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MISMATCHED PROPERTY RIGHTS

Virtual Parceling

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Although economists have long suggested that the privatization of land is one to solution to the tragedy of the commons, we observe that drawing a parcel boundary in fact often creates commons and anticommons for concurrent (spatially overlapping) natural resources. The property law doctrine of the severed estate allows land to be un-bundled from concurrent resources, allowing one person to own the land and another to control the air space. This un-bundling of land and resource rights largely mitigates the coordination failures that might otherwise result from boundary-drawing. It results in overlapping, parallel systems of ownership of land and resources in physical space. Property law focuses largely on land parcels, but there also exist overlapping system of parcels to values including water, air, wildlife. We term these resource boundaries unbundled from land "virtual parcels." Virtual parceling embeds flexibility into landscape governance, allowing a balance between resources and resource users through the allocation of property rights and subsequent limitations or expansion of those rights over time. We outline an array of public and private governance tools that function to re-draw boundaries around resources that require scales of ownership or governance that do not accord to underlying land rights. These include: statutes, public lands, public trust doctrine, custom, and contract. These tools are the joints and ligaments in the body of property—allowing the flexibility to rescale boundaries as natural and market conditions change. Any single landscape requires several of these tools to operate concurrently, an observation that calls into question the frequent dichotomization of "public" and "private" property or "state" or "federal" control of lands. In practice, the many overlapping resources on a landscape require varied ownership and governance structures. Virtual parcels provide a new way to view property law. It reveals that virtually all landscapes contain both public and private elements, subject in varying ways to local, state, federal, and tribal controls.

Keywords: Property rights; law; commons; sustainability

Introduction

In this paper, we identify an irony at the heart of property theory: Solving the tragedy of the commons through privatization of land in fact creates both commons and anticommons for concurrent (spatially overlapping) natural resources. Despite this anomalous result, legal doctrine counteracts the resultant coordination failures by allowing property rights to land to be un-bundled from the property rights to resources. Separated resources can be re-bundled according to their naturally efficient boundaries—a process we term "virtual parceling". Virtual parceling embeds flexibility into landscape governance, allowing a balance between resources and resource users through the allocation of property rights and subsequent limitations or expansion of those rights over time.

We outline an array of public and private governance tools that function to re-draw boundaries around resources that require scales of ownership or governance that do not accord to underlying land rights, including: statutes, public lands, public trust doctrine, custom, and contract. These tools are the joints and ligaments in the body of property. They provide rights-holders with the flexibility to rescale boundaries as natural and market conditions change. Any single landscape requires several of these tools to operate concurrently, an observation that calls into question the frequent dichotomization of "public" and "private" property or "state" or "federal" control of lands. In practice, the many overlapping resources on a landscape

require varied ownership and governance structures, meaning that virtually all landscapes contain both public and private elements, subject in varying ways to local, state, federal, tribal, and private governance.

Certainly, property theorists intuitively understand the interconnected nature of resources and rights. Yet, landscapes that are interconnected remain fractured in theory. Scientists once also considered living things in isolation. Ecosystem theory has since displaced piecemeal conceptions of nature by positing that every naturally occurring thing is in fact a component part of an interrelated whole. Property theorists have yet to make a similar leap—we continue with silos of land and natural resources. "Oil and gas law," "mining law," and "water law" exist largely as independent fields—each with their own boundaries, maps, systems of recordation, and industry groups. Artificial separations between the rights and governance of land and resources reflect a disconnect between theory and policy. We believe that vital information and new solutions can be found in the intersection of concurrent resources, mis-matched rights, and overlapping governance regimes.

We present a four-dimensional model of property, showing overlapping "virtual parcels" to resources operating in parallel with rights to land. Many resources span multiple land parcels, forming their own boundaries and maps. The separation of land and resources allows for fixed estates to land to coexist with a re-bundling of the component parts of the ecosystem so they can be flexibly and independently managed. We provide a descriptive account of how these virtual parcels are formed. We overview several of the legal and private governance mechanisms that bundle and divide resource parcels independently from land transactions.

To make the point that property rights are interconnected, we paradoxically begin by disentangling them. This reveals that a single piece of "land" in fact contains a mix of concurrent resources, property owners, and governance regimes. Indeed, we show that the very existence of the prototypical private land rights themselves necessitate public and communal management of other resources. Framing the problem as one of "virtual parcels" facilitates an integrated analysis of land and natural resources and explains how a variety of governance solutions resolve a paradox in property theory.[1]

I. The Paradox of Private Property

A. Motivation

Two seemingly unrelated tenets of economic theory in fact exist in stark tension. First, economists have noted that privatization effectively mitigates the tragedy of the commons (Gordon 1954; Hardin 1968).[2] Yet, fragmented property interests lead to mis-use of resources (Libecap and Wiggins 1984; Hansen and Libecap 2004; Heller 1998; Buchanan and Yoon 2000; Leonard and Parker, 2019). For decades, these findings did not seem to contrast—or even relate. But, the emergent discussion of overlapping resources—sometimes described as "mis-matched property rights"—shows that privatization used to avoid the tragedy of the commons for land in fact creates both commons and anticommons of large-scale resources bisected by land demarcation.

In *Contracting for Control of Landscapes*, Bradshaw and Lueck observed that many resources overlap on the same landscape and operate at varying scales of efficient management (2015). Their four-dimensional model of property depicts the theory of mis-matched property rights, which integrates various concurrent resources subject to different systems of demarcation, owners, and systems of governance. They illustrated that boundaries demarcating land parcels fragment some large-scale "landscape-level" resources, such as wildfire and wildlife habitat. Similarly, "long-and-skinny" resources, such as railroad tracks, power lines, and pipelines, must cross thousands of land parcels. Although land has long been our collective focal point, this symposium re-defines property as a four-dimensional and multifaceted system. Overlapping resources, rights, and governance interact in shared geophysical space as well as time.

Bradshaw and Lueck identified one specific tool to overcome the mismatch between land and resource boundaries: the use of contract to form boundaries around resources that do not correspond to land parcels.

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[1] We observe the potential that the idea of mismatched property rights may apply to any context in which groupings of public and communal rights simultaneously exist in a single system. Insights garnered from real property may also extend to patents (individual patent holders pooling patents), corporate structure (subsidiary and parent companies), industrial cooperation (as with farmers participating in marketing orders) and social organization (as with individual and group-level territoriality). How might a nested theory of overlapping rights inform intellectual property, anti-trust, and corporate law?

[2] The process of converting communal or public lands into privatized holdings incentivizes efficient control of natural resources because landowners internalize the costs of management decisions. Alston & Libecap (1996); Anderson & Hill (1975); Mason (1998); de Soto (2000); Joireman (2007); Musembi (2007); Deininger and Byerlee (2011); Libecap and Lueck (2011); Wily (2011); Butler and Gates (2012); Albertus and Kaplan (2013); Baldwin (2014); Epstein (2014b); Voors and Bulte (2014).

They provided a series of case studies in which landowners separated resource rights from the underlying land parcels and, through contract, assembled those resources. In this way, the demarcating of resources did not occur through physical features of the land (as with metes and bounds) or a uniform, standardized system of demarcation (as with the Public Land Survey System). Instead, contractual arrangements defined new ownership boundaries around non-land resources. Creating resource parcels by contract allowed landowners to retain the boundaries of land parcels but create contractual demarcation of other boundaries around different resources, which facilitated coordinated management at the natural scale of management for the resource.

An interdisciplinary group of scientists, economists, political scientists, and legal scholars have since begun re-defining property as an overlapping set of resources and associated rights. (Lueck 2018, Leonard and Parker 2019, Facemire and Bradshaw 2020, Cowen and Delmotte 2020). Yandle (2007) coined the term "mismatched property rights" in her exploration of overlapping rights regimes in New Zealand's Fisheries. Oil and gas law scholars have noted the potential explanatory power of overlapping resources to describe conflicts between surface and mineral estate owners. (Ehrman, 2020; Coleman 2019; van Biezenbos 2018–19; Righetti, 2018). Yael Lishiftz is cleverly developed the vocabulary around these ideas, using the term "vertical property" to describe resources intersecting in three-dimensional space. She further termed flat resources that extend across a landscape as "pancakes," and long and skinny resources, such as pipelines, "noodles." (Lishiftz work in progress). Challie Facemire's innovative work on the Wilderness Act extends the Bradshaw and Lueck observation of overlapping natural resources and property rights to overlapping administrative boundaries and sources of law (Facemire forthcoming 2021). The initial notion of mismatched property rights is both maturing with terminological development and case studies, but also expanding in complexity and application.

In a fascinating pair of recent papers, Lee Ann Fennell identifies the interplay between different components of property. Fennell terms the synergies between certain bundles of rights "complementary" and suggests that much of property law is about conflict between rights-holders (Fennell, 2016, forthcoming 2020). She explores cooperation and "configuration," which she defines as "getting the value-maximizing combination of land uses and land users in place" as a "prerequisite to meaningful coordination efforts." (Fennell, 2016). Fennell observes the fluidity of resources that flow best together, and complementary property, and need for flexibility in arrangements to re-group (Fennell, forthcoming 2020). Combinations of resource rights, as reflections of natural features, are nearly alive in their flexibility and changing nature.

This highlights a central paradox of private rights to real property: the creation of ostensibly private land creates the need for public or communal governance of other resources.[3] Privatizing land to avoid the tragedy of the commons necessarily requires demarcating land to create a fixed parcel. Yet, the land parcel will inevitably be sized differently than the natural scale of management for landscape-level resources. Because a given tract of land necessarily contains numerous resources operating at unique scales, mismatch between land parcels and *at least* one resource is an inevitable feature of property rights to land. To efficiently manage the bundle of resources associated with a given parcel, each resource may need to be managed at a scale that differs from the underlying land ownership.

On one hand, private property rights generate benefits precisely because entitlements are fixed and facilitate investment in physical and natural capital. On the other hand, the dynamic character of natural resources and the economic value ascribed to them requires ever-evolving institutions designed to facilitate spatially efficient management of economically valuable resources at any point in time.[4] Thus, although privatization encourages efficiency within a parcel, it necessarily and simultaneously impairs the efficient management for other resources that span multiple parcels.[5]

[3] We suspect, but do not argue, that this analysis extends beyond real property. Patent pooling, for example, may reflect a similar trend in intellectual property.

[4] The political economy of parceling seemingly favors small parcel allocations because large parcels lead to principle-agent problems associated with tenant-farmer arrangements and the associated efficiency losses (Cheung 1968; Stiglitz 1974; Allen and Lueck 1995). Further, it is politically expedient to allocate small tracts of land to a broad base of agricultural (Hibbard 1939). The notoriously unpopular English enclosure movement provides an unpopular example of large estate allocations. (Smith 1776; Gay 1905; Neeson 1984).

[5] There also exists the theoretical converse: consolidated ownership of lands necessitates subsequent separation of resources into smaller scales for efficient management. This is a familiar real-world phenomenon. Today, the federal government owns roughly one-third of the land mass of the United States, along with many mineral reserves. Federal land management agencies "parcel" landscape-level public land holdings into smaller pieces for uses such as grazing, recreation, and oil development. Additional examples include feudal England, tenant-farmer relationships, and timber owners who grant hunting rights to individuals.

Parceling land unwittingly creates inefficient scales for the management for large-scale resources such as air quality, mineral resources, and habitat if use and exclusion rights for these resources do not subdivide neatly. The nature of the resulting collective action problem depends on the characteristics of the resource that has been subdivided. When parcels are subdivided to a scale where exclusion rights cannot be enforced by each landowner, but subdivision creates many use rights there is a common-pool problem. Oil reservoirs are a classic example—subdividing land rights above the reservoir creates many use rights to the oil, but exclusion rights cannot be feasibly subdivided, leading to a race to extract (Wiggins and Libecap 1985).

The opposite problem—where exclusion rights are divisible but use rights are not—arises when there is a minimum spatial scale required for management of the resource that exceeds the scale of property rights to land. In this setting, many users across the domain of the resource can exclude others from access to the resource on their parcel, perhaps charging a fee for access. Because management of the resource requires access to all parcels, there is an input assembly problem that tends to result in under-use of the large-scale resource due to transaction costs and hold up problems, often referred to as an anticommons (Heller 1998; Heller and Hills 2008; Buchanan and Yoon 2000; Leonard and Parker 2019).

To solve this potential coordination failure, law and custom have developed a system for re-grouping resources to appropriate scales, which we term virtual parceling. Bradshaw and Lueck observed one form of virtual parceling using contract; we outline several other mechanisms below. Our exploration synthesizes a growing but diffuse body of recent empirical work on specific examples of parties re-bundling fragmented resources that can only be managed at the landscape level (Leonard and Parker 2019, Raghetti 2018, Facemire forthcoming 2020). It also draws upon the well-established literature on land assembly (Epstein 1985, 2014a; Heller 1998; Brooks & Lutz 2016; Isaac et al. 2016) to suggest that a parallel process of re-bundling occurs with commercially viable resources that begin as severable interests in land.

B. Virtual Parceling

We term the process of assembling and dividing resources by type "virtual parceling." Systems of virtual parceling exist for property rights to resources such as oil, airspace, water, and mineral rights—all distinct from the associated land right, but overlapping in physical space.[6] A virtual parceling map depicts ownership boundaries of the resource. The act of virtual parceling describes resource owners defining or adjusting resource boundaries.

The well-recognized legal doctrine of severability permits the unbundling of resources from the land on which they exist, thus facilitating coordination in resource management at a scale beyond an individual landowner. For example, a landowner may sell the oil and gas reserves under his land while retaining title to the land. Although severability has long been widely acknowledged and specific case studies abound, there is limited theoretical consideration of what happens to rights once severed—how they are bundled and unbundled over time in response to changed economic, social, and natural conditions.

Virtual parcels may be equally alienable and subject to regulation as the land which they overlay, depending on how formally they are defined. Virtual parceling allows dynamic resource management, shifting the scale of ownership and governance in response to changed ecological, social, or market conditions. Thus, it is an essential, but currently unrecognized, mechanism without which the efficiency gains of private property would be severely curtailed. The key components of virtual parceling are: concurrent (spatially overlapping) resources, property-rights holders, and governance mechanisms.

Formal property rights to concurrent resources can be as alienable and subject to regulation as land. There exist, however, key differences. Virtual parcels typically lack a centralized, free, publicly-accessible system of recordation across resources. The market for, and recordation of, the resources may be opaque or non-existent. Owned resources may not be visible when on the landscape—many are not possible to fence or otherwise mark. Finally, many virtual parcels operate informally, belying recordation and alienability.

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[6] The vocabulary scholars use to describe property rights attached to natural physical resources is disjointed. We must broadly gloss over widespread definitional confusions to make our point in this paper. Accordingly, we categorize many disparate concepts under three general terms: natural resources, administrative boundaries, and parcels.

For the sake of this paper, we use the term "natural resources" to broadly mean physical resources that exist in geographic space and are not man-made. This includes the typical usage associated with oil and gas, mineral rights, timber, and surface rights (land). We also include temporally disparate resources, as with wildlife habitat that a species seasonally occupies, firescapes in which fires are sometimes burning, and flood zones that waters only sometimes reach. And, lacking a better term, we include as "resources" things with a negative economic value that nevertheless fit the model—such as wildfires, pests (which could alternately be categorized as insect wildlife habitat). Scholars differ sharply on whether these various rights form real property or deserve an alternate definition; on this point we offer no insight but flag the need for clarity.

A variety of public and private mechanisms serve to coordinate landscape level resources and ameliorate the need to adjust land parcels to manage resources. Some of these mechanisms are considered encroachments on property rights, but in fact, they enable strong property rights by allowing them to coexist with dynamic, landscape-scale resource management.

Every landscape contains a mix of private, limited-access commons, open-access commons, and un-owned spaces (Ellickson 1993). To maximize the value of private holdings, common or public holdings must be well managed (Rose 1986). For example, a farmer is unable to manage her land absent pest control, water irrigation, and airspace rights. Administrative boundaries are similarly necessary—in a world without social norms, contract, and government, she may not have the ability to exclude others from her farm for the duration necessary for her seeds to yield crops.[7]

Individuals are made better off through cooperation with group members to produce the larger-scale rights and management regimes that facilitate individual gain by avoiding landscape-scale collective action problems. For individuals to invest in the maintenance of larger-scale resources, they require incentives promised by individual gain through private property. In this way, the seeming tension between privatization and fragmentation is resolved by scaling virtual parcels to match the scale of resource management needs and thus avoiding fragmented resource interests.

II. A Spatial Demonstration of Virtual Parceling

In this Part, we spatially depict how the concept of mismatched property rights expands existing two-dimensional conceptions of property into a three-dimensional model. To do so, we stack overlapping virtual parcels within a landscape, adding the vertical element of property. We specifically depict first land parcels, then resource maps, then virtual parcels. The spatial representation focuses on a single county – McKenzie County, North Dakota. We integrate government maps, land parcel maps, and GIS data to demonstrate how integrating parallel, overlapping systems of resources in the same space opens the door to new analysis. This spatial depiction of overlapping resource rights reveals that "private property" is in fact a small part of many overlapping resources, rights, and governance regimes that are associated with an ecosystem.

A. Land Parceling Creates Resource Fragmentation

To privatize land, one first must break it into pieces reasonably sized for individual owners. As depicted in **Figure 1**, in the United States, surveyors overlaid a grid across a landscape to create parcels of equal size, which could then be subdivided.[8]

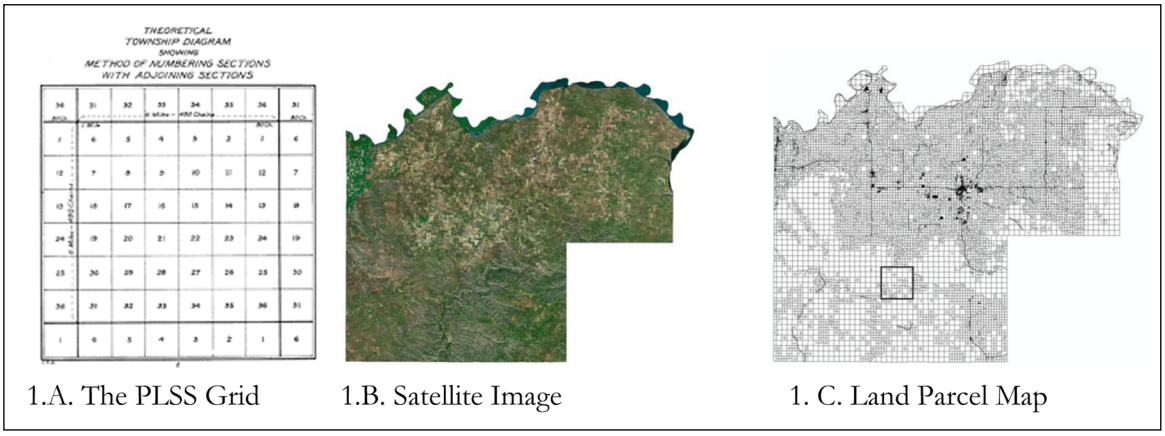

Figure 1: Parceling Using the Public Land Survey System. A. depicts the standard Public Land Survey System abstracted the township scale, which reflects 36 sections of 640 acres each. **B.** depicts a satellite photograph of McKenzie County, North Dakota. **C.** depicts the land parceling of McKenzie County, reflecting the application of the grid over the landscape.

[7] We use "administrative boundaries" to mean boundaries created through formal processes of law and government. Such as towns, counties, states, and administrative designations. We categorize the boundaries of parcels in three additional ways, as including formal property rights, informal uses, and naturally occurring physical boundaries.

[8] Individual parcels range in size from tens to thousands of acres; the 160-acre quarter-section allotted under the Homestead Act was the most common size (Hibbard 1939).

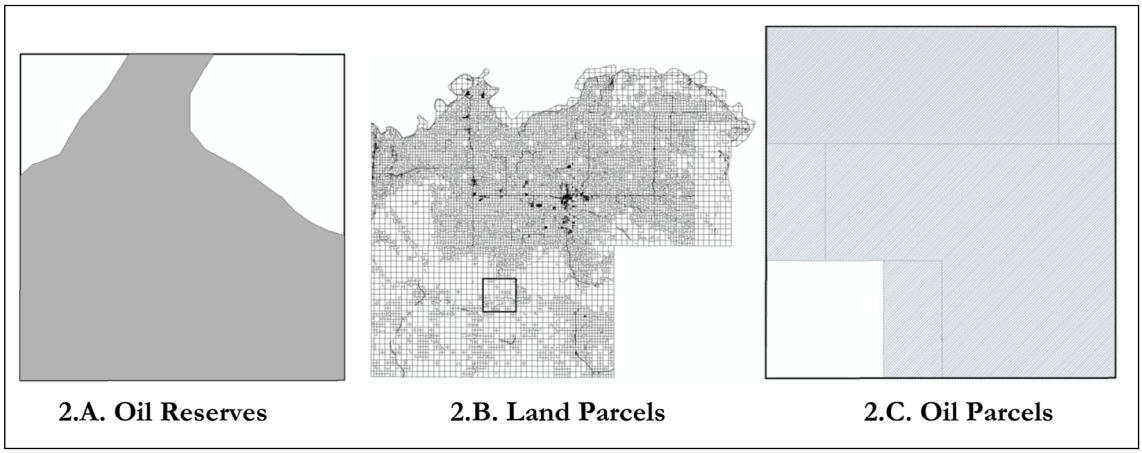

Figure 2: Land Parcels Fragmenting Natural Resources. 2.A. Depicts the naturally-occurring resource boundaries of oil reserves in for an example township McKenzie County, North Dakota. **2.B.** depicts land parcels. As illustrated, the land parcels fragment the naturally occurring distribution of oil. **2.C.** depicts a map of oil fields in an example township, the lines of which demarcate boundaries to oil rights—just as the lines in 2.B. demarcate land parcels. Note that the oil parcels are far larger than the land parcels.

Land parceling fragments landscape-level and long-and-skinny resources (Bradshaw and Lueck 2015). A simplified example illustrates this point: *A* owns a forty-acre parcel on land, on which she grows corn. *A* sells to *B* the rights to produce oil under her. Now, *A* and *B* hold separate rights to concurrent resources.

The land interests of *A* now exist theoretically separately from the oil interests of *B. A* can profitably operate her farm on the land parcel. *B* must assemble hundreds of such parcels to profitably manage her resource rights (a profitable horizontal well typically requires at least 1,280 acres).

As depicted in **Figure 2**, the conventional land recordation system and resulting parcel map represents *A* 's land rights but not *B*'s oil rights (2.B.). But, a land parcel map does not accurately depict the boundaries around *B*'s oil parcel. A map showing oil boundaries would reflect much larger parcels (2.C.).

As illustrated above, concurrent resources have different ownership boundaries that create mismatched property rights. Observe the two parallel, overlapping layers of property rights here—the land parcels and the oil parcels. They have different owners, systems of recordation, visibility, and governance. The land parcels are recorded with the county recorder and can be visible, as with fencing. The oil parcels are not systematically recorded at a national level and are invisible (Ehrman, 2020). Land use decisions are managed at the local level whereas oil and gas regulation occurs at the state level. Property and land use scholarship generally is envisioned as a separate field from oil and gas scholarship.

Despite these distinctions, the oil and gas resources share vertical space with the land. The ownership of land affects the ownership regime for oil; the reverse is also true. Economic and legal analysis traditionally ignores that these parallel resource regimes in fact overlap in three-dimensional space. Concurrent resources have different ownership boundaries—the mismatched property rights. Virtual parcels clearly exist, but only conceptually. If resource boundaries were coterminous with land boundaries, recording the former would be redundant. In practice, resource boundaries differ from the boundaries to land/surface boundaries.

B. Mis-matched Property Rights

Many concurrent resources have mis-matched property rights. A single plot of land may include separable rights to water, hunting, drone airspace, conservation easements, and paleontological or archeological digging rights. Moreover, the government holds monopolistic power to allocate other property rights overlapping land, such as rights to: airspace, broadcast spectrum, public utility easements, endangered wildlife habitat, and (in some cases) mineral rights. Finally, resource users without formal rights include animals, trespassers, and poachers. There exist are an almost endless variety of property rights in each geographic space.

To return to the previous example, consider the rights on the landscape in their typical, two-dimensional depiction presented in **Figure 3**.

Having identified some of the concurrent resources in isolation, now consider how they overlap, as depicted in **Figure 4**.

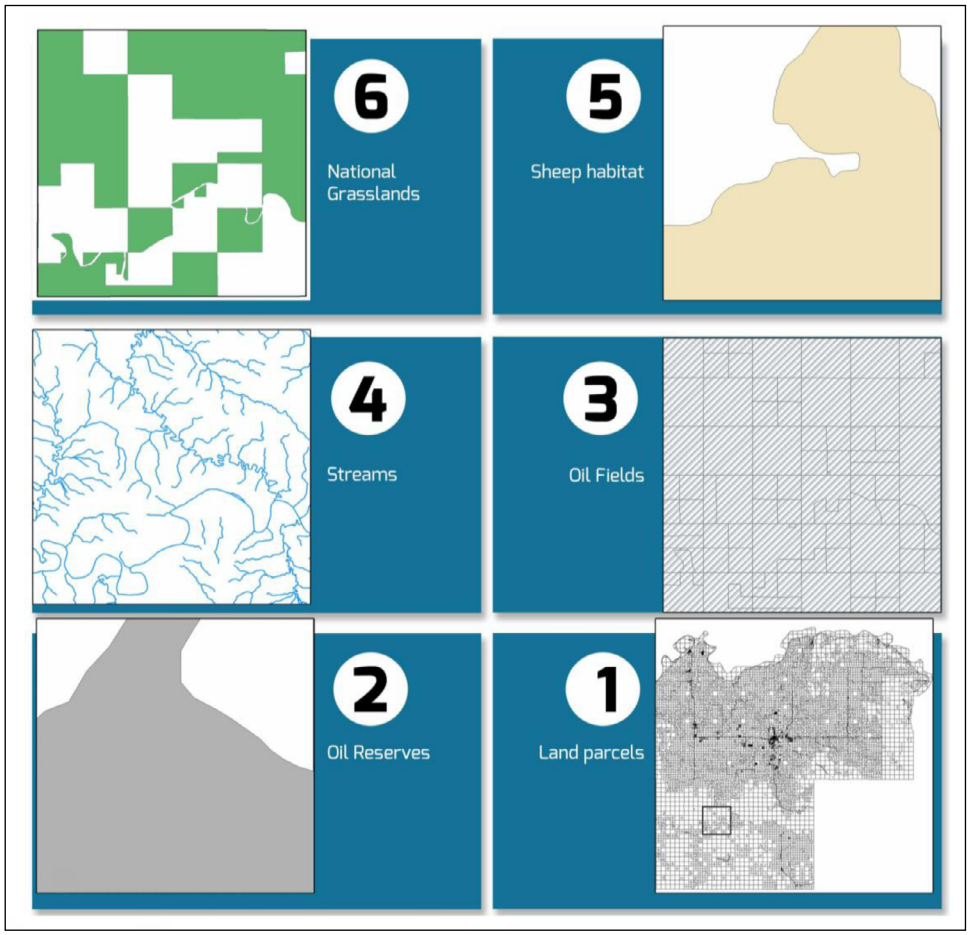

Figure 3: Resource Mix. Maps of six different natural resources and resource boundaries, which overlap in McKenzie County, North Dakota.

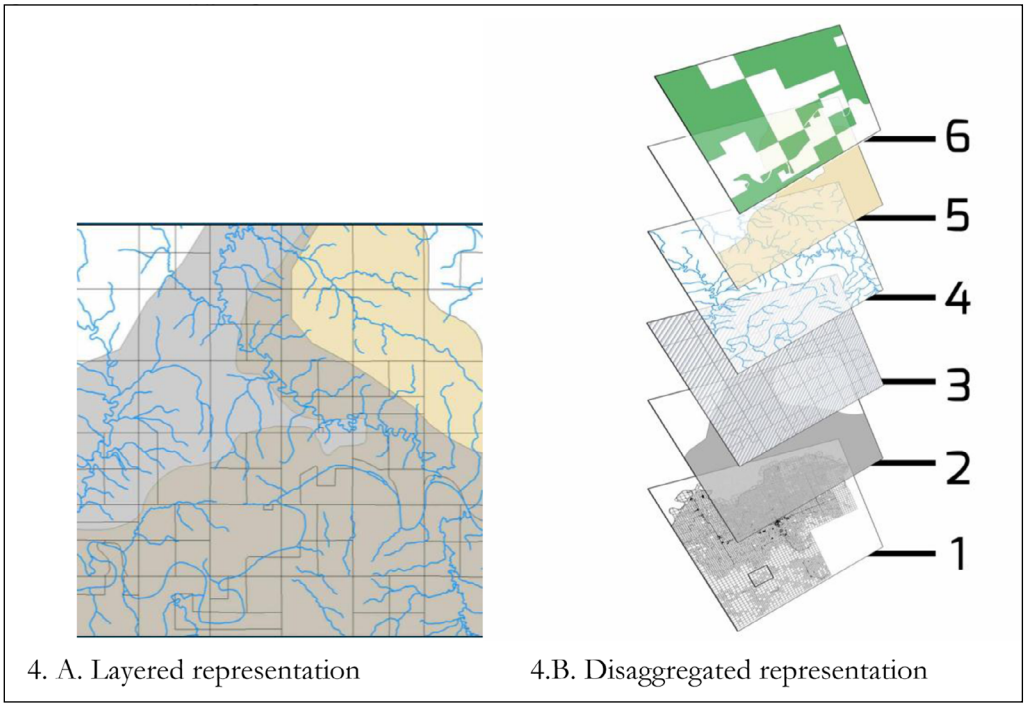

Figure 4: Overlapping Resources. Aggregated and disaggregated representations of the overlapping resources and resource boundaries in McKenzie County, North Dakota.

These concurrent rights are each subject to potentially different ownership, use rights, and governance. Considering these rights in an integrated and systematic way may reveal the interactions between various rights and policies in ways that will shed new light on existing legal conflicts and question some key aspects of economic theory. Our framework standardizes land use governance decisions through facilitating systematic review about the existence, relationship between, and prioritization of property-rights holders in an area.

III. Mechanisms Facilitating Virtual Parceling

Mechanisms to facilitate virtual parceling fall into two rough forms of governance: public (through statute, public land, and public interest in resources) and private (through custom and contract). Collectively, these tools serve to embed flexibility into use of the landscape, allowing a balance between resources and resource users through the allocation of property rights and subsequent limitations or expansion of those rights over time. Each of these tools is well-known and widely discussed. Yet, we argue that these familiar tools depicted in **Figure 5** serve a previously-overlooked function, that of facilitating virtual parceling.

A. Government Coordination

Public (governmental) mechanisms to facilitate virtual parceling include: statutory interventions, eminent domain, public lands, and the designation of public trust resources.

Statutory interventions. Anglo-Saxon legal tradition permits each landowner to determine both the level of resource use and acceptable resource users for his land. However, initial entitlements are not inviolable rights granted at a point in time, and then forever surrendered to operate henceforth at the whim of the owner. Instead, there remains a latent possibility that the rights granted may be increased, diminished, or revoked altogether by government in any subsequent period after the initial distribution. Government can use statutory requirements dynamically—responding to changes in population, land use, and natural resources as well as shifting social attitudes on each of these points.

We categorize several general statutory approaches. One approach is to promote coordination by aggregating ownership or management of the resource in question. Statutory requirements for coordination across parcels create virtual parcels that more closely match the scale of the resource under development, reducing rent dissipation. Forced pooling regulations in oil and gas development, which force groups of individual users to behave as a single decision-making unit, are a primary example (Libecap and Wiggins, 1985). Another approach is to target overuse of the commons more directly through restrictions on harvest of the resource, such as groundwater pumping restrictions (Brozovic and et al., 2006; Edwards, 2016). Anticommons problems can be similarly avoided by aggregating management decisions or by implementing price controls on fees for resource use. Statutory solutions may, however, only partially internalize the externalities and involve high monitoring and enforcement costs (Libecap and Smith, 2001; Libecap, 2005).

Government	**Example**
Eminent domain	Taking private land to build a highway
Statutory controls	Critical habitat designations under the Endangered Species Act; force-pooling & unitization of oil reserves
Public trust doctrine	State management of wildlife and beaches
Private	**Example**
Market transactions	Land assembly; buy-out of grazing rights for copper mining
Contracting	Road-sharing agreements
Custom	Wildfire suppression norms among timberland owners
Collaboration	Industry groups, certifications, collaborations

Figure 5: A non-exhaustive list of virtual parceling mechanisms.

Amidst heterogeneous initial distribution of land, statutory solutions create government-selected winners and losers; landowners may be disproportionately disadvantaged based upon the features of their property. Literature on environmental regulation suggests that interest group pressure and regulatory capture may produce suboptimal provision of public goods (Ando 1999). This is especially true because landowners subject to pending legislation tend to be a wealthy group upon whom a concentrated harm that generates dispersed benefits is about to be visited (Weingast et al. 1981).

Eminent domain allows the government to unilaterally re-group land and other resources into bundles appropriately sized for the public good. The Constitution authorizes government to convert land from individuals to public uses, which can involve assembling fragmented property to create landscape-level resources such as roads, railroads, or military bases. The prototypical use of eminent domain is for securing easement rights for "long and skinny" infrastructure, such as railroad tracks, power lines, or oil pipelines.

Public lands serve to consolidate ownership of landscape-level resources in a single owner—the government. Nearly one-third, or 640 million acres, of the American landscape is held and managed by the federal government. The government controls grazing, mining, oil and gas development, watershed maintenance, and wildfire risk reduction on these lands. Because many public lands are held at the landscape level—that is, in large swaths—the problems of virtual parceling are minimized; the same landowner owns both the land and underlying resource. This facilitates unilateral management of resources but requires subdivision of some resources better managed by private interests at a smaller scale.

Public land preserves flexibility and coordination for resource management that can be lost through parceling. If more land is public, one would anticipate that the government would provide a disproportionately large share of public goods associated with land. This is true with respect to clean air, wildlife habitat, and water. Adjacent and nearby landowners benefit from public provision of environmental public goods, as does the broader citizenry.

Government land management essentially subsidizes the activities of adjacent private landowners by mitigating their coordination failure in the provision of public goods associated with the landscape-level resource. For instance, many endangered species require a minimum amount of suitable habitat to survive. By managing its lands to provide habitat for creatures ranging from bighorn sheep to bald eagles, the government increases the amount of habitat in the landscape above the threshold level needed for species survival, mitigating the need for private efforts to protect habitat.

The fact that public ownership of land mitigates the challenges associated with the existence of landscape level resources with public good characteristics may help explain why we see a mix of public and private land across time and history. A mixture of individually and communally held land traces back to Roman law, and perhaps even the biological origins of property. (Epstein, 2016; Bradshaw, forthcoming). In general, the availability of public land as an institution for managing landscape level resources will depend on what portion of the landscape was privatized in the initial allocation of land. If the landscape is fully privatized initially, public land can only come through direct takings. In this setting, statutory or customary solutions to public good shortfalls may be more appealing.

Public ownership of landscapes and natural resources it not without its drawbacks, however. The efficiency of public ownership depends critically on the quality of governance. Government agencies face a variety of policy priorities that may compete with efficiency in the decision of how to manage publicly owned resources.

The *public trust doctrine* designates certain resources as public, such as the land under waterways, the beachfront, or lakes. This serves a variety of widely discussed purposes, but also creates the lesser-discussed function of creating unilateral ownership in the government to allow for control of important resources.

B. Private Coordination

Private mechanisms to facilitate virtual parceling include: market transactions, contracting (formally or informally), custom, and communal property.

Market transactions, or the sale of resources, allow for the assembly or subdivision of resource parcels. Much like the dynamics underlying land assembly, resource parcels can similarly be broken apart or pieced together through a series of private transactions.

Contracting. Bradshaw and Lueck discussed the use of contracts in managing landscapes in their 2015 paper. Subsequent scholars have studied similar contractual demarcations in the areas of oil and gas, wind, shale, and wildlife (Righetti 2018; Lueck 2018; Leonard and Parker 2019, Coleman 2019).

Custom or Communal Governance. Landowners may also cooperate to profitably exploit resources. Voluntary mechanisms to create virtual parcels at appropriate scales of management include both informal arrangements between landowners to overcome collective action problems and formal contracts and market exchanges or informal norms and institutions that leverage social ties between landowners (Ostrom 1990, Ellickson 1991, Bradshaw 2012).

Virtually re-parceling the resources to a communal governance regime operating at the resource scale enables landowners to reduce rent dissipation. Subgroups of resource users may privately order through custom and contract to select and maintain levels of the public good within units that span individual parcels. Examples of custom and cooperation range widely in sophistication, ranging from informal neighborly agreements to complex certification regimes (Ostrom, 1990; McKean, 2000).

Contract and custom allow landowners to pool and manage land and resources collectively. Adjacent landowners with pre-existing social networks can define use rules dynamically, in response to on-the-ground natural conditions and responsively adjust resource-use decisions in real time to changed circumstances at low cost (Ellickson, 1991). Ongoing cooperation establishes a platform of relationships as already established for quick and friendly negotiation for unpredictable resource fluctuations or threats, again embedding dynamic landscape amid a system of fixed entitlements.

Landowners fearing regulation may limit the loss of public goods to a socially-acceptable level to avoid legal intervention.[9] If the threat of involuntary external action is high, the likelihood of an internal voluntary response increases. Voluntary action to constrain resource use may presumptively or responsively lessen the threat of reform, and preserve the long-term control over the entitlement.

C. Mechanism Choice

The comparative advantage of each mechanism depends on the unique characteristics of the resource, landowners, and government agencies involved. In some settings, voluntary coordination avoids pitfalls of government ownership and regulation without inducing prohibitive transaction costs. Under other conditions, regulation is an important tool for overcoming collective action problems on a landscape that has already been privatized. In still other settings, government retains ownership and may manage resources most effectively.

The "right" strategy likely depends on a mix of the scale of the resource being governed, the preexisting norms and relationships of the adjacent community, and the effectiveness of public institutions. Communal governance will not work for national air quality; market-based solutions are an ill fit to public goods; statutes are unwieldy in mediating disputes between the owners of commercially valuable resources found on private lands. The pluralistic system of property management we observe is neither an accident nor a trend towards a mechanism. Instead, it likely reflects that many mechanisms can and should exist simultaneously to manage the inherent complexity of virtual parcels.[10]

Here, we must flag the fourth dimension of property, which is time. Natural conditions, social structures, and economic forces are ever-changing. So too must be the mechanisms that manage them. If land is distributed such that individuals can profitably use their land and pubic goods remain at socially acceptable levels, the balance of resources to resource users will remain relatively undisturbed.[11] Insensible allocations, or

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[9] If landowners' use of natural resources diminishes public goods beyond a socially acceptable level, citizens may demand restoration of the public good. Social reform limits landowner gains, although social movements and the passage of new laws generally lag resource depletion. Government enacts back-end controls weakening property rights or removing land from individual ownership and returning it to a system of communal governance. Absent reform, social movements form. In the extreme case, revolution and war may re-set landholdings (Ellickson, 1993). In this manner, strong property rights coupled with inadequate landowner resource management may produce subsequent statutory, judicial, and administrative interventions to ensure adequate production (and protection) of public goods.

[10] We note, however, that collective action problems manifest with both private and public ownership (Shepsle and Weingast, 1984; Schleifer and Vishny 1993; Heller 1998; Libecap 2018). Owners of individual parcels can hold out against the development of large-scale resources and extract rents from develops from projects that have specific spatial requirements. Conversely, voters, elected officials, and local governments and agencies all have some degree of hold-out power in their ability to block projects through the political process.

[11] Among animals, population pressures or resource shortages produce eventual exclusion of non-rights holders, which forces migration and extinction. Among humans, markets, custom and law shape prosocial behavior in the form of circumscribed property rights that are constantly, forever subject to latent intrusion on behalf of the common good. The Constitution reflects this need for some degree of collectively governed land in the Property Clause:

> The Congress shall have power to dispose of and make all needful Rules and Regulations respecting the Territory or other Property belonging to the United States; and nothing in this Constitution shall be so construed as to Prejudice any Claims of the United States, or of any particular State.

U.S. Const., art. IV, § 3, cl. 2.

once-sensible allocations that no longer accord to changed resource distributions, are subject to subsequent intervention. The initial allocation of property and subsequent strength of property rights creates the need for tools for governing those distributions over time.

An important question for future research is how virtual parcels operate when different resource uses conflict with one another. For the sake of clarity, our initial analysis here assumes that virtual parcels to different resource uses can be completely severed and do not interfere with one another—an appropriate assumption for cases like horizontal drilling, where surface uses are not disturbed by oil and gas extraction. Other uses like wind development or habitat protection may interfere with the primary use of land (e.g. agriculture, housing development). As the number of overlapping parcels associated with a given area of land increase, conflicts among uses may become more likely.

Conflicts among virtual parcels occupying the same space could perhaps be understood through an extension of existing property theory and how it treats conflicts among adjacent landowners. Such an extension is beyond the scope of this paper, but we note here that the framework developed by Coase (1960) and Demsetz (1967) does provide guidance. If a potential virtual parcel would conflict with existing parcels, there are two possibilities. On the one hand Demsetz (1967) suggests that the new resource use may *not* be explicitly parceled because the costs of doing so (e.g. conflict with existing uses) exceed the benefits. Conversely, Coase (1960) suggests that there may be some circumstances in which creating an explicit virtual parcel for the new use helps *resolve* conflict by setting the stage for negotiation.

IV. Conclusion

Natural resources co-exist in shared physical space; so too do resource users. Property law is essentially a system of rules to allocate use rights among competing resource users. The evolution of rights to include separate resources for different users has allows the bundling of rights at a natural scale of management. To achieve this, however, parties rely upon the under-theorized practice of virtual parceling—assembling and dividing concurrent resources.

From a policy perspective, identifying resource mixes, property rights holders, and relevant layers of governance allows for a systematic mechanism to identify the interests in a land dispute. This is more important than it may seem. Given distinct resource mixtures and sociopolitical features, property remains highly localized. At present, there exists no universal formula for identifying stakeholders or competing rights-holders. Explicitly identifying such interests when developing policy will likely incorporate potentially competing interests earlier in the process. We believe doing so holds great potential for resolving thorny problems like pollution control through a property-rights approach.

From a theoretical perspective, understanding the interconnectedness of property rights in four-dimensions serves to resolve a puzzle that has recently emerged. Privatization facilitates efficient land management but also divides other resources to a scale below their efficient management. Governance mechanisms have emerged to resolve this tension, by allowing land and resources to be split into different systems. Envisioning these systems as national in scope and subject to similar dynamics allows interdisciplinary scholars a new lens through which to view property law.

We believe these observations extend beyond the field of real property. For example, the patents system assigns patents to individual ideas. Yet, patent pooling allows companies to re-draw the boundaries around at a larger scale, assembling many individual patents. The government grants corporations to individual companies, but conglomerates re-draws boundaries that accompany many companies. Family farmers operate farms at a size they can individually manage but control supply at a regional industry level, through marketing orders. Foresters hold timberlands at an efficient scale of management for timber harvest operations but coordinate through certification regimes to create industry-level standards. Observing such parallels provides the opportunity for scholars beyond the field of natural resources to test and refine the importance of virtual parceling.

Competing Interests

The authors have no competing interests to declare.

References

Albertus, M., & **Kaplan, O.** (2013). Land reform as a counterinsurgency policy: Evidence from Colombia. *Journal of Conflict Resolution*, *57*(2), 198–231. DOI: https://doi.org/10.1177/0022002712446130

Allen, D. W., & **Lueck, D.** (1995). Risk preferences and the economics of contracts. *The American Economic Review*, *85*(2), 447–451.

Alston, L. J., & **Libecap, G. D.** (1996). The determinants and impact of property rights: Land titles on the Brazilian frontier. *Journal of Law, Economics, and Organization*, *12*(1), 25–61. DOI: https://doi.org/10.1093/oxfordjournals.jleo.a023360

Anderson, T. L., & **Hill, P. J.** (1975). The evolution of property rights: a study of the American West. *Journal of Law & Economics*, *18*(1), 163–179. DOI: https://doi.org/10.1086/466809

Ando, A. W. (1999). Waiting to Be Protected Under the Endangered Species Act: The Political Economy of Regulatory Delay*. *The Journal of Law and Economics*, *42*(1), 29–60. DOI: https://doi.org/10.1086/467417

Baldwin, K. (2014). When politicians cede control of resources: Land, chiefs, and coalition-building in Africa. *Comparative Politics*, *46*(3), 253–271. DOI: https://doi.org/10.5129/001041514810943036

Bradshaw, K. (2012). The Role of Norms in Wildfire Suppression. In *Wildfire: Law & Economics Policy Perspectives.* Routledge.

Bradshaw, K., & **Lueck, D.** (2015). Contracting for Control of Landscape-level Resources. *Iowa Law Review*, *100*(101), 2507–2549.

Brooks, L., & **Lutz, B.** (2016). From Today's City to Tomorrow's City: An Empirical Investigation of Urban Land Assembly. *American Economic Journal: Economic Policy*, *8*(3), 69–105. DOI: https://doi.org/10.1257/pol.20130399

Brozović, **N., Sunding, D.,** & **Zilberman, D.** (2006). Optimal management of groundwater over space and time. In *Frontiers in water resource economics* (pp. 109–135). Boston, MA: Springer. DOI: https://doi.org/10.1007/0-387-30056-2_6

Buchanan, J. M., & **Yoon, Y. J.** (2000). Symmetric tragedies: Commons and Anticommons. *Journal of Law & Economics*, *43*. DOI: https://doi.org/10.1086/467445

Butler, C. K., & **Gates, S.** (2012). African range wars: Climate, conflict, and property rights. *Journal of Peace Research*, *49*(1), 23–34. DOI: https://doi.org/10.1177/0022343311426166

Cheung, S. N. S. (1968). Private property rights and sharecropping. *Journal of Political Economy*, *76*(6), 1107–1122. DOI: https://doi.org/10.1086/259477

Coase, R. H. (1960). The Problem of Social Cost. *Journal of Law and Economics*, *3*(1), 1–44. DOI: https://doi.org/10.1086/466560

Cowen, N., & **Delmotte, C.** (2020). Ostrom, Floods, and Mismatched Property Rights. *International Journal of the Commons, 14*(1), pp. 583–596. DOI: https://doi.org/10.5334/ijc.983

De Soto, H. (2000). *The mystery of capital: Why capitalism triumphs in the West and fails everywhere else.* Basic Civitas Books.

Deininger, K., & **Byerlee, D.** (2011). Rising global interest in farmland: can it yield sustainable and equitable benefits? *World Bank Publications*. DOI: https://doi.org/10.1596/978-0-8213-8591-3

Demsetz, H. (1967). Toward a Theory of Property Rights. *The American Economic Review*, *57*(2), 347–359.

Edwards, E. C. (2016). What lies beneath? Aquifer heterogeneity and the economics of groundwater management. *Journal of the Association of Environmental and Resource Economists*, *3*(2), 453–491. DOI: https://doi.org/10.1086/685389

Ehrman, M. (2020). Application of Natural Resources Property Theory to Hidden Resources. *International Journal of the Commons, 14*(1), pp. 627–637. DOI: https://doi.org/10.5334/ijc.982

Ellickson, R. (1991). *Order Without Law: How Neighbors Resolve Disputes*. Cambridge: Harvard University Press.

Ellickson, R. C. (1993). Property in land. *Yale Law Journal* (pp. 1315–1400). DOI: https://doi.org/10.2307/796972

Epstein, R. A. (1985). *Takings: Private property and the power of eminent domain*. Harvard University Press.

Epstein, R. A. (2014a). What Is So Special About Intangible Property? The Case for Intelligent Carryovers. In G. A. Manne & J. D. Wright (Eds.), *Competition Policy and Patent Law Under Certainty: Regulating Innovation*, *42*, 46–47. DOI: https://doi.org/10.1017/CBO9780511974984.003

Epstein, R. A. (2014b). How Spontaneous: How Regulated: The Evolution of Property Rights Systems. *Iowa L. Rev*, *100*, 2341.

Facemire, C. R. (2021). *Parceling the Wild.* (Doctoral dissertation. Arizona State University, Tempe, AZ) Defense and publication forthcoming.

Facemire, C., & **Bradshaw, K.** (2020). Biodiversity Loss, Viewed through the Lens of Mis-matched Property Rights. *International Journal of the Commons*, *14*(1), pp. 650–661. DOI: https://doi.org/10.5334/ijc.985

Fennell, L. A. (2016). Fee Simple Obsolete. *New York Law Review*, *91*, 1457–1516. DOI: https://doi.org/10.2139/ssrn.2717111

Fennell, L. A. (2020). Property as the Law of Complements. In H. Dagan & B. Zipursky (Eds.), *RESEARCH HANDBOOK ON PRIVATE LAW THEORIES* (forthcoming).

Gay, E. F. (1905). The Inclosure Movement in England. *Publications of the American Economic Association*, *6*(2), 146–159.

Gordon, H. S. (1954). The Economic Theory of a Common-Property Resource: The Fishery. *The Journal of Political Economy* (pp. 124–142). DOI: https://doi.org/10.1086/257497

Hansen, Z. K., & **Libecap, G. D.** (2004). Small Farms, Externalities, and the Dust Bowl of the 1930s. *Journal of Political Economy*, *112*(3), 665–694. DOI: https://doi.org/10.1086/383102

Hardin, G. (1968). The Tragedy of the Commons. *Science*, *162*(3859), 1243–1248. DOI: https://doi.org/10.1126/science.162.3859.1243

Heller, M. A. (1998). The tragedy of the anticommons: property in the transition from Marx to markets. *Harvard law review* (pp. 621–688). DOI: https://doi.org/10.2307/1342203

Heller, M., & **Hills, R.** (2008). Land assembly districts. *Harvard Law Review* (pp. 1465–1527).

Hibbard, B. H. (1939). History of the Public Land Policies. University of Wisconsin Press.

Isaac, R., Kitchens, C., & **Portillo, J.** (2016). Can Buyer 'Mobility' Reduce Aggregation Failures in Land-Assembly? *Journal Of Urban Economics*, *95*, 16–30. DOI: https://doi.org/10.1016/j.jue.2016.06.001

Joireman, S. F. (2007). Enforcing new property rights in sub-Saharan Africa: the Ugandan constitution and the 1998 Land Act. *Comparative Politics* (pp. 463–480).

Leonard, B., & **Parker, D.** (2019). Fragmented Ownership and Natural Resource Use: Evidence from the Bakken. *Working Paper*.

Libecap, G. D. (2005). State regulation of open-access, common-pool resources. In *Handbook of new institutional economics* (pp. 545–572). US: Springer. DOI: https://doi.org/10.1007/0-387-25092-1_22

Libecap, G. D. (2018). Property Rights to Frontier Land and Minerals: US Exceptionalism (No. w24544). *National Bureau of Economic Research*. DOI: https://doi.org/10.3386/w24544

Libecap, G. D., & **Lueck, D.** (2011). The demarcation of land and the role of coordinating property institutions. *Journal of Political Economy*, *119*(3), 426–467. DOI: https://doi.org/10.1086/660842

Libecap, G. D., & **Smith, J. L.** (2001). Regulatory remedies to the common pool: The limits to oil field unitization. *The Energy Journal* (pp. 1–26). DOI: https://doi.org/10.5547/ISSN0195-6574-EJ-Vol22-No1-1

Libecap, G. D., & **Wiggins, S. N.** (1984). Contractual responses to the common pool: prorationing of crude oil production. *The American Economic Review*, *741*, 87–98.

Libecap, G. D., & **Wiggins, S. N.** (1985). The influence of private contractual failure on regulation: the case of oil field unitization. *Journal of Political Economy*, *93*(4), 690–714. DOI: https://doi.org/10.1086/261326

Lishiftz, Y. Vertical Property. *Working Paper*.

Lueck, D. (2018). The Comparative Institutions Approach to Wildlife Governance. *Tex. A&M L. Rev.*, *6*, 147.

Mason, T. D. (1998). "Take Two Acres and Call Me in the Morning": Is Land Reform a Prescription for Peasant Unrest? *The Journal of Politics*, *60*(1), 199–230. DOI: https://doi.org/10.2307/2648008

McKean, M. A. (2000). Common Property: What Is It, What Is It Good for, and What Makes It Work? In Clark C. Gibson et al. (Eds.), *People and Forests* (pp. 44–46).

Musembi, C. N. (2007). De Soto and land relations in rural Africa: breathing life into dead theories about property rights. *Third World Quarterly, 28*(8), 1457–1478. DOI: https://doi.org/10.1080/01436590701637334

Neeson, J. M. (1984). The opponents of enclosure in eighteenth-century Northamptonshire. *Past & Present*, *105*, 114–139. DOI: https://doi.org/10.1093/past/105.1.114

Righetti, T. (2018). Contracting for Sustainable Surface Management. *Arkansas Law Review*, *71*, 367.

Rose, C. (1986). The Comedy of the Commons: Custom, Commerce, and Inherently Public Property. *University Chicago Law Review*, *53*(3), 711–781. DOI: https://doi.org/10.2307/1599583

Shepsle, K. A., & **Weingast, B. R.** (1984). Political solutions to market problems. *American Political Science Review*, *78*(2), 417–434. DOI: https://doi.org/10.2307/1963373

Shleifer, A., & **Vishny, R. W.** (1993). Corruption. *The Quarterly Journal of Economics*, *108*(3), 599–617. DOI: https://doi.org/10.2307/2118402

Smith, A. (1776). An Inquiry into the Nature and Causes of the Wealth of Nations, 1976 Edition. R. H. Campbell & A. S Skinner (Eds.). with WB Todd. Volume I, Book III, Chapter II, Of the Discouragement of Agriculture in the Ancient State of Europe After the Fall of the Roman Empire.

Stiglitz, J. E. (1974). Incentives and risk sharing in sharecropping. *The Review of Economic Studies*, *41*(2), 219–255. DOI: https://doi.org/10.2307/2296714

van de Biezenbos, K. (2018). Enforcing Private Environmental Governance Standards Through Community Contracts. *Geo. Wash. J. Energy & Envtl. L.*, *9*, 45.

Voors, M. J., & **Bulte, E. H.** (2014). Conflict and the evolution of institutions: Unbundling institutions at the local level in Burundi. *Journal of Peace Research*, *51*(4), 455–469. DOI: https://doi.org/10.1177/0022343314531264

Weingast, B. R., Shepsle, K. A., & **Johnsen, C.** (1981). The political economy of benefits and costs: A neoclassical approach to distributive politics. *The Journal of Political Economy* (pp. 642–664). DOI: https://doi.org/10.1086/260997

Wiggins, S. N., & **Libecap, G. D.** (1985). Oil field unitization: contractual failure in the presence of imperfect information. *The American Economic Review*, *75*(3), 368–385.

Wily, L. A. (2011). 'The Law is to Blame': The Vulnerable Status of Common Property Rights in Sub-Saharan Africa. *Development and change*, *42*(3), 733–757. DOI: https://doi.org/10.1111/j.1467-7660.2011.01712.x

Yandle, T. (2007). Understanding the consequences of property rights mismatches: A case study of New Zealand's marine resources. *Ecology and society*, *12*(2). DOI: https://doi.org/10.5751/ES-02181-120227

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