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Commentary: Dryland Watershed Restoration With Rock Detention Structures: A Nature-Based Solution to Mitigate Drought, Erosion, Flooding, and Atmospheric Carbon

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A Corrigendum on

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INTRODUCTION

In their paper, the authors describe studies of rock detention structures (RDS) at four properties and create an argument to acknowledge RDS as nature-based solutions (NbS) based on their documented climate mitigation and adaption potential (Gooden and Pritzlaff, 2021). The adoption of national and international strategies to mitigate climate change and accompanying desertification and drought is dependent on decision-makers understanding the significance of impacts, acting on available anticipatory science, and assuring a commitment to financial investments (Bradford et al., 2018). As such in this invited commentary, I provide additional research describing RDS scalability throughout landscapes, perseverance over time, and contributions to a restoration stewardship economy that supports RDS as NbS.

Contemporary studies conducted on RDS span the United States-Mexico border in North America, describe multiple benefits they provide for people (ecosystem services), and are globally applicable to arid land environments (Norman, 2020). The installation of RDS sets biophysical cycles into motion that persist through centuries, providing anticipatory and restorative functions (Norman, 2020). Additionally, RDS allow capacity-building and risk mitigation that can alleviate climate change impacts in socio-environmentally vulnerable regions (Norman et al., 2021a; Norman et al. 2021a; Norman et al., 2021b). RDS provide sustainable NbS to address climate change and can be implemented to protect, sustainably manage, and restore ecosystems (International Union for Conservation of Nature, 2021).

SCALABILITY IN SPACE AND TIME

Over the past 1,000+ years, human populations in the arid North American Southwest have left archeological evidence of RDS across the landscape, but long-term ecohydrological, demographic and socio-economic drivers and impacts have yet to be explored in an integrative and iterative way (J. Dean, University of Arizona, written communication 11/12/2021; Fish and Fish, 1984; Hall et al., 2013; Norman, 2020). The scaling of RDS-NbS interventions and benefits from local to watershed scales and throughout time requires objective science. Researchers are working with land managers and restoration practitioners to establish experiments at multiple RDS installations throughout the Madrean Archipelago Ecoregion of North America to quantify the effects of RDS-NbS on hydrology, ecology, and soil productivity (Fandel et al., 2016; Norman et al., 2016; Norman et al., 2017; Norman et al., 2019; Norman, 2020; Callegary et al., 2021; Coy et al., 2021; Norman et al., 2021a; Wilson et al., 2021; Freimund et al., 2022).

Quantitative models and remotely sensed imagery expand site-based experiments at RDS into larger regional watersheds and allow forecasting and back-casting to extrapolate over time (Norman L. M. et al., 2010; Norman et al., 2014; Norman and Niraula, 2016; Norman et al., 2017; Wilson and Norman, 2018; Norman et al., 2019; Norman, 2020; Norman, 2021; Norman et al., 2021b; Petrakis et al., 2021; Lara-Valencia et al., 2022). RDS support vital ES that address societal problems, including flood regulation; water regulation, purification, and provisioning; habitat provisioning; erosion regulation, carbon sequestration and storage; social value and climate regulation (Norman, 2020; Norman et al., 2021b). These ES protect biodiversity and mitigate climate change with cumulative and multiplicative feedback effects that sustain their positive impacts in the long term (Norman L. et al., 2010; Norman et al., 2014; Norman et al., 2016; Norman and Niraula, 2016; Norman et al., 2017; Norman et al., 2019; Norman 2020; Norman et al., 2021a; Norman et al., 2021b).

WATER AND CLIMATE RESILIENCE INFRASTRUCTURE

The focal paper (Gooden and Pritzlaff, 2021) translates the ecosystem services of rock detention structures (RDS; Norman, 2020) into Nature-based Solutions (NbS) and relates them to sustainable development goals. NbS is a term that is often used to re-frame ecosystem services and green infrastructure projects, to make them more politically palatable (O'Sullivan et al., 2020). Like green infrastructure, RDS rely on vegetation, soils, and natural processes to manage water and create healthier environments. However, unlike green infrastructure, which promotes passive rainwater harvesting to retain water in the built environment, RDS are established to detain water (not retain it) in more remote areas; allowing water to slowly pass through, infiltrate the soils and regenerate landscapes (Norman et al., 2014; Norman et al., 2016; Norman and Niraula, 2016; Norman et al., 2017; Wilson and Norman, 2018; Norman et al., 2019; Norman 2020; Norman et al., 2021a; Norman et al., 2021a; Norman et al., 2021b).

EXAMPLE: COSTS AND BENEFITS

Costs: Check Dams

One of the disadvantages to using RDS is the associated costs and investment needed to secure them. It takes an average of 16 h of labor to install a 1-m-high RDS (check dam; **Figure 1**; J. T. Austin, former owner El Coronado Ranch, oral communication, 12/17/2021; Norman et al., 2022). Approximately 2000 RDS are installed on a remote, 769-ha forested watershed in southeastern Arizona (Norman and Niraula, 2016). Including current wages, equipment, and associated estimates, it costs approximately ~$2,210 per ha to treat a watershed based on this established rate (~2.6 check dams/ha; Callegary et al., 2021).

In this example, I use back-of-the-envelope calculations to roughly extrapolate how much it would cost to preemptively treat all Federal and Tribal riparian areas in the state of Arizona (33,182 ha) with check dams. This ballpark figure entails installing 86,273 check dams with an estimated cost of $73M. For comparison, climate-related disasters in Arizona spurred Legislation of $100M for recovery and support efforts to help deal with damages related to post-fire flooding in 2021 (Office of the Governor, 2021).

Benefits: Ecosystem Services, Economics, and Equity

There are a lot of advantages to be realized from using RDS. Thomas et al. (2016) estimated the economic impacts of restoration associated with Federal lands, to be between 13–32 job-years and $2.2-$3.4M for every $1M spent.

In the example provided above for costs and using economic impacts of restoration documented by Thomas et al. (2016), I estimate the potential return on this ecological restoration investment scenario of installing check dams in Federal riparian areas ($73M) to produce the equivalent of >1,000 job-years and >$160M of economic output to local, regional, and national economies. And, given the durability of RDS, with some ongoing investment in repair and maintenance, the initial investment will provide long-term benefits (Norman L. M. et al., 2010; Norman 2020; Norman et al., 2021a; Norman et al., 2021b).

Based on targeted science research and results of the Aridland Water Harvesting Study (Norman, 2020; Norman et al., 2021a; Norman et al., 2021b), this example scenario (to install ~86,273 check dams in Federal riparian areas of Arizona) could also:

✓ sequester ~7.5 M tons [0.0075 Pg (7.5 Tg)] of atmospheric C in the soil storage (Norman and Niraula, 2016; Callegary et al., 2021);
✓ maintain or increase vegetation and biomass—with extended growing seasons and using stored soil moisture (Norman et al., 2014; Wilson and Norman, 2018; Wilson et al., 2021), further increasing C sequestration;
✓ extend ephemeral duration and surface-water availability (Norman et al., 2016; Norman and Niraula, 2016; Norman et al., 2017);

FIGURE 1 | Author sitting on a 30-year-old check dam installed at the El Coronado Ranch study area, Chiricahua Mountains, southeastern Arizona, United States (photo by Gerry Norman, Oct. 2021).

✓ mitigate floods and associated emergency response expenditures (Norman L. M. et al., 2010; Norman L. et al., 2010; Norman and Niraula, 2016; Norman et al., 2021b; Freimund et al., 2022);
✓ promote lateral flows and onsite storage of water (Fandel et al., 2016; Fandel, 2016; Norman et al., 2016; Norman et al., 2019);
✓ control erosion and nonpoint source pollution, improving water quality (Norman L. M. et al., 2010; Norman L. et al., 2010; Norman and Niraula, 2016; Norman et al., 2017; Norman et al., 2019); and
✓ reduce ambient temperatures (Norman et al., 2021).

Water-related ES in drylands also increases the quality of life for socio-environmentally vulnerable communities (Norman L. et al., 2010, Norman et al., 2012; Norman et al., 2013; Villarreal et al., 2013). A restoration economy, based on improved hydrology in degraded waterways and associated riparian areas, can also be created that improve lives and livelihoods in restored areas (Adams, 2016; Norman et al., 2021a; Norman et al., 2022).

DISCUSSION

Over the past decade, a multi-disciplinary landscape-scale study has quantified anticipatory and restorative watershed functions of Rock Detention Structures (RDS) installed in the Madrean Archipelago Ecoregion of North America (Norman, 2020). In this commentary, I reference these larger temporal and spatial study extents to underpin RDS interventions as Nature-based Solutions (NbS) as presented in Gooden and Pritzlaff (2021), that restore dryland channels with impartial shares of social, environmental, and economic benefits.

Our planet needs solutions to mitigate impacts from our rapidly changing climate, and the ecosystem services of RDS justify the inclusion as NbS, useful to increase carbon storage and sequestration, increase water quality and quantity, buffer flood events, improve vegetation health and biodiversity, and help address global warming (Norman 2020; Norman et al., 2021a; Norman et al., 2021b). The focal paper proposes RDS as a feasible, cost-effective NbS that can contribute to climate mitigation (Gooden and Pritzlaff, 2021).

RDS-NbS are already being used to enhance preparedness, response, and resilience in vulnerable communities along the United States-Mexico border, where a restoration stewardship economy fosters hope, nourishes livelihoods, and establishes valuable ecosystem services via grassroots efforts (Norman et al., 2021a). Investments in RDS-NbS avert risk, damage, and cost associated with drought and flooding (Norman L. et al., 2010; Norman et al., 2014; Norman et al., 2016; Norman et al., 2019; Norman et al., 2021b). Moreover, capital appreciation, described herein, can double or triple restoration investments on Federal lands (Thomas et al., 2016), RDS-NbS provide a huge suite of benefits, and the structures can persist for millennium (Norman 2020).

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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