Print

Proceedings

Monitoring headcut migration over four decades on a rangeland area in the southwestern United States

Dirk H. Rieke-Zapp[1], Mary H. Nichols[2], and Christine Läderach[1]
[1]Institute of Geological Sciences, University of Bern, Switzerland;
zapp@geo.unibe.ch, chris_laedi@students.unibe.ch
[2]USDA-ARS Southwest Watershed Research Center, Tucson, AZ 85719, USA;
mnichols@tucson.ars.ag.gov

Abstract
Many semiarid rangelands across the southwestern United States are characterized by gullies and advancing headcuts. Recent gully formation is largely a response to general down cutting across the region that occurred in the 1880s in combination with intense land use through grazing and general variability in climate patterns. Headcut advance is proportional to the upstream contributing area of tributaries and therefore, is expected to slowdown over time. Today, some gullies and headcuts remain active. One active headcut in the Walnut Gulch Experimental Watershed was surveyed in spring of 2004. The data were compared to survey records dating back to 1966, 1973, 1977, and 1981 for calculation of the long term migration rates of the headcut and to estimate the volume that was eroded between 1966 and 2004. Headcutting remains a major sediment source in this climate region that is characterized by torrential rainstorms in the summer.

Introduction
The Walnut Gulch watershed is a tributary of the San Pedro River located near Tombstone, AZ. The semiarid climate of this region is characterized by torrential rainstorms of short duration and local extent in the summer. It is typical for the rangeland of the south western United States. Gully growth and headcutting are evident throughout the region and have been surveyed at irregular intervals since 1966 (Osborn and Simanton, 1986). A large active headcut in the 200 ha subwatershed 63.011 of the Walnut Gulch watershed was surveyed 1966, 1973, 1977, and 1981 to determine the rate of gully and headcut development, as well as the proportional headcut contribution to the total watershed sediment yield. Osborn and Simanton (1986) estimated that approximately 25% of the total sediment load of subwatershed 63.011 was produced by headcutting. Although the headcut remained active, the last survey to monitor headcut development was undertaken in 1982. Records of the 1982 survey were not available for this study.

Approximately 40 years after the headcut was first surveyed in 1966, new data have been generated in the spring 2004. Existing map data have been imported into a geographic information system (GIS) for detailed topographic analysis of the area. We will discuss the development of the headcut in subwatershed 63.011 over the last 40 years.

Materials and methods
Hand drawn paper maps of the surveys from 1966, 1973, 1977, and 1981 were scanned; elevation readings and breaklines in the scans were digitized in a GIS. Data collection and map preparation of the existing maps was done by several different people. Therefore, the amount of detail, and the information provided varied on the map sheets. All maps show breaklines of the headcut for the given year of the survey. In addition to that elevation readings have been taken in the area affected by the headcut. The vertical datum was set to

the relative elevation of two benchmarks; a local coordinate system was used as the horizontal datum.

The global coordinates of the two benchmarks are known in the North American Datum projection of 1983 (NAD1983). The scanned maps were georeferenced in ArcGIS 9.0 software. All GIS data were referenced to the NAD 1983 which is based on the Universal Transverse Mercator projection in Zone 12 North. The vertical datum of the scanned maps was adjusted from measurements originally recorded in decimal feet to meters to fit with the horizontal datum.

The paper maps were drawn by hand, based on a terrestrial survey measuring directions and distance to a measuring rod. The point density close to the breakline of the headcut was much denser than in the area around the active rim of the headcut. Most detail was recorded in the 1966 survey.

The survey of 2004 was based on aerial images taken from a helicopter. The ground sampling density per pixel was approximately 0.025 m. The block of overlapping stereo imagery was used to measure a digital elevation model of the area, by manual 3-d digitizing in Stereo Analyst of Leica Photoghrammetric Suite 8.7 software. Approximately 2000 XYZ coordinates were collected to cover the topography of the active headcut as well as the surrounding area in great detail. A digital orthophoto of the headcut area was generated from the images (Fig. 1).

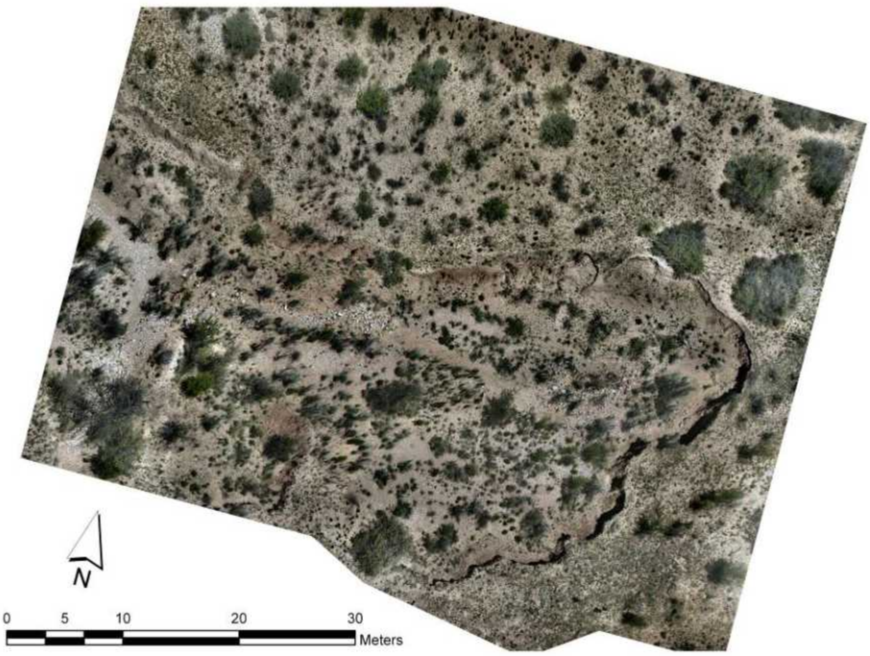

Figure 1. Digital orthophoto of the headcut in subwatershed 63.011. Images were taken in the spring 2004.

Standard GIS routines were used to calculate digital elevation models (DEMs) for each year of survey. The current data set allowed to calculate the volume removed in the active area of the headcut, as well as headcut retreat with time.

Results

From 1966 to 2004 the headcut remained active and retreated approximately 51 m (Fig. 2; Table 1). The rate of headcut growth (m²) since 1981 is less than from 1966 to 1976. The volume that was removed shows the same trend (Table 1). The headcut was more active during the early stages of the measurements.

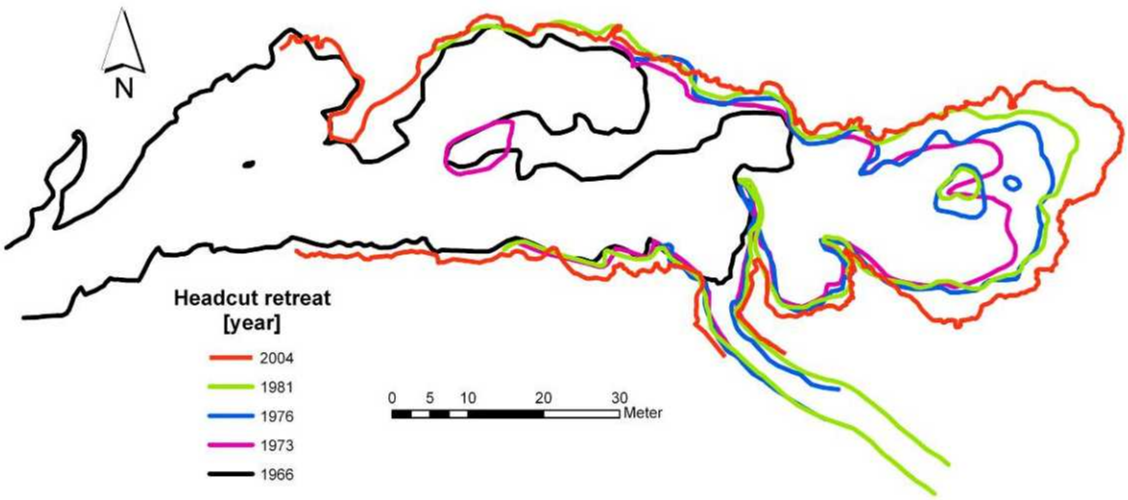

Figure 2. Headcut retreat fro 1966 to 2004. Shown are the breaklines of the active headcut for each year.

Table 1. Heacut changes between surveys.

Time interval	Growth rate [$m^2 a^{-1}$]	Removed volume [$m^3 a^{-1}$]	Retreat rate [m]
1966 - 1973	109	164	34
1973 - 1976	59	83	7
1976 - 1981	39	45	5
1981 - 2004	14	11	5

The headcut is growing towards East. Extension to the sides was less than 3 m in 40 years. Difference DEMs revealed that the material that was eroded in the active area of the headcut between 1966 and 2004 was not completely flushed out of the system, but was accumulated in the area below the active headcut (Fig. 3).

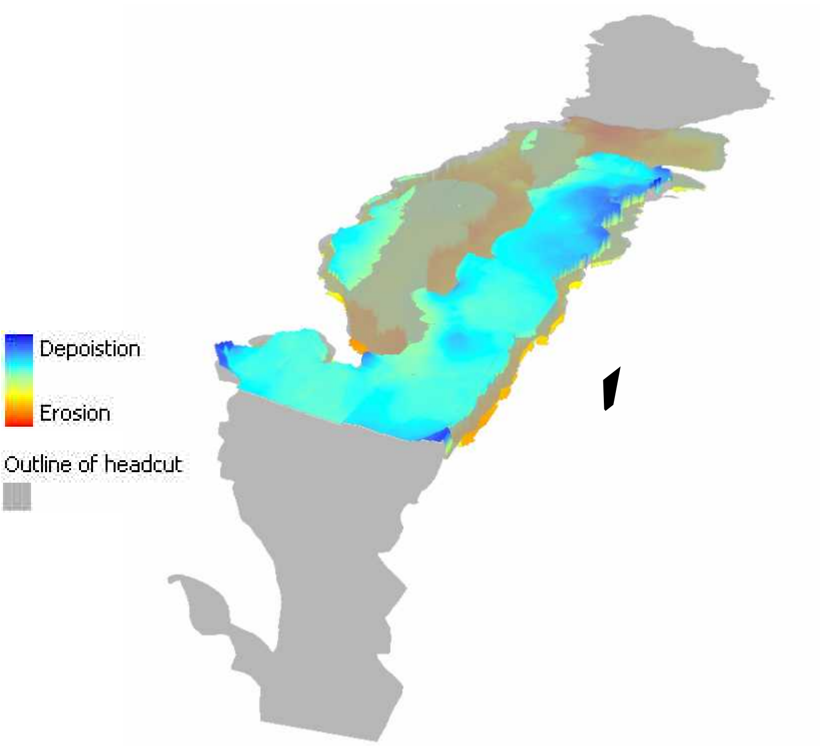

Figure 3. Accumulation of sediment in the area below the active headcut comparing DEMs of 1966 and 2004. The analysis was only possible for the overlapping area of the surveys from 1966 and 2004.

Discussion

The presented headcut remained active over the last 40 years. The rate of headcut growth and the removed volume decreased by almost one order of magnitude during the same period of time. The removed volume was not flushed out of the watershed, but accumulated in the area just below the active headcut. The material might be mobilized during extreme rainfall events or may serve as a continuous source of sediment, even with the headcut retreat rate slowing down with time. The drop height of the headcut's edge was approximately 2 m in 2004. When the headcut is retreating towards the headwaters of the subwatershed, the contributing drainage area is reduced at the same time. While it can be assumed that the headcut remains active in the future, we believe that the importance of headcutting itself will decrease and re-mobilization of eroded material stored below the active area will be a greater impact in the future.

Conclusion

The presented headcut is still active, but has lost momentum over the last 40 years. Re-mobilization of sediment stored below the active area might become a major sediment source while sediment eroded by backcutting will become less significant at the watershed scale. More headcuts in the area have been surveyed for long time spans. Extending the analysis on a wider variety of headcuts in this area will provide a broader data base for analysis.

Literature

Osborn, H. B., and J. R. Simanton 1986. Gully Migration on a Southwest Rangeland Watershed; Journal of Range Management 39(6): 558-561.