A STRATEGIC PLAN FOR FUTURE USDA ARS EROSION RESEARCH AND MODEL DEVELOPMENT

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USDA Agricultural Research Service

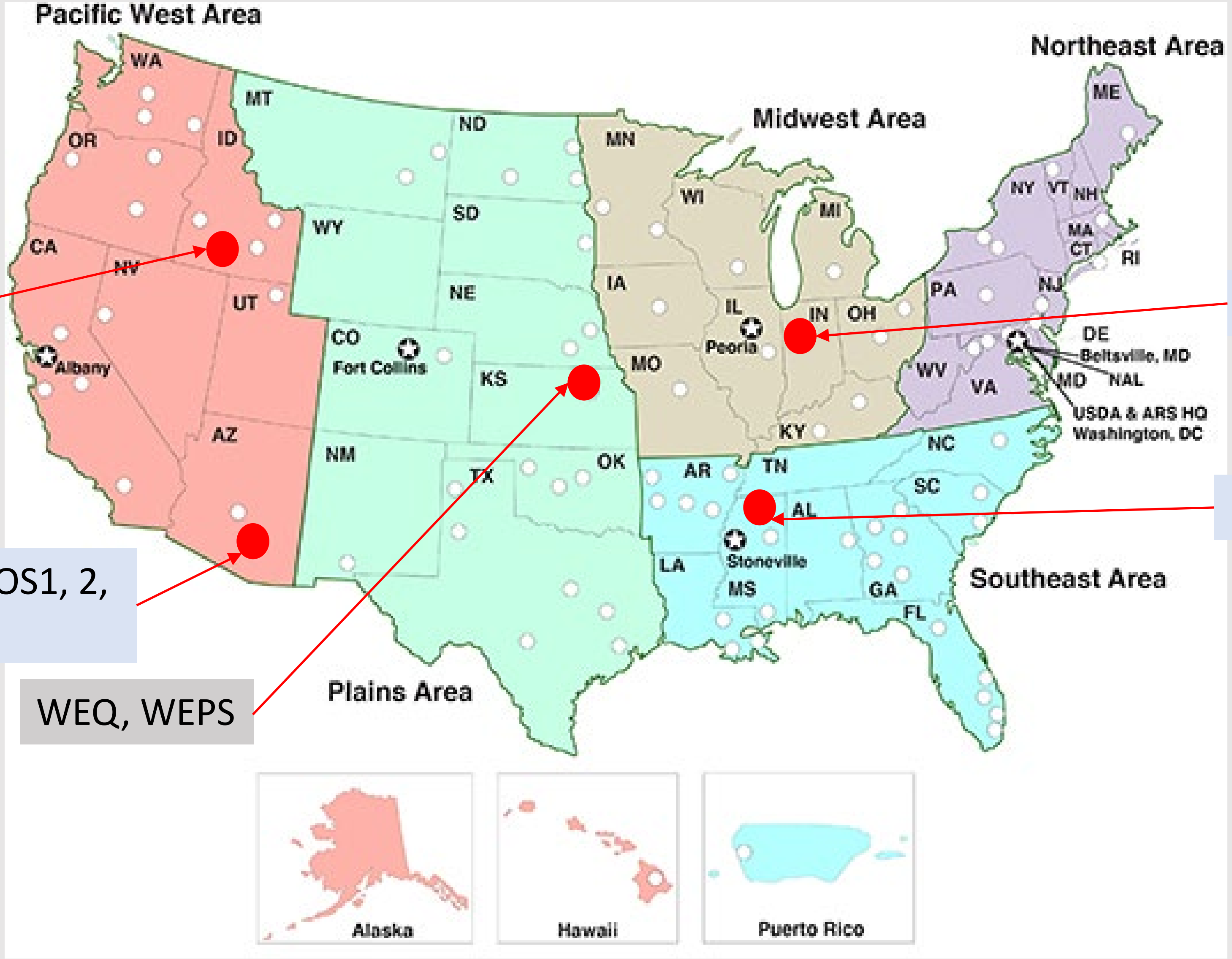
History of erosion research at USDA-ARS

- Pre-ARS era:
  - Earliest erosion research experiments Sampson and associates, 1912 overgrazed rangeland Utah; Miller, 1917 first plot experiments in Missouri
  - 1930s Dust Bowl era, soil erosion brought to national attention under advocacy of Hugh Hammond Bennett, congress funds soil erosion research
  - 1933, Soil Erosion Service (SES, USDOI) → 1935, Soil Conservation Service (SCS, USDA), erosion control demonstration + assistance + research, etc.
  - 1940s early equations linking erosion to slope, crop and conservation practices (i.e. Zingg, 1940; Smith, 1941)
- 1953, USDA-ARS as the primary research agency early work on erosion
- 1954, National Runoff and Soil Loss Data Center at Purdue University under the direction of Walt Wischmeier

History of erosion research at USDA-ARS

- 1965, empirical erosion equations developed:
  - Complete Universal Soil Loss Equation (**USLE**) technology published by Wischmeier and Smith
  - Wind Erosion Equation (**WEQ**) by Woodruff and Siddoway
- Late 1970s, Early developments in process-based modeling of soil erosion by water (e.g., Negev's equation in 1977, inception of CREAM model 1978), incorporates decades of fundamental research
- 1992, Revised USLE (RUSLE)
- 1990s – early 2000s, Transition from empirical to process-based models accelerated (RUSLE2 development initiated in 1993, Water Erosion Prediction Project – WEPP, 1995, Wind Erosion Prediction System – WEPS, 2005, Rangeland Hydrology and Erosion Model – RHEM, 2006)

Current state of erosion prediction at USDA-ARS

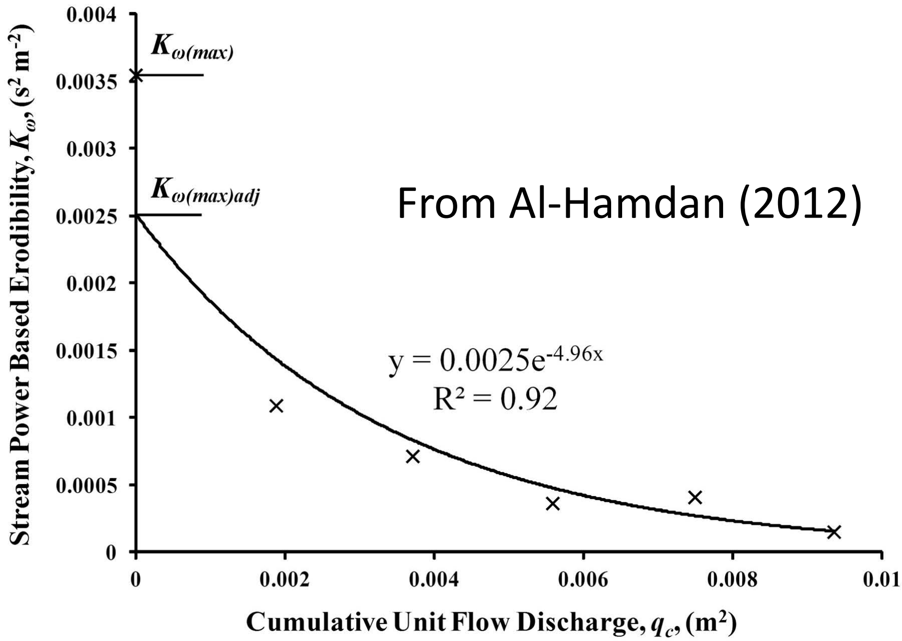


Current state of erosion prediction at USDA-ARS

- Vast body of fundamental and applied research on soil erosion processes disseminated in a variety of models
- Varied approaches ➔ variability in predictions across models ➔ challenges when predictions are used for policy
- At September 2019 meeting between ARS and stakeholders (NRCS, US Forest Service) a strategic plan was imagined for a more integrated soil erosion research and modeling program

Goal1: Advance wind and water erosion science

- Dynamic soil erodibility concept (influence of time, subsurface hydrology, topography, extrinsic factors, etc.)



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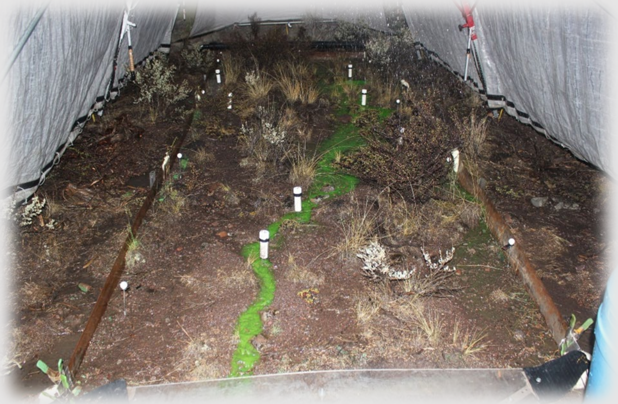
Goal1: Advance wind and water erosion science

- Sediment transport and deposition related to spillway and dam failure processes

- Improve understanding and incorporate scale processes (connectivity concepts), channel initiation, etc.



Goal1: Advance wind and water erosion science

- Unified wind and water erosion modeling framework
- Coupling between wind - water erosion

Goal1: Advance wind and water erosion science

- Wind and water erosion Interaction with nutrient cycling (effect on sink/source pools)
- Improve irrigation-induced erosion modeling
- Re-evaluation of the concept of soil loss tolerance
- Short- and long-term data networks (e.g., LTAR) integrating a range of novel technologies (tracers, 3D reconstruction, etc.)

Volume 51, Number 1

1 January 2023

GEOLOGY

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RESEARCH ARTICLE | DECEMBER 02, 2022

Pre-agricultural soil erosion rates in the midwestern United States

Caroline L. Quarrier; Jeffrey S. Kwang; Brendon J. Quirk; Evan A. Thaler; Isaac J. Larsen

Geology (2023) 51 (1): 44–48.

https://doi.org/10.1130/G50667.1 Article history

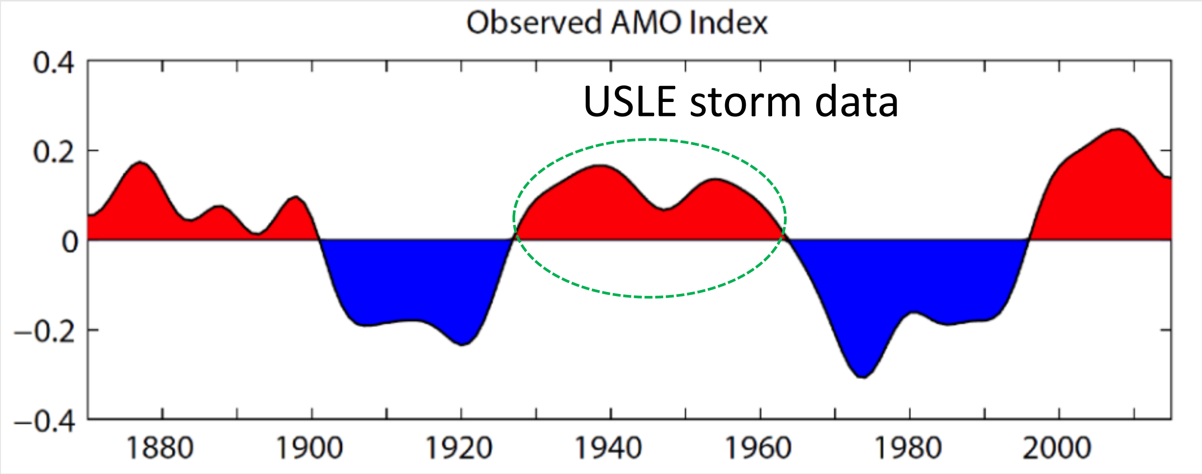
Cite Share Tools

Abstract

Erosion degrades soils and undermines agricultural productivity. For agriculture to be sustainable, soil erosion rates must be low enough to maintain fertile soil. Hence,

Goal 2: Improve climate model for erosion prediction

- Must be able to simulate past, present and future climate conditions
- Integration of traditional weather stations, gridded products (remote sensing, ground-based radar, etc.) and AI / ML
- Backward compatibility with existing databases
- Ability to separate long-term variability (e.g., Atlantic Multidecadal Oscillation) from climate change and inter-annual variability



Source: *https://climatedataguide.ucar.edu/climate-data/atlantic-multi-decadal-oscillation-amo*

Goal 3: Quantify factors affecting erosion

- Natural and anthropogenic factors on wind and water erosion
  - Tillage (random, oriented roughness)
  - Vegetation-erosion coupling / grazing / improved plant growth models
  - Fire effects short- and long-term
  - Winter processes (e.g., snow melt, transient erodibility)

Goal 4: An integrated wind and water erosion prediction system

- Unify core science, process components and reporting
- Include wind-water interactions
- Temporal and spatial flexibility
- Modular components for easy integration with other models (e.g., facilitate support for climate or plant growth model alternatives)
- Clearly quantify and communicate uncertainty
- Flexible interface to suit diversity of end users

Building future research capacity

- Identify and preserve continuity in wind and water erosion knowledge and expertise across the agency
- 50% of ARS scientists conducting wind and water research eligible for retirement as of 2020
- New scientists are needed across many disciplines
- Need to strengthen capacity in emerging technologies such as AI, ML and sensor networks for soil erosion modeling
- Need to enhance cooperation between ARS scientists, NRCS, University partners, Forest Service, and other national and international stakeholders

Building future research capacity

- Necessary research will be spread across multiple research units
- Teams to be formed around common goals
- New research project across different ARS National Programs

- Additional resource needs to succeed:
  - 26 new scientist positions
  - US$12 million base fund increase

Thank you

doi:10.2489/jswc.2020.0805A

FEATURE

A strategic plan for future USDA Agricultural Research Service erosion research and model development

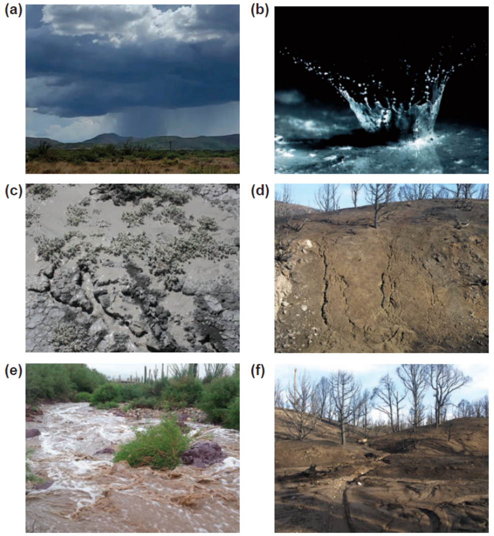
Mark A. Weltz, Chi-Hua Huang, Beth A. Newingham, John Tatarko, Sayjro K. Nouwakpo, and Teferi Tsegaye

Soil erosion is a natural process, and the erosion potential of a site is the result of complex interactions among soil, vegetation, topographic position, land use and management, and climate. Soil erosion occurs when aeolian and hydrologic processes exceed a soil's inherent resistance to these forces (figures 1 and 2). Soil erosion was recognized as a significant problem at both local and national scales in the United States in the 1920s; by 1935 soil erosion was considered a national disaster, covering over one-half of the country (Sampson and Weyl 1918; Weaver 1935), and is still a concern with 21% of the western United States degraded and vulnerable to accelerated soil erosion (Herrick et al. 2010; Weltz et al. 2014a; Duniway et al. 2019). In 1995, it was estimated that 4×10^9 t (4.4×10^9 tn) of soil was lost from US cropland (Pimentel et al. 1995). The most vulnerable areas for soil movement and thus erosion occur where annual precipitation is 100 to 400 mm y^{-1} (4 to 16 in yr^{-1}), which limits soil moisture available to sustain plant growth. Anthropogenic-driven dust emissions have dramatically increased across the globe (Webb and Pierre 2018) and in the United States (Neff et al. 2008) over last several decades. On-site and off-site costs associated with wind erosion exceeds US$8 billion y^{-1} (figure 2) (Huszar and Piper 1986; USDA 1993). The combined off-site and on-site costs of erosion from agriculture in the United States is estimated to be about US$44 billion y^{-1}, or about US$100 ha^{-1} (US$40 ac^{-1}) of cropland and pasture (Pimentel et al. 1995), and US$44.5 billion in the European Union (Montanarella 2007). Cropland and livestock production contribute US$132.8 billion or 1% of the US gross domestic product. Erosion increases production costs by ~25% each year.

The USDA has a long history of conducting basic research in soil erosion and developing erosion assessment tools used for conservation planning and risk assessment. However, research efforts and model development have historically been segregated, and researchers in these two fields have therefore developed separate soil erosion assessment tools. The basis of mathematical equations used to estimate water erosion can be traced to the work of Cook (1937), who identified three major variables: (1) the susceptibility of soil to erosion, (2) the potential erosivity of rainfall and runoff, and (3) the protection

Figure 1

Water erosion processes on rangelands: (a) convective thundershower; (b) raindrop splash erosion; (c) sheetflow erosion; (d) concentrated flow erosion; (e) channel erosion during a flash flow; and (f) gully erosion.



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Received August 5, 2020.