Evaluating the Dynamic Surface Water Extent (DSWE) Landsat Product for Use in Tracking Spatio-Temporal Adoption of Surface-Water Irrigation Infrastructure in the Arkansas Delta

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INTRODUCTION

We evaluate whether Landsat data offer an economical means to track the expansion of surface-water irrigation infrastructure over time and space.

Conjunctive use of surface and groundwater for irrigated agriculture is an important long-term water management strategy for its potential to reduce pumping costs, increase water quality, facilitate aquifer recharge, and increase farm net returns (Young et al. 2004, Wailes et al. 2004, Kovacs et al. 2014, Kovacs et al. 2015). Surface water impoundments built on farms to store water in the wet season for irrigation later in the year can reduce groundwater reliance and sustain aquifers. In the case of the Mississippi River Valley Alluvial Aquifer (MRVA) and the overlying agricultural region of the Arkansas Delta (Figure 1), federal and state policymakers have targeted conjunctive management as a leading strategy to address a declining aquifer.

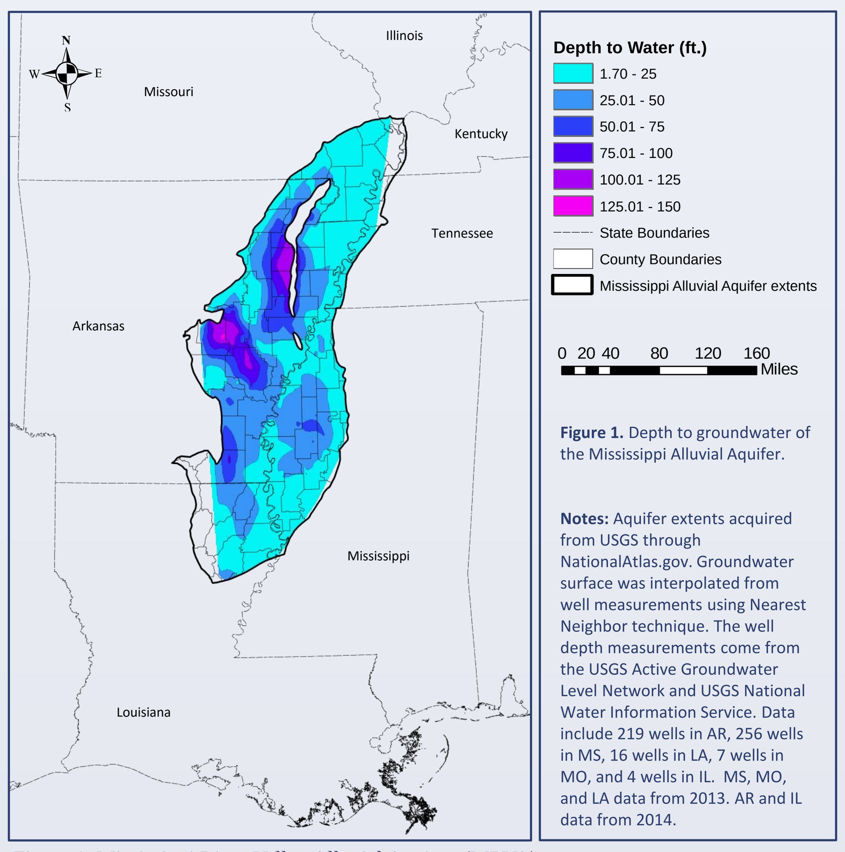


Figure 1. Mississippi River Valley Alluvial Aquiver (MRVA)

Despite the prevalence of programs that encourage efficient irrigation and contribute to voluntary adoption of long-term water management strategies – including the construction of surface-water irrigation reservoirs – there is limited information about the use of these management practices, and this is problematic for water managers and policymakers. Information about the age and distribution of on-farm irrigation reservoirs in the Arkansas Delta would be useful to formulate effective policies to encourage the construction of more surface-water systems. The information would help with characterizing the relative influences of economic, environmental, societal, and policy factors in driving reservoir adoption. It would also open avenues for water resource managers to better assess the dynamics of water quality and quantity on the agricultural landscape at watershed scale.

OBJECTIVES

Release of the provisional Landsat data product named "Dynamic Surface Water Extent" (DSWE) presents an opportunity to evaluate whether Landsat data offer an economical means to track the adoption of surface-water irrigation storage reservoirs in the Arkansas Delta agricultural region. Studies are needed to help determine whether DSWE accuracies are adequate for practical utility in resource management (Jones 2015). To do this, we pursued several objectives:

1. Develop an algorithm that extends the DSWE product to identify probable reservoirs annually in the critical groundwater area of Arkansas County (Figure 2)
2. Evaluate algorithm success by comparing annual outputs of probable reservoirs to reservoir locations verified using visual inspection of available aerial imagery
3. Use annual outputs of probable reservoirs, verified reservoir dates, and an analytic reasoning approach to construct a GIS data layer with annual temporal resolution from 1995 to 2015

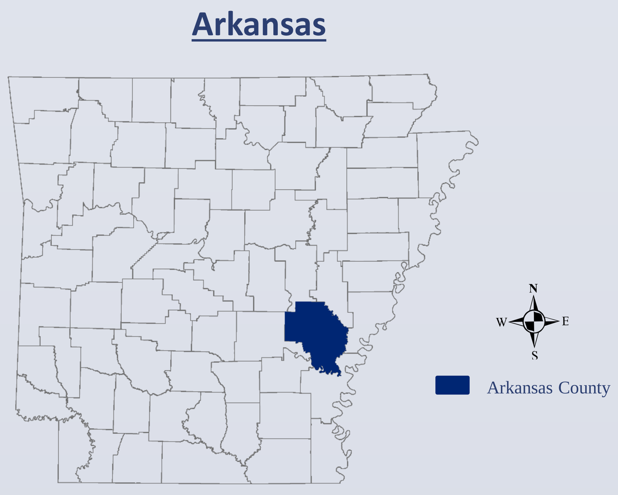
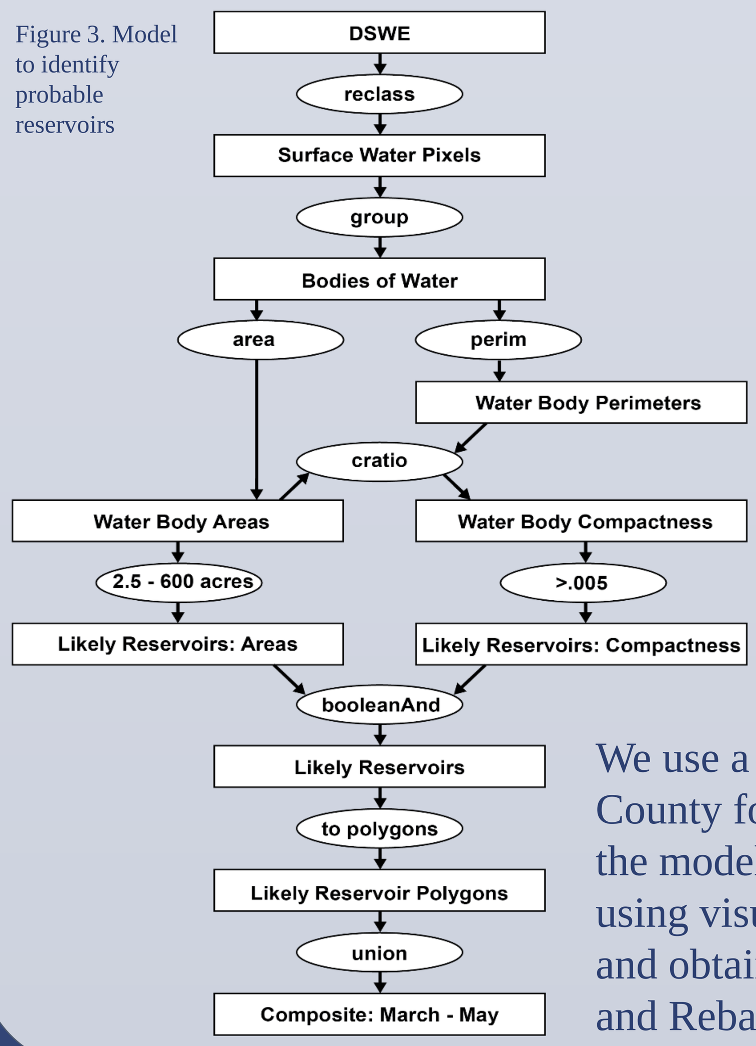


Figure 2. Study Area

DATA & METHODS

Landsat combines extended operation and suitably high spatial resolution (30m) and temporal resolution (16-day return interval) to be useful for observing land-use features at the scale of small irrigation reservoirs and observing change over time. Using the provisional DSWE product allows for methods which bypass spectral processing requirements.

Figure 3. Model to identify probable reservoirs



Provisional DSWE data representing inundated surface water were obtained from the U.S. Geological Survey (USGS) for every Landsat scene overlying Arkansas County from January 1995 to December 2015 (Jones and Starbuck 2015). We develop a conceptual model to identify probable reservoirs based on *a priori* and *a posteriori* knowledge of spatial characteristics like size and shape (Figure 3). We use Python and TerrSet GIS software to apply these filters to each scene of DSWE. The probable reservoir output takes a composite of the wet months prior to the growing season when reservoirs are most likely filled. This also helps to capture reservoirs missed due to cloud cover in particular scenes.

We use a GIS layer containing verified reservoir extents in Arkansas County for select years of the study period to evaluate the quality of the model upon comparison. Verified reservoir data were created using visual inspection of available NAIP and Google Earth imagery and obtained from USDA-ARS (see Wren, Ozeren, and Reba 2017 and Reba et al. 2017).

RESULTS

We compare outputs of probable reservoirs based on the conceptual model to available years of verified reservoir locations (1996, 2000, 2006, 2009, 2010, 2013, and 2015). Table 1 reports the percentage of verified reservoirs that were identified by the model for each verified year. The model successfully identifies between 95.7% and 99.1% of verified reservoirs. The most accurate model year was 2013 where 221 of 223 reservoirs were detected. The model output for 1996 was least accurate, failing to detect 7 of 164 verified reservoirs. Between 2000 and 2006, the number of reservoirs increased by 30 which is the largest increase between verified years. It is also the longest period of time without available high-resolution imagery.

Table 2 reports the percentage of water bodies from the outputs of the conceptual model that positively identify verified reservoirs. On average, approximately 10% of probable reservoirs detected by the model proved to be actual reservoirs in the verified layer. The least accurate model year was 2006 (5.1% positive ID), while 2015 was more than twice as accurate as the average (20.3% positive ID).

Figure 4. 2015 verified reservoirs (a), 2015 model output (b), positively identified verified reservoirs (c), and model output water bodies positively identifying verified reservoirs (d)

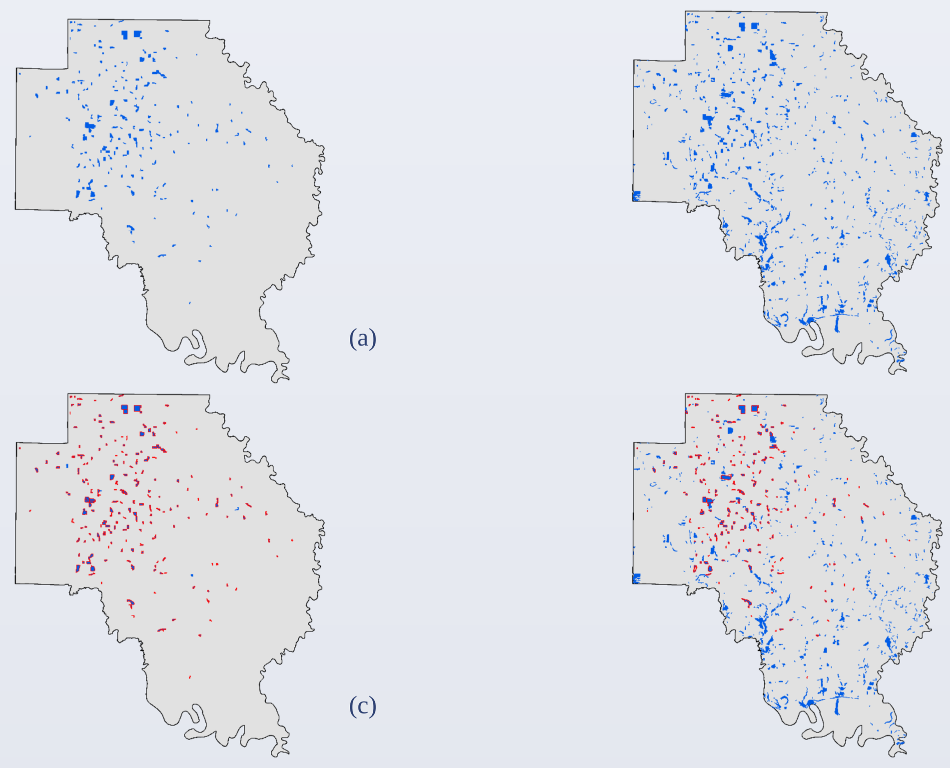


Table 1. Percentage of Verified Reservoirs Identified by Model

NAIP-verified years	Number of verified reservoirs	Number identified by model	Percentage Identified by model
1996	164	157	95.7%
2000	176	171	97.2%
2006	206	204	99.0%
2009	215	212	98.6%
2010	219	215	98.2%
2013	223	221	99.1%
2015	229	225	98.3%

Table 2. Percentage of Model Water Bodies Identifying Verified Reservoirs

NAIP-verified years	Total water bodies identified by model	Number positively identifying verified reservoirs	Percentage identifying verified reservoirs
1996	2476	150	6.1%
2000	1862	152	8.2%
2006	3763	193	5.1%
2009	2031	207	10.2%
2010	2597	201	7.7%
2013	2358	208	8.8%
2015	1115	226	20.3%

CONCLUSIONS

We develop an algorithm extending the DSWE Landsat product that is 98% accurate at identifying verified surface-water irrigation reservoirs. We use annual model outputs, verified years, and some cases of deductive reasoning to construct an annual GIS data layer for reservoirs in Arkansas County (Figure 5). With model water bodies positively identifying verified reservoirs at a rate of 10%, the algorithm can be a useful rubric to guide the verification of reservoirs via available high-resolution imagery. The ability to employ an accurate algorithm with Landsat imagery enables manual verification to be faster and more feasible. In addition, Landsat's frequent return times could allow a more granular investigation of the water levels at these storage systems using DSWE to help irrigation specialists understand how these systems are in use throughout the year. This information is useful for tailoring programs and policies to encourage more surface water use for irrigation and to help stabilize the aquifer levels in the MRVA.

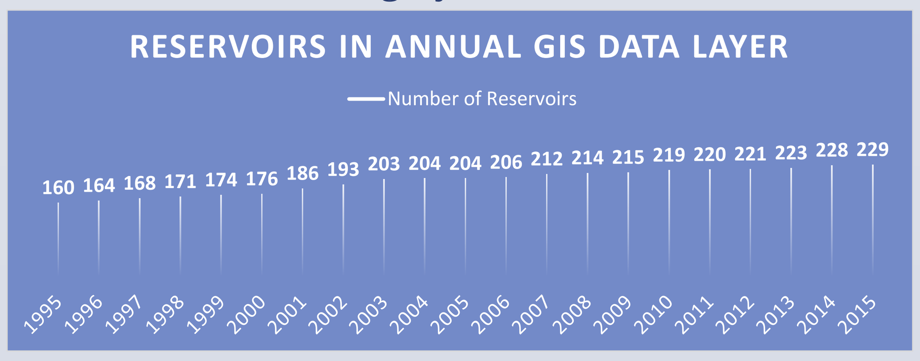


Figure 5. Annual reservoir summary

Future research to complement this study is to collect data on the groundwater levels, weather patterns, and producer characteristics near the farms where the storage systems are present. This should help us to identify which of the factors that potentially drives the adoption of these systems plays the greatest role.

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