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Hidden Resources

Monika U. Ehrman*

Vision is central to the human species' evolution and success. This dependence on sight is reflected in the construction of property frameworks governing natural resources. When humans encounter natural resources they cannot see—hidden resources—they have difficulties imagining an appropriate property regime. As a result, they rely on existing two-dimensional property systems to govern natural resources, which are often three- or four-dimensional in nature. These hidden resources, invisible to the human eye, may be subsurface, distant, or not composed of a visible form. Examples of hidden resources include groundwater, minerals, petroleum, porous space, wind, migratory paths, deep oceans, viruses, and planets. This Article proposes that a lack of natural resource sight affects the ability to efficiently use, manage, and conserve resources. It further examines how revelation of a resource's latent physical and visual traits results in efficient development and optimal law and policy, concluding that hidden resources should not be governed by the same property frameworks as visible property.

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INTRODUCTION

On Christmas Eve, 1968, NASA astronaut Lieutenant Colonel William Anders peered out one of the small windows of the lunar orbiter. Camera in hand, Anders took pictures of the various moon craters, documenting them as part of the Apollo 8 mission, which served as a predecessor to the Apollo 11 lunar landing. As he dutifully snapped the black and white photos of the previously unseen far side of the moon, Anders looked up to notice a small, blue object rising on the distant lunar horizon. It was the earth, vibrant and delicate, with white swirling cloud masses, nestled amidst the vast, midnight dark of space. The small world was juxtaposed against the barren, lunar landscape, pockmarked with the remnants of ancient collisions. Anders quickly asked fellow astronaut, Captain Jim Lovell, for a roll of color film. He and Lovell proceeded to shoot several pictures of their distant home.

One of Anders's shots would become one of the most iconic photographs ever taken in human history—Earthrise.[1]

Figure 1: Earthrise[2]

The Earthrise photograph represented more than a visual depiction of the third planet from the sun; it was an ever-enduring image of a solitary and fragile home. In fact, Anders's photograph may be "the most important legacy of the Apollo space program"[3] because for the very first time, humans could see their planet "as a world that was 'whole and round and beautiful and small'"[4] set against the vast emptiness of space. Even these disciplined, military-trained astronauts recounted how struck they were that everything most dear to them—their families,

1. For more information on Ander's *Earthrise* image, see Bill Anders, *50 Years After 'Earthrise,' a Christmas Eve Message from Its Photographer*, SPACE.COM (Dec. 24, 2018), https://www.space.com/42848-earthrise-photo-apollo-8-legacy-bill-anders.html [https://perma.cc/XN6R-FQPR]; Joe Moran, *Earthrise: The Story Behind Our Planet's Most Famous Photo*, GUARDIAN (Dec. 22, 2018, 5:02 AM), https://www.theguardian.com/artanddesign/2018/dec/22/behold-blue-plant-photograph-earthrise [https://perma.cc/43AN-P9A3].

2. *Apollo 8: Earthrise*, NASA (Dec. 23, 2020), https://www.nasa.gov/image-feature/apollo-8-earthrise [https://perma.cc/9LHF-9ND6].

3. Alex Scimecca, *How One Apollo 8 Photo Changed the World*, FORTUNE (Dec. 21, 2017, 4:00 AM), https://fortune.com/2017/12/21/apollo-8-earthrise-photo/ [https://web.archive.org/web/20171225201532/http://fortune.com:80/2017/12/21/apollo-8-earthrise-photo].

4. Robin McKie, *The Mission that Changed Everything*, GUARDIAN (Nov. 29, 2008, 7:01 PM), https://www.theguardian.com/science/2008/nov/30/apollo-8-mission [https://perma.cc/V6CG-SVPW] (quoting the poet Archibald MacLeish).

their loved ones, their entire lives—were contained on a sphere so diminutive that from the Moon it could be covered up with a thumbnail.[5]

This striking visual served as an unexpected catalyst for the burgeoning environmental movement. Historian Robert Poole surmises that the origin of our collective ecological conscientiousness is traceable to that picture's publication, replete with its "dazzling blue ocean, the jacket of cloud and the relative invisibility of the land and of human settlement."[6] The photo was "a rebuke to the vanity of humankind[—]Earthrise was an epiphany in space."[7] The image became a call to arms to protect a vulnerable and fragile world.[8]

Although Rachel Carson's 1962 book, *Silent Spring*, first brought mainstream attention to environmental issues and anthropogenic actions affecting wildlife, it was arguably the Earthrise photograph that helped galvanize citizen action and accelerated the nascent environmental movement.[9] Seeing the planet, especially in perspective to another celestial body, forever changed the way that its inhabitants viewed the earth and its environment. For a population that was in the chaotic grip of domestic and global conflicts, the Earthrise image—with its overwhelming beauty and absence of borders or monuments—provided awareness that the collective action of humankind was necessary to protect an irreplaceable world.[10] Sixteen months after its publication, the first Earth Day occurred, catapulting the powerful environmental legislation era of the 1970s.[11] The catalytic image gave perspective and insight to a previously blind population.

5. WILLIAM M. ADAMS, AGAINST EXTINCTION: THE STORY OF CONSERVATION 154 (2004); Kathleen Rogers, *Fifty Years After 'Earthrise': The Famous Photograph Bolstered the Environmental Movement*, USA TODAY (Dec. 24, 2018, 7:00 AM), https://www.usatoday.com/story/opinion/2018/12/24/earthrise-50th-anniversary-photograph-earth-day-climate-change-column/2401196002/ [https://perma.cc/P4FN-4LKZ] ("The vast loneliness is awe-inspiring, and it makes you realize just what you have back there on Earth." (comment of Jim Lovell, Apollo 8 Command Module Pilot)).

6. McKie, *supra* note 4; ROBERT POOLE, EARTHRISE: HOW MAN FIRST SAW THE EARTH 10 (2008).

7. McKie, *supra* note 4.

8. Rogers, *supra* note 5 ("The Earth looked so perfect, so radiant, so small . . . . The nascent environmental community agreed, for it confirmed what they already knew—that the Earth's environment was common to all of us, that the Earth's natural resources were finite, and that 150 years of unfettered industrial development was having a profound impact on our planet. All of this was easier for everyone to imagine, for everyone to believe, after Earthrise.").

9. *Id.*

10. Caitlin Dempsey, *The First Color Images of the Earth from Space*, GEOGRAPHY REALM (Mar. 13, 2019), https://www.geographyrealm.com/the-first-color-images-of-the-earth-from-space/ [https://perma.cc/E4M5-86E3].

11. Rogers, *supra* note 5; *see also The Modern Environmental Movement*, PBS: AM. EXPERIENCE, https://www.pbs.org/wgbh/americanexperience/features/earth-days-modern-environmental-movement/ [https://perma.cc/8CBE-SU27] (last visited Jan. 22, 2023). The era commenced with the creation of the U.S. Environmental Protection Agency (July 1970) and the National Oceanographic and Atmospheric Agency (October 1970), then proceeded with passage of the Clean Water Act (October 1972), the Coastal Zone Management Act (October 1972), and the Endangered Species Act (December 1973). It continued with the completion of studies providing evidence supporting the hypothesis of ozone depletion (June 1974) and concluded with the passage of the Safe Drinking Water

The ability to see hidden natural resources—*hidden resources*—is critical to resource understanding and development.[12] Hidden resources are those natural resources which are not visible to the human eye—they may be underground, distant, or microscopic. The ability to see hidden resources is *resource sight*, whereas the converse is *resource blindness*, which is the ignorance of the resource's physical and other sight-based characteristics.[13] Hidden resources include subsurface resources such as minerals, groundwater, petroleum, porous space, and geological formations. They also include such terrestrial and extraterrestrial resources as atmosphere, climate, wind, migratory paths, and astronomical bodies.[14]

This Article develops the idea first proposed in the author's *Application of Natural Resources Property Theory to Hidden Resources*,[15] which focused on subsurface mineral property as an example of a hidden resource that became visible.[16] The retrieval and development of subsurface minerals slowly revealed their latent physical and visual traits. As ancient miners plumbed the mineral-laden depths, they were able to see the geological structures beneath the surface. This vision provided an understanding of how to extract the valuable deposits. In other words, those miners acquired resource sight. Along with resource sight came the development of customs and policies that governed mineral extraction and ownership rights, which were eventually legislated. As a result, the mining of minerals served as a helpful analog to explain the importance of resource sight.

This Article expands upon the author's prior research by analyzing hidden resources in the broader natural resources field and proposing that hidden resources require a unique and multifaceted property ownership and governance approach. First, it discusses the importance of visual sight when examining hidden resources, particularly when creating governing law and policy. Second, it analyzes various categories of hidden resources, along with some challenges associated with resource blindness. Third, the Article examines how current property regimes may not best suit these resources, and questions designating certain natural resources as private

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Act (December 1974), the Toxic Substances Control Act (October 1976), the Resource Conservation and Recovery Act (October 1976), and the Comprehensive Environmental Response Compensation and Liability Act (July 1978, signed into law December 1980). *Id.*

12. Monika U. Ehrman, *Application of Natural Resources Property Theory to Hidden Resources*, 14 INT'L J. COMMONS 627, 628 (2020) [hereinafter Ehrman, *Application*]. This double-blind, peer-reviewed article was part of the 2019 N.Y.U. School of Law's Classical Liberal Institute & University of Indiana's Ostrom Workshop's Symposium on Mis-matched Property Rights to Landscape-Level Resources: Legal and Customary Solutions, (moderated by Michael Heller; symposium co-chairs, Karen Bradshaw, Billy Christmas, Richard Epstein & Dean Lueck).

13. *Id.*

14. *Id.*

15. *Id.*

16. *Minerals & Elements*, MINERAL EDUC. COAL., https://mineralseducationcoalition.org/mining-minerals-information/minerals-elements/ [https://perma.cc/N7JD-J53J] (last visited Nov 23, 2021) ("A mineral is a naturally occurring inorganic element or compound having an orderly internal structure and characteristic chemical composition, crystal form, and physical properties. Minerals may be metallic, like gold, or nonmetallic, such as talc.").

property. Fourth, it examines conflicts that arise when the natural resource is not understood, briefly referencing various forms of governance as potential adaptations for hidden resources. Finally, the Article concludes that hidden resources should not be governed by the same property framework as visible property. Rather, hidden resources require their own custom framework and governance structure that best suits the individual resource's properties.[17] Moreover, the author warns that failure to consider the unique nature of hidden resources, especially novel resources, will result in public and private actors forging ahead and creating sovereign- or self-serving property ownership structures.

Optimal hidden resource management requires visual sight to develop an understanding of the underlying resource itself. Without resource sight, these natural resources cannot be fully understood, which leads to the misapplication of law and policy. Moreover, the false attribution of anthropogenic ownership characteristics to natural resources results in complicated and poorly conceived property regimes, which aggravate ownership conflicts and resource inefficiencies. Lastly, this Article acknowledges that this theory is equally applicable in other natural spaces ranging from tree-root systems to the electromagnetic spectrum, and even Indigenous property. Although there may be applications to this concept in artificial, human-created property—such as intellectual property and digital currency—this Article focuses only on natural resources.

I. NATURAL RESOURCE PROPERTY THEORY AND VISUAL SIGHT

The long-standing intersection between human assertion of ownership and natural resources required the development of property rights. But the intrinsic character of natural resources challenges the imposition of artificial property constraints. As opposed to anthropogenic property, many types of natural resources property are often hidden resources that do not conform to an artificial property framework.[18] But whether individual or communal, there exists a long human

17. Ehrman, *Application*, *supra* note 12.

18. *See id.* at 628–29 (detailing the difficulty of managing and conserving hidden natural resources when the surface property framework is applied rather than the novel property theory of hidden natural resources). Sight became a central tenet of the development of natural resource property ownership. *Id.* For example, riparianism allocates property rights to those living closest to water. *Id.* at 628. This spatial proximity to water resources is one example of *resource sight*. *Id.* The metes and bounds system, a two-dimensional method of land description using physical geographic features, is yet another example. *Id.* Both these examples illustrate our common treatment of natural resource property applying a two-dimensional surface property framework for resources that are three- or four-dimensional in nature. *Id.* The inability to appreciate additional dimensions hinders our ability to conceptualize natural resources properly. *Id.* As three-dimensional beings, we cannot perceive time—the fourth dimension, mainly relying on technology to provide additional dimensional data. *Id.* "And because of *resource blindness*, humans do not even possess the ability to view any dimension of resources that lie within the earth's crust and at greater depths. Humans rely on technology to facilitate data collection and interpretation, in addition to" visual sighting such as mineral outcrops, indicating that minerals may be present below the surface. *Id.*

history of natural resource property ownership.[19] Often, this category of property has a utilitarian basis. For example, land may be acquired for agrarian purposes or to access water bodies for fishing, trading, and transportation. Both coal and petroleum were extracted for energy purposes. And mining developed as civilizations began using minerals for tools and currency.[20] Although the acquisition of these hidden resources is often the basis of war and territorial expansion, the overlay of private property rights further results in conflict.

While visible resources—such as agricultural land and timber—are easily viewed and measured, hidden resources—such as minerals, oil and natural gas, groundwater, and porous space—cannot be seen and are therefore difficult to evaluate. The challenges related to these forms of resources—typically categorized as common-pool resources[21]—include the assertion of property ownership rights such as those Ostrom and Hess identified: access, withdrawal, management, exclusion, and alienation.[22]

Problems arise when surface property framework is applied to hidden resources. *Id.* Commonly, hidden resource ownership consists of the extension of the two-dimensional surface property downwards or upwards "and establishing boundaries of resources that naturally transverse these artificial boundaries. The constraints of these artificial boundaries result in owner conflicts, weakening of correlative rights, and increased resource utility inefficiencies." *Id.* at 628–29 (citation omitted). In addressing these problems, "courts or legislatures set limitations or create exceptions that only increase confusion and add an additional layer of complexity to [allocation of] resources, which holistically, are integrated and dynamic systems." *Id.* at 629. Ensuing challenges are created as these complex and unnatural layers of limitations and exceptions accumulate. *Id.*

19. *See e.g.*, ANTHONY SCOTT, THE EVOLUTION OF RESOURCE PROPERTY RIGHTS (2008); Éva Jakab, *Property Rights in Ancient Rome*, *in* OWNERSHIP AND EXPLOITATION OF LAND AND NATURAL RESOURCES IN THE ROMAN WORLD 107 (Paul Erdkamp, Koenraad Verboven & Arjan Zuiderhoek eds., 2015).

20. *See* Bin Yang, *The Rise and Fall of Cowrie Shells: The Asian Story*, 22 J. WORLD HIST. 1, 2, 7–8 (2011) (footnotes omitted).

21. The authors explain:

> Common-pool resources are composed of resource systems and a flow of resource units or benefits from these systems. The resource system (or alternatively, the stock or the facility) is what generates a flow of resource units or benefits over time. Examples of typical common-pool resource systems include lakes, rivers, irrigation systems, groundwater basins, forests, fishery stocks and grazing areas. Common-pool resources may also be facilities that are constructed for joint use, such as mainframe computers and the Internet. The resource units or benefits from a common-pool resource include water, timber, medicinal plants, fish, fodder, central processing units, and connection time. Devising property regimes that effectively allow sustainable use of a common-pool resource requires rules that limit access to the resource system and other rules that limit the amount, timing, and technology used to withdraw diverse resource units from the resource system.

Elinor Ostrom & Charlotte Hess, *Private and Common Property Rights*, *in* PROPERTY LAW AND ECONOMICS 53, 58–59 (Boudewijn Bouckaert ed., 2010) (citations omitted).

22. Schlager and Ostrom identify five property rights that are most relevant for the use of common-pool resources, including access, withdrawal, management, exclusion, and alienation. These are defined as:

Relevant literature often makes no distinction between visible and hidden resources, conflating the characteristics of the two categories.[23] This research blends the variant categories seamlessly, applying law and economic theories and making conclusions about resource management or policymaking. But the similar treatment of disparate resources obfuscates an accurate and representative analysis of these individual resource systems.

A. Resource Blindness and Resource Sight

Humans evolved to rely on visual processing as a primary sensory mechanism, which enabled them to examine environments and assess risks and resources.[24] As a whole, the development of a visual organ allowed primordial organisms to escape harmful, ultraviolet radiation by diving deeper within the shallow seas, away from the surface.[25] As the eye developed within those ancestral marine animals over millions of years, its structure remained largely the same as life escaped the seas and diversified over land. Sight provided great advantage to our biological ancestors—it offered genetic success.

Access: The right to enter a defined physical area and enjoy nonsubtractive benefits (for example, hike, canoe, sit in the sun).

Withdrawal: The right to obtain resource units or products of a resource system (for example, catch fish, divert water).

Management: The right to regulate internal use patterns and transform the resource by making improvements.

Exclusion: The right to determine who will have access rights and withdrawal rights, and how those rights may be transferred.

Alienation: The right to sell or lease management and exclusion rights.

Id. at 59 (citing Edella Schlager & Elinor Ostrom, *Property Rights Regimes and Natural Resources: A Conceptual Analysis*, 68 LAND ECON. 249, 250–51 (1992)).

23. *See e.g.*, *id.* at 58 (listing "lakes, rivers, irrigation systems, groundwater basins, forests, fishery stocks and grazing areas" as examples of common-pool resource systems and also including "mainframe computers and the Internet" as examples of common-pool resources that are constructed for joint use); Susan Rose-Ackerman, *Inalienability and the Theory of Property Rights*, 85 COLUM. L. REV. 931, 931–32 (1985), (listing "[f]ish, pasture land, forests, oil pools, and minerals on the ocean bottom" as examples of resources that have been the subject of property analysis).

24. For humans, sight became the dominant method of sensory gathering and adaptation. Our eye organ reflects this dominance in its structural complexity. Although it provides stereoscopic vision, allowing the three-dimensional perception, the brain receives two-dimensional input and uses its processing power to transform two-dimensional data into three-dimensions. Sight dominance informs our worldly understanding, which in turn shapes our notions of property ownership, unlike other species, which may use glandular scents to mark territory. *See generally Eye & Retina*, U. MASS. CHAN MED. SCH.: PUNZO LAB, https://www.umassmed.edu/punzolab/research/what-we-do/ [https://perma.cc/DU9K-L8MH] (last visited Jan. 22, 2023); D.L. Williams, *Light and the Evolution of Vision*, 30 EYE 173 (2016); Eur. Molecular Biology Lab'y, *Darwin's Greatest Challenge Tackled: The Mystery of Eye Evolution*, SCIENCEDAILY (Nov. 1, 2004), www.sciencedaily.com/releases/2004/10/041030215105.htm [https://perma.cc/ABZ8-FNR5].

25. Eur. Molecular Biology Lab'y, *Simple Eyes of Only Two Cells Guide Marine Zooplankton to the Light*, SCIENCEDAILY (Nov. 23, 2008), http://www.sciencedaily.com/releases/2008/11/081119140705.htm [https://perma.cc/N6YS-KR7U].

As described above, resource blindness is the ignorance of the resource's physical and other sight-based characteristics.[26] But this ignorance does not prohibit the development of property ownership rights. Rather, the governing body tends to impose an ownership structure similar to existing surface property resources (i.e., visible resources). Using existing surface resource structures to govern dissimilar resources may have occurred due to the familiarity of the surface property framework and because hidden resource properties and scientific characteristics were unknown, both at origination and during early development of those hidden resource property structures.[27] But this misapplication of the surface property framework to hidden resources results in unnecessary property conflicts and increases difficulties managing and conserving those resources, which also increases waste.[28]

Waste is produced and conflicts arise because the law does not suit the identity and intrinsic characteristics of the natural resource. Over time, the continued misapplication compounds as courts and owners attempt to reconcile characteristics that become visible, making exceptions to laws that should never have been applied to those resources. Instead, hidden resources require their own custom and unique solution—one that is capable of evolution, as the resource is revealed.

B. Vision and its Role in Evolution and the Natural Sciences

Vision played an extraordinary role in the development of human property systems. Much of that credit belongs to the cellular complexity of the eye. Composed of both visual and neurological structures,[29] the eye organ is a marvel of biology, challenging Darwinian notions of evolution.[30] As the eye developed, it is

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26. Ehrman, *Application*, *supra* note 12.

27. *Id.*; *see also* Karen Bradshaw Schulz & Dean Lueck, *Contracting for Control of Landscape-Level Resources*, 100 IOWA L. REV. 2507 (2015).

28. Ehrman, *Application*, *supra* note 12.

29. *See generally How the Eyes Work*, N.I.H.: NAT'L EYE INST. (Apr. 20, 2022), https://www.nei.nih.gov/learn-about-eye-health/healthy-vision/how-eyes-work [https://perma.cc/HU79-6S83]. Light passes through the cornea, which is the clear front layer of the eye. *Id.* The corneal dome-shape bends light to help with focus. *Id.* Some of the light enters the pupil—the colored iris controls how much of this light passes through the pupil. *Id.* The light then travels through the lens, which is the clear, inner part of the eye. *Id.* Working with the cornea, the lens helps focus light correctly on the retina, which is the "light-sensitive layer of tissue at the back of the eye." *Id.* The specialty light receptor cells—photoreceptors—transform light waves into electrical signals. *Id.* The signals travel the optic nerve from the retina to the brain, which processes those signals into images. *Id.*

30. Williams recounts:

> Darwin is often quoted as seeing the development of the eye as a significant difficulty for his theory of evolution by natural selection. He writes in *The Origin of Species*:
>
> *To suppose that the eye, with all its inimitable contrivances . . . could have been formed by natural selection, seems, I freely confess, absurd to the highest possible degree.*
>
> But what is omitted by many is his answer to this conundrum, a few sentences further on:

reasonable to conclude that humans began to prefer sight over other sensory modalities; but this conclusion is not fully supported.[31] Humans are multisensory beings that depend on the range of senses to test, adapt, and live in their environment. Like most organisms, humans likely relied on all their senses to thrive, but unlike other species, our development of written language and printed materials likely reinforced visual preferences.[32] Still, the importance of vision, especially with respect to natural resources, cannot be discounted.

Sight and its resulting "visual impressions and changes" permeate the human experience and fluidly enter the consciousness.[33] That is because vision, as a distant sense, informs us about our surroundings and is especially important when it comes

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> *Reason tells me, that if numerous gradations from a simple and imperfect eye to one complex and perfect can be shown to exist . . . and if such variations should be useful to any animal . . . then the difficulty of believing that a perfect and complex eye could be formed by natural selection, should not be considered as subversive of the theory.*
>
> Indeed, he notes further.
>
> *How a nerve comes to be sensitive to light, hardly concerns us more than how life itself first originated; but . . . as some of the lowest organisms . . . are known to be sensitive to light, it does not seem impossible that certain elements . . . should become aggregated and developed into nerves endowed with this special sensibility.*

Williams, *supra* note 24 at 173 (citations omitted).

31. *See generally* Fabian Hutmacher, *Why Is There So Much More Research on Vision than on Any Other Sensory Modality?*, FRONTIERS PSYCH., Oct. 4, 2019, at 1, 8 (ascribing the volume of research on vision to researcher bias, as opposed to sensory importance). Hutmacher explains:

> Put differently, vision as a distant sense has a qualitatively different function than touch as a proximal sense. This qualitative difference renders conclusions about the absolute importance of a given sensory modality almost impossible. In this context, one may additionally consider olfaction: 'Often, we rely on our sense of smell in order to decide whether or not it is safe to engage further with a given stimulus.' Thus, although smell may play a rather minor role in everyday life, it becomes extremely important in potentially harmful or even life[]threatening situations, such as determining whether some food is rotten, detecting a gas leak or smelling fire.
>
> In short, the degree to which vision dominates the research on the different sensory modalities cannot simply be explained by claiming that vision is the most important modality.

Id. at 5 (citation omitted).

32. Hutmacher explains:

> First, consider the shift from an oral, hearing-dominated to a written, sight-dominated culture, which was a result of the 'Gutenberg Revolution.' While knowledge was predominantly transmitted orally before the invention of the printing press, vision has become the common means of acquiring information since then. Note, that this shift from hearing to sight arguably also changed interactions between people: The oral transmission of knowledge—and of literature, by the way—requires at least two people (a teacher and a student; someone who is telling a story and someone who is listening to it); in contrast, reading a book does not require any personal interaction—you can do it entirely on your own.

Id. at 8 (citations omitted).

33. *Id.* at 5.

to actively exploring and navigating the world.[34] "A view comprehends many things juxtaposed, as co-existent parts of one field of vision," which includes the ability to perceive the very small and the very far.[35]

When studying the natural sciences—the branch of science that relates to the physical world (e.g., biology, chemistry, physics)[36]—the use of the scientific method not only requires *observation and recordation* of empirical data,[37] it begins with "observation from which one formulates a question."[38]

Observation was also noted amongst ancient philosophers. Plato categorized *res*, or matter, into the visible and the intelligible in *The Republic*.[39] He believed that logic and deduction were superior to the imperfect material world, which relied upon observation as an analytic tool.[40] Aristotle disagreed; in his reflections on the nature of scientific inquiry in *Prior Analytics* and *Posterior Analytics*, Aristotle argued that inquiry into nature required passive observation (a forerunner to observation and experimental methods).[41] One thousand years ago, Iraqi mathematician Ibn al-Haytham first developed rigorous methods of experimental learning, incorporating the power and process of observation.[42] Throughout the Middle Ages and during the Scientific Revolution, the importance of observation increased.[43] In the 1700s, Swedish botanist, Carolus Linnaeus, developed a detailed taxonomy for biological classification. The taxonomy was distinctly categorized based on visual

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34. *Id.*

35. *Id.* (citing Hans Jonas, *The Nobility of Sight*, PHIL. PHENOMENOLOGICAL RSCH. 507, 507 (1954)).

36. RONGXING GUO, CROSS-BORDER RESOURCE MANAGEMENT 51, 69 (3d ed. 2018).

37. *See* M. Castillo, *The Scientific Method: A Need for Something Better?*, 34 AM. J. NEURORADIOLOGY 1669, 1669 (2013).

38. *Id.*

39. Brian Hepburn & Hanne Andersen, *Scientific Method*, STAN. ENCYCL. PHIL. ARCHIVE (June 1, 2021), https://plato.stanford.edu/archives/sum2021/entries/scientific-method [https://perma.cc/9MQG-N2YC].

40. *Id.*

41. *Id.*

42. Abdelghani Tbakhi & Samir S. Amr, *Ibn Al-Haytham: Father of Modern Optics*, 27 ANNALS SAUDI MED. 464, 465 (2007), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6074172/pdf/asm-6-464.pdf [https://perma.cc/9AQS-PQJ6].

43. Hepburn & Andersen, *supra* note 39.

aspects of animal anatomy and plant physiology.[44] Sans Newtonian humility,[45] the scientist briskly remarked, "God created, but Linnaeus organized."[46]

Technological achievements that provided vision also advanced resource sight. The invention and refinement of the compound microscope allowed Robert Hooke, in 1665, to discover the cell, which he named after a pine branch plant cell's resemblance to monasterial cells. His collection, *Micrographia*, published drawings of hundreds of specimens he observed using the tool.[47] In 1676, the resourceful cloth merchant Antony van Leeuwenhoek made microscope improvements intending to benefit his business; instead, he discovered the existence of bacteria and the field of microbiology was born.[48] In the 1800s, the German scientist, Walther Flemming, would discover the cell division process using a microscope.[49] The discovery led to the understanding of how cancer develops.[50] Fellow German pathologist Robert Koch's detection of the tuberculosis bacterium not only resulted in the identification of the disease's deadly origin, but also in the discovery of the causal relationship between certain microorganisms and their diseases.[51] Over a century later, immunologists would rely on their microscopic observation of the SARS CoV-2 virus and its signature spike structure. The identification of viral structure allowed the development of multiple vaccines in a

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44. Marta Paterlini, *There Shall Be Order: The Legacy of Linnaeus in the Age of Molecular Biology*, 8 EUR. MOLECULAR BIOLOGY ORG. REPS. 814, 814 (2007), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1973966/pdf/7401061.pdf [https://perma.cc/3NRV-WQLW] ("Linnaeus judged that the presence of mammary glands was an important distinction in some animals and, as such, quadrupeds were redefined as mammals."). In addition:

> Instead of looking at the whole of every plant, Linnaeus focused on one particular characteristic—the reproductive organs—and classified all plants according to their sexual morphology. His so-called sexual system organized plants based on the number, size and method of insertion of their stamens, and also on the female parts, the pistils. Despite some controversy and disapproval—Linnaeus was accused of being a botanical pornographer—the sexual system soon caught on because it was so straight-forward. It also brought a democratisation of science because now anyone—not just a specialist—could look at a flower and characterize it by counting the number of male and female parts.

Id. at 815.

45. Issac Newton wrote in a letter to Robert Hooke that, "[i]f I have seen further it is by standing on the shoulders of Giants." Jamie L. Vernon, *On the Shoulders of Giants*, 105 AM. SCIENTIST 194 (2017), https://www.americanscientist.org/article/on-the-shoulders-of-giants [https://perma.cc/ZFS3-SNEN].

46. Paterlini, *supra* note 44, at 814.

47. Laura Poppick, *Let Us Now Praise the Invention of the Microscope*, SMITHSONIAN MAG. (Mar. 30, 2017), https://www.smithsonianmag.com/science-nature/what-we-owe-to-the-invention-microscope-180962725/ [https://perma.cc/T5A4-3FG3].

48. *Id.*

49. *Id.*

50. *Id.*

51. Theresa Machemer, *How a Few Sick Tobacco Plants Led Scientists to Unravel the Truth about Viruses*, SMITHSONIAN MAG. (Mar. 24, 2020), https://www.smithsonianmag.com/science-nature/what-are-viruses-history-tobacco-mosaic-disease-180974480/ [https://perma.cc/TV2E-PQQY].

cooperative global effort, which would mark a significant turning point in combatting the deadly pandemic.[52]

None of that achievement would have occurred without sight. Viruses are very small—the COVID-19 virus measures only 0.1–0.5 microns (10^{-6} m). In comparison, a bacterium is one to three microns and a single grain of salt is a gargantuan sixty microns, hovering just above the limits of human visual perception.[53] Because of their infinitesimal size and a lack of technology to see them, the existence of viruses was heavily debated for years.[54]

The study of virology owes its beginnings to tobacco. In 1857, farmers noticed their tobacco plants were turning a mottled dark green, yellow, and grey, causing them to lose up to eighty percent of their crops.[55] Botanists attempted to isolate the pathogen that presumably caused the disease in accordance with the protocol first set out by Koch.[56] Although plant pathologist Adolf Mayer could show a diseased tobacco leaf's sap could infect a healthy leaf, he was unable to isolate or produce a pure pathogenic culture, nor could he even see the culprit using a microscope.[57] The disease was invisible.[58] Decades later, with the advent of x-ray technology and the invention of the electron transmission microscope, the "skinny, sticklike shape" of the veiled tobacco virus would be revealed.[59]

This revelation of the tobacco mosaic virus's shape "was a turning point in the scientific understanding of viruses because visual proof dispelled any doubt of their existence. The images showed that viruses are simple structures made of genetic material wrapped in a solid coat of protein molecules—a far cry from squishy, cellular bacteria."[60] Identification of the shape and makeup of viruses allowed them to be overcome, prolonging human life and increasing economic activity. Even now, in a world bombarded with the ravages of COVID-19, it was the ability to see the virus that allowed us to understand how to combat it.

The invention and continued refinement of the telescope, used for terrestrial surveying and military purposes,[61] allowed Galileo to see that the lunar surface was

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52. *See* Megan Scudellari, *How the Coronavirus Infects Cells*, 595 NATURE 640, 641–43 (2021) (detailing discovery of virus adaptations that allow infection of human cells).

53. Carmen Ang, *This Is How Coronavirus Compares to the World's Smallest Particles*, WORLD ECON. F. (Oct. 15, 2020), https://www.weforum.org/agenda/2020/10/covid-19-coronavirus-disease-size-compairson-zika-health-air-pollution/ [https://perma.cc/N7S2-GLAK] (stating that human visibility threshold is 10–40 microns).

54. Machemer, *supra* note 51.

55. *Id.*

56. *Id.*

57. *Id.*

58. *Id.* ("The tools did not exist to see a virus . . . [i]t was just this invisible contagion.")

59. *Id.*

60. *Id.*

61. *Galileo and the Telescope*, LIBR. CONG., https://www.loc.gov/collections/finding-our-place-in-the-cosmos-with-carl-sagan/articles-and-essays/modeling-the-cosmos/galileo-and-the-telescope [https://perma.cc/CS85-2L4V] (last visited Jan. 22, 2023).

covered with mountains and craters.[62] His discovery of Jovian moons in orbit led him to argue that the sun, not Earth, was the center of the solar system, and that the planets, including Earth, circumnavigated the star.[63] Followed by the further observations of astronomers and scientists,[64] Newton's theory of gravity would explain the mysterious force that bound the planetary bodies in their perpetual cosmic waltz. From the very small to the very large and distant, resource sight has been integral to the development of knowledge in the fields of the natural sciences.

C. Property and Sight

Back on Earth, the interweaving of resource and property threads has been a constant in the tapestry of human history. But the connection between ownership and visible property—most closely linked to surface property—has always been primary. In modern history, land was primarily used for agriculture and animal husbandry. The demarcation of property boundaries was often made using physical structures, which serve an exclusionary purpose for stationary property (e.g., crops) and an enclosure purpose for non-stationary property (e.g., cattle). Even original property descriptions relied on stationary property features to denote ownership boundaries.[65] Although many species rely on multimodal territorial systems,[66] such as olfactory scent markings[67] and auditory sound signals, humans rely on visual cues to inform ownership.

Dating back to ancient periods of history, land surveying remains the primary mode of describing real property and is wholly based on visual depiction and

62. *Id.*

63. *Id.*

64. *Whose Revolution? Copernicus, Brahe & Kepler*, LIBR. CONG., https://www.loc.gov/collections/finding-our-place-in-the-cosmos-with-carl-sagan/articles-and-essays/modeling-the-cosmos/whose-revolution-copernicus-brahe-and-kepler [https://perma.cc/982T-JF4Z] (last visited Jan. 22, 2023).

65. *See* Maureen E. Brady, *The Forgotten History of Metes and Bounds*, 128 YALE L.J. 872, 875 (2019). Brady explains that a "metes and bounds" description consists of:

> [R]ecords of boundaries that describe a parcel according to monuments (trees, rocks, stakes, or other markers) along its outskirts or by reference to neighbors' lands and other nearby features. Because it uses local markers, metes and bounds can be used to describe or lay out lots shaped like a rectangle, a many-sided polygon, or anything in between that is produced by the commands in the description. This method of demarcating boundaries was used in wide swaths of America—not only in the thirteen original colonies and other early states, but also in isolated sections of states as far west as California. The recording institutions of the nation are filled with references to piles of stone, all manner of trees, long-lost structures, and dried-up streams.

Id. (citation omitted).

66. The author does not intend to conflate territoriality with ownership; but uses the non-human species territoriality concept as a general comparative tool. For discussion on ascribing property ownership to wildlife, see KAREN BRADSHAW, WILDLIFE AS PROPERTY OWNERS: A NEW CONCEPTION OF ANIMAL RIGHTS (2020).

67. TRISTRAM D. WYATT, PHEROMONES AND ANIMAL BEHAVIOUR: COMMUNICATION BY SMELL AND TASTE 87 (2003).

subsequent description. Although modern land surveying relies on GPS, computer modeling, and other technological developments,[68] the surveying process still requires surveyors physically walk the property and identify the original monuments. This intimate connection with the soil provides firsthand knowledge of the land,[69] including any defects—both physical and legal—to be cured. This intimacy is further denoted by the early units of measurement, which were often tied to human physiology. For example, Ancient Egyptians and other Near East civilizations used the cubit, which was "the length of the forearm from the tip of the middle finger to the end of the elbow."[70] And although the *fathom* is roughly six feet, the measurement is the actual span encompassed by someone's outstretched arms from fingertip to fingertip.[71] Of course, the most well-known and widely-used of this type of unit is the *foot*; but even the *inch* first referred to the width of a man's thumb or the distance between the tip of the thumb and the thumb joint.[72] The basis for using human characteristics as a form of measurement not only supports the thesis that physical sight was fundamental to property ownership, but is also a Protagorean nod to the belief that "man is the measure of all things."[73] Ownership required measurement or knowledge of property; and using (typically male) human physiology as a basis for measurement provided a quick and accessible device, which could be repeated by others for relative uniformity.[74]

Natural resources have often been included as part of the description of two-dimensional land tracts. Rivers, streams, trees, and boulders have long comprised the boundaries or markers for land tract description. Although first-year Property courses in law schools often teach the history of land descriptions from an Anglo-Saxon perspective (beginning in 1066 with the Norman Conquest),[75] land

68. *Land Surveying in Ancient Times: Egypt, Greece and Rome*, POINT TO POINT LAND SURVEYORS: SURVEYING (Oct. 25, 2009), https://www.pointtopointsurvey.com/2009/10/land-surveying-in-ancient-times-egypt-greece-and-rome/ [https://perma.cc/G6HH-WRE7].

69. Claudia Baldwin, Tanzi Smith & Chris Jacobson, *Love of the Land: Social-Ecological Connectivity of Rural Landholders*, 51 J. RURAL STUDS. 37, 45 (2017).

70. Mark H. Stone, *The Cubit: A History and Measurement Commentary*, 2014 J. ANTHRO. 1, 1 (2014), https://downloads.hindawi.com/archive/2014/489757.pdf [https://perma.cc/RL8J-YHR4].

71. John Kelly, *Fathom*, MASHED RADISH (Sept. 17, 2013), https://mashedradish.com/2013/09/17/fathom/ [https://perma.cc/CU92-P68V].

72. Word Wizard, *The Origin of 'Foot' for Measurement (+ Why 12 Inches?)*, SPARK FILES (Sept. 23, 2019), https://sparkfiles.net/foot-whats-special-12-inches/ [https://perma.cc/R6BW-F6VP].

73. Stone, *supra* note 70. For more information on Protagoras's metaphor, see also Tazuko A. van Berkel, *Made to Measure: Protagoras' μέτρον* [Metron], *in* PROTAGORAS OF ABDERA: THE MAN, HIS MEASURE 37, 37 (Johannes M. van Ophuijsen, Marlein van Raalte & Peter Stork eds., 2013) (examining various metaphorical perspectives of the "measure is man" metaphor which fully states (as translated): "Of all things the measure is man, of those that are (the case), that/how they are (the case), and of those that are not (the case), that/how they are not (the case)" (citation omitted)).

74. Stone, *supra* note 70.

75. Robert C. Ellickson & Charles DiA. Thorland, *Ancient Land Law: Mesopotamia, Egypt, Israel*, 71 CHI.-KENT L. REV. 321, 324 (1995) (providing an overview of land regimes of Mesopotamia, Egypt, and Israel between 3000 B.C. and 500 B.C.). The authors note that though American pedagogical

measurement and description predate early medieval England. In Ancient Egypt, the Nile River was a common boundary for farms, which prized proximity to the fertile soil. But when the river overflowed its banks, the boundaries between farms became indistinct.[76] Boundaries were re-established using surveying techniques, which included knotted rope as a measurement device.[77] Millenia later, the Rio Grande would serve as a southern boundary of the *porciones* tracts. These long, skinny grants in dry, arid desserts were valued for their direct access to water and measured 1,000 varas[78] wide by 25–30,000 varas long.[79] The first measurement the surveyors made was along the river, where they would dig a ditch at every 1,000-vara interval.[80] The boundary lines extending up from the river were not actually surveyed until a later date.[81] Monuments marking the corners of the tract were placed and the remaining three lines were projected.[82] The long

focus on English legal history is appropriate given American law's origin, the "shortcoming of this . . . tradition . . . is that English struggles are presented as if they are without parallel." *Id.*

76. Point to Point Land Surveyors, *supra* note 68.

77. *Id.*

78. A *vara* is a Spanish measurement of distance that was used in the Spanish and Mexican surveys in Texas, which measures about 33.33 inches. *Vara*, TEX. ST. HIST. ASS'N (Feb. 5, 2019), https://www.tshaonline.org/handbook/entries/vara [https://perma.cc/9HM4-R2GS]. The *vara* was an actual measuring stick that became a unit of measurement. *See id.* For more information on the historical background of the *vara*, see *id.*; Marcos A. Reyes-Martinez, *The* Vara*: A Standard of Length with a Not-So-Standard History*, N.I.S.T. (Oct. 11, 2019), https://www.nist.gov/blogs/taking-measure/vara-standard-length-not-so-standard-history [https://perma.cc/BQ9C-QWKE] (describing how the *vara*, meaning "rod" in Latin, was first used as a uniform measure of length to survey forests for timber harvest and was then translated into a physical bar that was used to measure land).

79. TERRY COWAN, HISTORY OF THE TEXAS PUBLIC DOMAIN 6 (2015), https://cdn.ymaws.com/www.tsps.org/resource/resmgr/Convention15/TexasPublicDomain.pdf [https://perma.cc/2ZY6-FJEJ] (describing how the *Visita General*—administrators sent to deal with any problems within the Spanish bureaucracy—created the porciones after learning that no land grants had been awarded to settlers over 25 years after Jose de Escadon established the Rio Grande towns, including Laredo, Dolores, Revilla, Mier, Camargo, and Reynoso; preference was given to those who would actually live on the land).

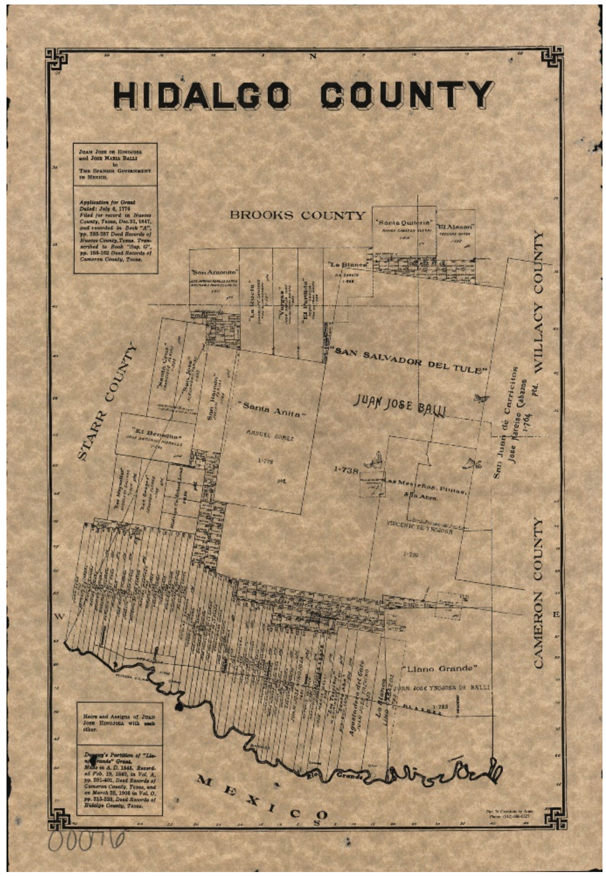
80. *Id.*

81. *Id.*

82. *Id.*

quasi-rectilinear *porciones* are shown below on an 1848 map of Hidalgo County (see Figure 2 below).

Figure 2: Map showing *porciones* tracts, in Hidalgo County, Texas[83]



Not only does Figure 2 depict the river as a boundary of the land tracts, but it also emphasizes the interconnection of natural resources and the value humans place on those interconnections (i.e., land close to water will be helpful for agricultural, ranching, and residential purposes).

II. Hidden Resources and the Impact of Resource Blindness

The world is dominated by hidden resources. Without resource sight to illuminate the complexities and interactions of these resources, there is little ability

83. *Porciones-Hidalgo County*, UNIV. TEX. RIO GRANDE VALLEY: LOWER RIO GRANDE VALLEY MAPS, https://scholarworks.utrgv.edu/maps/7/ [https://perma.cc/6UZY-ZNXV] (last visited Jan. 22, 2023) (photocopy of the original Hidalgo County 1848 Porciones map).

to regulate or accord property rights to them. Failure to see (and therefore understand) natural resources results in misallocation and maladministration of property rights, in addition to waste and inefficiencies. The relative inflexibility of property law does not adequately translate the fluid and temporal nature of natural resources. After all, *resource sight* also refers to the perception of natural resources in multidimensional space.[84] For example, many hidden resources are fugacious in nature—transient and not fixed. Resources, such as wind, water, petroleum, and porous space, either possess fluid dynamic properties or are affected by these properties. And a study of fluid dynamics is a study of movement over time, which requires study of the resource in a minimum of four dimensions—length, width, height, and time.[85]

While many physical sciences require the evaluation of a species or system from multiple perspectives, the law does not. A biologist examining a plant or animal would study not only its inherent characteristics, but also its interactions with competitors, predators, disease, and drought. The law requires no such systemic approach—it can examine a natural resource stick by stick, discretely parceling interests into neat piles. It also unapologetically pronounces ownership and use rights, in addition to regulating and legislating the same species without an understanding of its ecological whole. What is further harmful is the law's slow adoption of scientific knowledge about the hidden resource. While science's constant evaluation and testing furthers information about natural resources, the law is perfectly content to rely on antiquated notions of natural resources under the doctrine of stare decisis. This contentment explains why a nineteenth century case about a hunter and farmer pursuing a fox racing along a beach is still advanced by early twenty-first century courts to explain subsurface petroleum production and atmospheric wind turbines.[86]

Hidden resources continue to evolve, react, be discovered, and disappear. As American jurisprudence developed postindependence, it was either unfathomable or difficult to understand the behavior of certain hidden resources. For early legal theorists, a two-dimensional surface property framework was the easiest and most available treatment for hidden resources governance.[87] However, as discussed, this treatment does not suit the identity of the resource. Instead, it awkwardly wraps the resource, leaving parts jutting out and others misshapen and over-layered. As more information becomes known about the resource, the less the two-dimensional,

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84. *See* Karen Bradshaw & Monika U. Ehrman, *Unregulated Climate Mitigation*, 35 GEO. ENV'T L. REV. (forthcoming 2023) [hereinafter Bradshaw & Ehrman] (manuscript at 2).

85. Ehrman, *Application*, *supra* note 12, at 629.

86. *See* Pierson v. Post, 3 Cai. 175, 177–80 (N.Y. 1805); Bruce M. Kramer & Owen L. Anderson, *The Rule of Capture—An Oil and Gas Perspective*, 35 ENV. L. 899, 949 (2005); Elizabeth A. Weis, *Wind Energy Legislation Strategies for the Lone Star State*, 10 INQUIRIES J., no. 5, 2018, at 1, http://www.inquiriesjournal.com/articles/1738/wind-energy-legislation-strategies-for-the-lone-star-state [https://perma.cc/CY88-HALU].

87. *See generally* Kramer & Anderson, *supra* note 86.

disparate treatment fits. But no one undoes the wrapping and begins anew. Instead, it is taped together with a mishmash of custom, case law, regulations, legislation, or avoidance. And with one jostle, all may come apart.

A. Subsurface Hidden Resources

Laying beneath the surface, subsurface hidden resources are among those resources most routinely mischaracterized by the law. Not only are these resources, such as groundwater,[88] minerals, and petroleum, covered by rock overburden, they are subject to movement and displacement due to geologic pressure. Although many of these resources have long been extracted, their mechanics were not often understood. This combination of lengthy existence and use along with development of law and policy provided much opportunity for inefficient and improper governance.

1. Groundwater

The use of groundwater is as old as human civilization. Water is the lifeblood for all living things on earth and the need for proximity and access to water is central to human existence. The oldest known water control system—a water well—in the western hemisphere is Blackwater Draw, in Portales, New Mexico,[89] connected to the massive Ogallala Aquifer, which underlies eight states across America's High Plains.[90] The hand-dug well was likely made by nomadic Paleo-Indian peoples, who dug below a drought-dried lake bed and discovered water.[91]

Groundwater is the generic term for the water that fills spaces (pores and cracks) within underground rock formations.[92] Pressure differentials result in water moving to the surface via natural or artificial mechanisms. Groundwater is not typically found as Jules Verne-like cavernous lakes and snaking rivers deep within the earth.[93] Even the term *groundwater* is a misnomer—it is connected to and part

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88. Kerstin Mechlem, *Groundwater Governance: The Role of Legal Frameworks at the Local and National Level—Established Practice and Emerging Trends*, WATER, Aug. 2016, at 1, 3, https://www.mdpi.com/2073-4441/8/8/347/htm [https://perma.cc/VD2L-79Z5] (referring to groundwater as a "hidden resource"); William M. Alley, Lisa Beutler, Michael E. Campana, Sharon B. Megdal & John C. Tracy, *Making Groundwater Visible*, WATER RES. IMPACT, Sept. 2016, at 14, 14, https://aquadoc.typepad.com/files/makinggroundwatervisible-1.pdf [https://perma.cc/VTP6-8AUJ] ("Groundwater, and the boundaries that define it as a water management unit, are physically invisible to humans—unless you're in a cave, you can't see it. This lack of physical visibility has contributed greatly to its lack of visibility in many discussions of water policy, governance and management.").

89. *The Oldest Well*, MEDIUM: STEWARDING OUR AQUIFER (Sept. 19, 2017), https://medium.com/@meagan_65662/the-oldest-well-26f3b942338d [https://perma.cc/M3X6-NBPL].

90. Jeremy Frankel, *Crisis on the High Plains: The Loss of America's Largest Aquifer—the Ogallala*, 33 RENEWABLE RES. J., no. 33, 2019, at 14, 15.

91. *The Oldest Well*, *supra* note 89.

92. HELENE L. BALDWIN & C.L. MCGUINNESS, U.S. DEP'T OF THE INTERIOR, A PRIMER ON GROUND WATER 5 (1963).

93. *Id.* (noting that they do exist but are not common).

of the hydrologic cycle, which describes "the continuous movement of water above, on, and below the surface of the Earth."[94] The neat categorization of water as groundwater is only applicable at a particular moment in a continuous cycle.

The hydrologic cycle is in fact a multitude of hydrologic and atmospheric processes that "needs to be viewed at a wide range of scales and as having a great deal of variability in time and space."[95] It is composed not only of bodies of water (oceans, ice, groundwater, and atmospheric water), but also of processes (precipitation, evaporation, and evapotranspiration).[96] Certain of these resources, such as surface ice and shallow oceans, are visible resources that can be seen and explored; but others, like groundwater, are hidden.

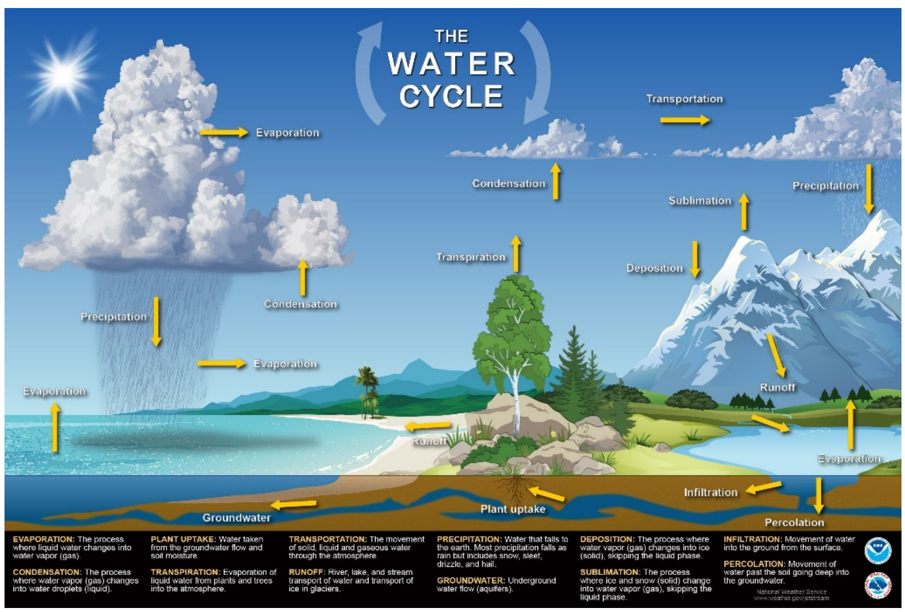

Figure 3: The water cycle[97]

94. The authors explain:

> The water on the Earth's surface—surface water—occurs as streams, lakes, and wetlands, as well as bays and oceans. Surface water also includes the solid forms of water— snow and ice. The water below the surface of the Earth primarily is ground water, but it also includes soil water.

THOMAS C. WINTER, JUDSON W. HARVEY, O. LEHN FRANKE & WILLIAM M. ALLEY, U.S. GEOLOGICAL SURV. CIRCULAR 1139, GROUND WATER AND SURFACE WATER: A SINGLE RESOURCE 2 (1998).

95. *Id.*

96. *Id.*

97. *Jetstream Max: Water Cycle Poster*, NAT'L WEATHER SERV., https://www.weather.gov/jetstream/hydrocycle_max [https://perma.cc/UP5B-PLNH] (last visited Jan. 22, 2023).

Although groundwater is only one part of the hydrologic cycle, it is also too broad a classification. Groundwater itself is comprised of many pieces and processes. Groundwater flow paths take water from recharge points through the subsurface, eventually flowing to discharge points, like streams.[98] Beneath the surface of land and the water table, groundwater flow paths also take water to surface water, like lakes, and through silt and sand to subaqueous springs.[99] Water beneath the surface is also categorized into zones: the (i) soil-water zone, (ii) unsaturated zone, and (iii) saturated zone.[100]

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98. *See* WINTER ET AL., *supra* note 94, at 5.

99. *Id.*

100. The authors explain:

> Water beneath the land surface occurs in two principal zones, the unsaturated zone and the saturated zone. In the unsaturated zone, the voids—that is, the spaces between grains of gravel, sand, silt, clay, and cracks within rocks—contain both air and water. Although a considerable amount of water can be present in the unsaturated zone, this water cannot be pumped by wells because it is held too tightly by capillary forces. The upper part of the unsaturated zone is the soil-water zone. The soil zone is crisscrossed by roots, voids left by decayed roots, and animal and worm burrows, which enhance the infiltration of precipitation into the soil zone. Soil water is used by plants in life functions and transpiration, but it also can evaporate directly to the atmosphere.
>
> In contrast to the unsaturated zone, the voids in the saturated zone are completely filled with water. Water in the saturated zone is referred to as ground water. The upper surface of the saturated zone is referred to as the water table. Below the water table, the water pressure is great enough to allow water to enter wells, thus permitting ground water to be withdrawn for use. A well is constructed by inserting a pipe into a drilled hole; a screen is attached, generally at its base, to prevent earth materials from entering the pipe along with the water pumped through the screen.

Id. at 6 (citation omitted).

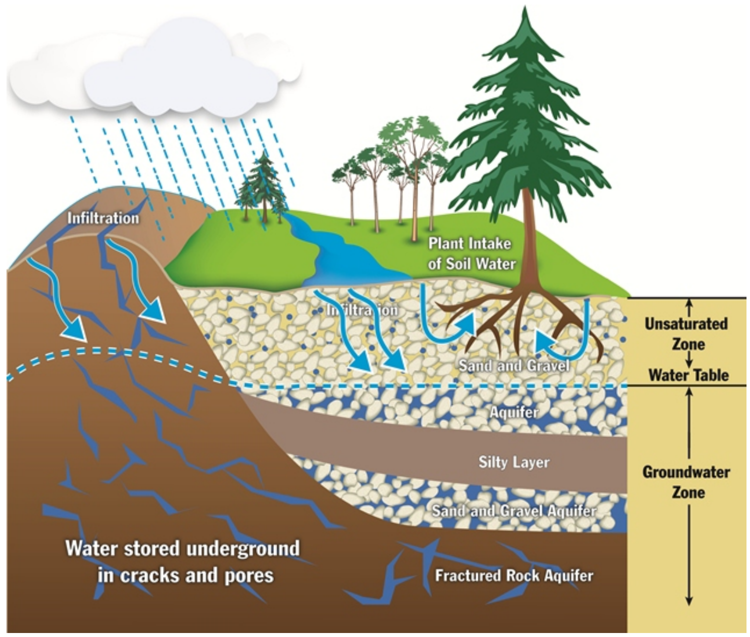

Figure 4: Groundwater flow diagram[101]

Most of these processes are invisible. While they are measurable using technology and their consequences observable at the surface, we still cannot see this dynamic resource in action. The fact that groundwater's workings were unknown was not lost on early American courts. In *Frazier v. Brown*, the Ohio Supreme Court proclaimed:

> In the absence of express contract, and of positive authorized legislation, as between proprietors of adjoining lands, the law recognizes no correlative rights in respect to underground waters percolating, oozing or filtrating through the earth; and this mainly from considerations of public policy . . . [b]ecause the existence, origin, movement and course of such waters, and the causes which govern and direct their movements, are so secret, occult and concealed, that an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would be, therefore, practically impossible.[102]

101. *Groundwater*, GOV'T NFLD., https://www.gov.nl.ca/ecc/waterres/cycle/groundwater/ [https://perma.cc/CK5K-MGQ2] (last visited Jan. 22, 2023).

102. Frazier v. Brown, 12 Ohio St. 294, 311 (1861), *overruled by* Cline v. Am. Aggregates Corp., 474 N.E.2d 324 (Ohio 1984).

Although the court admitted a lack of knowledge with respect to the "underground waters," it still pronounced judgment, declining to recognize correlative rights with respect to interference by an adjacent owner.[103] Earlier cases similarly recognize a lack of understanding of underground waters because they are hidden from sight.[104] Although centuries have passed, the problem of governing groundwater continues.[105]

2. Petroleum

Oil and natural gas (collectively "petroleum") deposits are found in geologic reservoirs, accumulated in porous spaces within rock. Similar to groundwater, natural and artificial pressure differentials within the subsurface cause petroleum to migrate. Deposits are found at varying depths onshore and offshore; and geophysical and geological technology exists to determine characteristics of the accumulations. However, it remains a hidden resource, locked away in layers of rock—often miles beneath the surface.

At the beginning of petroleum development—almost 160 years ago—the early prospectors relied on visual surface geological markers or evidence of surface petroleum deposits (where oil or gas has migrated to the surface) to site drilling rigs.[106] As technology developed, geophysicists began using wave energy to "see" underground. Seismic exploration uses sound waves to penetrate the subsurface. The waves traverse through rock where they are reflected or absorbed, and the reflected waves are captured by receivers placed on the surface. The aggregated data does not immediately provide an image of the subsurface depths. Instead, the captured sound data records the time it takes for the reflected wave to reach the rock formation. Geophysicists translate that time, using known wave velocity, into distance. The translated data provides an image of the target depths.[107]

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103. *Id.*

104. *Id.;* Roath v. Driscoll, 20 Conn. 533, 533 (1850).

105. Dave Owen, *Law, Land Use, and Groundwater Recharge*, 73 STAN. L. REV. 1163, 1165 (2021); Sharon B. Megdal & Jacob D. Petersen-Perlman, *Decentralized Groundwater Governance and Water Nexus Implications in the United States*, 59 JURIMETRICS 99, 99 (2018) (describing the "interconnectivities of groundwater to food, energy, and the climate, along with the strengths and shortcomings of state-level groundwater governance in addressing these interconnectivities").

106. JOHN S. LOWE, OWEN L. ANDERSON, CHRISTOPHER S. KULANDER, MONIKA U. EHRMAN, BURKE W. GRIGGS & JAMES W. COLEMAN, CASES AND MATERIALS ON OIL AND GAS LAW 2–5 (8th ed. 2022).

107. *Id.* at 20–22.

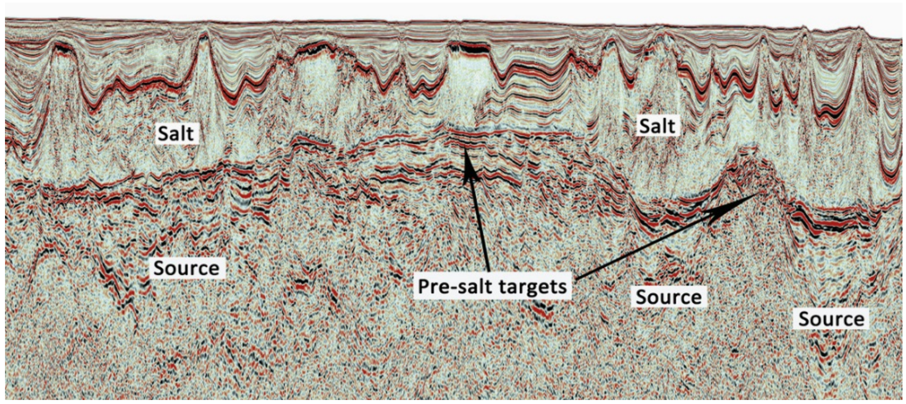

Figure 5. Seismic interpretation of Ultra-Deepwater Santos Basin[108]

The above figure shows an example of seismic interpretation in two-dimensional form. But more commonly in oil and gas exploration, seismic data is collected for three-dimensional interpretation, allowing explorationists to examine the subsurface petroleum resource from multiple perspectives.[109] However, seismic exploration is still an aggregation of interpretations from calculations of collected data. Technology enhances the ability for sight-by-proxy; but knowing whether a well will be productive requires capital-intensive operations and old-fashioned good luck.

Modern petroleum development, especially in the United States, requires the use of hydraulic fracturing. This well-completion technology involves the injection of high-pressure fluid into the subsurface to fracture rock formations, allowing the migration of petroleum into the proximate wellbore. Although hydraulic fracturing dates to the 1940s and is, in large part, responsible for the tremendous increase in domestic oil and gas production, there are few methods to control the fracture path. The fracture forms along zones of geologic weakness, which do not necessarily conform to asserted property boundaries.[110] Fractures crossing lease/tract lines have produced some of the most complex (and confounding) trespass issues, worthy of a 1L exam hypothetical.

108. Wei Mingchi, Shi Kuitai & Gao Jing, *A Global Exploration Hotspot*, GEOEXPRO, Oct. 2020, at 70, 71 (illustration from BGP-TGS multiclient 2D survey). The Santos Basin "is located in the south-east of Brazil and covers an area of 320,000 km2. It is a typical passive continental margin basin and is acknowledged as one of the most prolific hydrocarbon-producing basins in the world." *Id.* at 70.

109. LOWE ET AL., *supra* note 106, at 20–22.

110. Monika Ehrman, *The Next Great Compromise: A Comprehensive Response to Opposition Against Shale Gas Development Using Hydraulic Fracturing in the United States*, 46 TEX. TECH L. REV. 423, 432–33 (2014).

In *Coastal Oil v. Garza Energy Trust*, the Supreme Court of Texas held that the rule of capture prevented a finding of trespass.[111] Over a decade later, in *Briggs v. Southwestern Energy Production*, the Pennsylvania Supreme Court came to the same conclusion.[112] Each court declined to rule on whether a fracture crossing a property boundary was, in fact, a trespass. These rulings seem incongruous with doctrinal tort law, which requires no damage for the trespass tort—only an intentional act to cross the property of another without consent. But in both cases, the court noted the alleged tortfeasor's inability to guide the fracture path—without sight, there is less control over action.

3. Porous Space

The absence of physical material is also a hidden resource. Porous space refers to the interstitial areas between minerals. Much like the porous space in a kitchen sponge, these voids provide the ability to store fluids, such as groundwater, petroleum, and injected material. The space exists naturally but can also be enhanced by withdrawing fluids. Scientists are examining carbon capture and sequestration (CCS) projects as a method by which to gather carbon and other greenhouse gas waste products and then inject them into porous space reservoirs. The CCS process prevents the release of these gases into the atmosphere.[113]

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111. *See* Coastal Oil & Gas Corp. v. Garza Energy Tr., 268 S.W.3d 1, 13 (Tex. 2008).
112. *See* Briggs v. Sw. Energy Prod. Co., 224 A.3d 334, 352 (Pa. 2020).
113. LOWE ET AL., *supra* note 106, at 828.

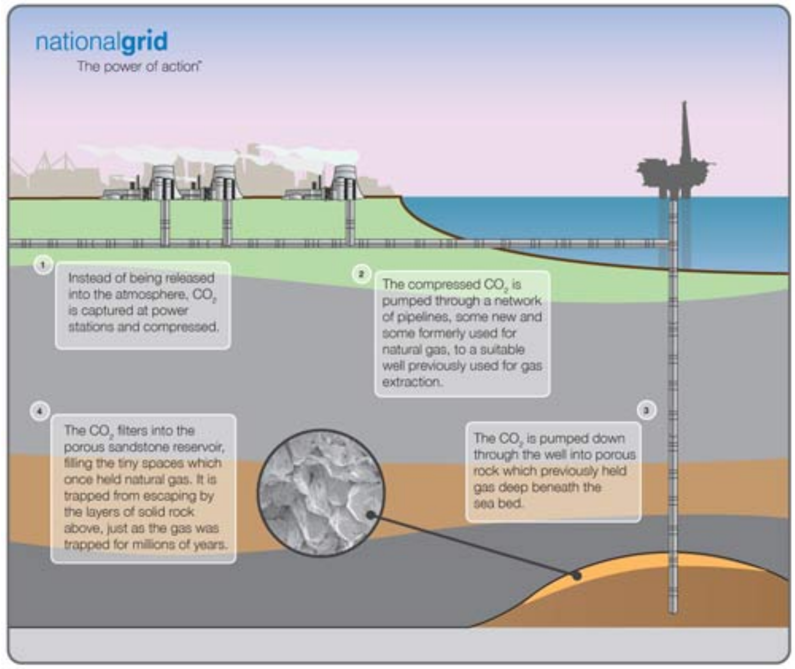

Figure 6: CCS diagram[114]

The challenge of porous space ownership is tied directly to its nature as a hidden resource. Filled porous space is not useful in its capacity to store. A storage unit that is filled completely has little value to a prospective renter. The value of porous space is in its storage potential. And often, that storage potential is artificially created by a subsurface owner's withdrawal of an originally existing material. Depleted oil and gas reservoirs and water-bearing aquifers are examples of artificial withdrawal. In those cases, the owner or user of the subsurface property created the void space that could now serve an additional use. Essentially, their labor created the property. But as discussed below in Part III, porous space ownership is unclear and does not ascribe to Lockean theory (ascribing ownership to natural resources upon the exertion of labor). Ultimately, a lack of resource sight promotes conflicts in resource ownership.[115] Here, there is a duality to the hidden nature of porous space—not only is it subsurface, but its existence requires absence itself.

114. WHITE ROSE CARBON CAPTURE & STORAGE PROJECT, ENVIRONMENTAL SCOPING REPORT 5 (2012), https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010048/EN010048-000354-121210_EN010048_Scoping%20Report.pdf [https://perma.cc/8RRQ-G78A] (refer to diagram labeled "nationalgrid").

115. For more information on pore space property, see Joseph A. Schremmer, *Pore Space Property*, 2021 UTAH L. REV. 1 (2021); Tara Righetti, Jesse Richardson, Kris Koski, & Sam Taylor, *The*

B. Atmospheric and Environmental Hidden Resources

Many hidden resources are found above the ground. Atmospheric and environmental hidden resources include those natural resources with utilitarian characteristics, such as wind for power generation and weather for commercial or climate modification purposes, in addition to those natural resources that are preserved for biocentric purposes, like climate.

1. Wind

Wind is a physical manifestation of changes in atmospheric pressure, caused by temperature variation due to the uneven heating of the earth's crust. Although the electricity generated by wind-driven turbines is referred to as "wind energy," wind itself is a form of solar energy. As air molecules are heated, they flow in response to air pressure differentials, modified by topography and planetary spin. This resulting kinetic energy can be harnessed to turn a generator using the blades of a wind turbine.

Wind turbines are massive structures, rising over 280 feet into the sky.[116] The greater the altitude, the greater the wind speed, which explains Appalachian coal country's interest in siting turbines on mountaintops.[117] But costs related to siting turbines on such challenging terrain and the required power transmission infrastructure are often prohibitive, which explains the prevalence of wind projects across the Great Plains.[118] Not only are the relatively level lands well-suited for efficient building, but the prairie's lack of varied terrain (e.g., trees, hills, etc.) allows the air molecules to flow freely, with less friction. As the world moves toward low-carbon power generation, wind energy offers a climate-friendly option.[119] States

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Carbon Storage Future of Public Lands, 38 PACE ENV'T L. REV. 181 (2021); Tara Righetti, *The Private Pore Space: Condemnation for Subsurface Ways of Necessity*, 16 WYO. L. REV. 77 (2016).

116. *Wind Turbine Heights and Capacities Have Increased over the Past Decade*, U.S. ENERGY INFO. ADMIN. (Nov. 29, 2017), https://www.eia.gov/todayinenergy/detail.php?id=33912 [https://perma.cc/W6QR-2FTM].

117. Linda Harris, *Wind Energy Still Isn't Mainstream in the Mountain State*, EXPONENT TELEGRAM (Mar. 29, 2018), https://www.wvnews.com/theet/news/wind-energy-still-isnt-mainstream-in-the-mountain-state/article_d9fec3b2-02b8-56fe-81dc-74c26e832322.html [https://perma.cc/5H3Y-9JTW]. For more on conflicts, see Adam Hochberg, *Wind Farms Draw Mixed Response in Appalachia*, NPR (Mar. 27, 2006, 4:32 PM), https://www.npr.org/templates/story/story.php?storyId=5300507 [https://perma.cc/Y62S-RSNC]; *see also* Jenna Portnoy, *After Coal, Appalachia to Wind Farm Proposal: 'It is insulting, really.*,' WASH. POST (Aug. 20, 2015), https://www.washingtonpost.com/local/virginia-politics/after-coal-appalachia-to-wind-farm-proposal-its-insulting-really/2015/08/20/68349002-3091-11e5-8f36-18d1d501920d_story.html [https://perma.cc/5SDE-JCQK].

118. *Wind Energy Is on the Rise in the Great Plains*, YALE CLIMATE CONNECTIONS (Nov. 26, 2019), https://yaleclimateconnections.org/2019/11/wind-energy-is-on-the-rise-in-the-great-plains/ [https://perma.cc/47RR-CSWL].

119. This contemplates only Scope 1 emissions.

are thus incentivized to implement property regimes for title certainty, in addition to regulatory and taxation purposes.[120]

But wind represents a significant challenge in terms of ownership and governance—not only is it invisible, but it cannot be enclosed. Subsurface property, like groundwater, petroleum, and even porous space (within its surrounding rock formations) can be physically trapped by overlaying rock at a precise moment in time. And because these resources generally move slowly—over geologic spans of time in some instances—they are easier to imagine as immovable or affixed property. Wind cannot be represented as solid—its very essence is a movement of energy.

Moreover, subsurface hidden resources can be produced and physically trapped at the surface, often transforming into personal property. Wind cannot be trapped or stored—it is only converted. From solar energy, a wind turbine transforms it to mechanical energy, where the rotating turbine transforms it to electrical energy. Typically, the only characteristic of wind capable of visual representation is its velocity.

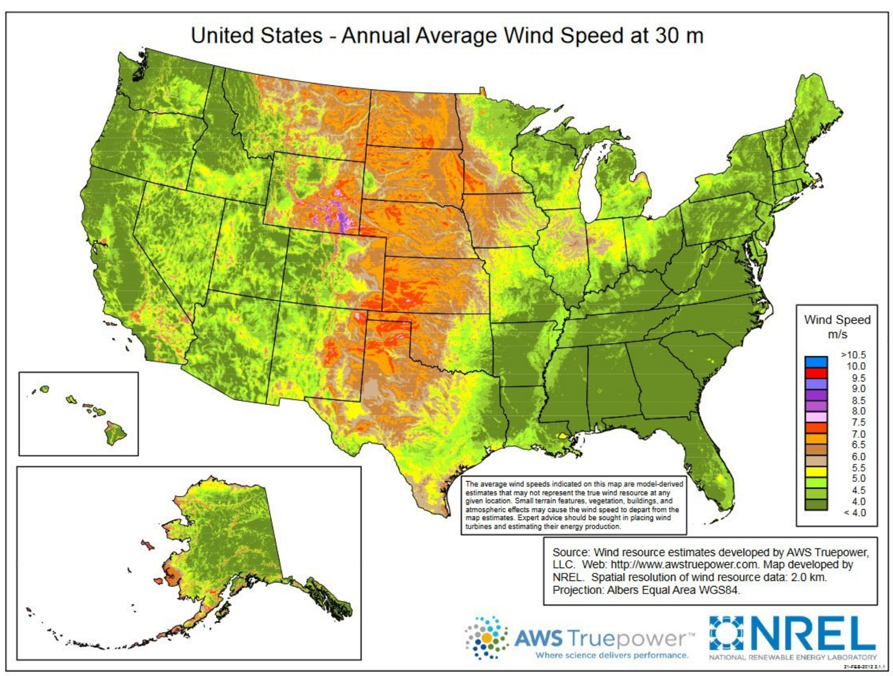

Figure 7: U.S. map showing average annual wind speeds[121]

120. Lucas Nelsen, *Wind Energy Yields Tax Revenue*, CTR. RURAL AFFS. (Dec. 27, 2018), https://www.cfra.org/blog/wind-energy-yields-tax-revenue [https://perma.cc/XV7R-97Z6].

121. Nat'l Renewable Energy Lab'y, *U.S. Average Annual Wind Speed at 30 Meters*, OFF. ENERGY EFFICIENCY & RENEWABLE ENERGY, https://windexchange.energy.gov/maps-data/325 [https://perma.cc/BNZ9-54FW] (last visited Jan. 22, 2023).

As with its brethren hidden resources, the law has risen slowly to the challenge of wind governance. That is not so with savvy property owners and their attorneys, who have begun creating *wind deeds*. These Aeolian deeds—deeds to wind rights—claim ownership over the *wind estate*, sometimes severing it from the surface estate.[122] Real property records now have assignments and transfers of wind rights, which may or may not transfer legal title. Whether these instruments indeed cloud[123] title is a question that courts and arbitrators will soon face.

2. Weather Modification[124]

Cloud seeding is an artificial weather modification used to increase precipitation from certain cloud systems for drought mitigation, agricultural, and recreational (e.g., increasing snowpack for ski hills) purposes.[125] It involves the release of silver iodide or dry ice from airplanes and weather towers into clouds to cause rainfall and snowfall.[126]

122. Dan Solomon, *West Texas Property Sales Don't Always Include the Wind Rights*, TEX. MONTHLY (Dec. 14, 2017), https://www.texasmonthly.com/news-politics/west-texas-wind-power-rights/ [https://perma.cc/L2P6-A7JF].

123. Pun intended. *See Cloud on Title*, CORNELL L. SCH.: LEGAL INFO. INST. (July 2022), https://www.law.cornell.edu/wex/cloud_on_title [https://perma.cc/7G35-VC9Z] ("A cloud on title is a claim or encumbrance that affects the ownership of a property. These claims or encumbrances can arise from easements or mortgages on the land, ... Clouds on title . . . may be lifted by a quiet title action.").

124. *See generally*, Bradshaw & Ehrman, *supra* note 84.

125. Cloud seeding may also be used as a form of geoengineering for climate change mitigation, whereby precipitation decreases associated rising temperatures and drought.

126. Chelsea Harvey, *Eight States Are Seeding Clouds to Overcome Megadrought*, SCI. AM. (Mar. 16, 2021), https://www.scientificamerican.com/article/eight-states-are-seeding-clouds-to-overcome-megadrought/ [https://perma.cc/BF2L-HM44].

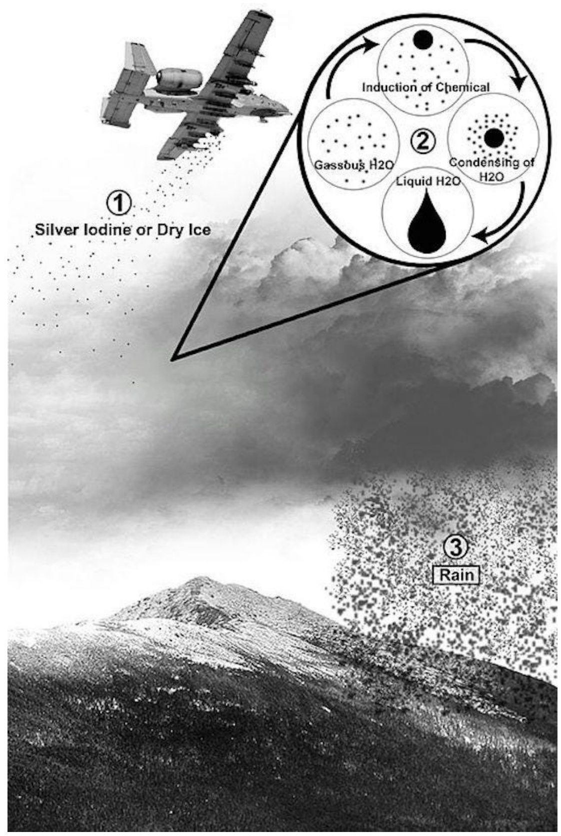

Figure 8: Aerial cloudseeding diagram[127]

The technology was first developed in the 1940s and 1950s and used as a form of meteorological warfare during the Vietnam War. This military purpose was eventually prohibited under a UN Charter, permitting weather modification for peaceful purposes only. Domestically, cloud seeding has a surprising lack of governance, which is confounding given its potentially detrimental impacts on the environment and human health.[128] Although users of silver iodide for seeding claim that the silver levels in the resulting precipitation are below Environmental

127. James Conca, *Seeding the Clouds—Should We Mess with Our Earth's Climate?*, FORBES (June 22, 2017, 6:00 AM), https://www.forbes.com/sites/jamesconca/2017/06/22/seeding-the-clouds-should-we-mess-with-our-earths-climate/?sh=3637414f696cS [https://perma.cc/35HT-J42W] (illustration by Spencer McNab).

128. *See e.g.*, Ronald B. Standler & Bernard Vonnegut, *Estimated Possible Effects of AgI Cloud Seeding on Human Health*, 11 J. APPLIED METEOROLOGY 1388 (1972) (discussing the potential harms of cloud seeding, including recognized harms of aerosolized silver iodide dating as far back as the 1930's).

Protection Agency (EPA) secondary maximum contaminant levels,[129] there is not enough data to conclude a minimal health effect. These often trans-boundary resources face limited federal regulation, and the National Environmental Policy Act (NEPA) does not require an environmental assessment before installation. Although private and other non-federal actors may be conducting the weather modification activity, applications are only required by the National Oceanic and Atmospheric Administration (NOAA).

3. Climate Change

The climate crisis is unquestionably the largest global challenge facing humanity. The potentially deadly effects will not discriminate; the entire planet will be affected. But even with such dire consequences and scientific consensus surrounding the same, there are still groups who doubt its existence. The prior Trump Administration is one such example of resistance. In his first year of office, President Trump removed the United States from the Paris climate agreement, which was negotiated over 25 years with 175 countries.[130] Although the majority of Americans polled opposed the withdrawal, Trump's base and many Republican politicians supported the exit.[131] A few years and another presidential administration later:

> [T]here are still 139 elected officials in the 117th Congress, including 109 representatives and 30 senators, who refuse to acknowledge the scientific evidence of human-caused climate change. All 139 of these climate-denying elected officials have made recent statements casting doubt on the clear, established scientific consensus that the world is warming—and that human activity is to blame.[132]

The invisibility of other natural resources makes interacting with them—or solving problems related to them—difficult. This difficulty helps explain why climate change is termed an existential crisis.[133] Despite decades of strong evidence

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129. For current EPA standards see *Secondary Drinking Water Standards: Guidance for Nuisance Chemicals*, E.P.A. (Feb. 17, 2022), https://www.epa.gov/sdwa/secondary-drinking-water-standards-guidance-nuisance-chemicals [https://perma.cc/9PAE-BT9H].

130. Renee Cho, *The U.S. Is Back in the Paris Agreement. Now What?*, COLUM. CLIMATE SCH. (Feb. 4, 2021), https://news.climate.columbia.edu/2021/02/04/u-s-rejoins-paris-agreement/ [https://perma.cc/QZ38-RAGW]; Firmin DeBrabander, *Why Is Climate Change Such a Hard Sell in the US?*, CONVERSATION (June 7, 2017, 10:36 PM) https://theconversation.com/why-is-climate-change-such-a-hard-sell-in-the-us-78794 [https://perma.cc/3UZH-9KV8].

131. DeBrabander, *supra* note 130.

132. Ari Drennen & Sally Hardin, *Climate Deniers in the 117th Congress*, CTR. AM. PROGRESS (Mar. 30, 2021), https://www.americanprogress.org/issues/green/news/2021/03/30/497685/climate-deniers-117th-congress/ [https://perma.cc/R7UF-CGMB].

133. Andrew Moseman & Kieran Setiya, *Why Do Some People Call Climate Change an "Existential Threat"?*, MIT CLIMATE PORTAL (July 12, 2021), https://climate.mit.edu/ask-mit/why-do-some-people-call-climate-change-existential-threat [https://perma.cc/G9CA-X4GE].

indicating anthropogenic climate change, there continues to be resistance from certain groups, which deny the existence of the threat or deny that humans are largely responsible for the climate threat. Contrarian views seem impossible to espouse. In 2021, the Nobel Prize in physics was awarded to Dr. Syukuro Manabe and Dr. Klaus Hasselmann for their work that showed how humans were changing Earth's climate.[134] Yet, climate deniers still voice their science-less objections.[135]

A problem central to the varying indifference or disbelief is that climate change is invisible—it is a hidden natural resource.[136] The greenhouse gases themselves are invisible. Although the white cloud-like emissions from power plant stacks are often used as a stock photo representation of pollution, the white "smoke" typically consists of water droplets and soot.[137] Carbon dioxide, methane, and nitrous oxide are all colorless—they can lurk in the atmosphere, as disastrous as the impending asteroid that ended the age of the dinosaurs over sixty-six million years ago,[138] but without the telltale portent of doom that shone in the sky. And though greenhouse gas emissions are present within the atmosphere, there is nothing to denote their visibility, unlike the tsunami waves of dust that blackened the skies during the Great Depression.[139]

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134. Geoff Brumfiel, *The Nobel Prize in Physics Honors Work on Climate Change and Complex Systems*, NPR (Oct. 5, 2021, 7:34 AM), https://www.npr.org/2021/10/05/1043278925/nobel-prize-physics-climate-change-winner [https://perma.cc/4HDB-CGSB]. In fact, Dr. Manabe "built one of the first climate models in the 1960s that explained how human-produced carbon dioxide could warm the planet." *Id.*

135. *See, e.g.*, Ellen Cranley, *These Are the 130 Current Members of Congress Who Have Doubted or Denied Climate Change*, INSIDER (Apr. 29, 2019, 10:36 AM), https://www.businessinsider.com/climate-change-and-republicans-congress-global-warming-2019-2 [https://perma.cc/3PAJ-ABBT]; Riley E. Dunlap & Peter J. Jacques, *Climate Change Denial Books and Conservative Think Tanks: Exploring the Connection*, 57 AM. BEHAV. SCI. 699 (2013).

136. DeBrabander, *supra* note 130.

137. *Art and Climate: Making the Invisible Visible*, PRINCETON U. ART. MUSEUM (2017), https://artmuseum.princeton.edu/object-package/art-and-climate-making-invisible-visible/96500 [https://perma.cc/NG6E-5RPF].

138. Emily Osterloff, *How an Asteroid Ended the Age of the Dinosaurs*, NAT'L HIST. MUSEUM, https://www.nhm.ac.uk/discover/how-an-asteroid-caused-extinction-of-dinosaurs.html [https://perma.cc/R2ZZ-XEMX] (last visited Jan. 22, 2023).

139. *See* Sophie Vaughn, *The Dust Bowl Offers Key Climate Change Lessons for the U.S.*, TEEN VOGUE (July 15, 2021), https://www.teenvogue.com/story/dust-bowl-climate-change [https://perma.cc/LW2Q-7TV6]; Jason G. Antonio, *WDM Talks Devastating Effects of the Great Depression During Coffee Club*, MOOSE JAW TODAY (July 4, 2021, 1:00 PM), https://www.moosejawtoday.com/local-news/wdm-talks-devastating-effects-of-the-great-depression-during-coffee-club-3927276 [https://perma.cc/GLN4-24FP] (describing the Dust Bowl in Canada).

Figure 9: A Black Blizzard approaching Rolla, KS on May 6, 1935.[140]

Unlike a dust storm, tsunami, tornado, or flash flood, climate change is the accumulation of climate-related effects. These effects are spread over many generations; and that span of time—greater than individual memory—is difficult for humans to comprehend.[141] While the causes of anthropogenic climate change affect the global commons, the effects are generally experienced at a local (individual) level. Moreover, the effects themselves are subjective. One person's hot summer is another's perfect season.[142]

C. Microscopic Resources

The invention of the microscope provided scientists with sight to identify the basic building block of life itself—the cell. Subsequent discoveries included bacteria and viruses, giving rise to such fields as cellular biology, microbiology, and—importantly in the age of COVID-19—virology. As discussed earlier, the ability to examine organisms at the cellular level reshaped our understanding of life and the evolutionary process.

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140. *48223719(33)*, FRANKLIN D. ROOSEVELT PRESIDENTIAL LIBR. & MUSEUM, http://www.fdrlibrary.marist.edu/archives/collections/franklin/?p=digitallibrary/digitalcontent&id=3054 [https://perma.cc/FL2Y-9TR2] (last visited Jan. 23, 2023).

141. Matthew Wilburn King, *How Brain Biases Prevent Climate Action*, BBC: FUTURE (Mar. 7, 2019), https://www.bbc.com/future/article/20190304-human-evolution-means-we-can-tackle-climate-change [https://perma.cc/39MA-SJ9E].

142. DeBrabander, *supra* note 130.

1. Microplastics[143]

In addition to biological resources, visual sight provides knowledge to address environmental harms. One potential global harm is biological absorption of microplastics, which are defined as plastic particles smaller than 5 mm (millimeters) across.[144] Marine ecologist, Richard Thompson, coined the term in 2004 to describe these plastics after finding them on British beaches.[145] Since his team's discovery, microplastics have turned up everywhere: in oceans; in Arctic snow and Antarctic ice; in shellfish, table salt, and drinking water; and "drifting in the air or falling with rain over mountains and cities."[146] Essentially, we live in a world of invisible, plastic particulates. Just like Hooke and his observations of distinct cellular structures, Thompson's finding of plastic debris could have massive implications on environmental and human wellbeing.[147]

The microplastic challenge illustrates a particular difficulty of hidden resources: How does one determine the extent of the resource spread when simple identification itself is problematic? Because of the profusion of microplastics in the natural environment, it is logical to assume that microplastics will be found in human organs.[148] However, finding direct causation between the microplastics in the environment and those plastics found in human organs is complicated.

Atmospheric microplastic contamination is also complex and creates the same conflicts that arise within the context of historic air pollution problems. For example, scientists understood that methane and carbon dioxide from various fossil combustion produced atmospheric emissions. It was theorized and greatly accepted by the scientific community that those small particles of non-combusted carbon and resultant emissions combined within the atmosphere to prevent solar radiation (sunlight) from escaping the earth's atmosphere, raising global temperatures. But greenhouse gases are invisible, hidden from human gaze. It has taken decades of environmental policymaking and education to come to public understanding and

143. Although microplastics are not a natural resource, they are discussed here in terms of their interaction with the environment and ecosystem.

144. XiaoZhi Lim, *Microplastics Are Everywhere—But Are They Harmful?*, NATURE, May 4, 2021, at 22, 22, https://www.nature.com/articles/d41586-021-01143-3 [https://perma.cc/6SHW-PN5Q].

145. *Id.*

146. *Id.*

147. Considered the world's leading scholar of microplastic pollution, Thompson is the recipient of many honors, including the Marsh Award for Marine and Freshwater Conservation from the Zoological Society of London (2016), the Order of the British Empire for services to marine science (2018), and election as a Fellow of the Royal Society (2020).

148. Dennis Thompson, *Autopsies Show Microplastics in Major Human Organs*, WEBMD (Aug. 17, 2020), https://www.webmd.com/a-to-z-guides/news/20200817/autopsies-show-microplastics-in-all-major-human-organs [https://perma.cc/4UHD-KKLX] ("Microscopic bits of plastic have most likely taken up residence in all of the major filtering organs in your body . . . .").

support of climate change. And even today, there are still groups who dispute climate science and the effect of greenhouse gas emissions.[149]

While some of the conflict is undoubtedly related to human behavior and social science, one part of it is because of resource blindness. Lack of visual sight fails to register these small particles as a threat. In 2020, Dunzhu Li and his research team identified "microplastic release from the degradation of polypropylene feeding bottles during infant formula preparation"—in other words, babies are drinking plastic along with milk from their bottles.[150] If plastic pieces were visible to the human eye, they would be removed from the bottle or plate of food prior to drinking or eating. No parent would knowingly permit children to ingest plastic. But what happens when those particles exist but are not seen? The answer may lie with the history of another latent microscopic particle—lead.

2. Lead

Lead has long been part of human civilization. Originally recovered as a by-product of silver mining, many ancient civilizations, including the Egyptians, Greeks, and Romans, valued the metal for its multiple useful properties, including malleability and resistance to corrosion by water.[151] These elemental properties and its relative abundance were crucial to Ancient Roman reliance on lead for plumbing, which is the derivation of the modern word *plumbing*—from the Latin *plumbum*, meaning lead. Although the effects of lead exposure were observed and known by early civilizations, the often-repeated (but still-debated) lesson of Ancient Romans succumbing to lead poisoning,[152] was not heeded by modern societies. Almost 2,500

149. *See* discussion *supra* Section II.B.3.

150. Dunzhu Li, Yunhong Shi, Luming Yang, Liwen Xiao, Daniel K. Kehoe, Yurii K. Gun'ko, John J. Boland & Jing Jing Wang, *Microplastic Release from the Degradation of Polypropylene Feeding Bottles During Infant Formula Preparation*, NATURE FOOD, Nov. 2020, at 746.

151. The use of lead in ancient and modern applications is a result of its many properties. More information and background on lead and lead mining follows below:

> Lead is a dense, soft, low-melting metal. Lead is the densest common metal except for gold, and this quality makes it effective in sound barriers and as a shield against X-rays. Lead resists corrosion by water, so it makes a long-lasting roofing material.
>
> Only about half of the lead materials used today are produced from mining, the rest is obtained from recycling, mostly from car batteries. The largest producer of lead materials in the world is Australia followed by the USA, China[,] and Canada.
>
> Lead is extracted from ores dug from under[]ground mines. Of the more than 60 minerals that contain lead, only 3 galena, cerussite and anglesite are commercially viable. Usually, lead is found in conjunction with other metals such as silver and zinc. Lead materials are mined as a byproduct of these other more valuable metals.

Lead Materials—Ore Extraction, NUCLEAD, https://www.nuclead.com/leadmaterials/ [https://perma.cc/8FND-RFVQ] (last visited Jan. 22, 2023).

152. Scholars continue to examine and question the relationship between lead exposure and death and illness in the Roman Empire. Although lead poisoning is a long-studied illness, with direct

years after the fall of the Roman Empire, residents of Flint, Michigan were exposed to high levels of lead in water originating from city pipes.[153]

Although the metal lead is visible to the human eye when mined, its industrial use often requires the conversion of the lead ore into refined lead, which is ground

causation between ingestion of lead and human morbidity and mortality, scholars are unsure of the extent that Ancient Romans may have suffered from lead poisoning and, if so, whether that poisoning contributed to the decline of the Roman Empire. *See, e.g.*, *Deadly Lead: How Lead Poisoning Affected the Roman Empire*, U. SHEFFIELD (Oct. 23, 2017), https://www.sheffield.ac.uk/news/nr/lead-poisoning-roman-empire-research-italy-archaeology-1.740191 [https://perma.cc/2EMS-RS8X]; Lenny Bernstein, *Lead Poisoning and the Fall of Rome*, WASH. POST (Feb. 17, 2016, 1:45 PM), https://www.washingtonpost.com/news/to-your-health/wp/2016/02/17/lead-poisoning-and-the-fall-of-rome/ [https://perma.cc/UM8K-LT4D]; Kristina Killgrove, *Archaeological Skeletons from London Prove Some Romans Were Lead Poisoned*, FORBES (Nov. 29, 2019, 10:12 AM), https://www.forbes.com/sites/kristinakillgrove/2019/11/29/archaeological-skeletons-from-london-prove-some-romans-were-lead-poisoned [https://perma.cc/2VJY-L9XL]; Brad Plumer, *Lead Water Pipes Didn't Destroy the Roman Empire, After All*, VOX (Apr. 23, 2014, 3:00 PM), https://www.vox.com/2014/4/23/5644330/lead-water-pipes-didnt-destroy-the-roman-empire-after-all [https://perma.cc/9XPY-ZKHD].

153. The Flint water crisis is an ongoing environmental justice tragedy. The events and insight of the crisis are examined thoroughly in Courtney L. Anderson, *Taking Flint*, 17 HOUS. J. HEALTH L. & POL'Y 107 (2017). Anderson explains, in part:

> The Flint River water crisis was the result of a culmination of actions by local, state, and federal actors in an effort to cut costs in a financially unstable city. In order to understand the current situation in Flint, Michigan, one must go back to 2010, the year in which the Karegnondi Water Authority (KWA) was incorporated. The KWA is an entity that, once completed, will utilize water from Lake Huron to provide water services to various communities throughout the State of Michigan, including Flint.
>
> . . . .
>
> Subsequently, the Flint City Council . . . approve[d] a resolution to become a partner in the KWA, the new regional water authority, and to cut ties with its current water provider, the Detroit Water and Sewerage Department (DWSD). This switch . . . was seen as a cost-saving move to improve Flint's financial stability.
>
> . . . .
>
> At the time of the vote to switch to the KWA, the pipeline from Flint to the KWA source was not yet completed.
>
> . . . .
>
> Beginning in June 2013, the City of Flint began to undertake the process of utilizing the Flint River as the city's main source of drinking water until the completion of the KWA pipeline.
>
> . . . .
>
> . . . On April 1, 2014, the [Michigan Department of Environmental Quality] (MDEQ) approved and issued a construction permit to begin the process of making the Flint Water Treatment Plant operational.
>
> . . . .
>
> . . . Despite the MDEQ's assurances, the Flint River was not safe to drink. Unlike the city's previous water from Lake Huron with the DWSD, the water from the Flint River is significantly more corrosive, which can cause leaching of iron and lead pipes. A corrosion control program . . . was not used in the treatment of Flint River water. The lack of a corrosive control program for the Flint River water is what ultimately led to the leaching of lead pipes into the drinking water.

Id. at 125–29 (citations omitted).

into powder form. These small lead particles[154] may measure only between 14–15 µm (micrometers) (1×10^{-6} meter). Once ground, the lead powder is mixed with oil and other solvents to form products such as lead-based paint. Lead paint was widely used in the United States because it is highly durable and resistant to water. It was eventually phased out in the 1970s,[155] but only for U.S. residential use.[156] However, the perils of microscopic lead and its associated resource blindness were not only limited to water pipes and painted walls and toys—it was even in the air.

In 1916, Standard Oil of New Jersey—John D. Rockefeller's storied company of Sherman Act fame—began focusing on a research problem: how to eliminate knocking or banging sounds in car engines.[157] After years of research, a General Motors engineer, Thomas Midgley, Jr., discovered that adding the compound *tetraethyl lead* to gasoline quieted the knocking sounds.[158] The resounding success and popularity of the fuel additive resulted in ramping up of production and employment of plant laborers. But then laborers at the chemical plant became ill.

> Some of the workers started getting lost on the familiar plant grounds, had trouble even remembering their friends . . . [I]n October of 1924, laborers from that same building started collapsing, going into convulsions, babbling deliriously. By the end of September, 32 of the 49 [tetraethyl lead] workers were in the hospital and five of them died.[159]

Standard Oil of New Jersey was not concerned.

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154. For more information on lead ore processing, see *Lead*, ESSENTIAL CHEM. INDUS.—ONLINE (Sept. 26, 2016), https://essentialchemicalindustry.org/metals/lead.html [https://perma.cc/6435-HJB7].

155. *Legislative History of Lead-Based Paint*, U.S. DEP'T HOUS. & URB. DEV., https://www.hud.gov/sites/documents/20258_LEGISLATIVEHISTORY.PDF [https://perma.cc/5BXE-5CMW] (last visited Jan. 22, 2023).

156. Lead paint is still produced and used in commercial and industrial applications. *See* Rebecca Kessler, *Lead-Based Decorative Paints: Where Are They Still Sold—and Why?* 122 ENV'T HEALTH PERSPS. A96 (2014), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3983718/ [https://perma.cc/MG78-C2PR]; *Despite Bans, Most Countries Still Have Lead Paint*, U.N. ENV'T PROGRAMME (Oct. 27, 2018), https://www.unep.org/news-and-stories/story/despite-bans-most-countries-still-have-lead-paint [https://perma.cc/K266-EFU4] (interviewing Dr. Olga Speranskaya, Senior Pol'y Advisor, Int'l Pollutants Elimination Network); Anne Harding, *Lead-Laden Paint Still Widely Sold Around the World*, REUTERS (Aug. 25, 2009, 1:21 PM), https://www.reuters.com/article/us-lead-paint/lead-laden-paint-still-widely-sold-around-the-world-idUSTRE57O64G20090825 [https://perma.cc/KQ23-BYSH].

157. Deborah Blum, *At the Door of the Loony Gas Building*, WIRED (Aug. 24, 2011, 12:54 AM), https://www.wired.com/2011/08/at-the-door-of-the-loony-gas-building/ [https://perma.cc/D7RL-9B23]; *see also*, David Rosner & Gerald Markowitz, *"A Gift of God"?: The Public Health Controversy Over Leaded Gasoline During the 1920s*, *in* DYING FOR WORK: WORKERS' SAFETY AND HEALTH IN TWENTIETH-CENTURY AMERICA 121, 122 (David Rosner & Gerald Markowitz eds., 1987); William Graebner, *Hegemony Through Science: Information Engineering and Lead Toxicology, 1925–1965*, *in* DYING FOR WORK, *supra*, at 140, 140–42.

158. Blum, *supra* note 157.

159. *Id.*

> [It] issued a coolly dismissive response: "These men probably went insane because they worked too hard," the building manager told *The New York Times*. Those who didn't survive had merely worked themselves to death, he continued, due to enthusiasm for the job.

Other than that, the company didn't really see a problem at all.[160]

The military, no strangers to chemical warfare, were quicker to deduce the problem.

Brigadier General Amos O. Fries, the Chief of the Army Chemical Warfare Service, knew all about tetraethyl lead. The military had shortlisted it for gas warfare, he told the *Times*. The killer was obvious—it was the lead.[161]

But it would take chemist Clair Patterson's remarkable experiment to calculate Earth's age to find that leaded gasoline was poisoning the planet's atmosphere.[162] Many in science and industry opposed Patterson's findings and conclusions.[163] One of his most stunning experiments included procurement and examination of ice cores from Greenland, which "showed a '200- or 300-fold increase' in lead from the 1700s to present day. But the most startling jump had occurred in the last three decades [1940s–1960s]."[164] Patterson's work and congressional testimony influenced the enactment of the Clean Air Act of 1970 and eventually the phasing out of lead in gasoline.[165]

One great difficulty in convincing legislators, manufacturers, and the public of the dangers of leaded gasoline emissions was that the emissions—and lead particles—were not visible. Had the omnipresent lead been visible, policymakers would have likely moved more quickly to address the pollution, as the British government did during the London smog disaster in 1952, when 12,000 people died from smog in five days.[166]

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160. *Id.*

161. Lucas Reilly, *The Most Important Scientist You've Never Heard of*, MENTAL FLOSS (May 17, 2017), https://www.mentalfloss.com/article/94569/clair-patterson-scientist-who-determined-age-earth-and-then-saved-it [https://perma.cc/DR7M-7FKM].

162. *Id.*; Avir Mitra, *Heavy Metal*, RADIOLAB (Sept. 24, 2021), https://radiolab.org/episodes/heavy-metal?transcript=true [https://perma.cc/GQ48-HFGB].

163. Mitra, *supra* note 162.

164. Reilly, *supra* note 161.

165. *Id.*

166. Alessandra Potenza, *In 1952 London, 12,000 People Died from Smog—Here's Why that Matters Now*, VERGE (Dec. 16, 2017, 6:00 AM) https://www.theverge.com/2017/12/16/16778604/london-great-smog-1952-death-in-the-air-pollution-book-review-john-reginald-christie [https://perma.cc/6YEH-ZGC9].

Figure 10: Following the smog disaster, in 1956, the U.K. passed the Clean Air Act, the first such national legislation in the world.[167]

D. Distant Resources (The Very Deep and the Very Far)

Visual sight has advanced the fields of astronomy, astrophysics, and oceanography. Sight acquisition in space and in our deep oceans and seas has provided knowledge about the origin of the universe and the evolution of planetary life. Astronomical visual information is collected by telescopes, satellites, and spacecraft, while oceanographic information is collected by remote and manned craft, probes, and other remote cameras. Many of these methods involve indirect collection of visual, pictorial imagery, which shall be referred to as *secondary sight*. Conversely, direct observation is referred to as *primary sight*. Although both primary and secondary sight are forms of resource sight, secondary sight requires intermediary processing, usually in the form of technology—the difference between looking at a tree and looking at a picture of the same tree.

1. Deep Oceans

Covering more than seventy percent of the world,[168] oceans are critical to planetary health. Life first formed in these saline waters, from which human biological ancestors emerged, beginning their measured evolution on dry land. Although humans have long sailed and explored the oceans, about eighty percent

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167. Christopher Klein, *The Great Smog of 1952*, HISTORY (Aug. 22, 2018), https://www.history.com/news/the-killer-fog-that-blanketed-london-60-years-ago [https://perma.cc/EG8P-VLXZ].

168. Nat'l Oceanic & Atmospheric Admin., *How Much of the Ocean Have We Explored?*, NAT'L OCEAN SERV. (Jan. 20, 2023), https://oceanservice.noaa.gov/facts/exploration.html [https://perma.cc/UZ4P-V8NK].

of "this vast underwater realm remains unmapped, unobserved, and unexplored."[169] Because of the high cost and degree of difficulty to explore the ocean using underwater vehicles, most ocean exploration is done using sonar—sound waves—just as geophysicists map the subsurface in search of petroleum.[170] In fact, sound waves are the best tool for underwater exploration. Sunlight travels through the ocean depths in significant amount only to about 200 meters (656 feet).[171] Depending on conditions, light waves may travel to about 1,000 meters (3,280 feet).[172] Past that, the ocean is in constant darkness.[173]

169. *Id.*

170. *Id.*

171. Nat'l Oceanic & Atmospheric Admin., *How Far Does Light Travel in the Ocean?*, NAT'L OCEAN SERV. (Jan. 20, 2023), https://oceanservice.noaa.gov/facts/light_travel.html [https://perma.cc/H3NJ-D37V].

172. *Id.*

173. *Id.*

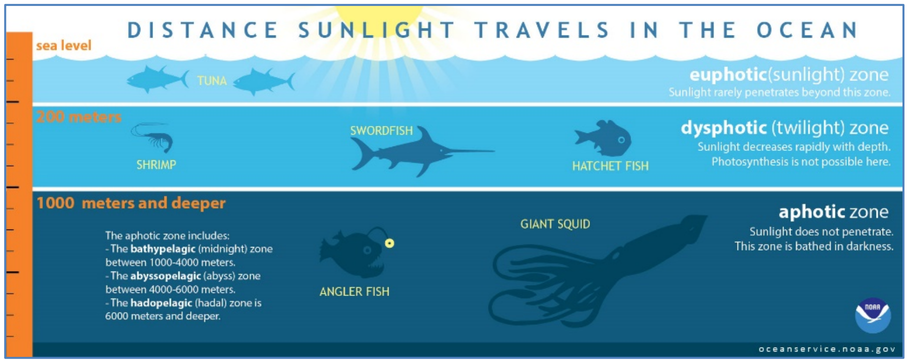

Figure 11: Diagram showing distances sunlight travels in ocean[174]

2. Outer Space

Humans have long been fascinated by the stars. Early humans noted patterns formed in the evening skies, creating constellations and stories describing the starry pictures.[175] Modern technology provides an opportunity for both primary and secondary sight acquisition—manned orbital and lunar spacecraft have provided visuals of the earth and the Moon from viewpoints previously unknown. The same technology has provided sight to galaxies and other interstellar phenomena light-years away.

Following the early lunar missions, Voyager I and Voyager II were launched in 1977.[176] Originally designed to explore Jupiter and Saturn with only a five-year lifespan, the resilient ships have traveled for forty years, exploring the outer planets and exiting the solar system—the farthest a human-made object has ever explored.[177]

Voyagers I and II sent images of the gas giants and outer solar system with breathtaking clarity.[178] For the first time, humans saw their solar system. Volcanic activity on Jupiter's moon, Io,[179] and the scarring of impact craters on Saturn's moon, Dione,[180] provided insight into Earth's early formation. But monetization and the quest for resources also drives space exploration. Many asteroids, neighboring planets, and their moons are believed to be sources of resource wealth.

174. *Id.*
175. *Early Astronomy*, N. ARIZ. U., https://www2.nau.edu/~gaud/bio301/content/erlast.htm [https://perma.cc/HX3N-SDD9] (last visited Jan. 22, 2023) (30,000-year-old cave drawings).
176. *Images Voyager Took of Neptune*, N.A.S.A., https://voyager.jpl.nasa.gov/galleries/images-voyager-took/neptune/ [https://perma.cc/EJ4E-8Z29] (last visited Jan. 22, 2023).
177. *Id.*
178. *Id.*
179. Daisy Dobrijevic & Mike Wall, *Voyager: 15 Incredible Images of Our Solar System Captured by the Twin Probes (Gallery)*, SPACE.COM (Sept. 22, 2022), https://www.space.com/voyager-spacecraft-best-images-solar-system [https://perma.cc/FR2S-BC47].
180. *Id.*

The Jovian moons, Europa and Ganymede, and Saturn's moon, Enceladus,[181] likely possess water ice,[182] which was photographed by Voyager II;[183] the original water vapor plumes were detected by the Hubble Space Telescope.[184] And NASA estimates that the asteroid belt, which lies between Mars and Jupiter, holds "wealth equivalent to a staggering $100 billion for every person on Earth."[185]

E. Additional Hidden Resources

Hidden resources abound the universe and cannot be covered within the scope of a single article. Voyager I and Voyager II are two of only five spacecraft to leave the solar system.[186] That momentous challenge lies in escaping the Sun's gravitational force, which binds the solar system.[187] Gravity is one of four fundamental forces, along with *electromagnetic*, *strong*, and *weak*. Although we do not see these forces, they are responsible for all interactions within the known universe.[188]

Hidden resources are also present in the microscopic forms of ancient life, preserved in the fossil record, which captures a moment in time—like a picture in an ancestral memory box. Fossilized organisms, like the tardigrade—"a charismatic group of microscopic invertebrates that are famous for their survival after exposure to extreme conditions"[189]—provide insight into the conditions that gave rise to life on Earth, in addition to information about our biological predecessors. Entire fields, like paleontology, nuclear physics, petroleum engineering, and hydrology rely on visual representations or proxies for visual sight. Both methods rely heavily on technology to create an image or model.

Other hidden resources are revealed without specialized technology. Trees regulate ecosystems by absorbing and storing carbon dioxide emissions. Research indicates that "a worldwide planting programme could remove just under one-third of all the emissions from human activities that remain in the atmosphere today

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181. *Id.*

182. Water ice is frozen water, which may harbor life beneath and which may be used as a resource for future human exploration of space.

183. *Id.*

184. *Id.*

185. Andrew Wong, *Space Mining Could Become a Real Thing—And It Could Be Worth Trillions*, CNBC (May 15, 2018, 7:00 AM), https://www.cnbc.com/2018/05/15/mining-asteroids-could-be-worth-trillions-of-dollars.html [https://perma.cc/98MC-EWLW].

186. Ethan Siegel, *NASA Finally Contacts Voyager 2 After Unprecedented Seven-Month Silence*, FORBES.COM (Nov. 4, 2020, 2:00 AM), https://www.forbes.com/sites/startswithabang/2020/11/04/voyager-2-phones-home-and-nasa-still-receives-the-call/?sh=15625bd7715c [https://perma.cc/T8YP-D5XE].

187. *Id.*

188. *The Standard Model*, CERN, https://home.cern/science/physics/standard-model [https://perma.cc/4LBV-FEJX] (last visited Jan. 22, 2023).

189. Marc A. Mapalo, Ninon Robin, Brendon E. Boudinot, Javier Ortega-Hernández & Phillip Barden, *A Tardigrade in Dominican Amber*, PROC. ROYAL SOC'Y B BIOLOGICAL SCIS., Oct. 13, 2021, https://royalsocietypublishing.org/doi/10.1098/rspb.2021.1760 [https://perma.cc/T6LM-NZ72].

[2019], a figure the scientists describe as 'mind-blowing.'"[190] Understanding how trees live, grow, and respond within an environment adds to their ability to fight climate change. And their lives are not only visible on their surfaces of bark, leaves, needles, and exposed roots. Tree growth layers, the rings in the tree trunk cross-section, "record evidence of disastrous floods, insect attacks, lightning strikes, and even earthquakes that occurred during the lifespan of the tree. They also hold excellent records of climate."[191] Although cutting down the tree reveals the resource, modern coring technology provides an ability to extract the growth ring core sample, without destroying the tree.[192] In fact, "[s]cientists match patterns from the early stages of a living tree's rings with the sequence formed in the latter parts of the lives of older, dead trees to assemble an unbroken paleoclimate record extending back thousands of years."[193]

Other novel forms of hidden resources include animal migratory paths. The monarch butterfly travels up to 3,000 miles to overwinter in the Sierra Madre Mountains, in Mexico, or in California.[194] Traveling 50 to 100 miles per day, migratory challenges include hunting by predators, climate, and difficulties finding food.[195] As diurnal creatures, monarchs must roost at night and these roosting sites are often used annually.[196] Pine, fir, and cedar trees are often chosen as roosting because of their thick canopies, which are used to moderate humidity and temperature.[197]

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190. Damian Carrington, *Tree Planting 'Has Mind-Blowing Potential' to Tackle Climate Crisis*, GUARDIAN (July 4, 2019, 2:00 PM), https://www.theguardian.com/environment/2019/jul/04/planting-billions-trees-best-tackle-climate-crisis-scientists-canopy-emissions [https://perma.cc/3AVX-ZAAQ].

191. *Tree Rings and Climate*, U.C.A.R., https://scied.ucar.edu/learning-zone/how-climate-works/tree-rings-and-climate [https://perma.cc/G5FR-DAGQ] (last visited Jan. 22, 2023) (noting that tree rings show periods of wet and cool, hot and dry weather, in addition to drought and cold winters); *see also Tree Rings Provide a 200-Year-Old Hurricane Record*, NAT'L SCI. FOUND. (Sept. 19, 2006), https://www.nsf.gov/news/news_summ.jsp?cntn_id=108010 [https://perma.cc/G442-342Z].

192. *Id.*

193. *Id.*

194. *Migration and Overwintering*, U.S. FOREST SERV., https://www.fs.usda.gov/wildflowers/pollinators/Monarch_Butterfly/migration/index.shtml [https://perma.cc/2PXR-FVN6] (last visited Jan. 22, 2023).

195. *Id.*

196. *Id.*

197. *Id.*

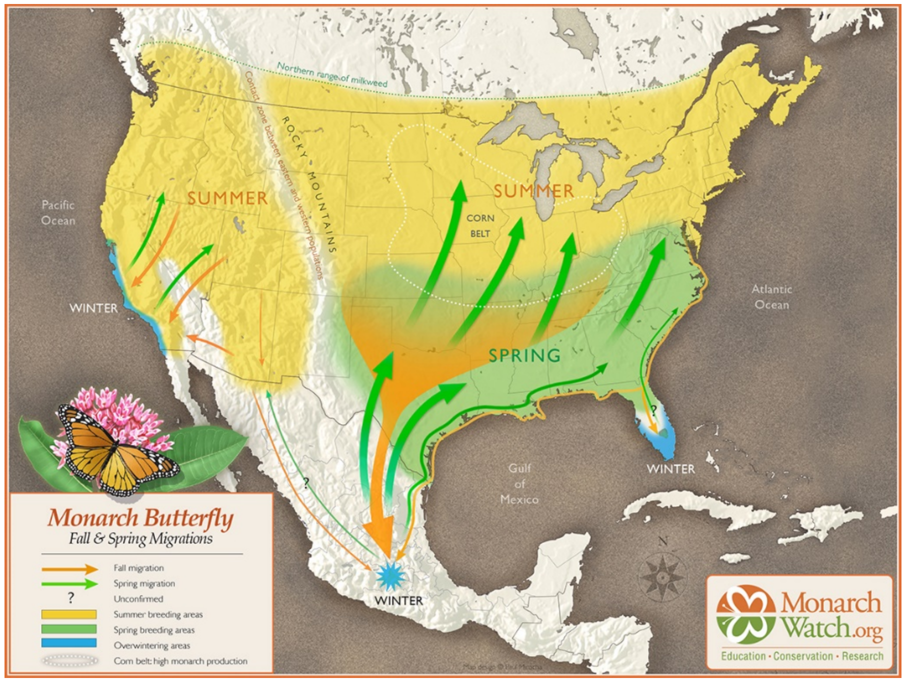

Figure 12: Migratory paths of monarch butterflies[198]

Other migratory animals, such as gray whales, caribou, Arctic terns, Chinook salmon, and blue wildebeest, travel vast distances, using memory and cognitive ecological processes to survive their travels.[199] Humans easily interfere with established migratory patterns because they are not visible. Development, pollution, destruction, or removal of native food, poaching, and other dangers can impact survival during an already precarious journey.

Finally, the author stresses that though this Article describes individual hidden resources, these resources should not be perceived as disparate. They are part of the same harmonious multidimensional system and coexist naturally.

III. HIDDEN RESOURCE OWNERSHIP

Hidden resources are not easily or intuitively "owned." The lack of sight prevents the establishment of recognized boundaries and fails to question whether the hidden resource is even one that should be owned and, if so, in what manner

198. *Monarch Migration*, MONARCH WATCH.ORG, https://www.monarchwatch.org/migration/ [https://perma.cc/H8KL-6BFW] (last visited Jan. 22, 2023).

199. Tovah Kashetsky, Tal Avgar & Reuven Dukas, *The Cognitive Ecology of Animal Movement: Evidence from Birds and Mammals*, FRONTIERS: ECOLOGY & EVOLUTION (Sept. 22, 2021), https://www.frontiersin.org/articles/10.3389/fevo.2021.724887/full [https://perma.cc/E2EP-PUNR].

(e.g., private v. common property, fee simple v. license). But the perceived need to own—and thereby optimize—resources has resulted in reliance on ancient doctrines that themselves originated during either unenlightened ages or soon thereafter. The simplistic *ad coelum* doctrine, which likely traces its origins to Roman law,[200] tidily addresses property ownership questions at the surface, subsurface, and atmospheric levels. The maxim, *cujus est solum ejus est usque ad coelum et ad inferos* essentially means: "He who owns the soil owns everything above and below, from heaven to hell."[201] In measured amount, the doctrine works best for small, local, visible resources with few users and is more unwieldy for hidden resources or large resources with many users. But the *ad coelum* doctrine still permeates the field of natural resources and hidden resources in particular.

Moreover, many hidden resources are fugacious, which allows them to migrate. These resources may traverse boundaries and exist within multiple ownership tracts and/or jurisdictions with conflicting or overlapping private contract and ownership regimes. For example, there are no less than five common law rules regarding groundwater ownership (or use) in the United States: (1) absolute dominion (English rule or absolute ownership rule), (2) reasonable use (American rule), (3) correlative rights doctrine, (4) Restatement of Torts rule, and (5) prior appropriation.[202] Groundwater use may further be limited by state interests, arising out of the Public Trust Doctrine and/or the concept of the "Waters of the State," which follows the broader "Waters of the United States," with more focus on those aspects of use regulation such as pollution.[203]

Petroleum, which may also be a trans-boundary hidden resource, is not only governed by various ownerships (e.g., federal lands, state lands, tribal lands, fee lands) but also different theories of property ownership by jurisdiction. For example, the mineral estate, which includes various substances set forth by common law or contract, may be classified as corporeal or incorporeal. More specifically, the oil and gas lease, which is both a conveyance of real property and a contract, may further be classified as a freehold interest or a servitude. Petroleum production is further complicated because physical equipment and fluid for hydraulic fracturing purposes must often be placed or injected subsurface, as opposed to

200. Although this legal maxim accurately describes Roman law, it was not coined until the Thirteenth Century. PAUL DU PLESSIS, BORKOWSKI'S TEXTBOOK ON ROMAN LAW 157 (4th ed. 2010). For a discussion of the several forms that the maxim has taken over time, see D.E. Smith, *The Origins of Trespass to Airspace and the Maxim 'Cujus Est Solum Ejus Est Usque Ad Coelum,'* 6 TRENT L.J. 33 (1982).

201. Lora D. Lashbrook, *The "Ad Coelum" Maxim as Applied to Aviation Law*, 21 NOTRE DAME LAW. 143, 154 (1946).

202. WATER SYS. COUNCIL, WHO OWNS THE WATER?: A SUMMARY OF EXISTING WATER RIGHTS LAW 4 (2016), http://nationalaglawcenter.org/wp-content/uploads/2017/03/Who-Owns-the-Water-2016-Update-FINAL.pdf [https://perma.cc/6ZHF-NU37].

203. *Id.*

groundwater, which uses limited surface-sited pumping mechanisms for extraction. Accordingly, adjacent- or concurrent-owner operation has the possibility of causing coordination failures.[204]

Attribution of hidden resources to a disconnected owner is yet another problem. Porous space, which may be used to alleviate climate change impacts using carbon capture sequestration or for marketable gaseous storage, has been conferred to the owner of the surface estate in some jurisdictions.[205] Conflict occurs when the porous space has been created by the withdrawal of a hidden resource—like petroleum—which is owned by another. However, the ease of assigning ownership to the surface owner outweighs the "inconvenience" of competing or unrelated interests. Likewise, wind ownership for wind power generation has often been associated with the surface owner for simplicity. And although the wind turbine does actually sit atop the surface, the resource itself is in the atmosphere, which has also been referred to as the wind estate.[206] Texas has been grappling with whether to formally sever the wind estate and treat it like the state treats groundwater—subject to the rule of capture.[207] The legislature's silence with respect to wind rights has not slowed private property owners from filing deeds severing the wind estate from the surface.[208] In response to worry about the hasty severance of an unknown estate from the surface, some states have passed legislation banning the severance of wind rights.[209]

The ability to sever estates in property further complicates the ownership and governance of natural resources. The oversimplified "bundle of sticks" analogy supports a finding of discrete and severable interests within property, but it is in tension with the temporal and physical dynamism inherent to hidden resources.[210] There is no surgically neat method to dissect the wind from the atmosphere.[211]

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204. *See* Lightning Oil Co. v. Anadarko E&P Onshore, LLC, 520 S.W.3d 39 (Tex. 2017); Coastal Oil & Gas Corp. v. Garza Energy Tr., 268 S.W.3d 1 (Tex. 2008); Briggs v. Sw. Energy Prod., 224 A.3d 334 (Pa. 2020).

205. *See, e.g.*, Schremmer, *supra* note 115, at 13 n.54.

206. Solomon, *supra* note 122.

207. *See* Coyote Lake Ranch, LLC v. City of Lubbock, 498 S.W.3d 53 (Tex. 2016).

208. *See supra* Section II.B.1; Robert Montgomery, Note, *Water to Wind: The Path Texas Groundwater Law Provides to Sever the Wind Estate and Prioritize Mutually Dominant Estates*, 50 TEX. ENV'T L.J. 107, 110 (2020); K.K. DuVivier, *Animal, Vegetable, Mineral—Wind? The Severed Wind Power Rights Conundrum*, 49 WASHBURN L.J. 69 (2009).

209. Montgomery, *supra* note 208 (noting that South Dakota, Colorado, Nebraska, Kansas, North Dakota, Oklahoma, Wyoming, and Montana have passed such legislation).

210. United States v. Craft, 535 U.S. 274, 274, 283 (2002) (explaining that the rights to exclude and to use property are two of the most crucial "sticks in the bundle of rights that are commonly characterized as property").

211. DuVivier, *supra* note 208.

IV. GOVERNANCE OF HIDDEN RESOURCES

Hidden resources require nontraditional governance mechanisms, which may include local governance, more frequent adoption of correlative rights, and a participatory commons or recognition of non-ownership (e.g., Carol Rose's property theories such as evolutionary rights and non-absolutism).[212] Like pollution control, efficient property oversight requires local solutions. In mineral mining, small, knowledgeable communities governed a resource (mine). The local miners were able to see the minerals as they removed rock, revealing their nature and characteristics. This revelation resulted in the local community understanding how best to manage the resource, which included enforcement of those local rules.[213] In fact, during the California Gold Rush, American mining laws were adapted from existing mining customs, which were passed on by international miners.[214] Each community, though geographically distant, possessed the common resource language of minerals—borne out of centuries of mining.[215] Their common knowledge allowed them to quickly develop the mining industry and accelerated the development of the General Mining Act.[216]

Resource sight may lead to accepted acknowledgment that certain natural resources should not be "owned." These interests would benefit from designation as "commons" property, which is already well studied.[217] For these integrated natural resources, such as the hydrologic system, treatment as a commons is intuitive. Other hidden resources would benefit from broader adoption of commons framework as many resources are trans-boundary systems. For example, oil and gas reservoirs are known trans-boundary systems; they may cross lease, unit, state, and even national boundaries. Likewise, porous space and atmospheric systems are continuous—there are no natural boundaries to these resources. Moreover, resource sight may lead to broader multi-institutional collaboration. For example, water stakeholders with resource sight could agree that discrete oversight of groundwater, surface water, and atmospheric water is contrary to the accepted scientific understanding of the hydrologic cycle. The patchwork quilt of laws and

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212. *See generally* Carol M. Rose, *Property in all the Wrong Places?*, 114 YALE L.J. 991, 1017 (2005) (reviewing MICHAEL F. BROWN, WHO OWNS NATIVE CULTURE? (2003); KAREN R. MERRILL, PUBLIC LANDS AND POLITICAL MEANING: RANCHERS, THE GOVERNMENT, AND THE PROPERTY BETWEEN THEM (2002)); CAROL M. ROSE, PROPERTY AND PERSUASION: ESSAYS ON THE HISTORY, THEORY, AND RHETORIC OF OWNERSHIP (1994).

213. Monika U. Ehrman, *Natural Resource Property Customs*, 41 UCLA J. ENV'T L. & POL'Y (forthcoming 2023).

214. *Id.*

215. *Id.*

216. *Id.*

217. Lee Anne Fennell, *Ostrom's Law: Property Rights in the Commons*, 5 INT'L J. COMMONS 9 (2011); S.V. Ciriacy-Wantrup & Richard C. Bishop, *"Common Property" as a Concept in Natural Resources Policy*, 15 NAT. RES. J. 713 (1975); Elisabeth Thuestad Isaksen & Andries Richter, *Tragedy, Property Rights, and the Commons: Investigating the Causal Relationship from Institutions to Ecosystem Collapse*, 6 J. ASS'N ENV'T RES. ECONOMISTS 741 (2019).

policies only exacerbates water conflicts and use inefficiencies. The typical "Special Master" appointed by the federal courts in interstate water conflicts and compacts is generally an academic skilled in water law.[218] But a much better system would be to have cases decided by experts in the fields of hydrology and atmospheric science, in addition to water law academics.[219]

A. Hidden Resource Trusts

Resource sight may also be the catalyst that hastens the realization that some categories of natural resources are not suitable for private or public ownership. These natural resource rights would implicate that the resource itself determines its destiny and should not be subject to artificial impositions of property rights: these resources would either have self-governing authority as a type of natural sovereign[220] or be un-ownable, that is, immune from any assertion of property right.

With respect to natural sovereignty, the mechanics of ascertaining and respecting these rights would be difficult without imposition of some sort of trust relationship.[221] The resource's interests are represented by a public or private trustee, which holds a fiduciary duty to the resource. But like many trust relationships, such as that between the federal government and Tribes, the reality often does not represent the original intent.

Although Native American Tribes are described as "domestic, dependent nations" and retain "attributes of sovereignty over both their members and their territory,"[222] they do not enjoy true sovereign status. Instead, Tribes possess only some powers that run parallel to federal and state power, such as the right to tax as well as powers to impose health and safety regulations protecting the Tribe or its members.[223] They do not possess the same powers as independent states, such as the power to raise armies or print currency.[224] Moreover, the lack of substantive decision-making authority over their lands and resources results in an unequal relationship between them and the federal government, whereby opportunities exist for exploitation.[225] Trust relationships between natural resource systems and a

218. L. Elizabeth Sarine, Note, *The Supreme Court's Problematic Deference to Special Masters in Interstate Water Disputes*, 39 ECOLOGY L.Q. 535 (2012) (describing the Supreme Court's deference given to Special Masters as a form of judicial abdication).

219. *See* Vanessa Casado Perez, *Specialization Trend: Water Courts*, 49 ENV'T L. 587 (2019).

220. *See* BRADSHAW, *supra* note 66.

221. *See id.* (discussing this innovative concept in her work on according wildlife property rights as a form of environmental conservation); *see also* Karen Bradshaw, *Animal Property Rights*, 89 U. COLO. L. REV. 809 (2018).

222. LOWE ET AL., *supra* note 106.

223. *Id.*

224. *Id.*

225. *See* Shoshone Indian Tribe v. United States, 56 Fed. Cl. 639 (2003) (holding that federal government breached fiduciary duty to Tribe to pay Tribe based on oil and gas settlement); Christopher S. Kulander, Note, *Take-or-Pay Royalties, the Trust Doctrine, and the* Shoshone *Case*, 29 AM. INDIAN L. REV. 101, 118–19 (2005). In *Cobell v. Norton*, which was cited in the *Shoshone* case, Plaintiffs claimed

designated private or public trustee may work on a small, local scale, but are likely unwieldy and inefficient over large resources.

B. No Man's Land

Another possible frame is to view hidden resources as un-ownable. Admittedly, there are a few problems with this philosophical framing. The first is that if natural resources are not owned by private or public parties, then somebody will take or use that property.[226] Ownership provides some protection from overuse and is a deterrent to tort. The second is that a "No Man's Land" type system does not address the multidimensional aspect of natural resources. In the No Man's Land, there is no ownership of the resource. The land is unclaimed and ungoverned.[227] Alaistair Pinkerton notes that the concept of No Man's Land has existed for over a millennium: "It first appears in the Domesday Book in the late 1000s to describe parcels of land that lie just beyond the London city walls . . . And in the UK there are several places called No Man's Land—extra-parochial spaces that were beyond the rule of the church, beyond the rule of different fiefdoms that were handed out by the king . . . ribbons of land between these different regimes of power."[228]

For example, a city may own the streets and therefore maintain them. A homeowner may own their home and front yard. But neither may own the sidewalk and therefore neither of them maintains the sidewalk or shovels the snow from it. The sidewalks are then a type of No Man's Land—lacking authoritative jurisdiction and oversight.[229] In international law, a No Man's Land may mean a demilitarized zone (DMZ), which is a space on a battlefield between two opposing front lines.[230] The Korean DMZ is a famous example of such a No Man's Land:

> [It] is a region on the Korean peninsula that demarcates North Korea from South Korea. Roughly following the 38th parallel, the 150-mile-long DMZ incorporates territory on both sides of the cease-fire line as it existed at the end of the Korean War (1950–53). The areas north and south of the demarcation are heavily fortified, though skirmishes between the two sides are

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that the U.S. government incorrectly accounted for Indian trust asset income. 240 F.3d 1081 (D.C. Cir. 2001). The class action settled for about $3.4 billion in 2010 and included a $1.9 billion Trust Land Consolidation Fund and $1.5 billion in direct payments to class members. *Id.* For more information on the settlement, see *Consultations on Cobell Trust Land Consolidation*, U.S. DEP'T INTERIOR, https://www.doi.gov/cobell [https://perma.cc/2XK8-VSVY] (last visited Jan. 22, 2023).

226. Bradshaw & Ehrman, *supra* note 84.

227. Jason Caffrey, *Adventures in No Man's Land*, BBC NEWS (Sept. 30, 2015), https://www.bbc.com/news/magazine-34319540 [https://perma.cc/WXG9-39GY].

228. *Id.*

229. Ashley Dager, *Property Owners Not Sure Who Is Responsible for Clearing Sidewalks Off of Busy Roads*, WSBT 22 (Feb. 7, 2022), https://wsbt.com/news/local/property-owners-not-sure-who-is-responsible-for-clearing-sidewalks-off-of-busy-roads? [https://perma.cc/ZGM7-V6KM].

230. Caffrey, *supra* note 227.

> rare. Located within the territory is the "truce village" of P'anmunjom, but most of the rest of the land has reverted to nature, making it one of the most pristine undeveloped areas in Asia.[231]

In fact, over sixty years of isolation in certain DMZ regions resulted in the flourishing of wildlife.[232] However, No Man's Lands not only refer to historical or currently militarized areas.[233] The term is now used—"at least colloquially—to refer to anywhere from derelict inner city areas to spaces between borders, and even tax havens."[234]

Because "nature abhors a vacuum,"[235] a non-ownership regime may create a vacuum of power that gets filled by selfish actors. In their study of No Man's Lands, Pinkerton and Leshem traveled across Europe and North Africa to examine the ecology of sites like this, in addition "to their relationships to the vulnerability of human individuals and communities."[236]

In Hertfordshire, England, their study of "Nomansland Common" revealed that the area between two church parishes (that could not decide which of them should cover it) "became a hang-out for 'brigands and cattle rustlers and highway men, and indeed highway women.'"[237] The Common was essentially "beyond the reach of any authority."[238] Lesham describes "the essence of No Man's Land as 'a place where there has been an intentional withdrawal of state power and sovereignty.'"[239] He further adds:

> At the same time that space has been delineated—there is a very clear sense of what is in it, and what is considered to be outside of it.
>
> So you have these two forces—on the one hand this intentional pulling back, and at the same time this setting apart.

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231. *Demilitarized Zone*, HISTORY (June 10, 2019), https://www.history.com/topics/korea/demilitarized-zone [https://perma.cc/5UVR-9D9S].

232. *Id.* ("Once farmland and subsequently a devastated battleground, the DMZ has lain almost untouched since the end of hostilities and has reverted to nature to a large extent, making it one of the most pristine undeveloped areas in Asia. The zone contains many ecosystems including forests, estuaries, and wetlands frequented by migratory birds. It serves as a sanctuary for hundreds of bird species, among them the endangered white-naped and red-crowned cranes, and is home to dozens of fish species and Asiatic black bears, lynxes, and other mammals.").

233. Caffrey, *supra* note 227.

234. *Id.*

235. Marcelo Gleiser, Opinion, *A Brief History of Nothing*, NPR (June 6, 2012, 10:55 AM), https://www.npr.org/sections/13.7/2012/06/06/154349295/a-brief-history-of-nothing [https://perma.cc/A8S2-XU2E] (describing Aristotle's famous quote that "absolute emptiness" does not exist).

236. Caffrey, *supra* note 227.

237. *Id.*

238. *Id.*

239. *Id.*

> The researchers use the words abandonment and enclosure to encapsulate these ideas, and point out that they apply logically to areas left too poisoned for human habitation by weapons testing or mining, or weapons of war.[240]

Another problem of designating hidden resources as a No Man's Land is that they only remain a No Man's Land—unwanted by individual or private interests—until there is perceived or actual value. For example, an abandoned lot in an undesired location may sit vacant until someone decides that the lot can be used to gather, store items, litter, play in, etc. If another decides the abandoned lot has more value than its current purposes, that person may take the lot—claiming it as a commons or attempting to acquire legal title via purchase or, after the requisite limitations period, adverse possession.

Administering natural resource trusts or asserting a No Man's Land status upon resources may be unsuccessful or difficult, especially at a system level. Importantly, addressing the problem of hidden resource pollution requires some sort of governance or oversight.[241] So how should we approach a property non-ownership framework with effective natural resource governance? Another possibility is to view hidden resource property as nonpossessory.

C. Nonpossessory Rights (Servitudes)

Property law designates certain interests as nonpossessory in nature—they are servitudes. A servitude is a nonpossessory right of ownership, that is still a defined and recognized property right, deserving of protection. Because hidden resources may not benefit from the possessory model of ownership—e.g., oil and gas (mineral rights) classified as a fee simple—servitude classification may be a more appropriate vehicle to encourage use, both utilitarian and conservatory; effectuate property transactions; and discourage waste, whether nonutility or pollution.

A property right right-to-use model, or license model, may be more flexible for hidden resources. Under a license model, there may be a public or private right to use the natural resources, but not to own them. In this model, the natural resource itself then has multiple licensees, with the licensor being the resource—in public trust (which yields the same problems as discussed above) or with another public agent (subject to inefficiency and bureaucracy). It is important to note that a public licensor need not mean government, but rather decisionmaking that is democratic and open to stakeholder participation.[242] The license model then allows use of the resource (perhaps a *profit a prendre*, or right to take), with limitations on that right, in addition to the ability to revoke the license for infractions or misuse.

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240. *Id.* (quoting Noam Leshem, researcher at Durham University and his work with Alasdair Pinkerton) (internal quotation marks omitted).

241. Bradshaw & Ehrman, *supra* note 84.

242. Karen Bradshaw, *Stakeholder Collaboration as an Alternative to Cost-Benefit Analysis*, 2019 BYU L. REV. 655.

Central to any model of hidden resource ownership is that these resources are complex and interwoven systems—not individual sticks in a bundle. Moreover, there should be recognition that there is not one all-inclusive form of ownership or a perfect or even "good" model of ownership. These acknowledgments reflect the nature of the resource. For example, we can save seeds from a flower to plant the next year. We can save artificial property—money—in an account. We cannot save time. As a three-dimensional organism, I cannot perceive or identify time—so it is impossible for me to interact with it. Hidden resources are the same. That does not mean we should not attempt interaction or governance—it only means we should recognize the limitations of existing or future property ownership structures.

CONCLUSION

Over 200 million miles from Earth, the Mars Perseverance spacecraft approached its entry to the Martian atmosphere.[243] Its two-year voyage to our planetary neighbor culminated with its landing, as NASA engineers and scientists around the world breathlessly waited. Its mission is glorious—a search for the existence of alien life.

The Perseverance landing site in the Jezero Crater appears to be an ancient lake, which exoplanetary scientists believed was once filled with water and may contain evidence of past life.[244] This distant hidden resource, made visible via technological sight, demonstrates how understanding hidden resources—acquiring resource sight—was critical to obtain knowledge of other hidden resources. Years before Perseverance's landing, NASA scientists studied Mars for potential landing sites. With the knowledge that all life on Earth requires water, the scientists targeted a Martian landing site that they believed once held the precious liquid. But how did they identify potential locations that were millions of miles away? They referenced Martian geological landforms using terrestrial topography of water systems. For instance, on Earth, aerial and satellite imagery provide glorious views of massive river deltas, like the Mississippi, shown below.

243. *Mission Timeline: Cruise*, N.A.S.A.: 2020 MISSION PERSEVERANCE ROVER, https://mars.nasa.gov/mars2020/timeline/cruise/ [https://perma.cc/LKK4-2SXG] (last visited Jan. 22, 2023).

244. *Perseverance Rover's Landing Site: Jezero Crater*, N.A.S.A.: 2020 MISSION PERSEVERANCE ROVER, https://mars.nasa.gov/mars2020/mission/science/landing-site/ [https://perma.cc/ZX8L-6Q5V] (last visited Jan. 22, 2023).

Figure 13: Satellite image of the Mississippi River Delta[245]

These deltaic systems form as rivers and deposit sediments into another body of water, like an ocean, sea, or even another river.[246] They are called "deltas" because of the geologic signature shape that resembles the Greek upper case letter delta—Δ. Although geologists and hydrologists studied river deltas prior to aerial technology, the addition of a true three-dimensional perspective was critical to understanding the importance of deltas, particularly when applied to climate change concerns and environmental justice issues related to river dredging, floods, and hurricanes.[247]

After five years of study, scientists chose the Perseverance landing site based on images of a Martian river delta, which they theorized may contain sediments from a river system almost 3.5 billion years old.[248] They hoped that like terrestrial deltas, water carrying clay minerals may have spilled into the ancient lake, where remnants of life might be found in the surrounding sediments.[249] From Mississippian muddy waters to an otherworldly antediluvian river delta, resource sight improves our knowledge of ancient climates in our solar system.

245. *Mississippi River-Delta Groundwater-Surface Water Interaction Study*, LSU: LA. WATER RES. RSCH. INST., https://www.lsu.edu/lwrri/research/mississippi_delta.php [https://perma.cc/5UAB-39H8] (last visited Jan. 22, 2023).

246. *Delta*, NAT'L GEOGRAPHIC, https://www.nationalgeographic.org/encyclopedia/delta/ [https://perma.cc/C7KU-V5FX] (last visited Jan. 22, 2023).

247. N.M. Gasparini & B. Yuill, *High Water: Prolonged Flooding on the Deltaic Mississippi River*, EOS (Mar. 20, 2020), https://eos.org/features/high-water-prolonged-flooding-on-the-deltaic-mississippi-river [https://perma.cc/G3RP-C7KF].

248. N.A.S.A., *supra* note 244.

249. *Id.*

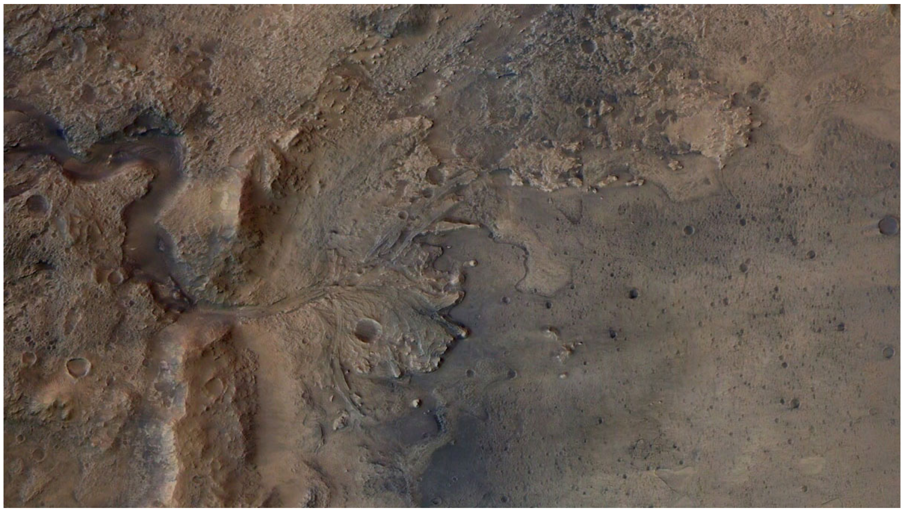

Figure 14: Jezero Crater and the Perseverance landing site on Mars[250]

But resource sight obtained on other worlds is also critical to understanding the earth's habitat and climate. In the early 1970s, ground-based telescopes revealed that the haze on Venus was aerosolized sulfur compounds.[251] That revelation allowed NASA climate modeler, James Hansen, to calculate that the combination of sulfates and carbon dioxide was responsible for the planet's Hadean heat.[252] Hansen extrapolated that these same particles in Earth's atmosphere would result in tremendous harm.[253] In 1988, Hansen testified before Congress, informing members that "the greenhouse effect has been detected and is changing our climate now."[254] Without question, resource sight was responsible for the discovery of global warming.

As humans take their first steps away from their home, venturing farther into and out of the solar system, resource sight will be critical. There will be an abundance of hidden resources on non-terrestrial worlds: fossils, minerals and precious metals, fresh or frozen water, methane and other hydrocarbons, biological specimen or other lifeforms, and other yet-to-be-discovered natural resources. Relying on antiquated notions of property and applying them to extraterrestrial resources will only incite or aggravate territorial and ownership disputes. And

250. *Id.*

251. *Venus & Mars*, AM. INST. PHYSICS: DISCOVERY GLOBAL WARMING (Jan. 2019), https://history.aip.org/climate/Venus.htm [https://perma.cc/7QQ3-P5WB].

252. *Id.*

253. *Id.*

254. Elizabeth Kolbert, *Listening to James Hansen on Climate Change, Thirty Years Ago and Now*, NEW YORKER (June 20, 2018), https://www.newyorker.com/news/daily-comment/listening-to-james-hansen-on-climate-change-thirty-years-ago-and-now [https://perma.cc/W4AD-YRXZ].

although there are recognized laws and customs, like maritime law, the United Nations Convention on the Law of the Sea, and space law, which includes the Outer Space Treaty,[255] there should not be reliance on large, blanket "solutions" to hidden resource ownership and utility. Cooperative development and efficient dispute resolution originate with a clear understanding of the nature of the resource.

There lies the conflict. The law evolves slowly and in linear fashion—looking behind in *stare decisis* fashion and only able to look forward long enough to resolve a case, promulgate a rule, or enact a law, perhaps referencing some policy or plan. But almost always, it proceeds at a glacial pace; and often, especially in the natural resource field, the law stagnates.

Industry and technology, however, progress at a rapid pace. In 2020, NASA Administrator Jim Bridenstine revealed that the agency will purchase lunar soil from commercial providers, further pressing that it was "time to establish the regulatory certainty to extract and trade space resources."[256] Although the Outer Space Treaty of 1967 provides that no country may assert sovereignty over the moon and other extraterrestrial bodies,[257] Bridenstine's announcement that a U.S. agency would solicit private entities to remove lunar material for pay triggered warnings of a space resource race. One policy advisor wisely observed that the "importance of this announcement is not so much the financial incentive (which is tiny) but in establishing the legal precedent that private companies can collect and sell celestial materials (with the explicit blessing of NASA/the U.S. government)."[258] The announcement appeared to limit a 2015 Obama Administration law, which allowed American companies the rights to any material they mine on extraterrestrial bodies.[259] So how does a federal agency reconcile ownership of natural resources found on distant bodies that supposedly are free from claims of national ownership? Bridenstine equates it to the high seas, stating that although "[y]ou do not own the ocean . . . you own the tuna."[260] Apparently, space tuna is the next tragedy of the commons.[261]

Problems such as lunar mining illustrate why hidden resources—and natural resources broadly—cannot afford these leisurely, linear paths. These multidimensional

255. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, Oct. 10, 1967, 613 U.N.T.S. 8843.

256. Christian Davenport, *NASA Announces It's Looking for Companies to Help Mine the Moon*, WASH. POST (Sep. 10, 2020, 2:00 PM), https://www.washingtonpost.com/technology/2020/09/10/moon-mining-nasa-search/ [https://perma.cc/MQ42-KCCQ].

257. *Id.*

258. *Id.*

259. *Id.*

260. Eric Berger, *NASA Says It Will Pay Private Companies to Gather Moon Rocks*, ARS TECHNICA (Sept. 10, 2020, 7:40 AM), https://arstechnica.com/science/2020/09/nasa-says-it-will-pay-private-companies-to-gather-moon-rocks/ [https://perma.cc/4HK7-3SYU].

261. Referring to the title of Chan Yuk Chi's *Space Tuna and Property Rights*, SORRY SPEAK UP BLOG (Sept. 10, 2020, 7:40 AM), https://sorryspeakup.substack.com/p/space-tuna-and-space-property-rights [https://perma.cc/3DGF-7XGR].

and dynamic resources, in concert with the technology to develop, preserve, or destroy them, require a legal ownership and governance structure that complements the resource—essentially, a legal system with resource sight.

Of course, overlaying the hidden resource ownership issue is the precautionary principle. Although the name suggests avoidance of risk, its etymological Germanic origins support a meaning of "foresight."[262] It is usually described in the following manner: "[W]hen an activity raises threat of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically."[263] The principle is similar to the Hippocratic oath in medicine, which advises "first, do no harm."[264]

From hidden resource and property perspectives, application of the principle prevents a hasty charge to tear apart centuries of jurisprudence. These barriers to reimagining a property system suitable for hidden resources include: (i) disruption to established title, (ii) effect on securitization of property assets, (iii) common law precedent, (iv) established legislation and regulation, and (v) takings claims. But the precautionary principle does not simply prohibit action; it serves as guidance to assess the risks of a particular course of action.[265] And risk assessment requires an understanding of the underlying action.

As we continue to apply property laws that are ill-suited to hidden resources, we are aggregating both known and unknown risks, in addition to the very real danger that the ill-suited law will be applied to yet another hidden resource (e.g., rule of capture for asteroids). Giving pause to reexamine the propriety of hidden resource ownership and the associated risks would provide much needed foresight.

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262. David Kriebel, Joel Tickner, Paul Epstein, John Lemons, Richard Levins, Edward L. Loechler, Margaret Quinn, Ruthann Rudel, Ted Schettler & Michael Stoto, *The Precautionary Principle in Environmental Science*, 109 ENV'T HEALTH PERSPS. 871, 871 (2001).

263. *Id.*

264. *Id.*

265. *Id.* at 872.