Agriculture, Ecosystems and Environment 240 (2017) 32–44

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Evaluating the ranch and watershed scale impacts of using traditional and adaptive multi-paddock grazing on runoff, sediment and nutrient losses in North Texas, USA

Jong-Yoon Park[a,b], Srinivasulu Ale[a,*], W. Richard Teague[a], Jaehak Jeong[c]

[a] Texas A&M AgriLife Research (Texas A&M University System), 11708 Highway 70 South, Vernon, TX 76384, USA
[b] Korea Environment Institute, 370 Sicheong-daero, Sejong, 30147, Republic of Korea
[c] Texas A&M AgriLife Research (Texas A&M University System), 720 East Blackland Road, Temple, TX 76502, USA

ARTICLE INFO

Article history:
Received 17 September 2016
Received in revised form 22 January 2017
Accepted 3 February 2017
Available online 17 February 2017

Keywords:
APEX
Continuous grazing
Hydrologic response
Rotational grazing
Rangeland management
Water balance
Water quality

ABSTRACT

Grazing management practices have a significant influence on ecosystem services provided by rangelands. An assessment of hydrologic and water quality impacts of traditional and alternate grazing management practices facilitates adoption of best management practices for long-term sustainability of rangelands. A study was conducted to quantify the runoff, sediment and nutrient losses under traditional continuous and adaptive multi-paddock (MP) grazing management practices in the rangeland-dominated (71% rangeland) Clear Creek Watershed (CCW) in north Texas in the United States using the Agricultural Policy/Environmental Extender (APEX) model. The model was calibrated and validated using observed herbaceous plant biomass and daily soil moisture data at four study ranches in the CCW [two under MP grazing and one each under light continuous (LC) and heavy continuous (HC) grazing practices], and using monthly streamflow, sediment, total nitrogen (TN) and total phosphorus (TP) data measured at the watershed outlet. Both ranch- and watershed-scale results indicated a strong influence of the grazing practice on runoff and water quality. When the grazing management was changed from the baseline MP to HC at one of the study ranches, the simulated average (1980–2013) annual surface runoff, sediment, TN and TP losses increased by 148%, 142%, 144% and 158%, respectively. At the watershed-scale, changing grazing management from the baseline HC to adaptive MP reduced the average annual surface runoff, sediment, TN and TP loads at the watershed outlet by 39%, 34%, 33% and 31%, respectively. In addition, implementation of adaptive MP grazing reduced streamflow during the high flow conditions that have $\leq$10% exceedance probability, by about 20%, and hence reduced the chances of flooding downstream of the watershed. Adaptive MP grazing was therefore found to be an effective conservation practice on grazing lands for enhancing water conservation and protecting water quality.

1. Introduction

Rangelands occupy approximately a third of the earth's land area, providing ecosystem services upon which the well-being of human societies depend (Millennium Ecosystem Assessment, 2005). They consist of natural plant communities that predominantly support livelihoods based on livestock production. Among the most important ecosystem services they provide are the maintenance of stable and productive soils by minimizing soil erosion and secure supply of clean water (Ragab and Prudhomme, 2002). Due to widespread overgrazing, many of the earth's rangelands are degrading with corresponding reduction in vegetation and soil physical and hydrological properties that are attributable to soil erosion and water pollution in rivers and water storage facilities (Nelson et al., 1996; Gerrish, 2004; Krzic et al., 2006; Teague et al., 2011). There is a need to investigate which land management can regenerate or maintain soil and watershed function and ecological resilience (Schepers and Francis, 1982; Owens et al., 1989; Teague et al., 2013).

The most common practice of grazing management is continuous grazing that is usually heavily stocked without adjustments in stock numbers in years of low production (Moreno García et al., 2014). The damage caused by this widespread practice is further exacerbated by using supplementary feeds to artificially maintain stock numbers during these periods (Diaz-Solis et al., 2009; Müller et al., 2015). While rangeland academics widely

* Corresponding author.
E-mail addresses: sriniale@ag.tamu.edu, Srinivasulu.Ale@gmail.com (S. Ale).

http://dx.doi.org/10.1016/j.agee.2017.02.004
0167-8809/

advocate the use of continuous grazing with low stocking rates to reduce the damage caused by heavy continuous grazing (Briske et al., 2008), there is much evidence that adaptive multi-paddock (MP) grazing is necessary to reverse the damage caused by continuous grazing (Teague et al., 2011, 2013; Müller et al., 2015). Adaptive MP grazing involves rotating livestock among multiple paddocks to distribute grazing pressure over the whole landscape of the ranch, better control grazing amounts, and ensure adequate recovery of grasses after grazing in the paddocks. During periods of low productivity, animal numbers under adaptive MP grazing are adjusted down to match available forage, and supplementary feeding is provided only to correct for forage quality, not quantity. If managed effectively, adaptive MP grazing can improve the range resource, and thus carrying capacity and profitability.

Previous field studies that evaluated various grazing management practices reported that the runoff, soil erosion and nutrient losses from continuously grazed pastures were generally higher than those under the adaptive MP grazing, where forage is usually better managed to avoid overgrazing (Weltz and Wood, 1986; Pluhar et al., 1987; Ritter, 1988; Mathews et al., 1994; Sovell et al., 2000; Stout et al., 2000; Haan et al., 2006; Webber et al., 2010; Schwarte et al., 2011; Teague et al., 2011). However, these studies focused mainly on assessing the impacts at the ranch-scale and a thorough evaluation of the effects of alternate grazing management practices on water catchment functions and water quality at the watershed-scale is needed to determine the best grazing management practices that contribute positively to the provision of numerous rangeland ecosystem services.

Where appropriate field data that meet statistical assumptions are available for a long term, statistical techniques and hydrologic and water quality models are useful to develop inference between hydrologic/water quality parameters and variables (Zhou et al., 2011). A properly validated model can be used as a fast and cost effective way of evaluating impacts of various agricultural practices on hydrology and water quality (Li et al., 2014). Among various models available for simulating the impacts of grazing management practices, the Agricultural Policy/Environmental eXtender (APEX; Williams and Izaurralde, 2006) model and the Soil and Water Assessment Tool (SWAT; Arnold et al., 1998) have been widely used. The APEX model was specifically developed to evaluate various land management strategies considering sustainability, economics, erosion, water supply and quality, soil quality, and plant competition in whole farm and/or small watershed (Williams et al., 2012). It has been used extensively for a wide range of livestock-related farm and nutrient management (manure and fertilizer) scenario analyses (Gassman et al., 2005) and environmental impact assessment studies (Osei et al., 2000, 2003a,b), and in an economic-environmental modeling system developed for a National Pilot Project (NPP) (Gassman et al., 2002). However, these studies focused on assessing the impacts of several agricultural practices including grazing management, and studies solely evaluating grazing management impacts on hydrology and water quality are lacking.

The overall goal of this study was to assess the effect of alternate grazing management practices on runoff, sediment and nutrient losses from the rangeland-dominated (71% rangeland) Clear Creek Watershed (CCW) in north central Texas in the United States (U.S.). The specific objectives were to: (1) develop a methodology to effectively simulate continuous and rotational grazing management practices in the APEX model, (2) calibrate the APEX model for the CCW using measured (herbaceous) plant biomass, soil moisture, streamflow and water quality data, and (3) assess the ranch and watershed scale impacts of alternative grazing management practices on water balances and water quality. Three

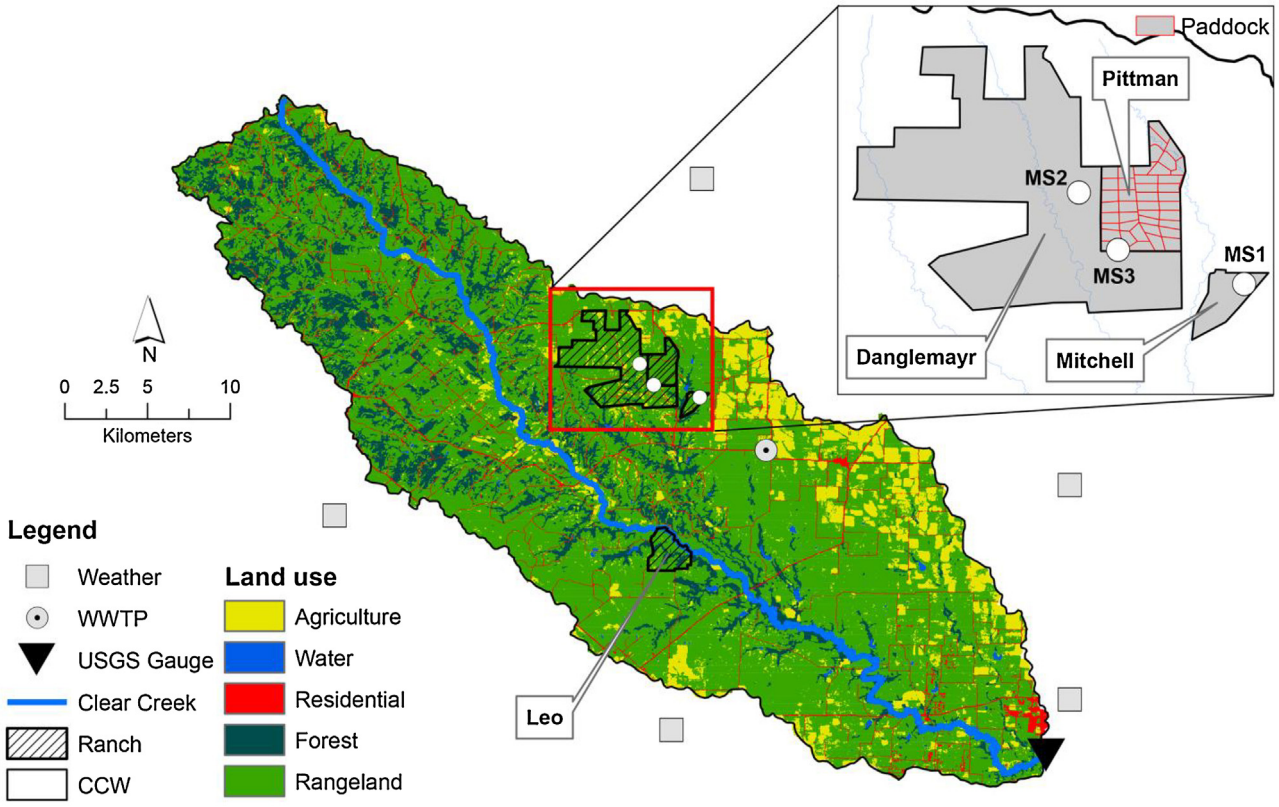

Fig. 1. Map showing the locations of four study ranches, three soil moisture and plant biomass monitoring sites (MS1 through MS3), five weather stations, Era waste water treatment plant (WWTP) and USGS streamflow and water quality gauging station in the Clear Creek Watershed (CCW) along with the 2011 land use in the CCW.