SRM Society for Range Management

Using Science to Bridge Management and Policy: Terracette Hydrologic Function and Water Quality Best Management Practices in Idaho

By Mark V. Corrao, Barbara E. Cosens, Robert Heinse, Jan U.H. Eitel, and Timothy E. Link

On The Ground

- Nonpoint source (NPS) pollution is a leading cause of water quality degradation on 40% of the semiarid lands within the western United States, with sediment from runoff on agricultural lands making up 15%.
- Managing NPS pollution through best management practices (BMPs) relies on site-specific knowledge and voluntary application.
- The dominant hydrologic processes in semiarid environments are a product of local climate, vegetation, and soil conditions; therefore, land use and ecosystem resilience invariably hinge on a balance of shifting, and often competing, social and environmental drivers.
- Our measurements of terracette hydrologic function and existence on more than 159,000 hectares within Idaho enabled an estimate of potential NPS erosion and sediment generation, emphasizing the value of site-specific scientific research for land managers.
- Our study provides an example of how microtopographic landforms, such as terracettes, are connected with state and federal clean water policy as one example of how interdisciplinary research can have far-reaching application.

Keywords: rangelands, terracettes, erosion, water, policy, best management practices.

Rangelands 37(5):191–199
doi 10.1016/j.rala.2015.08.003

Nonpoint source (NPS) pollution, as defined within the U.S. Clean Water Act (CWA) amendments of 1972, is described as nutrient, temperature, or sediment inputs by nondiscrete sources to public water ways and is currently the leading cause of water resource degradation within the United States.[1] Degraded waters within the United Sates are identified by the states and listed under section §303(d) of the CWA. The U.S. Environmental Protection Agency (EPA) has stated that nearly 40% of NPS pollution in the country is attributed to agricultural activities, with sediment comprising approximately 15% of that total.[1] Within Idaho, there are 27,481 stream kilometers listed as impaired by NPS pollution according to the Idaho Department of Environmental Quality.[2]

The mitigation of NPS pollution is currently through the application of "preferred actions," promulgated by the EPA and defined by the CWA as best management practices (BMPs).[i] BMPs have been extensively developed with the agricultural community through problem assessment, examination of alternative practices, and public participation to help mitigate the human impacts of land use on water quality.[3] All BMPs are applied in a process of give-and-take negotiation by local conservation districts and landowners on a strictly voluntary basis,[3,4] supported by an array of management guidance documents and funding available through many federal, state, and local sources. Therefore, application of BMPs to reduce NPS pollution, such as runoff-derived nutrients or sediment, remains at the sole discretion of local interests and private landowners unaided by a regulatory framework. The successful application of BMPs hinges on site-specific knowledge and the adoption of recommended practices by landowners,[5] conservation districts, and local interest groups.

Nearly 40% of the semiarid land in the western United States is managed as rangelands,[6,7] with grazing representing the single largest land type designation.[8] Since the 1940s, the number of cattle in the western United States has expanded by more than 60%, whereas the private acreage of rangelands (not counting public leases) has decreased by more than 15%.[9] Within Idaho, 6 million hectares (ha) (approximately 28%) of public lands are managed as grazing allotments, and nearly all

[i] For more on BMPs in the CWA, see section 319(b) of the Federal Water Protection Control Act (aka Clean Water Act).

are semiarid. On pasture lands such as these, animal stocking rates and erosion are of primary concern, often leading to management efforts focused on vegetation composition and biomass production.[10] Management of grazing land production often coincides with managing NPS pollution facilitated by the application of BMPs. Managers in semiarid lands also understand the continual challenges they face, resulting, in part, from the complexity of site-specific conditions and variable local climate.

Hydrologic research in semiarid ecosystems has been extensive, given the importance of water, vegetation, and topography on land use. At the hillslope scale, interactions of microtopography, soil properties, and soil water play a significant role in runoff, erosion, and vegetative growth.[11,12] Understanding these complex hydrologic interactions at the pasture scale is critical to the successful application of BMPs, given the influence they have on water quality through the suppression or amplification of NPS pollution. The role of water in land use, as well as a key variable in ecosystem function,[13] was the driving motivation behind our research aimed at improving our understanding of the effects of terracettes on vadose zone hydrologic processes. Our work represents a baseline mechanistic understanding of terracette hydrology and, coupled with a statewide survey of terracette occurrence, led to (1) a discussion of terracette-influenced soil water on semiarid rangelands, (2), an estimate of potential NPS pollution (soil loss) as a result of terracettes, and (3) potential implications for rangeland management.

Terracettes and Semiarid Rangelands

Microtopographic features referred to as "terracettes"[14] are repetitious "bench" (path-like) and "riser," (slope-like) features common in semiarid environments such as those throughout the western United States[15] (Fig. 1). The soil conditions of terracette benches and risers in active pasturelands are often impacted by animal use, resulting in altered vegetative cover and soil compaction.[16] For example, high cattle stocking densities on terracette sites primarily increase soil compaction on bench surfaces, with the degree of compaction being influenced by soil texture and water conditions.[16–18] Consequently, highly compacted soil conditions decrease the root growth ability of many plants, thereby reducing overall site vegetation,[19] which can lead to increased soil water at field capacity as a result of less plant transpiration and altered soil pore structure.[18,20] Vegetation is vital to rangeland use as feed for grazing animals[10] and, in the presence of semiarid terracettes, for reducing hillslope runoff by increasing infiltration at the outer edge of benches.[11] The hydrologic interactions of terracette features may be significant in reducing erosion[21] and increasing the amount of soil water on hillslopes[22] in semiarid rangelands within the western United States through the ability of these microtopographic features to impede surface runoff.[11] The significance of this may be that microtopographic landforms are capable of reducing NPS pollution when managed under human-ascribed BMPs.

Figure 1. Semiarid rangeland terracettes near Clarkston, Washington, on the north bank of the Snake River, March, 2014 (Photograph by Mark Corrao).

Assessing the Hydrologic Function of Terracettes in Idaho

Mean (30-year average) annual precipitation and temperature for our study area were 312.7 mm and 11.7°C, respectively. We measured field conditions (e.g., soil water content, soil texture, compaction, infiltration, and vegetation cover) at two terracette (east aspect, moderate/low cattle stocking density – EMD; and west aspect, high cattle stocking density – WHD) and two non-terracette sites (grazed and ungrazed) from 2013 to 2015[17] (Fig. 2 and Tables 1 and 2),[17] with the goal of capturing changes in transitional-period soil moisture by using soil core, soil probe, and penetrometer sampling methods. We also surveyed vegetative cover, bare earth, and rock and litter percentages during June 2013 at all sites. The two terracette field sites exhibited differing aspects, bench and riser dimensions, cattle stocking densities, and site characteristics (see Table 1).[17]

Subsequent field assessments provided detailed topographic surveys of both terracette sites through multiple scans from a Leica ScanStation II terrestrial laser scanner (TLS), merged into one layer to minimize terrain shadowing, for the creation of digital terrain models (DTMs) to characterize bench and riser morphology.[17] Laser scanning results were cross-referenced with manual measurements of terracette feature profiles from three transects across each site. Based on the TLS-derived DTMs, we calculated the relative area of benches and risers within each site. We used multivariate analysis of variance (ANOVA) to test for differences in soil water and compaction between features within each site and between sites. Two-sample, equal-variance Student's t tests[ii] were used to assess the statistical significance of differences in soil water and compaction among more than 100 benches and risers under differing site conditions. Based on t test results comparing benches and risers,[iii,17] we hypothesized that

[ii] $\alpha < 0.05$.

[iii] $P < 0.000$.