



Boundaries, limits, landscapes and flows: An analytical framework for boundaries in natural resource management

Bettina Bluemling^{a,*}, Hsing-Sheng Tai^b, Hyun Choe^{c,d}

^a Faculty of Social Sciences, University of Stavanger, Elise Ottesen-Jensen House, Kjell Arholmsgate 41, 4036, Stavanger, Norway

^b College of Environmental Studies, National Dong Hwa University, No.1, Section 2, Da Shueh Rd., Shoufeng, Hualien, 97401, Taiwan, ROC

^c SSK Research Center on the Commons and Sustainable Society, South Korea

^d Department of Sociology, Jeju National University, 102 Jejudaehang-ro, Arail-dong, Jeju-si, Jeju-do, South Korea

ABSTRACT

In times of increasing pressure on natural resources, resource boundaries have become more ambiguous. Resources are increasingly interlinked, and competing users may define a resource and its boundaries differently. At times, resource units are confined into “resource plots”, while at other times they are “resource stocks”. Nevertheless, according to Elinor Ostrom, “clearly defined boundaries” are an important design principle. Against this background, the aim of this article is to develop, based on the work of Achille Varzi, an analytical framework with the help of which a better understanding can be gained of boundaries and their ambiguities in CPR management. Applied to 33 publications from Elinor Ostrom, the framework shows that focus has been on spatial, social boundaries. Less attention has been paid to natural boundaries, and in particular to natural resource limits. Applied to three empirical cases from East Asia, the framework shows how a more nuanced understanding of boundaries and their ambiguities can inform environmental management on the role of ambiguity. On a theoretical level, the paper finds that we need to move away from understanding a resource as a plain landscape, to a landscape as composed of shifting equilibria of resource flows, the limits of which need to be incorporated in CPR management.

1. Introduction

Boundaries as a concept have somewhat been contested in recent years, with research rather focusing on networks or transitions that cross boundaries. Scholars using a “complex systems” perspective highlight the importance of networks of resources or information flows (Webb and Bodin, 2008), as well as of actor networks (Pahl-Wostl, 2007). Research in geography using “liminality” has emphasized the role of transitions (Thomassen, 2012) and suggested a focus on “in-between situations and conditions characterized by the dislocation of established structures” (Horvath et al., 2015: 2). Nevertheless, yet another approach to natural resource management, the “Common Pool Resources” school, still highlights the importance of boundaries (see e.g. Wilson et al., 2013). This to some extent reflects environmental management practice. Examples are land use planning or the designation of Marine Protected Areas with clearly defined coordinates (Timonet and Abecasis, 2020). In Norway, offshore petroleum exploitation is confined to and licensed based on spatially defined “blocks”, even if petroleum reservoirs “can extend into license areas allocated to different owners” (Chandler, 2018: 2.005). In these cases, boundaries delineate “natural resource lots” with related access and use rights. However, such an understanding of natural resources as embedded in a “landscape” does not always prevail. Forest

management in Austria calculates a sustainable stock of game to protect the forest from the damages caused by the animals (see e.g. TJG, 2004: §52). For European waters, the Council of fisheries ministers annually sets catch limits for fish stocks, and for each stock, allocation percentages across EU countries are agreed upon (European Commission, 2020). Here, the natural resource is not seen as a landscape composed of “natural resource lots” but rather, “resource stocks” are identified that have to be kept within sustainable limits. Therefore, it appears that also for so-called “Common Pool Resources”, we may need to reconsider the understanding of “boundaries”.

In this article, we attempt a conceptual revision of “boundaries” and to this end focus on the first of Elinor Ostrom’s design principles for successful CPR management, i.e. the principle that boundaries of the resource and community have to be clearly defined to ensure sustained CPR use (Ostrom, 1990). A revision is timely as, additional to above observations, previous research has also shown that users may define a resource and its boundaries differently (see e.g. Borde and Bluemling, 2020; Ryks, 2014). In a context of multiple users, resource boundaries hence are likely to be ambiguous. Furthermore, as with increasing pressure on natural resources, they become more and more interconnected, leading to the “resource nexus” (Bleischwitz et al., 2017), boundaries get even more ambiguous. In light of these developments, it

* Corresponding author.

E-mail address: bettina.bluemling@uis.no (B. Bluemling).

<https://doi.org/10.1016/j.jenvman.2021.112129>

Received 28 August 2019; Received in revised form 3 January 2021; Accepted 3 February 2021

Available online 17 February 2021

0301-4797/© 2021 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

may not be a coincidence that the first design principle is “the most frequent target of (primarily theoretical) criticisms” (Cox et al., 2010; see also Quinn et al., 2007). Nevertheless, research has also shown that clearly defined boundaries support successful CPR management (see e.g. Ostrom, 2009; Ostrom and Benjamin, 1993; Wilson et al., 2013).

We hence assume that boundaries have a role to play in successful CPR management, but that we need to go further in understanding and differentiating among different kinds of boundaries. Such an understanding needs to incorporate above-mentioned limits, as well as the ambiguities that come about with different users and interconnected uses. The aim of this article is hence to develop an analytical framework that supports a better understanding of boundaries in CPR management.

The article first takes a step back and asks what boundaries mean in the context of natural resource management. To this end, it carries out a structured review of Achille Varzi’s conceptualization of boundaries in geography that leads to a theoretical framework (section 2). To verify the usefulness of this theoretical framework for the analysis of CPRs, it is applied to Ostrom’s research, which reveals that some modification is required, resulting in an analytical framework (section 3.2). We test this analytical framework by applying it to Elinor Ostrom’s writings and to three examples of CPR management in East Asia (sections 4.1. and 4.2.). The article concludes with a discussion in how far the framework provides a more nuanced understanding of CPR boundaries and of the need to draw them clearly.

2. Theoretical framework of boundaries by Achille Varzi

In geography, boundaries are ubiquitous, yet, as Achille C. Varzi argues, as a concept, they often lack theoretical rigor (Varzi, 2001b). The following is to large degrees based on Varzi (2011), but also Varzi (2001a) and Varzi (2001b) to differentiate among different kinds of boundaries.¹

According to Varzi, ambiguity of “boundaries” to some extent is in the nature of the discipline, i.e. “virtually every geographic word and concept” suffers from vagueness (Varzi, 2001a: 49). When we refer to a region, we do so “without any need to think of its limit or boundary, never mind considering the boundary as being at some definite place” (Varzi, 2001a: 50). Varzi gives the example of the boundaries of Mt Everest, - while everybody agrees to its upper boundaries, the lower boundaries are either unknown, unknowable or indeterminate (Varzi, 2001b). Furthermore, because of a “multitude of equally acceptable semantic options” (Varzi, 2001b: 124), terminology in geography is somewhat vague. Taking again the example of mountains, Varzi posits that “[w]e normally know how to use mountain names – and geographic terms at large – without being able to provide a precise explanation of the grounds for this competence, just as we may know what sound a violin makes without being able to explain it” (Varzi, 2001b: 125). Additionally adding to ambiguity is that boundaries are likely to undergo continuous change. “Geographic boundaries are not static. They change all the time. And as boundaries change, so do the geographic entities that they bound” (Varzi, 2001b: 126). Defining boundaries hence suffers from this general conceptual ambiguity in geography.

Nevertheless, in the beginning of the 20th century, a first differentiation was undertaken into *artificial boundaries* and *natural boundaries*. Artificial boundaries are “the product of human decisions and stipulations” (Varzi, 2011: 130), and therefore not necessarily “correspond to any genuine physical or otherwise objective differentiations in the

underlying territory” (Varzi, 2011: 130). Boundaries that are independent from our organizing activity are referred to as “*natural boundaries*”. In the following, the major characteristics of these two kinds of boundaries are outlined. This forms the theoretical framework, based on which an analytical framework is devised.

2.1. Natural boundaries – “*de re boundaries*” and “*boundaries as limits*”

According to Varzi (2011), boundaries have to be understood as related to an entity, - without an entity, there are no boundaries. A *natural boundary* is a boundary of an entity whose “identity and survival conditions do not depend on us; it is a *bona fide* entity of its own” (Varzi, 2011: 137). Islands are examples for *bona fide* entities. Boundaries hence “reflect some genuine discontinuity in the underlying physical territory”. Boundaries of *bona fide* entities are referred to as *de re boundaries*. *De re boundaries* hence exist “independently of the geographers’ conceptualizing activity” (Varzi, 2001a: 53). And while Varzi understands *de re boundaries* as “crisp” (Varzi, 2001b: 125), they still can be ambiguous.

Three sources of ambiguity can be identified. The nature of the *bona fide* entity can create ambiguity, e.g. a river “meanders from time to time” (Varzi, 2001b: 126). This will be referred to as “*bona fide ambiguity*” (see Table 1). A lack of precision in the “identification and exploitation of those boundaries” (Varzi, 2001b: 126) can also lead to ambiguity, i.e. we may lack the tools to identify boundaries. This will be referred to as “*methodological ambiguity*”. And finally, vague concepts may not clearly enough depict the *bona fide* entity and/or its *de re* boundary (Varzi, 2001a: 52), e.g. above example of “a mountain”. This will be referred to as “*semantic ambiguity*”.

Varzi mentions yet another kind of natural boundary, i.e. boundaries that are “the limits within which we are allowed to act [and that] are set by Nature itself” (Varzi, 2011: 139; *addition not in original*). These boundaries have received increasing attention, - see e.g. the concept of “*planetary boundaries*” (Rockström et al., 2009), similar to “*limits to growth*” (Meadows et al., 1972) decades ago. These boundaries do not as much consist of geographical demarcations, but of the extent up to which use may not obstruct a natural resource to replenish itself – a quantitative limit –, or up to which a resource can still endure pollution without losing its functions to society and nature, – a qualitative limit. They will be referred to as “*boundaries as limits*”. Ambiguity of “*boundaries as limits*” originates from the same sources as for *de re boundaries*. “*Bona fide ambiguity*” here refers to ambiguity that e.g. comes about with changes in inflows from other (re)sources, which change the limits over time.

Table 1
Natural boundaries (based on Varzi 2011; 2001a).

Natural boundaries		
De re boundaries: boundaries that exist independently of the geographers’ conceptualizing activity (Varzi 2001a, 53).		
Sources of ambiguity		Example
<i>Methodological ambiguity:</i> Lack of precision in the identification of boundaries.		Lack of tools and means to determine boundaries.
<i>Bona fide ambiguity:</i> Ambiguity originates from the nature of the <i>bona fide</i> entity.		A meandering river.
<i>Semantic ambiguity:</i> Concepts do not depict the <i>bona fide</i> entity clearly enough.		The use of the concept “mountain”.
Boundaries as limits: boundaries that are “the limits within which we are allowed to act [and that] are set by Nature itself” (Varzi 2011, 139).		
Sources of ambiguity		Example
<i>Methodological ambiguity:</i> Lack of precision in the identification of boundaries.		Lack of tools and means to determine boundaries.
<i>Bona fide ambiguity:</i> Boundaries change because of inflows from other resources (or) over time.		Fish stock in a highly complex ecosystem.
<i>Semantic ambiguity:</i> Concepts do not depict the <i>bona fide</i> entity clearly enough.		The concept of a “fish swarm”.

¹ A note on the differentiation between *de re/de dicto* boundaries and *bona fide/fiat entities*, which is central to this paper: In Varzi (2001b), Smith and Varzi (2000) and Smith and Varzi (1997), there is no distinction yet between entity and boundary, boundaries that are referred to as *de re/de dicto* boundaries are, in these papers, named *bona fide/fiat* boundaries. It appears that the distinction into entity and boundary, which we follow, was developed in later publications (see Varzi 2011).

2.2. Artificial boundaries – de dicto boundaries

According to Varzi, as there are “too many differences” in the physical world, humans need to “privilege some over the others” by drawing boundaries (Varzi, 2011: 142). He refers to these artificial boundaries as *de dicto* boundaries. Accordingly, entities “begin to exist only when we draw their boundaries” (Varzi, 2011: 132). As entities “emerge from our social or cognitive *fiats*” (Varzi, 2011: 132), they are named “*fiat* entities”.

De dicto boundaries carve out parts of a natural entity, and in doing so, they endow it with individuality. The “North Sea” is somewhat the product of an “arbitrary choice” (Varzi, 2011: 137, citing Frege 1884) that decides “which part of all the water on the earth’s surface we mark off and elect to call the ‘North Sea’”. The *de dicto* boundary hence endows the North Sea with individuality, which depends, for its existence, on “the beliefs and customs of the people who inhabit” the area (Varzi, 2001b: 127) who themselves draw part of their identity from this *fiat* entity.

As *de dicto* boundaries are “a product of human decisions and stipulations” (Varzi, 2011: 130), we need to ask who draws the boundaries and how (see Table 2). Not only the authority of the person(s) drawing a boundary is pivotal (Varzi, 2011: 131), but also if a boundary is drawn by actors from both sides. A symmetric boundary is “the result of negotiation and mutual agreement” (Varzi, 2001b: 122). “Oriented boundaries” “bound a territory in one direction only, because only one of the geographic entities separated by the border recognizes the border itself” (Varzi, 2001b: 122).

Pertaining to how boundaries are drawn, Varzi furthermore distinguishes between “*fiat* entities that owe their existence to collective intentionality”, and entities that emerge from “beliefs and habits of a community” (Varzi, 2011: 137). Beliefs and habits are likely to draw fuzzy boundaries and therefore tend to bring about ambiguity. A boundary drawn from intentional processes of formal authorities (i.e. representing “collective intentionality”) instead entails a “geometric

Table 2
Artificial boundaries (based on Varzi 2011; 2001b).

Artificial boundaries	
De dicto boundaries: emerge from our social or cognitive fiats. As we draw de dicto boundaries, fiat entities take shape.	
Attributes	Example
1. <i>Individuality and identity</i> of a fiat entity result from how boundaries are drawn.	The North Sea, - “which part of all the water on the earth’s surface” is marked off and elected to be called the ‘North Sea’? (Varzi 2011, 137).
2. <i>Who draws the boundary</i>	
2.1. <i>Authority</i> : legitimacy to draw boundaries.	A representative from a cadaster department.
2.2. <i>Agency – symmetric boundaries</i> : “result of negotiation and mutual agreement” (Varzi 2001b, 122).	Two parties negotiate and agree on boundaries that delineate their forests.
2.3. <i>Agency – oriented boundaries</i> : “only one of the geographic entities ... recognizes the border” (Varzi 2001b, 122).	One party recognizes the boundary of a meadow.
3. <i>Process of drawing a boundary</i>	
3.1 <i>Intentionality from beliefs and habits</i>	The reach of land use practices “defines” boundaries.
3.2. <i>Collective intentionality</i>	Cadaster plans of land ownership define boundaries.
Sources of ambiguity	Example
1. <i>Fiat ambiguity</i> : Vagueness from the nature of the fiat entity.	The boundaries of a holy mountain.
2. <i>Ambiguity from discrepancy</i> : Mismatch between natural dynamics and <i>de dicto</i> boundaries.	<i>De dicto</i> boundaries of agricultural land that is increasingly encroached by a desert.
3. <i>Semantic ambiguity</i> : Concepts do not depict the <i>bona fide</i> entity clearly enough.	The concept of a “region”.

bias” (Varzi, 2001b: 127) and is likely to have more formal legitimacy.

Ambiguity of a *fiat* entity and its *de dicto* boundary hence is to some extent influenced by how a boundary is drawn. Ambiguity of *de dicto* boundaries can be the “source of troubles” (Varzi, 2001b: 121). As *de dicto* boundaries are artificial, they can be “ignored or deleted, and thereby go out of existence; they can be drawn anew, and thereby come into being” (Varzi, 2011: 131). The resulting ambiguity is referred to as *fiat* ambiguity. For example, boundaries are drawn differently depending on how a mountain is conceived, as a site for mining, or as a holy mountain with sites of worship (see Borde and Bluemling, 2020).

De dicto boundaries are also ambiguous as they are “intimately connected to the space that they occupy and yet also deeply infected by the activity of human conceptualization” (Varzi, 2001b: 127). Ambiguity can arise from a tension between how a boundary was devised and dynamics of the natural system. This will be referred to as *ambiguity from discrepancy*.

And finally, also for *fiat* entities, *semantic ambiguity* may arise, e.g. from the use of the concept “region”.

In conclusion, boundaries can be ambiguous out of a variety of reasons. “Clearly defined boundaries” are, according to Varzi, fairly difficult to draw.

3. Material and methods: from theoretical framework to analytical framework

As the theoretical framework still remains somewhat disconnected from the specific case of CPR management, it is applied to a systematic literature review of selected writings by Elinor Ostrom. By definition, CPRs represent an open access situation, i.e. CPRs are defined by two characteristics: “1) it is costly to devise physical (e.g., fences) and institutional (e.g., boundary rules) means of excluding potential beneficiaries, and 2) one person can withdraw valued resource units (e.g., water, fish, CPU time) from the system for the given infrastructure at a particular point in time that cannot be used by others” (Anderies et al., 2004: 18). This means that by definition, *de re* boundaries and *de dicto* boundaries are likely to differ, leading to “ambiguity from discrepancy”.

Before introducing the analytical framework, the methodology of the literature review is presented.

3.1. Literature review

The aim of this review was to understand the use and development of the first design principle in Ostrom’s work. The design principles were first published in “Governing the Commons” in 1990, and much of Ostrom’s related thinking took place in the 1990s., i.e. when publishing in peer-reviewed journals did not have the significance in the social sciences as it has today. For example, from 1990 to 1999, Elinor Ostrom published only 26.8 percent of all of her publications in journals that are nowadays indexed in Scopus (see supplement). As Google Scholar allows to retrieve so-called “grey literature” and book chapters, it was used for the literature search at hand. To verify the robustness of the findings, a Scopus search with the same search terms (see below) was later carried out. The Scopus sample was limited in size and would not have allowed for an analysis of the use and development of the first design principle. However, it confirmed that findings across Scopus and Google Scholar are robust (see supplement).

As in Google, previous searches with a browser influence search results, the browser cache and cookies were cleared before the search. The search was carried out twice, i.e. on two different computers with different browsers. The two searches took place in July 2018, with one week apart, in the Netherlands. Geographic location is known to affect Google search results.

The literature search used the terms “design principles”, “Ostrom” and “boundaries”. Among the first hundred entries, all publications were selected that were (co-)authored by Elinor Ostrom and dealt with the first design principle. This resulted in a total of 33 publications over a

period of 23 years (from 1990 to 2013) (see footnote for the sample²).

There is a fair distribution of publications over time (see Fig. 1), which allows for an analysis of the evolution of Ostrom's understanding of boundaries. Sixteen publications are peer-reviewed journal articles, while "grey literature" (i.e. published in conference proceedings, workshop papers, discussion papers and lectures) is represented with eleven papers. "Book chapters" refers to chapters in books published by an academic publisher or a non-profit organization. Different publication types imply that publications can also contain reflections or digressions from the topic, which may not always hold for strictly organized journal papers. A disadvantage turned out to be repetitive passages in grey literature.

Excerpts were retrieved³ that dealt with the first design principle and boundaries in a narrow sense, and were inserted in a table. Additionally, excerpts were retrieved that discuss the complexity of CPR management in a broader sense, as they could provide insight into Ostrom's understanding of changes in the conception of boundaries.

Given the focus on natural resources, new kinds of CPRs such as information were not included in the analysis (i.e. Hess and Ostrom 2003 are not part of the dataset).

The dataset was coded using the different kinds of boundaries and their ambiguities as outlined in section 3.2. Coding was then verified in a second round and, if necessary, modified. Data was entered in an Excel sheet to derive the frequency of occurrences (Fig. 1). Results for the different kinds of boundaries are presented in section 4.1.1., results pertaining to different sources of ambiguity are presented in section 4.1.2.

3.2. Analytical framework of boundaries in CPR management

In a first round of analysis, the concepts "de re boundaries", "boundaries as limits" and "de dicto boundaries" from Tables 1 and 2 were used to code excerpts. It became clear that for an analysis of boundaries in CPR management, the framework needed to be slightly modified, which resulted in the analytical framework (see Fig. 2).

The first round of analysis showed that, when it comes to the natural resource, Elinor Ostrom foremost writes about natural boundaries as devised by stakeholders, i.e. *de dicto* natural boundaries. The first distinguishing feature for boundaries hence needed to be whether they are drawn by users or not. A further distinction needed to be made based on the entities to which boundaries relate: Analysis revealed that apart from a few exceptions (see e.g. Anderies et al., 2003), no distinction is made between infrastructure and natural resource as a CPR. A focus on boundaries however requires differentiating between the two because physical infrastructure largely consists of human-made entities (e.g. irrigation canals, biogas systems) where boundaries come by design. For natural resources and infrastructure, boundaries are then again divided into boundaries *as limits* and boundaries as spatial, *landscape* boundaries.

The analytical framework hence distinguishes between seven kinds of boundaries. As *de dicto* boundaries are drawn by users, the process of drawing boundaries furthermore needs to be considered (see Fig. 2).

This analytical framework was used for coding in a second round of

² (Ostrom 1990, 1993a, 1993b, 1994a, 1994b, 1995, 1998, 1999a, 1999b, 2000a, 2000b, 2002, 2007, 2008a, 2008b, 2008c, 2009, 2010, 2011, 2012; Anderies et al. 2003, 2004; Basurto and Ostrom 2009; Becker and Ostrom 1995; Dolsak and Ostrom 2003; Hess and Ostrom 2003; McGinnis and Ostrom 1992; Ostrom and Benjamin 1993; Ostrom and Cox 2010; Ostrom et al. 1999, 2003; Stern et al., 2002; Wilson et al., 2013).

³ Book chapters, working papers and journal articles were read in their entirety. However, two publications could only be accessed through Google Scholar, and the online view did not cover all pages. Missing pages were: Ostrom (1998) (pages 153, 154, 160 and 161); Dolsak and Ostrom (2003) (7, 9, 14, 21–23, 28–34). Additionally, for this study, excerpts were selected based on the entry "design principles" in the Index of Ostrom's 1990 "Governing the Commons".

analysis, the results of which will be presented in the following.

4. Results: testing of the analytical framework

The analytical framework is tested in two ways. First, application should show in how far the framework supports a better understanding of boundaries and their ambiguities in the work of Elinor Ostrom (section 4.1.). Second, its explanatory value is tested on three empirical examples of CPR management in East Asia.

4.1. Application to Ostrom's writings

Additional to the application of the analytical framework to Ostrom's writings, findings from Ostrom's understanding of the increasing complexity in CPR management are presented for the interpretation of results.

4.1.1. Differentiation into different kinds of boundaries

In total, 147 entries were retrieved. Most frequently mentioned were *de dicto* social boundaries (69 entries; 46.9% of all entries), followed by *de dicto* natural boundaries (49 entries; 33.3% of all entries). *De re* natural boundaries were mentioned 13 times (8.8%). Not many entries were returned for boundaries *as limits*. *De re* natural boundaries *as limits* and *de dicto* natural boundaries *as limits* were mentioned eight times each (5.4%). A focus on *de dicto* social boundaries and *de dicto* natural boundaries hence can be observed. However, a number of entries stem from Ostrom just mentioning the first design principle, i.e. without discussing these boundaries extensively. *De dicto* infrastructural boundaries were named five times, and infrastructural boundaries *as limits* were mentioned once. Given their limited number, infrastructural boundaries were not included in Fig. 1.

Some trends can be inferred from Fig. 1. Until 1999, *de dicto* social boundaries played a more important role than natural (*de dicto* or *de re*) boundaries. Afterwards, in five out of the following eleven years, social boundaries received more attention, and in the remaining years, natural boundaries were paid more attention to. Particularly around the beginning of the millennium, "boundaries *as limits*" found wider recognition, but this interest did not expand into later years.

It appears that for Ostrom, most important for sustainable CPR management are clearly delineated *de dicto* social boundaries. Without *de dicto* social boundaries, CPR users cannot take action against free-riders (Ostrom, 1999a, 2000b, 2002) and risk losing revenues (Ostrom, 1990, 1993b, 1994a, 1994b, 1995, 1998, 1999b; Ostrom and Benjamin, 1993). *De dicto* social boundaries are seen as creating trust among resource users (Anderies et al., 2003, 2004; Ostrom, 2000a, 2008b, 2009) and as enabling cooperation (Ostrom, 2000a, 2008b, 2009). This also shows that boundaries in Ostrom's work were often "oriented boundaries" (see Table 2). The deterioration of a CPR is foremost understood as resulting from resource overuse originating from not clearly defined *de dicto* social boundaries (Ostrom, 1990, 1994a, 1994b, 1995, 1998, 1999b, 2009).

Pertaining to the process of drawing boundaries, Ostrom points at how (in particular *de dicto* social) boundaries are maintained through boundary rules. Boundary rules entail "complex rituals and beliefs" (Ostrom, 2000a: 149) or "tags" (Ostrom, 2008b: 12) and "frequently possess well understood attributes, such as residing in a particular community or joining a specific local cooperative" (Ostrom, 2008b: 12). They can also be based on the relationship to the resource (Ostrom, 2008c: 28). For *de dicto* natural boundaries, few examples are provided for boundary rules, such as stones or plant species as markers (Ostrom, 2009: 39).

Discrepancy between boundaries is discussed in later publications only. In a publication from 2002, Stern and colleagues write that there are instances where "[e]nvironmental systems do not neatly match the boundaries of the social systems within which they are managed. It is thus unlikely that the rules of any one social system will be adequate for

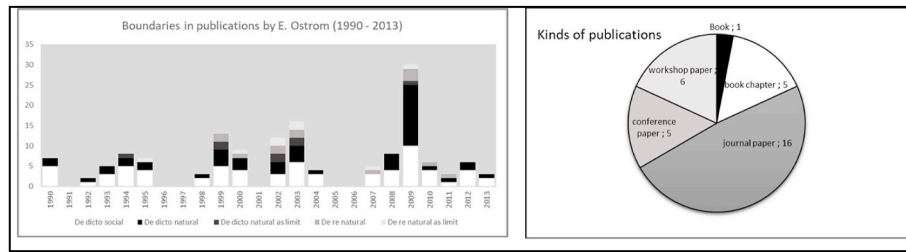


Fig. 1. Number and kinds of reviewed publications.

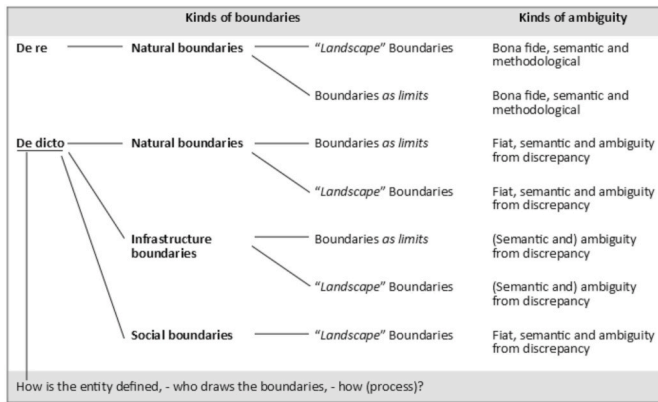


Fig. 2. Analytical Framework of boundaries in CPR management.

resource management” (Stern et al., 2002: 465). This concern about a discrepancy between social and natural boundaries comes back in later publications (Ostrom, 2007, 2008b, 2009, 2012). For example, in 2007, Ostrom writes that “[t]he important attribute of boundary rules is the degree of match between the provision organization and the local situation rather than the specific rule used Some provision units face considerable biophysical constraints when the good is a natural common-pool resource such as a groundwater basin or a river. Such resources have their own geographic boundary” (Ostrom, 2007: 248).

The observation of discrepancies led to theoretical refinement by Cox et al. (2010) who distinguish between social boundaries and ecological boundaries to “test, in the long run, whether the source of success or failure has to do with one, or the other, or both” (Ostrom, 2011: 26).

This refinement however appears to be somewhat modest in light of the complexity of CPR management that Ostrom pointed at already early on. Ostrom’s involvement in forestry projects drew her attention to the “[c]omplications of interlinked CPRs” (Ostrom et al., 1999: 281): “Specific resource systems in particular locations often include several types of CPRs and public goods with different spatial and temporal scales, differing degrees of uncertainty, and complex interactions among them” (Ostrom et al., 1999: 279). In 1995 already, Becker and Ostrom (1995: 124) pointed at how harvesting a certain species affects the availability of other species “with which it interacts. [...] The ecological and economic trade-offs associated with multispecies systems are extremely complex” (Becker and Ostrom, 1995: 124). Also with regard to sustainable yields, Becker and Ostrom (1995: 126) emphasize that replenishment is a result also of “interactions with other species [...]”. However, despite early insights, a first, albeit modest, conceptual modification was undertaken in 2010 only (see Cox et al., 2010).

In conclusion, while in Ostrom’s research, *de dicto* social boundaries appear to be most important to maintain CPRs, this does not mean that Ostrom did not see that resource uses and resources are interlinked, or that she did not see the impact of a discrepancy between social and ecological boundaries. However, only from 2010 on, a clear analytical distinction into social and ecological boundaries was made. While her writings include instances of *de re* natural boundaries and “*de re* natural

boundaries as limits”, there is no conceptual differentiation into *de re* and *de dicto* boundaries, or boundaries as limits and, what here is referred to as spatial, “landscape boundaries”.

4.1.2. Ambiguity

Bona fide ambiguity and methodological ambiguity are most often mentioned in Ostrom’s writings. Methodological ambiguity regarding *de dicto* natural boundaries foremost relates to local resource users’ lack of information (see e.g. Ostrom, 1994b: 47; Ostrom, 1995: 41; Ostrom, 2008a: 17–18; Stern et al., 2002: 465). *Bona fide* ambiguity pertaining to the natural entity (Cox and Ostrom, 2010; Dolsak and Ostrom, 2003; Ostrom, 1999a, 2000b, 2002, 2009, 2011) is often related to its size, which also makes drawing *de dicto* natural boundaries difficult (Ostrom, 1999a, 2000b, 2009). *Bona fide* qualities of a natural resource such as fluidity and seasonality can furthermore increase ambiguity of *de dicto* natural boundaries as limits (Dolsak and Ostrom, 2003; Ostrom, 2000b, 2002).

The process of drawing boundaries (see Basurto and Ostrom, 2009; Ostrom, 1994a; Ostrom, 2008b; Ostrom, 2009; Ostrom, 2012), and the question who draws the boundaries (Basurto and Ostrom, 2009; Ostrom, 1994a, 2008b, 2008c, 2009, 2012) receive some attention in Ostrom’s writings and hence show the contested nature of boundaries. Ostrom furthermore points at the social constructivist nature of boundaries, and how drawing boundaries brings about a natural entity. In Anderies et al. (2003: 4), the authors ask: “(1) What is the relevant system? (2) What are the desired system characteristics?”.

4.2. Empirical application

Insights from the analysis of Ostrom’s publications are complemented using three examples from East Asia. The introduction showed the need for a more nuanced understanding of “boundaries” to capture contemporary changes: boundaries at times delimit “resource stocks” rather than “natural resource lots”; users may define a resource and its boundaries differently; and boundaries have become more ambiguous because of the pressure on natural resources that have become increasingly interconnected. The below examples represent such challenges and shall show how the analytical framework can provide a more nuanced understanding of boundaries and their ambiguities, and as such can capture contemporary changes in an integrated manner.

The first example from Jeju Island, South Korea, exemplifies a situation as we can find it in the work of Elinor Ostrom. The example from Danungdafu, Eastern Taiwan, represents a situation where users define resource boundaries differently under conditions of social change. The example from Gansu Province, China, focuses on “resource stocks” and how their delineation may impact the *de dicto* boundaries of other resources. Each example explains in how far ambiguity, i.e. less clearly defined boundaries, is conducive or obstructive for natural resource management.

4.2.1. Default: boundary drawing and maintenance on Jeju island⁴

On Jeju Island, in pre-modern times, villagers jointly collected and distributed “olimi”, a sea algae that was washed to the shore and considered a “sea gift”. However, at times, not only olimi, but also dead bodies were washed to the shore. Villagers then had to jointly organize a funeral. Not organizing a funeral would make them lose the right to the seashore and related fisheries (see Go, 2012).

Originally, the boundary between the fisheries of the Jeju villages Geonip and Hwabuk was a *de re* boundary, i.e. the Hwabuk stream was the boundary. There are several seashores between the villages. Corpses often appeared at one particular shore, i.e. at Silaeguseok. Geonip villagers pushed the villagers of Hwabuk to hold funerals for the deceased that were washed to the shore of Silaeguseok. They used a huge rock, “Gamaepang”, which is about 1 km west of the Hwabuk stream and inscribed “粟” and “庚子五月中上入洞魚探契中書”, denoting that the rock was made a “boundary marker” in May 1901, a *de dicto* natural boundary. They hence gave up fisheries for the stretch between the rock and the stream. There is no evidence of an agreement with Hwabuk (Go, 2012), the demarcation is one-sided, it is an “oriented boundary” (Go, 2001).

In this example, villages demarcate clear *de dicto* social boundaries. Ambiguity may originate from discrepancy between the *de re* natural boundary and the *de dicto* natural boundary. In many cases, the former is self-evident but the latter is not. However, if the *de dicto* natural boundary is recorded (i.e. the boundary marker inscribed into the rock), it can become superior to the *de re* boundary. This example furthermore illustrates that access to the resource entity (the seashore) is conditioned by social practices to maintain related boundaries (funerals for the deceased).

4.2.2. Multiple users: social and resource boundaries in flux in Danungdafu⁵

The Danungdafu (DFA) is a plain area in Eastern Taiwan, which represents a typical indigenous traditional territory. Before the 20th century, an indigenous commons regime dominated the use of land and natural resources. There were clear-cut community boundaries and resource boundaries for commons use and protection. And while those boundaries changed over time, they did so at a slower pace than today.

In the 1910s, a modern state regime took over most land and natural resources as state assets. The DFA was used for sugar cane plantations. Since the 1980s, the indigenous community initiated the “Return my Traditional Territory” movement. In 2005, the Indigenous Basic Law was passed, which promises to recognize indigenous land rights and natural resource rights. In 2011, the Taiwan government designated the DFA as a forest park. The road towards revitalizing the indigenous commons regime is, however, full of challenges caused by ambiguous boundaries.

The forest park and the land surrounding it, provide numerous resources and ecosystem services, including forest, wildlife, tourism attractions, and carbon sequestration, which, together with land tenure, constitute the roots of ambiguous boundaries. As to land boundaries, some indigenous people insist that traditional territory should include public and private land that is located on the historical terrain. Others tend to accept the *de dicto* private natural boundaries, and only lay claim on state land on traditional territory. A further definition of *de dicto* natural boundaries comes from citizens of Chinese descent who to a large part do not accept the traditional indigenous territory.

Not only *de dicto* natural, but also *de dicto* social boundaries are in flux. With the younger generation of indigenous people migrating to

urban areas, the community of citizens of Chinese decent now makes nearly half of the population in the DFA. Additionally, with natural resource-based tourism, commercial interests expand into the park. Boundaries of communities and users hence are constantly changing, *semantic* and *fiat* ambiguity, and *ambiguity from discrepancy* likely result. This raises the question: What are the community boundaries for the respective group? Who has the right to access land and resources of the DFA? Most of the user groups realize, partly unwillingly, that only close collaboration can lead to successful resource conservation and use, because the management of these multiple resource uses requires a wide variety of expertise, capital, and cultural values.

Ambiguous boundaries are hence a daily reality. It does not seem to be possible to define clear-cut *de dicto* natural boundaries, or if it is done, it has the potential to trigger huge conflicts among groups, even among individuals in the same group. Instead, more flexible boundaries are considered more suitable, depending on the nature of the resources, and the degree to which boundaries adapt to the flux nature of modern society.

4.2.3. Boundaries as limits in Gansu⁶

Minqin County, Gansu Province, China, is located in a (semi-)arid climate. For decades, farmers used groundwater for irrigation, leading to groundwater over-extraction and even desertification (Aarnoudse et al., 2017, 2019). This changed in 2007 when the Shiyang River Basin Plan took effect. The plan foresees a reduction in groundwater use from 600 to 200 Mm³ over a period of five years (Aarnoudse et al., 2017, 2019). As a first step, 3000 out of 7000 wells were closed (Aarnoudse et al., 2019) and for the remaining wells, a water quota was established.

The quota includes surface water, rainwater and groundwater. Every farmer has a yearly water budget of 1200 m³ per household member, which is sufficient to irrigate and cultivate 2.5 mu of land per capita with low water demanding and drought resistant crops (Aarnoudse et al., 2017). Groundwater withdrawal is decided depending on precipitation and surface water inflow from the Qilian Mountain. Access to groundwater is regulated through a smart card machine that turns on electricity for a well as long as there is groundwater budget on the card. The variable groundwater budget hence is representative for *de dicto* natural boundaries as *limits*: farmers had to accept a shift from an open access situation to a situation where their groundwater use is limited within annual, clearly defined *de dicto* water use limits.

As a result of well closures and water use limits, land under crop cultivation decreased considerably, the per capita irrigated land prior to plan implementation was estimated at about 5 mu per capita (Aarnoudse et al., 2017). This shows how *de dicto* boundaries as *limits* for one resource also change the *de dicto* resource use boundaries of another resource (in this case land), i.e. the resource nexus.

5. Discussion

The following will discuss in how far the framework aids a more nuanced understanding of boundaries in CPR management. To this end, the use of boundaries in Ostrom’s work will be discussed conjointly with the three examples from East Asia.

Applying the analytical framework to Ostrom’s writings brings to light a more nuanced picture of what kind of boundaries have been the focus of analysis, i.e. *de dicto* social boundaries. Furthermore, as Ostrom sees CPRs as a *fiat* entity, and as she focuses on *de dicto* natural boundaries, we may understand Ostrom’s conceptualization of a CPR as being part of a landscape. What made drawing clear boundaries difficult, were *bona fide* ambiguity (e.g. the size of a resource, fluidity and seasonality) and methodological ambiguity (e.g. lack of knowledge). One

⁴ This example is based on an interview survey by Go Jayeon on Jeju Island on 10 May 2018, complemented with document reviews (Go, 2012 and Go, 2001).

⁵ Based on 23 qualitative interviews, conducted in August 2017 and February 2018 in Danungdafu.

⁶ See Aarnoudse et al. (2017) and Aarnoudse et al. (2019): Based on insights from a large-scale survey and qualitative interviews carried out in the Hexi corridor, Gansu Province, in 2014.

may argue that in her case studies, resources were relatively abundant, hence the focus on *de dicto* social and natural boundaries. The example from Jeju represents such a situation: as resources were still relatively abundant, Geonip villagers gave up a part of the seashore to draw an oriented and clear *de dicto* natural boundary.

In contrast, in Danungdaju, the multitude of natural resource uses and related overlapping *de dicto* natural boundaries under conditions of changing *de dicto* social boundaries, suggest that more flexible and hence ambiguous boundaries are conducive. While Danungdaju corresponds to Ostrom's understanding of a CPR as part of a landscape, it differs from many of Ostrom's cases with its focus on social change, resulting ambiguous *de dicto* social boundaries and redefinitions of resources and of their boundaries. Hence also the conclusion that negotiated, symmetric, albeit ambiguous as flexible *de dicto* natural boundaries may be more appropriate.

In Jeju and Danungdaju, delineation of *de dicto* natural boundaries was motivated by human resource use. In Gansu, the delineation of *de dicto* natural boundaries *as limits* rather orientates at *de re* natural boundaries *as limits*. As *de dicto* limits were implemented within an infrastructural system with smart card machines, they were relatively clearly drawn. However, as *de dicto* natural boundaries *as limits* orientate at *de re* natural boundaries *as limits*, in a situation of scarcity, this resulted in narrower *de dicto* land use boundaries. The framework hence can point at trade-offs in environmental management confronted with the resource nexus. Danungdaju and Gansu also show that a lack of ambiguity does not necessarily imply higher potential for conflict: In Gansu, while limits were clear, "*oriented limits*" were drawn, which let to conflicts with farmers.

Application of the framework hence shows that whether clearly defined boundaries lead to sustainable CPR management, depends on the kind of boundary and how it is drawn.

In 1990, when "Governing the Commons" was published, pressure on natural resource use may not have been as high or as prominently discussed. "[S]pace, technology, or time of harvest" (Ostrom, 1994a: 13–14) were considered better proxies to distribute resources than quantitative estimates of sustainable yield. However, not only planetary boundaries (Rockström et al., 2009), but also "the water-energy-food nexus" (Endo et al., 2017) have changed the view on natural resources.

Resource scarcity and multiple uses of one resource may require moving away from CPRs with spatial or "*landscape*" boundaries, to incorporate, or completely move to boundaries *as limits*. The definition of CPRs does indeed not only refer to devising boundaries for an open access situation, use limits also have to be defined, - they however have not received much attention. Limits have to be both quantitative and qualitative: What limit of pollution and/or degradation can a resource and resource uses accept, and how much of the resource do different uses need, and at what quality? Incorporating or changing to *de dicto* boundaries *as limits* can also be seen as transforming the view on nature as flows managed and withdrawn by different users. However, one could also argue that users jointly managing flows and their limits in certain, albeit temporarily changing equilibria, means to maintain the flows that build a landscape.

6. Conclusion

Pressure on natural resources has increased considerably since the 1990s. Resources have become more interconnected, user groups diversified in how they define resources and their boundaries, and "limits" of use at times replace "resource lots". Resource boundaries hence have become more ambiguous, which is why a reconsideration of Elinor Ostrom's first design principle is timely. This article devised a framework, based on the writings by Achille Varzi, that incorporates different kinds of boundaries. The application of the framework shows that whether clearly defined boundaries lead to sustainable CPR management, depends on the kind of boundary and how they are drawn. Furthermore, when allocation of resources orientates at *de re* natural

boundaries *as limits*, the framework points at the impacts on the *de dicto* boundaries of other, related natural resource uses. It hence supports an integrated analysis of natural resources as both, spatially bound and bound by limits. Future research may relate these insights to Design Principle 2.

Credit author statement

Bettina Bluemling: conceptualization, writing of theoretical & analytical framework, case study and discussion, revision, formal analysis, visualization, coordination. **Hsing-Sheng Tai:** writing of case study, formal analysis. **Hyun Choe:** writing of case study, formal analysis, raising research funds.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research was supported by the National Research Foundation of Korea Grant funded by the Korean Government (Grant Number NRF-2017S1A3A2067220). Research on Danungdaju was supported by the Ministry of Science and Technology, Taiwan (Grant number MOST 106-2621-M-259-001). Acknowledgments also go to Confucius' "Roads were made for journeys not destinations".

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jenvman.2021.112129>.

References

- Aarnoudse, E., Qu, W., Bluemling, B., Herzfeld, T., 2017. Groundwater quota versus tiered groundwater pricing: two cases of groundwater management in north-west China. *Int. J. Water Resour. Dev.* 33 (6), 917–934.
- Aarnoudse, E., Bluemling, B., Qu, W., Herzfeld, T., 2019. Groundwater regulation in case of overdraft: national groundwater policy implementation in north-west China. *Int. J. Water Resour. Dev.* 35 (2), 264–282.
- Anderies, J.M., Janssen, M.A., Ostrom, E., 2003. Design Principles for Robustness of Institutions in Social-Ecological Systems. <https://dcl.dlib.indiana.edu/dcl/bitstream/handle/10535/1777/Ostrom,Elinor.pdf?sequence=1>. (Accessed 15 July 2018).
- Anderies, J.M., Janssen, M.A., Ostrom, E., 2004. A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecol. Soc.* 9 (1), 18.
- Basurto, X., Ostrom, E., 2009. Beyond the tragedy of the commons. *Economia delle fonti di energia e dell'ambiente* 1, 35–60.
- Becker, C.D., Ostrom, E., 1995. Human ecology and resource sustainability: the importance of institutional diversity. *Annu. Rev. Ecol. Systemat.* 26, 113–133.
- Bleischwitz, R., Hoff, H., Spataro, C., van der Voet, E., VanDeveer, S.D. (Eds.), 2017. *Routledge Handbook of the Resource Nexus*. Routledge, Taylor & Francis Group, London.
- Borde, R., Bluemling, B., 2020. Representing indigenous sacred land: the case of the niyamgiri movement in India. *Appl. Econ. Lett.* <https://doi.org/10.1080/10455752.2020.1730417>.
- Chandler, J.A.P., 2018. *Petroleum Resource Management – How Governments Manage Their Offshore Petroleum Resources*. Edgar Elgar Publishing, Cheltenham.
- Cox, M., Arnold, G., Villamayor Tomás, S., 2010. A review of design principles for community-based natural resource management. *Ecol. Soc.* 15 (4), 38. <http://www.ecologyandsociety.org/vol15/iss4/art38/>.
- Dolsak, N., Ostrom, E., 2003. The challenges of the commons. In: Dolsak, N., Ostrom, E. (Eds.), *The Commons in the New Millennium: Challenges and Adaptation*. MIT Press, Cambridge, Massachusetts, pp. 3–34.
- Endo, A., Tsurita, I., Burnett, K., Orenco, P.M., 2017. A review of the current state of research on the water, energy, and food nexus. *J. Hydrol.: Reg. Stud.* 11, 20–30.
- European Commission, 2020. Fishing quotas. <https://ec.europa.eu/fisheries>. (Accessed 25 March 2020).
- Frege, G., 1884. *Die Grundlagen der Arithmetik*. Breslau: Köbner. English translation. In: Austin, J.L. (Ed.), *The Foundations of Arithmetic*. Oxford, Blackwell, 1950.
- Go, G., 2012. (In Korean) Chaegim tteoneomgimyeon jagi soyu badabatdo neomgyeojwoya [If you don't take responsibility for your fishery, you'll lost it]. *JejudominIlbo* 14 February 2012. <http://www.jejudomin.co.kr/news/articleView.html?idxno=27748>. (Accessed 19 February 2019).

- Go, Y., 2001. (In Korean) go yeongcheolui yeoksa gyoil [history class of go yeongcheol]. 21 september 2001. <http://www.jejuhistory.co.kr>. (Accessed 19 February 2019).
- Hess, C., Ostrom, E., 2003. Ideas, artefacts, and facilities: information as a common-pool resource. *Law Contemp. Probl.* 66 (1–2), 111–145.
- Horvath, A., Thomassen, B., Wydra, H., 2015. Introduction: liminality and the search for boundaries. In: Thomassen, B., Horvath, A., Wydra, H. (Eds.), *Breaking Boundaries: Varieties of Liminality*. Berghahn Books, Oxford/New York, pp. 1–8.
- McGinnis, M., Ostrom, E., 1992. Design principles for local and global commons. In: Paper Prepared for Presentation at a Conference on "Linking Local and Global Commons," Harvard Center for International Affairs, Cambridge, Massachusetts, April 23–25, 1992 (accessed 15 July 2018). <https://dlc.dlib.indiana.edu/dlc/handle/10535/5460>.
- Meadows, D.H., Meadows, D.L., Randers, J., Behrens III, W.W., 1972. *The Limits to Growth. A Report for the Club of Rome's Project on the Predicament of Mankind*. Universe Books, New York.
- Ostrom, E., 1990. *Governing the Commons – the Evolution of Institutions for Collective Action*. Cambridge University Press, Cambridge.
- Ostrom, E., 1993a. The Evolution of Norms, Rules, and Rights. In: *Beijer Discussion Paper Series No. 39*, 23 July 1993, D93 – 17.
- Ostrom, E., 1993b. Design principles in long-enduring irrigation institutions. *Water Resour. Res.* 29 (7), 1907–1912.
- Ostrom, E., 1994a. Neither Market Nor State: Governance of Common-Pool Resources in the Twenty-First Century. International Food Policy Research Institute, Washington, D.C. IFPRI Lecture Series No. 2, Lecture presented 2 June 1994.
- Ostrom, E., 1994b. Institutional analysis, design principles and threats to sustainable community governance and management of commons. In: Pomeroy, R.S. (Ed.), *Community Management and Common Property of Coastal Fisheries in Asia and the Pacific: Concepts, Methods and Experiences*. Proceedings of the Workshop on Community Management and Common Property of Coastal Fisheries and Upland Resources in Asia and the Pacific. Silang, Cavite, the Philippines, 21 - 23 June 1993, vol. 45, pp. 34–50. ICLARM Conference Proceedings. <https://www.worldfishcenter.org/content/community-management-and-common-property-coastal-fisheries-asia-and-pacific-concepts-methods>. (Accessed 15 July 2018). Manila.
- Ostrom, E., 1995. Designing complexity to govern complexity. In: Hanna, S., Munasinghe, M. (Eds.), *Property Rights and the Environment: Social and Ecological Issues. The International Bank for Reconstruction and Development/The World Bank*, Washington, D.C., pp. 32–45. <https://doi.org/10.1596/0-8213-3416-6>. (Accessed 15 July 2020)
- Ostrom, E., 1998. Scales, polycentricity, and incentives: designing complexity. In: Guruswamy, L.D., McNeely, J.A. (Eds.), *Scales, Polycentricity, and Incentives: Designing Complexity to Govern Complexity. Protection of Global Biodiversity: Converging Strategies*. Duke University Press, Durham, NC, USA, pp. 149–167.
- Ostrom, E., 1999a. Self-Governance and Forest Resources. Center for International Forestry Research. CIFOR Occasional Paper 20, Feb. 1999. Bogor, Indonesia. https://www.cifor.org/publications/pdf_files/OccPapers/OP-20.pdf. (Accessed 15 July 2018).
- Ostrom, E., 1999b. Design Principles and Threats to Sustainable Organizations that Manage Commons. Workshop in Political Theory and Policy Analysis, W9vols. 9–6. <http://dlc.dlib.indiana.edu/dlc/handle/10535/5465>. (Accessed 15 July 2018).
- Ostrom, E., 2000a. Collective action and the evolution of social norms. *J. Econ. Perspect.* 14 (3), 137–158.
- Ostrom, E., 2000b. Reformulating the commons. *Swiss Polit. Sci. Rev.* 6 (1), 29–52.
- Ostrom, E., 2002. Common-pool resources and institutions: toward a revised theory. In: Gardner, B., Rausser, G. (Eds.), *Handbook of Agricultural Economics*, vol. 2. Elsevier, North Holland, pp. 1316–1339.
- Ostrom, E., 2007. Challenges and growth: the development of the interdisciplinary field of institutional analysis. *J. Inst. Econ.* 3 (3), 239–264.
- Ostrom, E., 2008a. The challenge of common pool resources. *Environment* 50 (4), 10–20.
- Ostrom, E., 2008b. Polycentric Systems as One Approach for Solving Collective-Action Problems. <https://ssrn.com/abstract=1304697>. (Accessed 15 July 2018).
- Ostrom, E., 2008c. Institutions and the environment. *Econ. Aff.* 28 (3), 24–31.
- Ostrom, E., 2009. Design principles of robust property rights institutions: what have we learned? In: Ingram, G.K., Hong, Y.-H. (Eds.), *Property Rights and Land Policies. Proceedings of the 2008 Land Policy Conference*. Lincoln Institute of Land Policy, Cambridge, Massachusetts, pp. 25–51.
- Ostrom, E., 2010. Beyond markets and states: polycentric governance of complex economic systems. *Am. Econ. Rev.* 100, 641–672.
- Ostrom, E., 2011. The challenges of achieving conservation and development. In: Chamlee-Wright, E. (Ed.), *The Annual Proceedings of the Wealth and Well-Being of Nations*, pp. 21–27. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2176268. (Accessed 15 July 2020).
- Ostrom, E., 2012. Why do we need to protect institutional diversity? *Eur. Polit. Sci.* 11, 128–147.
- Ostrom, E., Benjamin, P., 1993. Design principles and the performance of farmer-managed irrigation systems in Nepal. In: Manor, S., Chambouleyron, J. (Eds.), *Performance Measurement in Farmer-Managed Irrigation Systems. Conference Proceedings of an International Workshop of the Farmer-Managed Irrigation Systems Network*, Mendoza, Argentina, 12 - 15 November 1991, vol. 53. International Irrigation Management Institute, Colombo, Sri Lanka, 62.
- Ostrom, E., Burger, J., Field, C.B., Norgaard, R.B., Policansky, D., 1999. Revisiting the commons: local lessons, global challenges. *Science* 284, 278–282.
- Ostrom, E., Cox, M., 2010. Moving beyond panaceas: a multi-tiered diagnostic approach for social-ecological analysis. *Environ. Conserv.* 37 (4), 451–463.
- Ostrom, E., Stern, P.C., Dietz, T., 2003. Water rights in the commons. *Water Resour. IMPACT* 5 (2), 9–12.
- Pahl-Wostl, C., 2007. Transitions towards adaptive management of water facing climate and global change. *Water Resour. Manag.* 21, 49–62.
- Quinn, C.H., Huby, M., Kiwasila, H., Lovett, J.C., 2007. Design principles and common pool resource management: an institutional approach to evaluating community management in semi-arid Tanzania. *J. Environ. Manag.* 84, 100–113.
- Rockström, J., et al., 2009. Planetary boundaries: exploring the safe operating space for humanity. *Ecol. Soc.* 14 (2), 32.
- Ryks, J.L., 2014. Land/seascapes of exclusion: the new colonial project. *Asia Pac. Viewp.* 55 (1), 38–53.
- Smith, B., Varzi, A.C., 1997. Fiat and bona fide boundaries: towards an ontology of spatially extended objects. In: Hirtle, S., Frank, A.U. (Eds.), *Spatial Information Theory: International Conference COSIT '97*. Springer, New York, pp. 103–119.
- Smith, B., Varzi, A.C., 2000. Fiat and bona fide boundaries. *Philos. Phenomenol. Res.* 60 (2), 401–420.
- Stern, P.C., Dietz, T., Dolsak, N., Ostrom, E., Stonich, S., 2002. Knowledge and questions after 15 Years of research. In: Ostrom, E., Dietz, T., Dolsak, N., Stern, P.C., Stovich, S., Weber, E.U. (Eds.), *National Research Council. The Drama of the Commons. Committee on the Human Dimensions of Global Change*. National Academy Press, Washington, DC, pp. 445–489. Division of Behavioral and Social Sciences and Education.
- Thomassen, B., 2012. Revisiting liminality – the danger of empty spaces. In: Andrews, H., Roberts, L. (Eds.), *Liminal Landscapes: Travel, Experience and Spaces In-Between*. Routledge, New York, pp. 21–35.
- Timonet, D.S., Abecasis, D., 2020. An integrated approach for the design of a marine protected area network applied to mainland Portugal. *Ocean Coast Manag.* 184, 105014.
- TJG, 2004. [Tiroler jagdgesetz]. www.ris.bka.gv.at. (Accessed 25 March 2020).
- Varzi, A.C., 2001a. Vagueness in geography. *Philos. Geogr.* 4 (1), 49–65.
- Varzi, A.C., 2001b. Philosophical issues in geography – an introduction. *Topoi* 20, 119–130.
- Varzi, A.C., 2011. Boundaries, conventions, and realism. In: Campbell, J.K., O'Rourke, M., Slater, M.H. (Eds.), *Carving Nature at its Joints: Natural Kinds in Metaphysics and Science*. MIT Press, Cambridge, Massachusetts, pp. 129–153.
- Webb, C., Bodin, Ö., 2008. A network perspective on modularity. In: Norberg, J., Cumming, G.S. (Eds.), *Complexity Theory for a Sustainable Future*. Columbia University Press, New York, pp. 85–118.
- Wilson, D.S., Ostrom, E., Cox, M.E., 2013. Generalizing the core design principles for the efficacy of groups. *J. Econ. Behav. Organ.* 90 (Suppl. ment). S21 – S32.