Simulating Soil Moisture and Grass Growth in a Eurasian Steppe Grassland by SWAP

Alston D. Chereskin[1], Devrick L. Johnson[1], Along Zhang[2], Ziyuan Qin[2], Dolan[3], Zachary C. Landis[1], Nicholas M. Potter[1], Ruizhong Gao[2], Yanyun Luo[2], Ruihong Yu[3], Fengling Li[2], Linmin Duan[2], Tingxi Liu[2], **Xixi Wang**[1*]

[1] Department of Civil and Environmental Engineering, Old Dominion University (ODU), Norfolk, VA 23529, USA

[2] College of Water Conservancy and Civil Engineering, Inner Mongolia Agricultural University (IMAU), Hohhot, Inner Mongolia Automatic Region, China

[3] College of Environmental and Ecological Engineering, Inner Mongolia University (IMU), Hohhot, Inner Mongolia Autonomous Region, China

* Correspondence: Email: xxqqwang@gmail.com; Tel.: +1 (757) 683-4882

Background, Objectives, and Study Approach

- The Eurasian Steppe, the vast steppe ecoregion including the native grasslands in Inner Mongolia of China, stretches from Romania in west to Manchuria in east
- It is a global biome supply, provides multifaceted ecological services, and functions as carbon sink and source
- It is an important regulator of regional and global environment, mitigating climate change and its impacts
- However, it has been degrading at an accelerating rate since 1980s due to overgrazing and climate change
- This has raised serious eco-environmental concerns (e.g., loss of productivity, desertification, and dust storm)
- Our understanding of steppe hydrology and water consumption by steppe grasses is incomplete
- The objectives of this study were to:
  - ☺ Advance our understanding of how and to what extent the natural hydrologic processes have been altered
  - ☺ Examine hydro-climatic and anthropogenic factors triggering degradation of steppe grasslands
- In this regard, a systematic framework (Figure 1) that seamlessly integrates three core components, namely field observation and laboratory measurement, remote sensing analysis, and modeling, was adopted
- The 5350 km^2 Balagaer River watershed (44°00' to 44°15' N, 117°40' to 117°48' E), located in northeast Inner Mongolian Autonomous Region of China (Figure 2), was selected as the study site

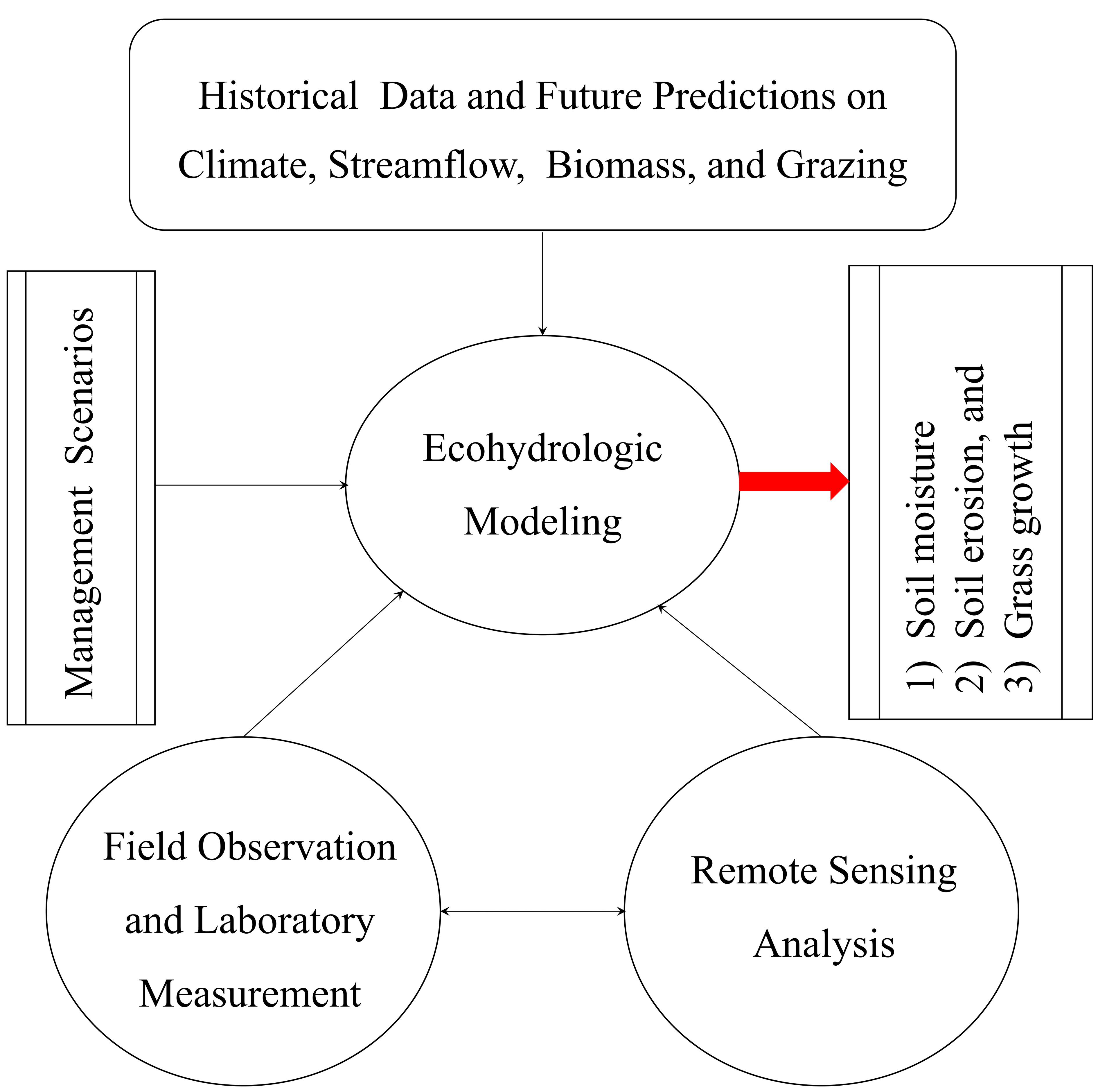

Figure 1. The general framework developed and used in this study.

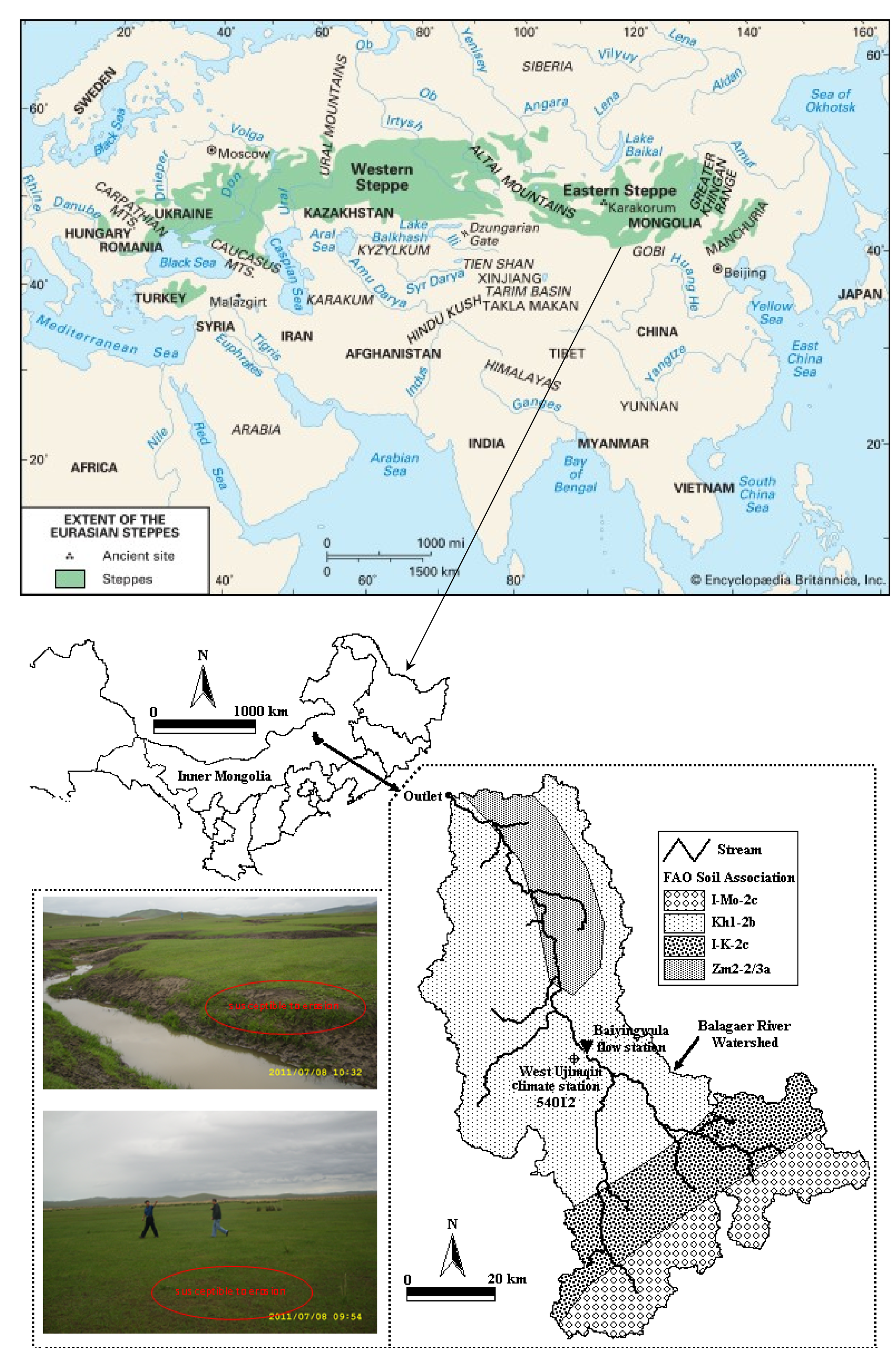

Figure 2. The study watershed.

SWAP and Its Parameterization

- This study used Soil-Water-Atmosphere-Plant (SWAP) model developed by Schaik *et al.* (2014)
- SWAP is a physically-based agro-hydrological model and simulates water-soil-vegetation interactions (Figure 3)
- SWAP simulates rainfall interception, evapotranspiration, heat and soil water dynamics, and vegetation growth as influenced by climate change and human activities (e.g., grazing)
- This study parameterized a SWAP model for a selected site in the study watershed using the site-specific data (Figure 4)

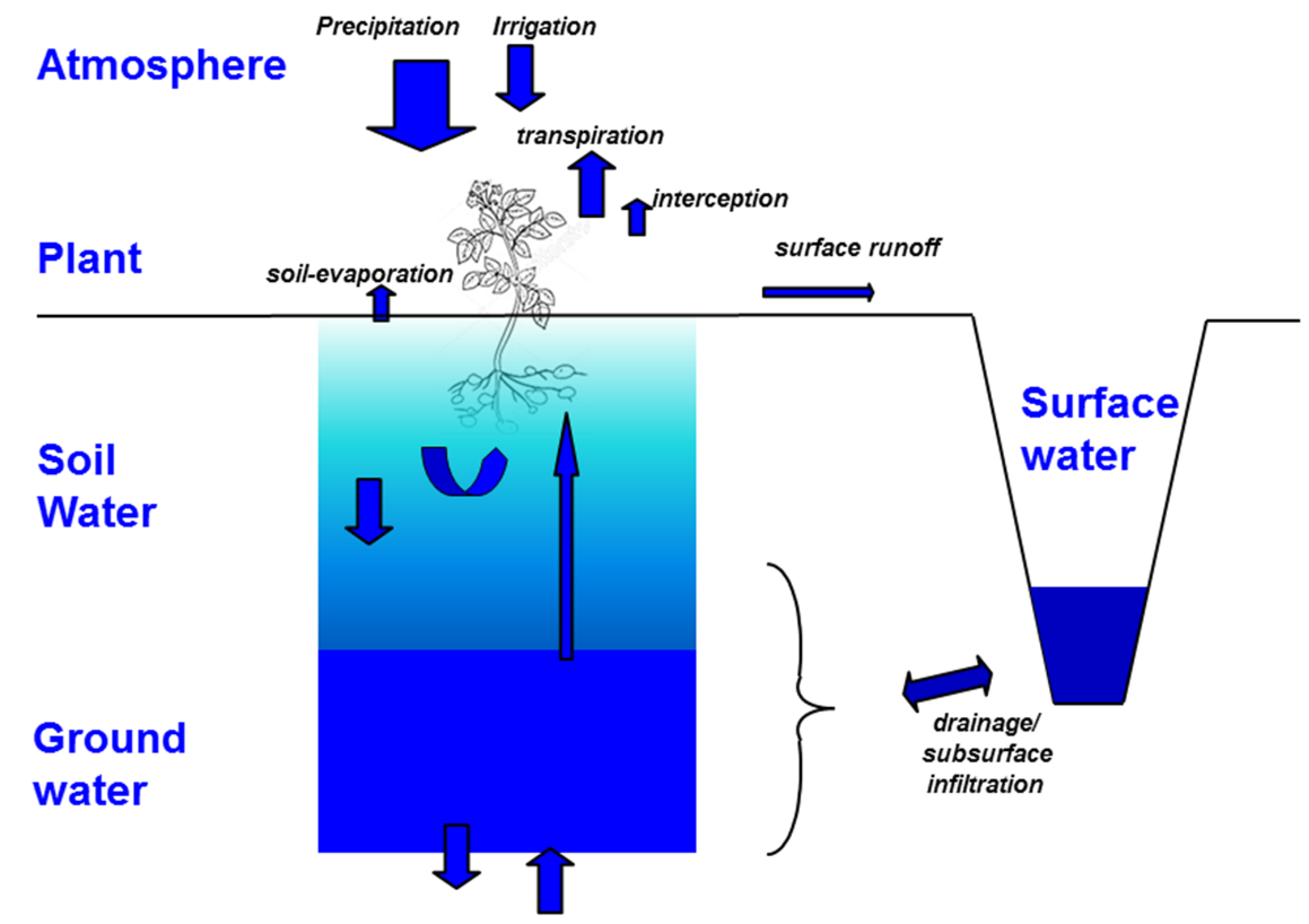

Figure 3. Schematic of SWAP.

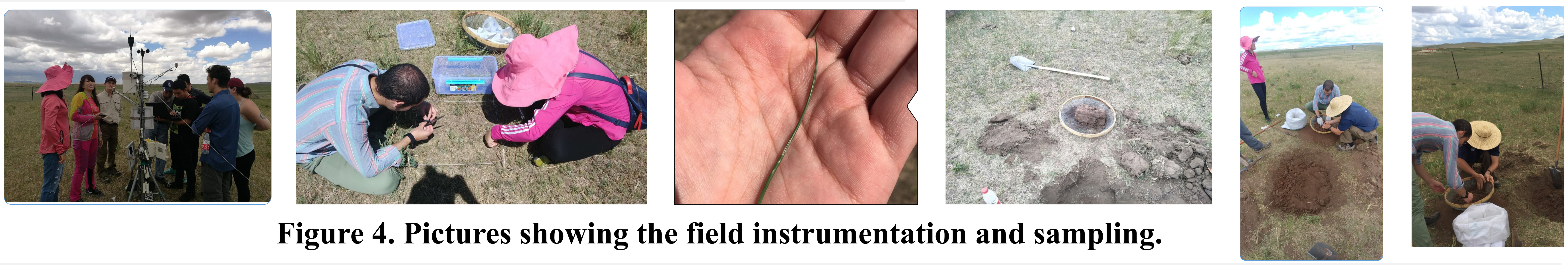

Figure 4. Pictures showing the field instrumentation and sampling.

Results and Discussion

- The SWAP model was run for 62 years from 1955 to 2017
- Both the actual and potential evapotranspiration (ET) had a decreasing trend, with an average ratio of 0.7
- The mean annual infiltration varied from 35 to 105 cm, indicating that the site soils are highly permeable
- As expected, the infiltration, hydraulic conductivity, and actual ET were larger in a wetter than a drier year
- For a given year, most of the precipitation was lost to ET and infiltration, leading to a small runoff
- The primary runoff was generated from melting snow in spring (March to May) due to low ET and infiltration
- The soil erosion might become severe once soil moisture $\theta \leq 0.05$ and leaf area index LAI ≤ 0.1
- For a given year, the grass growth was especially dependent on the May to July precipitation, while it was also controlled by spatially-varied environment factors, such as topography, soil properties, and grazing intensity

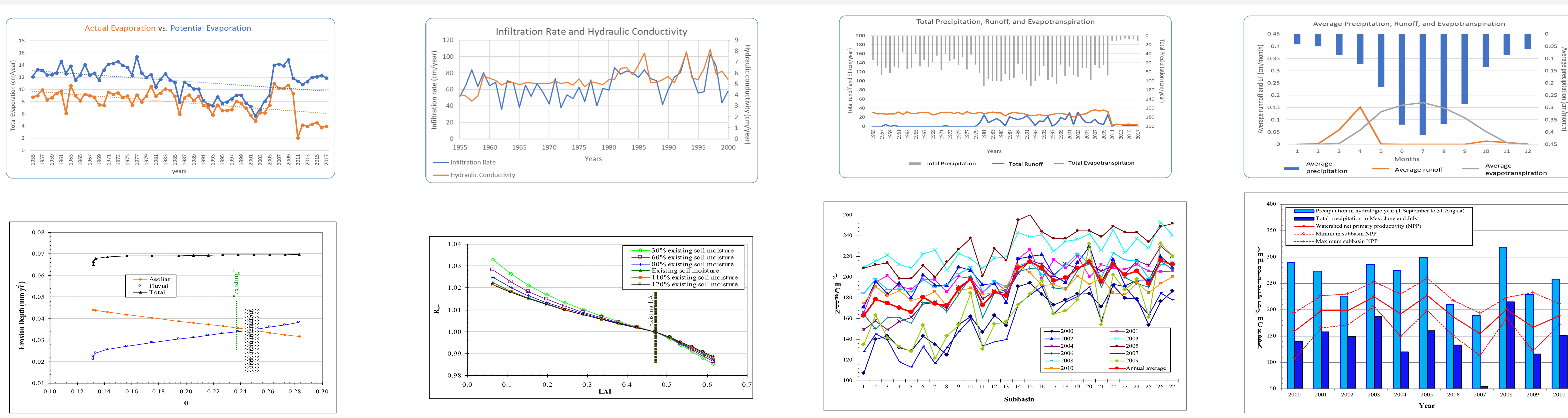

Figure 5. The simulated evapotranspiration, runoff, infiltration, soil erosion, and net primary production (NPP) .

Conclusions

- Conditions with a low soil moisture and vegetation coverage are in favor of steppe grassland degradation
- Such a condition will likely be resulted from climate change and/or overgrazing

Acknowledgements

This study is part of a ODU-IMAU-IMU collaborative project, funded by NSF-IRES (#1654957) and NFC (# 51469019)