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IEEE planet positive 2030

Strong Sustainability by Design

PRIORITIZING ECOSYSTEM AND HUMAN FLOURISHING WITH TECHNOLOGY-BASED SOLUTIONS

CASE STUDIES BY CHAPTER

An initiative supported by the IEEE Standards Association

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Strong Sustainability by Design

This Compendium has been created by committees of the IEEE Planet Positive 2030 Initiative supported by the IEEE Standards Association (IEEE SA). The IEEE 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 seventy members of this community from about thirty countries have contributed directly to this Compendium and have worked to identify and find consensus on timely issues.

The Compendium's purpose is to identify specific issues and 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 GHG emissions by 2030.
- Significantly increase regeneration and resilience of the Earth's ecosystems.
- Be well on the path to achieving net zero GHG emissions by 2050 and negative GHG emissions beyond 2050.
- Continue to widely deploy appropriate 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 Compendium:

- Provides a scenario-based challenge (how to achieve "Planet Positivity by 2030") as a tool to inspire readers to get engaged.
- Advances a public discussion about how to build from a "Net Zero" mentality to a "Net or Planet Positive" ("do more good," that is, doing "more" than "don't harm") societal mandate for all technology and policy.
- Continues to build a diverse and inclusive community for the IEEE Planet Positive 2030 Initiative, prioritizing the voices of indigenous and marginalized members whose insights are acutely needed to help make technology and other solutions more valuable for all. Of keen interest is how to encourage more in-depth participatory design in these processes.
- Inspires the creation of technical solutions that can be developed into technical recommendations (for example IEEE SA recommended practice for addressing sustainability, environmental stewardship and climate change challenges in professional practice, IEEE P7800™) and associated certification programs.
- Facilitates the emergence of policies and recommendations that could potentially be intraoperative between different jurisdictions (e.g., countries).

By inviting the general public to read and utilize *Strong Sustainability by Design*, the IEEE Planet Positive 2030 community provides the opportunity to bring multiple voices from the related scientific and engineering communities together 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. You are invited to Join related IEEE activities, such as standards development and initiatives across the organization.

- For further information, learn more at the IEEE Planet Positive 2030 Initiative website
- Get in touch at: PlanetPositive2030@ieee.org to get connected to and engaged with the IEEE Planet Positive 2030 community.
- Please, subscribe to the IEEE Planet Positive 2030 newsletter here.

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

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

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Strong Sustainability by Design was created in two versions ("draft" and this current edition) that were iterated over the course of two years. The IEEE Planet Positive 2030 Initiative follows a specific consensus building process where members contributing content identify specific potential issues and proposed recommendations.

Membership

IEEE Planet Positive 2030, 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 four hundred experts involved, and remains eager for new voices and perspectives to join in this work.

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STRONG SUSTAINABILITY BY DESIGN: PRIORITIZING ECOSYSTEM AND HUMAN FLOURISHING WITH TECHNOLOGY-BASED SOLUTIONS

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CASE STUDIES BY CHAPTER

Chapter 1: Guiding Principles

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Guiding Principle 1: Responsible and ethical leadership from governments, individuals, businesses, organizations, academic institutions, and communities

Case studies

1. Engineering Change Lab—USA

   According to Engineering Change Lab—USA, there are two key elements to the leadership imperative:

   a. Stepping up to leadership roles:

      - Communicating, connecting, convening, and caregiving
      - Challenging the status quo and catalyzing change
      - When necessary, taking the heat and holding steady

   b. Building bridges:

      - Collaborating across disciplines and with all other stakeholders
      - Proactively reaching out across divides and between factions
      - Managing polarities and resolving conflicts
      - Committing to an open-source ideology that also recognizes sources
      - Maintaining cultural awareness and empathy

Guiding Principle 2: Justice, diversity, equity, and inclusion

Case studies

1. Co-Designing Climate Services to Integrate Traditional Ecological Knowledge: Bali, Indonesia

   Biskupska, Natalia, and Albert Salamanca. *Co-Designing Climate Services to Integrate Traditional Ecological Knowledge: A Case Study for Bali, Indonesia*. Stockholm: Stockholm Environment Institute, Oct. 2020.

2. Climate Justice Case Studies

   Second Nature. "Climate Justice Case Studies." Accessed 15 Jan. 2023.

Guiding Principle 3: Global energy systems transformation

Case studies

1. Blind Spots in Energy Transition Policy: Case Studies from Germany and USA

   Elshurafa, Amro M., Hind M. Farag, and David A. Hobbs. "Blind Spots in Energy Transition Policy: Case Studies from Germany and USA." Energy Reports 5 (Nov. 2019): 20–28.

2. Japan's Resilient, Renewable Cities

   Fraser, Timothy. "Japan's Resilient, Renewable Cities: How Socioeconomics and Local Policy Drive Japan's Renewable Energy Transition." *Environmental Politics* 29, no. 3 (17 Mar. 2017): 500–523.

3. Renewable Energy Transition in the Caribbean

   Harrison, Conor. "Geographies of Renewable Energy Transition in the Caribbean: Reshaping the Island Energy Metabolism." *Energy Research & Social Science* 36 (Feb. 2018): 165–174.

4. Renewable Energy Cooperatives, Rotterdam, The Netherlands

   Hentschel, Moritz, Wolfgang Ketter, and John Collins. "Renewable Energy Cooperatives: Facilitating the Energy Transition at the Port of Rotterdam." *Energy Policy* 121 (Oct. 2018): 61–69.

5. A Multiple Case Study on the German Energy Transition

   Lutz, Lotte Marie, Lisa-Britt Fischer, Jens Newig, and Daniel Johannes Lang. "Driving Factors for the Regional Implementation of Renewable Energy: A Multiple Case Study on the German Energy Transition." *Energy Policy* 105 (June 2017): 136–147.

6. Contributions from Community Sustainable Energy Transitions in Thailand and the Philippines

   Marquardt, Jens. "Reimagining Energy Futures: Contributions from Community Sustainable Energy Transitions in Thailand and the Philippines." *Energy Research & Social Science* 49 (Mar. 2019): 91–102.

7. Public Participation in Renewable Energy Transitions, India

   Pandey, Poonam, and Aviram Sharma. "Knowledge Politics, Vulnerability and Recognition-Based Justice: Public Participation in Renewable Energy Transitions in India." *Energy Research & Social Science* 71, art. 101824 (Jan. 2021).

8. Renewable Energy and Transition-Periphery Dynamics, Scotland

   Robertson Munro, Fiona. "Renewable Energy and Transition-Periphery Dynamics in Scotland." Environmental Innovation and Societal Transitions 31 (June 2019): 273–281.

9. Clean Energy Transition of Heating and Cooling in Touristic Infrastructures Using Shallow Geothermal Energy, Canary Islands

   Santamarta, Juan C., Alejandro Garca-Gíl, María del Cristo Expósito, Elías Casañas, Noelia Cruz-Pérez, Jesica Rodríguez-Martín, Miguel Mejías-Moreno, et al. "The Clean Energy Transition of Heating and Cooling in Touristic Infrastructures Using Shallow Geothermal Energy in the Canary Islands." *Renewable Energy* 171 (June 2021): 505–515.

10. Energy Poverty and Low Carbon Just Energy Transition, Lithuania, Greece

    Streimikiene, Dalia, Grigorios L. Kyriakopoulos, Vidas Lekavicius, and Indre Siksnelyte-Butkiene. "Energy Poverty and Low Carbon Just Energy Transition: Comparative Study in Lithuania and Greece." *Social Indicators Research 1*58 (Apr. 2021): 319–371.

Guiding Principle 5: The regenerative imperative and a circular economy

Case studies

1. Singapore Turns Sewage into Clean, Drinkable Water, Meeting 40% of Demand

   "The tiny island nation has little in the way of natural water sources and has long had to rely principally on supplies from neighboring Malaysia. To boost self-sufficiency, the government has developed an advanced system for treating sewage involving a network of tunnels and high-tech plants."

   Agence France-Presse. "Singapore Turns Sewage into Clean, Drinkable Water, Meeting 40% of Demand." VOA News. 10 Aug. 2021.

2. Zero-Waste Communities Across the Globe

   "Eight cities in Asia, Europe, and North and South America, along with four online communities, showcase approaches to zero waste."

   "Zero Waste Communities Across the Globe." *Zero Waste* (blog). 3 Mar. 2021.

3. Nine Examples That the Transition to a Regenerative Economy is Underway

"Southface Institute has created the following series of case studies to share success stories from regenerative economy pioneers. Each case study examines its subject through the interdependent lenses of the natural environment, the social environment and the built environment."

Shea, Bailey, and Shane Totten. "Nine Examples That the Transition to a Regenerative Economy is Underway." *Southface Institute* (blog). 23 Mar. 2021.

4. 9 Ways to Create a Local Regenerative Economy

   "Nine steps towards creating decentralized cooperative local economies that emphasize local production with local resources to meet local needs to build local wealth."

   Bjonnes, Roar. "Nine Ways to Create a Local Regenerative Economy." Shareable, 11 Aug. 2021.

5. Achieving One-Planet Living Through Transitions in Social Practice: A Case Study of Dancing Rabbit Ecovillage

   "This article examines DR's extraordinary energy and resource savings through the lens of social practice theory, which focuses on the meanings, competencies, and materials that individuals combine to form everyday practices."

   Boyer, Robert H. W. "Achieving One-Planet Living through Transitions in Social Practice: A Case Study of Dancing Rabbit Ecovillage." *Sustainability: Science, Practice and Policy* 12, no. 1 (2016): 47–59.

6. The EU's New Digital Product Passport

   The EU's new Digital Product Passport *"will provide information about products' environmental sustainability. This information will be easily accessible by scanning a data carrier and it will include attributes such as the durability and reparability, the recycled content or the availability of spare parts of a product. It should help consumers and businesses make informed choices when purchasing products, facilitate repairs and recycling and improve transparency about products' life cycle impacts on the environment. The product passport should also help public authorities to better perform checks and controls"*

   European Commission. "Ecodesign for Sustainable Products Regulation." Energy, Climate Change, Environment; Standards, Tools and Labels; Products, Labeling Rules and Requirements; Sustainable Products.

7. Circular Economy of digital devices

   The APC's "Guide to the Circular Economy of Digital Devices" includes the right to repair.

   Association for Progressive Communications (APC). "A Guide to the Circular Economy of Digital Devices."

Guiding Principle 6: Balance between today's needs and the needs of the future

Case studies

1. Balancing Socioeconomic Development with Ecological Conservation towards Rural Sustainability, China

   Li, Qirui, Hua Ma, Zhuqing Xu, Hao Feng, and Sonoko D. Bellingrath-Kimura. "Balancing Socioeconomic Development with Ecological Conservation towards Rural Sustainability: A Case Study in Semiarid Rural China." *International Journal of Sustainable Development & World Ecology* 29, no. 3 (Oct 2021): 246–262.

2. Quantifying the Sustainability of Water Use Systems: Calculating the Balance between Network Efficiency and Resilience

   Li, Y., and Z. F. Yang. "Quantifying the Sustainability of Water Use Systems: Calculating the Balance between Network Efficiency and Resilience." *Ecological Modelling* 222, no. 10 (May 2011): 1771–1780.

3. Sustainable Linear Infrastructure Route Planning Model to Balance Conservation and Socioeconomic Development

   Wu, Shuyao, and Binbin V. Li. "Sustainable Linear Infrastructure Route Planning Model to Balance Conservation and Socioeconomic Development." *Biological Conservation* 266, art. 109449 (Feb. 2022).

Guiding Principle 7: Alignment of global goals with local goals and actions

Case studies

1. Interconnected Place-Based Social–Ecological Research

   Balvanera, Patricia, Rafael Calderón-Contreras, Antonio J. Castro, María R. Felipe-Lucia, Ilse R. Geijzendorffer, Sander Jacobs, Berta Martín-López, et al. "Interconnected Place-Based Social–Ecological Research Can Inform Global Sustainability." *Current Opinion in Environmental Sustainability* 29 (Dec. 2017): 1–7.

2. Stockholm Royal Seaport

   Holmstedt, Louise, Nils Brandt, and Karl-Henrik Robèrt. "Can Stockholm Royal Seaport be Part of the Puzzle towards Global Sustainability? — From Local to Global Sustainability Using the Same Set of Criteria." *Journal of Cleaner Production*140 (Jan. 2017): 72–80.

3. Systems Integration for Global Sustainability

   Liu, Jianguo, Harold Mooney, Vanessa Hull, Steven J. Davis, Joanne Gaskell, Thomas Hertel, Jane Lubchenco, et al. "Systems Integration for Global Sustainability." *Science* 347, no. 6225 (Feb. 2015).

4. Earth System Science for Global Sustainability: Grand Challenges

Reid, Walter V., Davidson Chen, Leah Goldfarb, Heide Hackmann, Yuan-Tseh Lee, Khotso Mokhele, et al. "Earth System Science for Global Sustainability: Grand Challenges." *Science* 330, no. 6006 (Nov. 2010): 916–917.

5. Community Networks

   Munshi, Kaivan. "Community Networks and the Process of Development." *Journal of Economic Perspectives* 28, no. 4 (Fall 2014):49-76.

   Clark, A. "Understanding Community: A Review of Networks, Ties and Contacts." ESRC National Centre for Research Methods, 2007.

Guiding Principle 8: Culture of sustainability

Case studies

1. Corporate Mission Statements

   There are many corporations with inspiring mission statements including sustainability, climate change, biodiversity and/or other similar goals.

2. Finland's Plans: It Aims to be Net Zero by 2035 and Net Negative by 2040

   Lo, Joe. "Finland Sets World's Most Ambitious Climate Target in Law." *Climate Home News*, 31 May 2022.

3. "Aiming for Sustainability Isn't Good Enough—The Goal Is Much Higher"

   Former CEO Paul Polman Says "Aiming for Sustainability Isn't Good Enough—The Goal Is Much Higher". Companies should "take responsibility for that total impact in the world. I call it the total handprint, all consequences intended or not."

   Polman, Paul. "Former Unilever CEO Paul Polman Says Aiming for Sustainability Isn't Good Enough—The Goal is Much Higher." By Adi Ignatius. *Harvard Business Review,* 19 Nov. 2021.

4. How to Make Supply Chains/Systems More Sustainable

   "More intractable sources of a company's carbon footprint, Scope 3 emissions, include everything outside of direct operations, such as travel, waste, and supplies."

   Lapan, Tovin. "How Salesforce Wants to Make Its Supply Chain More Sustainable." *Fortune*, 22 June 2021.

5. Carbon Emissions

   McKibben, Bill. "Could Google's Carbon Emissions Have Effectively Doubled Overnight?" *The New Yorker*, 20 May 2022.

6. IoT Emissions

   Freedman, Andrew. "First Look: Salesforce Teams Up with AT&T to Cut Emissions." *Axios*, 23 June 2022.

7. The World's Most Sustainable Companies

Annual rankings since 2007 by Corporate Knights

Mc Carthy, Shawn. "The Global 100 List: How the World's Most Sustainable Corporations Are Driving the Green Transition." Corporate Knights, 17 Jan. 2024.

Guiding Principle 9: Responsible use of technology and technology labeling

Case studies

1. Drug/Pharmaceutical Labels

   Drug labels came into widespread use in the 1800s. Early pharmacy labels can be found on the website of the Bristol-Myers Squibb European Apothecary here and the AIHP "History of Drug Containers and Their Labels here.

   Wallace Janssen discusses the history of US laws regarding the Food and Drug Act of 1906.

   > *"The United States was slow to recognize the need for a national food and drug law. Frederick Accum's "Treatise on Adulterations of Food and Methods of Detecting Them" had been published in London and Philadelphia in 1820, and Great Britain's first national food law was passed in 1860. A variety of U.S. state laws dated from colonial times." (Janssen, Wallace F. "The Story of the Laws Behind the Labels." FDA Consumer. June 1981. page 1.) "Changes from an agricultural to an industrial economy had made it necessary to provide the rapidly increasing city population with food from distant areas. But sanitation was primitive compared to modern standards".*

   Janssen, Wallace F. "The Story of the Laws Behind the Labels." FDA Consumer, June 1981, pg. 3.

2. The 1962 drug amendments

   > *"The Drug Amendments of 1962, passed unanimously by the Congress, tightened control over prescription drugs, new drugs, and investigational drugs. It was recognized that no drug is truly safe unless it is also effective, and effectiveness was required to be established prior to marketing—a milestone advance in medical history. Drug firms were required to send adverse reaction reports to FDA, and drug advertising in medical journals was required to provide complete information to the doctor—the risks as well as the benefits."*

   Janssen, Wallace F. "The Story of the Laws Behind the Labels." FDA Consumer, June 1981, pg. 12.

3. Vehicle Information Labels

   Vehicle information labels in the United States include the 17-digit vehicle identification number (VIN) and also some or all of these: the vehicle emissions label, the certification (safety) label, tire information label, service parts identification label, air-conditioning label, coolant label, and belt routing diagram.

   U.S. Tape & Label (USTL). "The Complete Guide to Automotive Labels."

   Tiberio, Guy. "Vehicle Information Labels: The Stickers You Need to Know!" Slide Presentation.

4. The Trend Toward Prevention

   One theme in the FDA's history is the change from primarily "criminal statute—protecting consumers through the deterrent effect of court proceedings—to" laws that are primarily "*preventive,"* including "informative regulations and controls before marketing" can begin. "The laws requiring approval" before marketing formed important changes in the FDA's methods regulating food and drugs in the United States (www.fda.gov). "They specifically required the agency to issue regulations explaining the requirements and procedures. The 1962 Drug Amendments" (see above) "called for current good manufacturing practice" (GMP) "regulations to set standards for plant facilities, maintenance," and l"aboratory controls," and to help "prevent errors or accidents" that "could harm consumers." In 1969, the first GMPs for food establishments were issued based on actual industry practices.

   Janssen, Wallace F. "The Story of the Laws Behind the Labels." FDA Consumer, June 1981.

5. Nutrition Labels

   The Nutrition Labeling and Education Act of 1990 (NLEA) "marked the culmination of a groundbreaking effort to provide information on food labels to help consumers make better choices and encourage food companies to produce healthier food." "The NLEA required food packages to contain a detailed, standardized nutrition facts label with information such as: serving size; the number of calories; grams of fat and saturated fat; total carbohydrate, fiber, sugars, and protein; milligrams of cholesterol and sodium; and certain vitamins and minerals." The 2020 Nutrition Facts label required "the largest food manufacturers (those with over $10 million in annual food sales) to use the revised label after the U.S. FDA announced an extension to its 27 May 2016 final rule."

   Food Insight. "The Nutrition Facts Label: Its History, Purpose and Updates." Food Insight (website). 9 Mar. 2020.

   Greenberg, Eric F. "The Changing Food Label: The Nutrition and Education Act of 1990." *Loyola Consumer Law Review* 3, no. 1 (1990).

   U.S. Food and Drug Administration (FDA). *FDA Extends Nutrition Facts Label Compliance Dates*. 3 May 2018.

   U.S. Food and Drug Administration (FDA). *FDA in Brief: FDA Issues Final Rule to Extend Compliance Date on Updated Nutrition Facts Label and Serving Size Rules to Allow Industry More Time to Make Required Changes.* 3 May 2018.

   U.S. Food and Drug Administration (FDA). *Food Labeling: Revision of the Nutrition and Supplement Facts Labels*. FDA-2012-N-1210-0875. 21 CFR Part 101. 27 May 2016.

Chapter 4: Global Methodologies

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Issue 5: Lack of linking and mapping

Case Studies

1. US Climate Change Dashboard

   US government dashboard application CMRA (Climate Mapping for Resilience and Adaptation) that integrates information from across the federal government to help people learn about climate-related hazards: CMRA home site.

   a. Case studies listed at CMRA site
   b. Open data at CMRA site.
   c. Southwest Sky Islands case sample
   d. Bracing for Heat case example

Chapter 5: Forests and Trees

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Issue 1: Deforestation and forest degradation are key drivers in the climate crisis

Case studies

1. Deforestation in the Amazon Rainforest

   The Amazon rainforest is the largest rainforest in the world and plays a critical role in regulating the global climate by absorbing carbon dioxide from the atmosphere. However, deforestation in the Amazon has been occurring at an alarming rate, with an estimated 17% of the forest area lost in the past 50 years. This deforestation is largely driven by cattle ranching, soybean farming, and logging and has led to significant carbon emissions, loss of biodiversity, and changes in regional weather patterns.

   One example of the impact of deforestation in the Amazon is the severe drought that occurred in 2005. Researchers found that the loss of vegetation due to deforestation reduced the amount of water released into the atmosphere through evapotranspiration, leading to a reduction in rainfall and an increase in temperature. This feedback loop resulted in a severe drought that affected millions of people and caused economic losses of over $3 billion (Saatchi et al., 2012).

2. Forest Degradation in Indonesia

   Indonesia is home to some of the world's most biodiverse forests, but the country has been experiencing rapid forest degradation due to illegal logging and conversion of forests for palm oil plantations. Forest degradation refers to the gradual decline in the quality of forest ecosystems, which can lead to a loss of biodiversity, carbon emissions, and changes in local climate patterns.

   In Indonesia, forest degradation has led to the loss of critical habitats for endangered species such as orangutans and tigers. Additionally, the conversion of forests for palm oil plantations has resulted in significant carbon emissions, as well as air and water pollution. The impact of forest degradation is not limited to Indonesia, as the country is a major exporter of palm oil and the demand for this commodity has contributed to deforestation and forest degradation in other countries as well (Riyou, 2016).

3. Deforestation in the Congo Basin

   The Congo Basin is the second-largest tropical forest in the world, and its forests play a crucial role in regulating the global climate by storing large amounts of carbon. However, deforestation in the region has been occurring at an alarming rate, with an estimated 4.3 million hectares lost between 2000 and 2014. The main drivers of deforestation in the Congo Basin are agriculture, logging, and mining.

One example of the impact of deforestation in the Congo Basin is the loss of habitat for endangered species such as gorillas and elephants. Additionally, deforestation has led to soil erosion, reduced water quality, and changes in local climate patterns. The loss of forest cover also has significant implications for the livelihoods of local communities who rely on the forest for food, medicine, and other resources (Tchatchou, 2015).

Issue 2: There is no assignment of value for the existence of nature

Case studies

1. Costa Rica's Payments for Environmental Services Program

   Costa Rica's payments for environmental services (PES) program (PAS in Spanish) is a nature-based solution that provides financial incentives to landowners who engage in conservation efforts. Under the program, landowners receive payments for preserving forests, protecting watersheds, and other conservation activities. The program has been highly successful, with over 1.2 million hectares of forest protected since its implementation in 1997.

   The PES program has had a significant impact on forest conservation in Costa Rica, helping to reduce deforestation rates from 4% in the 1980s to less than 1% in the early 2000s. Additionally, the program has provided economic benefits to rural communities, creating jobs in the forestry and conservation sectors and promoting sustainable tourism (UNFCCC, 2023).

2. China's Giant Panda Conservation Program

   China's giant panda conservation program is a nature-based solution that has helped to protect and restore critical habitat for the endangered giant panda. The program involves the restoration of degraded forests and the creation of wildlife corridors to connect isolated panda populations.

   The program has had a significant impact on the conservation of giant pandas, with the population increasing from just over 1,000 in the 1970s to over 1,800 today. Additionally, the program has promoted sustainable tourism, providing economic benefits to local communities (Hua Xia, 2023).

3. The US Great Lakes Restoration Initiative

   In the United States, the Great Lakes Restoration Initiative is a nature-based solution that aims to restore and protect the Great Lakes ecosystem, including its forests, wetlands, and coastal habitats. The program involves a range of activities, including the restoration of degraded wetlands, the control of invasive species, and the reduction of nutrient pollution.

   The program has had a significant impact on the Great Lakes ecosystem, helping to reduce the harmful algal blooms that have plagued the region in recent years. Additionally, the program has provided economic benefits to local communities, promoting tourism and creating jobs in the conservation and restoration sectors (NOAA Fisheries, 2024).

4. Brazil's Forest Code

   Brazil's Forest Code is a nature-based solution that regulates the use and protection of forests in the country. The code requires landowners to maintain a certain percentage of their land as forest and establishes protections for sensitive areas such as riverbanks and hilltops.

   The Forest Code has had a significant impact on forest conservation in Brazil, helping to reduce deforestation rates in the Amazon region. Additionally, the code has provided economic benefits to rural communities, promoting sustainable agriculture practices and creating jobs in the forestry and conservation sectors. However, enforcement of the code has been challenging, and there have been concerns about the impact of recent changes to the code that have weakened some of its protections (Chiavari & Leme Lopes, 2015).

Issue 3: The sudden death of forests from infectious diseases is a major concern in the management and conservation of forests worldwide

Case studies

The state of California and the USDA (with the help of the Department of Homeland Security and the US Customs and Border Protection) are vigilant to limit the influx of infection vectors. Dutch elm disease, which affects species in the genera *Ulmus* and *Zelkova,* was a major challenge in northeastern North America (US/Canada) more than 40 years ago. Another pest is the spruce budworm.

1. Budworm

   "Budworm outbreaks can have significant economic impacts on the ***forestry*** *industry. As a result, the eastern spruce budworm is considered one of the most destructive forest pests in North America, and various methods of control are utilized. However, the species is also ecologically important, and several bird species are specialized on feeding on budworms during the breeding season."* (Schadel et al., 2020; Wikipedia, "Choristoneura fumiferana")

2. Asian Citrus Psyllid

   Citrus trees are also victims of Asian Citrus Psyllid (ACP), which can spread very fast from infected trees to healthy ones by the psyllid (USDA, 2024).

3. Dutch Elm Disease

   Dutch elm disease is caused by a fungus and affects elm trees. It was first identified in the Netherlands in the early 1900s and has since spread throughout Europe and North America. The disease is spread by bark beetles and can kill a tree within one to three years of infection. It has had a significant impact on elm tree populations, particularly in urban areas (Potter et al, 1966).

4. Chestnut Blight

   Chestnut blight is caused by a fungus and affects American chestnut trees. The disease was introduced to North America in the late 1800s and has since spread throughout the range of the

American chestnut. The fungus infects the bark of the tree and can kill a tree within a few years of infection. The loss of American chestnut trees has had a significant impact on forest ecosystems and the many ecological, economic, and social benefits they provide (Rigling, 2018).

5. Ash Dieback

   Ash dieback is caused by a fungus and affects ash trees. The disease was first identified in Poland in the early 1990s and has since spread throughout Europe. The disease is spread by wind-borne spores and can cause significant damage to ash tree populations. In some areas, up to 90% of ash trees have been killed by the disease (Klesse et al., 2021).

Issue 4: Global reforestation potential has a large and cost-effective mitigation potential when done right

Case studies

1. The REDD+ Program in Brazil

   The REDD+ program in Brazil has been successful in reducing deforestation rates in the Brazilian Amazon. According to a study by the Center for Global Development, the program led to a 70% reduction in deforestation in the Amazon between 2005 and 2012, which avoided the emission of approximately 1.2 billion tons of CO_2. The program also helped protect an estimated 60 million hectares of forest, which is equivalent to the size of France. (Fraser, 2023)

2. The Sustainable Agriculture and Forests Program in Indonesia

   The Sustainable Agriculture and Forests program in Indonesia has helped reduce deforestation rates while also providing economic opportunities for farmers and improving food security. According to a report by the World Resources Institute, the program has helped protect an estimated 5.5 million hectares of forest, which is equivalent to the size of Costa Rica. The program has also helped reduce greenhouse gas emissions by an estimated 0.4 billion tons of CO_2. (Global Waters, 2022)

3. The Forest Stewardship Council (FSC)

   The Forest Stewardship Council is an international organization that promotes sustainable forest management practices. According to a study by the University of Wisconsin-Madison, FSC-certified forests store an average of 6.7 metric tons of CO_2 per hectare per year, which is 37% more than noncertified forests. The study also found that FSC-certified forests have higher biodiversity and support local communities. (Forest Eco Certification)

4. The Green Belt Movement in Kenya

   The Green Belt Movement is a grassroots organization that promotes reforestation and community empowerment in Kenya. Since its founding in 1977, the organization has helped plant over 51 million trees and has provided economic opportunities to over 30,000 women through its tree-planting initiatives. According to a study by the University of Oxford, the trees planted by the Green Belt Movement have sequestered an estimated 2.5 million metric tons of CO_2, which is equivalent to taking more than 500,000 cars off the road for a year. (Green Belt Movement)

5. The Bonn Challenge

   The Bonn Challenge is a global effort to restore 150 million hectares of degraded and deforested land by 2020 and 350 million hectares by 2030. The initiative is led by the International Union for Conservation of Nature (IUCN) and the German government, and it has been endorsed by over 50 countries. According to a report by the IUCN, if the Bonn Challenge is successful, it could sequester up to 1.7 billion tons of CO_2 per year by 2030, which is equivalent to the annual emissions of India. (Caya, 2016)

Issue 5: Monitoring, verification, and reporting of nature-based solutions is capital- and labor-intensive

Case studies

1. The Implementation of the Verified Carbon Standard (VCS) in the Rimba Raya Biodiversity Reserve Project in Indonesia

   The Rimba Raya Biodiversity Reserve project in Indonesia was the first REDD+ project to receive VCS certification. The project involves the conservation of more than 64,000 hectares of tropical forest, which has sequestered an estimated 20 million metric tons of CO_2. The use of standardized MRV protocols under the VCS certification process helped streamline the MRV process and reduce the cost of certification while also increasing the credibility and transparency of the project (InfiniteEARTH).

2. The Collaboration Among Project Developers in the Community-Based REDD+ Project in Nepal

   The Community-Based REDD+ project in Nepal is a community-led initiative that aims to conserve and restore forests while also providing economic opportunities to local communities. The project involves the collaboration of several community groups, nongovernmental organizations (NGOs), and government agencies who share information and resources on MRV best practices. This collaboration has helped reduce duplication of effort and facilitate the development of cost-effective MRV approaches (ANSAB, 2013).

3. The Provision of Financing and Technical Support in the BioCarbon Fund Initiative for Sustainable Forest Landscapes (ISFL)

   The BioCarbon Fund ISFL is a partnership between the World Bank and several donor countries, providing financing and technical assistance to support forest conservation and restoration in developing countries. The initiative has provided financing and technical support to several forest carbon offsetting projects, including in Brazil, Indonesia, and Ethiopia. This support has helped overcome barriers to entry and increase access to the resources needed for MRV (Initiative for Sustainable Forest Landscapes, “BioCarbon Fund”)

4. The Provision of Policy Support in the California Compliance Offset Program

   The California Compliance Offset Program provides incentives for companies to invest in forest carbon offsetting projects, such as the Improved Forest Management project in the Sierra Nevada mountains. This project involves the sustainable management of more than 22,000 hectares of forest, sequestering an estimated 2 million metric tons of CO_2. The policy support provided by the California Air Resources Board has helped increase the demand for legitimate carbon offsetting

projects while also creating a more favorable environment for investment in MRV technology and best practices (California Air Resource Board, “Compliance Offset Program”).

Issue 6: Nature-based carbon offsets currently lack trust and integrity standards, harming the world’s climate

Case studies

1. For Independent Third-Party Auditors

   The California Air Resources Board (CARB) Compliance Offset Protocol requires the use of independent third-party verifiers to help ensure the accuracy and reliability of forest carbon offsetting projects. The verifiers must be accredited by the American National Standards Institute (ANSI) and meet other qualification requirements. The use of independent third-party auditors helps prevent over-accounting by ensuring that carbon stock estimates are independently verified.

2. For Clear Standards and Protocols for Measurement and Audit

   The Forest Stewardship Council (FSC) has established clear standards and protocols for forest carbon offsetting, including requirements for MRV and third-party verification. These standards and protocols are based on best practices and are subject to regular review and revision. The use of clear standards and protocols helps prevent over-accounting by providing a consistent and transparent framework for carbon accounting.

3. For Frequent and Random Spot Checks

   The Verified Carbon Standard (VCS) requires project developers to conduct frequent and random spot checks of their MRV processes for accuracy and reliability of carbon stock estimates. The VCS also requires independent third-party verification of carbon stock estimates to confirm that these spot checks are conducted properly. The use of frequent and random spot checks helps prevent over-accounting by detecting any irregularities that may occur.

4. For Blockchain Technology

   HBAR Foundation, the foundation behind Hedera Hashgraph, has created the Guardian, a tool for recording digital MRV. The Guardian is an open source blockchain library to support registration for carbon offsetting. It is developing a platform that provides secure and transparent carbon accounting. The use of blockchain technology helps prevent over-accounting by providing a decentralized and transparent record of carbon transactions.

5. For Disclosure and Reporting of Over-Accounting

   The Rainforest Alliance, a nonprofit organization that works to promote sustainable forestry, requires project developers to disclose any instances of over-accounting or other irregularities as part of its certification process. This information is publicly available on the Rainforest Alliance website. The use of disclosure and reporting helps prevent over-accounting by increasing transparency and accountability.

Issue 7: Individual tree accounting is almost nonexistent, making various techniques such as selective logging and selection cutting difficult to execute, monitor, and verify

Case studies

1. Tree-Climbing Robots

   The startup Treebot[1], based in Switzerland, has developed a tree-climbing robot equipped with sensors and cameras that can climb trees up to 70 meters tall. The robot can collect data on the tree's structure, including its size, shape, and biomass, as well as identifying potential hazards such as weak or dead branches.

2. Genetic Barcoding for Trees

   Researchers at the University of British Columbia, Canada, have developed a genetic barcode for individual trees, allowing them to track the carbon sequestration potential of each tree over time. The genetic barcodes can be used to inform forest management decisions, such as selectively harvesting trees with high carbon sequestration potential.

3. Remote Sensing Technologies

   The Global Ecosystem Dynamics Investigation (GEDI) satellite from the National Aeronautics and Space Administration (NASA) uses lidar technology to provide detailed information on the structure and biomass of individual trees in forests around the world. This data can be used to inform forest management decisions and improve forest carbon stock estimates.

4. Drones for Aerial Surveys

   The startup DroneSeed[2], based in Seattle, WA, uses drones equipped with lidar and multispectral cameras to map out forest ecosystems and identify areas that require reforestation. The drones can also plant new trees using a precision planting system.

5. Mobile Apps for Data Collection

   The Rainforest Connection[3], a nonprofit organization that works to prevent illegal deforestation, has developed a mobile app that uses ML to detect sounds of illegal logging activities in real time. The app also collects data on forest biodiversity, helping to inform forest management decisions.

6. Satellite Mapping

   Earth observation with machine learning-based methods plays a crucial role in environmental and climate sciences. Being able to continuously monitor and report changes is an important tool for decision-makers to address urgent challenges in climate change mitigation and adaptation, especially

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[2] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

[3] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

for forestry where land-use change is one of the key factors to understand. Earth observation data is stored in the petabyte scales. Public institutional data such as the European Space Agency's Sentinel-1 synthetic aperture radar data and Sentinel-2 optical images produce four petabytes of data. Private providers such as Maxar have reportedly stored more than 110 petabytes in its image library since 2000, adding up to 80 terabytes of satellite data per day. Leveraging this data, researchers have developed global maps on tree cover loss and gains (Hansen et al., 2011), reforestation potential (Bastin et al., 2019), and biodiversity richness (Jetz et al., 2012).

7. Digital Twins

   Creating digital replicas that mirror the existence and dynamics of physical objects, processes, assets, or arrangements is known as the creation of *digital t*wins. Using advances in satellite, aerial, and on-ground sensing technologies, realistic records of land cover, forest type, biomass, and canopy height can be created. The ever-growing spatiotemporal data records are used to improve the accuracy of digital twins, namely climate and land surface models, such that it can forecast the state and health of forests. Forest digital twins could be advanced toward mapping ecosystem health, carbon content, and biodiversity or the rapid exploration of climate policy impacts, visualizing future scenarios. Advances in digital twins have historically been applied extensively in architecture, BEAM modeling, and simulation design. For the sake of the IEEE Planet Positive 2030 application, focusing on data curation, collection, sensing, mapping, and simulating challenging forest landscapes and the interior canopy of rainforests is proposed.

8. Decentralized Ledgers and On-Chain Representation

   Decentralized ledger technology as a whole is oriented towards the use of an open and public decentralized ledger to create a permanent record keeping of account. This is for the sake of economic support, as well as representation of digital environmental attributes such as carbon removal credits and hectares of land preservation.

9. AI NLP Speech Partners

   Drawing from the existing advancements in artificial intelligence for natural language processing (NLP), there are opportunities to make an AI chatbot that can persuasively and humanely interact with external audiences, bringing an emphatic "voice" and "character" to an otherwise amorphous concept of trees and hectares. Key tools and advances in AI can be used to represent and design at scale a mass market-facing awareness-building tool, for example, by allowing the AI to actively engage with conversations on social media platforms.

Issue 8: Despite the social media-driven push for corporate engagement on tree planting, numerous organizations have advocated that the process of tree and forestry protection is much more effective than that of virgin tree planting

Case studies

1. GainForest[4]

> *"GainForest is an open platform that empowers sustainable conservation efforts by unifying 1) accessible and automated monitoring, 2) auditable and decentralized payments, and 3) stakeholder engagement and user-focused token incentives into one system...Tracing the impact of a donor's individual donation is difficult, making it hard for them to develop a sense of ownership. GainForest NFTrees make payments to conservation organizations more tangible. They are unique digital assets that track the ownership of virtual sites of a conservation or restoration project using blockchain technology. Virtual sites correspond to a predefined land area within the project with possibly multiple plants."* (GainForest Primer)

2. NFTree Tokens

> "NFTree tokens include unique artwork from local communities and Indigenous artists for each project. Each token links to a unique" monitoring "website…that provides geospatial and ecological information of the corresponding site, displaying recent drone and satellite data, current and potential tree cover," the existing "species of flora…and how much carbon is currently stored or could potentially be stored if the ecosystem was intact. The group of corresponding plants within an NFTree can change during its lifetime due to survival rates and active restoration efforts. NFTree holders can follow recent updates and progress on their respective conservation areas through the NFTree profile website," dynamic artwork, and data airdrops. "Investments raised from NFTrees are first parked in a decentralized fund. Payments are automatically released to conservation organizations after achieving specific milestones during the verifiable 'Proof-of-Care'" stage, which consists of automated digital MRV. *(GainForest Primer)*

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Chapter 6: Rivers and Lakes

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Issue 1: Water access rights are becoming increasingly complex, especially with transboundary waters

Case studies

1. Serious Gaming as a Tool to Model and Communicate Considerations for Water Resource Management

   Serious games, such as "SimBasin,"[5] 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 modeling software (SEI, 1992–2015), to facilitate the communication of the complex, long term and wide range relationships between hydrologic, climate, and human systems present in river basins, and enable dialogue between policy-makers and scientists" (Angarita et al., 2016). The game was used in Columbia, applicable to the Magdalena-Cauca River Basin (Craven et al., 2017). It was also tried in Thailand for the Upper Nan River Basin (Gunathilake, 2020).

2. Water Scarcity and Agriculture

   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 (UN FAO, 2012). 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.* (UN FAO, 2020)

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Issue 2: Humans treat water as an endless resource that causes unnecessary waste

Case studies

1. Water Management in San Diego County, USA.

   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 other 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 (Naishadham, 2022).

2. Balancing the Use of Water Through Water Trading Markets—Australia

   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 (Australian Government, DCCEEW; Hughes, 2021).

Issue 3: Community overexpansion can overtax water resources, whereas the scaling effect, while seemingly efficient from a financial sense, may have the unexpected impact of overtaxing available water resources

Case studies

1. River of Life Project—Kuala Lumpur

   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:

   > *Restoring river habitat and ecological processes not only enhanced the quality of the human experience, it also added resilience to local economies.* (Schneider, 2018)

2. Smart Growth—New Jersey, USA

   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”:

> *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.* (WeConservePA, 2012)

Issue 4: City infrastructure detracts from healthy river and lake ecosystems

Case studies

1. Huangpu River Development—Shanghai

   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, to make new ecological connections, to reuse industrial heritage, and to add new landmarks. More than 50 kilometers of new waterfronts have been already implemented.* (den Hartog, 2021)

2. Sabarmati Riverfront Redevelopment—Ahmedabad, India

   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…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*. (World Bank, 2016)

3. Riverfront Project—Omaha, Nebraska, USA

   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.

   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. ("Omaha, Nebraska's Riverfront Revitalization Project," 2021)

Issue 5: Excess fertilizer, pesticide, and animal waste pollute water sources and increase the chances for toxic harmful algal blooms (HABs)

Case studies

1. Remediation of the Pleasant Valley Branch of the Pecatonica River, Wisconsin, USA

   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 along the river (Into the Outdoors, 2017; Environmental Trading Network).

2. Building the Future of Freshwater Protection

   Lake George Association—The Jefferson Project: Building the Future of Freshwater Protection.

3. Impacts of climate change on coastal blooms

   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).

   Algal Blooms—Root Causes

   Moleaer's nanobubble technology is used for various purposes, including for treating the root cause of algal blooms.

Issue 6: Water flow diversions disrupt critical ecosystems

Case studies

1. Dam Removal—Selune River, France

   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:

   > *"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."* (Dekimpe, 2022)

2. Dam Modification to Support Atlantic Salmon Population—Poutes Dam, France

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 (Dekimpe, 2022).

3. Dolphin Population Decline in the Ganges River—Assam, India

   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 the health of the rivers they inhabit. Any indication of their population decline is a sign of an unhealthy river (Swinton & Gomez, 2009; Guha, 2022).

4. Environmental Flows—Human and Environmental Water Needs Study, USA

   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.* (Chen & Olden, 2017)

5. Large Dam Study

   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 (Chen, 2018).

Issue 7: Growing water-intensive crops in arid zones accelerates water scarcity

Case studies

1. Crop Water Intensity and Natively Resilient Crops

   Extensive evidence exists that farmers are aware of the issue of crop water intensity 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:

   > *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.* (Elbein, 2021)

   > *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. (U.S. Senate Bill S.1251)

2. Water Reclamation from Wastewater—Israel

   Being an arid nation with a growing population, Israel has improved water reclamation from wastewater to upward of 85% and has learned to employ drip irrigation to enrich its agriculture (Smith & Freemark, 2016).

Issue 8: Physical trash/plastics pollute freshwater ecosystems and play a significant role in ecosystem degradation and destruction

Case studies

1. Ganga River Water Quality—India

   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 ultrasound to alert whenever oil leaks are detected (Pal, 2017).

2. Cross Border Waterway Contamination—Balkan

   Balkan nations try yet struggle to coordinate the prevention of trash from entering shared waters. Often trash landfills are inappropriately located next to waterways, compounding the problem (CBS News, 2021).

3. Menhaden Return to the Coast of New Jersey, USA

   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:

   "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. (Fallon, 2022)

Issue 9: Chemical and hazardous waste adversely affects river and lake ecosystems

Case studies

1. Microbubble Technology to Clean Up Pollution in Water Bodies

A way has been found to clean up polluted lakes using a microbubble solution that attracts viruses and bacteria ("A Man from Peru, Bright Side).

2. Transport of Contaminants in Groundwater—Case Study Collection

   "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." (Bekins, 2018)

3. Waste in Lake Malawi, Malawi

   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 paper 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." (Tsuro, 2021)

4. Cleanup of the Lower Duwamish River, Seattle, Washington, USA

   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 (NOAA, "Hazardous Waste").

Issue 10: Raw human sewage pollution causes degradation of river and lake ecosystems

Case studies

1. Marine Conservation—UK

   Grassroots UK organization, Surfers Against Sewage (SAS), is an education program that not only teaches sustainable practices but also provides teach-the-teacher workshops (SAS, "Get Learning"). 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. "Stop, Don't Flush That" Campaign by the Water Environment Foundation (Water Environment Foundation, 2013)

   WEF members work to solve the 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 is flushed down the toilet.

Issue 11: Invasive species threaten freshwater ecosystems

Case studies

1. Invasive Species Management

"Understanding population-level responses to removal and immigration rates are essential aspects of invasive species management." (Weber et al., 2016)

2. Invasive Phragmites on Beaver Island in Lake Michigan

   Examples of Case Studies for Invasive Species Action—Michigan's Great Lakes Islands. 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. (Higman et al., 2019)

Issue 12: Engineering education lacks sufficient ecological literacy content

Case studies

1. Hands-on Education at Riverside Intermediate School, Fishers, Indiana, USA

   An effective way to improve planet stewardship is by local community "hands-on" education. Educators need more community involvement. The Riverside Intermediate School in Fishers, Indiana, a part of the Hamilton Southeast (HSE) school district, uses its proximity to nature to help students better interact with it. HSE succeeds by engaging the community to support raising goats and chickens on the school property, so the children, as well as community residents, gain appreciation for these farm animals. (Muljat, 2023)

2. Centre for Regenerative Design & Engineering for a Net Positive World, Bath, UK

   University of Bath in England has a Centre for Regenerative Design & Engineering for a Net Positive World. "We offer global research leadership in regenerative design and engineering, co-evolving solutions with societal, cultural, ecological, and economic co-benefits." (University of Bath Center for Regenerative Design & Engineering for a New Positive World.)

Issue 13: Freshwater ecosystems face multiple challenges

Case studies

1. River Danube Restoration, Romania

   Restoration of a portion of the Danube River in Romania. Efforts continue to reconnect the Garla Mare marshland to the Danube, restoring the natural river floodplains by removing dykes. The expectation is improved biodiversity such as migratory birds, better flood control, and improved freshwater quality. (WWF, 2010)

2. Cross-border Collaboration in Water Management—Eastern Africa

   Collaboration among countries and organizations in Eastern Africa, especially inclusive of input from women, are improving water conditions. There is increased awareness and education on the importance of hygiene, trees, and animal management on the creation and maintenance of clean freshwater, and the impact on the surrounding flora and fauna. (Indakwa & Wamba, 2021)

3. Recovery from Freshwater Biodiversity Loss

   "Bending the Curve of Global Freshwater Biodiversity Loss: An Emergency Recovery Plan." (Tickner et al., 2020)

4. Freshwater Biodiversity in the Western Ghats, India

   "The status and distribution of freshwater biodiversity in the Western Ghats, India." (Molur et al., 2011)

Chapter 8: Oceans and Coasts

This information is given solely for the convenience of users of this document as examples of case studies that were known at the time of publication, and does not constitute an endorsement of any company, product, service or organization by the IEEE or IEEE Standards Association (IEEE SA).

Issue 1: Imminent threat of sea-level rise to coastal communities

Case studies

1. CoastSnap—A Global Citizen Science Project to Capture Changing Coastlines

   "CoastSnap is a global citizen science project to capture our changing coastlines. No matter where you are in the world, if you have a smartphone and an interest in the coast, we welcome you to participate! CoastSnap relies on repeat photos at the same location to track how the coast is changing over time due to processes such as storms, rising sea levels, human activities and other factors. Using a specialised technique known as photogrammetry, CoastSnap turns your photos into valuable coastal data that is used by coastal scientists to understand and forecast how coastlines might change in the coming decades…"

2. Land Change Assessment, Monitoring, and Prediction Using Landsat

   "LCMAP Monitoring uses all available Landsat observations to perform nationwide characterization of change in land cover and condition annually. Validation provides a measure of map accuracy for use in evaluating the appropriateness of a map for a specific application. LCMAP collects reference data that is used to perform a validation analysis, and all datasets are available…."

3. Environment | Mangroves for the Future—Investing in Coastal Ecosystems

   "All coastal ecosystems such as mangroves, coral reefs and seagrass beds are under threat from climate-change and variability; however, the long-term survival and functioning of key ecosystems is crucial for the communities depending on ecosystem services such as provisioning (e.g., timber, fuel wood, and charcoal), regulating (e.g., flood, storm and erosion control; prevention of salt water intrusion), and habitat (e.g., breeding, spawning and nursery habitat for commercial valuable fish species)…."

4. National Oceanic and Atmospheric Administration's Sea Level Rise viewer and NASA's Sea Level Change Portal

Issue 2: Warming and acidification of the ocean

Case studies

1. The OSPAR 2017 Intermediate Assessment and the OSPAR 2023 Quality Status Report 2023 confirms acidification in the northeast Atlantic Ocean. OSPAR, 2023.

   "Climate Change Thematic Assessment." In: *OSPAR, 2023: Quality Status Report 2023*. OSPAR Commission, London. Available at:

2. The UN Intergovernmental Panel on Climate Change (IPCC) and its latest status report.

Issue 3: Impacts of unsustainable ocean-based food production

Case study

1. Farhan et al. Calculation Model of Economic Losses Due to Illegal Fishing Activities in Indonesian Territorial Waters. 2018.

Issue 4: Destruction of important biodiverse and climate-resilient habitats

Case studies

1. Living Seawalls

   "Sydney Harbour has shown that after 1-2 years Living Seawalls already support at least 36% more species than plain, unmodified seawalls, with as many as 85 species of invertebrates, seaweeds and fish living and growing on the panels."

2. Monitoring of Marine-Protected Areas

   "eDNA as a metabarcoding tool for monitoring marine protected areas" (Gold et al., 2021).

Issue 6: Ocean pollution due to offshore extraction and processing of fossil fuels, and the difficulties associated with attributing damage to specific polluters

Case studies

1. Satellite oil spill detection and case study

   Sea Empress was grounded near the town of Milford Haven, Wales, on 15 Feb. 1996.

Issue 7: Influx of excess nutrients is polluting the ocean environment

Case studies

1. Use of Biochar to remove toxins from different harmful algal blooms

   "Biochar May Help Fight Against Harmful Algal Blooms"
2. Nanobubble ozone technology (NBOT) to control cyanobacteria and their toxins
3. Case studies of biofiltration systems from the Minnesota storm water manual
4. Blue-Green Roof technology
5. The development of smartphone applications (Apps), which can be used by citizen scientists to cost-effectively measure and record surface reflectance, water color, and water quality parameters
6. Environmental Protection Agency Participatory Science Water Projects

Issue 9: Path to decarbonization for new and existing ships is unclear

Case studies

1. Voluntary certification programs
   a. Green Marine (North America)

      *"The Green Marine program demonstrates year after year its ability to encourage its participants to go beyond regulatory requirements." (*Green Marine, "Certification, Results")

   b. First Movers Coalition (Global):

      "The FMC is a coalition of companies using their purchasing power to create early markets for innovative clean technologies across eight hard to abate sectors. These in-scope sectors are responsible for 30% of global emissions–a proportion

expected to rise to over 50% by mid-century without urgent progress on clean technology innovation." (World Economic Forum, "First Movers Coalition")

2. Marine protected areas
    a. Mongabay—MPA Impact Review (US-based non-profit)

    "To find out if marine protected areas achieve their environmental and socioeconomic goals, we read 42 scientific studies and talked to seven experts. Overall, marine protected areas do appear to help marine animals recover within their boundaries. But a lot more rigorous research is needed. The effects of marine protected areas on socioeconomic outcomes and fisheries are less clear." (Dasgupta, 2018)

    b. PEW—The Case for MPAs (Charitable trust)

    "In 2016, members of the International Union for Conservation of Nature, a global authority on the status of the natural world, adopted a motion recommending that nations protect 30 percent of their waters from all extractive activities by 2030. Safeguarding ocean space in marine protected areas (MPAs) has been proved to help conserve marine life and associated habitats. Creation of MPAs can improve ocean health and provide multiple benefits to the people whose lives and traditions are linked to these waters." (Pew Charitable Trusts, "The Case for Marine Protected Areas")

    c. WWF Effects of MPAs (World-wide conservation organization)

    "WWF scientists collaborate on a geographically expansive, long-term study to quantify the impacts of marine protected areas on both people and nature." (Morgan, 2016)

3. Future fuels and propulsion
    a. Lloyd's Register—Zero-carbon fuel readiness monitor (Marine classification society)

    "Zero-emissions solutions have so far only been deployed in niche applications, solutions for large scale ocean shipping are not yet established." (Lloyd's Register, "Zero-Carbon Fuel Monitor")

    b. International Transport Forum—Market Forces Driving Decarbonisation (Intergovernmental organization)

    "This chapter spells out the drivers and barriers of decarbonisation and the conditions under which it could be achieved. One of these conditions is strong financial incentives, such as carbon pricing. The chapter concludes with implications for regulation." (Kirstein, Halim, & Merk, 2018)

    c. Bureau Veritas—Challenges and Impact of Adopting Wind Propulsion (Marine classification society)

    "In addition to turning to low- and zero-carbon fuels, many owners are researching alternative propulsion methods as a way to limit their impact. Among developing options, wind-assisted propulsion is considered a strong contender for achieving significant emissions reduction. As a free, clean energy source available worldwide,

wind can power ships renewably through the use of sails – both advancing the shipping industry and returning it to its roots. However, much of the technology needed to support wind-assisted propulsion systems is still in the early stages of development. While a handful of pilot projects are underway, several environmental, technical, design and financial challenges remain before widespread adoption of wind-assisted systems is possible." (Bureau Veritas, "Powering Marine Decarbonization")

Issue 10: Increased noise from ships is destroying underwater habitats

Case studies

1. Marine protected areas (see Issue 9 of this chapter)
2. URN target setting and mitigation measures
    a. BC Ferries—URN Mitigation Study (Passenger Ferry Industry)

    "Key learnings for other vessel operators considering the implementation of underwater radiated noise targets: Obtain baseline measurements of your fleet to determine where your starting point is before setting underwater noise reduction goals; Make design decisions in consideration of the larger system. Underwater radiated noise is a function of many complex interactions within a vessel, and as such, it is important to design the propeller and propulsion systems in concert with the hull design to account for functional requirements; Engage an underwater radiated noise expert to assess design impacts and conduct trade-off analysis. Make expertise available for working closely with the selected shipyard throughout the detailed design and build process; Anticipate conflicting requirements as a part of the design optimization process. For BC Ferries, for example, meeting underwater radiated noise reduction requirements while achieving improved energy efficiency is a balancing act that requires careful consideration." (Peterson, 2021)

3. Incentive programs
    a. Port of Metro Vancouver—EcoAction Program (Port Authority)

    "Through the port authority's EcoAction Program, shipping companies can qualify for up to 75% off their harbor dues fees by taking voluntary measures to reduce their environmental impact, such as by using renewable energy to reduce air emissions, installing propeller technologies that reduce underwater noise, or obtaining third-party environmental designations." (Port of Vancouver, "EcoAction Program")

b. Santa Barbara Channel—Speed reduction incentive program (National Marine Sanctuary and Port)

"Commercial shipping is the dominant source of low-frequency noise in the ocean. It has been shown that the noise radiated by an individual vessel depends upon the vessel's speed. This study quantified the reduction in source levels (SLs) and sound exposure levels (SELs) for ships participating in two variations of a vessel speed reduction (VSR) program. SLs and SELs of individual ships participating in the program between 2014 and 2017 were statistically lower than non-participating ships ($p < 0.001$). In the 2018 fleet-based program, there were statistical differences between the SLs and SELs of fleets that participated with varying degrees of cooperation. Significant reductions in SL and SEL relied on cooperation of 25% or more in slowing vessel speed. This analysis highlights how slowing vessel speed to 10 knots or less is an effective method in reducing underwater noise emitted from commercial ships." (ZoBell et al, 2021)

4. Impact of noise on aquatic species

a. Measuring Impact on Cetaceans (Canadian Conservation)

"This report presents an analysis of high-risk areas in Canadian waters where shipping activity poses an elevated threat to cetaceans, and it is founded in in-depth interviews and a literature review of four working groups developing mitigation measures to manage impacts of shipping on cetaceans in the country. … Based on these case studies, we summarize best practices and draw the following recommendations: 1. Where possible, separate ships from cetaceans by modifying routes or designing vessel exclusion zones in high-risk areas. 2.Where it is not possible, apply speed restrictions in known sensitive cetacean habitats, such as feeding aggregation or nursing areas. 3.Evaluate the co-benefit of speed restrictions for cetacean conservation and for the environment in general to better quantify benefits versus costs. 4.Consider all endangered, threatened and protected species when designing mitigation measures. 5.Apply best practices to create an effective and collaborative structure to coordinate communication between relevant stakeholders, and base management decisions on the best available knowledge (scientific, local and Indigenous). 6.In areas where place-based measures are not enough, encourage certification or port-led incentive schemes and the development of quantifiable noise-reduction targets and/or noise thresholds to regulate shipping." (Dalili, Ushio, and Cosandey-Godin, 2020)

b. Managing Noise Impacts—Context and Monitoring Approach (US-based Ocean Noise Strategy Roadmap)

"This case study provides a place-based context for examining recommendations …expanded focus and attention to NOAA-managed and acoustically sensitive fishes and invertebrate species, …. extended use of existing authorities to address noise impacts to acoustic habitats for sensitive fish and invertebrate species, and … prioritized development of NOAA-maintained long-term passive acoustic monitoring capacity." (Gedamke, Harrison, & Hatch, 2021)

Issue 11: Waste streams and emissions from ships in the ocean are difficult to trace

Case studies

1. Marine protected areas (see Issue 9 of this chapter)
2. Invasive species
    a. Lake Tahoe—Multi-jurisdictional Coordination (US-based conservation)

    "Biological invasions are increasing in frequency and the need to mitigate or control their effects is a major challenge to natural resource managers. Failure to control invasive species has been attributed to inadequate policies, resources or scientific knowledge. Often, natural resource managers with limited funds are tasked with the development of an invasive species control program without access to key decision-support information such as whether or not an invasive species will cause damage, and what the extent of that damage may be. Once damages are realized, knowing where to allocate resources and target control efforts is not straightforward. Here we present the history of invasive species policy development and management in a large, multi-jurisdictional and multi-use aquatic ecosystem. We present a science-based decision-support tool for on-the-ground aquatic invasive species (AIS) control to support the development of a sustainable control program. Lastly, we provide a set of recommendations for managers desiring to make an AIS control implementation plan based upon our development of novel invasive species research, policy and management in Lake Tahoe (USA). We find that a sustainable invasive species control program is possible when science, coordination and outreach are integrated." (Wittmann et al., 2015)

3. Cruise ships
    a. Cruising Tourism Environmental Impacts (Marine tourism Dubrovnik, Croatia)

    "Cruise tourism is new economic, social and environmental phenomena with potential serious impacts on the three pillars of sustainability. This paper will look into the environmental impacts in order to disclose potential hazards in port of Dubrovnik. Subsequently, existing mechanisms to deal with the hazards will be analyzed to determine their effectiveness to mitigate the impacts. This process will use direct pollution costs calculations to enable cost benefit analysis. Other impact analysis will be conducted in form of environmental (pollution) foot printing that compare environmental loads of cruise tourist vs. local inhabitant. The two (cost benefit analysis and environmental foot printing) analysis will provide information on general aspects of cruise tourism carrying capacity and its current direction of development. Finally, the discussion will point to key pollution management issues, possible solutions to some of the pollution aspects, and stress other direct ecological threats." (Carić, 2011)

b. Cruise Ships Wastewater Pollution (Marine tourism Adriatic Sea):

"The global growth of cruise tourism has brought increasing concern for the pollution of the marine environment. Marine pollution from sanitary wastewater is a problem especially pronounced on large cruise ships where the number of people on board may exceed 8,000. To evaluate future marine pollution in any selected period of time it is necessary to know the movement of ships in the Adriatic Sea. This paper presents the problem of marine pollution by sanitary wastewater from cruise ships, wastewater treatment technology and a model of cruise ship traffic in the Adriatic Sea considering MARPOL Annex IV areas of limited wastewater discharge. Using the model, it is possible to know in advance the routes of the cruisers and retention time in certain geographic areas. The data obtained by this model can be used as input parameters for evaluation model of wastewater pollution or for evaluation of other types of pollution from cruise ships." (Perić, 2016)

c. Cruise Ship Waste Generation and Management (Marine tourism in Aegean Sea)

"In a medium-sized cruise ship, 140808 m3 of all types of waste is produced annually. A high amount of the waste volume (90 %) is legally discharged at sea. Minor quantities are disposed to port reception facilities (8 %) or incinerated (2 %). The waste management infrastructure at land in the Caribbean area is poor. Management of ship generated waste is a prerequisite for sustainable cruising." (Kotrikla, 2021)

Issue 12: Ubiquitous presence of micro- and macro-plastics in the ocean

Case studies

1. The Great Bubble Barrier

   "Bubble Barriers capture plastic in waterways with bubbles. We create a bubble curtain by pumping air through a perforated tube on the bottom of the waterway. The bubble curtain creates an upward current which directs plastic to the surface. By placing the Bubble Barrier diagonally across the river, the natural flow of the water will push the plastic waste to the side and into the catchment system.

   The catchment system is designed to work in harmony with the bubble curtain to collect and retain plastics. Following collection, it will be removed for processing and reuse.…

   The Bubble Barrier comprises three main components: the bubble curtain, the compressor, and the catchment system. The three components are designed to work together to create the optimum solution for each location." (The Great Bubble Barrier website)

2. Plastic Fischer

   Installing a boom system in rivers can be up to 300 times more cost-effective than fishing plastic out of the ocean.

3. Lonely Whale

   Lonely Whale has trained thousands of young leaders across dozens of countries and engaged tens of thousands more through the OH-WAKE Media Network at ohwake.org.

4. NextWave

   This organization focuses on considering plastic no longer as waste, but a valuable raw material for the circular economy. "Keeping plastics in the economy and out of THE ocean."

5. Global Plastic Innovation Network

   An innovative network to crowdsource innovations of high potential innovators to tackle plastic pollution.

6. Mi Terro

   Sustainable and durable bio-based materials for packaging, textiles, contact lenses, and other applications. Using biomaterials that can be returned to nature after used, reducing harm to the environment.

Issue 13: Management and the lack of global ocean data

Case studies

1. "The World Meteorological Organization (WMO) Executive Council has endorsed plans for a new Global Greenhouse Gas Monitoring Infrastructure to fill critical information gaps and support action to reduce heat-trapping gasses, which are fueling temperature increases." (UNEP, "Spotlight on Climate Action")
2. The Ocean Data Platform—HUB Ocean: Data: An open collaborative tool that unlocks and aggregates ocean data to encourage scientific collaboration, industry transparency, and layered analysis.
3. Port Integration and Enhancement of Data Project—Canada's Ocean Supercluster: Shows the importance of data through artificial intelligence to support economic growth both as an ocean transport hub and as a software hub.
4. Ellipsis Earth Ltd: To detect patterns of litter behavior through detailed monitoring and the ability to identify more than 47 types of litter. This technology identifies trends, measures impact, and targets critical hotspots. It can help to demonstrate direct success or failure of solutions by allowing for more efficient spending with less wasted time and money and eliminating greenwashing.

Chapter 9: Farmlands and Grasslands, Mountains and Peatlands

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Issue 2: Extraction—Pollution and biodiversity losses undermine human survival

Case studies

1. Air Pollution and Food Production

   UNECE Sustainable Development Goals. "Air Pollution and Food Production." UNECE, Environmental Policy, Air Pollution.

   "[Ammonia and nitrogen compounds affect] soil quality and thus the very capacity of the soil to sustain plant and animal productivity."

   "Ozone precursor emissions (nitrogen oxides and volatile organic compounds) are of particular concern for global food security as these compounds react to form ground-level ozone. This, in turn, penetrates into the plant structure and impairs its ability to develop. Ozone was estimated to cause relative global crop losses for soy 6-16%, wheat 7-12% and maize 3-5%. At a European level, a study in 2000 of the economic losses due to the impact of ozone on 23 crops amounted to 6.7 billion Euros."

2. Short-Lived Climate Pollutants and Food Security

   Climate & Clean Air Coalition. "Short-Lived Climate Pollutants and Food Security." About SLCPs, Benefits of Action, Food Security.

   "A warmer climate adds many challenges to food production. There is an increase in pests and diseases, and more frequent and extreme droughts and floods. Heat stress causes poor yields, or worse, crop failures. Together these impacts put pressure on domestic and global food systems and increase the likelihood of supply chain disruptions and competition for increasingly limited resources."

   "Air pollution stunts crop growth by weakening photosynthesis. Tropospheric ozone alone causes annual losses of approximately 110 million tonnes of major staple crops: wheat, rice, maize and soybean. This represents around 4% of the total annual global crop production, and up to 15% in some regions."

   "Black carbon (a component of fine particulate matter or PM2.5) also harms crops when it covers their leaves, where it absorbs more sunlight and increases the plant's temperature. While in the atmosphere, black carbon affects plants by reducing the amount of sunlight that reaches the earth and disrupting rainfall patterns."

3. Special Report—Climate Change and Land

   IPCC. Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. P. R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H. -O. Pörtner, D. C. Roberts, P. Zhai et al., eds. In press. 2019.

   "Four pillars of food security: availability, access, utilization, and stability"

   "Observed climate change is already affecting food security through increasing temperatures, changing precipitation patterns, and greater frequency of some extreme events."

4. Roundup Lawsuit Update August 2022

   Gaines, Mari. "Roundup Lawsuit Update." *Forbes Advisor,* updated 2 Feb. 2024.

   "Studies have shown that the chemical might cause illness to humans and cause damage to the environment. The International Agency for Research on Cancer categorizes glyphosate as possibly carcinogenic to humans—essentially, the IARC is saying this toxin may cause cancer."

   "A study from the University of Washington found that exposure to glyphosate increased an individual's risk of non-Hodgkin's lymphoma by 41%."

   "The CDC recently released findings that up to 80% of Americans may have traces of Roundup in their urine, showing they have been exposed to it. Considering that 200 million pounds of Roundup are sprayed annually on U.S. crops, it is not surprising most of the population has been exposed to it."

5. Microplastics in Food

   Alexis, Amber Charles. "What Do We Know About Microplastics in Food?" *Medical News Today*, 18 Feb. 2022.

   "The microplastic chemicals present in food are a mixture of those that manufacturers deliberately add, such as fillers and stabilizers, and those that accumulate as byproducts, such as residues and impurities."

   "Using eco-friendly packaging reduces Trusted Source the exposure to and migration of microplastics in the food supply."

Chapter 11: Sustainability Commons

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Issue 7: Steps to help building a sustainability commons initiative

Case Studies

1. California Climate Commons (website).

   Description quoted from the website:

   *"**Science and data supporting climate change resilience in California.** The California Climate Commons digital library was launched in 2011 by the California Landscape Conservation Cooperative (The CA LCC, one of 22 LCCs in North America). It provided unprecedented access to climate change science for conservation practitioners, introducing innovative ways to understand and incorporate this emerging information.*

   *In 2018 the National Landscape Conservation Cooperative program was discontinued and is now the **California Landscape Conservation and Adaptation Partnership (CAL CAP)**.*

   The Climate Commons digital library ceased being updated in 2018, but you may still search the archived Climate Commons catalogs and articles."

2. Creative Commons (website).

   Description quoted from the website:

   "Creative Commons is an international nonprofit organization that empowers people to grow and sustain the thriving commons of shared knowledge and culture we need to address the world's most pressing challenges and create a brighter future for all."

3. Crowdsourcing Sustainability (website).

   Description quoted from the website:

   "Crowdsourcing Sustainability is unleashing the power of people everywhere to help reverse global heating as quickly and equitably as possible. Join our community of over 200,000 people from 150+ countries to rebuild a safe, healthy, and just world together!"

4. Earth Journalism Network, Climate Commons (website)

   Description quoted from the website:

   *"**Internews** initially developed the **Earth Journalism Network** (EJN) in 2004 to enable journalists from low- and middle-income countries to cover the environment more effectively. This is now a truly global network working with reporters and media outlets in virtually every region of the world. Following the mission to improve the quantity and quality of environmental reporting, EJN trains journalists to cover a wide variety of issues, develops innovative online environmental news sites and produces content for local*

media–including ground-breaking investigative reports. EJN also establishes networks of environmental journalists in countries where they don't exist and builds their capacity where they do."

5. Future Earth Networks. "Knowledge-Action Networks."

   Description quoted from the website:

   "The Future Earth Knowledge-Action Networks (KANs) bring together innovators from academia, policy, business, civil society and more to address the world's most pressing sustainability challenges.

   KANs are collaborative frameworks that facilitate highly integrative sustainability research on some of today's most pressing global environmental challenges. Their aim is to generate the multifaceted knowledge needed to inform solutions for complex societal issues."

6. UN Climate Change. "Global Climate Action."

   Description quoted from the website:

   "The Global Climate Action portal is an online platform where actors from around the globe - countries, regions, cities, companies, investors and other organizations - can register their commitments to act on climate change.

   Launched by UN Climate Change, Peru and France in 2014, the portal was born of the realization that addressing climate change will take ambitious, broad-based action from all segments of society, public and private."

7. The Oxford Climate Tech Initiative's Real Time Crowdsourced R+D Systems Map.

8. Shareholders Commons (website).

   Description quoted from the website:

   "Founded in 2019, this is an independent, non-profit organization that addresses social and environmental issues from the perspective of shareholders who diversify their investments to optimize risk and return."

9. UN Environment Programme (UNEP). "Publications and Data.")

   Description quoted from the website:

   "The UN Environment Programme offers more than 15,000 items, from real-time data tools and platforms to key reports, publications, fact sheets, interactives and more."

10. WWF Climate Crowd (website).

    Description quoted from the website:

    "Climate Crowd is a bottom-up community-driven initiative. Working with communities and local organizations in over 30 countries, Climate Crowd collects data on climate impacts to communities, analyzes the data, presents the data back to the communities, and works with them to develop, fund and implement on-the-ground solutions that help people and nature adapt to a changing climate."

Chapter 12: The Arts

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Issue 4: Need to sensibilize business leaders to act through art interventions

Case Studies

1. Partnership between Manufacturer and an Arts Foundation

   As a practical example of how companies can interact with artists to create more sustainable business, a global manufacturer of kitchen products has created a steady partnership with an associated arts foundation. The company has manufacturing plants in Italy, Poland, Mexico, Germany, India, and China.[6] The collaboration has created a steady residency of artists inside company locations to boost constant innovation, creativity, and a different way of thinking and has pioneered the investigation of the potential link between art and industry[7] to create a more sustainable company culture.

2. Partnership between a Construction Company and a Museum

   Another good example of this practice are the shows of a construction company in the spaces of the Triennale Museum in Milan, Italy (Webuild with Triennale Milano, 2023).[8] Three large shows were used to tell the world about the construction challenges of the company. In this case, exhibition making, large-scale installations, and good curatorial practice make evident the impact of the activities of the company in construction sites all around the world. Creating specific shows that connect company history, business challenges, and the concept of *greenshift* can be an efficient way to sensibilize people and leaders in companies to act in a more sustainable way.

[6] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

[7] Fondazione Ermanno Casoli is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

[8] This information is given as an example for the convenience of users of this document and does not constitute an endorsement by the IEEE. Similar or equivalent products and services may also be available from other companies and organizations.

Issue 5: The need for artists and scientists to join forces toward achieving environmental sustainability—the power of STE(a)M

Case study

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In a video of a Pashupati seal from Indus Valley civilization, the artist uses traditional hand gestures and body movements from Bharatnatyam, a classical Indian dance form, to illustrate the water cycle as part of his interpretation of an ancient Sanskrit hymn (Shoklam, "Akasat Patitam Toyam"), stating, "As water from all resources reaches the sea so do all seekers to knowledge." It is a classic case study in how art creates a bridge between a scientifically verifiable phenomenon (i.e., the water cycle and ocean being the ultimate sink of falling water) and the theological journey of spiritual seekers toward divine knowledge and wisdom. The traditional idea of knowledge and spirituality explored here also inherently includes the idea of respecting water bodies like rivers as a sustainable natural resource. The Namami Gange effort by the government of India also uses the mythical and artistic visualization of the River Ganga (Ganges) as a mother to harness sustainability efforts (Namami Gange, Anthem, 2016; Namami Gange, Official Anthem of National Mission on Clean Ganga, 2020).

Similar ecologically sensitive cultural practices abound in most Indigenous cultures around the world, often observed to this day with rituals seeking blessings from the earth, river, air, and other natural elements. Such rituals, which acknowledge the profound importance of the natural ecosystem and humanity's place in it, also were built on ancestral knowledge of ecological sustainability, passed down among the generations. Such practical knowledge was often driven by practical "from-the-field" observations that were similar, albeit primitive, compared with modern-day empirical studies. This knowledge was also imbued with rich artistry of mythological storytelling, sculptures, paintings, dance traditions, and so on that informed and engaged the public with the need to uphold their stewardship of natural land they inherited from their ancestors.

Today, however, with rapid degeneration of the natural environment due to large-scale deforestation, urban growth, and water/air pollution, these ancient practices designed for the ancestral environment may need to adapt to better connect the public psyche toward modern-era sustainability goals. Artists can still remind people us of these root practices through ancient art traditions, inspire growth beyond ritualistic habits to seek greater meaning, and engage the public to connect back with nature, just like in ancient times. The practical modern-era issue then is how environmental science and engineering (e.g., pollution studies) can inform art to encourage public opinion toward making this change. This fundamental issue ties deeply to the issues of cross-disciplinary training, dearth of sponsorship, and the technically reliable collaborative platforms mentioned above.

Sometimes the choice of a broad "popular" audience over a technical one for dissemination of new findings can be a mechanism for leveraging collective interest, understanding, and attitudes about issues deemed important by specialists whose communicative tools don't have much societal impact. This approach requires collaboration and conversations among the STEM population and the art and culture population to create bridges and mutual understanding of the details and the large patterns of technical material, as well as of the cultural contexts, currents, and media. One example of this is a book (Bennett, 2003) published for a general, nonacademic readership in Colombia that provides an accessible heuristic and cultural framework, as well as graphics that effectively convey the large patterns of the country's primate fauna, along with their beauty, ecosystem importance, and vulnerability.

A more theoretical yet profound example of successful STEaM collaboration would be the celebrated interactions between the Dutch artist MC Escher and scientists of his time (especially Sir Roger Penrose, see O'Leary, 2023). Such collaborations influenced both mathematics and art and, in its wake, architecture and human perceptions of reality (Overstreet, 2022). One wonders what Escher, with his seemingly endless mathematical curiosity and inspiration from nature's motifs, would create today in this era of extreme environmental vulnerability. And yet, despite these successes, the issue of disengagement between artists and scientists remains a reality to this day if for no other reason than a simple lack of connection between the art and STEM disciplines.

The complementary pursuit of the measurable and the meaningful regarding environmental sustainability challenges can be harnessed using STEaM-powered projects. What needs to happen now, in the wake of climate change and related extreme events, is the harnessing of objective understanding of the environment with emotional cognition that enables responsible stewardship of the natural resources all people inherit from their ancestors.

The ancient Sanskrit saying *Satyam Shivam Sundaram* translates into English as "The truth leads to divinity, which leads to beauty." As creative thinkers, both artists and scientists seek the beauty inherent in nature as their intellectual reward, and harnessing this common interest toward sustainability can indeed restore the environment to its natural sanctity.

Issue 14: The need to create empathy toward the environment—artistic listening exercises

Case study

For the use of the soundwalk as a tool for developing environmental awareness in city design in different places such as Berlin, London, and other cities, see Radicchi, A. and others, 2021, "Sound and the healthy city" in *Cities & Health* 5, no.1-2: 1-13.

Issue 16: Effective "narratives" about climate change are urgently needed for people to get engaged—use the work of Indigenous artists to educate and inform wider audiences about the impact of climate change to create possible solutions stemming from Indigenous wisdom?

Case studies

1. Yuméweuš

   Steve Yazzie is a Navajo artist whose work "Yuméweuš" consists of hydroponic towers that explore the interconnectedness of "you," "me," "we," and "us" and the relationships that exist between these words. The towers are the intersectionality of Indigenous customs and science. The sand paintings feature the chemical structure for amaranth, which grows in the hydroponic towers instead of healing Indigenous designs (Yazzie, 2022).

2. Gold King & Associates

   A secondary work by Yazzie consists of a real estate advertising sign for Gold King & Associates placed outside a property that asks people to call a number (720.281.9199), where they hear a message that could be a story or poem about colonization of Indigenous lands, the impact of climate change and environmental destruction, or the idea of kinship. Callers then have the option of leaving their own message.

3. Rise: From One Island To Another

   'Poetry, as with other art forms, can speak to us" on "various"…levels. I feel that in the art space, you leave room for mistakes, for conversation. For humanity. I am not an expert on a scientific level, but I am an expert on being a human being. And we definitely need our humanity in this situation."
   (Aka Niviâna at the 2019 Global Landscapes Forum)

   Rise is a visual collaborative project between two young climate activists and poets, Aka Niviâna from Greenland and Kathy Jetnil-Kijiner from the Marshall Islands. Through poetry and imagery, they take the viewer on a journey of two island homelands impacted by climate change: the rising sea levels affecting the Marshall Islands and the melting glaciers of Greenland. The film places both poets on top of a melting glacier in Greenland where their collaborative effort tells the story of their ancestors, humanity's interconnectedness, the damage inflicted to the land, and their resilience in the face of monumental environmental loss. The result is a visually stunning film that highlights human interdependence and is a call to action.

4. Unceded Territories

   Artist Lawrence Paul Yuxweluptun from the Musqueam, Squamish, and Tsleil-Waututh First Nations (currently known as "British Columbia") collaborated with filmmaker Paisley Smith to create an immersive virtual reality experience where viewers throw oil paint in the environment that is Yuxweluptun's artwork. Once the viewer has finished throwing the paint, they are shown that the oil paint has destroyed the painting beyond reversal. Unbeknownst to the viewer, they are the colonizers, and by exercising their will on the environment, they are leaving a trail of destruction and devastation in their wake. The intent is to bring awareness to non-Indigenous populations as to how

they are participants of habitat destruction and pollution through consumption and how hundreds of years of consumption in the name of progress has directly impacted Indigenous communities who have lost their lands and livelihoods (Guo, 2020).

5. Ngapulara Ngarngarnyi Wirra (Our Family Tree)

   Australian football player Adam Goodes has performance data recorded via a biometric device. Adam is Adnyamathanha, where the peoples belong to two blood groups and their kinship ascribes to either the North or South winds. The sounds of the North and South wind were recorded as they moved around a sacred tree (wirra) on Adnyamathanha land. Inside the tree, an elder is recorded speaking in the Adnyamathanha language. A machine learning model combines the spoken Adnyamathanha language with the sounds of the North and South winds. In the culmination of the piece, Adam's biometric is used to create a point cloud around a 3D model of the tree (wirra) where the North and South winds combined with spoken language move through the point cloud. By combining ancestral ways and artificial intelligence, it demonstrates a way to illustrate kinship between humans and algorithms, as well as a way to preserve ancestral ways and customs respectfully (Abdilla, 2020).

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