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Reflections on "Some Unsettled Problems of Irrigation"

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It is instructive to read the article that Katharine Coman published in the first issue of the American Economic Review to gain insight into the problems of collective action related to irrigation in the American West. One gains further understanding of the problems Coman identifies by using a social-ecological system (Ostrom 2007, 2009) to organize the diverse variables identified by Coman. One gains a general lesson from this analysis that changing the formal governance structure of irrigation is not sufficient to ensure efficient investment in facilities or that farmers are able to acquire property and make a reasonable living. Building knowledge and trust are, however, essential for solving collective-action problems. (*JEL* B31, N51, Q15, Q25)

Katharine Coman wrote a fascinating article in the first issue of the *American Economic Review* dealing with the challenge of organizing effective irrigation systems in the United States west of the one hundredth meridian in the late nineteenth and early twentieth century (Katharine Coman 1911). This was an era when national government policies were oriented to encouraging migration to the "empty" West by offering a variety of homesteading options for acquiring land after completing a variety of formal applications and providing evidence of farming on newly settled land. Given the arid or semi-arid conditions, farmers who migrated to this region were unable to grow crops without access to flowing water provided by a nearby irrigation system. Rainfall that varied from 2 to 20 inches was insufficient for establishing productive agriculture.

Coman described tough collective-action problems half a century before Mancur Olson (1965) and Garrett Hardin (1968) identified the challenging theoretical problem facing many groups. When groups need to cooperate to achieve a collective good (such as building and running an irrigation system), strong temptations exist for participants to "hold out" and not contribute. Holdouts receive the benefits of joint work whether or not they contribute if the others contribute. If most participants adopt the holdout strategy, however, the collective benefit is not produced. The remedy proposed by many theorists to such collective-action problems (also referred to as social dilemmas) is to turn them over to governments to solve.

Coman, who founded the Economics Department at Wellesley College and became its chair, described a number of diverse experiences. In her article, Coman starts with

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a brief description of the successful efforts of the Mormon pioneers to overcome the challenges of farming in the mesa above the Great Salt Lake, and the pioneers in California who drew on the experience of their Spanish predecessors. As an economic historian, she was particularly fascinated by the challenges facing homesteaders in the boom decade of 1880 to 1890 when they stopped focusing on the dwindling returns of cattle ranches and gold mining and began to open the desert for farming. "Speculation ran riot. The capacity of lakes and streams was overestimated, and the agricultural value of land and climate exaggerated by over-enthusiastic promoters" (Coman 1911 p. 5). Many of the promoted irrigation systems failed. Many small investors irretrievably lost all. Promoters and farmers had a hard time distinguishing between a "boom and a boomerang."

Coman identifies two continuing problems that increased the difficulties farmers faced and the number of failures. The first problem was the tendency of government officials who lacked information about the problems facing participants to focus on legislative details rather than appreciating the need for innovative solutions to difficult problems that are not outlined in formal law. This problem continues into the present time. The second problem was related to overcoming the inadequacies of the water rights systems adopted by many western states. The legal doctrine of riparian water rights—all those living adjacent to a source of water have rights to the "full flow" of water—that originally evolved in the English system of common law had successfully been implemented in the eastern United States, which shared many climatic features with England. Since that was the dominant legal doctrine applied in the nineteenth century, it was adopted by many western state legislatures as the official state law related to water. When water is scarce, however, an appropriative rights system—rights that are assigned to users in terms of their history of use—is recommended by many resource economists as a more appropriate legal foundation for irrigation development. This problem has been tackled through legislation in many western states. Water producers in others, such as California, must work out arrangements through the court system to overcome the difficulties of relying on riparian water rights (see William Blomquist 1992; Blomquist and Ostrom 2008; Brian Steed 2010).

The article is filled with descriptions of failures in achieving productive outcomes in an environment characterized by water scarcity and unpredictability. In the midst of failures, however, Coman also identifies several successful efforts. These include the efforts of Mormon migrants to the mesa above the Great Salk Lake to farm the desert and the work of 600 settlers on the Snake River in Idaho to dig 90 miles of bench canals. It is intriguing to read an article in the first issue of *American Economic Review* that describes empirical settings where some participants, but not all, overcame collective-action problems. We now know from the existence of a large number of cases beyond those described by Coman (Fikret Berkes 2007; Ashwini Chhatre and Arun Agrawal 2008; Bonnie J. McCay and James M. Acheson 1987; National Research Council Panel on Common Property Resource Management 1986) that participants facing collective-action problems do sometimes succeed to overcome the problems contrary to the prediction derived from models of these problems (Colin W. Clark 2006). We also know that many cases of failure also exist (Ransom A. Myers and Boris Worm 2003). Partly as a result of these failures, many scholars presume that an external government must intervene in order to enforce

rules on participants to change their incentives and enable them to achieve productive outcomes.

Coman's article illustrates that the typical solution posed to the problem of collective action—turn the problem over to the government—is not a panacea. Among the failures that she reports are efforts by national and state governments in the United States to construct irrigation systems to provide water for new settlers in sufficient time for them to start growing crops and survive in the harsh environment of the American West. Coman mentions multiple factors that jointly affect the success or failure of diverse efforts to govern and manage complex resource systems. Given her focus on one type of ecological resource—the western plains—she substantially reduces the complexity of analysis by holding the attributes of the ecology broadly similar while describing the outcomes achieved within diverse institutional arrangements. Her article is, however, filled with many descriptive details that are not analytically linked to explain why success is achieved in some settings and failure occurs in others.

I. Updating the Theory of Collective Action

A central problem facing contemporary scholars is updating the theory of collective action so as to explain the diversity of results noted by Coman and in many other historical records of collective-action problems in the field. What are the factors that enable some groups to achieve difficult collective outcomes while others fail? Over time, we have gained greater insights into the multiple factors affecting the likelihood of individuals (and/or their government) to solve diverse forms of collective-action problems—particularly those dilemmas related to natural resources (Amy R. Poteete, Marco A. Janssen, and Ostrom 2010; Ostrom 2010). To explain behavior and outcomes in social dilemmas we need to adopt two broad strategies: (i) use a behavioral approach for understanding individual action to analyze whether those involved can gain essential trust that the others involved in a repeated situation are trustworthy and willing reciprocators of trust and (ii) develop better frameworks for identifying the working parts of social-ecological systems that citizens and officials face in trying to develop resources productively.

A. *A Behavioral Approach for Understanding of Human Action*

Multiple studies of collective-action problems illustrate both the likelihood of many failures as well as some notable successes. Evidence challenges the usefulness of continued reliance on a theory of human behavior in these settings that assumes individuals have complete information about all strategies available to them and their likely outcomes and that they will choose the strategy that generates the highest net benefit to themselves in the short run.[1] Considerable work is currently underway, building on the earlier work of Herbert A. Simon (1955, 1995) and the extensive experimental research conducted on collective-action problems (see

[1] In an open and highly competitive market with pure private goods, however, predictions derived from rational choice theory are still appropriate and frequently supported.

Colin F. Camerer 2003; Charles A. Holt 2007), to construct a better theory of human behavior relevant to explaining outcomes in collective-action situations.

While individuals do not have complete information in most settings, we can assume that individuals learn more accurate information about the structure of the situation they are in and the behavior of the others involved when they can communicate in a repeated situation (Norman Frohlich and Joe Oppenheimer 2000). Further, we can assume that individuals do value outcomes for themselves, but also outcomes for others when they know the others involved or, at least their reputations for trustworthy behavior and recognize the interconnections between their own outcomes and the outcomes achieved by others (Ernst Fehr and Klaus Schmidt 1999; Mark R. Isaac and James M. Walker 1988; Cox and Deck 2005).

Using a behavioral approach does not, however, enable an analyst to predict behavior and outcomes by positing simple models of the nonmarket situations that individuals face. Thus, simply knowing that individuals are facing a collective-action problem is not sufficient to predict likely behavior. The structure of the micro and broader situations that individuals face affects both the type of individuals who are attracted to participate and the development of the strategies they adopt over time. Unfortunately, we do not find that single variables such as size of group or amount of potential payoff are *always* associated with failure or success in achieving collective action. We are, however, slowly accumulating knowledge about a dozen variables at a microsituational level that tend to increase the likelihood of individuals cooperating (see chapter 9 in Poteete, Janssen, and Ostrom 2010).

B. *Drawing on a Social-Ecological Framework*

Coman did not focus on microsituational variables in her analysis but rather on broader variables related to social-ecological systems (SES) in the field. Fortunately, we have started to make progress in the identification of a set of decomposable variables in multiple conceptual tiers that affect a range of action situations in the field similar to those discussed by Coman (Ostrom 2007, 2009). As shown in Figure 1, research about a focal SES, such as the western plains at the turn of the twentieth century, can be organized by positing four broad variables (embedded in a social, economic, and political system as well as related ecosystems) as these affect interactions and outcomes in diverse action situations. One can address how the attributes of a resource system (e.g., the western plains), resource units generated by that system (e.g., the amount and variability of rainfall), a governance system affecting who is authorized to undertake what actions under what conditions, and actors jointly affect and are affected by outcomes achieved in related action situations. Each of the broad variables shown in Figure 1 can be further unpacked depending on the research questions to be explored.

II. Applying the SES Framework to Irrigation Problems in the American West

To gain some understanding of the difficult problems that Coman discusses, we will use the SES framework to organize the complex network of variables that Coman mentions throughout her article. I will first discuss the three action situations

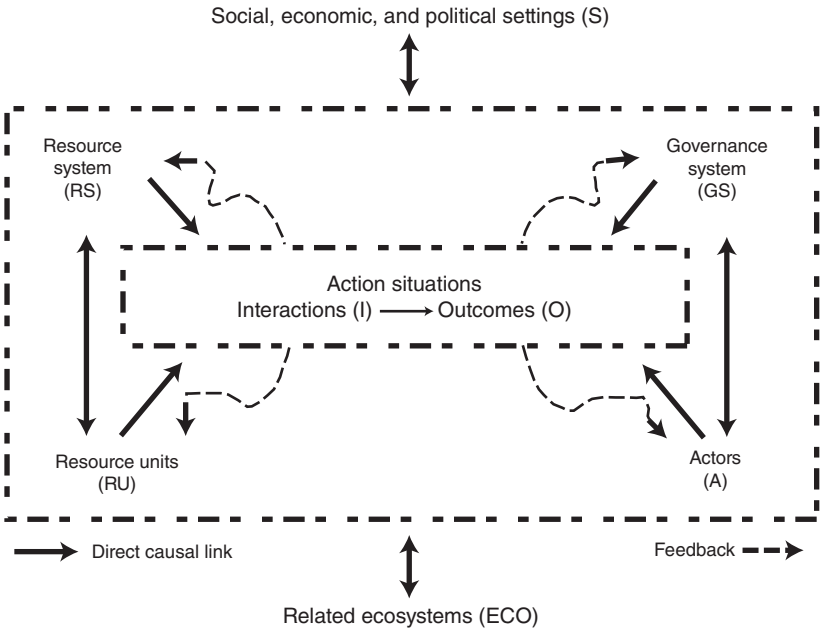

FIGURE 1. ACTION SITUATIONS EMBEDDED IN BROADER SOCIAL-ECOLOGICAL SYSTEMS

Source: Adapted from Ostrom 2007: 15182.

that Coman mentions—constructing irrigation systems, keeping them maintained, and sustaining the economic survival of the homesteaders. Then we will discuss the resource systems, resource units, and actors in her examples. In Section III, we will turn to a more in-depth analysis of four of the governance systems she discusses as they interact with the other core variables of the SES framework.

A. *Three Action Situations*

Throughout her article, Coman refers to the interactions and outcomes that occur in three types of collective-action situations affected by the broader variables shown in Figure 1. The first problematic situation she discusses is the initial construction of an irrigation system adjacent to where farmers are settling. Some of these engineering works were constructed by the national government, but others were constructed by local private entrepreneurs or by local government irrigation districts established by a state government. The speed and reliability of the construction varied substantially. Whether it was a government or a private firm that was responsible for construction, however, was not the major factor affecting the speed and reliability of system construction. Outcomes were affected primarily by incentives of the participants resulting from the specific rules established by the governance system for a particular project and whether these incentives fostered an increase or decrease in the level of trust that actors had in others doing their part to achieve positive outcomes for themselves and others.

The second collective-action problem she discusses is the ongoing maintenance of an irrigation system in this environment. "Nothing goes to wreck more quickly

than irrigation works where repairs are not maintained; the ditches fill with sand or silt, the flumes warp in the sun, and the cement dams disintegrate under the alternate action of frost and heat" (Coman 1911 p. 5). In situations where an irrigation system was built on time and generated water for farmers to start production, they were willing to take over the ownership and maintenance of the system (and to collect dues from each other for this service), but on other systems, the project "ended," no one undertook maintenance for it, and the system disintegrated rapidly.

The third problem Coman discusses is sustaining the economic survival of the homesteaders who moved west to increase their economic welfare. One might not think of this as a collective-action problem, but in this setting the survival of farm families was dependent on the availability of water (as a result of the first two action situations mentioned above), on the rules related to length of time and investment that had to be made before the title to land could be turned over to a homesteader, and on the level of reciprocity and trust established in a project to help when a family was facing particular problems.

B. *Resource System*, *Resource Units*, *and Actors in the Western Plains of the United States*

At the time of Coman's research, the western plains were considered to be "the curse of the Continent" (Coman 1911 p. 1) since they were a particularly difficult environment to convert into productive farming country. Thus, throughout her account, Coman focuses on one broad type of resource system, one set of relevant resource units, and one set of actors involved in undertaking irrigation. The attributes of each of these broad variables that she mentions as important factors are listed in Table 1.

The resource systems and resource units of the plains underlie the biophysical problems she identifies as occurring under each of the diverse governance systems she discusses. They form a relatively constant "environment" in which to study the impact of diverse governance systems as these affect the level of trust achieved among participants and the behavior of farmers and officials.[2] While the specific set of actors involved in particular action situations did vary, they came from a general set of actors whose characteristics are identified in Table 1. An important commonality was that most of the homesteaders were newcomers and had little knowledge relevant to farming in the west. Little variation exists in the type of resource system, resource units, and actors involved across the diverse governance systems. Thus, the general attributes of these core variables as she describes them are listed in Table 1 and need to be taken into account when analyzing how a governance system affected action situations and outcomes.

III. Diverse Governance Systems and the Outcomes Achieved

Most of Coman's article focuses on legal sources of authority to constitute and maintain diverse types of irrigation systems and to gain ownership of land through

[2] While particular subregions would be characterized by differing specific variables, such as amount and variation of rainfall, Coman's analysis was not focused on the physical problems of managing particular locations but rather on the general problems facing the entire region west of the one hundredth meridian.

TABLE 1—RESOURCE SYSTEM, RESOURCE UNITS, AND ACTORS THAT AFFECT IRRIGATION ACTION SITUATIONS AND OUTCOMES FROM THEM IN THE WESTERN UNITED STATES IN THE LATE NINETEENTH CENTURY AS DESCRIBED BY KATHARINE COMAN

Resource system	*Attributes described by Coman*
Type of resource system	Semi-arid plains
Location	United States west of 100th meridian
Productivity of land for farming	Varied but generally low
Clarity of watershed boundaries	Difficult to assess without careful measurement
Constructed infrastructure	Not well developed as of 1910
Diversion dams	Extremely expensive requiring advanced engineering
Headworks	Expensive to build in many settings
Channels	Less expensive—manual labor sufficient for some projects
Road network	Patchy and expensive to construct
Resource units	*Attributes described by Coman*
Spatial distribution of rainfall	Irregular
Temporal distribution of rainfall	Irregular—from 2 to 20 inches per year
Economic value of land	Low
Economic value of water	High
Actors	*Attributes described by Coman*
Homesteaders	
Economic status	Relatively poor without knowledge of farming in west
Dependence on irrigation	Very dependent on availability and reliability of supply
Federal officials	
Members of Congress	Passed legislation without much knowledge of plains
Federal agency officials	Built and operated systems authorized by federal law
State officials	Involved in planning when authorized by federal law
Local officials	Frequently not involved unless local water districts created
Shared knowledge about resource system	Low at the initial stages of a project
Shared norms among actors	Relatively low unless established organizations involved
Construction technology available	Relatively primitive

homesteading. Coman examines the structure and performance of several national and state governance systems as these interact with the resource system, resource units, and actors to affect the structure and outcomes of three action situations. In this section, I plan to address four governance systems established under national and state laws as they interacted with the other major SES characteristics to affect collective-action situations and outcomes obtained in the plains of the western United States. Among the multiple systems she discusses, Coman gives special attention to (i) the governance system established under the Desert Land Act of 1877, (ii) the governance system of the Wright Act of the state of California, (ii) the governance system established under the US Carey Act of 1894, and (iv) the governance system created by the US Reclamation Act of 1902.

A. *Outcomes Achieved under the Desert Land Act of 1877*

The Desert Land Act was "put through Congress by men who knew little of western conditions" … assuming that "water would always be found upon the land and in such form that it could be readily diverted to the fields" (ibid. 4). Congress authorized the

Table 2—Governance System and Outcomes of Action Situations under Desert Land Act of 1877

Governance system	*Attributes described by Coman*
National legislation	Desert Land Act of 1877
State legislation	Not relevant
Rules regarding homestead process	
Amount of land assigned	Homesteader assigned 320 acres
Formal rights to land assigned	Pay 25 cents per acre at time of entry, must irrigate the land within 3 years, then pay $1 per acre
Property rights to water	Riparian in most states
Ownership of irrigation system	Private for profit companies
Financing of irrigation system	Companies charged farmers flat rate per acre of their homestead
Monitoring of relevant transactions	No one assigned this responsibility
Conflict = resolution arenas	Regular court system
Action situations	*Outcomes reported by Coman*
Construction of irrigation systems	Private companies without adequate engineering entered and built faulty systems with exaggerated claims. Majority of projects failed.
Maintenance of irrigation systems	Few maintained
Farmer economic survival	Most funds contributed by farmers to acquire land and pay for irrigation water were lost. Many settlers ruined.

allocation of large units of land (originally a full section of arid land but revised in 1891 to 320 acres) to homesteaders who initially paid the federal government $0.25 per acre, agreed to irrigate the land within three years, and then to pay $1.00 per acre. The settling farmers tended to have little knowledge or historical information about the region. Many private entrepreneurs set up water companies, also without much knowledge of either the relevant engineering needed in this challenging terrain or of the attributes of the resource system itself or much about the settlers who came from all over the eastern coast. Companies tended to exaggerate the amount of water they could provide and charged farmers a flat rate for delivery of the promised water. (See Table 2 for the structure of the governance system and the outcomes obtained in the action situations.)

The outcomes achieved in the three action situations were generally not positive. Private companies entered with the dream of making good money but without appropriate engineering knowledge. Many of the projects failed and few were maintained. Since the farmers had to irrigate their land both for their own survival and to gain final title to the land they had registered, the lack of an irrigation system near their land led to financial ruin for many of the settlers.

B. *Outcomes Achieved under the California Wright Act*

In a legislative move to support the establishment of local government irrigation districts to take on the responsibility of supplying water to landowners in the state of California, the Wright Act was passed in 1887. Under this system, resident freeholders could hold a vote to establish a local irrigation district under state supervision. An established district had the legal authority to issue bonds that would be secured by a mortgage on the lands included within district boundaries as well as to tax the land included in the district to cover the interest on the bonds and local maintenance when systems were completed (see Table 3).

TABLE 3—GOVERNANCE SYSTEM AND OUTCOMES OF ACTION SITUATIONS UNDER CALIFORNIA WRIGHT ACT OF 1887

Governance system	*Attributes described by Coman*
National legislation	Not relevant
State legislation	California—Wright Act of 1887
Rules regarding homestead process Amount of land assigned Formal rights to land assigned	Not relevant
Property rights to water	Riparian
Ownership of irrigation system	Irrigation districts organized by freeholders under state supervision
Financing of irrigation system	Bonds issued by district secured by mortgage on farmers' lands. Taxes imposed to cover maintenance.
Monitoring of relevant transactions	Elected board of trustees and voting by freeholders for extraordinary contracts
Conflict-resolution arenas	State courts involved in long and costly litigation
Action situations	*Outcomes reported by Coman*
Construction of irrigation systems	Many systems started but frequently underestimated costs, and initial bond did not generate sufficient funds. Many systems were not completed.
Maintenance of irrigation systems	Few systems maintained
Farmer economic survival	Many farmers faced financial ruin exacerbated by the need to finance two bond issues in some systems.

Unfortunately, many problems were involved with the acquisition of water rights that turned out to be contested or worthless, resulting in long and costly court cases. While the construction of many irrigation systems was started, few were completed due to lack of engineering knowledge, inadequate initial financing, and overestimation of the benefit-cost ratio in general. Coman reports that the economic temptations led some districts to resort "to illegal means, and the district was in consequence dissolved" (Coman 1911 p. 7). Thus, the completion rate of irrigation systems under this legislation was low and few systems were maintained. Further, many farmers were ruined by this type of governance system. Coman points out that irrigation districts could "only succeed where cost of construction is light, and where soil and climate render the lands highly productive…" (Coman 1911 p. 7).

C. *Outcomes Achieved under the Carey Act of 1894*

A congressional law written by Senator Carey of Wyoming in 1894 was based on his own extensive knowledge of the challenge of solving irrigation problems in the American West. While earlier efforts to encourage private water companies to develop effective projects had a high failure rate (as noted above regarding the outcomes of the Desert Land Act), the Carey Act involved state administrative offices in oversight activities that reduced some of the basic risks involved. Under this governance system, the national government agreed to hand over one million acres of public land (or a segment thereof) based on an actual survey that demonstrated that the land was amenable to irrigation (see Table 4).

The State Lands Commission must assume responsibility for the projects undertaken as well as for assessing projects proposed by private water companies in regard to adequacy of water rights, the engineering plans, and the financial standing of the

Table 4—Governance System and Outcomes of Action Situations under the US Carey Act of 1894

Governance system	*Attributes described by Coman*
National legislation	Carey Act of 1894
State legislation	Acts adopted Idaho, then by Montana, Utah, Colorado, Arizona, California, and New Mexico
Rules regarding homestead process	Established by State Lands Commission
Amount of land assigned	20 to 160 acres
Formal rights to land assigned	Contract with water company, reside for at least 30 days, cultivate one-eighth of tract
Property rights to water	Landowners must purchase water rights that are linked to land
Ownership of irrigation system	Initially private company. Water users association buys completed system. Farmers own stock and voting right proportional to amount of land owned.
Financing of irrigation system	Landowners through cooperative company in proportion to land owned
Monitoring of relevant transactions	State engineer monitors processes and appraises value of irrigation system
Conflict-resolution arenas	State courts
Action situations	*Outcomes reported by Coman*
Construction of irrigation systems	Many systems constructed in Idaho, but some system failures in other states where project land is particularly unproductive.
Maintenance of irrigation systems	Water users association maintains most completed systems.
Farmer economic survival	Rate of financial security is high. Farmers may sell holding. Financial difficulties primarily when land quality is inferior.

private company. The land can then be sold by state officials at a rate determined by the state in tracts that range in size from 20 to 160 acres. Settlers who wish to gain clear title must (1) sign a contract with the water company agreeing to purchase the relevant water rights at a specified charge per acre, (2) furnish proof of residence for at least thirty days, and (3) cultivate one-eighth of the tract.

Under the Carey Act governance system, a private water company has strong economic incentives to build operational irrigation systems rapidly in order to increase the earning of the farmers. The farmers can then buy out the original company that can then use its profits to move on to new endeavors. A water user association is created to maintain the irrigation system, and each farmer holds stock (and voting rights) in proportion to the amount of land held. The high success rate achieved in Idaho, and earlier in Wyoming with a state law similar to the one that Carey took to the US Congress, led many states including Montana, Utah, Colorado, Arizona, California, and New Mexico to authorize their State Lands Commission to acquire land under the provisions of the Carey Act. Failures of Carey Act projects did occur when it turned out to be difficult to market bonds sufficient to finish the project or when the construction was unexpectedly difficult due to floods or other problems. Coman points out, however, that the basic incentives were positive but could not overcome problems when the basic conditions of the soil and climate did not make tillage profitable for the farmer who then did not make water rights payments. Thus, relatively well-designed irrigation systems were constructed and maintained under this governance system and farmers on many systems were able to achieve financial security.

TABLE 5—GOVERNANCE SYSTEM AND OUTCOMES OF ACTION SITUATIONS UNDER THE US RECLAMATION ACT OF 1902

Governance system	*Attributes described by Coman*
National legislation	US Reclamation Act of 1902
State legislation	Not relevant
Rules regarding homestead process	Homestead Law applies as administered by Reclamation Service
Amount of land assigned	Between 10 and 160 acres as determined by engineers to support a family
Formal rights to land assigned	10 annual payments, 5 year's residence, and proof of half of land farmed
Property rights to water	Acquired after 10 payments received
Ownership of irrigation system	US government
Financing of irrigation system	US government for construction, farmers for maintenance and distribution
Monitoring of relevant transactions	US Reclamation Service
Conflict-resolution arenas	Federal court system
Action situations	*Outcomes reported by Coman*
Construction of irrigation systems	Systems had good engineering designs but were constructed very slowly by US government dependent on congressional allocation of funds.
Maintenance of irrigation systems	Maintenance and water distribution of completed projects paid for by farmers and undertaken by government engineers.
Farmer economic survival	Requirement that farmers must live on property five years before gaining ownership led to high rates of farmer relinquishments and loss of funds needed to survive, to start farming, and to invest in farm infrastructure.

D. *Outcomes Achieved under the Reclamation Act of 1902*

At the turn of the century, the Reclamation Services was created within the Department of the Interior. Some of the "ablest hydrographic experts the country afforded" (Coman 1911 p. 12) were hired to conduct surveys and make engineering designs for new irrigation projects in the seventeen arid and semi-arid western states. During the eight years that Coman could report, the Reclamation Service had opened thirty-one projects, but construction was dependent on funding to be made available by the national government. While the amount of funds made available by Congress was substantial, division among thirty-one projects reduced the amount that could be used to complete individual projects rapidly (see Table 5).

Coman describes the problems she found on visiting the Minidoka project on the Snake River of Idaho (where many successful projects under the Carey Act had been undertaken). The federal allocation of money for the Reclamation Fund that year was just under $8 million, but this had to be divided among thirty-one projects (Coman 1911 p. 16). The amount allocated to the Minidoka project was only $70,884, which was insufficient to install the equipment needed and to build the lateral canals needed to get water to the fields. Hundreds of farmers were still without water and very discouraged and many had relinquished their rights. In the spring of 1908, the Reclamation Service authorities indicated water would not be available for the lands located on the south side of the project for yet another year. It looked like many other farmers would have to relinquish and lose all they had put into their land.

Coman tells a story about a brilliant idea of a project engineer and its consequences, which illustrates the challenges faced in these projects. The engineer proposed that "all the government money should be devoted to the necessary power and pumping machinery, while the farmers should build the connecting canals" (Coman 1911 p. 16–17). Further, he recommended that the Secretary of the Interior pay for the labor building the canals in "water-scrip" that could then be used to pay for acquisition of water rights. Coman points out that persuading a group of thoroughly disheartened men to have sufficient faith in one another that they would cooperate with one another and the government was a challenge.

> But the project engineer had full faith in the method and his enthusiasm was contagious. The water-users' association was organized, contracts for earthwork and excavation were given out in sections feasible for the farmer … Six hundred men set to work on April 17th, with an energy born of despair. The three "bench" canals, ninety miles in all, and the principal sub-laterals were completed by June 23rd—in less time than professional contractors had estimated the work could be done. It seemed a stroke of genius. Labor that was running to waste was brought to bear where it was most needed, and the farmers were enabled to forestall their obligations to the Government in their one available asset … Meantime, the water-scrip was accepted by bankers and local merchants and served to pay for immediate necessities (Coman 1911 p. 17).

The device was approved by the Secretary of the Interior and the innovation was then adopted in six additional government projects facing similar delays. But then, the Attorney General declared the water-scrip illegal, leading to increased uncertainty by the farmers as well as by the Reclamation Service engineers. In March of 1910, however, ways to redeem the water-scrip were announced and bonds authorized by Congress to support the completion of the other Reclamation Service projects.

The farmers on the southern slope were able to contribute essential labor for digging the canals and the Reclamation Service purchased the equipment necessary to make the canals on this segment operational. Many Reclamation Service projects were very slow in being completed and the homesteaders were frequently unable to farm without water. Many farmers were not able to stay on their property long enough to gain title and their economic well being was very low. Coman reports on a study of relinquishments among homesteaders made by Thomas H. Means, a project engineer on the Reclamation Service Truckee-Carson project. He found that of the 544 homesteaders who had filed for land under that project, almost one-half (238) of the farmers gave up their effort by either cancelling or relinquishing their entries. Means reported that this high failure rate was due to the Reclamation Act requirement of actual and continuous residence on the land for five years—a requirement that was ill suited to the problems facing poor homesteaders who frequently could not earn sufficient funds during those early years to sustain themselves and continue farming (Coman 1911 p. 18).

IV. What Do We Learn from Coman's Cases?

Coman was wise in calling her article "Some *Unsettled* Problems of Irrigation." While many irrigation systems had been successfully organized in the eastern sections of the United States, overcoming the difficulties posed by the resource system and resource units of the American western plains was a far more challenging

problem. Coman devotes a substantial portion of her article to describing failures. She does, however, describe some fascinating success stories. Is it possible to derive some general lessons from this analysis using a behavioral approach to explaining human actions and the SES framework? Yes, lessons can be drawn out of this analysis, but they are different from the frequently stated solutions to collective-action problems related to resources—turn the resource over to a government or privatize it. In other words, changing the formal governance system *alone* is not a sufficient solution to difficult collective-action problems.

A. *Changing Governance Structure Alone Is Insufficient for Solving Collective-Action Problems*

In all four cases discussed above, there was an effort to privatize the ownership of the land and allocate it to homesteaders who met certain conditions that varied from relatively reasonable investments of time and effort by the homesteader, under the California Wright Act and the US Carey Act projects, to a very heavy investment in time and resources, under the Desert Land Act and especially under the US Reclamation Act. The legal conditions were so difficult to meet under the Desert Land Act and the Reclamation Act that many farmers failed to acquire private property even though this was an avowed goal of the effort.

Further, turning the responsibility for planning and building irrigation systems over to a government agency in this environment did not guarantee success in any of the three relevant action situations. One of the more successful governance structures—organized under the Carey Act—did involve an overt policy to stimulate private ownership by easing the problems for farmers to acquire land, for private companies to build the systems, and eventually for the farmers to own jointly the irrigation systems serving their area. While successful when first implemented, Coman does mention that organization under the Carey Act did not guarantee success. She specifically mentions the collapse of the "Conrad Land and Water Company, and the Big Lost River Irrigation Company, which went into the hands of receivers with outstanding bond issues of $150,000 and $1,355,000 respectively…" (Coman 1911 p. 12).

A big lesson from thinking about the cases that Coman described in light of a century of additional research is to reinforce our understanding that overly simplified characterizations of governance arrangements are not sufficient to predict results. Simply changing the governance system to one of two idealized structures—government or private ownership—is not sufficient. What more can we learn from the cases described by Coman? Instead of recommending simple solutions such as government or private ownership, we need to ask how specific types of governance systems (operating in particular types of ecological settings) are likely to increase the knowledge possessed by actors and their level of trust in others. The Carey Act was written by a congressman with considerable knowledge and experience with organizing irrigation in this ecological terrain. The Carey Act did not set up a simple system of private or government ownership. Private firms had incentives to gain knowledge and trust as fast as possible so as to convince the farmers that they had built a reliable system that the farmers could take over and manage. They then could make a profit and move on to the next opportunity.

B. *Building Knowledge and Trust Are Essential for Solving Collective-Action Problems*

What we need to learn from the analysis of the cases described by Coman is the importance of knowledge and trust—two attributes related to the individual making decisions that are frequently not included in contemporary analysis. When one uses the classical assumption that individuals have complete information about the situation in which they are making decisions, one is assuming that individuals already have knowledge about how a resource functions, the technical means for managing a resource, and about the trustworthiness of the others involved. That assumption is appropriate in simple settings where participants have acquired knowledge of system structure and dynamics and the others involved over a long period of interaction. But, in the era of homesteading in the American West, both homesteaders and public officials lacked sufficient knowledge about the diversity of specific conditions existing in a particular watershed, or even where the boundaries of the watershed were. The appropriate institutions that one would design to solve complex resource problems involve mechanisms to ensure that participants were either selected for the knowledge they had about this type of system or to provide ways to gain that information rapidly. As Coman points out, farmers that settled in areas where Agricultural Extension Services were available, gained higher returns from their farms and faced less risks of financial ruin.

It is also important for future theoretical work to address whether the structure of action situations created by governance systems enhance or detract from participants' capacities for building trust (James Walker and Ostrom 2009). While Kenneth J. Arrow (1974) long ago stressed the importance of trust as the most efficient mechanism to govern transactions, this pathbreaking work has not been taken as seriously as needed. In undertaking analysis of potential governance systems to cope more effectively with a problem, we should be asking whether future rules support or undermine the development of trust and reciprocity over time (Samuel Bowles 2008; Bruno S. Frey 1994, 1997). Coman was surprised that the Reclamation Service engineer could motivate six hundred men to undertake the hard labor of digging miles and miles of canals. The engineer organized this work, however, so that the farmers could gain trust in each other and see that by working together they gained important outcomes for them all.

Thus, an important lesson from Coman's study is the need to self-consciously address whether "solutions" proposed to solve collective-action problems are likely to enhance the knowledge and trust of the actors involved. Simply imposing general solutions, such as government or private property, will rarely work in practice unless those involved gain sufficient knowledge and trust to make the systems work over the long run.

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