TITLE PAGE

Project title: Quantifying the Amount and Impact of Agricultural Water Use in the Upper Red River Basin

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TECHNICAL PROPOSAL AND EVALUATION CRITERIA

EXECUTIVE SUMMARY

Date: April 21, 2021

Applicant name, city, county, and state: Oklahoma State University, Stillwater, Payne County, Oklahoma

Applicant Category: Category B

Project Summary: Oklahoma State University, with the support of the Lugert-Altus Irrigation District, will quantify agricultural water use across the Upper Red River Basin by combining geospatial analyses, remote sensing techniques, and ground-truthing. Our objectives are to: (1) estimate the acreages of irrigated agricultural lands and the type of crops being grown; and (2) apply and evaluate remotely sensed energy balance models to quantify actual crop water use and irrigation application on a distributed basis. To achieve these objectives, we will build a database of agricultural census data collected by the USDA, Cropland Data Layers available from USDA's National Agricultural Statistics Service, hydro-climate data, and water rights permits. We will also conduct a remote sensing-based image classification approach similar to the method regularly employed by the US Bureau of Reclamation, but with some improvements. In addition, we will collect a comprehensive ground-truthing database using smartphone apps that can be used in the future to assess the accuracy of image classification algorithms. We will estimate consumptive agricultural water use based on spatially distributed modeling of actual crop evapotranspiration (ETc) as a residual component of the surface energy balance. Finally, we will estimate irrigation application amounts based on the spatially distributed ETc estimates by incorporating field-level information on irrigation scheduling and irrigation application efficiency. Net irrigation application will be estimated over a fifteen-year period (2007-2022) that includes the recent extreme drought. Results will help evaluate the water supply reliability to sustain irrigated agriculture in the face of water shortage during droughts, while also supporting water availability for rural communities and economically-important recreational activities and ecosystem services. Upon completion of the project, we will disseminate results to key water management agencies and stakeholder groups in the basin to support drought-adaptive water resources planning and management. The findings of this comprehensive modeling and monitoring effort will provide valuable information on the accuracy of the approaches currently implemented by the U.S. Bureau of Reclamation to map irrigated farms and their water use, with potential applications in other agricultural watersheds and irrigation districts across the US.

Proposed duration of project (Completion Date): 24 months (September 30th, 2023)

Is the proposed project located on a Federal facility? No

TECHNICAL PROJECT DESCRIPTION AND MILESTONES

Preparing to cope with reduced water availability in hotter and drier conditions during prolonged droughts in the Upper Red River Basin and hydro-climatically similar areas requires a robust understanding of consumptive water uses to allow adaptive decision making based on reliable water accounting. To this end, the proposed project has two main objectives: (1) to estimate the area of irrigated agricultural lands and the type of crops being grown; and (2) to apply and evaluate remotely sensed energy balance models to quantify crop water use and applied irrigation amount on a distributed basis. We have established tangible milestones to ensure steady progress towards achieving the project objectives. The two primary objectives, the specific activities that will be conducted to achieve them, and the project milestones are explained in detail in the following sections.

Objective 1. Quantifying Crop Types and Irrigated Area

Identifying the extent of irrigated area, type of crops in each irrigated field, and their inter-seasonal variability is of paramount importance in estimating and projecting crop water requirement. When aggregated over larger areas (district, basin, watershed), these estimates provide critical information on local and regional water resources requirement. Historically, state and federal agencies have relied on either self-reported estimates or those obtained from basic remote sensing approaches, such as supervised image classification based on visible and near-infrared wavebands of polar orbiting satellites. Although remote sensing approaches are usually more accurate than self-reported estimates and have the capability of providing distributed (versus lumped) data, both methods have significant deficiencies due to their limitations and the highly dynamic nature of crop decisions made by agricultural producers. We will perform three steps of technical analysis to attain the objective of quantifying crop types and irrigated area (Objective 1). These steps include: (1) characterization of agricultural lands (**Milestone 1**); (2) remote sensing based delineation of irrigated agricultural lands (**Milestone 2**); and creating a geo-referenced photo repository of irrigated fields (**Milestone 3**).

Milestone 1. Build a database of agricultural lands and provide a preliminary estimate of crop-specific irrigated areas by the end of the second quarter of the project (Year 1).

Characterization of Agricultural Lands

We will build a database of agricultural lands using available land use/land cover data from multiple sources to characterize different types of crops grown in the study area and obtain a preliminary estimate of crop-specific irrigated areas. More specifically, we will compile and cross-examine land use/cover data from the USDA's Census of Agriculture data, Cropland Data Layers (CDL) available from USDA's National Agricultural Statistics Service (NASS), self-reported crop acreage and irrigation water use data, and water right permits. We will also obtain hydro-climatic data from the US Climate Divisional Data and Oklahoma Mesonet. A brief description of these data sources follows:

Census of Agriculture Data. The USDA's Census of Agriculture offers a uniform and comprehensive count of US farms and ranches and the people who manage agricultural lands producing and selling $1,000 worth or more of agricultural products during each census year. The Census is taken once every five years and provides a range of valuable information, including land use and ownership, operator characteristics, production practices, income and expenditures. We will use the National Agricultural Statistics Service's (NASS) searchable database to obtain agricultural census data for three census cycles (i.e., 2007, 2012, and 2017) to establish a fundamental understanding of land use and agricultural practices in our study area.

Cropland Data Layers. Cropland Data Layer (CDL) is a raster, geo-referenced, crop-specific land cover data layer created annually for the continental US by the USDA's NASS. CDL is produced using moderate resolution satellite imagery and extensive agricultural ground-truth. All historical CDL products are available for use and free for download through CropScape website. We will take advantage of geospatial crop-specific land cover raster data provided by the CDL for different years (i.e., from 2008 through 2020) to capture year-to-year fluctuation of crop acreages in our annual estimate of irrigation water use. Figure 1 shows the changes in the acreage of cotton in the study area of this project in two example years, demonstrating the impact of a recent drought that forced farmers to take significant cotton fields out of production due to the lack of water availability for irrigation. The figure illustrates the importance of annual crop-specific mapping of irrigated areas for high-accuracy estimation of crop water requirement.

Self-reported Crop Acreage and Irrigation Water Use. Irrigation districts produce annual reports of irrigation water use and acreages of different crops within the district. They also provide estimates of volume of water from surface water used for irrigation, as well as information about crop production and yield. The self-reported crop acreage and irrigation water use data will be converted into Excel Spreadsheets for cross-examination with agricultural census data and CDLs. It is expected that self-reported crop acreage and water use data provide a lower bound estimate of the actual crop acreage and water use in different years. Our cross-examination of data from multiple sources will provide an opportunity to verify this assumption.

Hydro-climatic Data from the US Climate Divisional Database and Oklahoma Mesonet. The National Oceanic and Atmospheric Administration's (NOAA) Divisional Climate Database provides long-term annual and monthly precipitation and temperature data sets. The datasets are organized by climate zones that are drawn based on an array of hydrologic factors. Oklahoma Mesonet is a network of 121 climate monitoring stations, providing a database for long term climate and environmental data. Several parameters are measured every five minutes, including barometric pressure, rainfall, relative humidity, solar radiation, air temperature, wind direction, and wind speed. Additionally, soil temperature measurements are taken every 15 minutes, and soil moisture measurements are taken every 30. These national and state datasets will allow agro-climatic characterization (e.g., water availability and evapotranspiration) of the fifteen irrigation seasons (2007-2022) examined in this project.

Water Rights Permits. GIS shape files are readily available for lands with water rights permits in Oklahoma. Assuming all permitted crop lands will be irrigated, overlaying the CDL raster files and water rights permits GIS shape files will help arrive at a first estimate of irrigated areas under cultivation of different crops. For Texas where water rights permits data are not readily available, the county-based Census of Agriculture data for 2007, 2012 and 2017 will be used to calculate the ratio of census-reported irrigated croplands to CDL total croplands for each county. Furthermore, the corresponding hydro-climatic data will be retrieved from the US Divisional

Climate Database to determine the annual ratio suitable for other years based on the similarity of hydro-climatic conditions. The county ratios will subsequently be applied uniformly to sub-basin CDL in the respective Texas county. To ensure the estimates obtained in this manner are reasonable, the approach will be verified for Oklahoma counties where water right permit data are available. The water right permit layer will be used along with USDA's agricultural census data and CDLs to calculate the ratio of census-reported irrigated croplands to CDL total crop lands for each Oklahoma county within the study area.

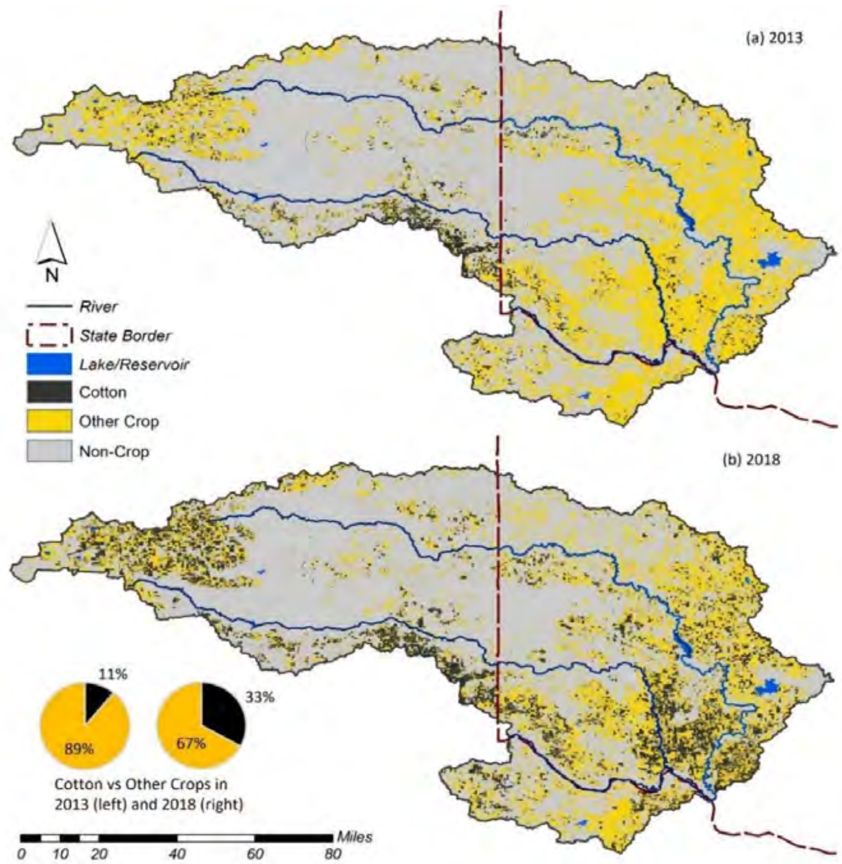
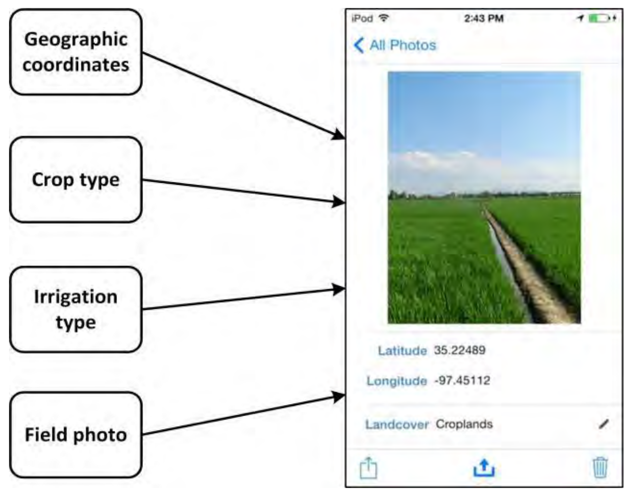


Figure 1- Changes in agricultural land in 2013 and 2018 based on Cropland Data Layer (CDL) raster files. The maps and pie charts show significant inter-annual variability of crop-specific acreages using cotton (~420,000 ac in 2018) as an example irrigated commodity crop.

e sixth quarter of the project (Year 2).

Remote Sensing Based Delineation of Irrigated Agricultural Lands and Supplemental Ground-truthing

In this project, we will improve the accuracy of remotely sensed irrigated area and land use classification by including the thermal band of satellite imagery in image processing (**Milestone 2**). The thermal signature of irrigated fields is significantly different from non-irrigated fields and can improve the accuracy of the results, especially in wet years when visible and near-infrared wavebands can be ineffective in differentiating irrigated and non-irrigated pixels. In addition, we will develop a robust ground-truthing database that can be used in evaluating the accuracy of the classification approach implemented in this project and any other approach/project in the future (**Milestone 3**). Relying on the help of local extension educators who know local producers, we will receive permission, will visit a large number of irrigated fields in the study area, and will record the geographic coordinates, crop type, irrigation system type, and a photo of land surface using smart-phone applications such as Field Photo (Figure 2). This database will be included in project deliverables for future use by Reclamation.



Objective 2. Mapping Crop Water Use and Irrigation Application

Besides the extent of irrigated area and the types of irrigated crops, the actual amount of water use by irrigated crops and the amount and timing of water extraction for irrigation application (**Milestone 4**) are key parameters in estimating the current and future water demands, as well as studying the effects of variations in these parameters on downstream water availability (**Milestone 5**).

Milestone 4. Quantify actual crop water use based on remotely sensed energy balance models by the end of the seventh quarter of the project (Year 2).

Milestone 5. Map the annual irrigation application on a distributed basis by the end of the seventh quarter of the project (Year 2).

To estimate crop water use, Reclamation and other agencies rely on an approach known as the crop coefficient (Kc). In this approach, a time-variable coefficient (Kc) is assigned to each field based on the type of the crop (Huntington et al., 2015). The daily Kc is then multiplied by the reference evapotranspiration (ETo) measured at nearby weather stations to obtain crop evapotranspiration (ETc) as an indicator of crop water requirement. The Kc values are obtained from appropriate tables in the FAO-56 publications (Allen et al., 1998), or from locally developed Kc databases available for a few locations across the US.

The crop coefficient method is a widely-used approach, but it has several caveats. The first caveat is that assigning the right daily coefficients requires the knowledge of planting date and the length of major growth stages. Since such information is not available for each field and crop variety, the Kc approach relies on assumed planting dates and growth stages. This could result in significant deviations from actual conditions since planting date and growth stages are highly variable among seasons, fields, and varieties of the same crop. Another shortcoming of the Kc method is that its estimate represents standard conditions where all stresses (water, heat, nutrients, and pests) are absent. Under actual field conditions, crops are frequently exposed to such stresses and thus their actual ETc is smaller than the rate estimated by the crop coefficient approach. Due to this limitation, estimates of the Kc method cannot be easily converted to the volume of irrigation water applied to irrigated field, as the actual amount of applied irrigation may be significantly less than what is potentially required to maintain stress-free conditions.

Remotely Sensed surface Energy Balance (RSEB) models can serve as an effective alternative to the crop coefficient method. These models provide spatially distributed estimates of the latent heat flux as the residual of the surface energy balance. Once other energy balance components (i.e. net radiation, sensible heat flux, and soil heat flux) are determined, the latent heat flux can be estimated for each day of satellite overpass and converted to actual ETc (Figure 3):

Latent heat flux = Net radiation - Sensible heat flux - Soil heat flux (1)

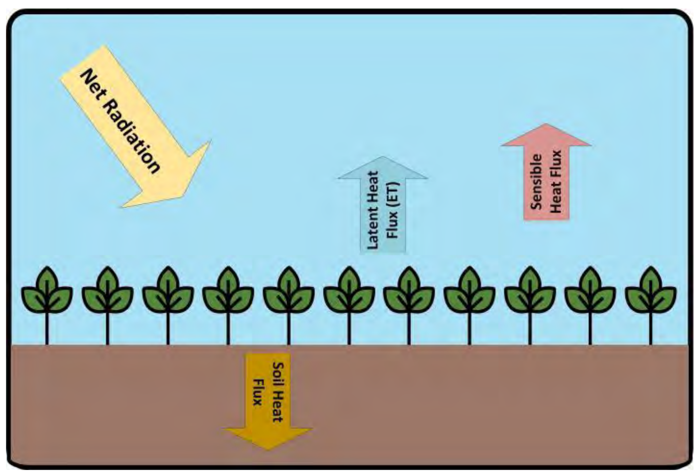
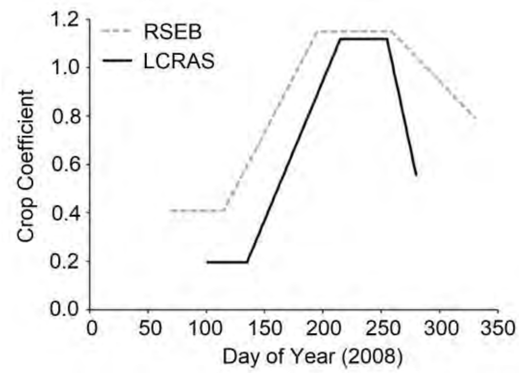


Figure 3- Major components of surface energy balance. The three components of net radiation, sensible heat flux, and latent heat flux can be estimated on a distributed basis using RSEB models, allowing for calculation of the latent heat flux (ETc) as the residual term (**Milestone 4**).

The RSEB models do not require crop type, planting date, and growth stage information. Variations in visible and near-infrared bands capture temporal changes in crop biomass, while canopy temperature allows for quantifying the effects of stresses on crop water consumption. Hence, they have the ability to capture crop and management variabilities that the Kc method fails to account for. As an example, a study conducted by co-PI Taghvaeian found that the Kc approach implemented for irrigated cotton by Reclamation in the Lower Colorado River Accounting System (LCRAS) assumed a shorter growing season and missed a heavy pre-season irrigation event that cotton producers had started to practice a few years earlier (Figure 4). In contrast, a RSEB model was able to account for these deviations from normal practices

(Taghvaeian et al., 2012). As a result of these differences, the seasonal cotton water use based on LCRAS was 909 mm, significantly smaller than the estimate based on the RSEB model (1,507 mm). The RSEB results matched ETc estimates based on a root zone soil water balance approach at several instrumented fields. Another study by co-PI Taghvaeian showed that LCRAS significantly overestimated water use of riparian vegetation along the riparian corridor of the lower Colorado River, while RSEB models were far more accurate when compared to the estimates of Bowen ratio flux towers (Taghvaeian et al., 2014).

Figure 4- Cotton Kc curve used by Reclamation in the Lower Colorado River Accounting System (LCRAS) and a similar curve developed based on the results of a Remotely Sensed surface Energy Balance (RSEB) model.



After mapping actual ETc over irrigated fields, the next sub-objective (milestone) is to convert these estimates to irrigation application amounts, which represent the amount of water extraction from ground- and surface-water resources. Accomplishing this task requires field-level information on irrigation scheduling and irrigation application efficiency. We will instrument irrigated fields at Oklahoma State University's research stations within or near the Upper Red River Basin, namely Southwest Agronomy Research Station, Panhandle Research and Extension Center, Southwest Research and Extension Center, and Sandyland Research Station. Instrumentation will include irrigation flow meters, rain gauges installed below sprinkler nozzles, and soil moisture probes to quantify the amount of water extracted, the amount of applied water that reached the soil surface, and the amount of water that percolated below the root zone. We will also estimate irrigation application efficiency and uniformity using the Oklahoma Mobile Irrigation Lab (MIL). The MIL is managed by co-PI Taghvaeian and an energy management extension specialist and has been in operation for several years. The MIL unit has all the required equipment to estimate irrigation application efficiency and uniformity and has conducted irrigation audits for several fields in the study area. More audits will be conducted during the project at irrigated fields selected for installing rain gauges and soil moisture probes. The data on irrigation fluxes at extraction point, soil surface, and below the root zone will be combined with irrigation efficiency estimates to develop relationships between remotely sensed ETc and irrigation application amounts on a distributed basis.

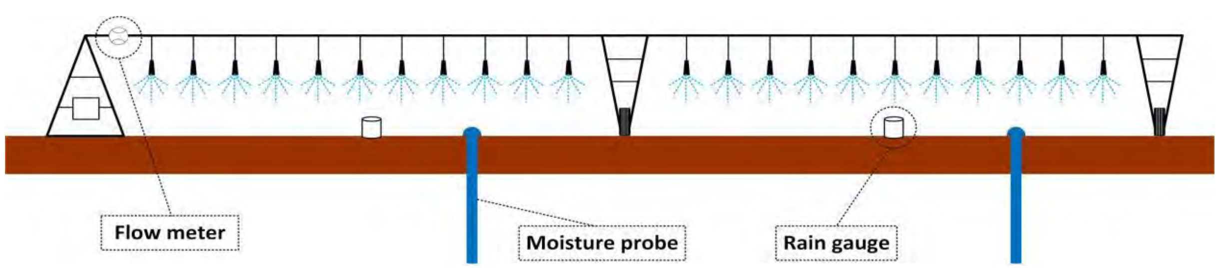


Figure 5- Schematic of the type and setting of sensors that will be installed at selected research stations to allow accomplishing **Milestone 5**.

Overall, the proposed technical approach will combine geospatial analysis, remote sensing techniques, and ground-truthing to significantly improve the capability to determine crop-specific irrigated areas and accurately estimate and map crop water use. Together, the technical components will facilitate the identification of the location of irrigation, as well as the amount of irrigation, which are essential for assessing water availability and impacts of agricultural water management across the basin.

PROJECT LOCATION

The geographic scope of the proposed project is the Upper Red River Basin (~4,000 square miles, Figure 6), which occupies all or parts of nine counties in southwestern Oklahoma and fourteen counties in the Texas panhandle. The water resources management challenges in the Upper Red River Basin underscore growing vulnerability of agricultural production in the face of the scarcity of freshwater resources for irrigation, especially during droughts. Water availability in the region has been negatively impacted by extreme wet and dry cycles and upstream extractions. Communities in this region have experienced severe droughts within the past 10 years, a situation which is projected to be exacerbated by increased climate variability (McPherson and Kellog, 2016). Freshwater demands are met primarily by federally-managed reservoirs (e.g., Tom Steed and Altus Reservoirs providing 99 percent of the surface water supply to about 45,000 people and irrigation water for about 50,000 acres of land in Oklahoma), while groundwater is used to make up for surface water shortfalls (OWRB, 2012).

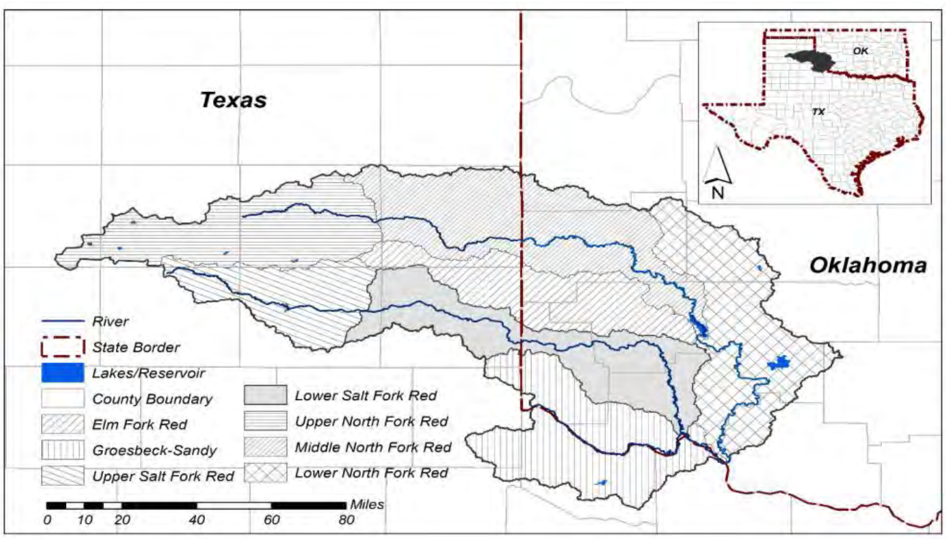


Figure 6-Proposed study area in the Upper Red River Basin.

DATA MANAGEMENT PRACTICES

Data Management

PI Mirchi is ultimately responsible for the management and retention of the data generated during the course of this project. Mirchi will coordinate and assure data storage related to individual project tasks. Mirchi will work with Co-PIs Taghvaeian and Alian to store and manage data related to geodatabase development, land classification, and ET modeling results on OSU data repositories.

Types of Data

The data created by this project will come in the form of data collections and technical analysis results provided by project personnel. The data will include the USDA Census of Agriculture data, Cropland Data Layers available from USDA's National Agricultural Statistics Service, hydro-climate data, and water rights permits. Project personnel will also make tables, graphs, or computer codes for various analyses, and will lead the ground-truthing of cropland classification and irrigation application using smartphone apps. These data will be in common file formats such as Microsoft Word, PowerPoint documents, Python scripts, or JPEG.

Metadata Standards

Metadata will include information about time/date of dataset creation, creator, last update, file size, file extension, and contact person. We will use Metadata Wizard 2.0 to create metadata records for data sets used in modeling tasks.

Plans for Archiving and Preservation of Access

Data and products developed as a result of this project will be backed up on multiple computers and external drives. Possible mechanisms for storing data include flat files (e.g., text), multimedia files (e.g., image), Access database, Arc Map file geodatabase, and Microsoft Excel spreadsheets. Data and products will be archived on a quarterly basis in long-term repositories through Oklahoma State University's Department of Biosystems and Agricultural Engineering's Windows Server 2008 file server named BAE-FS02, more commonly referred to as the "T:" drive. The hardware that underlies BAE-FS02 consists of one Dell R610 server, one Dell hard drive array directly connected to the R610 server and one Dell tape backup unit directly attached to the R610 server. The storage array contains enough drives to provide 9 TB of storage in a RAID 6 configuration. Furthermore, a directly attached tape unit contains two magazines containing 15 1.5 TB tapes and one cleaning tape. This provides 22.5 TB of uncompressed backup space. Symantec Backup Express 2010 is the software that is used to provide the backups.

Policies and Provisions for Re-use and Re-distribution

Products will be available for reuse, reproduction, and modification with the least amount of restrictions. We will use the GNU General Public License v3.0 and Creative Co ns —both popular open licensing schemes with several advantages. Published data and products will be free to be copied and redistributed in any medium or format. Products are also free to be adapted or transformed as long as appropriate credit is given to the project by providing a link to the established license and indications of ade changes.

EVALUATION CRITERIA

Evaluation Criterion A — Benefits to Water Supply Reliability

1. What are the water management issue(s) that the project will address?

The proposed project will primarily benefit water supply reliability by providing the capability to conduct robust water accounting through improved estimates of irrigation water requirements, which is essential for water resources planning and management. Objective evaluation of water supply reliability contributes to better management of water deliveries, coordinated drought management activities, and conjunctive use of groundwater and surface water while informing water rights administration and developing plans to increase water conservation and irrigation efficiency. Water managers will benefit from improved understanding of potential water supply shortfalls or uncertainties, the need to meet competing demands for water, complications arising from drought, and coordinated efforts to mitigate conflicts over water, among others.

Reliable estimates of where and how much irrigation is applied is key information for planning reliable regional water supply through design of irrigation systems, climate impact assessments, basin water balance analysis, and analysis of potential water right applications. Spatially distributed understanding of irrigation water requirements and associated surface water and groundwater withdrawals across the basin supports (1) better groundwater management using existing permitting frameworks, and (2) providing the necessary information to initiate dialogues aiming at voluntary groundwater pumping curtailments through lease exchanges that increase the reliability of water availability in vulnerable areas where agricultural production is more profitable. Levering possible regulatory and voluntary adaptation options based on quantitative understanding of water supply and demand is, in turn, expected to improve water availability in Lake Altus and Tom Steed Reservoir. This will provide additional benefit as the reservoirs support a number of recreational and educational opportunities in Quartz Mountain Arts & Conference Center, Quartz Mountain Nature Park, and Great Plains State Park, which support regional economic activity and ecosystem services in the Upper Red River Basin (Piper, 2018).

2. How severe are the water management issues to be addressed?

Water supply reliability issues and associated water management challenges have severe consequences for agricultural production in the Upper Red River Basin. The sub-humid climate of the region is conducive to high agricultural productivity, if adequate water resources are available for irrigation during hot and dry summers (Kottek et al., 2006). The importance of irrigation is evidenced by the stark difference it makes in the value of cropland in the region. In southwest Oklahoma, for example, the cash rent of irrigated cropland was about three times more than that of non-irrigated cropland during 2014-2016 (ODAFF, 2016). Average irrigated cotton yield (1030 lb/ac) is significantly larger than non-irrigated cotton yield (~429 lb/ac) in the study area. The same holds true for wheat yield (irrigated: 43 Bu/ac; non-irrigated: 30 Bu/ac).

Freshwater demands of agriculture, communities (e.g. the city of Altus and Altus Air Force Base), and industry are met primarily by Reclamation reservoirs (e.g., Lake Altus (154,092 acre-ft) and Tom Steed (117,865 acre-ft)) and secondarily by groundwater wells, which are strained with heavy demand (OWRB, 2012). During the extreme prolonged drought of 2011-2015, water levels in Lake Altus, which supplies water to approximately 50,000 ac of irrigated land in the Lugert-Altus Irrigation District, dropped below the intake level of the main canal (Figure 7). Consequently, water delivery to irrigated farms within the district was halted for several years, imposing a devastating impact on the local economy (more than $200 million/yr (The Oklahoman, 2013)). The drought ended with above-normal precipitation in spring 2015 (Figure 8).

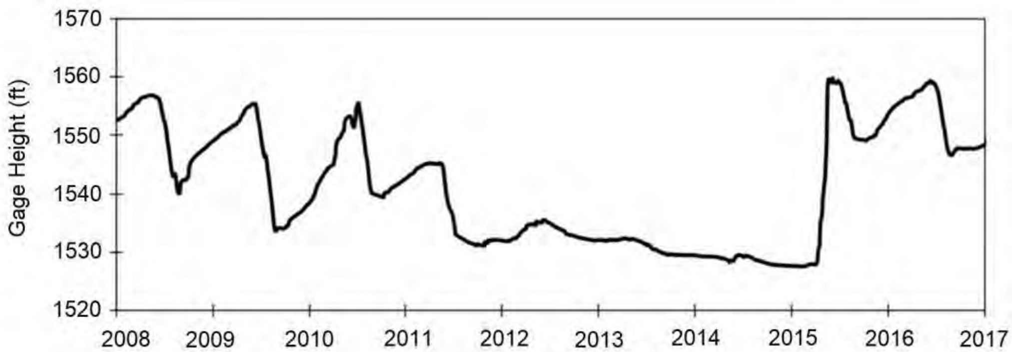


Figure 7- Lake Altus level fluctuations (Khand et al., 2017). Water deliveries to irrigated lands were halted between 2011 and 2015 due to low water level in the reservoir.

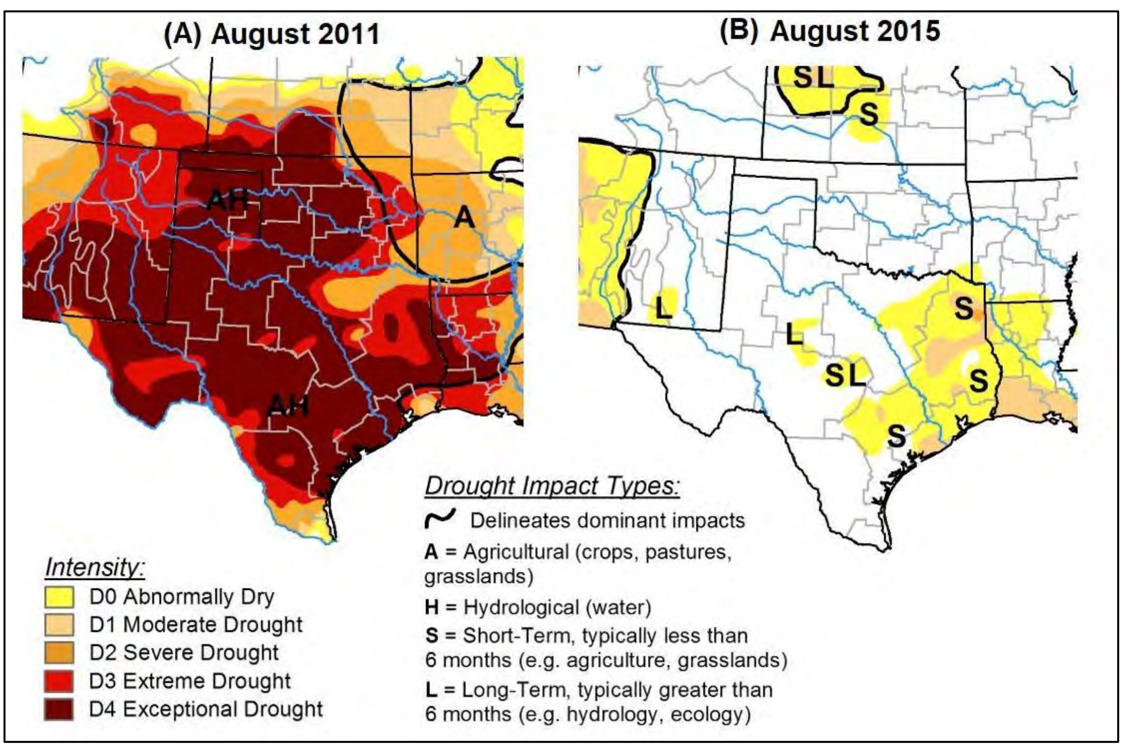


Figure 8-Drought severity maps: (A) 2011, and (B) 2015. A new drought-of-record (D4 Exceptional Drought) was registered in 2011 during a prolonged drought in the study area, which lasted until 2015 (Source of drought maps: US Drought Monitor, droughtmonitor.unl.edu).

3. How will the project address the identified water management issue(s)?

The proposed technical approach will increase the accuracy of estimated irrigation water use as compared to the widely used crop coefficient method. We will provide a practical technical framework for objective evaluation of water supply reliability using geospatial analyses, ground-truthing, and remote sensing capabilities to characterize water availability dynamics across irrigated lands. Extreme climate variability and agricultural water management practices affect the magnitude, timing, and duration of watershed processes (e.g., runoff, streamflow, return flows, and groundwater recharge) that govern water supply reliability across the basin. The changes in water supply due to high irrigation demand and associated impacts on the availability and flow of water across the basin during droughts can trigger conflicts between upstream and downstream water users. These water issues will be addressed through:

(1) rigorous calculation of crop-specific irrigated areas using multiple data sources (e.g., Census of Agriculture, CDLs, self-reported crop acreage and water use data, water rights permits, etc) and remote sensing techniques; and

(2) accurate estimation of crop water consumption using state-of-the-art remote sensing based energy balance models to directly calculate actual crop evapotranspiration in a spatially distributed way, which indicates crop water use. The irrigation application rates will be also estimated using ground-based data collected at Oklahoma State University's field research stations within or near the study area, capturing the spatial variability of irrigation application and irrigation efficiency.

The project will improve the capability for reliable agricultural water supply planning by quantifying the extent of cop-specific irrigated lands based on detailed crop land classification using data from multiple sources. Furthermore, we will provide accurate estimates of the amount of water used for crop production in irrigated croplands determined in the previous step. The results of the project will provide key information for adjusting the management of surface water reservoirs during wet and dry cycles to increase water supply reliability based on a robust understanding of agricultural water accounting. Likewise, the results will guide conjunctive surface water-groundwater management scheme to maintain high reliability of water supply by better understanding the location and magnitude of agricultural water withdrawal and consumptive uses that affect water availability across the basin.

4. To what extent will the project benefit one of the water management objectives listed in the Funding Opportunity Announcement (R21AS00289)?

Our project addresses the need for better understanding of irrigation water use to maintain basin scale reliable water supply under the constraints of growing demand for limited freshwater resources and climate variability and change in the Upper Red River Basin. By addressing this need, the project will reduce uncertainties in irrigation planning, basin water balance assessments of conjunctive use of surface water and groundwater, drought management activities, management of water deliveries, and administration of water rights. Like many other irrigation districts in the western US, quantitative understanding of the extent of irrigated croplands and actual irrigation water use in the Upper Red River Basin remains poor. In this situation, water management agencies and technical service providers rely on self-reported crop acreage and irrigation water use data, which may underrepresent the actual extent of and magnitude of irrigation. We will apply a combination of data analyses, geospatial analysis and remote sensing to identify opportunities to improve the reliability of agricultural water supply by spatially distributed calculation of irrigation water use. By examining a fifteen year period (2007-2022) that contains the drought of record (2011-2015), we will improve the technical capability to understand and manage the effects of irrigation during periods of extreme water shortage.

5. How will the project complement similar studies in the region?

The proposed project complements other similar efforts in estimating irrigation water use and characterizing water resources availability in the Upper Red River Basin by Reclamation, USGS, and other technical service providers. A number of studies have documented hydrologic and hydrogeologic characteristics of the upper Red River Basin. The main surface water resources include Red River and its major tributaries (e.g., North Fork Red River, Elm Fork Red River, and Salt Fork Red River). Average total annual surface water available from these tributaries is approximately 689,500 acre-ft (Varghese, 1998). Only North Fork Red River (~90,600 acre-ft/yr), the primary source of surface water inflow to Lake Altus, is used for irrigation because of the large total dissolved solids (TDS) concentrations in other tributaries (e.g., up to ~5,000 mg/L in Salt Fork Red River, averaging 2,751 mg/L at Elmer, OK (OWRB, 2020)). The main aquifers in this region are the Blaine aquifer and the alluvium and terrace deposits underlying the rivers. Estimates of safe groundwater yield are provided by the USGS using MODFLOW groundwater flow models based on estimates of major groundwater withdrawals, lateral flows, seepage, and aquifer recharge (Kent, 1980; Smith et al., 2017). Reclamation has applied crop coefficient method using 2012 land use to provide supplemental agricultural irrigation demand estimates as part of an ongoing basin study for the proposed study area (personal communication, n.d.).

Our project will add significant value to these previous and ongoing efforts by applying a dynamic land use and crop water use estimation approach to provide time series estimates of crop-specific irrigation in the study area. We propose to apply a combination of GIS-based crop-specific irrigated land classification refined by the application of remote sensing techniques to improve mapping of irrigated areas and quantification of irrigation water use.

Evaluation Criterion B — Need for Project and Applicability of Project Results

1. Does the project meet an existing need identified by a water resource manager(s) within the 17 Western States?

Yes. The technical components of this proposal have been developed with direct input from Lugert-Altus Irrigation District, especially Mr. Tom Buchanan, manager of the Lugert-Altus Irrigation District located in southwestern Oklahoma. The project team performed additional background research about the need for this project by consulting experts at Reclamation. Water supply reliability issues are expected to be exacerbated in the future as Red River streamflows in the study area may be reduced by 18-32% (OWRB, 2012). Fresh groundwater depletions in the Lugert-Altus Irrigation District are forecasted to be as high as 17,220 acre-feet per year by 2060 (Balcombe, 2014), in part due to growing demand and North Fork Red River streamflow depletion related to withdrawal of fresh alluvial groundwater for irrigation of upstream agricultural lands (Krueger et al., 2017). This project and its intended outcomes will directly support long-term water resource planning and management at the Lugert-Altus Irrigation District and Texas Agricultural Statistics Service (TASS) District 11 (Northern High Plains). If selected for funding by Reclamation, the irrigation district will support the project and will participate in it by sharing data and field experiences to facilitate the attainment of project objectives (see Support Letter).

2. Will the project result in an applied science information that is readily applicable, and highly likely to be used by water resource managers in the West?

Yes. The applied science information produced as a result of this project will be in the form of high-accuracy mapping of crop-specific irrigated lands and the amount of irrigation applied in each year during a fifteen-year example time series. This information will be readily applicable and highly likely to be used by water resources managers in southwestern Oklahoma and the Texas Panhandle. Furthermore, the technical framework consisting of database development, GIS analysis, remote sensing, and ground-truthing will be readily applicable for other water management districts in the West where high-accuracy mapping of irrigated croplands and the amount of irrigation water use is unavailable.

The results of the project will be used to inform water resource management actions and decisions immediately upon completion of the project. In the short run, the results will inform the planning of irrigation system improvements, irrigation water management, and basin scale water balance analysis. With additional work and creating a dialogue around the future of water resources management to support irrigated agriculture in the Texas Panhandle and southwestern Oklahoma, the results will support developing coordinated conjunctive surface water-groundwater management schemes, and assessment of water rights applications and potential disputes. Our transferable, systematic, technical framework described in detail in Technical Project Description and Milestones will facilitate assessing water supply reliability under future climate conditions and irrigation scenarios. Many irrigation districts in the western US face water supply reliability issues, which are tied to their inability to use existing water resources due to lack of information about the extent of irrigated croplands and magnitude of irrigation water used.

Evaluation Criterion C — Project Implementation

Project objectives, milestones and timeline

The primary objectives of the project are (1) estimating the acreages of irrigated agricultural lands and the type of crops being grown; and (2) applying and evaluating remotely sensed energy balance models to quantify actual crop water use and irrigation application on a distributed basis. We have established several milestones to ensure timely progress of the work. The project milestones are as follows:

Milestone 1. Build a database of agricultural lands and provide a preliminary estimate of crop-specific irrigated areas by the end of the second quarter of the project (see details under Objective 1, Pages 2-4).

Milestone 2. Delineate irrigated agricultural lands using remote sensing techniques by the end of the fourth quarter (see details under Objective 1, Pages 4-5).

Milestone 3. Create a geo-referenced photo repository of irrigated fields by the end of the sixth quarter (see details under Objective 1, Pages 4-5).

Milestone 4. Quantify actual crop water use based on remotely sensed energy balance models by the end of the seventh quarter (see details under Objective 2, Pages 5-8).

Milestone 5. Map the annual irrigation application on a distributed basis by the end of the seventh quarter (see details under Objective 2, Pages 5-8).

The project team will work closely to complete project tasks within a two-year time frame as chronologically outlined in Table 1. PI Mirchi will be responsible for managing the project and delivering outcomes. We will meet monthly throughout the course of the project for coordinated integration of project components and attainment of the specified milestones.

Table 1. Project tasks and timeline.

Project Task (Milestone; M)	**Yr 1**				**Yr 2**			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Collect data and develop the project geodatabase (M1)	X							
Preliminary estimate of crop-specific irrigated areas	X							
Delineate irrigated agricultural lands using remote sensing (M2)		X	X	X				
Create a geo-referenced photo repository of irrigated fields (M3)		X	X	X	X	X		
Quantify actual crop water use based on remotely sensed energy balance models (M4)				X	X	X	X	
Map annual irrigation application on a distributed basis (M5)		X	X	X	X	X	X	
Information transfer		X		X		X		X
Final report writing and manuscript development								X

Availability and quality of existing data and models

The input data for applying the proposed technical framework are publicly available through a number of different data sources that perform data quality assessments prior to public release. An exception is self-reported agricultural acreage and water use data that are collected at the irrigation district level without completing rigorous data quality assessment protocols. Table 2 summarizes the existing data that will be used in this project and the sources where the data will be obtained from.

Table 2- Existing data and data sources.

Data	**Tool or Model**	**Source(s)**
Census of Agriculture	Excel spreadsheets and Arc GIS 10.8	USDA NASS web-based data retrieval system (https://quickstats.nass.usda.gov/)
Cropland Data Layers	Arc GIS 10.8	SDA NASS CropScape: https://nassgeodata.gmu.edu/CropScape/
Self-reported Crop Acreage	Excel spreadsheets	Lugert-Altus Irrigation District and Texas Agricultural Statistics Service (TASS) District 11
Self-reported Irrigation Water Use	Excel spreadsheets	Lugert-Altus Irrigation District and Texas Agricultural Statistics Service (TASS) District 11
Regional scale hydro-climatic data	Excel spreadsheets	SA Divisional Climate Data: https://wrcc.dri.edu/spi/divplot1map.html
Ground-based meteorological data (air temperature, relative humidity, incoming shortwave solar radiation, wind speed and atmospheric pressure)	Excel spreadsheets, text files, and energy balance model	Oklahoma Mesonet: http://www.mesonet.org/index.php/past_data/category/past_data_links
Water rights permits	rc GIS 10.8	ttps://www.owrb.ok.gov/maps/PMG/owrbdata_WR.html
Irrigated fields characteristics	Smartphone apps	Field Photo: http://www.eomf.ou.edu/photos/
Remotely sensed data (surface reflectance, land surface temperature, and emissivity)	Land use classification and energy balance model	USGS Earth Data: https://lpdaac.usgs.gov/data/ Energy balance model: Khand et al. (2019)
Field-level irrigation schedule and irrigation application efficiency	Excel spreadsheets	Field research station staff and research team, Oklahoma State University

Project team members and qualifications

Our team has expertise in hydrology and water resources systems (Mirchi and Taghvaeian), irrigation engineering (Taghvaeian), remote sensing (Taghvaeian and Alian) and geographic information systems (Alian, Taghvaeian, and Mirchi). The project personnel will work closely with Mr. Tom Buchanan, manager of the Lugert Altus Irrigation District in southwestern Oklahoma. Furthermore, we will use the technical review services of the Reclamation's Technical Service Center (TSC) in Denver, Colorado, to ensure our project builds on ongoing efforts and adds significant new technical information. The project team is capable of proceeding with tasks within the proposed project immediately upon entering into a financial assistance agreement with Reclamation.

Dr. Ali Mirchi is an Assistant Professor of water resources engineering at the Department of Biosystems and Agricultural Engineering at Oklahoma State University. He holds a Ph.D. in civil/water resources engineering from Michigan Technological University, a Master's in water resources engineering from Lund University, and a BSc in civil/water engineering from the University of Tabriz. Mirchi has over 14 years of experience in various applications of water resources engineering. He applies systems modeling and analysis techniques, including system dynamics simulation, hydro-economic optimization and watershed hydrologic modeling to advance understanding of coupled human-natural systems at different scales. His research focuses on water resources planning and management to derive policy insights that promote water sustainability by understanding the tradeoffs associated with meeting the water demands of the agricultural sector and growing urban areas while maintaining the ecological integrity of natural environments. Dr. Mirchi is currently working on similar projects in the southwestern US. (funded by the USDA NIFA, USDA ARS, and USGS) and northeastern Tunisia (funded by USAID), investigating adaptive water resources management strategies in the face of population growth, competing demands, and climatic extremes.

Dr. Saleh Taghvaeian is an Associate Professor and Irrigation Extension Specialist at the Department of Biosystems and Agricultural Engineering at Oklahoma State University. He holds a Ph.D. in irrigation engineering from Utah State University, as well as Master and Bachelor of Science degrees in irrigation and drainage engineering from Ferdowsi University, Iran. For the past 13 years, Dr. Taghvaeian has been working on quantifying water fluxes in irrigated agriculture across California, Utah, Colorado, and Oklahoma. He has conducted numerous research projects on mapping crop water use, monitoring soil moisture and deep percolation, developing precision irrigation scheduling, and estimating irrigation pumping energy efficiency and application uniformity. He has several ongoing projects in southwest Oklahoma and has established a network of agricultural producers within and outside the Lugert-Altus irrigation district who collaborate with him on a range of extension and demonstration projects. He is also involved in collaborative research projects in the Texas Panhandle with his irrigation engineering counterparts from Texas A&M University and USDA-ARS in Bushland, TX.

Dr. Sara Alian is a Teaching Assistant Professor of geographic information systems (GIS) at the Department of Biosystems and Agricultural Engineering at Oklahoma State University. She holds a Ph.D. and a Master's degree in Forest Sciences from Michigan Technological University. Alian has over 9 years of experience in geospatial science applications in natural resource management and geospatial science education. Her expertise is in the areas of geospatial sciences, GIS technology, and remote sensing to inform resource management decisions, including land, water, and forest management. She has worked on interdisciplinary projects funded by the National Science Foundation (NSF), Great Lakes Protection Fund, and US Department of Agriculture (USDA) to generate new information, geospatial data, and insights for sustainable biofuel feedstock management and production of biofuel feedstocks, to evaluate ecological water stress in the Great Lakes Region, and New Mexico-Texas-Mexico border region. Dr. Alian has also applied geospatial technologies including remote sensing and GIS to assess the impact of land use change on payment for hydrological services programs and ecosystem services and their relationship with social and economic drivers and responses in Veracruz, Mexico.

The project team will collaborate with the Water Resources Engineering and Management Group at the Reclamation's Technical Service Center (TSC). Mr. Mark Spears will be the point of contact and our main collaborator at the TSC, providing technical review services to evaluate the procedures and analysis results during the course of the project. This peer review arrangement helps ensure the technical framework and results will complement and add value to the Reclamation's ongoing effort to characterize irrigated agricultural lands and crop water requirement in the study area.

Summary description of expected *products*

The project will produce several important products. First, the developed database and accompanying metadata will provide ready-to-use applied science information generated as a result of this project. The database and metadata, which will be prepared for the Upper Red River Basin, will serve as a practical example for use by other irrigation districts in the West. Second, the geo-referenced ground-truth data will provide regionally relevant information to refine the mapping of irrigated croplands. Third, the applied science information, including the crop-specific irrigated area mapping and quantification of actual crop water use, will capture the historical variability of the extent and magnitude of agricultural water use in the study area. This historical characterization is essential for improving basin water balance assessments and future adaptive water resources planning in the project area. Fourth, the technical framework and results of the proposed project, which will be published in technical reports and peer-reviewed scientific manuscripts, will inform agricultural water management impact assessment studies to take advantage of high-accuracy crop-specific irrigation mapping and actual irrigation water use estimation. The framework will be applicable to irrigation districts in the West and the results will be of interest to water management agencies in the region (See Support Letters).

These outcomes will provide to water managers and stakeholders in the Upper Red River Basin an applied science framework and information that empower them to make technically sound well-informed decisions to improve agricultural water management to cope with extreme water shortage. Furthermore, the project will support and provide training opportunities for a water professional at doctoral level.

Evaluation Criterion D — Dissemination of Results

Our dissemination plan will facilitate effective communication of project results within our proposed study area and beyond. We plan to maximize the project's impact using the following methods to share the results and policy implications with key stakeholder groups at different levels (i.e., local to national):

- Delivering the final results and policy implications to Lugert-Altus Irrigation District, Texas Agricultural Statistics Service (TASS) District 11 (Northern High Plains), Oklahoma Water Resources Board, Texas Water Development Board, Choctaw Nation, and Chickasaw Nation through a virtual presentation, published technical reports, and meetings with the stakeholders.

- Developing policy briefs, fact sheets, and infographics to communicate the results of our water adaptation analysis to decision makers (from county to state to congressional representatives) and the public in the proposed study area and beyond, leveraging Oklahoma State University's traditional extension and outreach efforts.

- Sharing results with other researchers and water professionals through a Reclamation-sponsored webinar to disseminate deliverable(s) and discuss application of deliverables to management questions, a seminar in the USGS South Central Climate Adaptation Science Center's seminar series, as well as participation in national/international professional meetings (e.g., American Society of Agricultural and Biological Engineers).

- Publishing the technical framework and project results in reports and peer-reviewed journal articles for wider application of the methodology in the US.

SUPPORTING THE DEPARTMENT OF THE INTERIOR PRIORITIES

By addressing the challenge of agricultural water supply reliability, the project supports a number of Department of the Interior Priorities, including creating a conservation stewardship legacy second only to Teddy Roosevelt (Priority 1) and modernizing our infrastructure (Priority 5). More specifically, the project approach and resulting applied science information about irrigated cropland mapping and actual agricultural water use quantification using data analysis, geospatial mapping, and remote sensing techniques will be useful for (i) utilizing science to identify best practices to manage land and water resources and adapt to changes in the environment; (ii) reviewing Department of the Interior water storage, transportation, and distribution systems to identify opportunities to resolve conflicts and expand capacity; and (iii) supporting the White House Public/Private Partnership Initiative to modernize US infrastructure.

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PROJECT BUDGET

Funding plan/letters of funding commitment

The non-Federal portion of project costs will be provided by Oklahoma State University as a cost match using salaries and wages and unrecovered indirect costs. A letter of funding commitment is provided in this proposal package.

Budget proposal

Table 1. Total project costs

SOURCE	AMOUNT
Costs to be reimbursed with the requested Federal funding	$135,469.00
Costs to be paid by the applicant	$135,723.00
Value of third-party contributions	$0.00
TOTAL PROJECT COST	$271,192.00

Table 2. Budget Proposal

Budget Item Description	COMPUTATION		Quantity Type	TOTAL COST
	$/Unit	Quantity		
Salaries and Wages				
PI Mirchi	7,100	1	USD	7,100
Co-PI Alian	5,200	1	USD	5,200
Co-PI Taghvaeian	8,000	1	USD	8,000
Experiment station staff	27,000	1	USD	27,000
Experiment station staff	27,000	1	USD	27,000
Grad Student	48,000	1	USD	48,000
Fringe Benefits				
PI Mirchi	2,805	1	USD	2,805
Co-PI Alian	2,055	1	USD	2,055
Co-PI Taghvaeian	3,160	1	USD	3,160
Experiment station staff	12,572	1	USD	12,572
Experiment station staff	12,572	1	USD	12,572
Grad Student	2,040	1	USD	2,040
Travel				
In-state	2,400	1	USD	2,400
Out-of-state				
Equipment				
NA				
Supplies and Materials				
NA				
Contractual and Construction				
TSC	22,831	1	USD	22,831
Third Party In-Kind Contributions				

NA				
Other				
Tuition Remission	,144		SD	,144
TOTAL DIRECT COSTS				**91,879**
Indirect Costs				
Agency	34,314		SD	34,314
Oklahoma State University	44,999		SD	44,999
TOTAL ESTIMATED PROJECT COSTS				**71,192**

BUDGET JUSTIFICATION

All personnel transactions required to fulfill the provisions of this proposal will be made in accordance with, and will be governed by, the appropriate University Personnel Policies and Regulations. All salary increases will conform to University policies, subject to the availability of funds. No officer, member, or employee of the University and no other public officials for the governing body of the locality or localities in which the project is situated or being carried out who exercise any functions or responsibilities in the review or approval of the undertaking or carrying out this project, shall participate in any decision relating to this project which affects his personal interest or have any personal or pecuniary interest, direct or indirect, in this project or the proceeds thereof.

A. Salaries and Wages – Senior Personnel:

Dr. Ali Mirchi (PI) will direct the project work and perform the overall management of the progress over the year-round activities conducted at Oklahoma State University (OSU). $6,000 is requested to cover 0.26 of a month of summer salary per year for the PI for the duration of the two-year project. In addition, the PI will contribute 0.22 months of salary in project year 1 and 0.18 months of salary in project year 2 in cost share for a total of $3,100. The PI will dedicate time year round to lead the technical activities to implement the proposed methodology. Mirchi will also provide guidance to one PhD student in Biosystems and Agricultural Engineering, and will ultimately be responsible for and produce project reports and delivering project outputs.

Dr. Saleh Taghvaeian (Co-PI) will lead the remote sensing based classification of irrigated agricultural areas and application of energy budget methods for estimation of crop evapotranspiration and irrigation requirements. $6,000 is requested to cover 0.22 months of summer salary per year for Dr. Taghvaeian for the duration of the two-year project. In addition, the Co-PI will contribute 0.08 months of salary in project year 1 and 0.06 months of salary in project year 2 in cost share for a total of $1,200. Dr. Taghvaeian will co-advise the graduate research assistant with PI Mirchi.

Dr. Sara Alian (Co-PI) will lead geospatial analysis and data management tasks, and development of infographics using GIS data products. Alian will also assist with remote sensing based classification of irrigated agricultural areas. $6,000 is requested to cover 0.36 of a month of summer salary per year for Alian for the duration of the two-year project. In addition, the Co-PI will contribute 0.36 months of salary per year in cost share in project years 1 and 2 for a total of $4,000. Dr. Alian will also contribute to advising the graduate research assistant.

B. Other Personnel:

Graduate Student: $48,000 is requested to support a full-time PhD student in Biosystems and Agricultural Engineering (BAE) for the duration of the project. The BAE PhD student will receive a full year of research assistantship support per project year ($24,000/Yr for 2 Years) to help with geodatabase development, GIS based land use classification, and remote sensing analysis of crop water requirement.

C. Fringe Benefits:

Fringe benefits are calculated using the OSU federally negotiated rate of 39.52% for faculty, 46.56% for staff and 4.25% for graduate student. A total of $6,780 is requested from federal funds and $28,424 will be provided as cost share.

D. Equipment:

None

Travel:

A total of $2,400 is requested to cover in-state travel expenses for OSU project team members for the duration of the project ($1200/yr for 2 years) to perform ground-truth assessments of presence or absence crops and irrigation systems in the upper Red River Basin.

E. Other Direct Expenses:

Tuition Remission at the rate of 19.05% of the graduate student salary, a total of $9,144.

F. Indirect Costs:

Indirect costs are calculated based on the OSU's federally negotiated rate of 49.6% of Modified Total Direct Costs.

G. Environmental and Regulatory Compliance Costs:

N/A

H. Subawardees:

USBR Technical Service Center (TSC) in Denver: A total of $22,831 will be subawarded to TSC for the duration of the two-year project. TSC will assign a staff member to provide technical review assistance in light of past USBR technical work in the proposed study area and hydro-climatically similar agricultural watersheds.

ENVIRONMENTAL AND CULTURAL RESOURCE CONSIDERATIONS

The proposed technical framework will primarily involve analysis of existing geospatial and remotely sensed data. As such, the project will be compliant with Environmental and Cultural Resource Considerations.

• Will the proposed project impact the surrounding environment (e.g., soil [dust], air, water [quality and quantity], animal habitat)? Please briefly describe all earth-disturbing work and any work that will affect the air, water, or animal habitat in the project area. Please also explain the impacts of such work on the surrounding environment and any steps that could be taken to minimize the impacts.

The proposed project will not impact the surrounding environment. Installation of soil sensors will be the only earth-disturbing work, which will not impact the soil, air, water, or animal habitat in the project area.

• Are you aware of any species listed or proposed to be listed as a Federal threatened or endangered species, or designated critical habitat in the project area? If so, would they be affected by any activities associated with the proposed project?

No. No species listed or proposed to be listed as a Federal threatened or endangered species, or designated critical habitat will be affected by any activities associated with the proposed project.

• Are there wetlands or other surface waters inside the project boundaries that potentially fall under CWA jurisdiction as "Waters of the United States?" If so, please describe and estimate any impacts the proposed project may have.

No wetlands or other surface waters inside the project boundaries that potentially fall under CWA jurisdiction as "Waters of the United States" will be affected by any activities associated with the proposed project.

• When was the water delivery system constructed?

Lake Altus is the major reservoir providing irrigation water to Lugert-Altus Irrigation District. The construction of Lake Altus was completed in 1947. The system of canals delivering Lake Altus irrigation water to farmlands were completed by 1953. No major reservoir exists in the Texas Panhandle portion of the study area.

• Will the proposed project result in any modification of or effects to, individual features of an irrigation system (e.g., headgates, canals, or flumes)? If so, state when those features were constructed and describe the nature and timing of any extensive alterations or modifications to those features completed previously.

No.

• Are any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places? A cultural resources specialist at your local Reclamation office or the State Historic Preservation Office can assist in answering this question.

We are not aware of any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places. However, we are sure that the proposed project activities will not impact any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places in the study area.

• Are there any known archeological sites in the proposed project area?

We are not aware of any known archeological sites in the proposed project area. The proposed project activities will not impact archeological sites.

• Will the proposed project have a disproportionately high and adverse effect on low income or minority populations?

No.

• Will the proposed project limit access to and ceremonial use of Indian sacred sites or result in other impacts on tribal lands?

No.

• Will the proposed project contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area?

No.

DATE: April 8, 2021

FROM: Tom Buchanan

Re: Letter of Support for Oklahoma State University's WaterSMART- Applied Science Grants Proposal

TO WHOM IT MAY CONCERN

I am writing in support of Oklahoma State University's WaterSMART- Applied Science Grants proposal entitled "Quantifying the Amount and Impact of Agricultural Water Use in the Upper Red River Basin." The proposed project will investigate the acreages of irrigated agricultural lands and crop water requirements and irrigation water use in the Upper Red River Basin. The investigators work in developing databases and tools for quantifying the magnitude of water withdrawal for irrigation will be critical for sustainable agricultural water management in the region. The project team at Oklahoma State University will apply a combination of GIS analyses and modeling methods to quantify irrigation water use and derive insights for agricultural water management.

This project and its intended outcomes will directly support long-term water resource planning and management at the Lugert-Altus Irrigation District. If selected for funding by the Bureau of Reclamation, I will support the project by sharing data and field experiences to facilitate the attainment of project objectives.

Thank you for your consideration.

Sincerely,

Tom Buchanan

Manager

Lugert-Altus Irrigation District

JULIE CUNNINGHAM
EXECUTIVE DIRECTOR

KEVIN STITT
GOVERNOR

STATE OF OKLAHOMA
WATER RESOURCES BOARD
www.owrb.ok.gov

April 19, 2021

Dr. Ali Mirchi
Assistant Professor
Department of Biosystems and Agricultural Engineering
Oklahoma State University
219 Agricultural Hall
Stillwater, Oklahoma 74078

RE: Letter of support for proposed study in the upper Red River Basin

Dear Dr. Mirchi,

The Oklahoma Water Resources Board (OWRB) supports your proposal for a WaterSMART applied science grant in the upper Red River Basin.

The mission of the OWRB is served by managing and improving Oklahoma's water resources to ensure clean and reliable water supplies, a strong economy, and a safe and healthy environment and I believe this project and its intended results to be in line with supporting our mission. The results of the proposed work have the potential to provide detailed data on water use, which is useful for OWRB hydrologic investigation reports that help determine maximum annual yields for groundwater basins within the upper Red River Basin, The data can also used to corroborate reported water use in groundwater-dependent area within the region where irrigation water use is prevalent. Knowing areas in the state where water use is highest could benefit our efforts supporting the Water For 2060 Act, which was adopted by the state of Oklahoma in 2012 with a goal of consuming no more fresh water in 2060 than was consumed in 2010.

The OWRB intends to support the project team by sharing any available data as well as providing technical insight when possible.

Sincerely,

Julie Cunningham
Executive Director
Oklahoma Water Resources Board

cc: Derrick Wagner, Environmental Programs Manager

3800 N. CLASSEN BOULEVARD • OKLAHOMA CITY, OKLAHOMA 73118
TELEPHONE (405) 530-8800 • FAX (405) 530-8900

USDA United States Department of Agriculture

Farm Production and Conservation

Natural Resources Conservation Service

Oklahoma NRCS State Office
100 USDA Suite 206
Stillwater, OK 74074

April 20, 2021

Re: Letter of Collaboration for Oklahoma State University's WaterSMART Proposal

TO WHOM IT MAY CONCERN

NRCS is fully supportive of working with partners such as the Oklahoma Conservation Commission, Oklahoma State University, Oklahoma Association of Conservation Districts, The Nature Conservancy, Noble Research Foundation, Oklahoma Water Resources Board, American Farm Land Trust, Oklahoma Tribal Conservation Advisory Council, Tribes, Conservation Districts and others to obtain additional irrigation data while working with Oklahoma farmers and ranchers. This data would help the entire partnership while coordinating with farmers and ranchers in a better quantitative understanding of irrigation water use which will be critical for sustainable agricultural water management and natural resource conservation. This will increase adoption of critical systems and help them become more successful in addressing water resource management in the Upper Red River Basin and beyond.

Respectfully,

Gary O'Neill

GARY L. O'NEILL
State Conservationist

Vice President for Research
Oklahoma State University
203 Whitehurst Hall
Stillwater, Oklahoma 74078-1020
(405) 744-6501
www.research.okstate.edu

April 15, 2021

Bureau of Reclamation
Financial Assistance Support Section
Attn: Applied Science NOFO
P.O. Box 25007, MS 84-27133
Denver, CO 80225

SUBJECT: Resolution of Support, Quantifying the Amount and Impact of Agricultural Water Use in the Upper Red River Basin

Dear Mr. Reichert,

Oklahoma State University, Division of Agricultural Sciences and Natural Resources, is pleased to submit the above referenced proposal under the direction of Dr. Ali Mirchi. This proposal falls within the guidelines of our strategic plan for the Division of Agricultural Sciences and Natural Resources at Oklahoma State University and has been reviewed and approved in accordance with Oklahoma State University policy.

OSU's requested funding is $135,469. We also agree to provide $135,723 to meet the agency's cost share requirement, in the form of salaries and wages and unrecovered indirect costs. We look forward to working with the Bureau of Reclamation to meet established deadlines for entering into a grant or cooperative agreement.

Questions of a technical nature can be directed to Dr. Mirchi at amirchi@okstate.edu or 405-744-8425. Administrative, contractual, or budgetary questions can be directed to Melissa Harrison, at melissa.harrison@okstate.edu or 405-744-7004.

Sincerely,

Kenneth W. Sewell
Vice President for Research