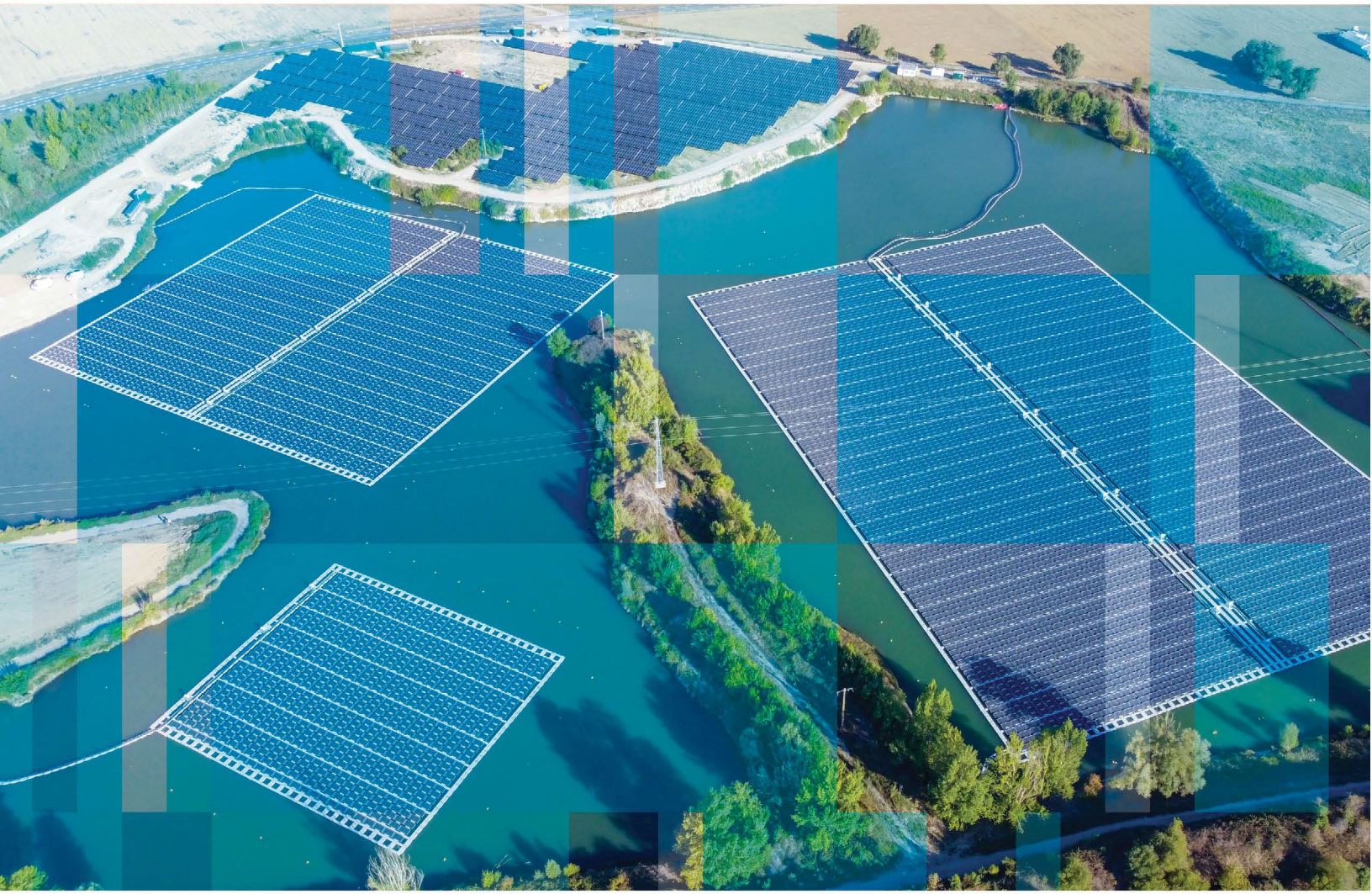
IEEE SA STANDARDS ASSOCIATION

planet positive 2030

Strong Sustainability by Design

RIVERS AND LAKES



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IEEE

SSbD Chapter 06, draft version 1, 2023 - 07 - 14

Strong Sustainability by Design - Version 1 (Draft)

Request for Input

Public comments are invited on the first version of ***Strong Sustainability by Design: Prioritizing ecosystem and human flourishing with technology-based solutions*** that identifies specific issues and pragmatic recommendations regarding sustainability and climate change to achieve "Planet Positivity" by 2030.

This draft compendium has been created by committees of the Planet Positive 2030 Initiative[1] that is supported by IEEE Standards Association (IEEE SA). The Planet Positive 2030 Initiative community is composed of several hundred participants from six continents, who are thought leaders from academia, industry, civil society, policy and government in the related technical and humanistic disciplines. At least one hundred fifty members of this community have contributed directly and have worked to identify and find consensus on timely issues.

The document's purpose is to identify specific issues and candidate recommendations regarding sustainability and climate change challenges to achieve "Planet Positivity" by 2030, defined as the process of transforming society and infrastructure by 2030 to:

- Reduce GreenHouse Gas (GHG) emissions to 50% of 2005 emissions by 2030[2]
- Significantly increase regeneration and resilience of earth's ecosystems[3]
- Be well on the path to achieving net zero GHG emissions by 2050 and negative GHG emissions beyond 2050
- Continue to widely deploy technology as well as design and implement new technological solutions in support of achieving technological solutions designed and deployed to achieve "Planet Positivity"

In identifying specific issues and pragmatic recommendations, the document:

- Provides a scenario-based challenge (how to achieve "Planet Positivity by 2030") as a tool to inspire readers to provide contextual technical and general feedback as part of this RFI.
- Advances a public discussion about how to build from a "Net Zero" mentality to a "Net or Planet Positive" ("do more good") societal mandate for all technology and policy.
- Continues to build a diverse and inclusive community for the Planet Positive 2030 Initiative, prioritizing the voices of indigenous and marginalized members whose insights are acutely needed to help ensure technology and other solutions are valuable for all. Of keen interest is how we can encourage more in-depth participatory design in our processes.
- Inspires the creation of technical solutions that can be developed into technical standards (IEEE Standards Association, for example ICT and power & energy related standards, IEEE P7800™ series) and associated certification programs.
- Facilitates the emergence of policies and regulations; regulations that would potentially be interoperative between different jurisdictions (countries).

[1] Planet Positive 2030is part of The Sustainable Infrastructures and Community Development Industry Connections program

[2] As described in the United Nations Climate Change Conference (COP 21) Paris Agreement of 2015.

[3] According to the High Ambition Coalition for Nature and People, "In order to address both the biodiversity crisis and the climate crisis, there is growing scientific research that half of the planet must be kept in a natural state….experts agree that a scientifically credible and necessary interim goal is to achieve a minimum of 30% protection by 2030." Protection for land and water of "30 x 30 by 2030" was recommended during COP15 United Nations Convention on Biological Diversity.

By inviting comments for *Strong Sustainability by Design*, the Planet Positive 2030 community provides the opportunity to bring together multiple voices from the related scientific and engineering communities with the general public to identify and find broad consensus on technology to address pressing environmental and social issues and proposed recommendations regarding development, implementations and deployment of these technologies.

Details on how to submit public comments are available in the **Submission Guidelines**.

Comments in response to this request for input will be considered by the Planet Positive 2030 Initiative committees for potential inclusion in the first public edition of *Strong Sustainability by Design* ("*Strong Sustainability by Design*, First Edition") anticipated to be made available to the general public during the fourth quarter of 2023.

- For further information, learn more at the Planet Positive 2030 Initiative website.
- For our Frequently Asked Questions (beyond RFI submission), please click here.
- Get in touch at: PlanetPositive2030@ieee.orgto get connected to a committee or any other reason.
- Please, subscribe to our newsletter here.

If you're a journalist and would like to know more about the Planet Positive 2030 Initiative, please contact: Standards-pr@ieee.org

Disclaimers

Strong Sustainability by Design is not a code of conduct or a professional code of ethics. Engineers and technologists have well-established codes, and we wish to respectfully recognize the formative precedents surrounding issues of sustainability and the professional values these codes represent. These codes provide the broad framework for the more focused domain addressed in this document, and it is our hope that the inclusive, consensus-building process around its design will contribute unique value to technologists and society as a whole.

This document is also not a position, or policy statement, or formal report of IEEE or any other organization with which is affiliated. It is intended to be a working reference tool created in an inclusive process by those in the relevant scientific and engineering communities prioritizing sustainability considerations in their work.

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A Note Regarding Recommendations in This Document

Strong Sustainability by Design is being created via multiple versions that are being iterated over the course of two to three years. Planet Positive2030 is following a specific concurrence-building process where members contributing content are proposing “candidate” recommendations so as not to imply these are final recommendations at this time. This is also why the word, “Draft” is so prominently displayed.

Our Membership

Planet Positive2030, an initiative supported by the IEEE Standards Association as part of the Industry Connections Program, Sustainable Infrastructures and Community Development program (SICDP) currently has more than 400 experts involved in our work, and we are eager for new voices and perspectives to join our work.

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The Institute of Electrical and Electronics Engineers, Incorporated
3 Park Avenue, New York, NY10016-5997, USA

Request for Input Draft ("Version One") Published June 2023

Printed in the United States of America.

PDF: ISBN978-0-7381-xxxx-x STDVxxxxx
Print: ISBN 978-0-7381-xxxx-x STDPDVxxxxx

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Rivers and Lakes

Future Vision

It is 2030.Key technology developments, policy implementations, and perhaps most difficult of all, the focus of humans have together resulted in the regeneration of the ecosystems of the world's rivers and lakes. Inspired to address the many problems brought about by an exploding population engaged in unsustainable environmental practices, people chose to come together. They chose to imagine what was possible, and as a result, achieved the victories in these areas that all experience today.

Access to clean potable water has been democratized across cultural and economic divides. Water-use rights and access to water have expanded even as water waste has dramatically dropped.

The world's commercial agriculture businesses have diversified. Crops include more regionally appropriate "less thirsty" crops, decreasing the demand for agricultural irrigation, as well as diminishing the runoff from pesticides, fertilizers, and other nutrient pollutants into neighboring rivers and lakes. The need for flow diversion via dams and other artificial means has also decreased. In response, freshwater ecosystems have rebounded with an increasing number of healthy plant and animal species.

Pollution from Earth's manufacturing facilities and urban infrastructure is significantly reduced. New technologies, bolstered by educational and media efforts, have addressed physical, chemical, and biological pollutants at their source, bringing back a biological diversity not seen in generations. The world's urban areas have made significant progress in integrating natural ecosystems into their urban developments. Parks, woodlands, rivers, and lakes have an expanded natural presence within their boundaries, helping to reduce the effects of climate change.

Human influences on water's temperature and flow direction affected the natural water and land interaction in the past, disrupting its chemical makeup, affecting the diversity of flora and fauna, of which, and this is the ironic and salient point, humans are included. Most humans viewed themselves as occupants, settlers, even conquerors of this planet, using its resources to fulfill their needs and desires. This attitude shifted in 2023 when most of Earth's people recognized that all are indigenous planet Earth members, reliant on its rich diversity of species to survive. They began to realize that as much as species depend on a healthy habitat for their survival, habitats rely on each other too. And as people knew the importance of their cardiovascular health, they also began to recognize the sacred importance of Earth's lungs and heart and made better efforts to understand it for their own good. People all around the world recognized they needed to become a responsible species.

This shift was inspired by science and the realization that the Earth's "**wetlands store about five times more CO_2 than forests and as much as 500 times more than oceans.**"[4] This is phenomenal! And this was back in 2023! The shift represented a significant turning point for humans as they began to consider nature as something to care for (rather than to dominate). Before this, over centuries, humans drained wetlands,

[4] Duke University, Nicholas School of the Environment, "Land-Building Marsh Plants Are Champions of Carbon Capture," May 2022, https://nicholas.duke.edu/news/land-building-marsh-plants-are-champions-carbon-capture.

treating them as obstructions or undesirable swamps (literally mucking up people's foolhardy) attempting to reclaim as much inhabitable land as possible for agriculture and settlement purposes. Why? Renowned novelist and journalist, Annie Proulx elegantly reflected on this with respect to the early settlement of North America in "Swamped," published in *The New Yorker*:

> The original occupants of the continent knew the rivers and swamps, the bogs and lakes, as they knew the terrain and one another. But for most English settlers and European newcomers' nature consisted of passive and inanimate substances and situations waiting to be used to human advantage. **Preservation and care of nature were not what they had come for.**[5]

Regarding the North American continent, for example, over the decades in the short history of its settlement, according to the US Environmental Protection Agency (EPA), there were approximately 220 million acres of wetlands in the area comprising the continental United States in the 1600s, and by 2009, roughly half of that was gone.[6,7] This is not isolated to the North American continent. A United Nations (UN) report cited a source revealing even more stunning data: Worldwide "some 85 percent of wetlands present in 1700, were lost by 2000, many drained to make way for development, farming or other 'productive' uses." While evidence suggests it is slowing, we will lose 1% of the world's wetlands by 2023; however, "the good news is, people now know how to restore these wetlands at a scale that was never before possible and in a way that both stops this release of carbon and re-establishes the wetland's carbon storing capacity."[8,9,10]

It was with this knowledge, and in the spirit of pioneer conservationist Rachel Carson, that collectively, Earth's riverbanks and lakes now enjoy regeneration.

Today, in 2030, our water planet predictably spins on its axis propelling winds in opposite directions above and below its equator, driving surface and deep ocean currents affecting temperature changes across this azure and tawny sphere. Evaporation occurs. Clouds form. Storms develop. Rain falls. Watershed commences, and water's journey back to the sea begins. Like blood vessels, rivers and lakes work with oceans and the atmosphere to pump water around the globe. It's the earth's cardiovascular system: life imitating life.[11] Along its way, water runoff enlivens and enriches ecosystems on a mass scale beginning in the Lilliputian world of a phytotelma, ending in an estuary that slow dances with its ocean partner to the tune of

[5] Annie Proulx, "Swamps Can Protect Against Climate Change, If We Only Let Them," *The New Yorker,* 27 June 2022, https://www.newyorker.com/magazine/2022/07/04/swamps-can-protect-against-climate-change-if-we-only-let-them.

[6] US EPA, "Wetlands—Status and Trends," https://archive.epa.gov/water/archive/web/html/vital_status.html.

[7] Thomas E. Dahl and Gregory J. Allord, "History of Wetlands in the Conterminous United States," *United States Geological Survey Water Supply Paper* 2425, US Geological Survey, National Water Summary on Wetland Resources, https://water.usgs.gov/nwsum/WSP2425/history.html.

[8] Dahl and Allord, "History of Wetlands in the Conterminous United States."

[9] Duke University, "Land-Building Marsh Plants are Champions of Carbon Capture."

[10] NSW Government, "The Nimmie-Caira Project," Water in New South Wales, NSW Dept of Planning and Environment within Australia, https://www.industry.nsw.gov.au/water/plans-programs/state-significant-projects/nimmie-caira. Project completed 2019.

[11] Romullo Baratto, trans. Nicolás Valencia, "Global Watersheds and Waterways Captured in Vibrant Colorized Maps," *Arch Daily*, 9 June 2020, https://www.archdaily.com/940976/global-watersheds-and-waterways-captured-in-vibrant-colorized-maps.

a tide. In between, millions of species of flora and fauna, including humans, now live symbiotically and sustainably with our planet, surviving and thriving in habitats naturally created in an amalgam of water and land, adapting to temperature and gravity forces compelling water along its way.

Introduction

This chapter covers human population growth and its impacts on the earth's river and lake ecosystems. It explores the impacts of urbanization, commercial farming, and manufacturing; resulting pollution types; and the overall impacts occasioned by climate change.

Issue: Water access rights are overly human centric as humans control access to many clean water sources through legal arrangements impacting numerous species, not just humans.

Background

Waterways naturally and unforgivingly flow across geopolitical borders. Historically, around the globe, most species evolved near a reliable clean source of water. Times have changed such that water may no longer be reliable, and what water there is may be beyond the control of a given society or species. Typically, the upstream societies or human legal policy arrangements retain water access to the potentially disastrous detriment of all others. Where there is little water upstream, there may be none downstream, or where there may be plenty of water upstream, the controlling societies may use most of it to establish, sustain, and grow their economies that may be ruinous to downstream needs. Conversely, a controlling community may redirect an overflow of water to avert a local disaster only to convey the disaster to downstream communities.

Water access rights are centuries old. Colonization activities empowered governments to control access for whatever purpose they prioritized.[12] Today, water access control, from a global perspective, ranges from full public access to government regulated to private access. Each of these approaches is nuanced; for example, private access may be further restricted by either riparian or prior appropriation access rights.[13] Then there is the consideration of groundwater versus surface water. It's complicated.[14]

The core challenge, then, is how do we equitably share fresh water, the lifeblood of this planet among all its inhabitants? This challenge is a policy one. In 2010, the UN adopted resolution 64/292 recognizing the human right to water and sanitation, rallying the international community to action, especially in support of developing nations.[15] As of 2020, one in four people on this globe still did not have access to sanitary drinking water.[16]

Recommendations

1. Indigenous peoples should be consulted regarding their knowledge of water usage that may have been passed along, and from societies that have taken steps to rectify and improve equitable water access for all. Additionally, consider the guidance in the United Nations report, The Human Rights to Water and Sanitation in Practice.[17]

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[12] Kevin Mwanza, "African Countries Should 'Decolonize' Water, Recognize Customary Rights: Report," *Reuters*, Oct. 2018, https://www.reuters.com/article/us-africa-water-rights/african-countries-should-decolonize-water-recognize-customary-rights-report-idUSKCN1N300C.

[13] National Agricultural Law Center, "Water Law: An Overview," https://nationalaglawcenter.org/overview/water-law/.

[14] National Agricultural Law Center, "Water Law."

[15] United Nations, International Decade for Action "Water for Life" 2005–2015, https://www.un.org/waterforlifedecade/human_right_to_water.shtml.

[16] Hannah Ritchie and Max Roser, "Clean Water," OurWorldInData.org, Sept. 2019, updated June 2021. https://ourworldindata.org/water-access.

[17] United Nations, *The Human Rights to Water and Sanitation in Practice* (Economic Commission for Europe, 2019) https://unece.org/fileadmin/DAM/env/water/publications/WH_17_Human_Rights/ECE_MP.WH_17_ENG.pdf.

2. Local organizations should be missioned with championing clean water access and protection. Such organizations should be contextually aware and aligned around key water regions. Organizations should be linked within and across nations to improve decision-making, goal-setting, and knowledge sharing. Examples may be the US Water Alliance[18] or Stockholm Environment Institute (SEI).[19]

3. Considering that agriculture uses 70% of freshwater, and contributes toward polluting the freshwater through nutrient pollution, efforts need to be continued on improving approaches to agriculture that make more efficient use of water while minimizing pollutants.[20]

4. The use of "serious gaming" modeling tools should be explored, such as SimBasin to help engage stakeholders in decision-making exercises.[21,22]

5. Clean water standards targeted at, and appropriate for specific communities, should be explored, encompassing the native species of the region. Local context is important.

6. A weather-forecasting approach should be devised that better incorporates water impact to aid communities/states in better forecasting long-term water availability and its capacity to support community viability as populations grow. For example, the use of satellite and thermal technology could evolve to aid "in both monitoring and measuring both surface and groundwater extractions, and consumptive use"[23] .

Humans control access to many clean water sources through legal arrangements impacting numerous species, not just humans.

Technological Insights and Recommendations

This space is intentionally left blank to encourage technically oriented feedback for public Request for Input.

Case studies

1. Serious games, such as "SimBasin," may hold promise in helping communities improve their approach to water management within given water basins. With SimBasin, "the engine allows to easily create a simulated multiplayer basin management game using WEAP water resources modelling software (SEI, 1992-2015), to facilitate the communication of the complex, long term and wide range relationships

[18] US Water Alliance (website), https://uswateralliance.org/about-us.

[19] Stockholm Environment Institute (website), https://www.sei.org/topic/water/.

[20] UN Food and Agriculture Organization (FAO), *The State of the World's Land and Water Resources for Food and Agriculture (SOLAW): Managing Systems at Risk* (Oxford and New York: FAO by Earthscan, 2011), http://www.fao.org/docrep/017/i1688e/i1688e.pdf.

[21] Wikipedia, s. v. "Serious Game," https://en.wikipedia.org/wiki/Serious_game.

[22] H. Angarita, J. Craven, F. Caggiano, and G. Corzo, "SimBasin: A Serious Gaming Framework for Integrated and Cooperative Decision-Making in Water Management, *American Geophysical Union,* Fall Meeting 2016 (Dec. 2016), https://ui.adsabs.harvard.edu/abs/2016AGUFM.U42A..03A/abstract.

[23] Sarah Ann Wheeler, "Assessing Water Markets around the World," Global Water Forum, Nov. 2021, https://www.globalwaterforum.org/2021/11/16/assessing-water-markets-around-the-world/.

between hydrologic, climate, and human systems present in river basins, and enable dialogue between policy-makers and scientists."[24]The game was used in Columbia, applicable to the Magdalena-Cauca River Basin.[25] It was also tried in Thailand for the Upper Nan River Basin.[26]

2. The Food and Agriculture Organization (FAO) of the UN has engaged in a program titled, "Coping with Water Scarcity - the Role of Agriculture," based on its framework for agriculture and food security.[27] The program focused on Egypt, Jordan, and Lebanon. The FAO indicates their program is having success per a separate 2020 evaluation of the project in Lebanon:

> *"FAO projects made positive impacts on their beneficiaries, in terms of enhanced capacity, higher productivity and increased income. The impact was greater when the interventions addressed institutional, policy and cross-sectoral issues as in the case of forest management, statistics and vocational training projects."*[28]

Further resources

1. Guest Blogger for the Internationalist. "Navigating Rough Waters: The Limitations of International Watercourse Governance." *The Internationalist* and *International Institutions and Global Governance Program* (blog), *Council on Foreign Relations*, 2 Sept. 2020.

2. "Nebraska and Colorado Face Off Over Water." *AP News*, 18 May 2022.

3. NPR Staff. "Water Wars: Who Controls The Flow?" *NPR All Things Considered*, 15 June 2013.

4. Meshel, Tamar, and Moin A. Yahya. "International Water Law and Fresh Water Dispute Resolution: A Cosean Perspective." *University of Colorado Law Review* 92, no. 2 (18 Mar. 2021).

5. "Potential Problems with Cross-Border Water Issues: The U.S. and Canada in the 21st Century." In *Canada and the New American Empire*. (University of Victory, CA: Center for Global Studies and CBC News World.)

6. Singh, Shashwat. "The American Southwest's Water Crisis, and Why Canada May Have the Solution." *Glimpse from the Globe*. 10 Jan. 2022.

7. UN Department of Economic and Social Affairs (UNDESA). "Transboundary Waters." International Decade for Action 'Water for Life' 2005–2015.

[24] Angarita et al., "Sim Basin."

[25] Joanne Craven, Hector Angarita, G. A. Corzo Perez, and Daniel Vasquez, "Development and Testing of a River Basin Management Simulation Game for Integrated Management of the Magdalena-Cauca River Basin," *Environmental Modelling & Software* 90 (Apr. 2017), https://www.sciencedirect.com/science/article/pii/S1364815216302006.

[26] Miyuru Gunathilake, Yasasna Amaratunga, Anushka Perea, Chamaka Karunanayake, Anura Gunathilake, and Upaka Rathnayake, "Statistical Evaluation and Hydrologic Simulation Capacity of Different Satellite-Based Precipitation Products (SbPPs) in the Upper Nan River Basin, Northern Thailand," *Journal of Hydrology: Regional Studies* 32 (Dec. 2020), https://www.sciencedirect.com/science/article/pii/S2214581820302172.

[27] UN Food and Agriculture Organization (FAO), *Coping with Water Scarcity* (Rome: FAO, 2012), https://www.fao.org/3/i3015e/i3015e.pdf.

[28] UN Food and Agriculture Organization (FAO), *Evaluation of FAO'S Country Programme in Lebanon, 2016–2019* (Rome: FAO, 2020), https://www.fao.org/3/ca9581en/CA9581EN.pdf.

Issue: Humans treat water as an endless resource that causes unnecessary waste, especially in regions where water is scarce or is under threat of becoming so.

Background

To those living in the developed world, water can seem limitless, just a turn of a knob away. This easy and ready water access in some societies triggers wasteful habits, which could run the gamut, from letting water run in a sink while brushing teeth or washing dishes, to the obsession of watering residential grass in pursuit of the idyllic green lawns. The problem extends beyond individual household waste. Water overuse and waste happen in agricultural, commercial, and industrial settings too. Where it is plentiful and inexpensive, there will be a tendency toward neglectful water spillage and runoff. Even where water is scarce, in less developed countries, water rights owners or those with means to pay for the water may feel entitled to water use as if it is a limitless resource.

It is projected that even as "the U.S. water supply decreases, demand is set to increase." Specifically, "On average, each American uses 80 to 100 gallons of water every day, with the nation's estimated total daily usage topping 345 billion gallons – enough to sink the state of Rhode Island under a foot of water." As the population increases, water stress will increase accordingly. Progress is happening with simple technological creations such as effective household graywater capture systems that might affect greater impact with broader adoption.[29,30,31]

Recommendations

1. Maintenance of old infrastructure, such as leaky pipes, should be supported. Old fixtures should be replaced with new, efficient ones, and installation of water-efficient fixtures and appliances should be incentivized.[32]

2. Use of water-efficient technology must be encouraged.[33] Ongoing innovation in this area is needed; therefore, promoting imaginative study, experimentation, and entrepreneurship may help to continue to raise the bar. For example, where appropriate, advocate for more use of greywater technology to capture and reuse household water from laundry, bath, and kitchen usage to be applied toward nonedible landscape vegetation.[34,35]

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[29] Jon Heggie, "*Why is America Running Out of Water?" National Geographic*, 12 Aug. 2020, https://www.nationalgeographic.com/science/article/partner-content-americas-looming-water-crisis.

[30] Joe Gelt, "Home Use of Graywater, Rainwater Conserves Water—and May Save Money," University of Arizona Water Resource Research Center, 1993, https://wrrc.arizona.edu/publications/arroyo-newsletter/home-use-graywater-rainwater-conserves-water-and-may-save-money.

[31] Fulvio Boano et al., "A Review of Nature-Based Solutions for Greywater Treatment: Applications, Hydraulic Design, and Environmental Benefits*,"Science of the Total Environment* 711 (Apr, 2020), https://www.sciencedirect.com/science/article/pii/S0048969719347229.

[32] US EPA, "Statistics and Facts," Water Facts, Why Save Water?, *WaterSense,* accessed May 2022, https://www.epa.gov/watersense/statistics-and-facts.

[33] Federal Energy Management Program, "Water-Efficient Technology Opportunities*,"* Energy.gov, accessed Aug. 2022, https://www.energy.gov/eere/femp/water-efficient-technology-opportunities.

[34] Gelt, "Home Use of Graywater, Rainwater Conserves Water."

[35] Boano et al., "A Review of Nature-Based Solutions for Greywater Treatment."

3. New water use habits should be formed. Inclusive campaigns could help people from all generations, backgrounds, and roles to reverse the power of old habits (e.g., such as learning to run dishwashers only when full). With an eye to the future, especially focus on building new habits with children.[36] Leaders and influential managers should be empowered to use water conservation means in commercial buildings.[37] The role cultural values play should also be considered, while inspiring new values for beauty. One option would be to encourage the use of plants that conserve water rather than growing grass lawns. Outdoor water use should be limited.[38]

4. The potential for using water markets to help determine a fair price for water that encompasses all stakeholders should be explored.[39,40] Water markets, like any market can help manage scarce resource usage by assigning appropriate value to it. Be mindful, however, that capital markets are human centric. Today's water markets may trend more toward agricultural benefits, weighing the water value against crop value. To benefit all of society, such markets should continue to broaden their participation to encompass all water users, attributing a fairness factor that considers the importance of the water to each stakeholder, beyond just humans, balancing seasonal, environmental, economic, and safety factors, to name a few.[41] New technologically applied ideas may be of help to further promote/market/educate, increase accessibility, and assure equitable and inclusive participation among all stakeholders, including nonhumans (corporate, policy, community).

Technological Insights and Recommendations

This space is intentionally left blank to encourage technically oriented feedback for public Request for Input.

Case studies

1. San Diego County, California, has actively managed its water resources for many years. Its leaders were especially motivated to rectify their water situation during a drought period in the 1990s. Their approach incorporates a combination of water rights access, appropriate pricing, infrastructure (aquifers, stopping leaks, and desalination plants), and educating their constituents, including both industry and households about common-sense water conservancy practices. Today, when the rest of California residents need to make major adjustments to reduce water consumption, San Diego County inhabitants are less impacted given they have already been conditioned for water scarcity.[42]

[36] US EPA, "Water Sense for Kids," Water Facts, *WaterSense*, accessed Mar. 2022, https://www.epa.gov/watersense/watersense-kids.

[37] US EPA, "*Commercial Buildings*," *WaterFacts, WaterSense*, accessedJune 2022, https://www.epa.gov/watersense/commercial-buildings.

[38] Soumya Karlamanga, "Here's Where California Really Uses Its Water," *New York Times*, 10 Dec. 2021, https://www.nytimes.com/2021/12/10/us/california-water-drought.html.

[39] Wheeler, "Assessing Water Markets around the World;" Sarah Ann Wheeler, Adam Loch, Lin Crase, Mike Young, and R. Quentin Grafton, "Developing a Water Market Readiness Assessment Framework," *Journal of Hydrology* 552 (Sept. 2017): 807–820, https://www.sciencedirect.com/science/article/pii/S0022169417304614.

[40] Richael Young, "Trading Water, Saving Water," *PERC* 40, no. 1, 19 July 2021, https://www.perc.org/2021/07/19/trading-water-saving-water/.

[41] BrianRitcher, *Water Share: Using Water Markets and Impact Investment to Drive Sustainability,*(Washington, DC: The Nature Conservancy, 2016), https://www.nature.org/content/dam/tnc/nature/en/documents/WaterShareReport.pdf.

[42] Suman Naishadham, "How San Diego Secured Its Water Supply, at a Cost," *AP News*, 29 May 2022, https://apnews.com/article/california-droughts-environment-san-diego-81ab84fafe94a0c5c298ede24fd2f7f1.

2. Water trading markets in Australia have exhibited reasonable success as a means to balance the use of water as a scarce resource among competing parties. The market approaches vary by the water rights being traded (e.g., access entitlement, allocation, irrigation, and delivery). The markets accommodate both economic and climate demands.[43,44]

Further resources

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11. Water Science School. "Trends in Water Usage in the United States, 1950 to 2015." USGS, US Department of the Interior. 18 June 2018.

[43] Australian Government Department of Climate Change, Energy, Environment and Water, "Australian Water Markets," https://www.dcceew.gov.au/water/policy/markets.

[44] Neal Hughes, "Water Markets Are Not Perfect, But Vital to the Future of the Murray-Darling Basin," *The Conversation,* Mar. 2021, https://theconversation.com/water-markets-are-not-perfect-but-vital-to-the-future-of-the-murray-darling-basin-155880.

[45] "Thermoelectric power and irrigation remained the two largest uses of water (in the USA) in 2015, and total withdrawals decreased for thermoelectric power but increased for irrigation."

Issue: Community overexpansion can overtax water resources Where the scaling effect, while seemingly efficient from a financial sense, may have the unexpected result of overtaxing available water resources.

Background

As populations grow in various countries, the pressure for already scarce water resources increases exponentially. The surrounding infrastructure on which people rely to sustain themselves in various regions needs to scale to meet the demand of ballooning populations. Notably, "according to the World Health Organization (WHO), between 50 and 100 litres of water per person per day are needed to ensure that most basic needs are met, and few health concerns arise."[46] Community planners should accommodate such a fundamental requirement. Compounding this basic infrastructure demand in water-stressed regions is the competition for water among a community's flora and fauna, human residents, and businesses, including agriculture, where that applies. The aggregate of all water-consuming parties amplifies the potential for disaster in such areas.[47]

Recommendations

1. Better planning models need to be built that incorporate a richer set of variables inclusive of the surrounding species, the stakeholders. For example, the use of "serious gaming" modeling tools should be explored, such as SimBasin, to help engage stakeholders in decision-making exercises.[48,49]

2. Local indigenous communities should be consulted, as well as local research universities and nongovernment organizations (NGOs), to advise on environmental impacts. Those impacts should reflect not just that of human projects on the environment, but rather the converse, the impact of a potentially damaged environment on the community. Also, the UN should be partnered with, using the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) to devise methods for the public, businesses, and local governments to understand and apply its guidance.[50]

3. On a global scale, the UN and nations should be leveraged to identify regions of increasing water scarcity, breaking down that scarcity by its cause at local situational levels: natural, water diversion, pollution, industrial/commercial usage, and so on (all the issues listed in this chapter). Then the effect can be modeled as human-controlled water scarcity culprits are scaled down.[51]

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[46] UN-Water Decade Programme on Advocacy and Communication and Water Supply and Sanitation Collaborative Council, *The Human Right to Water and Sanitation: Media Brief*, https://www.un.org/waterforlifedecade/pdf/human_right_to_water_and_sanitation_media_brief.pdf.

[47] Katherine Derla, "4 Billion People Face Water Shortage: Rising Populations, Agriculture Drive Water Demand," *Tech Times*, 15 Feb. 2016, https://www.techtimes.com/articles/133631/20160215/4-billion-people-face-water-shortage-rising-populations-agriculture-drive-water-demand.htm; Giles Parkinson, "France's Troubled Nuclear Fleet a Bigger Problem for Europe Than Russia Gas," *Renew Economy,* 5 Aug. 2022, https://reneweconomy-com-au.cdn.ampproject.org/c/s/reneweconomy.com.au/frances-troubled-nuclear-fleet-a-bigger-problem-for-europe-than-russia-gas/amp/.

[48] Wikipedia, s. v. "Serious Game."

[49] Angarita et al., "SimBasin," https://ui.adsabs.harvard.edu/abs/2016AGUFM.U42A..03A/abstract.

[50] E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo, eds., *The Global Assessment Report on Biodiversity and Ecosystem Services*, Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Bonn, Germany: IPBES Secretariat, 2019), https://doi.org/10.5281/zenodo.3831673.

[51] Y. Wada et al., "Modeling Global Water Use for the 21st Century: The Water Futures and Solutions (WFaS) Initiative and Its Approaches," Geosci. Model Dev. 9 (2016): 175–222, https://gmd.copernicus.org/articles/9/175/2016/gmd-9-175-2016.pdf.

4. The masses need to be educated on the effect of scaling, as well as on how to balance water needs with enterprise. Bigger is not necessarily better.

Technological Insights and Recommendations

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Case studies

1. Kuala Lumpur invested more than $1 billion via its "River of Life" project to clean and revive its Klang River with the intent to balance the area's natural resources with economic development. The city has been transformed by these changes:52

   > "Restoring river habitat and ecological processes not only enhanced the quality of the human experience, it also added resilience to local economies." 53

2. Evidence shows that "smart growth," applying environmental conservation principles, can increase property values within communities that apply them. Conservation Tools Org discusses these principles and successful use cases in its paper, "Economic Benefits of Smart Growth and Costs of Sprawl."54

   > "This impact assessment compares two possible growth plans for New Jersey, one in which growth is managed according to the State Development and Redevelopment Plan, and one in which it continues according to historical trends." 55

[52] Keith Schneider, "A River Restored Breathes New Life into Kuala Lumpur," Mongabay, Aug. 2018, https://news.mongabay.com/2018/08/a-river-restored-breathes-new-life-into-kuala-lumpur/.

[53] Schneider, "A River Restored Breathes New Life into Kuala Lumpur."

[54] WeConservePA, "Economic Benefits of Smart Growth and Costs of Sprawl," Apr. 2012, https://conservationtools.org/guides/96-economic-benefits-of-smart-growth-and-costs-of-sprawl#heading_11.

[55] WeConservePA, "Economic Benefits of Smart Growth and Costs of Sprawl."

Issue: City infrastructure detracts from healthy river and lake ecosystems

Our opportunity is to invest in city infrastructure that enables rather than detracts from healthy river and lake ecosystems by minimizing barriers, elevating natural systems, and advocating for sustainable practices.

Background

Cities have a "profound relationship" with rivers and lakes. Infrastructure development "affects both the quantity and quality of water by changing the natural flow of stormwater runoff in a watershed. When rain hits impervious surfaces such as roofs, streets, and parking lots, it flows off in large quantities, carrying pollutants it picks up from the surfaces. The runoff's increased quantity and speed erode stream channels and destabilize [sic] their banks, while pollutants harm plants and wildlife in rivers, streams and bays."[56] But it is not only the functional aspects of city infrastructure that matter to rivers and lakes. Now, rivers and lakes also serve as sources of pride for cities and their urban dwellers as leaders invest to build infrastructure that enhances the beauty of the waterfront and that invites people to use these bodies of water for recreational purposes. "A good waterfront development considers diversity, community engagement, safety and security, environment and sustainability."[57] Therefore, the ecosystem needs of rivers and lakes must be considered, not only to maintain their functionality and their beauty but also to ensure the health and safety of urban dwellers. To do this, building an infrastructure to support sustainable rivers and lakes and to minimize human-made pollution is essential.

Recommendations

1. Cities should implement "green Infrastructure." Such infrastructure includes technologies that manage storm water safely, effectively, and sustainably using "natural infrastructure" and "techniques that protect, restore, and replicate natural systems." It might also mean "[r]estor[ing] floodplains, and preserv[ing] wetland forests through conservation programs." These programs might include things such as energy efficiency, water access, and green walks along the waterfront.[58]

2. Cities should create more public greenspaces. "Urban greenspaces" help reduce air, water, and noise pollution, and they may offset greenhouse gas emissions through CO_2 absorption. As it relates to the health of river and lake ecosystems, "Urban greenery also provides storm water attenuation, thereby acting as a measure for flood mitigation."[59]

3. Cities should consider initiatives to create and protect healthy watersheds[60] as part of a holistic infrastructure planning process. Organizations such as the EPA partner with local states to encourage "holistic protection of aquatic ecosystems."[61] This alliance results in joint efforts to employ such things as

[56] US EPA, "Smart Growth and Water,"https://www.epa.gov/smartgrowth/smart-growth-and-water.

[57] R. M. R. Hussein, "Sustainable Urban Waterfronts Using Sustainable Assessment Rating System," World Academy of Science, Engineering and Technology, *International Journal of Architectural and Environmental Engineering* 8, no. 4 (2014).

[58] Hussein, "Sustainable Urban Waterfronts Using Sustainable Assessment Rating System."

[59] Andrew Chee Keng Lee, Hannah C. Jordan, and Jason Horsely, "Value of Urban Green Spaces in Promoting Healthy Living and Wellbeing: Prospects for Planning," *Risk Manag Healthc Policy* 8 (Aug. 2015), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4556255/.

[60] US EPA, "Smart Growth and Water."

[61] US EPA, "Initiatives to Create and Protect Healthy Watersheds," Healthy Watersheds Protection, https://www.epa.gov/hwp/initiatives-create-and-protect-healthy-watersheds.

monitoring and assessment approaches, goal development, transparent communication with the public, and strategic habitat protection partnerships.[62] When used as part of a coherent strategic planning process, all of these may inform how best to approach modifications to city infrastructure or future planning for such infrastructure.

4. As cities retrofit out-of-date industrial riverfront properties, they should approach planning for the future use of the space by keeping in mind not only the human desire for "live, work, play[63]" but also the ecosystem's needs. The ecosystem itself, the river, should play an equally important role as the human stakeholders in the planning process.

Technological Insights and Recommendations

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Case studies

1. Shanghai is experiencing a renaissance devised through development along the Huangpu River with the river as the centerpiece:

> *"The urban regeneration of the Huangpu riverfronts plays a key role with no less than 120 kilometers of waterfront transformation intended to eliminate polluting industries, create a continuous open public space (den Hartog, 2019), to make new ecological connections (den Hartog, in press), to reuse industrial heritage (den Hartog, 2020), and to add new landmarks. More than 50 kilometers new waterfronts have been already implemented."*[64]

2. In Ahmedabad (India), "the closure of mills along the Sabarmati Riverfront caused unemployed laborers to form large informal settlements along the riverbed, creating unsafe and unclean living areas and reducing the flood management capacity:"[65]

> *"In response, the city created a development corporation to reclaim 200 hectares of riverfront land on both sides and paid the project costs through the sale of 14.5 percent of the reclaimed land, while the rest of the riverfront was transformed into public parks and laborers resettled through a national program."* [66]

[62] US EPA, "Initiatives to Create and Protect Healthy Watersheds."

[63] John Tierney, "Wasted Waterfronts Why Cities Struggle to Build Along Rivers," *The Atlantic*, Oct. 2013.

[64] Harry den Hartog, "Shanghai's Regenerated Industrial Waterfronts: Urban Lab for Sustainability Transitions?"*Urban Planning* 6, no. 3 (Feb. 2021) in Cogitatio, https://www.cogitatiopress.com/urbanplanning/article/view/4194/4194.

[65] The World Bank, "How Eight Cities Succeeded in Rejuvenating Their Urban Land," press release, Who We Are, 13 July 2016, https://www.worldbank.org/en/news/press-release/2016/07/13/How-eight-cities-succeeded-in-rejuvenating-their-urban-land.

[66] The World Bank, "How Eight Cities Succeeded in Rejuvenating Their Urban Land."

3. In Omaha, Nebraska, "The Riverfront" project "became the first in Nebraska to earn an "Envision" award for sustainability," with a "Platinum sustainability rating." The project transformed downtown Omaha along the Missouri River by "connecting three parks near the city's downtown core:"[67]

> ***"Preserving undeveloped land and remediating a brownfield.*** *To preserve undeveloped land, one hundred percent of the project has been located on previously developed areas. The Lewis and Clark Landing, representing approximately 41% of the site, is located on a brownfield site where a lead smelting and refinery company operated for decades. A response action to install a geosynthetic clay liner was started in the late 1990s to cap the contaminated soils and was fully completed in 2016."* [68]

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5. Lubell, Sam. "7 Cities Transforming their Rivers From Blights to Beauties**."** *Wired*, 4 Aug. 2016.

6. Phong, L. H. "The Relationship Between Rivers and Cities: Influences of Urbanization on the Riverine Zones: A Case Study of Red River Zones in Hanoi, Vietnam." *WIT Transactions on Ecology and The Environment* 193 (2015).

7. Rivers and Lakes in European Cities. EEA Report, no. 26/2016. (Copenhagen, Denmark: European Environment Agency, 2016).

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US Environmental Protection Agency (EPA). "Why Urban Waters?" Urban Waters Partnership. Last updated 10 June 2022.

[67] "Omaha, Nebraska's Riverfront Revitalization Project on a Brownfield Wins International Sustainable Infrastructure Award," *Revitalization, The Journal of Urban, Rural and Environmental Resilience* 159, 15 Nov. 2021, https://revitalization.org/article/omaha-nebraskas-riverfront-revitalization-project-success-on-a-brownfield-has-won-an-international-sustainable-infrastructure-award/.

[68] "Omaha, Nebraska's Riverfront Revitalization Project on a Brownfield Wins International Sustainable Infrastructure Award."

Issue: Excess fertilizer, pesticide, and animal waste pollute water sources and increase the chances for toxic harmful algal blooms (HABs).

Background

Humanity has been applying fertilizer and pesticide to crops for ages. There is a limit, however, to how much of it the waterways can filter before it impacts us and our surrounding environment.[69,70,71] A US EPA "assessment found that 48% of water quality impairment in American surface waters is attributable to agriculture."[72] This problem isn't just an agriculture challenge, then, but also a household cultural problem. In the United States, household lawns may be the largest crop. "Lawns comprise over 150 000 km^2 of land in the US, an area larger than that of any irrigated crop."[73]As a result, people are overfertilizing. In lakes and ponds, the result is increasing algal blooms. Here are some quotes from a few different sources:

> *"Using lots of fertilizer wouldn't necessarily be a bad thing if all of it was used by the crops. Unfortunately, most of it isn't."*
> *"It means that **less than half of the nitrogen we apply to our crops is actually taken up by them. The rest is excess that leaks into the natural environment.**"* [74,75]

> *"Nutrient pollution is the process where too many nutrients, mainly nitrogen and phosphorus, are added to bodies of water and can act like fertilizer, **causing excessive growth of algae.**"*[76]

Apart from occurring naturally, toxic algal blooms can be caused by the flow of nutrients like nitrogen and phosphorus into the lake ecosystem. These nutrients may originate from fertilizers used in agriculture and through household use of chemicals and so forth.

HABs "occur when colonies of algae –simple plants that live in the sea and freshwater–grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds. The human illnesses caused by HABs, though rare, can be debilitating or even fatal."[77]

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[69] University of Oxford,"Manure Used by Europe's First Farmers 8,000 Years Ago," *ScienceDaily,* 16 July 2013, https://www.sciencedaily.com/releases/2013/07/130716134740.htm.

[70] "A Short History of Pest Management," PennState Extension, updated 30 June 2022, https://extension.psu.edu/a-short-history-of-pest-management.

[71] "A Short History of Pest Management."

72 Dan Nosowitz, "Study: There Are Ways to Dramatically Reduce Agricultural Water Pollution," Modern Farmer, 4 Aug. 2021, https://modernfarmer.com/2021/08/study-there-are-ways-to-dramatically-reduce-agricultural-water-pollution/.

[73] Peter M. Groffman et al., "Satisfaction, Water and Fertilizer Use in the American Residential Macrosystem," *Environ. Res. Lett*. 11, no. 3 (Feb. 2016), https://iopscience.iop.org/article/10.1088/1748-9326/11/3/034004.

[74] Hannah Ritchie, Max Roser, and Pablo Rosado, "Fertilizers,"OurWorldInData.org, 2022, *https://ourworldindata.org/fertilizers*.

[75] Luis Lassaletta, Gilles Billen, Bruna Grizzetti, Juliette Anglade, and Josette Garnier, "50 Year Trends in Nitrogen Use Efficiency of World Cropping Systems: The Relationship between Yield and Nitrogen Input to Cropland," *Environ Res. Lett.* 9, no. 10 (Oct. 2014), https://iopscience.iop.org/article/10.1088/1748-9326/9/10/105011/meta.

[76] National Oceanic and Atmospheric Administration (NOAA), "What is Nutrient Pollution?" National Ocean Service, last updated 20 Jan. 2023, https://oceanservice.noaa.gov/facts/nutpollution.html.

Costs to the economy include healthcare costs for affected human beings, as well as from tourism to mitigate the damage. There is also a cost to marine life.[78]Progress is being made! Effective sustainable farming practices are evolving, however. They balance the objectives of a healthy environment and economic profitability with social and economic equity.[79]

Recommendations

1. Natural, native solutions should be considered to let nature repair nature. For example, it's been known for many years now that some native grasses, such as switchgrass, serve as filters. "Grassy riparian buffers, either alone or in a forested buffer system, trap or transform sediments and plant nutrients before they enter streams. Native grasses might also be used in contour filter strips that can retain 50-70% of nutrients, pathogens, and sediment."[80]

2. From an agriculture perspective, regenerative farming[81] or, at minimum, crop rotations, can reintroduce natural nutrients from a crop back into the soil for future crop benefit. This approach can also reduce the need for fertilizers and pesticides. Research has already made progress in identifying food crops that require less fertilizer.

3. Financial incentives or disincentives are needed to avert the overuse of fertilizers. For example, continued evolving and popularizing the use of water quality trading (WQT) is needed. Much like voluntary carbon markets (VCMs) use greenhouse gas (GHG) offsets traded among carbon producers to achieve lower carbon output to meet policy goals, WQT enables waterway nutrient polluters to achieve something similar. Its advantage is in attracting private capital market investment toward infrastructure required to clean the water. It brings together key stakeholders (e.g., government, nongovernment, agriculture, private industry, and capital markets) to achieve water quality policy goals such as the 1972 Clean Water Act in the United States.[82,83]

4. Sustainable agriculture practices need to continue to evolve. "Growers may use methods to promote soil health, minimize water use, and lower pollution levels on the farm"[84] (academia, community).

5. The efficiency of fertilizer application should be improved using new advances in science, both in analyzing the results of applications (e.g., plant sap analysis)[85] and in exploring the viability of using super-absorbent polymer (SAP) technology:

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[77] National Oceanic and Atmospheric Administration (NOAA), "What is Harmful Algal Bloom?," last updated 27 Apr. 2016, https://www.noaa.gov/what-is-harmful-algal-bloom.

[78] Florida Department of Health, "Harmful Algae Blooms—Economic Impacts," https://www.floridahealth.gov/environmental-health/aquatic-toxins/_documents/economic-impacts.pdf.

[79] UC Sustainable Agriculture Research and Education Program, "What is Sustainable Agriculture?" UC Agriculture and Natural Resources, last updated 3 Aug. 2021, https://sarep.ucdavis.edu/sustainable-ag.

[80] Ronald Schnabel, "Improving Water Quality Using Native Grasses," USDA Agricultural Research Service, Nov. 1999, https://www.ars.usda.gov/research/publications/publication/?seqNo115=108867.

[81] "Center for Regenerative Agriculture," University of Missouri, https://cra.missouri.edu/.

[82] "Water Quality Trading," Chesapeake Bay Foundation, https://www.cbf.org/issues/water-quality-trading/index.html.

[83] US EPA, "Water Quality Trading," National Pollutant Discharge Elimination Systems (NPDES), last updated 14 Dec. 2022, https://www.epa.gov/npdes/water-quality-trading.

[84] UC Sustainable Agriculture Research & Education, "What is Sustainable Agriculture?"

"Besides improving water use efficiency of soil, SAPs are also used for controlled release of fertilizers. It is reported that about 40–70% of nitrogen (N) and about 80–90% of phosphorus (P) in conventional fertilizers cannot be absorbed by crops due to their high solubility in water and high diffusivity to the surrounding environment"[86]

6. From a household perspective, ways to encourage a natural lawn and disrupt the pursuit of an unnatural manicured lawn that requires more chemical treatment to maintain it are needed. Growing native species encourages and supports a healthy habitat for surrounding indigenous flora and fauna. For households unwilling to switch to a natural lawn, suggestions to mow at taller heights that "can reduce pest problems, such as weeds, insects, and diseases"[87]are useful. Also, they could use a landscaping service mindful of and better educated about overfertilizing that provides more natural means of pest control.

7. Tactically speaking, implementing sustainable algae management practices such as increasing the level of oxygen in lake water through technologies like aeration, educating and encouraging households to reduce the use of detergent, control algae using ultrasonic waves, judicious use of aquatic herbicides, and investigate the potential use nanobubbles technology are viable technologies.[88] These tactical approaches should advertise to the community that it is clearly temporary and requires pairing with more natural strategic solutions. Such tactics should avoid leaving the community with the sense that temporary remediation solves the underlying problem to the point where they lose interest.

Water quality should be monitored in real time.

Technological Insights and Recommendations

This space is intentionally left blank to encourage technically oriented feedback for public Request for Input.

Case studies

1. The Pleasant Valley Branch of the Pecatonica River in Wisconsin managed to reduce sediment and chemical runoff by proactively engaging stakeholders to rally around a solution. That solution included government agencies, NGOs, and farmers (voluntarily) applying a SNAP PLUS program (Soil Nutrient Application Planner) to identify "hot spots" and assess appropriate remediation. They managed to reduce the phosphorus pollution by 40%, which improved the health of the fish and other species reliant on the river as their habitat; it also dramatically reduced the algae growth in downstream waters. Thus, they incorporated a sustainable management model by introducing an automated sampler mechanism

[85] Lauren Barrera, "Reducing Fertilizer, Boosting Yields with Sap Analysis," No-Till Farmer, 31 Dec. 2021, https://www.no-tillfarmer.com/articles/11078-reducing-fertilizer-boosting-yields-with-sap-analysis.

[86] Liangyu Chang, Liju Xu, Yaohu Liu, and Dong Qiu, "Superabsorbent Polymers Used for Agricultural Water Retention*,"Polymer Testing* 94 (Feb. 2021), https://doi.org/10.1016/j.polymertesting.2020.107021.

[87] Clear Choices Clean Water, Indiana, "Fertilizer and Water,"https://indiana.clearchoicescleanwater.org/pledges/lawns/fertilizer-impacts/.

[88] Tatek Temesgen, Thi Thuy Bui, Moonyoung Han, Teschung-il Kim, and Hyunju Park, "Micro and Nanobubble Technologies as a New Horizon for Water-Treatment Techniques: A Review," Advances in Colloid and Interface Science 246 (Aug. 2017), https://www.sciencedirect.com/science/article/abs/pii/S0001868617301719.

along the river.[89,90]

The farmers integrated old practices such as contour farming but also timed their fertilizer applications in suspect areas such that it minimized runoff from seasonal heavy rains that might typically flush the fertilizer into the waterways. They also applied more no-till planting, retaining surface residues, all of which helped minimize soil runoff. Plus, they began more off-season cover-crop planting that helps consume the residual phosphorus.

2. Lake George Association - The Jefferson Project: Building the Future of Freshwater Protectionhttps://lakegeorgeassociation.org/science-protection/jefferson-project

3. The National Centers for Coastal Ocean Science (NCCOS) are working to monitor and address the impacts of climate change on coastal blooms - Monitoring and Event Response (MERHAB)https://coastalscience.noaa.gov/research/stressor-impacts-mitigation/merhab/

4. Moleaer's nanobubble technology is used for various purposes, including for treating the root cause of algal bloomshttps://www.moleaer.com

Further resources

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[89] "A Water Pollution Solution—A Case Study in Success," *Into the Outdoors* YouTube channel, Aug. 2021, https://www.youtube.com/watch?v=Uglod5nIEdc.

[90] The Environmental Trading Network, "Organizations and Tools," http://www.envtn.org/water-quality-trading/organizations-and-tools.

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13. National Institutes of Environmental Health Sciences (NIEHS). "Algal Blooms." NIH. Last updated 8 Sept. 2021.

14. National Oceanic and Atmospheric Administration (NOAA), "What is Harmful Algal Bloom?" Last updated 27 Apr. 2016.

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27. USDA Farm Service Agency, US Department of Agriculture. "Feed Grains and Oilseeds Analysis."

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29. "When it Comes to Protein, How Much is Too much?" *Harvard Health Publishing*, Harvard Medical School, 30 Mar. 2020.

Issue: Water flow diversions disrupt critical ecosystems

Background

The human need for energy, irrigation, transportation, household, and industrial products often alters the natural flow of rivers and streams through construction and deforestation. Modification of the natural environment has a detrimental impact on rivers and lakes by either increasing or impeding the natural flow of water, by increasing pollutants in the water, and/or by disrupting the natural processes of interconnected ecosystems.

The land area through which water naturally flows is called a *watershed*. Any human modification to the watershed interrupts the natural flow of water, including modifications humans make every day such as construction ranging from dams and irrigation channels to buildings and dwellings to roadways and parking lots. Interrupting the watershed by building structures such as parking lots can dramatically increase rainwater runoff, resulting in increased volumes of water, which results in flooding and erosion. Construction is not the only culprit, though. Other uses of the land, such as harvesting materials like lumber, impact the natural flow of water. When the natural flow of water is interrupted, the receptacles of the water, such as streams, rivers, and lakes, are impacted. When trees are removed for human use, the natural process they play in our ecosystem is disrupted too. For example, trees facilitate the natural rivers in the sky. They do this by absorbing and then releasing water into the atmosphere that travels "hundreds or even thousands of miles away," feeding rivers and lakes across the world. Other impacts can range from increases in water flow, where barriers are reduced, which results in flooding and erosion, to the polluting of water as pollutants are collected during flow. When humans introduce barriers within the natural watershed, as water flows, it can pick up contaminants and pollutants, which impact rivers and lakes downstream.

The fact that people have made choices over centuries to alter natural water flows without understanding their impact on other species also affects humans in the long run. For example, one study finds a correlation of human disease increases with the 20th-century construction of two large dams in Egypt.[91] Regarding dams, numerous articles and studies provide evidence of their disrupting nature, but it is prudent to ask whether dams could be used in other ways that benefit other species as well as humans. Alternative sources of energy are needed to relieve dependency on fossil fuel, and dams provide such a choice. Of course, there are trade-offs. Each action by any species on Earth affects others, sometimes negatively. It's a dance! And like a "dance," troupes must work in unison to achieve harmony.

Recommendations

1. The appropriate timing of dam water releases should be examined to balance the needs of multiple stakeholders.[92]The impact of dam creation on the habitat of the native species that are important to maintaining the sustenance of the surroundings should be considered. In Assam, a state in India, the xihu (river dolphin) population is in serious decline in the Ganges River, which is partly attributable to dams that restrict the dolphins' movements. Being at the top of the food chain, these dolphins help maintain

[91] Jennifer Derr, "The Dammed Body: Thinking Historically about Water Security & Public Health," Daedalus, *Journal of the American Academy of Arts & Sciences* 150, no. 4 (Fall 2021) https://www.amacad.org/publication/thinking-historically-about-water-security-public-health.

[92] William Chen, "We Can Make Large Dams More Friendly to the Environment," *Scientific American*, Apr. 2018, https://blogs.scientificamerican.com/observations/we-can-make-large-dams-more-friendly-to-the-environment/.

the health of the rivers they inhabit. Any indication of their population decline is a sign of an unhealthy river.[93,94]

2. More permeable construction materials should be employed to minimize water flow impact. For example, studies have trialed the use of permeable pavement for roadways or walkways that has the potential for improving water flow disruption.[95]

3. Artificial intelligence (AI) based on trusted data models should be employed to aid in assessing the motivations and the impact of building a dam, even in its removal. Alternative approaches may reveal themselves.

4. Where the motivation for a dam is for irrigation, determination must first be made whether more appropriate crops could grow in a region that would lower or minimize the demand for water from the irrigation channels. An example is in Arizona where local alfalfa farmers are looking at substituting their usual non-native alfalfa with a native plant, guayule, that has uses in the latex market.

Technological Insights and Recommendations

This space is intentionally left blank to encourage technically oriented feedback for public Request for Input.

Case studies

1. France has been making concerted efforts to reduce the river flow diversions of its dams by scientifically researching and applying approaches. A major dam was removed from the Selune River with acknowledged success:[96]

> "The way the river has been reborn is such an important message, a message of hope," says Roussel. "Just when you think that everything is going wrong with the environment, sometimes you can get a sign, a concrete example of nature reclaiming its territory. And I think that's really comforting."

Another dam, the Poutes Dam was retained but lowered by nearly two thirds with modifications to both its operational structure and schedule to provide a migration path for the declining Atlantic salmon population. This project is still in progress but with encouraging results so far.[97]

[93] Jonathan Swinton and Whitney Gomez, s. v. "Platanista Gangetica, Ganges River Dolphin; Susu" in Animal Diversity Web, https://animaldiversity.org/accounts/Platanista_gangetica/.

[94] Nabarun Guha, "Gangetic River Dolphins in Assam Decline in the Wake of Anthropogenic Pressures," Mongabay, 24 Aug. 2022, https://india.mongabay.com/2022/08/gangetic-river-dolphins-in-assam-decline-in-the-wake-of-anthropogenic-pressures/.

[95] USGS, Upper Midwest Water Science Center, "Evaluating the Potential Benefits of Permeable Pavement on the Quantity and Quality of Stormwater Runoff," Mar. 2019, https://www.usgs.gov/centers/upper-midwest-water-science-center/science/evaluating-potential-benefits-permeable-pavement#publications.

[96] Valérie Dekimpe, "Dam Busters: Tearing Down Concrete Walls to Save Atlantic Salmon," *France24*, 15 Apr. 2022, https://www.france24.com/en/tv-shows/down-to-earth/20220415-dam-busters-tearing-down-concrete-walls-in-the-name-of-biodiversity.

[97] Dekimpe, "Dam Busters."

2. A 2017 study from the *University of Washington School of Aquatic and Fishery Sciences* provides some hope of a possible positive compromise addressing this problem, "Designing flows to resolve human and environmental water needs in a dam-regulated river":

> "One of the most promising approaches to **integrating human uses into the larger scope of ecological sustainability** is the concept of environmental flows, or the provision of water within rivers to support positive ecological outcomes while maintaining the water needs of human society."[98]

3. Another promising example of compromise is described in this *Scientific American* article, "We Can Make Large Dams More Friendly to the Environment," which provides some hope of a possible positive compromise addressing this problem.[99]

Further resources

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[98] William Chen and Julia Olden, "Designing Flows to Resolve Human and Environmental Water Needs in a Dam-Regulated River," *Nature Communications* 8 (Dec. 2017), https://www.nature.com/articles/s41467-017-02226-4.

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Issue: Growing water-intensive crops in arid zones accelerates water scarcity

Background

The agriculture industry is incentivized to grow crops that provide the greatest yield for their investment and available resources. In some cases, the crops require more water than the local ecosystem is natively capable of providing.

Thirsty crops: It's an economic problem:[100]

> *"When growers are producing things, they think in terms of what income can you generate per unit of water, so a crop that doesn't use as much water per acre, might not generate much income"*
> *~George Frisvold, Researcher, Univ of Arizona Dept of Agricultural and Resource Economics*[101]

For example, the United States produces almonds largely in California and Arizona, two water-stressed areas. Almonds natively grow in the Mediterranean region, and they do require a great deal of water. This crop, therefore, may no longer be practical from a water usage perspective. The issue becomes more complicated when intricate dependencies are unveiled about crops grown at scale to fulfill the demands of the entire vertical food industry from farm to wholesale to industrial to commercial to consumer.

This 2016 article in the Austin American-Statesman, "5 Reasons Farmers Grow Thirsty Crops in Dry Climates," reveals a great deal about the problematic relationship specifically in the United States between agriculture and water. Here are some key snippets:[102]

> *"**Corn's production value is higher than that of soy or wheat**, making it an attractive choice for farmers to plant. But corn also demands more water."*
>
> *"**Most of the corn grown in America goes to fatten up livestock**. It's also **used in starch, corn oil, beverage and industrial alcohol, sweeteners such as corn syrup, and fuel ethanol**.*
>
> *"**Irrigated land is worth more** than non-irrigated land in low-rainfall regions."*
>
> *"Farmers have a choice: **Fully irrigate or risk losing** the lease to a neighbor who's willing to do so."*
>
> *"Farmers who want to cut irrigation to conserve water only qualify for **dryland insurance policies that don't compensate** them nearly **as much** as an irrigated policy."*
>
> *"**Farmers** often purchase the equipment using **loans**. **To pay down the debt**, they **need to keep up production**, which usually **means irrigating**."*

[100] Stacey Vanek Smith, "The Twisty Logic Of The Drought: Grow Thirsty Crops To Dig Deeper Wells," *NPR All Things Considered*, 6 Aug. 2015, https://www.npr.org/2015/08/06/430077437/the-twisty-logic-of-the-drought-grow-thirsty-crops-to-dig-deeper-wells; Natasha Foote, "How to Plant, Grow, and Care for Almond Trees," *Gardener's Path,* 25 March 2023, https://gardenerspath.com/plants/nut-trees/growing-almonds/.

[101] Megan Myscofski, "Not Here for Some Agrarian Fantasy," *Arizona Public Media*, 25 July 2022, last updated 1 Aug. 2022, https://news.azpm.org/p/news-topical-nature/2022/7/25/211927-not-here-for-some-agrarian-fantasy/.

[102] Lindsay Wise, "5 Reasons Farmers Grow Thirsty Crops in Dry Climates," *Austin American-Statesman*, 23 Sept. 2016, last updated 25 Sept. 2018, https://www.statesman.com/story/news/2016/09/23/5-reasons-farmers-grow-thirsty-crops-in-dry-climates/10049886007/.

Recommendations

1. The agricultural industry needs to be educated and incentivized regarding growing native crops (i.e., farmers need to avoid planting water-thirsty crops in water-stressed regions). For example, an Arizona alfalfa and cotton farmer is learning to grow and develop a market for guayule (pronounced "why-YOU-lee"), a desert shrub plant that provides a natural rubber useful for latex and other similar products.[103,104]

2. The public must be educated on the water stress impact of their product choices. For example, if a reliable measure could be developed, that information could be added to food product labels.

3. The public should be incentivized to look more at the advantages of locally sourced foods, where possible, as well as at alternative sources of protein to aid in rebalancing the demand across protein choices. The cattle and dairy industry, however, should be supported through this transition, that is, in fairness to their business investment, both their financial and sweat equity. Support for this industry during this transition will bolster greater support and avoid blowback that could turn political, completely undermining such efforts. One way to improve incentivization is to use tokens layered on blockchain technology to open access to a broader population that wishes to participate in affecting such changes.[105]

4. Ways s to educate societies should be developed on how to improve the valuing of water and other environmental resources when analyzing the costs/benefit of growing a crop in a particular land. The intent is to improve the decision-making of crop selection with more accurate resource cost information.
5. Advanced moisture sensors should be paired with AI to improve water management system options.[106]

6. Alternative forms of irrigation should be considered, such as drip irrigation used in Israel to improve the water efficiency in plant growth, especially when paired with native crops.[107]

Technological Insights and Recommendations

This space is intentionally left blank to encourage technically oriented feedback for public Request for Input.

[103] USDA AgResearch, "Guayule Go Native With This Promising Biofuel—and Biomedical—Crop," Agricultural Research, Feb. 2009, https://agresearchmag.ars.usda.gov/2009/feb/biofuel.

[104] Joanna Allhands, "Pinal Farmers are Facing Water Shortages. Shouldn't They Be Growing Less Thirsty Crops?," *AZCentral*, 6 June 2021, https://www.azcentral.com/story/opinion/op-ed/joannaallhands/2021/06/06/bridgestone-guayule-effort-could-change-farming-amid-water-shortages/5255875001/.

[105] Joy Guo, "How Can Blockchain Open Access to Carbon Markets?," World Economic Forum, 28 July 2022, https://www.weforum.org/agenda/2022/07/how-can-blockchain-open-access-to-carbon-markets/.

[106] Evja provides solar-powered agriculture water management system. See https://www.evja.eu/#features.

[107] Stephen Smith and Samara Freemark, "Thirsty Planet—Israel: Using Technology, Engineering to Cut Reliance on Galilee," *APM Reports* (American Public Media), 12 May 2016, https://www.apmreports.org/story/2016/05/20/water-israel.

Case studies

1. Evidence exists that farmers are aware of this issue and are taking measures to address it. They are looking at farming crops natively resilient to the local climate extremes, and they are seeking a market for them. Farmers then become market-makers as opposed to merely growing crops in the most cost-effective manner to meet existing world consumer demand:[108]

   > "Some farmers are also starting to grow crops based not on what faraway foreign consumers already demand, but raising animals and crops which thrive on increasingly arid lands, and then create a demand for those commodities abroad."[109]

   Accelerating such activity requires more financial help that supports farmers in this pivot. Programs such as the Environmental Quality Incentives Program (EQUIP) aim to do just that with participation from the National Resource Conservation Stewardship (NRCS). Also, the United States has passed recent legislation to further encourage and support such endeavors by way of bill S.1251, the Growing Climate Solutions Act.[110]

2. Being an arid nation with a growing population in a warring region, Israel has had to learn to become self-sufficient with water. As a result, it has improved water reclamation from wastewater to upward of 85% and has learned to employ drip irrigation to enrich its agriculture.[111]

Further resources

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2. Oletic, Dinko, and Vedran Bilas. "How Thirsty the Crops Are: Emerging Instrumentation for Plant-Based Field Measurement of Water Stress." *IEEE Instrumentation & Measurement* 23, no. 2, Apr. 2020.

Qazi, Moin. "Water Crisis: Thirsty Crops Drain India Dry." *QRIUS*, 18 Mar. 2018. (Discusses water problems in India's agriculture.)

[108] Saul Elbein, "As Climate-Driven Drought Slams Farms in U.S. West, Water Solutions Loom," Mongabay, 17 Dec. 2021, https://news.mongabay.com/2021/12/as-climate-driven-drought-slams-farms-in-u-s-west-water-solutions-loom/.

[109] Elbein, "As Climate-Driven Drought Slams Farms in U.S. West, Water Solutions Loom."

[110] US Senate Bill S.1251, *Growing Climate Solutions Act*, https://www.congress.gov/bill/117th-congress/senate-bill/1251.

[111] Smith and Freemark, "Thirsty Planet—Israel."

Issue: Physical trash/plastics pollute freshwater ecosystems and plays a significant role in ecosystem degradation and destruction

Background

A steady stream of physical trash ends up in our rivers and lakes. A significant amount is generated by people's processes in disposing of end-use materials in their homes, such as plastic, cardboard, paper, building materials, abandoned items, and illegally dumped items.

Single-use plastics are a particularly toxic form of trash pollution. Unlike cardboard, paper, and many metals, their biodegradability has a particularly long lifespan. Additionally, they are often physically harmful to plants and animals.

The continuing single-use economy exacerbates the problem.[112]

Regional, cultural, and economic differences complicate things further, leading to the need for a multifaceted approach.

Recommendations

1. Transition from single-use resource economies to sustainable, regenerative, and circular economies appropriate for areas of differing physical, cultural, and economic development. Tactics for such a transition should be tailored to the specific physical, cultural, and economic context of each area and be based on strategies developed around education, local partnerships, policies and incentives, and research and development of technological solutions.

2. Populations should be educated globally and locally through primary, highly visible private, government, and media channels to change the principle worldview of societies.

Strategically, develop and improve waste disposal technologies that have a more modest impact on the air, land, and water environments.

Technological Insights and Recommendations

This space is intentionally left blank to encourage technically oriented feedback for public Request for Input.

Case studies

1. Three start-ups are taking different approaches to improving and protecting India's Ganga River water quality. One uses autonomous robot, or ro-boat, technology to monitor and clean the river surface waters. Another focuses on the capture and repurposing of the flower pollution contributed by the historical religious floating floral arrangements. Still another monitors the river bed pipeline using

[112] Plastic Action Centre, "Here's Where the World's Plastic Waste Will End Up, by 2050," https://plasticactioncentre.ca/directory/heres-where-the-worlds-plastic-waste-will-end-up-by-2050/.

ultrasound to alert whenever oil leaks are detected.[113]https://www.thebetterindia.com/81881/clean-ganga-innovative-technology-startup/

2. Balkan nations try yet struggle to coordinate the prevention of trash from entering shared waters. Oftentimes trash landfills are inappropriately located next to waterways, compounding the problem.[114]https://www.cbsnews.com/news/lake-of-garbage-serbia-balkans-pollution-landfills-water-eu/

3. Humpback whales and one of their food sources, Menhaden, have returned to the shores of New Jersey, a reflection of prior long-term policy-driven efforts to clean the waterways feeding the US coastal areas:[115]

   "There is still a lot of ongoing research to determine why they're here, but certainly we're seeing the long-term benefits of action taken in the 1970s like the Clean Water Act and the Marine Mammal Protection Act," said Brown, a Rutgers doctoral candidate and head researcher for the advocacy group Gotham Whale.

Further resources

1. American Rivers. "National River Cleanup."https://www.americanrivers.org/make-an-impact/national-river-cleanup/

2. Chesapeake Bay Foundation.https://www.cbf.org/join-us/more-things-you-can-do/12-things-you-can-do-to-clean.html"14 Things You Can Do to Clean Up Your Rivers, Streams, and the Chesapeake Bay."https://www.cbf.org/join-us/more-things-you-can-do/12-things-you-can-do-to-clean.html

3. **"**5 Technologies That Are Making Waste Disposal More Efficient." *SENSA Networks* (blog). 6 Nov. 2018.

4. Gergel, Igor. "Waste to Energy Technologies: Overview." Waste To Energy International, 19 May 2021. Antony, Anu. "What Are Some of the Latest Waste-to-Energy Technologies Available?" PreScouter, Oct. 2017.

5. Gray, Brian, Jennifer Harder, and Karrigan Bork. "Implementing Ecosystem-Based Management." *Duke Environmental Law & Policy Forum* 31 (2021).

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7. River Cleanup (website).

8. The Rivers Trust. "Cleaning Up Rivers."

9. US Department of Energy. "Waste-to-Energy." Department of Energy, Office of Energy Efficiency & Renewable Energy.

[113] Sanchari Pal, "How Three Startups Are Using Innovative Methods to Clean and Restore River Ganga", The Better India, 12 Jan. 2017, https://www.thebetterindia.com/81881/clean-ganga-innovative-technology-startup/.

[114] CBS News, "Lake of Garbage: Every Winter Pollution is Swept from Overflowing Landfills into Balkan Waterways," 26 Jan. 2021, https://www.cbsnews.com/news/lake-of-garbage-serbia-balkans-pollution-landfills-water-eu/.

[115] Scott Fallon, "Humpback Whales Continue Surprising Resurgence off NJ Shores." NorthJersey.com, 19 July 2022, https://www.northjersey.com/story/news/environment/2022/07/19/humpback-whale-sightings-continue-resurgence-in-new-york-bight-waters/65376083007/.

10. US Environmental Protection Agency (EPA). "Learn About Aquatic Trash." Trash-Free Waters. Last updated 31 Oct. 2022.
11. US Environmental Protection Agency (EPA). "Sustaining Healthy Freshwater Ecosystems." Watershed Academy. Last updated 7 Mar. 2023.
12. Water Detective. "How Can a River Clean Itself?"
13. Water Encyclopedia. "Pollution of Lakes and Streams." http://www.waterencyclopedia.com/Oc-Po/Pollution-of-Lakes-and-Streams.html
14. "Water Pollution: Everything You Need to Know." NRDC, 11 Jan. 2023.

Issue: Chemical and hazardous waste adversely affects river and lake ecosystems

Background

Hazardous waste from commercial and private sources adversely affects the world's river and lake ecosystems, leading to ecosystem degradation and destruction, loss of biodiversity, and increasing human food and water insecurity.

The US EPA characterizes hazardous waste threats according to four broad categories: ignitability, corrosivity, reactivity, and toxicity.[116]https://www.epa.gov/hw/defining-hazardous-waste-listed-characteristic-and-mixed-radiological-wastes"**Ignitable waste** can catch fire spontaneously or burn easily. Examples include charcoal lighter fluid, gasoline, kerosene, and nail polish remover. **Corrosive wastes** can cause a chemical action that eats away materials or living tissue. Battery acid is an example. **Reactive waste** can react with air, water, or other substances to cause rapid heating or explosions. Acids that heat up rapidly and spatter when mixed with water are examples. **Toxic wastes** can cause illness or death. Some such wastes are more dangerous than others. Exposure to a small concentration of a highly toxic chemical may cause symptoms of poisoning. Pesticides, cleaning products, paints, photographic supplies, and many art supplies are examples."[117]https://nasdonline.org/1436/d001236/disposal-of-hazardous-household-waste.htmlWaste with these characteristics is introduced into Earth's river and lake ecosystems from both commercial and private sources.

Commercial sources include manufacturing across a wide range of industries; mining activities[118]; commercial agriculture; and construction. Introduction of their hazardous waste byproducts into rivers and lakes results from inadequate disposal technology, water runoff, groundwater,[119]https://www.visualcapitalist.com/nasa-satellites-show-disturbing-trends-in-water-supply/acid rain, and illegal dumping.

Residential sources consist of the products consumers buy. Hazardous residue from these products enters rivers and lakes through runoff, groundwater, and illegal dumping.[120]https://www.nrdc.org/stories/water-pollution-everything-you-need-know

Management of hazardous wastes includes management at the source, disposal technologies, cleanup technologies, and infrastructure developments.

[116] US EPA, "Defining Hazardous Waste: Listed, Characteristic and Mixed Radiological Wastes," Hazardous Waste, https://www.epa.gov/hw/defining-hazardous-waste-listed-characteristic-and-mixed-radiological-wastes.

[117] National Ag Safety Database (NASD), "Disposal of Hazardous Household Waste," Clemson University Cooperative Extension Service, https://nasdonline.org/1436/d001236/disposal-of-hazardous-household-waste.html.

[118] Ecowatch, "Rivers, Lakes, and Oceans Poisoned with 180 Million Tons of Mine Waste Every Year," Deep Green Resistance News Service, https://dgrnewsservice.org.

[119] Jeff Desjardins, "NASA Satellites Show Disturbing Trends in Water Supply," Visual Capitalist, 22 June 2015, https://www.visualcapitalist.com/nasa-satellites-show-disturbing-trends-in-water-supply/.

[120] Melissa Denchak, "Water Pollution: Everything You Need to Know," NRDC, 11 Jan. 2023, https://www.nrdc.org/stories/water-pollution-everything-you-need-know.

Recommendations

1. Increase education around, and public exposure to, messaging regarding the environmental hazards of pouring oils, antifreeze, paint, solvents, cleaners, preservatives, and prescription drugs down household and storm drains.

2. The problem must be treated at the source, which is the most efficient means of dealing with hazardous waste. This approach includes employing disposal technologies, public education, and engagement.

3. Improve traditional disposal technologies such as landfills, incineration, and chemical treatment. Further technologies must be developed, such as bioremediation, encapsulation, plasma arc technologies, thermal desorption, ion exchange, and electrochemical remediation.

4. Groundwater and freshwater "friendly" infrastructure should be designed, such as inert permeable paving systems that manage surface runoff by allowing rainwater to be introduced into groundwater. Roads, driveways, sidewalks, and other urban infrastructure can be developed that allow for more direct introduction of rainwater into groundwater. Current concrete production has a high carbon footprint cost. Asphalt paving is fossil oil and gas resource intensive. Both additionally channel various forms of pollution into freshwater ecosystems: https://www.visualcapitalist.com/sp/the-road-to-decarbonization-how-asphalt-is-affecting-the-planet/

Technological Insights and Recommendations

This space is intentionally left blank to encourage technically oriented feedback for public Request for Input.

Case studies

1. A Japanese-Peruvian man found a way to clean up polluted lakes using a microbubble solution that attracts viruses and bacteria.[121]

2. "Case Studies in Groundwater Contaminant Fate and Transport" is a collection of case studies that focuses on "natural processes that control the fate and transport of contaminants in groundwater rather than on active remediation methods."[122]

3. A paper, "The impacts of waste dumping in Lake Malawi" reveals "the challenges and dangers that occur due to waste dumping globally and how individuals, water species and even the water itself are affected." This is about an important lake in the African nation, the Republic of Malawi. It considers local context, sharing "what the local inhabitants are saying about this issue, and their recommendations for improving the condition of the lake."[123]

[121] "A Man From Peru Has Found an Ingenious Way to Clean Lakes, and It's a Breakthrough the Earth Was Crying For," Bright Side, 30 March 2019, https://brightside.me/wonder-people/a-man-from-peru-has-found-an-ingenious-way-to-clean-lakes-and-its-a-breakthrough-the-earth-was-crying-for-719560/.

[122] Barbara Bekins, "Case Studies in Groundwater Contaminant Fate and Transport", *Oxford Bibliographies*, 26 April 2018, https://www.oxfordbibliographies.com/display/document/obo-9780199363445/obo-9780199363445-0096.xml.

[123] Lewis Tsuro, "The Impacts of Waste Dumping in Lake Malawi," *ResearchGate*, 7 May 2021, https://www.researchgate.net/publication/351441045_The_impacts_of_waste_dumping_in_Lake_Malawi.

4. The National Oceanic and Atmospheric Administration (NOAA) runs a Damage Assessment, Remediation, and Restoration Program (DARRP) wherein they publicly share documented activity of projects. In this example, "Lower Duwamish River", DARRP information is being shared about the progress in the cleanup of the Lower Duwamish River in Seattle, Washington, USA.[124]

Further resources

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3. National Ocean and Atmospheric Administration (NOAA), Damage Assessment, Remediation, and Restoration Program (DARP). "Hazardous Waste." Last updated 27 Apr. 2023.https://darrp.noaa.gov/hazardous-waste

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[124] "Lower Duwamish River," NOAA Damage Assessment, Remediation, and Restoration Program, last updated Jan. 2023, https://darrp.noaa.gov/hazardous-waste/lower-duwamish-river.

Issue: Raw human sewage pollution causes degradation of river and lake ecosystems

Background

While land and water can naturally treat sewage, everything has a capacity. Where humans have concentrated in growing population areas, if no separate sewage treatment mechanisms are in place, then the nearby natural waterways are likely polluted with human sewage.

Sewage from outdated treatment plants and growing populations pollutes rivers and lakes worldwide.[125] Medicines, household cleaners, biologic waste, and a host of other pollutants make their way into water supplies, damaging ecosystems and threatening public health. Changing or conflicting policies exacerbate the problem.[126] Climate change only worsens the problem.[127]

Recommendations

1. Public awareness and education are needed. https://www.sas.org.uk/water-quality/

2. Infrastructure must be rebuilt in light of local climate change parameters/forecasts.

3. Advanced filtration technologies are required, such as a membrane bioreactor, a moving bed biofilm reactor, integrated fixed-film activated sludge, granulated activated carbon, and oxonation.

Technological Insights and Recommendations

This space is intentionally left blank to encourage technically oriented feedback for public Request for Input.

Case studies

1. Grassroots UK organization, "Surfers Against Sewage" education programs that not only teach sustainable practices but also teach-the-teacher.[128]From a handful of activists to a nationwide movement…over the last 30 years Surfers Against Sewage has grown into one of the UK's most successful marine conservation and campaigning charities.

2. Don't Flush that campaign.[129]"WEF members work to solve non-dispersibles problem. Perpetrators mucking up the system are known as "non-dispersibles," which currently means anything other than human waste and toilet paper that's flushed down the toilet…"

[125] American Rivers, "How Sewage Pollution Ends Up In Rivers," https://www.americanrivers.org/threats-solutions/clean-water/sewage-pollution/.

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Further resources

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6. Seametrics. "15 Interesting Facts About Water Pollution That You Should Know."

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Issue: Invasive species threaten freshwater ecosystems

Background

Invasive species are "non-native (or alien) to the ecosystem under consideration and … introduce causes or are likely to cause economic or environmental harm or harm to human health."[130] River and lake ecosystems are being threatened by invasive species because of the climate changing and human introduction of non-native species. These invasive species in some cases thrive due to being introduced into an ecosystem with no predators along with a substantial source of accessible food allowing them to prosper and outcompete other species.

With warmer temperatures in rivers and lakes, the native species are shifting and migrating to cooler environments, and they are being replaced by invasive species that can better adapt to the warmer water. These invasive species pose serious challenges to the entire ecosystem. Furthermore, the native species that cannot move to tolerable areas face extinction.

Recommendations

1. Create strategies to prevent the introduction of invasive species because "once invasive species become established and spread, it can be extraordinarily difficult and costly to control or eradicate them."[131] To do this, preventive measures should be deployed such as:

    a. Enforcing strict boat cleaning rules at boat ramps and docks preventing species from transferring from one body of water to another
    b. Educating fisherman on releasing live bait into bodies of waters
    c. "Creat[ing] monitoring systems for detecting new infestations"[132]

2. Use scientifically defensible methods to identify species at high risk of becoming invasive species, with a specific focus on those who import fish or plant species for home aquarium use. Policies and methods are needed to prevent accidental introduction of such species into river and lake ecosystems.[133]

3. Preventative measures should be focused on waterway connections.[134] "The places where waterways connect are vulnerable to the movement of aquatic invasive species. Both natural and artificial connections pose a risk for the transmission of such species. "By focusing on these connections, we can protect them and stop the two-way movement of aquatic and invasive species."[135]

4. When preventative strategies are not effective, mitigation and removal strategies should be employed, such as:

[130] USDA National Invasive Species Information Center, "What Are Invasive Species?," About Invasive Species, https://www.invasivespeciesinfo.gov/what-are-invasive-species.

[131] National Wildlife Foundation, "Combatting Invasive Species." https://www.nwf.org/Our-Work/Environmental-Threats/Invasive-Species.

[132] National Wildlife Foundation, "Combatting Invasive Species."

[133] The Nature Conservancy, "Great Lakes Aquatic Invasive Species," https://www.nature.org/en-us/about-us/where-we-work/priority-landscapes/great-lakes/great-lakes-aquatic-invasive-species-/.

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[135] The Nature Conservancy, "Great Lakes Aquatic Invasive Species."

a. Moving rapidly to remove newly detected invasive species[136]
b. Encouraging mitigation strategies like the hunting/harvesting of non-native species

5. Public education campaigns about the problem of invasive species are crucial as the public can help. Campaigns like "Don't move a mussel" should be considered. Such a campaign includes "general information and outreach materials to increase awareness of invasive species issues."[137] In addition to using billboards, technology may be employed to help through online and social media campaigns.

6. Remote-sensing technology (from an airplane) could determine the potential effects and locations of invasive species.[138]

Technological Insights and Recommendations

This space is intentionally left blank to encourage technically oriented feedback for public Request for Input.

Case studies

1. Care should be taken on introducing new species while trying to control non-native species growth. "Understanding population-level responses to removal and immigration rates are essential aspects of invasive species management."[139]

2. A report from the Michigan Natural Features Inventory demonstrates success of early detection and subsequent removal in minimizing the impact of the invasive phragmites on Beaver Island in Lake Michigan.[140]

Further resources

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3. "Keeping Shoreland Lakes Free of Invasive Species." University of Minnesota Extension. Reviewed 2018.

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[138] Lake George Association, "Invasive Species are Challenging our Water Quality and Landscape," https://www.lakegeorgeassociation.org/act-now/stop-invasive-species.

[139] M. J. Weber, M. J. Hennen, M. L. Brown, D. O. Lucchesi, and T. R. S. Sauver, "Compensatory Response of Invasive Common Carp Cyprinus carpio to Harvest, Fisheries Research," 10 Mar. 2016, retrieved 20 Aug. 2022, https://www.sciencedirect.com/science/article/pii/S0165783616300546.

[140] P. J. Higman, H. D. Enander, D. A. Hyde, P. J. Badra, and K. M. Korroch, *Examples of Case Studies for Invasive Species Action—Michigan's Great Lakes Islands*, Michigan Natural Features Inventory, Michigan State University, *MNFI Report Number 2019-19*, 2019, https://mnfi.anr.msu.edu/reports/MNFI-Report-2019-19.pdf.

5. Owens, Brian. "AI Technology Could be Used to Monitor Invaders in the Great Lakes." Great Lakes Now, 24 May 2022.

6. Sackett, Heather. "Declining Levels at Lake Powell Increase Risk to Humpback Chub Downstream." *Aspen Journalism*, 13 June 2022.

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