Geophysical Research Abstracts
Vol. 21, EGU2019-2067, 2019
EGU General Assembly 2019

Mapping Extent and Distribution of Center Pivots in Saudi Arabia using Landsat Imagery

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Center pivot irrigation, which is also referred to as water-wheel or circle irrigation, is used for crop irrigation, where pipes with sprinklers, typically attached to wheeled trusses for support, is rotated around a pivot, creating a distinct circular pattern from a satellite perspective. In Saudi Arabia, ground water pumps, located in the center of each center pivot, are used to extract nonrenewable fossil water for irrigation. Estimating center pivot location and extent is required to predict water use and future irrigation needs to support desert agriculture. Knowing the location and distribution of active center pivots is essential for national and regional auditing, production forecasts and optimization, product traceability, management of water, fertilizer and pesticides, and biosecurity purposes. A time-series of imagery is required to map active center pivots within a year, because of variations in seasonal activities of agricultural practices. We developed an object-based image analysis approach to automatically identify and delineate active center pivots in Saudi Arabia, using the complete time-series of available Landsat imagery within a year. First, a panchromatic and near infrared image was produced, representing the minimum pixel values, occurring within the image time-series. Similarly, an NDVI image was produced with the maximum value, occurring within the image time-series. The maximum NDVI and minimum NIR images were used to identify the extent of active center pivots based on the presence of vegetation and wet irrigated soil, respectively. If these contrasted from the surrounding non-cultivated soil and at the same time formed a circular shape, they were classified as center pivots. As most center pivots occurred in close proximity, with parts of their perimeters bordering each other, an edge filtering approach based on the minimum panchromatic image was used to separate adjoined center pivots that had a length $>$ 1,200 m, length/width ratio $>$ 1.1 and an elliptic fit $<$ 0.90. Several object growing and shrinking steps were used based on shape characteristics to produce uniform center pivot outlines with smooth edges. As many center pivots were only partly active within a year, they produced half circular or “pac man” like shapes. These were mapped based on their length, area, length/width ratio, maximum NDVI values, and proximity to other center pivots. A total of 34,828 fields with center pivot irrigation were mapped in Saudi Arabia for 2015, covering a total area of 10,554 km^2. The largest center pivot was 1.12 km^2, with the first quartile, median and third quartile being 0.15, 0.25, and 0.42 km^2, respectively. Based on maps of leaf area index, land surface temperature, albedo and meteorological data, this amounted to an estimated 14 km^3 of water used in 2015 for center pivot irrigation. Future work will focus on mapping center pivots from 2010-2018 to support regional and national management and crop production practices, while ensuring optimization of water use. Changes in center pivot extent will also be related to existing crop production estimates, water management practices, fuel subsidies and policy implications.