Using an Experimental Landscape to Develop a Regional Ecosystem Services Approach to Watershed Restoration

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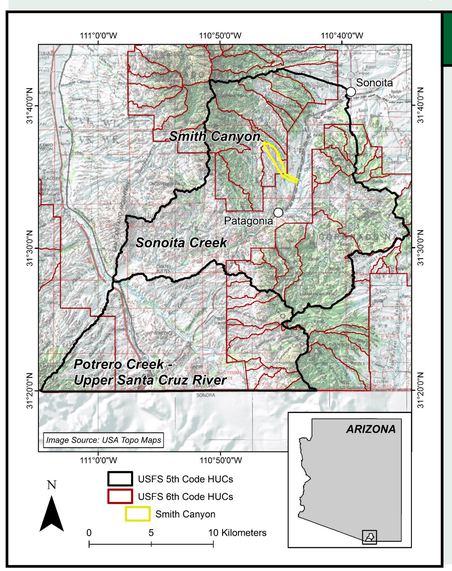
Introduction and Background

- Arid and semi-arid watersheds have been severely degraded due to a combination of both anthropogenic and natural processes, including: unsustainable grazing and timber harvests, long-term droughts, and acute flooding events
- We are investigating the effectiveness of holistic watershed restoration techniques, used by land managers, to combat the negative effects of these processes, and the impacts watershed restoration may have on the various ecosystem services provided
- Restoration treatments will focus on the use of erosion-control and water retention structures – varying by location, size, and construction material – designed to reduce erosion impacts from runoff after rainfall events
- We plan to use these research results to provide a protocol for the development of a large-scale, localized spatial database and hydrological modeling network, with the overarching goal of catalyzing a viable payment for an ecosystem services program in the region
- Additional benefits in the construction of these structures include sediment control (i.e., containing E.coli bacteria), aquifer regeneration, downstream flood control, and improving habitat conditions for native grasslands

Research Objectives

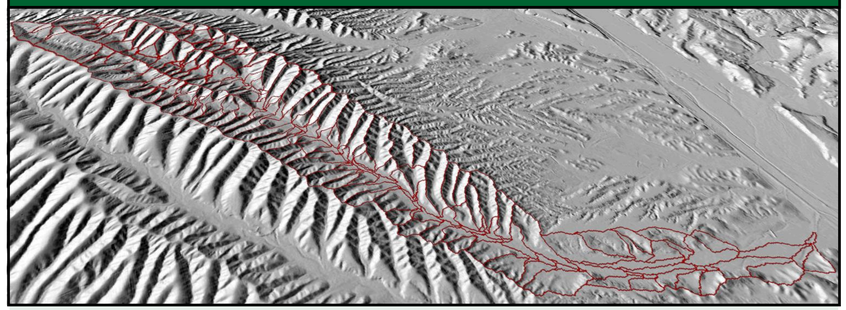
1. Develop a spatial database to allow for experimental design as well as hydrological modeling of numerous watersheds
2. Run statistical analysis to determine groups of sub-basins and construct erosion-control and water retention restoration structures within sub-groups at varying levels of density
3. Quantify the amount at which varying levels of erosion-control and water retention structures impact water flow on the landscape
4. Develop a protocol to improve future restoration efforts based on the impact of such restoration structures on ecosystem services and the value of water



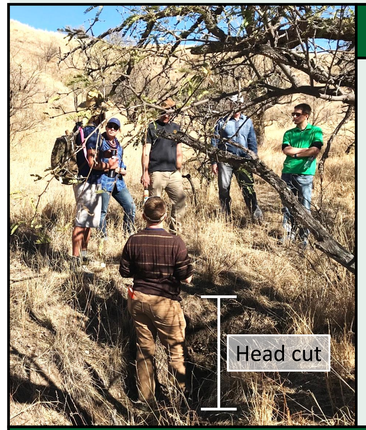
Study Area

- Smith Canyon Watershed (SCW) within the Nogales Ranger District of the Coronado National Forest (left)
- ~100 structurally-similar sub-canyons, each covering approximately 5-10 acres
- A unique and fairly uniform landscape presents an opportunity for rigorous large-scale experimentation since each sub-canyon can be treated as a replicate unit
- Smith Watershed drains into the Sonoita Creek 5th Unit Code, upstream of Patagonia, AZ

Methodological Approach



- An airborne LiDAR Digital Elevation Model (DEM) (per. com. Tyson Swetnam) was used to produce boundaries of the sub-basins (SUBs) within SCW (above)
- Holistic erosion-control and water retention structures for restoration will be placed with varying levels of density in structurally similar SUBs
- A hydrologic modeling process will be initialized using the USDA Automated Geospatial Watershed Assessment (AGWA) tool

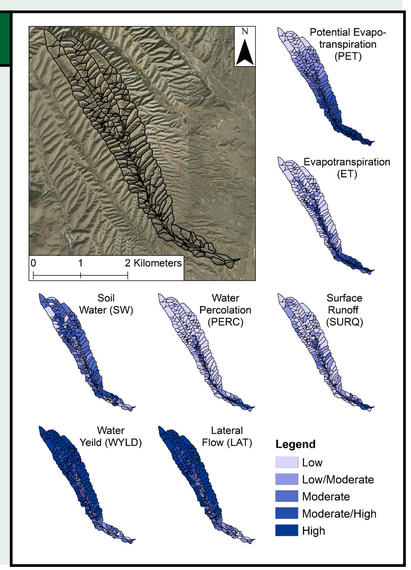


Erosion-Control Structures

- Large head cuts (left) have developed and moved upstream within many of SUBs
- Initial work for this project will use statistical analysis to develop an experimental approach and investigate how to best implement erosion-control structures on the landscape by grouping similar SUBs
- A holistic approach will be applied to construct the erosion-control structures, including the use of local dead vegetation

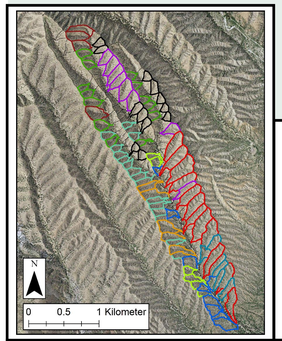
Hydrological Modeling

- Initial Soil and Water Assessment Tool (SWAT) model results (right), show:
  - Low to moderate surface runoff through a majority of SCW
  - High water yield and lateral flow within most SUBs
- Higher densities of erosion-control structures should increase surface runoff (SURQ) and soil water (SW) and reduce lateral flow (LAT) and water yield (WYLD)
- Continued modeling will compare the ability of various levels of restoration structures to reduce erosion and flood impacts from single rainfall event runoffs

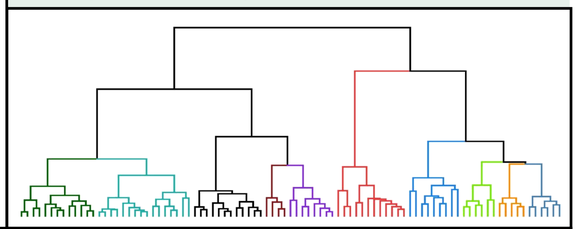


SUB Clustering

- We used hierarchical clustering techniques in R to form groups of SUBs for the five divisions of the SCW: 1) full Smith Canyon Watershed (shown below), 2) main channel, and 3) north, 4) middle, 5) south forks
- The clustering tendency and optimal number of clusters were determined in R using the "factoextra" and "cluster" packages – with "magrittr" and "ggplot2"
- The full SCW (below) was grouped into 10 main clusters (colors) – sub-groupings are also present in the hierarchy
- Variables included in the clustering analysis are based on the following four themes, 1) topography, 2) general characteristics of each SUB, 3) land use/land cover/soil information, and 4) vegetation indices

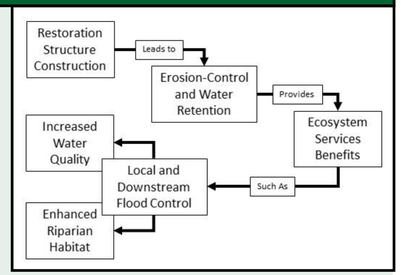


- We will develop a restoration plan with increasing levels of density of holistic erosion-control structures within each SUB cluster for experimental analysis



Ecosystem Services

- Ecosystem Services feedback loop:
  - Implementation of restoration structures leads to ecosystem services benefits and potentially viable payments
  - Healthier watersheds could provide flood control and increased water quality, with indirect benefits to surrounding systems and habitats



- We plan to consider both flood control and carbon sequestration, i.e.,
  1. What are the impacts on downstream flood insurance rates depending on the level of restoration and density of erosion-control and water retention structures?
  2. What are the impacts on carbon sequestration payments in response to various densities of watershed restoration structures?

Acknowledgements

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- The use of trade, product, or firm names is for descriptive purposes only and does not constitute endorsement by the U.S. Government

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