Desertification in Global Drylands

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Writer's Comment: In August, nothing is further from the day-to-day reality of the northern California coast than the notion of expanding desert; beaches—occasionally sandy, invariably cold and foggy—are about as close as you get. Yet last summer, while taking classes at UC Davis's Bodega Marine Laboratory, I chose that very topic to write about. Whether desertification appealed to me in spite or because of the environmental mismatch, I'll never know. What I do know is I owe at least part of my interest to scattered bits of desert intrigue, most associated with north Africa: the bleak Algerian landscapes of Albert Camus' The Stranger *and the final lines of Percy B. Shelley's "Ozymandias." In this paper, I had the pleasure of exploring these themes in detail, often as a cultural backdrop to desertification's scientific intricacies. As I soon discovered, desertification is much more than an African phenomenon. It is also much more complicated than my romanticized preconception of "lone and level sands" would suggest—and maybe, just maybe, if potential solutions pan out, a lot less foreboding.*

Instructor's Comment: Humans now operate as the greatest agent of ecological change on Earth, with an imprint that extends from the tropics to the poles. Michael Montgomery discusses the complex relationships between the activities, desires, and needs of people, and the process of desertification—the transition of arid lands to an impaired state. Michael's contribution doubled as his final report for EVE 120 (Global Change Ecology), and surpassed in scope and sophistication the typical bounds of a term paper. Using vivid language and

crisp turns of phrase, Michael provides a measured consideration of the history and drivers of desertification, together with a brief but empathetic commentary on its social and cultural consequences. Like many global issues, desertification is rife with nuance; Michael's commentary provides a hopeful indicator that our next generation of citizens is prepared to think coherently and compassionately about such environmental challenges.

—Brian Gaylord, Department of Evolution and Ecology

> *The people are living on the edge, not of a volcano, but of a desert whose power is incalculable and whose silent and almost invisible approach must be difficult to estimate. But the end is obvious: total annihiliation of vegetation and the disappearance of man and beast from the overwhelmed locality.*
>
> E.P. Stebbing, *The Encroaching Sahara, 1935*

Abstract

From classical times to the present, civilization has been haunted by the specter of an insidiously encroaching desert. In its modern scientific articulation, this notion of desertification has generated worldwide concern. Even as scientists and scholars continue to debate desertification's dynamics and causes, its worst threats are being responded to with pragmatic measures, including promoting alternative lifestyles and sustainable agriculture, remediating degraded land, and turning to traditional knowledge as a means of maintaining vulnerable ecosystems.

Introduction

While the phenomenon of desertification is a global one, affecting all six inhabited continents and up to 250 million people (MEA 2005; Reynolds et al. 2007), the history of the term itself begins in early twentieth-century Africa, where French colonial officials and foresters

used it to describe what they perceived as human-caused creation of desert from once-productive forest and cropland (Davis 2004). The most famous such colonial account was that of Andre Aubréville, who wrote in 1949 about erosion and deforestation in the West African Sahel, and who is widely credited with the first formal use of the word "desertification" (Reynolds 2013). But even before Aubréville, the public's imagination had latched onto the notion of a man-made desert. Bolstered by a long-held misconception of north Africa's fertile past as the "granary of Rome," accounts by observers like E.P. Stebbing (1935) helped popularize the mistaken belief that the Sahara itself was an unnatural product of nomadic Arabs and their overgrazing livestock (Davis 2004).

In the 1970s, a series of devastating, drought-induced famines in the Sahel brought desertification international attention, culminating in the 1977 United Nations Conference on Desertification, or UNCOD (Reynolds 2013). The conference marked a first attempt at systematically addressing the problem, but its alarmist tone and the ambiguity of its adopted definition of desertification invited controversy and politicization (Oswald and Harris 2016).

Only in the 1980s and 1990s did the scientific and international community come to understand that desertification was neither as one-dimensional nor as sinister as they had once thought. A more holistic view was taking shape, in which humans were not the sole actors, but especially important contributors in a complex and interdependent system involving natural and anthropogenic climate variability, environmental feedbacks, and sociocultural practices. This view crystallized during the 1992 "Earth Summit" of the United Nations Environment Programme, and has only been augmented since (Oswald and Harris 2016).

Statement of Problem

Despite a history of international attention, desertification remains one of the most acute threats facing arid regions today. Its coupled processes of human and natural landscape transformation take many forms and are made difficult to combat by the presence of regional differences, cultural biases, and multiple causes acting on both long and short time scales.

Key Considerations

Although definitions of desertification vary, at its core the term describes environmental degradation in dryland ecosystems. Drylands, as their name suggests, are characterized by a relative lack of water. They range from hyper-arid deserts to dry sub-humid savannas (MEA 2005), and generally occur in regions with high summer temperatures; episodic, extreme drought; sparse, xerophytic plant cover; strong winds; unstable, nutrient-poor soils; and intense, infrequent rainfall. In most such systems, desertification takes two forms: soil erosion and soil degradation. In both cases, land loses its ability to support life in the way it once did; it loses, in UNCOD's definition, its "biological potential." Erosion can be caused by wind or water, while degradation occurs primarily via salinization and nutrient depletion. Since dryland soils are inherently thin and nutrient-poor, it doesn't take much of either effect to have dramatic consequences (Oswald and Harris 2016).

Historically, most human inhabitants of drylands subsisted on pastoralism (Adhikari 2013). In recent decades, however, globalization and the spread of industrialized agriculture have vastly altered and intensified land use practices. Faced with growing demand for their crops, and equipped with the mechanized tools, artificial irrigation, fertilizers, and genetically modified seeds necessary to cultivate those crops in even the most marginal environments, cash-strapped farmers are increasingly expanding production into regions that may be ill-suited for it. In the short term, this conversion to cropland can be quite profitable, especially when it involves commodity crops like wheat or sugarcane. But often, agricultural intensification has unwanted ramifications. Insufficient fallow periods strip soil of its nutrients (Oswald and Harris 2016). Dams built for water and electricity flood watersheds and decrease downstream water availability (Zafarnejad 2009). Deep plowing exposes fields to erosion. Over-irrigation leads to waterlogging, evaporation, and salinization of soil and groundwater. Overdrafting depletes aquifers of already scarce water reserves (Oswald and Harris 2016). In addition to no longer supporting crops, the loose, degraded soil that results from these processes is easily picked up by wind or water, which can mobilize sand dunes (e.g., the Taklimakan desert; Wang et al. 2008), create dust storms laden with agro-chemicals (e.g., the Aral Sea; Oswald and Harris 2016), and carve unsightly erosion gullies (e.g., Israel's Negev Highlands;

Avni 2005).

Meanwhile, nomadic herders face a dilemma of their own. At the same time as global demand for animal products like cheese and wool is rising, government policies and agricultural expansion give pastoralists less space and less freedom to graze their livestock, leaving little choice but to overstock their herds and keep them in one location for longer periods. This initiates a process of soil degradation, in which overgrazing denudes the surface of vegetation and makes it more prone to erosion, and trampling from animals' hooves compacts the soil and decreases its ability to retain water, thus increasing runoff (Oswald and Harris 2016). In many cases, native grasslands and the wildlife they support are displaced or put at risk; in one extreme example, certain valleys in Israel's Negev Highlands lost up to 90 percent of their floral biomass over 11 years, mostly due to overgrazing and the formation of erosive gullies from inefficient irrigation (Avni 2005). The net effect of these changes is to upset ecosystems' fragile equilibrium, setting productivity and nutrient cycling on a downward spiral and leading ultimately to the "desertified" state that so preoccupied colonial French foresters (Davis 2004).

Yet contrary to certain alarmist connotations of the word "desertification," it is rare that deserts themselves are actually increasing in size or advancing on non-desert regions. Even in areas where that has been the case, such as northwestern China in the latter half of the twentieth century, the trend has proven reversible, and seems more attributable to natural climate variability than anthropogenic forcing (Wang et al. 2008). Similarly, the popular image of the Sahara marching inexorably south toward the Sahel because of human-caused desertification (e.g., Stebbing 1935) has now largely been discredited, with recent work showing contractions and expansions that align with decadal patterns of drought (Nicholson et al. 1998).

In these and other cases, it is becoming apparent that human land use is only part of the problem, and that natural variability is more important than once thought. To continue with the example of northern Africa, it now appears that the Sahara historically cycled between two distinct climate regimes: a humid, "green Sahara," the most recent instance of which ended 5,500 years ago; and the current, hyper-arid phase, or "desert Sahara." The existence of these alternative stable states, and the clear historical precedent for sudden transitions between them, makes it difficult to distinguish between local, human-caused degradation, most

of which is potentially remediable, and longer-term climate shifts (Foley et al. 2003). Similar climatic variability exists in most drylands, both on longer (Fredrickson et al. 1998) and shorter (Wang et al. 2008) time scales than in the Sahara, complicating efforts to identify desertified regions. This uncertainty is further compounded by the presence of numerous poorly understood feedbacks, some involving humans, which may or may not apply to all regions equally. A prime example is the relationship between plant cover, albedo, and precipitation (Foley et al. 2003), which has profound implications for local hydrologic cycles.

Anthropogenic climate change introduces still more complexity and regional variability. Global warming is expected to increase the severity and frequency of droughts across much of the world's drylands, thus making them more vulnerable to desertification (Reynolds 2013); for western China, however, thawing glaciers may actually reverse desiccation in the short term by supplying additional water to lowlands (Wang et al. 2008), a possibility that highlights desertification's often conflicting manifestations.

Regardless of desertification's ultimate trajectory, it is clear that human activities exacerbate it—and it is humans who bear the brunt of its effects. This human dimension, more than the scientific complexities, is what makes combatting desertification so difficult. The majority of people in regions experiencing desertification live in poverty. From collecting firewood to harvesting medicinal plants, their livelihoods intimately depend on ecosystem services their dryland homes provide. When those services are disrupted or diminished, the people suffer. Even though poor land use is often to blame for this degradation, faulting local inhabitants and forcing them to change their lifestyle—as many governments have done (Oswald and Harris 2016; also, see below)—does little to help, and raises numerous questions of its own. For one, who gets to judge a landscape "desertified?" An over-tilled field that appears degraded to a United Nations soil scientist might be an Algerian pastoralist's only hope of feeding his family (Reynolds 2013). Second, who benefits from mitigation, and for what reasons? In former European colonies, for instance, colonial antipathy towards indigenous pastoralists has carried over into present-day politics, with governments in Africa and the Middle East taking advantage of the attention on desertification to rally against political opponents, secure international funding for purported "development" programs of questionable integrity, and forcibly

sedentarize and relocate nomadic livestock herders they deem responsible for the damage (Oswald and Harris 2016). Third, whose voices are heard in the decision-making? Historically, groups most affected are the ones least consulted, due to both physical isolation from bureaucratic centers and cultural marginalization in a globalizing society (Reynolds 2013).

When developing countries attempted to address desertification in the past, usually with help from Western governments and aid organizations, they largely ignored these questions; increasingly, innovative new solutions are proposing answers. The solutions fall into three categories: detecting desertification before or as it is happening, mitigating it once it has begun, and remediating or making use of the land after it has been degraded.

Regarding the first category, at the same time as satellite sensing has greatly improved scientists' ability to detect desertification from afar, the use of social media and online data portals has enhanced identification and mapping efforts on the ground, with an added benefit of encouraging collaboration between scientists, policymakers, and community members (Oswald and Harris 2016). As for mitigating desertification, farmers can be educated about sustainable practices—intercropping instead of monoculture, piped water instead of flood irrigation, contour farming to reduce hillside erosion, construction of ponding banks to catch runoff (Ludwig and Tongway 1995). They can also be encouraged to adopt livelihoods other than agriculture that would relieve stress on the land, such as beekeeping, brickmaking, solar power generation, and ecotourism (Adhikari 2013). In many cases, emphasis is being placed on local, indigenous knowledge that helped communities cope with environmental change before the advent of modern agriculture. Instead of planting water-intensive, non-native cash crops like cotton, farmers are returning to drought-tolerant, traditional ones like dates and cumin (Oswald and Harris 2016). Even in severely desertified landscapes, there are still ways of restoring biological and economic potential, ranging from the radical—cyanobacterial crusts that improve soil stability (Park et al. 2017)—to the practical: reforestation. Ambitious schemes have also been proposed for making use of degraded systems, including using salinized water for aquaculture; Pakistan and Honduras have already implemented such programs (Adhikari 2013).

Not all of these solutions are feasible for every dryland ecosystem. But the diversity of approaches, as well as their interdisciplinary scope,

recognition of complexity, and purposeful effort to involve local stakeholders, is evidence that progress is possible.

Synthesis and Conclusions

One of the most global of environmental threats, and one of the most difficult to pin to a single cause or definition, desertification has long been an issue of scientific contention. Over the last half-century, as our understanding of its dynamics has improved, so too has our ability to craft an appropriate response. Effective programs against desertification should take into account social and biophysical idiosyncrasies; be aware of regional history and cultural biases; and combine methods from multiple disciplines, from economics to biotechnology (e.g., Park et al. 2017), each tailored to specific circumstances.

There will undoubtedly be costs. Dryland agriculture will either have to downscale or dramatically shift its approach. Pastoralists will have to adapt. Perhaps most notably, the required economic investment will be enormous, especially to restore already desertified landscapes, and will come largely contingent on the whims of nations and organizations far removed from affected regions (Reynolds et al. 2007).

Yet, ironically, these challenges may prove to be desertification's greatest strength. Its wide scope and even wider implications, encompassing issues as varied as biodiversity loss, agricultural output, indigenous land rights, poverty alleviation, and anthropogenic climate change, give desertification a global relevance and urgency few environmental challenges possess. Moreover, the very same nuances that make desertification difficult to address make it uniquely suited to international and interdisciplinary collaboration. One can only hope that this combination of exigency and universal interest will continue to spur action and innovation long into the future.

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