# Curve Number (CN) Development using Normalized Difference Vegetation Index (NDVI) for the Contiguous United States in EPA's Hydrologic Micro Services

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## Background

**Curve Number (CN)** is an empirical method used in hydrology for determining direct runoff from a rainfall event based on topographic characteristics. The CN method was developed by the USDA-Soil Conservation Services (SCS) in the 1950s and is widely used in rainfall-runoff models. The CN is estimated based on land use type, hydrologic soil group, crop treatment, and hydrologic conditions.

**Normalized Difference Vegetation Index (NDVI)** is derived from atmospherically-corrected reflectance in the near-infrared and red wavebands of the NASA Moderate-resolution Imaging Spectroradiometer (MODIS) Earth Observing System Data and Information System (EOSDIS). A time-series of NDVI can be used to examine the dynamics of the growing season; to monitor phenomena such as droughts; and to characterize the global range of vegetation states and processes. NDVI data are available at 250 meter spatial resolution for every 16 days.

## Rationale

The SCS-CN method is typically implemented as a constant value, lacking temporal and seasonal variability. Dynamic, national mapping of CN that accounts for vegetation seasonality will benefit researchers and land-water managers.

## Objective

Develop curve number (CN) using MODIS-NDVI for the contiguous United States to address the seasonality of land use/cover effects on hydrologic processes and to accurately capture the spatiotemporal variability of hydrologic conditions.

## Geographic Coverage of the Project

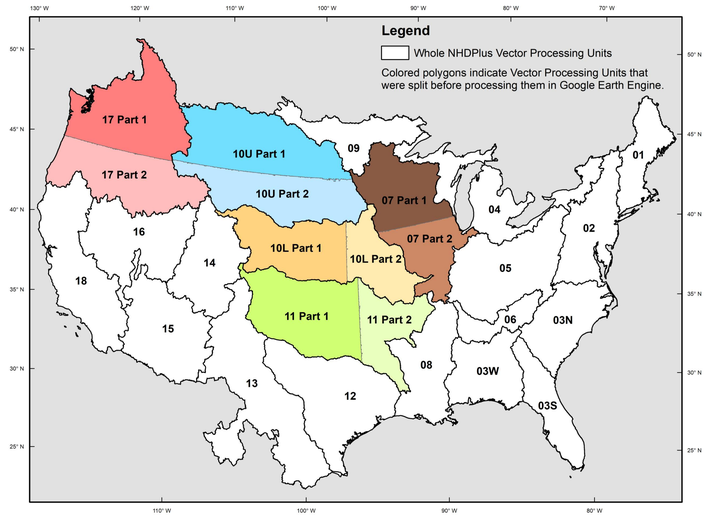


Figure 1. NDVI Processing with Water Resources Regions of the Contiguous United States.

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## Curve Number Processing in HMS

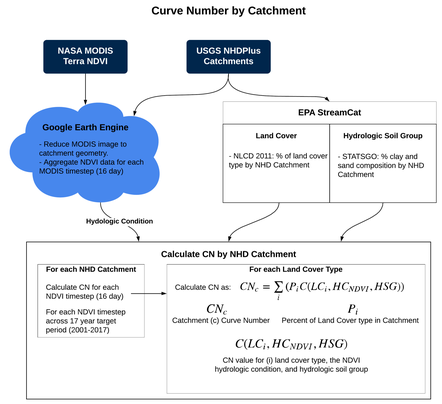


**Figure 2: Hydrologic Micro Services (HMS) Infrastructure and the overall method of dynamic curve number development.**

NDVI is used as an indicator of hydrologic conditions by incorporating Land use/cover and hydrologic soil group as part of CN estimation.

## Selected HUC-8 level Watersheds

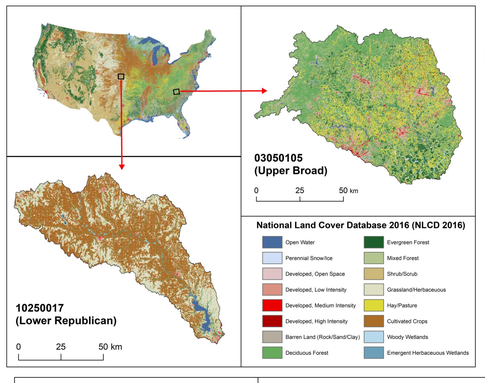


**Figure 3: Selected HUC-8 watersheds with NLCD land use/cover, Lower Republican Watershed in Kansas and Upper Broad in North/South Carolina.**

The two watersheds were selected for this analysis based on their differences in land use/cover and also as representatives of different precipitation regimes. Lower Republican is agriculture dominated, whereas Upper Broad is forested dominated.

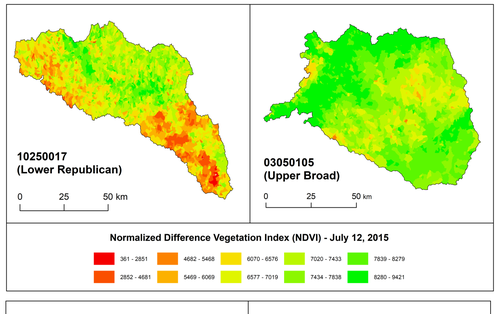


**Figure 4: Selected study HUC-8 watersheds MODIS-NDVI (July 12, 2015).**

250m 16 days NDVI from MOD13Q1 VIs is used for CN development; it is 16-bit signed integer data types (valid range -2000 to 10000).

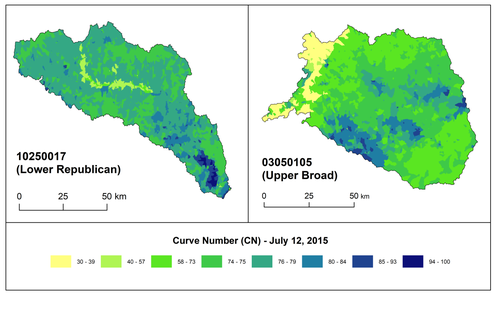


**Figure 5: Selected HUC-8 watersheds; Curve Number estimates based on MODIS-NDVI (July 12, 2015).**

## Seasonality and Spatiotemporal Variability

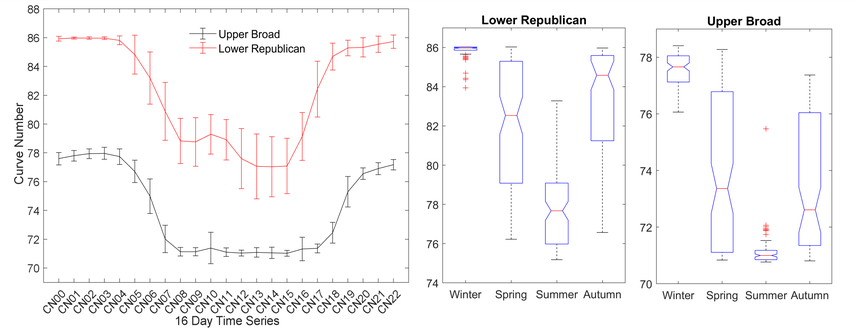


**Figure 6: Seventeen year (2001 - 2017) average of CN showing a) error bars and b) seasonal boxplots of study watersheds.**

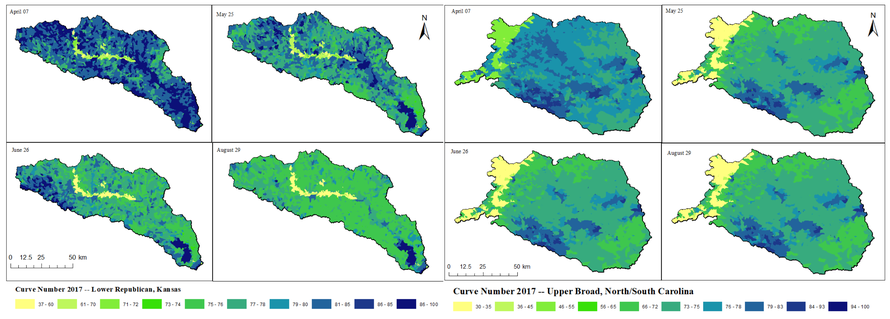


**Figure 7: CN maps showing spatiotemporal variability in selected periods in 2017.**

The variation in CN related to seasonality of hydrologic conditions will have significant effect on surface runoff. For example, if a 50.8 mm (2 inches) rainfall event happens in any watershed and the CN increases from 70 to 71, surface runoff increases by 10.5%; for a similar rainfall event, if the CN increases from 70 to 75, runoff increases by 58.3 %.

## Conclusion

- The analysis shows NDVI-based CN could be used to better capture the spatiotemporally variable rainfall-runoff relationship; and could capture inter and intra-annual variations.
- NDVI-based CN mapping in HMS can be easily used to study rainfall-runoff relationships in contiguous US at watershed, regional, and/or country level.

### *Limitations*

The main limitation is the SCS-CN method's imprecise assignment of hydrologic condition categories in some land use/cover types (e.g. shrubs).

## Future Directions

- Adjusting NDVI ranges for hydrologic conditions in order to reflect near-actual situations to better capture estimates of runoff from rainfall events.
- Exploring options of estimating CN from NDVI with no land use/cover and soil data.
- Performing validation to assess the efficiency of the method compared to other hydrologic model surface runoff estimation methods.

## Acknowledgements

Members of HMS Team