Kansas Agricultural Experiment Station Research Reports

Volume 6
Issue 5 *Kansas Field Research*

Article 2

2020

A Pilot Experiment to Replace Missing Rainfall Events Using Soil Moisture Information from the Kansas Mesonet

N. Parker
Kansas State University, parkernath32@k-state.edu

A. Patrignani
Kansas State University, andrespatrignani@ksu.edu

Recommended Citation

Parker, N. and Patrignani, A. (2020) "A Pilot Experiment to Replace Missing Rainfall Events Using Soil Moisture Information from the Kansas Mesonet," *Kansas Agricultural Experiment Station Research Reports*: Vol. 6: Iss. 5. https://doi.org/10.4148/2378-5977.7918

A Pilot Experiment to Replace Missing Rainfall Events Using Soil Moisture Information from the Kansas Mesonet

Abstract

The Kansas Mesonet is a state-of-the-art environmental monitoring network that provides accurate rainfall measurements across Kansas. However, missing rainfall records are common problems in weather stations that rely on tipping bucket rain gauges. In this study, we conducted a pilot experiment to estimate missing rainfall records from root-zone soil moisture information recorded at Kansas Mesonet stations. Soil moisture is recorded at depths of 5, 10, 20, and 50 cm using the Campbell Scientific CS655 soil water reflectometer. Hourly rainfall and soil moisture data from mid- August 2017 to mid-May 2018 were taken from three stations (Lakin, Manhattan, and Hays) of the Kansas Mesonet. Rainfall was estimated as the difference in soil moisture storage between 1 hour before and 1 hour after a given rainfall event. Preliminary results show that soil moisture-derived rainfall can be more accurate than using rainfall data from nearby stations. Soil moisture could serve as very useful information in quality control procedures to flag missing rainfall events.

Keywords

soil moisture, Kansas Mesonet, precipitation

A Pilot Experiment to Replace Missing Rainfall Events Using Soil Moisture Information from the Kansas Mesonet

N. Parker and A. Patrignani

Summary

The Kansas Mesonet is a state-of-the-art environmental monitoring network that provides accurate rainfall measurements across Kansas. However, missing rainfall records are common problems in weather stations that rely on tipping bucket rain gauges. In this study, we conducted a pilot experiment to estimate missing rainfall records from root-zone soil moisture information recorded at Kansas Mesonet stations. Soil moisture is recorded at depths of 5, 10, 20, and 50 cm using the Campbell Scientific CS655 soil water reflectometer. Hourly rainfall and soil moisture data from mid-August 2017 to mid-May 2018 were taken from three stations (Lakin, Manhattan, and Hays) of the Kansas Mesonet. Rainfall was estimated as the difference in soil moisture storage between 1 hour before and 1 hour after a given rainfall event. Preliminary results show that soil moisture-derived rainfall can be more accurate than using rainfall data from nearby stations. Soil moisture could serve as very useful information in quality control procedures to flag missing rainfall events.

Introduction

Rainfall is the main water input in the soil water balance and serves as the major source of water supply to Kansas rainfed agricultural systems, surface water reservoirs, streams, and aquifers. Accurate rainfall information is therefore vital in monitoring drought, flood, and determining runoff and groundwater recharge rates. However, missing rainfall is a recurring problem in weather monitoring stations that rely on a tipping bucket rain gauge (the most commonly used rain gauge type for rainfall measurement) due to instrument malfunction, bucket collector clogging by spider webs and dust, and distortion by high winds and flooding (Sypka, 2019). The simplest and most popular existing method for missing rainfall estimation is using rainfall data from neighboring weather stations (i.e. same variable from a different station), which may not be representative of the missing record due to the spatial variability of rainfall.

In recent years, the growing number of in situ environmental monitoring networks measuring both atmospheric and soil moisture variables (Dorigo et al., 2011) provides new opportunities to fill precipitation gaps caused by malfunctioning of the tipping bucket rain gauges. Can we compute missing rainfall records using in situ soil moisture information (i.e. located at the same station) instead of using rainfall data from neighboring stations? The objective of this study was to estimate missing rainfall records using in situ soil moisture observations.

Procedures

Rainfall and soil moisture data used in this study were obtained from the Kansas Mesonet. The Kansas Mesonet is a network of weather stations established by K-State Research and Extension in 1986 and currently consists of 40 out of the 60 total stations that monitor root zone soil moisture across the state of Kansas. The stations monitoring soil moisture have CS655 soil moisture sensors (Campbell Scientific Inc.) installed at 5, 10, 20, and 50 cm depths in the soil profile (Kansas Mesonet, accessed January 5, 2020).

Hourly rainfall and soil moisture data from mid-August 2017 to mid-May 2018 were taken from three stations of the Kansas Mesonet. The stations were: (1) Lakin located in Kearny County in western Kansas with a sandy loam-textured soil, (2) Manhattan in Riley County in northeastern Kansas with silty clay loam soil, and (3) Hays in Ellis County in central Kansas with silty loam.

Soil moisture-derived rainfall at a given location was estimated as the difference between the profile soil moisture storage 1 hour before the rainfall event and the storage at 1 hour after the rain. In addition, we took the rainfall data from the nearest neighboring station to each of the three locations to help assess the performance of soil moisture-estimated rainfall as against that of the neighboring station data in predicting missing rainfall events. The nearest neighbor stations to Lakin, Manhattan, and Hays Mesonet respectively, are Grant (15 miles from Lakin), Ashland Bottoms (5 miles from Manhattan), and La Crosse (19 miles from Hays).

Results and Discussion

There were 13 total hourly rainfall events in Lakin. The median amount was 6.3 mm and lasted for 4 hours while the maximum, 44.2 mm, and minimum, 1.3 mm lasted for 15 and 4 hours, respectively (Figure 1-A). The Manhattan station (Figure 1-C) recorded 42 hourly rainfall events in total with a median of 3 mm lasting for 4 hours while the maximum, 33.3 mm, and minimum, 1 mm, lasted for 7 and 5 hours, respectively. Hays (Figure 1-E) had 21 total number of events with the median, 3.6 mm lasting for 2 hours while the maximum, 28.7 mm and minimum, 1 mm, lasting for 10 hours, and 2 hours, respectively.

The estimated rainfall from in situ soil moisture was more highly correlated with the observed rainfall measurement from a rain gauge (R = 0.92, 0.96, and 0.94, respectively) than estimation from the nearest station rainfall (R = 0.8, 0.84, and 0.49, respectively) in Lakin, Manhattan, and Hays (Figure 1). Likewise, the rainfall estimation error from soil moisture was lower (root mean square error [RMSE] = 6, 3.3, and 6.5 mm, respectively) than that of the nearest station data (RMSE = 9 mm, 4.3 mm, and 10.5 mm, respectively) in Lakin, Manhattan, and Hays. Ashland Bottoms, located 5 miles from the Manhattan station, is much closer than the neighboring stations to Lakin and Hays and thus gave the best performance (R = 0.84, RMSE = 4.3 mm) for the nearest station method (Figure 1-D); however, it still performed poorer than the soil moisture approach. Occasionally, our proposed soil moisture method underestimated rainfall events totaling more than 30 mm due to the soil reaching saturation because of the high preceding soil moisture conditions. In some cases, it overestimated rainfall events exceeding 30 mm due to the infiltration of run-on water from the catchment.

Our preliminary results suggest that soil could serve as a natural rain gauge for the estimation of missing precipitation records. Soil moisture-derived rainfall resulted in a more accurate estimation of precipitation than using rainfall measurements from nearby stations. Soil moisture information could be used in quality control procedures to flag missing rainfall events.

References

Dorigo, W.A., Wagner, W., Hohensinn, R., Hahn, S., Paulik, C., Xaver, A., Gruber, A., Drusch, M., Mecklenburg, S., Oevelen, P.V. and Robock, A., 2011. The International Soil Moisture Network: a data hosting facility for global in situ soil moisture measurements. Hydrology and Earth System Sciences, 15(5), pp. 1675-1698.

Kansas Mesonet, 2020. Network Architecture. Accessed January 5, 2020. http://mesonet.k-state.edu/about/network/.

Sypka, P., 2019. Dynamic real-time volumetric correction for tipping-bucket rain gauges. Agricultural and Forest Meteorology, 271, pp. 158-167.

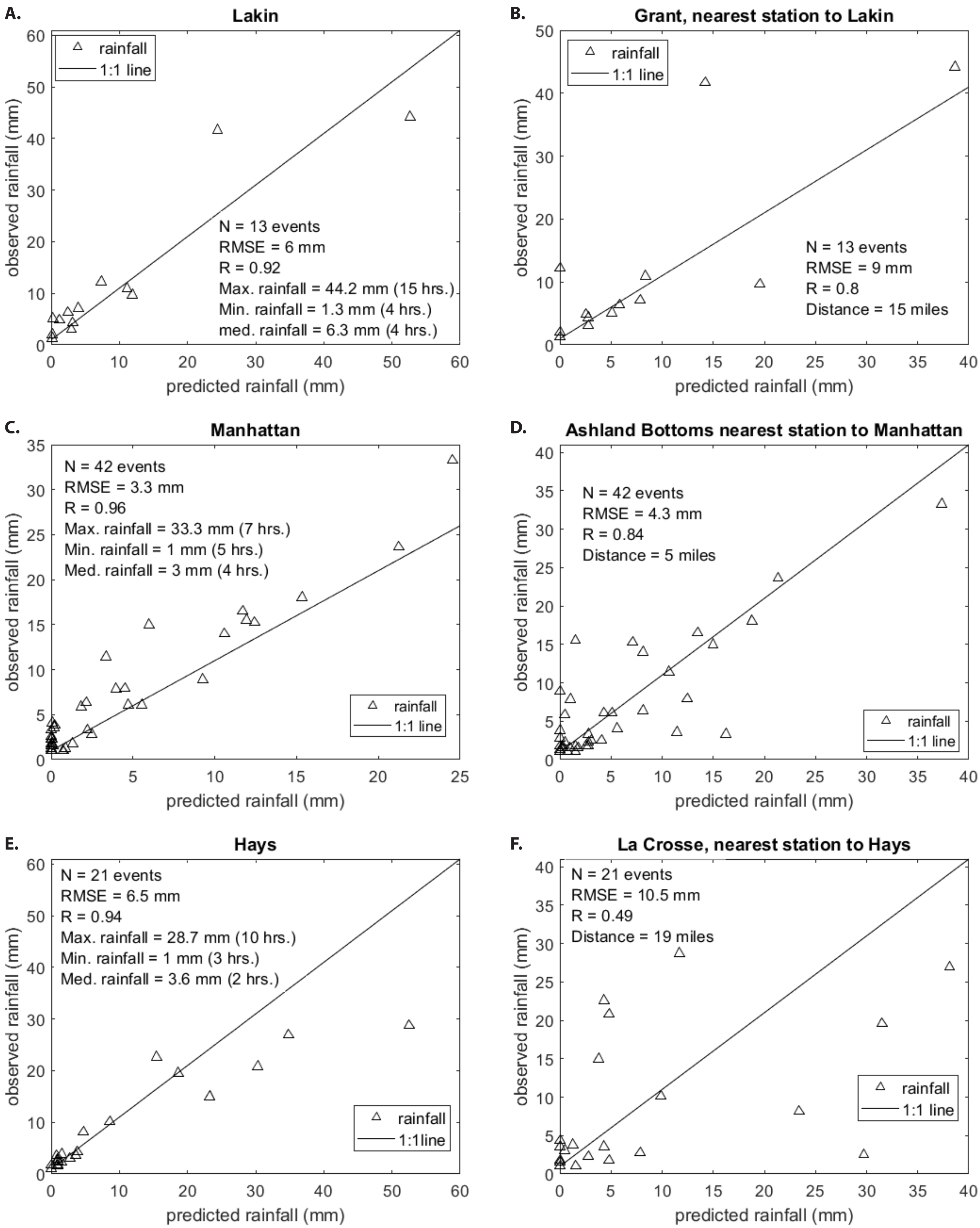

Figure 1. Predicted rainfall from in situ soil moisture (subplots A, C, and E) and data from the nearest station (subplots, B, D, and F) compared to the observed rainfall from a rain gauge. N is the number of hourly rainfall events analyzed and numbers in parenthesis represent the rainfall duration of the particular rainfall amount.