Evaluation of Landsat derived Snow Covered Area in the Wood River Basin for Predictive Streamflow Modeling

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Remotely sensed snow cover extent has been explored as a means to represent snow derived water availability in conjunction with Snotel data in our predictive streamflow model. I used Google Earth Engine (GEE) to extract snow covered extent (SCE) from Landsat images (16 day return interval, 30m resolution). For the purposes of this exploratory analysis, I used data from Landsat5 TM from 1983-2013 (Table 1). I've developed a script in GEE that gathers all images over the Wood River Basin (WRB), filters out pixels that are cloud covered, or otherwise problematic, and applies the Normalized Difference Snow Index (NDSI) to the remaining pixels.

NDSI = (Band 3 - Band 6) / (Band 3 + Band 6)

This index uses optical properties of the image to identify snow covered pixels, where values of greater than or equal to 0.4 are considered to be snow (Hall et al., 2015). This threshold was applied to the images and the GEE script provides output of 1) date, 2) percentage of pixels with good data, and 3) percentage of pixels with snow. From 1983-2013 there are 408 images of the WRB, of these images 220 of them have over 50% clear pixels that could be analyzed for snow, but these images largely do not capture winter months (Figure 1). The threshold of 50% was arbitrarily selected, but could be explored further.

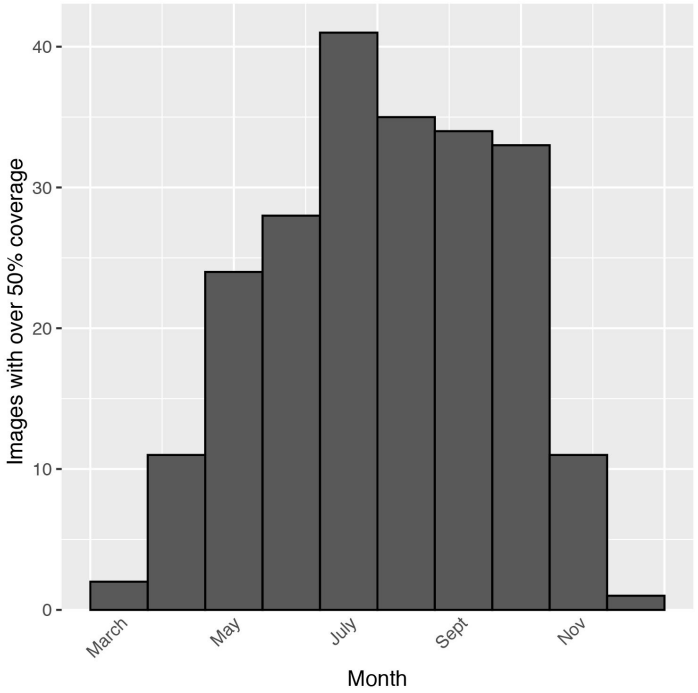

Figure 1: Number of Landsat images captured in each month from 1984-2013 that have over 50% data coverage in the Big Wood River Basin. Winter months have little to no images where more than half of the watershed is cloud-free.

This output was then combined with all Snotel data in the WRB to evaluate how well the datasets compare (Figure 2). Of major note, 75% of landsat scenes with anywhere from 50-100% snow covered area were associated with zero snow water equivalent (SWE) recorded at the snotel sites. This could be valuable information in locations that are higher elevation, or retain more snow than the Snotel sites, but the quality of this information is questionable given the high concentration of images through the summer season. An example of how this would occur is a light snow that covers a significant portion of the watershed, but not enough snow to accumulate on a Snotel pillow, which would suggest there is more water available than there actually is. Concerns with using SCA as a proxy for water availability is largely a function of the fact that even if a given location has snow (as observed by the satellite), it does not provide any information about the depth of that snow (Margulis et al, 2015). There are numerous efforts going on to improve our ability to remotely sense snow packs, namely the SnowEX project where airborne lidar is used to determine snow depth at numerous time points during the season at a few study basins across the country. While Woodruff & Qualls, 2019 show a promising method to integrate MODIS imagery with Snotel data using principal component analysis to define the seasonal spatial snow melt pattern, that modeling would go beyond the scope of this project.

Figure 2. Comparison of SWE measured at Snotel Sites in the Wood River Basin versus snow covered area quantified from Landsat 5 data.

Recommendation: I would suggest that we move forward with the modeling without using remotely sensed snow covered area given the uncertainty of how well it is representing snow pack conditions in the basin (without further modeling) and the associated literature.

Table 1. Time frame and number of images for the WRB from each Landsat Satellite

Product	Time Frame	Total number of images	NDSI Bands
Landsat 5	1984-2013	408	3 (0.63-0.69), 6 (10.40-12.50)
Landsat 7	1999 - 2020*	--	3,6
Landsat 8	2013 - current	--	Green 3 (0.53-0.59) SWIR 6 (1.57-1.65)

*In 2003, the Scan Line Corrector on Landsat 7 failed, so images are missing up to 22% of the data that should be contained in a given path.

Google Earth Engine Code:
https://code.earthengine.google.com/?scriptPath=users%2Fkendrakaiser%2Fdefault%3Awrwc_ndsi * there are some challenges sharing GEE scripts, so this link may not work without permissions

GitHub Repository with R analysis code:
https://github.com/kendrakaiser/WRWC/blob/master/code/SCA_exploration.R