need for an environmental focus with specialist groups established such as Biodiversity, Agriculture, Soil, and Environment (BASE) in France, the United Kingdom and Ireland.

5 Conclusion

Ultimately, the future must hold the achieving of all of the SDG 6 objectives. This paper has focused largely on the use of integrated management and of natural processes to produce cleaner water from land and the barriers that these holistic endeavors must break. However, the objectives of SDG 6 are strongly interlinked. The objective to ensure integrated management is developed across the world could be considered a mechanism towards meeting the earlier objectives of SDG 6. With cleaner natural waters we can reduce the financial burden of cleaning water for drinking as well as improving the natural environment for ecosystem protection and enhancement.

All of these objectives require funding and partnership both of which are improving but appear to still be in their infancy. Large increases in funds allocated to environmentally sustainable measures are vital if the world is to meet the climate change crisis along with the biodiversity and social crises. Some advancement has been made with increasing funds allocated to environmentally focused sustainability but remains only a small proportion of global wealth.

Along with funding we also need "buy in" both financially and professionally from land practitioners in the quest for cleaner water using natural processes. Stakeholder engagement remains paramount to the success of these measures, once they have been financed, with continuing maintenance and ownership still a consideration. What is clear is cleaner water will be possible when the practitioner is involved.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

This article has been solely prepared by LC.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Afshar, R. K., Cabot, P., Ippolito, J. A., Dekamin, M., Reed, B., Doyle, H., et al. (2022). Corn productivity and soil characteristic alterations following transition from conventional to conservation tillage. *Soil Tillage Res.* 220, 105351. doi:10.1016/j.still.2022.105351

Albek, E. (2003). Estimation of point and diffuse contaminant loads to streams by non-parametric regression analysis of monitoring data. *Water Air Soil Pollut.*, 147(1), 229–243. doi:10.1023/a:1024592815576

Beierkuhnlein, C. (2021). Nature-based solutions must be realized - not just proclaimed - in face of climatic extremes. *Erdkunde* 75 (3), 225–244. doi:10.3112/erdkunde.2021.03.06

Bennett, N. J., Whitty, T. S., Finkbeiner, E., Pittman, J., Bassett, H., Gelcich, S., et al. (2018). Environmental stewardship: A conceptual review and analytical framework. *Environ. Manage.* 61 (4), 597–614. doi:10.1007/s00267-017-0993-2

Bouleau, G., and Pont, D. (2015). Did you say reference conditions? Ecological and socio-economic perspectives on the European water framework directive. *Environ. Sci. Policy* 47, 32–41. doi:10.1016/j.envsci.2014.10.012

Bouma, J. (2022). How about the role of farmers and of pragmatic approaches when aiming for sustainable development by 2030? - Bouma - 2022 -. *Eur. J. Soil Sci.* 73 (1). doi:10.1111/ejss.13166

Brambilla, M., and Pedrini, P. (2013). The introduction of subsidies for grassland conservation in the Italian Alps coincided with population decline in a threatened grassland species, the Corncrake Crex crex. *Bird. Study* 60 (3), 404–408. doi:10.1080/00063657.2013.811464

Bredemeier, M. (2011). Forest, climate and water issues in Europe. *Ecohydrology*, 4(2), 159–167. doi:10.1002/eco.203

Brockwell, E., Elofsson, K., Marbuah, G., and Nordmark, S. (2021). Spatial analysis of water quality and income in Europe. *Water Resour. Econ.* 35, 100182. doi:10.1016/j.wre.2021.100182

CaBA (2022b). "Water Co-Governance," in *Catchment Based Approach*. Retrieved 20/06/2022 from. Available at: https://catchmentbasedapproach.org/learn/water-co-governance/.

CaBA (2022a). *Catchment sensitive farming*. Retrieved 20/06/2022 from. Available at: https://catchmentbasedapproach.org/learn/catchment-sensitive-farming/.

Cheng, Y. X., Chen, J., Wu, D., Liu, Y. S., Yang, Y. Q., He, L. X., et al. (2021). Highly enhanced biodegradation of pharmaceutical and personal care products in a novel tidal flow constructed wetland with baffle and plants. *Water Res.* 193, 116870. Article 116870. doi:10.1016/j.watres.2021.116870

Dai, L. (2014). Something old, something new, something borrowed and something Blue
Tackling diffuse water pollution from agriculture in China: Drawing inspiration from the European union. *Utrecht Law Rev.* 10 (2), 136–154. doi:10.18352/ulr.274

De Castro-Catala, N., Munoz, I., Armendariz, L., Campos, B., Barcelo, D., Lopez-Doval, J., et al. (2015). Invertebrate community responses to emerging water pollutants in Iberian river basins. *Sci. Total Environ.* 503, 142–150. doi:10.1016/j.scitotenv.2014.06.110

DEFRA (2019). *Net gain: Summary of responses and government response Crown Copyright*.

Delabre, I., Alexander, A., and Rodrigues, C. (2020). Strategies for tropical forest protection and sustainable supply chains: Challenges and opportunities for alignment with the UN sustainable development goals. *Sustain. Sci.* 15 (6), 1637–1651. doi:10.1007/s11625-019-00747-z

EC (2022). *The Common agricultural policy at a glance*. European CommissionRetrieved 20/06/2022 from. Available at: https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en.

Eric, A., Chrystal, M.-P., Erik, A., Kenneth, B., and Robert, C. (2022). Evaluating ecosystem services for agricultural wetlands: A systematic review and meta-analysis. *Wetl. Ecol. Manag.* doi:10.1007/s11273-022-09857-5

Eurosoil (2022). *Eurosoil 2021; 20th anniversary*. Available at: https://eurosoil-congress.com/.

Exelby, E. (2019). *An analysis of farming in england without subsidy: A challenge or an opportunity? [MSc rural and estate management thesis] edgmond*. Shropshire, UK: Harper Adams University.

Giangrande, N., White, R. M., East, M., Jackson, R., Clarke, T., Coste, M. S., et al. (2019). A competency framework to assess and activate education for sustainable development: Addressing the UN sustainable development goals 4.7 challenge. *Sustainability* 11 (10), 2832. Article 2832. doi:10.3390/su11102832

Grimvall, A., and Stålnacke, P. E. R. (1996). Statistical methods for the source apportionment of riverine loads of pollutants. *Environmetrics*, 7(2), 201–213. doi:10.1002/(sici)1099-095x(199603)7:2<201::aid-env205>3.0.co;2-r

Hole, M. (2015). Managing for nature: A farmer's view on wildlife schemes. *ECOS - A Rev. Conservation* 36 (3/4), 26–28.

Hüesker, F., and Moss, T. (2015). The politics of multi-scalar action in river basin management: Implementing the EU Water Framework Directive (WFD). *Land Use Policy*, 42, 38–47. doi:10.1016/j.landusepol.2014.07.003

Jarvie, H. P., Sharpley, A. N., Spears, B., Buda, A. R., May, L., and Kleinman, P. J. A. (2014). Water quality remediation faces unprecedented challenges from "Legacy Phosphorus". *Environ. Sci. Technol.*, 47, 8997–8998. doi:10.1021/es403160a

Jarvie, H. P., Withers, P. J. A., Bowes, M. J., Palmer-Felgate, E. J., Harper, D. M., Wasiak, K., et al. (2010). Streamwater phosphorus and nitrogen across a gradient in rural–agricultural land use intensity. *Agric. Ecosyst. Environ.*, 135(4), 238–252. doi:10.1016/j.agee.2009.10.002

Johannesson, K., Andersson, J., and Tonderski, K. (2011). Efficiency of a constructed wetland for retention of sediment-associated phosphorus. *Hydrobiologia* 674, 179–190. doi:10.1007/s10750-011-0728-y

Jones, G. (2021). "Future farming blog," in *The farming investment fund: An overview - future farming*. Available at: https://defrafarming.blog.gov.uk/2021/03/30/the-farming-investment-fund-an-overview/.

Lal, R. (2020). Managing soils for resolving the conflict between agriculture and nature: The hard talk. *Eur. J. Soil Sci.* 71 (1), 1–9. doi:10.1111/ejss.12857

Laukkanen, M., and Nauges, C. (2011). Environmental and production cost impacts of no-till in Finland: Estimates from observed behavior. *Land Econ.* 87 (3), 508–527. doi:10.3368/le.87.3.508

Malone, M., and Polyakov, V. (2020). A physical and social analysis of how variations in no-till conservation practices lead to inaccurate sediment runoff estimations in agricultural watersheds. *Prog. Phys. Geogr. Earth Environ.* 44 (2), 151–167. doi:10.1177/0309133319873115

Mooney, H. A., and Cleland, E. E. (2001). The evolutionary impact of invasive species. *Proc. Natl. Acad. Sci. U. S. A.* 98 (10), 5446–5451. doi:10.1073/pnas.091093398

Moss, B. (2018). *Ecology of freshwaters: Earth's bloodstream*. New Jersey, USA: John Wiley & Sons.

Musekiwa, N., and Mandiyanike, D. (2017). Botswana development vision and localisation of UN Sustainable Development Goals. *Commonw. J. Local Gov.* (20), 135–145. doi:10.5130/cjlg.v0i20.6469

Pittelkow, C. M., Linquist, B. A., Lundy, M. E., Liang, X., van Groenigen, K. J., Lee, J., et al. (2015). When does no-till yield more? A global meta-analysis. *Field Crops Res.*, 183, 156–168. doi:10.1016/j.fcr.2015.07.020

Ranalli, A. J., and Macalady, D. L. (2010). The importance of the riparian zone and in-stream processes in nitrate attenuation in undisturbed and agricultural watersheds – a review of the scientific literature. *J. Hydrol. X.*, 389(3), 406–415. doi:10.1016/j.jhydrol.2010.05.045

Rolph, C. A., Villa, R., Jefferson, B., Brookes, A., Choya, A., Iceton, G., et al. (2019). From full-scale biofilters to bioreactors: Engineering biological metaldehyde removal. *Sci. Total Environ.* 685, 410–418. doi:10.1016/j.scitotenv.2019.05.304

Sherriff, S. C., Rowan, J. S., Melland, A. R., Jordan, P., Fenton, O., and Ó hUallacháin, D. (2015). Investigating suspended sediment dynamics in contrasting agricultural catchments using *ex situ* turbidity-based suspended sediment monitoring. *Hydrol. Earth Syst. Sci.* 19 (8), 3349–3363. doi:10.5194/hess-19-3349-2015

Shore, M., Murphy, S., Mellander, P.-E., Shortle, G., Melland, A. R., Crockford, L., et al. (2017). Influence of stormflow and baseflow phosphorus pressures on stream ecology in agricultural catchments. *Sci. Total Environ.*, 590–591, 469–483. doi:10.1016/j.scitotenv.2017.02.100

Simonit, S., and Perrings, C. (2011). Sustainability and the value of the 'regulating' services: Wetlands and water quality in Lake Victoria. *Ecol. Econ.*, 70(6), 1189–1199. doi:10.1016/j.ecolecon.2011.01.017

UN (2021). *State of finance for nature*. Available at: http://www.unep.org/resources/state-finance-nature.

UN (2018). *Sustainable development goal 6, synthesis report 2018 on water and sanitation - executive summary*.

UN (2022). *The 17 Goals | sustainable development*. Available at: https://sdgs.un.org/goals.

van Emmerik, T., and Schwarz, A. (2020). Plastic debris in rivers. *WIREs Water* 7 (1). Article e1398. doi:10.1002/wat2.1398

Vaughan, T. (2019). *How do forests infiltrate water compared to other land uses in the UK and what effect does this have on flooding*. Shropshire, UK: Harper Adams University. [BSc (hons) countryside management, thesis] edgmond.

Wells, J., Labadz, J. C., Smith, A., and Islam, M. M. (2020). Barriers to the uptake and implementation of natural flood management: A social-ecological analysis. *J. Flood Risk Manag.* 13. Article UNSP e12561. doi:10.1111/jfr3.12561

Williams, O., A. (2021). *World's wealth hits half A quadrillion dollars*. New Jersey, USA: Forbes.

Zimon, D., Tyan, J., and Sroufe, R. (2020). Drivers of sustainable supply chain management: Practices to alignment with UN sustainable development goals. *Int. J. Qual. Res.* 14 (1), 219–236. doi:10.24874/ijqr14.01-14

Zinabu, E., Kelderman, P., van der Kwast, J., and Irvine, K. (2018). Evaluating the effect of diffuse and point source nutrient transfers on water quality in the Kombolcha River Basin, an industrializing Ethiopian catchment. *Land Degrad. Dev.* 29 (10), 3366–3378. doi:10.1002/ldr.3096