ARE WE KILLING THE RAIN? MEDITATIONS ON THE WATER CYCLE, BIOPRECIPITATION, AND IDEALISM AS THE NEW PRAGMATISM

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ABSTRACT: Multi-disciplinary research on "bioprecipitation" advances the thesis that ice nucleators of biological origin are a principal cause of rain. This same research finds that the world's most prolific ice nucleator is a plant pathogen treated within agronomy as the enemy of the good through campaigns of aggressive eradication. This as well as other common practices may be destroying precipitation potential and may be a causative feature of desertification and drought. This Essay draws out some of the legal and policy-based implications of these theses and considers the introduction of a new call to ethical principle.

KEY WORDS: bioprecipitation; climate change; hydrological cycle; rainfall; American water law and policy reform

I. INTRODUCTION:

Faithful to its historic traditions more than to its present and future needs, United States water law, including the principles that animate it, the policy choices it relies on, and even the pedagogy that transfers its fundaments, has experienced difficulty granting serious attention and respect to the hydrological cycle. This lack operates through several modes. Two are especially salient:

First, there has been a failure to attend, normatively, or even to observe descriptively, the cyclical nature of water's movement through the biosphere. Conceptually, precipitation is acknowledged, but often casually, to be a hydrological contributor. For example, within the pedagogy of water law, one of the most widely used casebooks mentions precipitation once per page for 5 of its 937 pages of text (J. Sax et al., 2000 at 4-8). Sometimes, however, precipitation does not come in for any mention at all. (A popular and well-respected environmental casebook that devotes extensive coverage to water contains not a single reference to it (J. Rasband, et al., 2000). Indeed, the crucial role of water as it rises above and falls onto the earth's surface has traditionally escaped both doctrinal and pedagogical detection, except where it appears as an unnamed ghost, subsumed under such categories as "drainage" and "diffused surface water". These are doctrines that get called into play by rainfall's excesses, viewed within this framework as the enemy of the good.

The basis for this abject conceptual neglect is found in the history of American water law. Its structure and early substance derive largely from that of England. English water law, while not taken formally from Roman law, borrowed liberally from its precepts (J. Getzler, 2004). According to these precepts, the seas were taken to be a vast commons that could be enjoyed but not privately owned, while groundwater and surface water were theorized as capable of private ownership, at least when they were set apart in possession as the basis of usufructary rights. Rain was not understood as a feature of either the public or the private domain in any but incidental terms: when it diffused in over-abundance and caused harm. The idea, therefore, that there is or might be a public interest of majestic proportion in a rainwater commons lacks centuries—even millennia—of intellectual and social development, let alone the opportunity to take root as a great and significant thing within the practical realm of law.

Second and causally, it is law's pragmatic tendencies, whether or not as entire as some contemporary theorists have proclaimed (see, e.g., R. Posner, 2003), that have perspicuously dominated the evolutionary development of both English and American water law. Within this Anglo-American frame, what has, indeed, developed was motivated, early on, by two principal concerns of immense practical import that have remained dominant, though joined by others over time: One has been the need to devise and maintain a system of rights to water, a system of rules about allocation. The other has been the need to devise and maintain a system pertaining to wrongs for the resolution of claims of injury and done on account of the management and use of water. Suppressed, in large measure, as a result of the vastness of these requirements for law, and on account of the politics that early grew up around them, has been the articulation and development of a systematic role for obligation toward water resources reflective of their crucial importance to all life on earth.

The need for a system of rights easily translated into the need for public authority to allocate water under the rule of law. This occasioned the need for a regime of rights to settle which parties should have entitlements to how much water from which water body and in what order of precedence. That, without more—the specification and articulation of private rights-- has been an extremely preoccupying enterprise and a highly particularistic one, based on each water body taken to be a "resource" onto itself. It has become an enterprise that has treated individuated, party-based need, as siphoned through the filters of localized politics, and local knowledge, whatever its state, as of shaping importance to the long-time detriment of systemic need—the need for conservation and preservation, for example-- and generalized knowledge—the knowledge that science has increasingly, albeit only recently, been able to impart.

The long absence of scientific knowledge—especially any substantial understanding of hydrology and the hydrological cycle—has only served to reinforce particularism under the guiding authority of the pragmatic drivers of the law. Thus did it occur, over the centuries, that water resources became managed by analogy to the Roman military strategy "Divide et Impera"—divide and conquer: a strategy that easily gives on to the most crudely pragmatic of all Anglo-American water law decisions: the decision, by now deeply rooted, to manage groundwater as an entirely separate subject from surface water as the very basis of what has been, in effect, dual legal regimes. (Compare Texas SB 332, 2011, for example, with Vermont stat.10 sect. 1410, 1986. The former, which is based on the exclusivity of groundwater management, without reference to surface water, is but the most recent example of the American predilection to divide water law and management along spacial lines. The latter, which mandates the unitary management of groundwater and surface water, is the rare exception to the American regime of divided rule. For a relatively early articulation of the unwisdom of this position, see J. Castleberry, 1975).

This extraordinarily important, system-wide insult to the hydrological cycle was invited during the formative period of English water law in the mid-nineteenth century by the absence of any scientific knowledge or understanding of groundwater. This void occupies the justificatory center of the decision by English judges to base their most fundamental early opinions about liability as a result of drainage—the most influential renderings about the consequences of injury in a water context in the early common law –on the "secret" and "occult" nature of groundwater. These characteristics were taken to put liability for the ill-consequences of drainage beyond the pale of legal responsibility, for how could a mining company be liable for damage done to a cottager's well if the company could not be held to an understanding of the foreseeable consequences of its acts (see Acton v. Blundell, 1843)? Through the pragmatic utility of the reception doctrine, this rule of liability-preclusion, known as the "Rule of Capture", became the basis for much, if not all, of the correspondent rule of American common law (see, e.g., Frazier v. Brown, 1861 and Houston & C.T. R'y Co. v. East, 1904), one that persisted for well over a hundred years in many jurisdictions and persists in one of them to this day (compare Cline v. American Aggregates Corp., 1984, with Sipriano v. Great Ozarka Bottling Company, 1996, and Texas SB 332, not yet codified, 2011).

The law of wrongs, almost exclusively parented, in the case of water, by the torts system, is the place that rain surreptitiously enters the history of Anglo-American water law as a ghost in the machine. Within its confines, diffused surface waters—waters tending to flow sporadically and outside defined channels—have given onto three separate rules, one generated by the civil law that prohibits diversions—a rule of induced helplessness; one, occasioned by the common law, that allows landowners to create any and all diversions of this "common enemy" with legal impunity; and one inflected by the equitable rule of reason. Though only one of these three explicitly categorizes diffused surface water—which includes rain—as an "enemy", all three rules confront the issue of liability as a result of harms done through a combination of natural excesses and self-interested human design (see J. Fairchild, 93 A.L.R. 3rd 1193 and Argyelan v. Haviland, 1982). That is the only place within the development of the Anglo-American common law of water where rain, whether represented as a "common enemy" or, in paler fashion, "diffused", manages to achieve attention.

Today, legal attention to rain has somewhat broadened, if only to include such narrow advances as a split-the-baby conflict-settlement rule, reflected in statute, that announces a right, within a lone-sentry jurisdiction, to collect what falls from the sky (C.R.S.A. Title 37, sect. 90-105, 2006). But this is no less particularized an object of focus than the Common Enemy rule, even as it represents a normative improvement by signaling the recognition of rainfall as a friend.

Other aspects of the contemporary American legal regime too numerous to detail in this gestural rendering continue to reinforce, in a multiplicity of ways, the disaggregated treatment of the hydrological cycle and lack of respect for its importance on which water law and policy in the U.S. remains steadfastly based. These significantly include the fundamental divide within water law and management over federal versus state control: Following federalism's broad principles, federal hegemony over all but international waters is a sometime-thing:

Under the quasi-sovereignty doctrine (for the most concise modern description, see Massachusetts v. E.P.A., 2007 at pp. 15-17), most responsibilities devolve as a matter of right to the fifty states, which have entered into "compacts" with each other concerning geographically shared water bodies (R. Mann, 2010), often, as an historical matter, on noisomely inflexible, scientifically-ill-managed terms. Meanwhile, hopes for a federal presence derived from a magisterial respect for the water cycle are not much bolstered by history, as we have come to be reminded through the physical division, at the hands of federal agencies, of rivers of lesser and greater proportion into segments set apart by literally thousands upon thousands of dams, leaving to relatively few the integrity of unimpeded flowage throughout their natural lengths.

Finally, for immediate purposes, just as it should be coming clear that water policy must turn to face increasingly-powerful warnings about the risks of unimpeded climate change, it may be important to observe that the doctrines and precepts that represent the public interest in water—potential sources of inspiration and norm-revision in the service of the common weal—remain anchored in most of the states to their restrictive Roman origins and to their doctrinal past. In many, if not most, the historical divide between groundwater and surface water management continues to be reflected in the hydrologically-nonsensical notion that the "character" of surface water is distinct from groundwater, such as to support the ownership distinction that early doctrine insisted on, namely, that surface water is held in public ownership, while groundwater can be held as a matter of private right. While the functional import of this difference has been abraded by the increasingly powerful role of permitting systems as to both, the conjunctive management of groundwater and surface water has been damaged everywhere that this distinction as to "character" has been maintained. In only a very few states, moreover, has the "public trust" doctrine derived from Roman law been used to forge new and valuable understandings of law's ability to protect a water resource from depletion in the name of present and future benefit for the common good. (For a review of these recent developments, see A. Klass and L. Huang, 2009).

Even these recent developments of the public trust doctrine, wholesome and encouraging as they are, represent no move, in substance, away from particularistic problem-solving and local design. Not yet do they even point to the necessity of a new panoptics of conjunctivity, a recognition as a matter of first principle and descendant policy that the planet's water is an integrated system that is represented by a comprehensive hydrological cycle in which evaporation and transpiration, precipitation, groundwater, and surface water constitute parts of the whole. So, it is against the prime, mutually-reinforcing forces of localism, particularism, and pragmatism, which I take to be the normative mainstays of Anglo-American water history, that newly integrative and comprehensive motivating forces of vast significance to the improved maintenance of the hydrological cycle—ones that reflect the holistic nature of the water cycle itself-- must contend.

In the meditations that follow, I will look to advance the position, obvious from these introductory remarks, that respect for the hydrological cycle and its workings must become the foundation for a new and different kind of water law and water policy in the United States, one that is based on an integrated framework attendant to the regenerative needs of the water cycle itself. In fact, I can see no reason for this shift to be exclusive to the United States. Rather, the need is for water policy worldwide to embrace this new norm of norms so that the conservation of the earth's aquatic resources becomes the basis for the development of an equitably and peaceably managed rainwater commons, amongst other things. In this paper, I will store this claim in a capsule of ethical principle, for which my provisional name is a modestly unstylish one: "systemic integrity". This becomes the meditation on which the paper ends. But I will earlier re-make these claims in three other meditations, the first based in current scientific inquiry; the second, in a critique of current policy; the third, in reported fact.

As reference points for these, I have summarized the state of water law's Anglo-American history. This, I have characterized as amounting to the regulation of the water cycle, willy-nilly, through a largely static and unsorted favoring of the values and interests embedded in particularism, localism, and pragmatism. On my account, the hydrological cycle has been left un-understood, normatively under-attended, and physically uncontrolled. All is misfortune, in these regards, as we begin inevitably to confront changing epiphenomena within the biosphere that are understood, with increasing clarity, to be highly dynamic and causally-linked to vastly repetitive and damaging human acts. (For a very straight and simple rendition of the evidence for human intervention and climate change generally, see H. Affek, 2010.)The innocence of response to these actions of ours—the need for address through law, policy, and guiding principle-- is what needs suddenly and forcefully to change.

In Part II, I will address this paper's methods.

In Part III, I will sketch one set of such potentially adverse human actions, conventionally repeated, that may be damaging the water cycle by interfering with the formation of precipitation and then, as a consequence of this interference, driving changes in where and how precipitation falls. From the vantage of this first meditation, there

are two shifts from the synoptic view acquired by means of our legal perch: At the level of fact, the new thing we will learn is that the hydrological cycle is coming to be more greatly understood than present law and policy reflects. At the level of guess, the second thing we will explore--an hypothesis I have drawn from this new knowledge—is the possibility that precipitation may not be uncontrolled, but may be suffering from unwitting human interference or at the least, negative influence, as an unintended consequence of conventionally-intended acts.

The research that brings this possibility into focus is not speculative. Its findings elucidate the relationship between certain plant pathogens and ice nucleation. They derive from the observation of these highly proliferative pathogens at the microbiological level; and the published research cluster that elucidates the relevant findings draws on nearly three decades of mutually-reinforcing contributions made not only by plant pathologists and microbiologists but by meteorologists, cloud physicists, and scientists trained in other fields. This extraordinarily provocative work goes by the name of “bioprecipitation”. The Part will begin with a review of the literature. Whether or not my hypothesized extrapolations from this literature deserve to be treated as more than speculation, the immediate goal of these musings is to amplify the audience for bioprecipitation research.

My further goal in this Part is to dare to imagine how some physical experimentation could suggest ways to help to right the balance between agronomic good and hydrologic harm. Through two very different thought experiments—one, modest; the other ridiculously bold—I will explore that method of approach. My name for these experiments is “invited precipitation”. In the bold one, I call up the use of what I have termed “sacrificial crops”.

In Part IV, I look in on a different approach to invited precipitation, one that appears to have been conducted as an experiment last summer by the government of Abu Dhabi. I rely on only the barest report of its success, but for present purposes, I treat the report as fact. It will suffice to announce two thoughts, one of these, again, modest; the other admittedly far out: The modest suggestion is that experiments with invited precipitation are already in the world, and they may have entered a phase different from the precedent one characterized by quite unsatisfactory work that has involved the use of silver iodide to “seed” clouds. The altogether immodest suggestion is that invited precipitation could become a strategy with a double valance: On the one hand, it could promote a newly generative ability to improve the hydrological cycle, as it affects a given place, under the stressful influences of climate change. On the other, it could someday become a potent force, a weapon that could be deployed by aggressively competitive and completely self-interested states vying for enhanced agricultural productivity under the increasingly challenging conditions imposed by a changing climate. These entities might gain significant measures of control over the rainwater commons, thereby manipulating invited precipitation so as to disinvite its occurrence within the borders of neighboring states, thus doing wittingly what present agronomic practices in regard to plant pathogens may be doing unwittingly—my subject in Part III.

In Part V, I recur to the hope of a different and altogether benign set of outcomes—cooperative ones set on the foundation of a widely-shared—perhaps a universally-shared—principle of respect for the systemic integrity of the earth’s water ways. There I will argue, principally by assertion, that a basis in shared principle can serve as an ameliorative force against the ethical complexities that future water allocations are sure to visit on thirsty populations under threat from chimerical weather systems. This will be the case regardless of whether new benefits come about through break-through adaptations such as invited precipitation and whether or not paradoxical new harms inspired by the double-valent effects of today’s plant pathogens provoke new harms alongside.

It should be obvious that I don’t see the old stabilities—the static elements of water law and policy that have become our legacy-- as capable of managing whatever the destabilizing new realities—including the potential political realities--of climate change are turning out to be. That is why this paper invites its audience to think in new and meditative terms—tentative, experimental terms—about the challenges we may face, including ones that we may, without a significant turn toward new knowledge, cause.

It isn’t that rain can literally be “killed” within the biosphere, as my title is wont to suggest. But the trope may yet prove apt as to local conditions, if it should be proven that uncompensated-for derogations from ice propagation capability eventuate in rain deprivation or, at the least, in rain-deprived locales. If so, the problem may well extend beyond the limits of the bacterial eradication in which, worldwide, we prolifically engage. Other physical interventions may similarly be altering rainfall patterns through different means, rendering some loci unsuccessful sites for the development of ice nucleators, while others are becoming less receptive to the receipt of rain. These are only potential matters of fact, but if this proves a valid theory, they will be potent ones. I grant them a generous audience here.

II. METHOD:

The method on which this paper is based is expository. It is housed in these further Parts:

Part III introduces the subject of bioprecipitation. It begins with a standard-form, if highly condensed literature review in two segments, the first to lay out the role of bacterial plant pathogens and conventional responses to them; the second, to offer an understanding of the new role of plant pathogens that is under current inter-disciplinary study, namely, their role as ice nucleators in the generation of ice, snow, and rain. Through this sub-section, I will describe the scientific basis of the claim on which I rely concerning the general epiphenomenon of bioprecipitation and the more specific claim of success as an ice nucleator that seems fairly attributed to Pseudomonas Syringae (P. Syringae), a bacterium widely opposed for its pathogenic relationship to agricultural plants.

Within this same Part, I will pursue two brief excursions into the policy sphere, with a continuing focus on P. Syringae and the potential influence of bioprecipitation as the inspiration for some practical research. In the first excursion, I quickly outline a practical experiment involving what I will call "invited precipitation", on the basis of the propagation of "sacrificial crops". This experiment depends on my tentative hypothesis that the aggressive eradication of P. Syringae and other ice nucleators could be having an inhibitory effect on the generation of rainfall because a significant form of ice-nuclear material that operates very proficiently at warm temperatures is being widely and systematically destroyed. In the second excursion, I will look in on the longstanding debate about over-grazing on federal lands. Here, I will ask whether the introduction of a new, factual element like bioprecipitation can and should serve as a tipping point within the longstanding debate.

Part IV seeks to domesticate the idea of "invited precipitation" by incorporating the recent journalistic report of an experiment of similar ilk conducted by the government of Abu Dhabi. The Part contains some meditations on the potential consequences of such actions.

In Part V, I draw on the possibility that the morality of any attempts at policy influence should be placed under the conceptual umbrella of a principle I propose to call "systemic integrity". The concluding idea is that an ideal capable of garnering influence through study and ethical allegiance, though not currently in fashion within the domestic politics of environmental policy, could yet prove beneficial in stating the imperative nature of this cause.

Part VI sends up a cheer for new knowledge, here in the form I have been exploring in relation to bioprecipitation research; attempts a final rally in favor of respect for the hydrological cycle; and warmly invites comments on this paper.

III. ON BIOPRECIPITATION:

(A) LITERATURE REVIEW:

While significant questions remain to be addressed, the increasingly well-replicated findings concerning bioprecipitation would seem already to have validated their essential hypothesis: that organic material serves as a basis for ice nucleation—and as a basis, therefore, of rain. Recently, moreover, by means of research carried out in a diverse range of locations, a secondary hypothesis appears to have been established, namely, that there is a single biological ice nucleator (BIN) of extraordinary significance. This prolific contributor is a bacterium-- one that, within modern agronomy, is universally treated as an enemy of the good. That is because it is an effective plant pathogen, causing it to be subjected to aggressive eradication. What makes this bacterium and other BIN's of special interest includes the fact that they appear to be the most active propagators of ice nucleation at warm temperatures—a fact of potentially immense significance for a planet that continues to warm.

Research into the relationship between plant pathogens and the generative causes of precipitation came about organically, as it were, though the initial hypotheses, based substantially on logical induction by plant pathologists and others, had to await validation through developments in microbiology, meteorology, and other fields that have taken over twenty years to occur: The scientific acceptance of bioprecipitation, thusly, did not come tripping serendipitously downstairs from the storehouse of potent ideas.

A traditional field, one of ancient origin, has involved the study of plant pathogens in agricultural contexts, where the costs of common parasitic activity of this kind have, throughout history, been high. While cultivated host plants have been found, within current research, not to constitute a necessary niche for the development of virulence mechanisms, the existence of these mechanisms within and among plants that represent important sources of human sustenance has conventionally focused almost exclusive attention on agriculture, rather than on alternative biological niches, and has stimulated the development of first organic and, more recently, pharmacological cures (Morris et al., 2007).

Modal research of this kind has led to the discovery of diseases that attack specific types of edible plants. Indeed, a single pathogen and its bacterial relatives have, on a non-exclusive but highly persistent basis, been found responsible for disease vectors that commonly destroy or injure an impressive variety of plants. Thus, the bacterium Pseudomonas Syringae (hereafter, P. Syringae) has been found to be an aggressive and successful pathogen responsible for basal kernel blight in respect to barley (A. Braun-Kiewnick et al., 2000). P. Syringae has been discovered to be a principal causal agent of halo blight in many bean cultivars (I. Bozkurt et al., 2011). A common varietal of P. Syringae has been determined to be a prolific cause of bacterial shoot blight in tea plants, widely infecting them in tea-growing countries including Japan (T. Tomihama et al., 2009). P. Syringae's career as an antagonist of tomato plants, on which it causes a blight called bacterial speck, has been widely researched (see e.g., Y. Bashan et al., 2002).

The function of much modern agronomic research has been to locate and develop effective agonists to respond to agricultural blights including, with very significant levels of attention, those propagated by P. Syringae. This research has led to the discovery and wide dissemination of several effective, though not wholly successful, bactericides, some based on human antibiotic agents (see, e.g., Y. Bashan 2002). (After application, these join the water supply as an element of agricultural run-off, an aspect of the contemporary menace to the health of the hydrological cycle that I do not pursue here. See G. Eckstein et al., 2011). Other responses include combinations of singularly ineffective treatments, such as inoculation with bactericides both before and after spraying with other anti-bacterial agents (see e.g., Y. Bashan et al., 2002) and applications of increasing concentrations of antagonistic biological agents at prescribed intervals of host plant growth (A. Braun-Kiewnick, 2000).

It was in the course of such research that a basic research question became the method by which P. Syringae enters plants with the vast successes that it does, destroying their economic viability as it then propagates on the in and the outside. Prominent plant pathologists such as David Sands, who has worked on P. Syringae for over forty years, invested significant labors in this quest, eventually making the discovery that P. Syringae bases its propagative success on its ability to cause frost damage to plants, the damaged tissue then becoming a vector for entry into the plant, a metabolic activity that a specific range of temperatures promotes. This, P. Syringae is able to accomplish through its specialized ability to bind to water, the talent of a highly unusual protein that is found in the outer membrane of the microorganism's single cell (C. Morris, 2004). Even after this discovery, the questions that lay importantly open to inquiry included how the bacterium, which appears to migrate exceptionally long distances, negotiates passage through the air. Sands hypothesized that the same property that lends efficacy to the bacteria's ability to bind water to plant surfaces might also lend efficacy to P. Syringae's ability to mobilize after dissemination into the atmosphere. Still, the question remained: how? The concise answer is that P. Syringae is at least as successful as a catalyst for precipitation as it is for ice nucleation on plants, and by the identical means, using its special ability to bind water to the surface of its cell.

The basal hypothesis—that ice nucleation may be of biological origin—was advanced by three different research teams some thirty years ago (K. Jayaweera et al., 1982; J. Lindemann et al., 1982); D. Sands et al., 1982). Earlier work prepared the way (e.g., G. Soulage, 1957; R.C. Schnell, 1972; L. Maki et al., 1974; S.E. Lindow et al., 1978; J.P. Paulin et al., 1978). The theory could not be well-tested until more recently, as its validation through wide replication has required DNA testing as well as satellite-based meteorological technologies not then available. It has also required the cross-disciplinary collaboration of microbiologists, plant pathologists, meteorologists, geophysicists, and statisticians, among others. With the advent of these techniques and the assemblage of cross-disciplinary teams came the widespread ability to test the claim.

As of this writing, positive findings related to biological ice nucleation (BIN) have been confirmed by some forty scientific teams working out of dozens of laboratories in at least six countries in the world. (See bibliography for citations too numerous to list here). The work has advanced substantially since 2005. David Sands and his former students, among others, have published some definitive research in just the past few years (Christner, 2008).

Among the consistent findings are these:

Through the process known as "ice nucleation", aerosolized particles that may be made of organic matter, such as bacteria, fungi, or pollens or that also may be made of inorganic matter, such as mineral dust (as we shall further consider in Part IV), sea salt, smoke, or particulate pollution convert water in the atmosphere from vapor or liquid to ice. As ice, these particles get suspended in the atmosphere. There, they cause larger particles to coalesce through a phase-change that produces cascades of crystal formation (Christner et al., 2008).

These larger ice crystals can trigger precipitation, carrying the ice nucleators back to earth as rain, snow, or hail. If the nucleators are bacterial, they may then attach to host plants and there multiply. They may also travel between hosts on currents of wind. Wind currents may cause them to travel long distances and then carry them aloft, into the sky, where they may again spur ice formation in clouds, then, as precipitation, fall back to earth and get carried to host plants where they may further propagate before getting borne further, into the sky.

What is responsible for this process microbiologically, in the case of BIN's, involves an active protein in their outer membrane. It is this protein, a consensus octapeptide, that binds single molecules of water into an aggregated orderly arrangement. And it is this arrangement that then provides a template which encourages ice to form into crystals (Id.).

While the leading research efforts in regard to the workings of biological agents as ice nucleators has been taken by microbiologists and plant pathologists, atmospheric scientists have recently added a new and powerful arm to these discoveries. In early research, they have demonstrated the potential of BIN's to act also as cloud condensation nuclei (CCN). Through this added process, BIN's can "contribute to the initial cloud formation stages and the development of precipitation through giant CCN and IN processes" (Mohler et al., 2007). In an early overview paper, the authors have called for a wide-spectrum effort to understand the cloud-formative role of BIN's, through a combination of field, laboratory, and modeling (Id.).

Much of the most recent research into BIN activity has centered on the role of P. Syringae, which appears to be a stand-out not only in its microbial class (Christner et al., 2008) but among ice nucleators across types. The reasons for the substantial interest that this BIN is generating are several. For one, BIN's as a class have been found to be the most efficient catalysts for atmospheric ice formation across a range of relatively warm temperatures (warmer than –10 C.)—a function of possibly tremendous import for a planet whose atmosphere is undergoing significant warming on account of the increasing build-up of heat-trapping gases. (But a reason for special caution, given that P. Syringae fails to operate above a certain warm range.) For another, amongst all of the BIN varieties, P. Syringae has been found in the greatest abundance as well as in the widest distribution throughout the world.

Since current ability to study the concentration of ice nuclei in the atmosphere is extremely limited, rain and snow samples on land have served thus far as proxies for understanding dispersion and concentration modes and as the basis for predictive modeling. In the case of P. Syringae, its concentration in particle suspension in rain and snow samples obtained in Antarctica, Louisiana, Montana (Christner et al. 2008), the French Alps (Amato, et al., 2006), the Yukon Territory, and Alberta, Canada (Vali et al.) have dominated all other IN types, though seasonal differences obtained. For a third finding of note, the dominance of P. Syringae as an IN was found to exist despite ecosystem differences, moisture source differences, and differences in air mass trajectories (Christner et al., 2008). BIN's, it has been concluded, are of "ubiquitous" dispersal (Finlay et al., 1999). This seems due in no small measure to the highly efficient dispersal properties, together with the ecological niche-creating talents, of P. Syringae.

As its principal long-term investigator, David Sands, posited some thirty years ago, there is a "bioprecipitation cycle" within which certain biological agents, such as the bacterium P. Syringae, commute between their pathogenic roles on earth and their benevolent roles in the sky. Intrinsic to the formation of rain (though it appears to be a temperature-restricted, jointly sufficient, not a necessary, cause), BIN's demonstrate the inadequacy of "the hydrological cycle" conceived as a hermetic system, placing water's cyclical movements within a singular, complex, and dynamic system involving earth's elements and properties, instead.

Still, the well-articulated understanding of the hydrological cycle that bioprecipitation grants does not render the idea of a "hydrological cycle" vacant, or lead to a conceptual rally in favor of a unitary biospheric model as the only typology of choice. Like the relationship between cells and the organism of which they are a part, the water cycle has systemic integrity, while contributing to and receiving benefit from a larger whole.

As Professor Sands points out, it behooves us now to understand, in ways that further research involving biological ice nucleators can help to do, the relationship between the "tended" and the unintended consequences of our dealings with earth's interdependent systems. Taking in hand the questions that a fully-systemic approach raises for the treatment of double-agents like P. Syringae (Sands, cv at dsands@montana.edu) creates a compelling probe. After all, it has now been demonstrated that when P. Syringae isn't behaving as a plant pathogen it is—provocatively—leading "other lives" (C. Morris, 2007).

(B) Meditations on Bioprecipitation:

(1) Our Knowledge Gap:

Surveying the growing inter-disciplinary research on biological ice nucleators, as we have done, allows us to develop a due regard for the remarkable athleticism of plant pathogens like P. Syringae as they commute within

their cyclical realm, enjoying a pleasantly destructive life on earth, then hitch-hiking on the wind so as to lead a creative one—that of rain-maker—in the sky, only to fall back to earth again, presumably in a new place to which the winds and the rain have carried them. There, they may begin the cycle anew.

Some scientists have hypothesized that this ambitious commute—P. Syringae and other bacteria may be transported to altitudes of several kilometers and they have been located on several continents (C. Morris et al., 2007)--seems a well-adapted strategy for propagation (B. McDonald et al., 2002). It even includes what may be a static phase—offering a kind of respite? (my interpolation)-- when the bacteria merge with diverse other biological materials, including algae and nematodes, often in aquatic settings, where they attach to rocks to form "biofilms". They are also prominently found in tree canopies—perhaps one of their launching pads into the upper altitudes?, or at least a place to dry off before becoming air-borne (again, my extrapolations). The discovery of P. Syringae's apparently benign occupation of this range of gathering places has been verified, though not widely studied, lending favor to the understanding that these are not "obligate" pathogens and that they may perform biological functions yet unknown in these "environmental niches" (C. Morris et al., 2007). (Down the road, it will be open to question to discover whether the life cycles of bacterial pathogens of value, like P. Syringae, have been negatively influenced by the pollution levels of many rivers and streams. I wonder especially about the role of pharmaceutical pollutants because their molecular size and increasingly prominent concentrations in relatively shallow aquatic environments may create special conditions for the development of newly-compromised biofilms in which P. Syringae might also play a part. On the growing threat of pharmaceutical pollutants, see G. Eckstein et al., 2011).

Because almost all research related to bacteria of this kind has for so long been centered on their eradication, as we have seen, we know very little about these other phases of their life cycles. Surely the most striking thing about our knowledge gap is that it includes our knowing essentially nothing about the unintended consequences of our "tended" interference (D. Sands) with their existences. This lack of understanding reaches to the effects on the propagation and distribution of rain of the aggressive eradicative programs in regard to plant pathogens that are currently and have by now been long engaged in, not least exemplified by efforts within the United States.

Questions of causation would be difficult to fill directly. There are several categories of strenuous difficulty in the way. Just one involves the possibility that significant contributors to the droughts and increasing desertification that are being experienced involve not only the intentional, programmed eradication of biological ice nucleators like P. Syringae, on account of their pathogenic ways, but also the unconsidered and unprogrammed eradication of countless small aquatic sites where biofilms can form. To this, add the destruction of tree canopies through presently-lawful as well as presently unlawful deforestation activities all over the world. And to these, add cut-backs in forestation programs, as pulping for the production of the print media shrinks in favor of the production of paperless text. And then add common land-use choices that result in widely-practiced clear-cutting regimens throughout the market for suburban housing development—practices that have been going on for decades. And add in wild-species habitat destruction through such obvious mechanisms as urban sprawl. With these go the loss of wild grains. Like grain cultivars, these host plants constitute the equivalent of population centers for the propagation of pathogenic organisms such as the adaptively-peripatetic, yet still potentially habitat-vulnerable P. Syringae. As this early inventory suggests,, there are many unintended social norms that favor the eradication or radical displacement of plant pathogens. It would be reductive, in any full-scale analysis, rather than a new and provisional one such as this, to limit the focus to agronomic hostilities over-all.

Other issues include: How would study designs be formulated that appropriately model critical mass reductions against baseline supplies of bacterial ice nucleators? Given the global hitch-hiking skills of these unicellular organisms, how could the study of a potentially destructive cause of induced bacterial scarcity in a given locale be validly tied to a potentially influenced effect somewhere else? It seems more than possible that we inhabit an era of unknown length that resembles the state of biological systems before the discovery of DNA, even though, with the benefit of the microbiological advances that have followed, we can peer into the multiple lives of organic ice nucleators and begin to question their deaths.

This, the primitive state of knowledge that we seem to inhabit could lend to a not- unjustified form of chronic passivity: Let's wait to see what we may someday see. Or, it could lead to a concentration of potentially productive thought-experimentation at any time, beginning with now, even beyond the conceptual terrain of experts in the relevant fields. Inspired by the provocations the reported bioprecipitation research engenders, I hereby volunteer to initiate the latter cause.

My purpose here, I hesitate to add, is not to design a new research program to validate the hypothesis that the widespread destruction of those bacterial pathogens that exhibit the specialized capacity to serve as ice

nucleators produces a negative influence on the formation and distribution of precipitation. Nor is it to design a research program to demonstrate that the intensive cultivation of these pathogens can positively influence these events. It is simply to point toward that idea, immediately below.

(2) A First Thought-Experiment: Invited Precipitation Through Sacrificial Cropping:

One way to study changes in precipitation patterns would be to try to induce rather than simply to follow them. This is not a new idea. Cloud-seeding, a meteorological technique developed several decades ago, has amounted to a by-now conventional attempt to put that same idea into effect. Sporadically, it gets returned to. Indeed, it may have crossed the line into predictable efficacy as recently as last year, though not in the United States, as I will describe in Part IV below.

The experiment I want to sketch is based on two assumptions. One is that understandings of cloud physics and wind patterns can be utilized to stabilize precipitation distributions, at least sufficiently to allow experimental purposes to be met. The second is that a very large tract of land not relevantly proximate to existing agricultural production could be devoted to the cultivation of, in effect, P. Syringae. The technique would be to devote substantial acreage to the production of the bean and tomato cultivars, for example, that P. Syringae is well-known to treat as beckoning hosts. These standard agricultural products would, correspondingly, become sacrificial crops, intentionally exposed to the destructive capabilities of P. Syringae and other bacterial pathogens, too, for that matter, to encourage their highly concentrated and prolific propagation. Of greatest interest would be to learn whether long and wide cleavages made in desert areas could support this work. It is known that desertification is a process that overtook vegetated regions at times past. If precipitation can be invited, desertification could be reverse—the subject of Part IV below. But the experiment I am calling for will require irrigation and, possibly, proximity to a tree canopy, so for a first experimental outing, the desert is not the place to start.

The rest of the cycle, culminating in P. Syringae's migration into the atmosphere to populate clouds with ice nucleators, I am, in this altogether unsophisticated rendering, prepared to leave to the natural forces of the precipitation cycle itself. That is the pattern that the prominent use of bactericides and other agents, including widely-deployed, vastly desiccating land-use strategies, may have unintentionally impeded, or substantially shifted, if not, in some places, destroyed.

Unlike the current methodology of cloud-seeding, which relies on the physical placement of inorganics, as intended nucleation material, within a particular atmospheric range, my thumb-nail experimental design relies on but reverses the process of human intervention. It remediates the gross interferences with the bacterial formation of precipitation that have become conventional agronomic practice by inviting back into the hydrological cycle the single, land-based activity that has been demonstrated on the basis of multi-disciplinary consensus to be causally related to nearly-ubiquitous, successful ice nucleation: propagation by plant-pathogenic bacteria whose earthly vices become a significant virtue in the sky.

In effect, instead of attempting mechanical intervention at the top of the hydrological cycle, I propose to invite the natural characteristics of organic agency back to work at the cycle's earthly bottom, instead. Rather than ignore biology in favor of meteorology, I propose to emulate bioprecipitation research by uniting the two. So, rather than depend on inorganic cloud-seeds, I propose that we embrace nature's own well-proven strategy for re-cycling organic matter to get this essential job done.

The plan, then, is to reverse top-to-bottom interventions and to replace inorganic with organic agents. Instead of thinking outside the box, as current interventions do, I propose that we think in sympathy with nature by mimicking the natural sequence of plant-pathogenic activity within the hydrological cycle. Inside the box of naturalistic reasoning, that is nature's own mind-set, as it were.

This said, it may be that we should follow the lead of sometime-futurist "green guru" Amory Lovins, who, when an interviewer deployed the phrase "outside the box", famously replied, "There is no box." (E. Kolbert, The New Yorker, 2007). The annotations I provide in Part IV to a very different experimental strategy involving invited precipitation assume there is no box that should contain our reach to engage with that which we have spent far too much time not reaching to engage. And that the time isn't later, as I have been willing to concede. It may be right now.

(3) A Second Thought-Experiment: Refocusing the Over-Grazing Debate:

(a) Earlier, I noted that there may be a multiplicity of unintended ways that bacterial pathogens are being excluded from their timeless propagation haunts, whether on and within agricultural crops; in previously uncultivated, now built-upon areas where wild grasses have been destroyed; or in tree canopies: As "ubiquitous" as bacteria are commonly called out to be, it is treated as somewhere between an assumption and a fact by

bioprecipitation scientists that colony size, in the case of biological ice nucleators during their earthly phase, participates in the problems of critical mass and that the extent of earthly proliferation plays a role of some significance in their proficiency in taking productive action in the sky.

Assuming this to be a valid concern, the reclamation of very large land tracts to invite bacterial self-propagation would seem a desirable end. Perhaps it may prove to be a necessary one, if the present hypothesis should become validated: that the aggregative destruction of ice-nucleating bacteria negatively influences the propagation of rain. In advance of that proof, we may engage in a full-blown strategy of doing nothing, as suggested earlier, or we may choose to experiment with solicitations toward the natural order for the production of rain. A bold venture would be to see what a large-scale policy change might do. Let us first see what might qualify for such a candidacy and why:

Given the localism and particularism that afflict state land-use policies in the same way that they afflict policies that motivate the governance of water, as we have observed in Part I, the most efficient change in land-use policy would be to effectuate a single bold revision in the use of public lands. Approximately one- third of the land mass of the United States is owned as public land. Of this, the vast majority--unto the extravagant millions of acres—is found in the western states. And of this western land, most is administered by the federal government for reasons that attached at the Founding and in the early Republican era (see, generally, P. Gates,1968).

Of these federally-administered western lands, many millions of acres—"seemingly limitless" land, as it was early understood (Estate of Hage v. U.S., 2008)—constitute a part of what is known as the "public domain," the subset of public lands not committed to a specific purpose, such as the national parks. These lands are required under federal law to be administered and maintained, primarily by federal agencies, for the public benefit, in ways that are statutorily prescribed, the age of many of the statutes within this skein giving rise to the pertinent view that they are the "lords of yesterday" (C. Wilkerson, 1992).

A strikingly long-standing problem within land-use policy as it pertains to the western public domain involves chronic over-grazing. There has been a persistent debate about the federal tolerance of over-grazing that has rocked back and forth across the margin of its factual predicates for well over a century. During that extraordinary span, the relevant analysis has, on one side, at least, become ever more factually precise and refined. But this has hardly moved the dial in favor of a major public policy change. In fact, it has not moved the dial, in substantive terms, at all. (For a noteworthy example of a private contribution toward policy change involving federal grazing permits, see J. Carey, 2011).

The authors of a highly-respected environmental law casebook, to which I am much indebted on this subject, devote fully a tenth of the book to this vast failure of land-use management. Their introductory synopsis begins thusly:

"Few natural resources better illustrate the challenges for natural resource law and policy than our nation's public rangelands. It is no coincidence that grazing provided the archetype for Garrett Hardin's tragedy of the commons nor that it has served as the classic example of agency capture. The current debate over rangeland management also provides a fascinating instance of environmental aspirations butting heads with longstanding tradition, culture and reliance interests" (J. Rasband et al., 2004 at 880).

The story begins not with aspirations or traditions but with law. The tragedy of the commons in respect to over-grazing, due to the environmental degradation that it had caused, became such a full-blown problem early in the twentieth century, and even before, that a major piece of statutory architecture was put in place to try to control it. The central pillar of the regulatory scheme—still, the central pillar today—was the turn to a permitting system administered under federal agency authority, the governing standards for which are circumscribed by the language of the statute itself (Taylor Grazing Act, 1934, hereafter "TGA"). These standards were echoed in a subsequent statute that now serves as the comprehensive management schema for federal lands (Federal Land Policy and Management Act, 1976, hereafter "FLPMA").

The federal regulatory regime that controls the destiny of millions upon millions of acres of the public domain in the West was the product of a bifurcated scheme of entitlements from the start. On the one hand, the TGA and, later, the FLPMA insist that grazing on public lands is not a right but a privilege (TGA sect. 315 (b) and 316) and that the permits and leases under which grazing has statutorily taken place do not confer any rights in property to the lands themselves. Be that as it may, the permits and leases have run unto the generations—not only of cattle but of people who have made multi-generational ranching on these lands into a highly-romanticized way of life, an iconic way of life that is bound up with the history and traditions of the American west. The permits have functioned as items of value which, unlike, for example, intellectual property protection, confer their value over an indefinite life much in the manner of Anglo-American land titles, the traditional paradigm of property rights themselves. When the government buys out permits to transfer or to retire them—

the latter, a stratagem that has begun to foster more active conservation of land and water than has existed before, the permit-holders are entitled to gain compensation under the federal Takings clause for the value of the benefits that they have lost. Permit-holders and lessors are also entitled to receive compensation for improvements they have made to the federal lands over which their permitted rights grant them de facto possessory rights. In a recent case, the retirement of grazing rights cost the federal government over 4 million dollars in compensation, to one family alone (Estate of Hage v. U.S.) The judicial interpretation of these statutorily-limited non-property rights has been an interesting saga on its own.

The TGA and the FLPMA do not contain a mandate to the effect that all land within the public domain has to be put to work for grazing or for any other purpose. Rather, the two agencies responsible for managing the lands are required to look to "multiple uses" and "sustained yield" (43 U.S.C. sect. 1732 (a)). Because of the entrenched nature of cattle-raising on these lands, however, shifting to other uses has not proven easy to implement or maintain, particularly when competing uses are not compatible with the needs of cattle or the desires of the well-organized and politically influential ranchers who run them. The authority of the two agencies is derogated from the land management right granted to Congress under the Property clause of the federal constitution (U.S. Constitution, Art. IV, sect. 3, cl. 2). It includes the right to impose a regulatory carapace over the lands. Its terms include the requirements that "grazing use shall not exceed the livestock carrying capacity of the allotments", and that uses shall not impair watershed function, riparian habitat, water quality, or wildlife habitat (43 C.F.R. Sect. 4130.3-1(a) and 43 C.F.R. sect. 4180.1 and 4180.2(c).) Beyond cavil, all of those damaging excesses have become chronic features of the grossly impaired landscape. This has been true for many, many years.

What has engendered the chronic maintenance of irresolution as an infamous feature of agency function has amounted to an effort to effectuate a compromise involving incommensurable variables, plus apparent helplessness in tackling the stasis that attends entrenched norms, played out against a backdrop that, as with several other deep political conflicts, involves the strength of single-issue interest groups that never relax their gaze.

What is most deeply problematic about cattle-raising, without reference to the proportionality issue that implicates the "carrying capacity" of land, is that, more than many types of heavy, roaming animals, such as bison, cattle strip away vegetation in a manner that discourages re-growth and compounds this problem by compacting the earth. The environmental casebook authors write:

"An important environmental concern related to grazing is desertification, [which] refers to prolonged abuse of land that weakens its ability to support plant growth through loss of soil productivity, increased soil deterioration, and loss of biodiversity. Overgrazing…is one of the prime contributors to desertification (J. Rasband et al., at 891)."

A rival to cattle-raising on federal lands has been the development of recreational activities of many forms. These include hiking, camping, hunting, fishing, and water-craft use. Licenses and admissions charges for these activities have already demonstrated that they are more extensive sources of federal revenue than is cattle-raising, though the development of several of these uses—fishing being among them-- have been impeded by the degraded state of the resources that cattle have polluted or driven down (J. Rasband et al., 2004). Still, even with cost-benefit analysis on recreation's side, the lessening of grazing's hold has been more gradual than precipitous. And there seems to be no program in place that constitutes a system of financial accountability for the known and catalogued environmental degradation that has injured portions of the environment where tourism would otherwise flourish but cannot.

The authors of a major report on the totality of these circumstances have titled their work, "Welfare Ranching: The Subsidized Destruction of the American West" (G. Wuerthner et al., 2002). In its dedication, they decry "the use of America's public lands as private feedlots" (Id, at frontispiece, unpaginated). With no pretense toward even-handedness, the tenor of the book is captured by this fragment from a pungently-worded speech: "[M]ost ranchers don't work very hard. They have a lot of leisure time for politics and bellyaching (which is why most state legislatures in the West are occupied and dominated by cattlemen…[S]ubsidized Western range beef is a trivial item in the national beef economy. If all of our 31, 000 Western public-ranchers quit tomorrow, we'd never even notice" (E. Abbey, Id. at 60).

But these ranchers are not quitting en masse. Some are waiting to be bought out; others are not. As long as they are determined to remain, the relevant agencies and Congress at the fore continue to lack the political will to buy them out. And the desertification of public lands in the West goes on.

(b) There is reason to suppose, as an extrapolation from the bioprecipitation research and other research as well, that soil degradation and concomitant flora destruction organically sponsor more of the same. To use an example outside the landscape of federal lands, it may well be that the reason that Seattle is very

green is not because it rains a lot in Seattle; rather, it may rain a lot in Seattle because its tree canopy sends generous numbers of ice nucleators into the atmosphere after which they rain back down. In other words, the greenness and the grayness are equally intrinsic to the water cycle, which may bear a resemblance, as a matter of accurate description, to chickens and eggs.

Desertification processes may work the same way in reverse: Losses of soil and soil nutrients foster a lack of plant growth. The lack of energized plant materials may fail to attract bacterial pathogens such as P. Syringae. So, to shorten our by-now familiar story, it rains somewhere else, like Seattle, where conditions in the tree canopy are welcoming—a locus of invited precipitation, as it were.

If further research sanctifies this hypothesis, then the need to oppose bacterial-pathogenic habitat destruction through over-grazing could become the game-changer within the politics of endless debate over the present and future of western public lands. That would depend on whether it is understood to be vital to the West to capture the organic forces of greenness, rather than succumb willingly—intentionally—to the forces of brown across the vastness of the public lands. The question of how the debate might play out in a newly-explicated form such as this might depend on which aspects of the built environment sit adjacent to public lands, such that their own supplies of rain either are or are not at risk on account of the spread of desertification. Likely, perhaps, some towns or cities on the public lands frontier will be subject to enhanced risk if bacterial-pathogenic habitat isn't greatly restored. That is a new way for the debate over over-grazing—and maybe, under increasingly fragile conditions, grazing itself—to end.

(c) Coda: In respect to a similarly-widespread set of environmentally destructive forces, the author of a closely-observed, elegiac monograph on wildlife habitat loss adds: "Economists and social scientists endlessly debate the pros and cons of the changing character of American agriculture. From an ecological perspective, however, it has clearly been an unmitigated disaster for the grassland fauna" (D. Wilcove, 1994). The author goes on to describe the extremity of the loss of all three types of grassland flora: tallgrass, mixed-grass, and short grass (Id. at 103):

"The midwestern prairies have not suffered as much on account of cattle-grazing as through a mixture of persistent urban sprawl and aggressive consumption by industrial agriculture. But the losses to these former prairies have been overwhelming, in terms of the destruction of grasslands alone. The author concludes: "A few visionaries have pondered the unsustainable nature of modern agriculture in the western portion of the central plains—the declining aquifers, the disappearance of ancient topsoil…-- and have proposed grand schemes to tear down fences, remove the cattle, [and] restore the vegetation…Political reality suggests we are a long, long way from enacting anything so bold, and perhaps we never will (Id, at 103)."

My suggestion is that the cultivation-versus-prairie-restoration debate, which was over at the start, could be vitalized by becoming a subset of a powerful new public conversation about the needed vitality of the hydrological cycle. Invitations to precipitation, instead of their diametric opposite, might not be far behind.

IV. THE DESERT AWAKES…ONLY, NOT OURS:

For the purposes of the two meditations just recounted, I was content to follow in the footsteps of that "green guru" culture hero, Amory Lovins, and don futurist robes. But now, I will offer the fact that the idea of "invited precipitation", my term of general embrace for humanly-caused interventions in the precipitation cycle, has apparently received forward thrust in real-time:

In the summer of 2010, it has been reported, the United Arab Emirates succeeded wildly in its sponsorship of a research program involving invited precipitation. Their program, which had been pursued in secret, according to the source (J. Sanburn, 2011), at a cost of $11 million—a bargain rate, it would seem—managed to create 52 precipitation events in the Abu Dhabi desert, none of which had been forecasted to occur. These included rain, hale, lightning, and gales.

Even discounting for some number of lightning strokes, as these are of a somewhat different ilk, there appear to have been a non-random number of precipitation events in a highly non-propitious place: The government tourism office of Abu Dhabi maintains a website that, in listing the emirate as a "place of distinction" describes the fact that it has a "sub-tropical, arid climate and that the country only receives an average of 12 cm of rain per year (www.visitabudhabi.ae/en/about.abudhabi/climate.aspx).

The method of employ was not the hyper-protection of plant pathogens—a highly unlikely strategy for the desert. Instead, the program relied on steel ionizers, which created charged particles. These negatively-charged ions then rose in the hot air (the tourism website doesn't neglect to mention that average summer temperatures can hover at 118 degrees) attracting dust. When moisture collected around the charged dust particles, some of them evolved into rain clouds and precipitation followed on that. This experiment is one among others that tell

us that arid countries in the Middle East which have both sovereigns and sovereign wealth funds may be closing in on buying their way into ingenious solutions to centuries of virtual barrenness, a condition that has caused them to rely very heavily on imported foods.

There are other indications that a big push toward change is on: In a piece titled “Farming the Desert”, it was reported this Spring that water from the Red Sea is being piped to a location in the Sahara Desert, where, through a condensation technique, the water both cools and humidifies a huge interior greenhouse with the no-nonsense name “Seawater Greenhouse”, after which it gets separated into freshwater and mineral by-products (G. Dunmall, 2011). The process allows some water to escape by design so that the outside air can be humidified by it. This secondary process is intended to provide sufficient moisture for the growth of living plants directly in the desert—a nice step toward my first meditative idea for the development of sacrificial crops to invite precipitation, an idea that has barely made it onto the page but might yet see its time!

While I await a day in the sun, as it were, for my discovery, I should note that Seawater Greenhouse is not the investment vehicle of a Middle Eastern sovereign wealth fund—at least, not entirely. The piece mentions that the government of Norway teamed up with the government of Jordan as well as a Norwegian NGO to create the project, and that other locations including Oman, the UAE once again, and Tenerife have already received “greenhouses”, following this same model, of their own. The design team is part-British, part-Norwegian for Seawater Greenhouse, and it intends to keep building these around the world.

The fully-extended version of these proof-of-concept vehicles is intended to produce structures in each locale that are 50-hectares in size and can generate 34, 000 tons of vegetables, while employing 800 people, exporting 155, 000 megawatt-hours of electricity, and sequestering some 1500 tons of carbon dioxide. The prices of the experimental model now underway and of the full-bore version are not given—at least, not here.

One immodest point to be made is: The future is now. To control these amazing break-throughs will be to reinvent the history of entire nations and even entire regions of the world. But to do so, there has to be a generative political process that succeeds in inviting not just rain but beyond-common-sense ingenuity into design laboratories and then, into the out-of- doors, where large land tracts will have to be placed at the disposal of a multiplicity of project-types until questions of efficiency and efficacy can get sorted out.

This goes to a second large point about the content of meditation on these themes: The days when land-use policy can be held apart from water policy are numbered. This is bound, at least in an advanced democracy such as ours, to give rise to important new governance issues that go to matters of scale—Can localism continue to play a dominant role in water law and policy, as it has traditionally within the United States, for example? That is just one of many questions about how much institutional reinvention, in the name of good governance, is going to need to go on. And that question must itself spawn another, which is the very ancient but hopefully ineradicable question of how water justice is to be achieved with the benefit of the radical improvements in old ideas that are going on? All is not efficiency and efficacy, after all. Governance challenges will abound in regard to both cost-spreading and the distributional issues that will arise in regard to food, water, and the generation of renewable energy by products of this kind.

I suppose I need to eat at least a handful of dust for not admitting, until now, that the relatively cheap cost of the Abu Dhabi project and the efficacy of its results may put my sacrificial cropping project to shame. If so, that’s the price of going where you don’t actually belong. But it may be one-step too early to give up on pathogenic problem-solving compared with the sleekness of a desert project that is fed by dust. As I relayed but only mentioned in the literature review (Part III (A)), rain nuclei include not only plant pathogens and dust but also algae and pollens and fungi and even chemical pollutants, among other things. The hypothesis of choice among researchers right now is that P. Syringae is an example of a highly-successful self-propagation strategy, a theory that is redolent of Darwinism and latter-day “selfish-gene” theories in type. I am not in a position to dispute this hypothesis, but I might want to hitch a ride on it for a further idea: While experiments are being done that examine the nuclear properties of molecular material, it might be well to attempt to learn whether all nuclei have equivalent properties as mechanisms for inducing agricultural productivity: Are all drops of rain born equal when it comes to a talent for fecundity? It may be that the virulent pathogens confer superior riches on the plant world relative to other nuclear ingredients. Only experimentation might tell. If it did, P. Syringae could both produce rain and fertilize your garden, all at the same time. Perhaps it has been doing just that for the past billion years, afterwards rewarding itself with a share of the crop.

A final, less humorous thought wafts through the meditative haze: It may be in the coming age of water’s technological revolution that projects that are all about greening the desert and desalinating sea water for hyper-productive “greenhouses” will be the only news. But assuming we retain as fact the notion that there is a fixed amount of water in the biosphere, and assuming, further, that rain aggregates in the clouds in order to develop

the mass needed to fall, the processes of super-aggregation that new projects could call for could have critical implications for sovereign states that are not regionally liked or even enjoyed as neighbors.

One must not forget that rainfall is a commons and that, to avoid tragedies in the nature of collective-action failures like over-grazing as well as tragedies that might come about by design rather than inattention, ingredients thus far in shortest supply in many parts of the world and throughout much of history are going to have to be inculcated as a feature of governance and collectively maintained. The ingredients are fairness and justice. There is a reason why a law professor wrote this Essay after all!

V. SHOULD WE ADD A BANNER PRINCIPLE, SUCH AS "SYSTEMIC INTEGRITY"?

In a more mature version of this Essay, the final question to be explored will be how to develop a rhetoric of engagement for the subjects we have considered if they are to enter the public realm and acquire an influential voice. The expository structure employed in these pages relied on brief explanations of law and science, in the first instance, taking a run at the description of a millennium's worth of water law on two continents; in the second, trying to convey the basic findings and the precipitant excitement in the work of some 150 scientists from temporarily-convergent disciplines who have been working for nearly three decades in labs across the world to understand the roles of specific organic matter in the nucleation and the descent as precipitation of atmospheric ice or, far more commonly, in developing agronomically-favored responses to virulent plant pathogens.

Woven around these, after observing their oppositional pulls to the past and to the future, was some instrumental material designed to focus new attention on the biological threats that severe inattention to the hydrological cycle may have begun to yield. Nested within these threatening pronouncements was the story of a sensationally active plant pathogen, as apparently successful at initiating precipitation as in invading and injuring edible plants. Concededly less compelling—perhaps—than a character in a classic morality play, Pseudomonas Syringae is the dualistic hero and anti-hero of this tale.

In the increasingly standard accounts we read of climate change, we are the anti-heroes, a terrible and stubbornly myopic force unto ourselves. The tale of wide-scale habitat destruction, added to pathogen-destruction itself, that may be affecting the skyward performance of P. Syringae and its mates doesn't cast us in a better light, in terms of outcomes. Instead, it takes the story of severe inattention to the unintended consequences of our wantonly species-ist collective behaviors to a more detailed level than do popular accounts of greenhouse gas emissions, and right down to the ground.

Forming underneath everything that grows, to reuse an antiquated family law phrase (M. Minow, 19), is the idea of a new ethic of environmental care, one that will need to pledge allegiance to the full hydrological cycle and to the comprehensive linkage of hydrology to all biological systems. The latter is not an optional matter, according to the work led by David Sands, Brent Christner and others on bioprecipitation. That is because, as they have shown, specially-adapted prokaryotes may not only traverse the world exerting their influence but they may also rule the skies and if so, we will need to bow to their superior force.

What besides a practical change of attitude inspired by new knowledge and motivated by fear—the fear of perpetual, localized drought or the fear of water wars implicating rainfall—is needed for us to take the forces of the universe on their own respectful terms? Does the change that is called for depend on principle or demand one? That may be an essential question for a move involving ethics to confront. But does the new biology that is the new hydrology require an ethic or is that merely a trope, the obverse of "killing" the rain?

It is widely asserted that we are all consequentialists now [cite]. Fears of the unintended and deeply unwanted consequences of heedlessness toward the hydrological cycle, such as aquifer depletion, surface water pollution, and precipitation diminution, are likely to propel many toward that camp, whether "we" all smoke that brand or not. The ends of such a migration can only be salutary. The pragmatism that has been water law's historic stance, and one of its greatest limitations, has philosophical dimension, like the "precautionary principle," but isn't yet an ethic or an obvious derivative of applied ethics, which has stood as a troubling example for decades of jury-built ethics the pedigrees of which are infirm. (Even moralities with firm pedigrees belonging to the unchallenged western tradition can lead strained public lives, as the contemporary career of virtue ethics shows.)

On another side, despite the understandable tendency of legal scholars to append ever more weighty limbs to the public trust doctrine (see, e.g., Sax, 1980; Reiser, 1991), it seems dubious that there is an easy doctrinal fix for the problem of establishing a proper pedigree in ethics or in law for a new obligation to nature's incredible cycles—this, when we are so little honor-bound in the conduct that is required in order to take the public trust

seriously; so little honor-bound that we fail to take the requirements of welfare ethics seriously though there is poor health and poor nutrition amongst our fellow men.

Where do these ethical deficiencies leave our potential willingness to undertake an enormous obligation, however founded outside the cause of expediency? Eerily, we have been asked to face the same question, with the same tinges of principled reflection before.

Commenting on a 1967 case, here is how an author put the issue of foundational ethics as long ago as 1991:

"It seems clear that the court was influenced by the same ideas and forces that led to the adoption of the legislative policies of the….Act: recognition of a broad inter-relationship among natural resources, their susceptibility to piecemeal destruction, a concern for future generations and cognizance of the irreplaceability of the natural functions of the Bay (Reiser, Id, at 409)."

As a call to conscience, perhaps every call to ecological principle simply brings us back home. But where is home? What causes us to be ethically susceptible to writing certain ecologically-protective language in a statute, or to voting for judges who will heed its call? Or to responding to a well-articulated call for some version of water justice ourselves? As the old adage goes, "There is many a slip 'twixt the cup and the lip". Water-ethicists envision things the other way round: ethics is a seamless web albeit with a somewhat mysterious point of origin. I, myself, tried to elude detection as one of them when I wrote in Part I that I planned to place my final meditation in an "ethical capsule". So, where do convenient "ethical capsules come from"?

I intend to respond to more critical—and self-critical—musings than these when I next return to this theme.

VI. CONCLUSION:

This Essay's interventions have been funded by the claim that the link that joins the formation of rain to the propagation of plant pathogens may constitute a missing piece of basic knowledge that should be fundamental both to water conservation and land-use policy. This knowledge may be necessary in order for wise normative approaches to the hydrological cycle and policy choices reflective of them to prevail.

The point of this Essay has not been to unfurl specific policy endeavors or research programs regarding land use and water conservation, though I have succumbed to the temptation to provide glimpses of a few. Nor has it been to delineate the precise function that a formal, policy-based acknowledgement of bioprecipitation might serve. Instead, I have meant to point toward the kinds of practical and political choices that may be made possible by new knowledge that is being generated by the energized pursuit of inter-disciplinary science.

Throughout, I have attempted to be clear that, while the theory of bioprecipitation has taken on the contours of a settled account as to its chief finding—the near-ubiquity and prolific participation of bacteria as precipitation-inducing ice nucleators-- my attempts to draw significance from those findings for purposes of land and water policy have been in the nature of thought experiments on the frontier. As far as I know, recent research into bioprecipitation has not yet crossed the thresholds of water law or water policy studies. My interest, therefore, has been in beginning to colonize this frontier.

My interest is also in inviting critical responses to this paper. And that is not only a genuine invitation, but one that means to generate as warm an invitation as it is possible to state.

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