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An Analysis of the Global Applicability of Ostrom's Design Principles to Diagnose the Functionality of Common-Pool Resource Institutions

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Received: 24 May 2017; Accepted: 13 July 2017; Published: 24 July 2017

Abstract: There are a number of gaps in reviews relating Ostrom's design principles (DPs) to common-pool resource (CPR) institutions. These include the geographical distribution of CPRs, the performance of young CPRs relative to the DPs, and the relationship between robustness and success in adherence to the DPs. This research aims to: (i) explicitly analyze the geographical distribution of the case studies that have used the DPs, (ii) explore the relationship between the DPs and young CPR institutions, (iii) examine the relationship between robustness and success of CPR institutions based on the DPs, and (iv) identify additional factors contributing to the performance of CPR institutions. In relation to Ostrom's DPs, the CPRs under review involve management only by the community, co-management between the community and the state, and co-management between the community and non-governmental organizations. The results show that: DPs have been applied in all the inhabited continents; the expression of the DPs is affected by the geographical settings; the DPs do not conclusively diagnose the functionality of young and viable CPR institutions, whereas they may do so for either the short-lived (failed) or the long-lasting institutions; the relationship between robustness and success appears weak; and there are additional factors that contribute to the outcomes of CPR management.

Keywords: common-pool resources; community-based natural resources management; design principles

1. Introduction

The study of long-lasting common-pool resources (CPRs) that are user-governed led Elinor Ostrom to propose her well-known design principles (DPs) [1], which have been broadly used to diagnose the functionality of CPR institutions dependent upon different types of natural resources across the world. From the analysis of a variety of community-based management of CPRs, ranging from pastures and forests of Swiss villages to the Spanish, Japanese and the Philippine irrigation systems, she identified some important common features of these CPRs that characterized their governance system and contributed to their enduring existence (robustness) over a range of 100 years to more than 1000 years, surviving droughts, floods, wars, pestilence and changes of economy and

politics [1]. While these robust CPR institutions were different with regard to specific operational rules, they shared some characteristics that Ostrom organized into the eight DPs. According to Ostrom [1], a DP is defined as an important element or condition that helps to account for the success of institutions in sustaining the CPR.

1. **Clearly defined boundaries:** Individuals or households who have rights to withdraw resource units from the CPR must be clearly defined, as must be the boundaries of the CPR itself.
2. **Congruence between appropriation/provision rules and local conditions:** Appropriation rules restricting the time, place, technology, and/or quantity of resource units are related to local conditions.
3. **Collective-choice arrangements:** Most individuals affected by the operational rules can participate in modifying the operational rules.
4. **Monitoring:** Monitors who actively audit CPR conditions and appropriate behavior are accountable to the appropriators or are appropriators themselves.
5. **Graduated sanctions:** Appropriators who violate operational rules are subject to graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, officials accountable to these appropriators, or both.
6. **Conflict-resolution mechanisms:** Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.
7. **Minimal recognition of rights to organize:** The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.
8. **Nested enterprises:** Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises (for CPR that are parts of larger systems).

The formulation of these principles was based on extensive fieldwork and wide reviews of case studies and theoretical literature on institutions [2]. The claim that the eight DPs were the reason for the success of the CPRs, however, was not the ultimate conclusion by Ostrom. She called for the need for further theoretical and empirical work before a strong assertion is made that they are the necessary conditions for achieving institutional robustness in CPR settings. Following this call for action, the eight DPs have been tested in many situations and contexts. However, most of the literature is focused on the analysis of one or several case studies, and explains the robustness or lack of robustness of CPR institutions according to the presence/absence of the DPs. Other issues, such as the diversity of geographical settings that may influence the expression of the DPs and the relationships between the DPs and young CPR institutions, as well as between robustness and success, have received little attention. This research is based on the meta-analysis of data existing in the literature, covering the different types of CPRs in the five inhabited continents, with the objective to:

- Explicitly address the geographical distribution of the case studies that used the DPs, and its effect on the expression of the DPs;
- Explore the relationship between the DPs and the performance of young CPR institutions;
- Examine the relationship between robustness and success of CPR institutions;
- Identify additional factors that contribute to success or failure of a CPR institution;

This study addresses these objectives by exploring the following research questions:

- How widely are the DPs applied across the world?
- What is the effect of geographical settings on their expression?
- What is the relationship between the DPs and the performance of young CPR institutions?
- Is robustness equivalent to success?
- Could there be additional factors that contribute to the performance of CPRs?

2. Methods

To achieve the objectives, the first step was a literature search. In selecting the material for analysis, we used keywords for Ostrom's Design Principles on Google Scholar, which returned a number of articles including that by Cox et al. (2010). This particular document has been highly useful for choosing literature on the DPs. Hence, concentrating on geographical location and the type of CPR, we selected a number of case studies. Because the work by Cox et al. (2010) focused on the DPs, irrespective of their explicit geographical distributions, we complemented it with an internet search for case studies belonging to different types of CPRs (water, forest, fishery and pasture) distributed over the entire inhabited globe. We used combinations of key words such as "community based fishery Asia", "community based forestry Europe", etc., and were able to identify specific case studies for each continent. Google Scholar was used because it returns more results than the Web of Science.

In total, 54 papers consisting of case studies and reviews were analyzed. Twenty-two documents were examined for multiple case studies. Thirteen of these explicitly addressed Ostrom's eight DPs, and the remaining nine addressed them either indirectly or not at all. For the latter cases, the existing DPs were identified by the present authors. The remaining 32 documents referred to the study of commons and other related issues, but the issue of the DPs could still be discerned. The rationale behind choosing the literature for analysis was based on geographical diversity, which ultimately encompasses social, economic, cultural, political and resource diversity. The five continents were included, even if the number of countries chosen in each continent was not the same (Figure 1). The cases were selected to address a more or less similar number of cases representing the main types of resource systems (see Figure 1 and Tables 2–5)



Figure 1. Map showing the distribution of case studies across continents

Therefore, the choice of literature concentrated on three aspects: (i) the applications of the DPs within CPR institutions across the world, (ii) the time the CPR institutions had been in place, and (iii) the performance of the CPR institutions and the main factors that contributed to the outcome. To determine the institutional performance of case studies, a coding system was established to express the range of options existing between the absence and presence of a DP. We gave values to the coded DP frequencies from 0 to 1 indicating absence and presence of the DPs respectively (Table 1) as well as the intermediate options: Rarely Present (RP), Sometimes Present (SP), Mostly Present (MP). Values were intuitively assigned to these options (RP = 0.25; SP = 0.5; MP = 0.75), excluding No Data (ND) and Not Applicable (N/A). The values were finally multiplied by the frequency of the DPs, and

the products were summed up to provide scores for the final outcome (see supplementary material). The determination of the performance of institutions was based on the judgments of the original authors, and in the absence of this, we determined it. In both cases, the exercise was made in adherence to the DPs. Furthermore, a “Robust/Weak” category was added, when the analysis showed duration, but not good performance. Finally, institutions were determined as young if they had been in place for 10–15 years adapting Berkes [3], who considered 10 years to be the time needed to build simple, local-level institutions. To code the different categories according to the details in Table 1, we relied on the information included in the documents analyzed. Where the original authors had not addressed the DPs, we presented our conclusions, based on these scores, but where the original authors had explicitly addressed the DPs, we have also added our interpretation.

Table 1. Values of the coded frequency of the design principles (DPs) and range of scores for outcomes.

Code for DP's Frequency	Value	Score	Outcome
Absent (A)	0	0–2.9	Failed
Rarely Present (RP)	0.25	3–3.9	Fragile
Sometimes Present (SP)	0.5	4–4.9	Weak
Mostly Present (MP)	0.75	5–8	Successful
Present (P)	1		

3. Results and Discussion

A description of the different cases analyzed can be found in Supplementary Material 1. The presence/absence of the DPs, the degree of success of the CPRs and the duration of the management systems were reviewed (supplementary material). Figure 1 shows the type of CPR and the distribution of the case studies around the world. The main results have been summarized in Tables 2–5. The case studies are arranged according to geographical distribution and the types of CPRs.

3.1. Geographical Settings

The DPs in this study cover all inhabited continents (Figure 1) and a wide range of CPRs (Tables 2–5). The geographical, socio-economic, political, cultural and resource conditions affect the characteristics of a CPR institution. Hence the presence and absence of the DPs depend on these. The geographical setting in its pure sense, i.e., as referring to a mere location, has little effect on communities' self-organization, but it is within the geographical settings that all socio-economic, cultural and political activities occur.

The cases of Japan and Bulgaria serve as examples of the role of the interplay of socio-economic, cultural and political settings in developing collective action. The former succeeded because of the positive roles of the settings, but the latter case may have failed to organize collective action due to the combination of socio-cultural difficulties coupled with differences in the procedures for organizing collective action between the old and the new political systems. The role of political settings as expressed by government intervention has been shown to be both positive and negative for self-organization. The Tanzanian Duru-Hatiemba forestry and the Australian Murray–Darling basin ground water resource case studies demonstrate how democratic settings in which the government interacts with the community constructively can solve resource-sharing problems. On the contrary, the robust community forest management system in Slovakia known as Urbar [4] likely ceased to exist as a result of the political transformation to socialism. As shown by Vien [5], the importance of traditional religious beliefs and economic considerations when creating rules for natural resource protection was clearly manifested in several Vietnamese villages.

Table 2. Water common-pool resources (CPRs).

CPR	Country	Study Site	DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8	Duration (Years)	Remark	Conclusion	Interpretation	Reference
Water Resources (Irrigation & Potable Water)	Nepal	Koshi, Gandaki, Karnali, Mahakali	MP	MP	P	MP	MP	P	P	RP	10–200	Young–Robust	Successful	Successful	[6]
	Thailand	Ping, Kok, Namchi, Maeklong, Chao Phraya, Rayong, Songkhla	MP	MP	P	MP	MP	P	RP	MP	10–300	Young–Robust	Successful	Successful	[6]
	Pakistan	Dera Ghazi Khan (Punjab lowland)	A	P	A	A	P	P	P	N/A	Post-colonial period	Robust	Weak–Average	Weak	[7]
		Dera Ghazi Khan (Punjab highland)	P	P	P	P	A	P	P	N/A	Pre-colonial period	Robust	Robust	Successful	[6]
	Japan	Nishikanbara	P	P	P	P	P	P	P	P	Since 1945	Robust	Robust	Successful	[8]
	Bulgaria	Haskovo, Pavel Bania, Veliko, Tarnovo	A	A	A	A	A	A	P	N/A	Since 2000	Young	Failed	Failed	[9]
	Australia	Murray–Darling Basin	P	P	MP	P	A	P	P	P	Since 2000	Young	Successful	Successful	[10]
	Spain	Campo de Montiel	MP	P	MP	P	RP	P	P	MP	Since 1985	Robust	Successful	Successful	[10]
		Western Mancha	RP	MP	RP	MP	A	RP	P	A	Since 1985	Robust	Weak	Weak	[10]

Note: DP = Design Principles; A = Absent; P = Present; MP = Mostly Present; RP = Rarely Present; N/A = Not Applicable (For small discrete CPRs that are not part of a larger system).

Table 3. Forest common-pool resources (CPRs).

CPR	Country	Study Site	DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8	Duration (Years)	Remark	Conclusion	Interpretation	Reference
Forestry	Peru	Palcazu Valley	P	A	A	ND	ND	A	P	A	1986–1994	Young	Failed	Failed	[11]
	Honduras	La Campa	P	SP	RP	RP	RP	P	SP	P	Since 16th century	Robust	Weak	Weak	[12]
	Tanzania	Duru-Hatiemba	P	P	P	P	P	P	P	N/A	Since 1995	Young	Successful	Successful	[13]
	Ethiopia	South Gonder	MP	MP	P	MP	MP	P	P	N/A	Since 368	Robust	Successful	Successful	[14]
	Nepal	Dhulikhel	SP	SP	A	SP	A	A	SP	N/A	ND	-	Failed	Failed	[15]
		Jyalachitti	P	P	P	P	SP	P	P	N/A	Since 1992	Young	Successful	Successful	[15]
	Mexico *	San Antonio (Pseudonym), Oaxaca	P	P	P	P	P	P	P	P	Since 1988	Young	Successful	Successful	[16]
	Mexico *	San Martin Ocoltan (Pseudonym), Oaxaca	A	A	A	A	A	A	A	P	Since 1980	Young	Failed	Failed	[16]
	Canada *	Ontario	P	P	P	P	P	ND	P	N/A	Since 1996	Young	Successful	Successful	[17]
	Vietnam *	Ta Bo Cahn	P	P	P	ND	P	N/A	P	N/A	100	Robust	Successful	Successful	[5]
	Vietnam *	Na Tong, Bong	P	P	P	ND	P	N/A	P	N/A	Since 1960s	Robust	Successful	Successful	[5]

	Vietnam *	Dong Tien	P	P	P	ND	P	N/A	P	N/A	Since 1990s	Young	Successful	Successful	[5]
	Vietnam *	Mo Tom, Lam	P	P	P	ND	P	N/A	P	N/A	ND	-	Successful	Successful	[5]
	Slovakia *	Non-site-specific	P	P	P	P	P	N/A	P	N/A	18th century–1940s	Robust	Successful	Successful	[4]

Note: DP = Design Principles; A = Absent; P = Present; RP = Rarely Present; SP = Sometimes Present; MP = Mostly Present; ND = No Data; N/A = Not Applicable (For small discrete CPRs that are not part of a larger system).

Table 4. Fisheries common pool resources (CPRs).

CPR	Country	Study Site	DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8	Duration (Years)	Remark	Conclusion	Interpretation	Reference
Fisheries	New Zealand	Non-site-specific	RP	RP	RP	RP	A	P	P	SP	Since 1990s	Young	Fragile	Fragile	[18]
	Kenya	Non-site-specific	P	P	SP	RP	SP	P	P	SP	Since 1990s	Young	Average	Successful	[19]
	Madagascar	Non-site-specific	P	P	SP	A	SP	P	P	SP	Since 1996	Young	Average	Successful	[19]
	South Korea *	Kagodo Island	P	P	P	P	P	P	P	N/A	Since 1960s	Robust	Successful	Successful	[20]
	Brazil *	Pranha do Canto Verde (Ceara)	P	P	P	P	P	ND	P	N/A	Since 1990s	Young	Successful	Successful	[21]
	Canada *	Lennox Island, Abegweit (Prince Edward Island)	P	P	P	A	P	P	P	N/A	Since 1990s	Young	Successful	Successful	[22]
	Nigeria *	Badagry Creek (Ogun)	P	P	A	RP	RP	A	A	N/A	ND	-	Failed	Failed	[23]

Note: DP = Design Principles; A = Absent; P = Present; RP = Rarely Present; SP = Sometimes Present; ND = No Data; N/A = Not Applicable (For small discrete CPRs that are not part of a larger system).

Table 5. Multiple common-pool resources (CPRs).

CPR	Country	Study Site	DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8	Duration (Years)	Remark	Conclusion	Interpretation	Reference
Forest	Tanzania	12 villages in semi-arid regions of Tanzania	P	P	MP	MP	RP	P	P	RP	ND	-	Successful	Successful	[24]
Water Resources			P	P	P	MP	SP	MP	P	SP	ND	-	Successful	Successful	[24]
Pasture			SP	MP	SP	MP	A	MP	P	A	ND	-	Weak	Weak	[24]
Game Reserve	South Africa *	Sabi Sand Game Reserve (Mpumalanga)	P	P	P	P	P	P	P	P	ND	-	Successful	Successful	[25]

Note: DP = Design Principles; A = Absent; P = Present; RP = Rarely Present; SP = Sometimes Present; MP = Mostly Present; ND = No Data; N/A = Not Applicable (For small discrete CPRs that are not part of a larger system).

Notes on Tables 2–5:

- a. In line with the argument concerning the relationship between robustness and success, the conclusions to facilitate comparison and analysis are classified as “Successful”, “Weak” or “Failed”: robustness is not included in this classification. The conclusions, unless otherwise indicated, were made by the authors of the respective papers.
- b. * The case studies marked with asterisks did not explicitly examine the presence/absence of the design principles (DPs). The present authors identified the DPs. The conclusions and interpretations were also made by the present authors.
- c. In line with the argument that there should be a minimum threshold for years of existence when classifying the Robustness of a CPR, more than 15 years was considered “Robust” and 15 years or less was considered “Young” (adapting Berkes [3]).
- d. The conclusions “Weak” to “Average” indicate weak to average performance for specific CPR institutions in this study.
- e. “Young” to “Robust” indicates short to long duration respectively for specific CPR institutions in this study.

Finally, an insight into the global influence of DPs as a diagnostic tool for commons’ studies will be obtained with the knowledge of the geographical distribution of their application. Its wide usage could provide an impetus for focused and accurate analyses of social-ecological systems (SES).

3.2. Relationships between the Design Principles and Performance of Young Common-Pool Resource Institutions

Depending on the number of DPs, a considerable number of authors diagnosed common property institutions as either Weak/Fragile or Robust, implying a respective demise or success. However, no valid conclusion could be made while the institutions were relatively young. In light of the existence of many factors influencing CPR management enumerated by several commons’ scholars (e.g., Wade, 1988; Baland and Platteau, 1996— cited in [26], p 1654; [27]), fragile CPRs could evolve into strong institutions by developing pertinent adaptive features. A reasonably confident conclusion could be made that the definitive demise of an institution was linked to an absence of the DPs only if a CPR institution permanently failed. Similarly, only long-term survival with an effective achievement of the management objectives could show that an institution possessing all or most of the DPs was successful. This makes the research on robustness related with the DPs highly time-dependent. Therefore, setting a minimum time frame for the duration of a CPR institution with the expected performance that distinguishes it as successful may improve the accuracy of the conclusions.

3.3. Relationships between Robustness and Success in Relation to the Design Principles

There is uncertainty in the relationship between robustness and success (based on the number of DPs). Does robustness imply success in adherence to the number of DPs? Several authors equated success with robustness. Ostrom equated robustness with long durations, lasting from centuries to a millennium, through many ups and downs, and many adaptive changes to disturbances. Although, one can sense success in this assertion, taking robustness as the ability of a disrupted SES not to decline as rapidly as its non-robust counterpart [2], endurance does not necessarily imply success; for, success should mean both endurance and achievement of objectives with efficiency and effectiveness. The objectives of environmental management cannot be different from maintaining both resource sustainability and the benefits for users. This argument is close to that of Baggio et al. [28], who stated that resource sustainability, collective choice and equity of users characterize success. However, due to the uncertainties mentioned above, it has been difficult in this work to show either success or failure for the analyzed case studies, except by adopting the judgments of the authors for each, and relying on the number of DPs identified by us for those cases in which the original authors did not address them.

In relation to the DPs, what measurement can be used to judge a CPR management a failure? How many of the DPs must be absent for a CPR institution to be judged fragile or a failure? Here, Ostrom's works do not help either. In fact, the subjective judgment seems to be inherited from her studies in which the absence of four or five of the DPs implied the fragility of CPRs [1]. Basurto and Ostrom [29] wrote that sustainable self-organizations tend to be characterized by the presence of "most" of the DPs, while fragile institutions tend to be characterized by only "some" of them, and failed institutions by a "few". The qualifiers "most", "some" and "few" do not convey precise measurements. It may be appropriate to set a certain standard measurement, for example, a minimum threshold of time (in years) and number of DPs to determine the robustness of an institution.

Baggio et al. [28] attempted to explain success and failure of CPR institutions based on the relationship between performance and the co-occurrence and configuration of the DPs. The study was an appreciable attempt to replace the subjective judgment of determining performance with an objective method. It also addressed the relative importance of DPs both within and across activities. Barnett et al. [30] addressed the temporal issue of a certain CPR being successful at time 1 and unsuccessful at time 2, or a seemingly unsuccessful CPR succeeding in later years. Although these observations are true, the dynamics of relativity should not be overlooked. Nothing is absolute. Success may not necessarily be permanent, but neither is failure. Therefore, setting a minimum temporal boundary, together with the number of DPs, may help address the problems associated with outcomes (success/failure/robustness) relative to the time of the study. In retrospect, it could be possible to objectively state that a certain CPR institution was successful because: (i) a certain number of DPs were present; (ii) it endured for a certain extent of time; and (iii) the environmental safety was maintained; then, due to some concrete reasons, it failed after existing for a definite number of years. This can put a clear demarcation on the number of years the CPR institution was successful and then failed. Or it could be that the CPR institution was initially fragile, and succeeded in the later years.

3.4. Causes of Success/Failure of Common-Pool Resource Institutions

Barnett et al. [30] attributed inconsistent conclusions for CPR governance based on DPs to investigator's bias (missing data), procedural (coding process) and substantive (codebook development) errors. Whereas these factors are attributable to the scholars' studying cases, another important factor attributable to the CPR institution itself is the nominal presence of the DPs affected by poor implementation of CPR management. Therefore, although the DPs are good indicators of success of a given CPR, they cannot be taken as a final diagnosis for its failure. In addition to the presence of the DPs, there are other factors that can influence the endurance of CPR institutions. A number of factors contributing to the success and failure of CPR management systems in the case studies are summarized in Table 6. We extracted factors that contributed to the governance outcomes of the case studies. The factors included both the DPs and others that did not fall under the category of the DPs. We hope that future studies will identify yet more factors and find ways to categorize them into certain classes.

3.5. Frequency of the Different Design Principles

Baggio et al. [28] used the frequencies of DPs' co-occurrence and combinations to classify CPR governance into successful and unsuccessful cases. What we have presented here are our observations of the frequency of DPs, irrespective of the governance outcome. As can be seen in Tables 2–5, the DPs that were more commonly present included DP1, DP2 and DP7; those less common were DP4 and DP5, with DP3 and DP6 occupying an intermediate position. As most of the CPRs were small in scale, DP8 was not relevant. On the basis of these observations, it is probable that users had reasonable knowledge of their resource boundaries (DP1) and followed rules compatible with resource characteristics (DP2). Additionally, governments seemed to mostly recognize the rights of communities to self-organize (DP7). However, both the monitoring activities (DP4) and the sanctions for rule violations (DP5) were weak. This situation may have important implications for

resource management because, despite awareness of resource boundaries and efforts to follow rules compatible with the resources characteristics, the absence of monitoring and graduated sanctions would enable “free riders”, leading to an overuse of the resource and its ultimate deterioration. As the devising of a conflict-resolution mechanism (DP6) is a result of a collective-choice arrangement (DP3), it was logical that these two principles shared the same position.

Table 6. Summary of causes for success and failure of CPR institutions.

Reason for Success	Example
Non-coercive presence of government (DP8)	Japanese Irrigation CPRs
Social capital (strong group consciousness, mutual trust and a high moral standard)	
Small size	Nepalese Irrigation CPRs
Autonomous community management (DP7)	Pakistani Irrigation CPRs (highland)
Government community collaboration (DP8)	Lower and Upper Murray–Darling Basin (Australia)
Democratic settings	
Lower number of users	Campo de Montiel (Spain)
Strong leadership	
No tendency for illegal use	
Voluntary community participation (DP3)	Duru-Hatiemba’s Forest CPR (Tanzania)
Livelihood dependence on resources	Vietnamese Forest CPRs
Religious beliefs	
Community participation (DP3)	Dhulikel’s Forest CPR (Nepal)
High level of organization	
Strong association	San Antonio’s Forest CPR (Mexico)
Strong leadership	
Community participation (DP3)	South Korean Fisheries CPRs
Equity	
Strong conflict resolution methods (DP6)	
Reasons for Failure	Example
Absence of social capital (distrust, envy, opportunism, and corruption)	Bulgarian Irrigation CPRs
Information asymmetry	
Large size	Thai Irrigation CPRs
Government intervention (DP7)	Pakistani Irrigation CPRs (lowland)
Non-consultations of stakeholders (DP3)	Upper Murray–Darling Basin (before plan revision was performed; Australia)
Tendency to maximize profit illegally	Western Mancha (Spain)
Low government resources for controlling	
Lack of strong political leadership	
Political change	Urban Forest CPR Management (Slovakia)
Government intervention (DP7)	
Generational gap (lifestyle change, heterogeneity, profit seeking, and economic diversity)	
Government intervention (DP7)	Several Semi-Arid-Zone CPRs (Tanzania)
Lack of conflict resolutions method (DP6)	
Absence of graduated sanctions (DP5)	
Inability to cope with change	Jyalachiti Forest CPR (Nepal)
Low level of organization	
Conflict of interests (DP6)	San Martin’s Forest CPR (Mexico)
Corruption	
Mismanagement	Fisheries CPR (New Zealand)
Ethnic heterogeneity and lack of shared values	
Exclusion of stakeholders	
Formative stage of the cooperative	Fisheries CPR (New Zealand)
Weak graduated sanctions (DP5)	

DP = Design Principles.

3.6. Significance of the Frequency Combinations of the Design Principles

Tables 2–5 further shows that those case studies for which most (six or more) DPs were present or mostly present exhibited successful community-based resource management. On the contrary, in those case studies for which almost all DPs were absent (A), rarely present (RP) or only sometimes present (SP), the CPR institutions were considered failed, and indeed as Theesfeld [9] asserted, the absence of the DPs in the irrigation CPRs existing in three regions of Bulgaria turned them into open access resources.

As indicated in Tables 2–5, despite equal numbers of DPs present, the conclusions of any two case studies might differ. This depends on the frequency combination of the DPs. For example, if three P's were combined with four MP's, or two P's were combined with five MP's, the conclusion would be "success" (e.g., Nepalese and Thai cases). However, if four P's were combined with three A's, then the conclusion would be "failed" (e.g., Pakistani lowland cases). Additionally, where four P's were combined with three SP's, the conclusion was an average performance (e.g., Kenyan and Malagasy fisheries cases). An average performance was interpreted by the present authors as a success. Another notable observation was that in some CPRs, DP5 was present in the absence of DP4. This might have indicated only a nominal presence of DP5. Therefore, in adherence to the DPs, the conclusion was only an average performance (e.g., Kenyan and Malagasy fisheries cases).

As noted by Baggio et al. [28], it seems that the frequency combinations of DPs play important roles in the determinations of CPRs as successful or failed. Nevertheless, this conclusion is not without flaws. Most of the case studies consisted of multiple CPRs, such that flaws arise where the DPs were counted for each CPR, but the conclusion was based on the collective result.

3.7. Work on the Design Principles

In most of the case studies, the DPs were used as a lens to examine the management of common-pool resources; some researchers attempted to modify or expand some so that they fit to specific conditions not addressed by Ostrom. Only few of the case studies above did not explicitly search for the presence/absence of Ostrom's DPs in the CPR institutions.

The modifications on the first, seventh and eighth principles by Morrow and Hull [11] attempted to be more inclusive and expressive. The expansion of the principles was meant to enable the local community to be sturdier, while the external agencies could still assist more effectively in establishing enduring CPR institutions. This approach may be useful in the modern, interconnected world, where communities are no longer isolated and little opportunity exists for pure self-organization. Moreover, the attempt to expand the second DP was reasonable, for which the local condition included the social and cultural dimensions. Similarly, Sarker and Itoh [8] modified the seventh principle by adding "non-interventionary investment in the solicited physical capital entrusted to the appropriators' organizations". This modification is justified on the grounds that the state did not interfere in the workings of the Land Improvement District (LID), in spite of its substantial capital contribution for the institution. Similarly, Gautam and Shivakoti [15] argued for the inclusion of socio-cultural and economic aspects to this DP. This same DP was modified by Bastakoti and Shivakoti [6], in what seems only a repetition of the previous works [11,15], with the exception of a suggestion to include "topography". In continuation, the fifth DP-graduated sanction was also expanded to include an "enforcement mechanism", such as reverting to state law enforcement institutions [5]. Monitoring was also expanded to address the impact of external forces such as government development projects on the local monitoring activities [15]. The authors suggest the expansion of the seventh principle, calling for the absence of a single powerful user group that prevents self-organization of others. These two modifications seem reasonable, as external forces may disrupt monitoring, and a powerful group may be a hindrance to devising institutions with differing objectives. Finally, Cox et al. [31], in their analysis of literature on community-based management systems in relation to the DPs, subdivided some (DP1, DP2 and DP4) and increased the number to 11.

Ostrom, in her later works (e.g., [32]), appreciated the critiques on the first, second and fourth DPs, and admitted the need for a revision. For example, she condoned Aggrawal's [33] suggestions

to divide the first DP into two parts, and proposed to clarify what “clear boundary” meant. Ostrom reasoned that even in a “fuzzy set theory”, the boundaries of resources are relatively clearly defined. Similarly, the critiques of Morrow and Hull’s [11] first and second principles and their modifications were accepted by Ostrom. Further, she considered the suggestion of Gautam and Shivakoti [15] concerning the fourth DP to be appropriate.

However, not all modifications were always able to fulfil their aims. For example, Cinner et al. [19] increased the number of the DPs to 10, hardly adding new ideas. For example, the second and the third principles of the study were in fact Ostrom’s principle 2, whereas the fourth and fifth principles were DP3. The fourth principle, in fact, repeated itself thus: (4) resource users have rights to make, enforce, and change the rules; (5) individuals affected by the rules can participate in changing the rules (Underlined for emphasis).

3.8. Contribution of the Case Studies to the Commons Management

The case studies undoubtedly contribute to the commons study by supplying new and varied experiences regarding commons management. First, they provide for improvement of the DPs. Second, they present relatively new forms of CPR management in which the communities cooperate with the government or with other external entities to co-manage resources (e.g., [17,20,21,25,34,35]). The works provide some examples in which positive community–government cooperation could provide a successful institution, such as the Japanese irrigation CPR. As the modern world is no longer composed of isolated communities, Community-Non-Governmental Organization cooperation could also provide a fertile ground for the creation of strong resource co-management regimes. As a counter argument, there are some works (e.g., [36,37]) that doubted the fashionable approaches of participatory community-based management, and called for a more in-depth understanding of the dynamics and evolution of institutions. In analyzing the case studies, the roles of three major classes of factors that contributed to the governance outcomes of the CPRs were noted: social capital, group size and heterogeneity, and government intervention. Several scholars have addressed, with varying details, the influence these three classes of factors exert on the organization for collective action [38–54]. Therefore, we do not attempt a detailed discussion of them. We present here how these classes of factors were manifested in our specific case studies.

3.8.1. Social Capital

The contrasting cases of the Japanese and the Bulgarian irrigation systems show that social capital contributes significantly to the robustness of self-organization [8,9]. In both cases, the governments have made well-intentioned gestures to the communities. While the former case succeeded due to the presence of social capital, the latter failed due to the lack of it. Similarly, the Spanish case of the Western Mancha aquifer [10] shows that even well-intentioned government intervention needs a favorable environment to initiate a collective action. The favorable environment can be characterized as a product of the culture, mentality and the material needs of the society. On the contrary, in the Campo de Montiel (Spain) case [10], the presence of social capital was manifested in the unwillingness of the community to use water illegally, and the presence of a consistent organization. As shown by Klooster [16], corruption as an expression of the absence of social capital can be associated with the failures of several Mexican community forestry management regimes in the state of Oaxaca. On the contrary, measures to eradicate corruption by enforcing useful social norms contributed to the success of similar community management systems in the Mexican state of Michoacan. The Murray–Darling Basin of Australia [10] shows the importance of a democratic political setting in which the government listens to the society and adjust its stance accordingly. This “minimal recognition of rights for self-organization” encourages the manifestation of the collective-choice arrangement and—with other conditions fulfilled—can lead to a strong self-organization.

3.8.2. Group Size and Heterogeneity

Although the relationship of group size and heterogeneity with collective action is controversial (e.g., [38–48]), the small-scale irrigation CPRs in Nepal and the large CPRs in Thailand showed the importance of size (resource system and user group) for collective action. The former CPR owed their relative success to their small sizes, whereas in the latter, the large size constrained monitoring. Further, the role of ethnic heterogeneity as a negative force for collective action could be discerned in the community forestry management of the Yanasha people of Peru [11] and the failed Mexican forestry management systems [16], as well as the revived Slovakian forest management systems [4]. The failure of the Acadja system in Nigeria [23] to produce a robust institution due to perceptual differences demonstrated the importance of heterogeneity in working against collective action. On the contrary, heterogeneity in Canadian forest management [17] was not a hindrance to management. The above examples demonstrate that while small size may favor self-organization, the role of heterogeneity may be contextual.

3.8.3. External Interventions

The failures of the lowland irrigation systems in Pakistan, the community forestry management of the Yanasha people of Peru and the Mexican forest management systems serve as examples of how collective action can be affected by the intervention of external forces, including the state. This is true especially when close attention is not paid to the fabric of the society. The same can be said of some of the CPR institutions in the semi-arid regions of Tanzania [24] and the American West [45]. On the contrary, the non-interventionary support of the government highly benefited the irrigation CPRs of Japan. Comparably, a positive intervention of government institutions, cognizant of the rights of the community for self-organization, can contribute a great deal to the development of collective action, as exhibited by the communities of Lenox Island and Abgewit in Canada [22]. The cases of Malagasy and Kenyan marine resource management [19] exhibited relative success in developing collective action. This indicates that government intervention does not always play a negative role in developing a Community-Based Natural Resources Management (CBNRM) if thoroughly planned, taking into consideration the needs of the community, the local socio-economic and cultural characteristics and, most importantly, whether the concerned communities have genuinely participated in the process.

4. Conclusions

The geographical distributions of case studies were explicitly addressed where DPs were used to analyze and diagnose the functioning of CPR institutions. It was found that the set of DPs is widely applied in all the inhabited continents, emphasizing the usefulness and popularity of this tool. The extensive geographical distribution of this tool should encourage improvements to DPs for more focused and accurate analysis of SES. The expression of the DPs and the initiative for collective action also highlighted the influence of socio-economic, political, cultural and resource contexts, embedded within geographical settings. The analysis of the case studies showed that identifying a young CPR institution as successful/failed and robust/fragile based on the number of DPs, was inconclusive. It seems that the DPs were unable to fully explain the performance of young CPR institutions, unless backed by some objective measurement of time. Likewise, although the DPs may be good indicators of the success of a given CPR, they cannot be taken as final diagnosis for its failure. Moreover, the relationship existing between robustness and success based on the number of DPs of a CPR institution is doubtful, as robustness implies more a long duration rather than achievement of goals with efficiency and effectiveness. The case studies provided a number of lessons, such as illuminating the various forms of modern CBNRM, and highlighting the additional factors leading to the success or failure of institutions. Finally, the major contributions of this work to the present body of knowledge can be summarized as: (i) explicit addressing of the geographical distributions of the case studies that used the DPs; (ii) pointing out the relationship between the DPs, performance, and robustness/fragility on the one hand, and the age of a given CPR institution on the

other; (iii) revealing the doubtful relationship between robustness and success in adherence to the DPS; and (iv) a modest share in pointing out additional factors contributing to the performance of CPR institutions.

Supplementary Materials: The following are available online at www.mdpi.com/2071-1050/9/7/1287/s1.

Acknowledgments: This research is supported through the Erasmus Mundus program EMJD MACOMA and the EC 7FP Grant agreement 282845 (COMET-LA, <http://www.comet-la.eu>).

Author Contributions: Sirak Robele Gari collected, reviewed and analyzed data and wrote the paper. Alice Newton reviewed and analyzed data and edited the manuscript. John D. Icely reviewed and edited the manuscript. Maria del Mar Delgado-Serrano reviewed and structured the manuscript.

Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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