Factors Controlling Infiltration Rates in a Semi-Arid Landscape

Britton Mosley, Jr.*, Francis Rengers+ , Gregory Tucker+
*Department of Geoscience, Jackson State University, Jackson, MS; +Department of Geological Sciences, University of Colorado, Boulder, CO

Introduction

Gully erosion has societal impacts including the destruction of infrastructure, and high sediment delivery. Gully erosion can remove fertile topsoil, undermine roads and bridges, and reduce water quality by delivering fine sediment to downstream waterways. Gullies are formed from runoff erosion following flash floods caused by severe thunderstorms. We hypothesize that runoff is the main mechanism in creating gullies, thus we have investigated how runoff varies across our landscape. We made infiltration measurements at different locations across our study area to determine the generation of run-off. These infiltration measurements allowed us to develop infiltration rate curves that allow us to estimate how infiltration will vary temporally and spatially. The infiltration measurements are a first step towards understanding the role of surface water runoff on gully erosion.

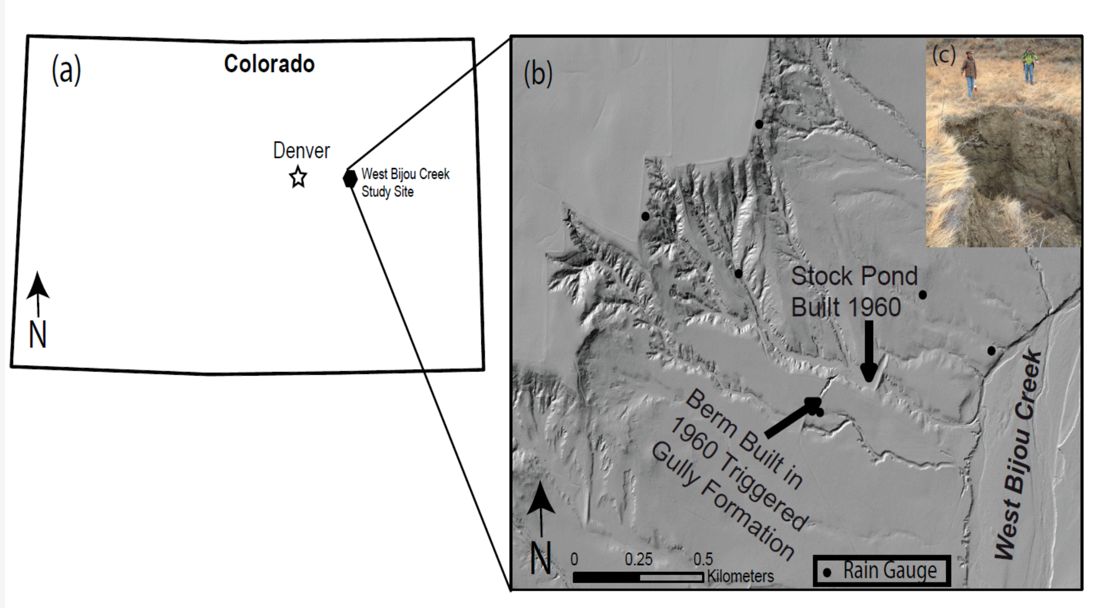

Figure 1. The map on the left is a) the location of West Bijou Creek Study Site, 40 miles SE of Denver, Colorado. b) A LiDAR DEM map of West Bijou Creek and an event that contributed to a gully erosion. c) A photograph of a gully head cut.

Materials & Methods

Using a double ring infiltrometer, we measured infiltration rates at 15 locations that consist of different underlying rock types, vegetation conditions, and different topographic settings. In order to determine how infiltration capacity varies with soil, topography, and vegetation, we grouped our measurement sites into the following categories:

- Bare sandstone derived soil
- Bare shale derived soil
- Grass covered alluvial terrace surface
- Valley floor upstream of headcut
- Valley floor downstream of headcut

To perform an infiltration test using an infiltrometer, we followed the following steps:

- Install double ring infiltrometer 25 – 50mm into the ground.
- Place a ruler or measuring tape inside of the inner ring.
- Pour 710 mL of water into the inner ring and 2120 mL of water into the outer ring. Record water level of the inner ring.
- After the water level falls 1cm in the inner ring, pour 170 mL of water into the inner ring and 530 mL into the outer ring to keep a constant pressure head.
- Repeat the steps above until you observe a constant rate of infiltration between multiple falling head intervals. Record data.

Figure 2: A grassy terrace with a double ring infiltrometer installed to perform an infiltration test. The bar with the red handles is used to push the rings into the surface. The pink flag marks the GPS location of the site.

Results

Infiltration rates varied over different locations (Figure 3). The lowest rate was 39 mm/hr. The highest infiltration rate was 402 mm/hr, which was the site named 'Gully Upstream Low' (Table 1).

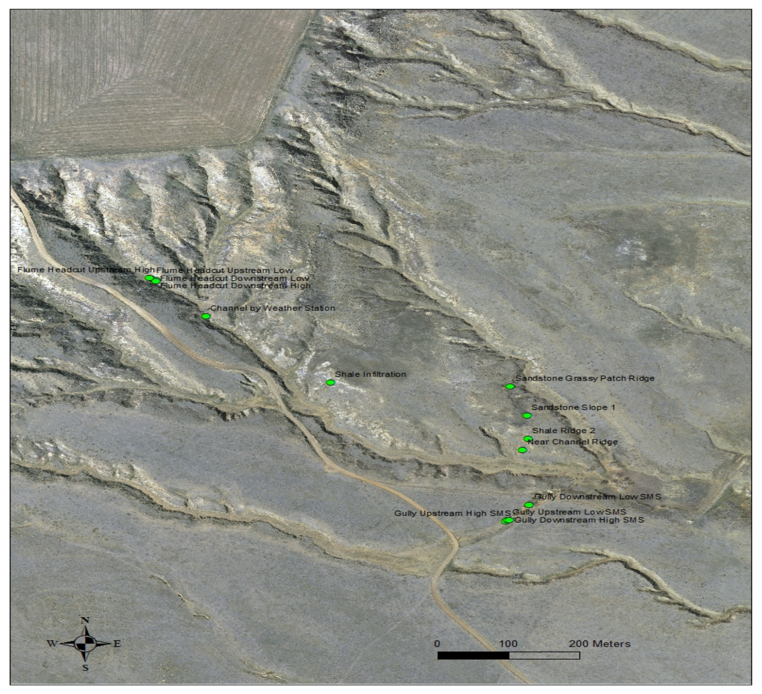

Figure 3: A map of the 15 different locations where infiltration measurements were taken with a double ring infiltrometer over the West Bijou Creek site.

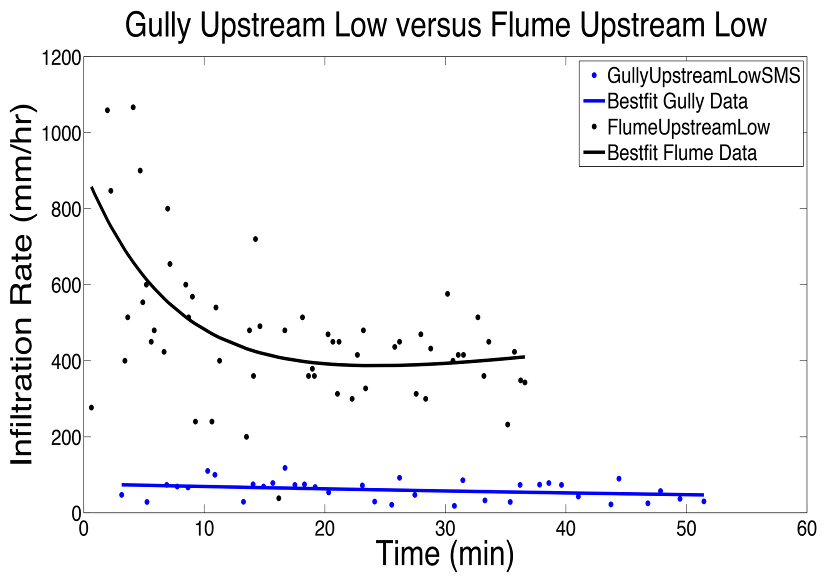

Figure 4: The comparison graph of two gullies at different locations. The location is 2 meters upstream of a headcut on each gully. The constant rates of infiltration for the site 'Gully Upstream Low' is 402 mm/hr. The constant rate for the site 'Flume Upstream Low' is 39.1 mm/hr.

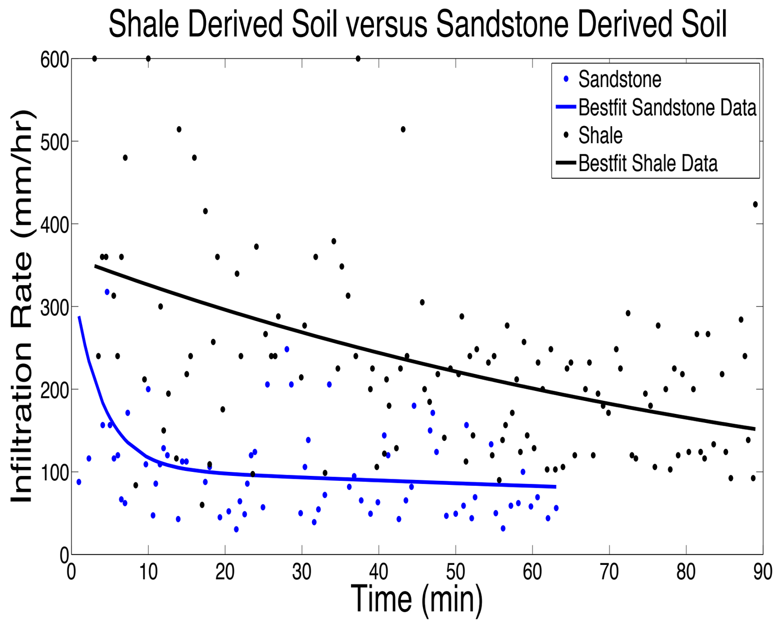

Figure 5: The comparison graph of sandstone and shale bedrock at different locations. Both locations were located on hillslopes.

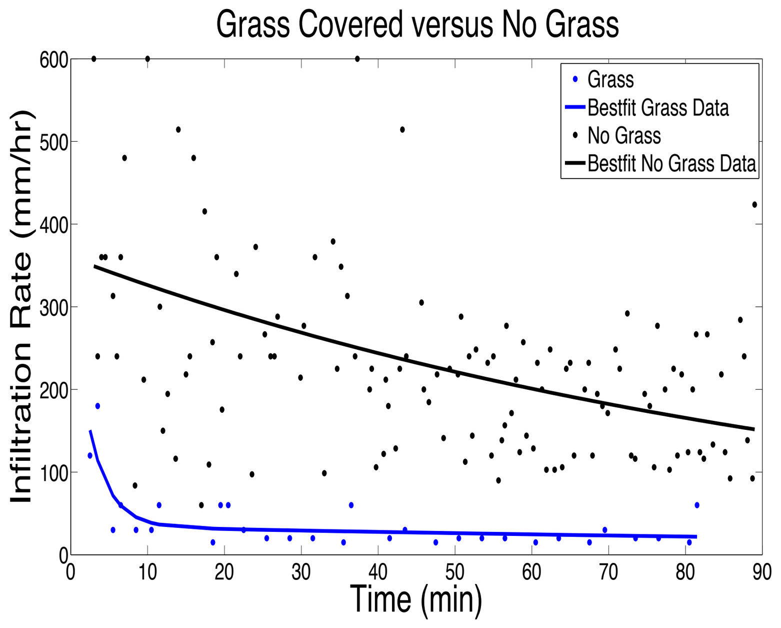

Figure 6: The comparison graph of a grassy area and an area without grass (the shale derived soil).

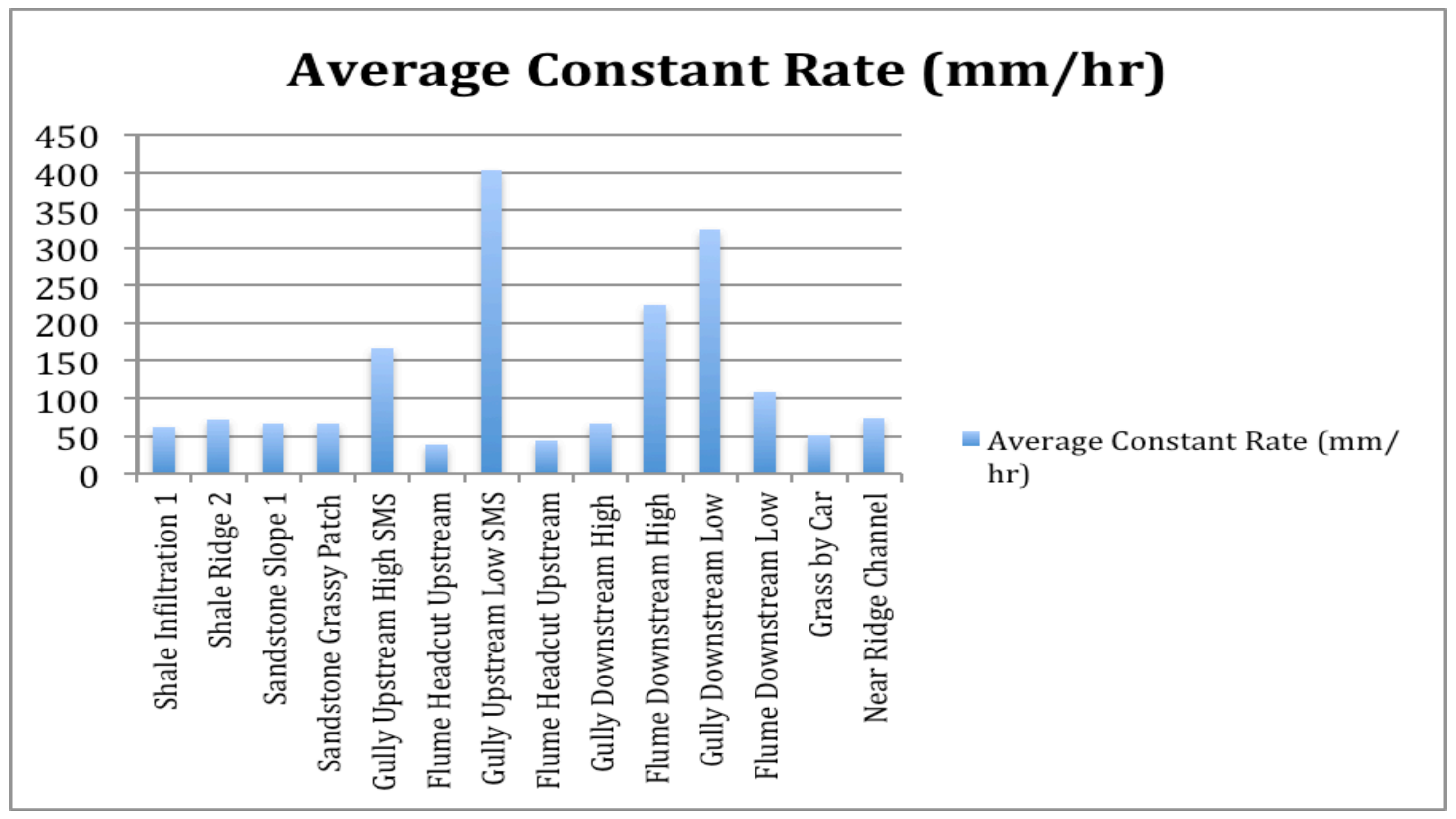

Figure 7: A bar chart showing the spatial variations in the infiltration rate at 14 of the 15 locations where infiltration tests were performed.

Name	Infiltration Rate (mm/hr)	Characteristics
Shale Infiltration 1	61.1 mm/hr	Shale
Shale Ridge 2	72.8 mm/hr	Shale
Sandstone Slope 1	66.6 mm/hr	Sandstone
Sandstone Grassy Patch	66.6 mm/hr	Sandstone
Gulley Upstream High SMS	166.3 mm/hr	Grassland
Flume Headcut Upstream High	39.1 mm/hr	Grassland
Gulley Upstream Low SMS	402 mm/hr	Grassland
Flume Headcut Upstream Low	43.2 mm/hr	Grassland
Gulley Downstream High SMS	66.6 mm/hr	Grassland
Flume Headcut Downstream High	224.7 mm/hr	Grassland
Gulley Downstream Low SMS	323.2 mm/hr	Grassland
Flume Headcut Downstream Low	108.0 mm/hr	Grassland
Grass by Car	50.7 mm/ hr	Grassland
Near Ridge Channel	74.4 mm/hr	Grassland
Shade Tree 1	62.3 mm/hr	Grassland

Table 1: A table of variations for each constant rate at all locations where infiltration tests were performed. The locations are distinguished in soil types and land cover.

Conclusion

Our data indicate that the highest infiltration rates at our study site can be up to 10 times larger than the lowest infiltration rates. We observed that shallow soils overlying bedrock had similar infiltration rates, but there is a large difference in the infiltration rate between a grass covered terrace and a shallow soil. The shallow soil actually infiltrated more than the grass surface probably due to the availability of macropores in the cracked soils. There was a very high variability in infiltration rates in two similar soils upstream of a gully headcut (Figure 4). We attribute these differences to vertical cracks in the soil at one location and not the other.

The variability across the landscape means that the amount of surface runoff available to create gullies is largely dependent on the type of soil vegetation upstream of a gully. Moreover, on our study site, we expect to see the highest runoff rates on grassy terraces and bare soils.

These results are helpful in understanding how to realistically model gully systems. We have determined that using a constant infiltration rate across an entire landscape would be invalid. This field work should ultimately help us to understand the complex dynamics of gully erosion.

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