Kansas Phosphorus Index: Identifying a Runoff Estimation Method that Works Best within a Component P Index.

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Background

Updating from a multiplicative P index to a component index may improve the overall representation of soil, climate, and management factors that influence P loss. A component P index requires average annual runoff as one of the inputs. However, the current Kansas P index uses a Soil Runoff classification that is a categorical variable which would not work as an input to a component index.

Objective

The objective of this research is to identify a runoff estimation method that is simple to implement, uses readily available data sources, and accurately represents the effects of soil, climate, and management on average annual runoff.

Methods

1. **Method 1**: Daily runoff was estimated with the curve number (CN) method as described in the NRCS Engineering Handbook (USDA-NRCS, 2004) using daily precipitation.
   - Uncalibrated: A static CN representing hydrologic condition II (CNII) was determined based on NRCS guideless for the given cropping system and soil hydrologic group. This CN was used to estimate daily runoff with input of daily precipitation.
     - I. Static inputs: CNII, daily precipitation
     - II. Calibrated inputs: none
   - Calibrated: The CNII was adjusted to CNI or CNIII based on antecedent precipitation. The amount of antecedent precipitation and the number of days used to calculate the amount of antecedent precipitation were used for calibration parameters. The CNII was determined based on the Hydrologic Soil Group and the cropping system with CN for moisture conditions I and III determined from tables in the NRCS Engineering Handbook (USDA-NRCS, 2004).
     - I. Static inputs: CNII; daily precipitation;
     - II. Calibrated inputs: maximum antecedent precipitation for CNI; number of days to sum antecedent precipitation for CNI; minimum antecedent precipitation for CNIII; number of days to sum antecedent precipitation for CNIII
2. **Method 2:** Daily runoff was estimated with the modified CN method as described by Guswa et al. (2018). In brief, this modification used annual precipitation in place of daily precipitation and then assumed an exponential distribution of rainfall depths throughout the year.

$$\bar{Q} = \alpha - S\,exp\left(-\frac{\lambda S}{\alpha} + \frac{S^2}{\alpha}\right) exp\left(\frac{(1-\lambda)S}{\alpha}\right) E_1\left(\frac{S}{\alpha}\right)$$ Equation 1 (Guswa et al., 2018)

Where $\bar{Q}$ is the average runoff per event, α is the average precipitation per event (calculated as P_A/n_P, where P_A is annual precipitation and n_P is the number of precipitation events in a year), S is the maximum potential retention computes as (1000/CN)-10, λS is the initial abstraction, and $E_1(x)$ is the exponential integral. Annual runoff is computed as $\bar{Q} \bullet n_P$.

   - Uncalibrated: Annual runoff was computed with Equation 1 where n_P = number of days during the year with precipitation > 0.25 mm.
     - i. Static Inputs: CNII, annual precipitation (P_A), number of precipitation events per year (n_P)
     - ii. Calibrated inputs: none
   - Calibrated: Annual runoff was computed with Equation 1 where n_P was computed as the number of days with precipitation above a given threshold (t), with t ranging from 0.25 mm to 12.7 mm.
     - i. Static Inputs: CNII, annual precipitation (P_A),
     - ii. Calibrated inputs: number of precipitation events per year (n_P)

Calibration and Validation Datasets

Calibration and validation datasets are annual measured runoff from edge-of-field runoff studies conducted in four different locations in eastern Kansas, USA.

Calibration data are from the Kansas Agricultural Watershed (KAW) field laboratory from 2016 through 2021. Data are average runoff from no-till corn-soybean cropping systems either with cover crops or without cover crops, for a total of 12 site-years (6 years, two cropping systems).

Validation data were collected in Crawford County, Franklin County, and Geary County, Kansas.

- Crawford data – average runoff from 5 cropping systems in no-till or conventional till grain sorghum production from 2005 through 2008 with various fertility management.
- Franklin data – average runoff from 3 cropping systems in no-till or conventional till grain sorghum-soybean production from 2001 to 2004 with various fertility management.
- Geary data – average runoff from 2 cropping systems in no-till corn-soybean production with or without winter cover crops from 2018 through 2021.

Results and Discussion

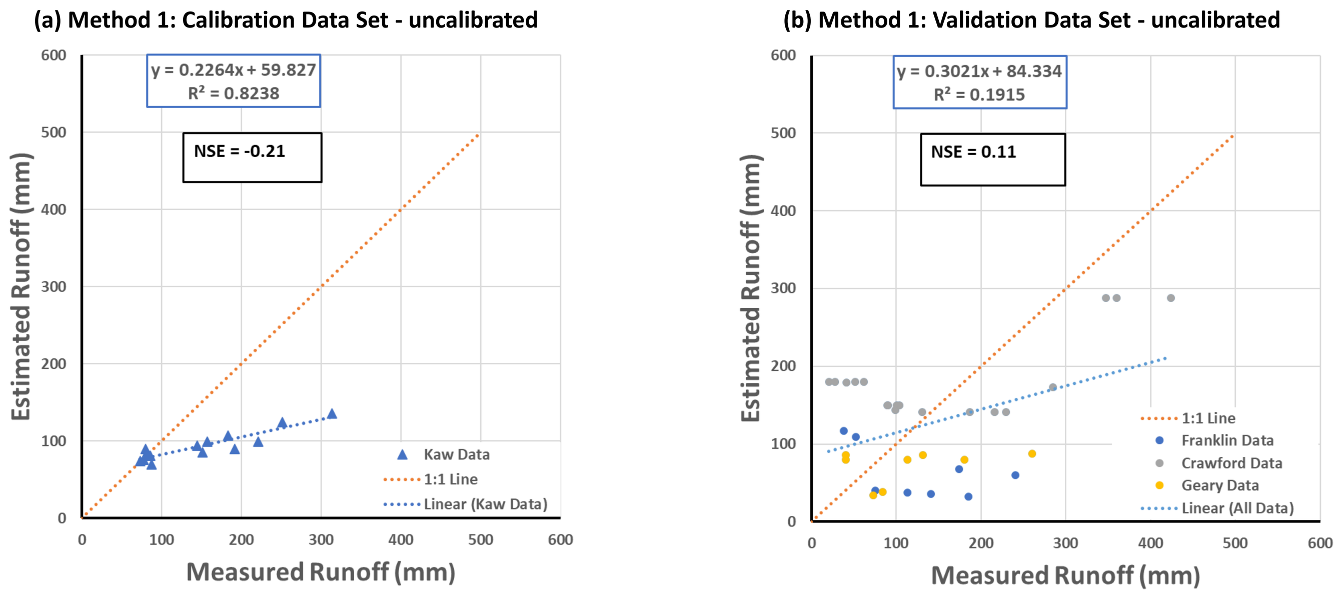

Figure 1. Represents method one without calibration, comparing measured runoff with runoff estimated from the uncalibrated CN method for the calibration data set (a) and the validation data set (b). The model had poor performance for both datasets, indicating calibration may be needed.

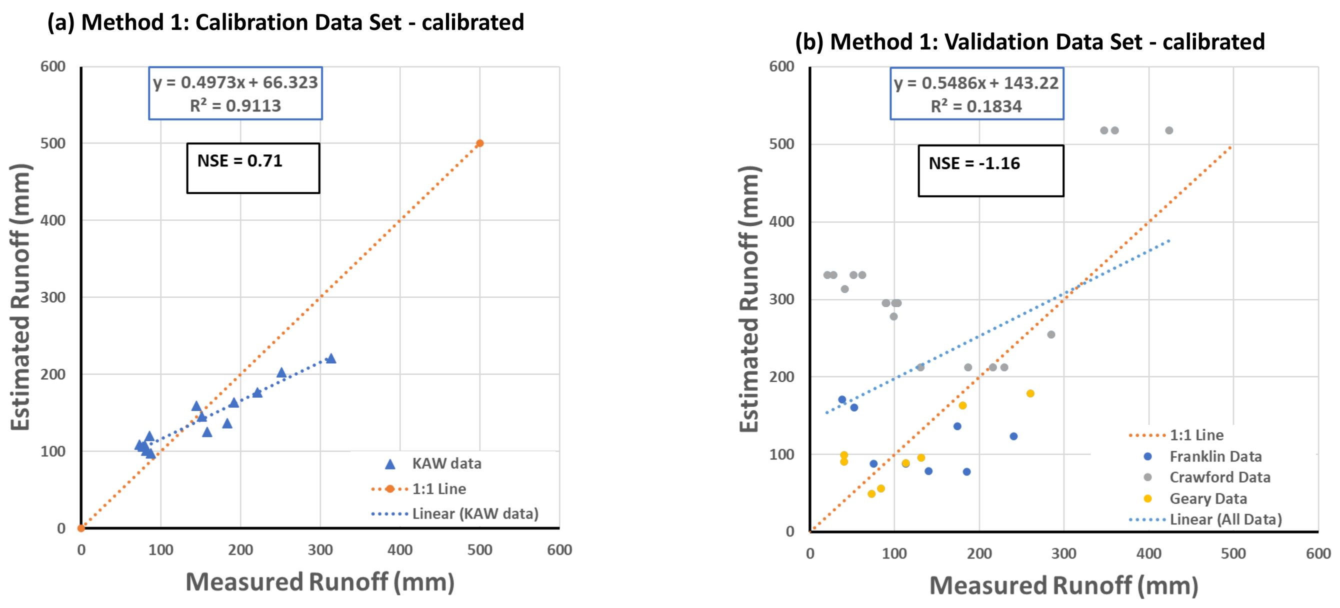

Figure 2. Represents method one after calibration, comparing measured runoff with runoff estimated from the CN method for the calibration data set (a) and the validation data set (b). The calibrated model adjusted CN for three different moisture conditions: CNII for average conditions, CNI for dry conditions if the antecedent precipitation in the prior 10-days was less than 5 mm, and CNIII for wetter conditions if the antecedent precipitation in the prior 3-days was greater than 10 mm. Calibration increased model performance considerably for the calibration data set while the model performance decreased for the validation data set. Poor model performance for the validation data set could be due to drastically different soil hydrologic conditions at sites used for validation, for example, the Crawford site had a clay pan soil.

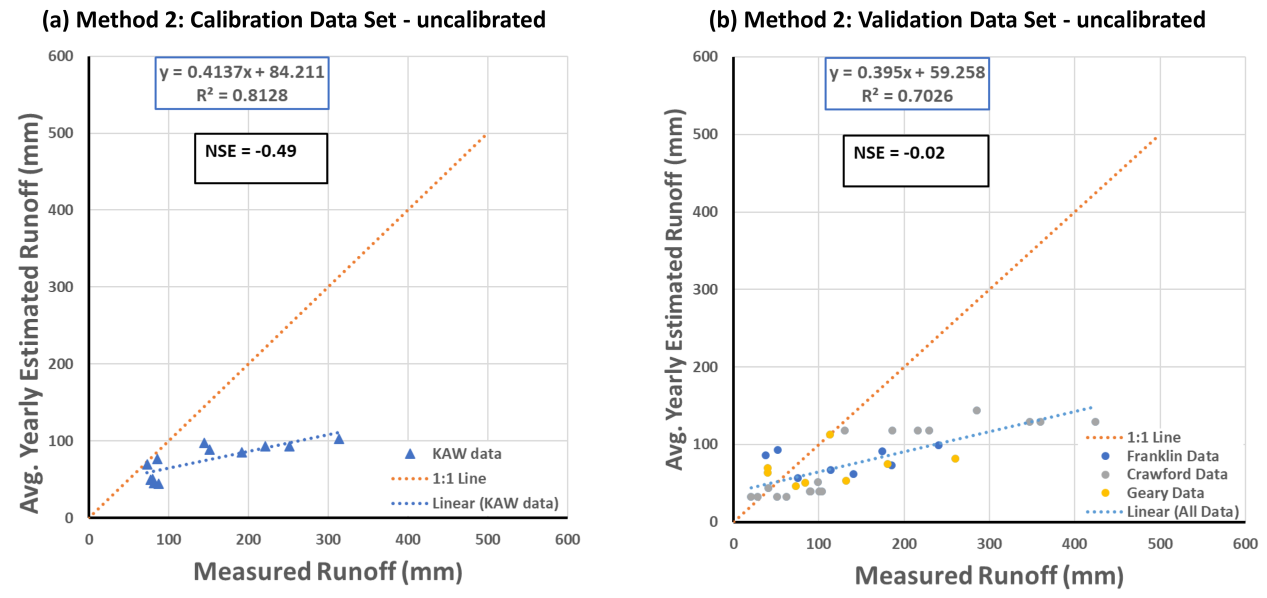

Figure 3. Represents method two without calibration, comparing measured runoff with runoff estimated from the uncalibrated modified CN method for the calibration data set (a) and the validation data det (b). The number of precipitation events in a year was determined by counting every day with precipitation greater than 0.25 mm as an event. The model had poor performance for both datasets, indicating calibration may be needed.

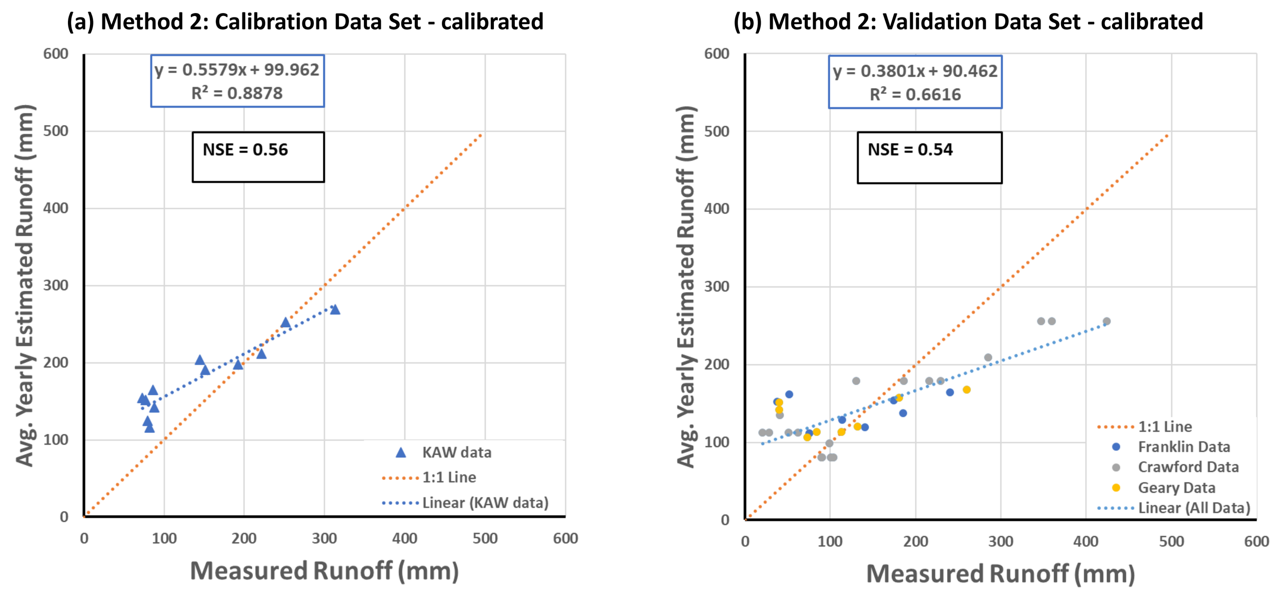

Figure 4. Represents method two after calibration, comparing measured runoff with runoff estimated from the calibrated modified CN method for the calibration data set (a) and the validation data det (b). Through heads up calibration, it was determined that the best model fit (maximum NSE) was obtained determining the number of precipitation events as every day with precipitation greater than 2.5 mm. The model had good performance for both the calibration and validation data sets.

Conclusion

- The calibrated modified CN method had the best estimations of annual runoff for both calibration and validation datasets.
- While the calibrated models had good model performance, It can be difficult to accommodate for all known hydrologic soil conditions which can affect runoff amounts.
- For method one calibration, adjusting for moisture conditions did have good model performance when adjusting to a single specific site but the method seemed to over and underestimate runoff when applied to soils with different hydrologic conditions.
- The method two calibrated model had better model performance and adjusting the minimum precipitation amount used to count the number of runoff events in a year appeared to be an appropriate and robust method of calibration.

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