




## RESEARCH AND OBSERVATORY CATCHMENTS: THE LEGACY AND THE FUTURE

# Long term agroecosystem research experimental watershed network

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### Abstract

The vision of the Long Term Agroecosystem Research (LTAR) network is to enable multi-decadal, trans-disciplinary, and cross-location science to ensure the long-term sustainability of U.S. agriculture. LTAR's primary goals are to: (1) Intensify agricultural productivity, (2) Improve ecosystem services related to agricultural production, and (3) Improve rural prosperity. The LTAR network includes 18 locations (sites). It includes 10 existing hydrologic observatories from the Agricultural Research Service-

Experimental Watershed Network (ARS-EWN) that were established before the creation of LTAR. Background and an overview of the network are presented.

#### KEYWORDS

agroecosystems, ecosystem services, food and forage production, research watersheds, rural prosperity, water use efficiency

## 1 | DATASET NAME

Long-Term Agroecosystem Research (LTAR) Ag Data Commons

## 2 | BACKGROUND

As we enter the third decade of the 21st century global population projections for 2050 are roughly 9.5 billion persons. Nearly 5 of the 9.5 billion persons are likely to live in water stressed regions. This presents a major challenge in ensuring adequate food and water, while maintaining natural resources and the ecosystem services they provide. This challenge is made more difficult under the constraint of decarbonizing our energy systems and dealing with a warmer and more erratic climate. The challenge requires that our agroecosystems be better understood, not just at the field scale but within watersheds and landscapes. Sustainability and a more circular economy will be necessary to meet the challenge of sufficient food and water. The USDA specifies four goals to ensure sustainability: (1) Satisfying human needs; (2) Enhance environmental quality, ecosystem services and the resource base; (3) Sustain the economic viability of agriculture; and (4) Enhance the quality of life for farmers, ranchers, forest managers, workers, and society as a whole (U.S. Department of Agriculture, 2011). This will require a long-term approach with a strong multidisciplinary scientific foundation and observational infrastructure to discern the complexities and interactions of agricultural production at watershed and landscape scales.

Robertson et al. (2008) argued that developing sustainable wide-scale agricultural production should be undertaken over a wide range of production systems using systems-level research over the long-term. They noted that such an effort would be analogous to the National Science Foundation's Long-Term Ecological Research (LTER) network. Calls for a transformation in agriculture to meet the challenges noted above have also arisen from the National Academy of Sciences (National Research Council, 2010). With these goals in mind Walbridge and Shafer (2011, 2013) of the USDA-Agricultural Research Service (ARS) envisioned the creation of a Long Term Agroecosystem Research (LTAR) network that would heavily leverage existing USDA long-term observatories; the ARS Experimental Watersheds and ARS Experimental Ranges.

The vision of the LTAR network is to enable multi-decadal, trans-disciplinary, and cross-location science to ensure the long-term sustainability of U.S. agriculture. LTAR's primary goals are to; (1) intensify agricultural productivity, (2) improve ecosystem services related to agricultural production, and (3) improve rural prosperity. LTAR will

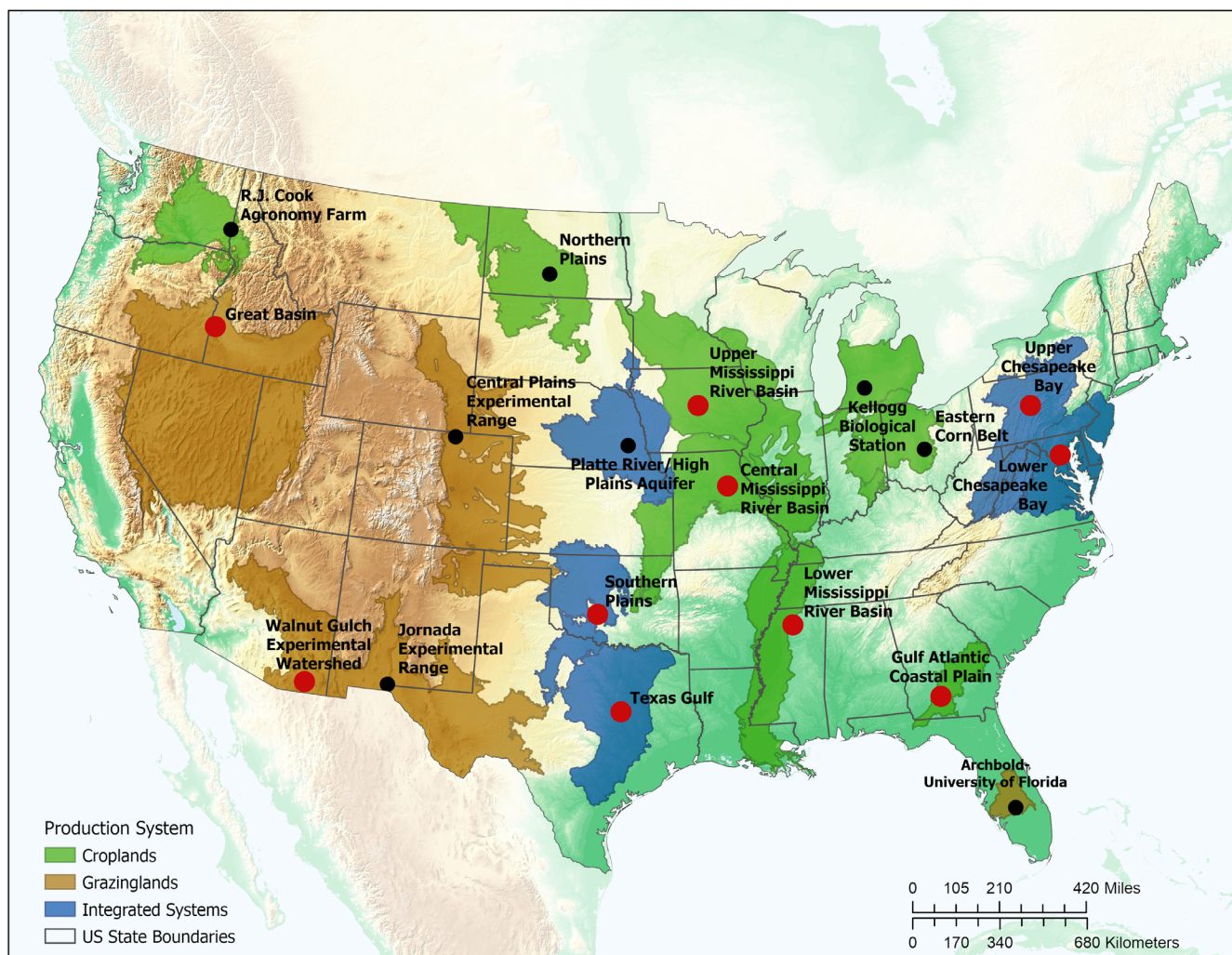
sustain a land-based infrastructure for research, environmental management testing, and education that enables understanding and forecasting of the Nation's capacity to provide agricultural commodities, ecosystem services, and rural well-being under changing environmental, economic, and societal conditions. Selection of LTAR sites was initiated with two "Requests For Information" (RFI) that were released as part of the selection process in 2011 and 2012. A long history of natural resources observations was a requirement to be considered for designation as an LTAR location.

The two RFI calls resulted in the selection of 18 LTAR locations made up of the following long-term observatories: (1) Eight long-term ARS experimental watersheds, (2) two medium-term ARS experimental watersheds, (3) three ARS experimental ranges, (4) two biological stations; and, (5) three ARS—University partnership sites (Goodrich et al., 2021; Steiner et al., 2015). LTAR's 18 locations are distributed across the U.S., representing most of the nation's major agroecosystems (Figure 1). The polygons surrounding an LTAR site in Figure 1 denote an agricultural production region that the enclosed LTAR represents (Bean et al., 2021). Those sites designated with a red dot are LTAR locations that include ARS Experimental Watersheds that were created before LTAR was formed. Additional details on the LTAR network can be found in Kleinman et al. (2018—Table 1) and <https://ltar.ars.usda.gov/>.

## 3 | OVERVIEW

Table 1 provides links to all of the LTAR sites including web links for data access and to site bibliographies. Table 2 provides further information on basic hydrometeorological data collections and selected hydrologic research accomplishments. In some cases, including most of the ARS Experimental Watersheds, sites have published a special section or issue with multiple data papers. The reference for the introductory paper to the collection of papers on that watershed is listed in column two of Table 2. The special collection of papers typically provide site details, experimental watershed history, instrumentation specifications and accuracy, observation methods, and examples of how the data have been used.

All LTAR locations collect a basic suite of hydrometeorological measurements including precipitation (weighing bucket with a wind shield), air temperature and relative humidity, short, long-wave, and photosynthetically-active radiation, barometric pressure, and wind speed and direction. Some sites include multiple locations with these measurements. Common QA/QC procedures and programs are being developed in cooperation with NOAA Climate Reference Network. All the sites also include one or more eddy covariance (EC) towers, and



**FIGURE 1** Locations of the USDA-ARS LTAR sites. Coloured polygons depict production systems regions represented by the enclosed LTAR sites. Sites denoted with a red dot depict ARS experimental watersheds

phenocams co-located with the EC towers. Phenocams are web cameras that collect red, green, and blue images and transfer the images every 30 min to a central repository. Images at all of the LTAR sites are achieved and can be obtained at: <https://phenocam.sr.unh.edu/webcam/>. Discharge is measured at all but one of the LTAR sites using a combination of flumes, weirs, and detention ponds. When possible, manual discharge measurements are made to assess the uncertainty of the discharge measurements with a goal of no more than 10% uncertainty of automated methods. The ARS Experimental Watersheds followed the guidance published in the ARS Field Manual for Research in Agricultural Hydrology (Brakensiek, 1979) for instrumentation, siting, field maintenance, data collection and reduction. Water quality measurements are made at most sites with water temperature and nutrients being the most commonly measured variables. Water quality observations vary across the LTAR sites, typically selected to reflect regional water quality concerns. For example, in the western U.S. erosion and sediment are emphasized as this is the most cited reason for impaired water bodies. In regions with cultivated agriculture, nutrients and pesticides are commonly collected (Goodrich et al., 2021).

LTAR has an active Information Management Task Force and over 10 working groups that focus on a variety of measurements (e.g., water and energy fluxes, climate and weather, water quality, etc). They are working toward a common set of methods to measure variables with common protocols across LTAR sites with associated QA/QC procedures. As a collective the various LTAR sites contain a broad range of accredited laboratory capabilities. To avoid duplication and simplify QA/QC, samples are shipped to LTAR sites with the appropriate instrumentation and skills when possible.

The broader set of LTAR goals requires the collection of data beyond those typically associated with experimental watersheds (e.g., productivity, economic, social, biodiversity, and nutrition data, among others). These data, and Federal open data requirements, have elevated data archive and access needs to a department level archival system called the Ag Data Common (ADC) housed at the National Agricultural Library (<https://data.nal.usda.gov/>). In 2017, efforts were initiated to provide metadata for all available data sets for the 18 LTAR locations and begin migrating LTAR data into the ADC. In conclusion, the LTAR network is providing a wide range of data that will be

TABLE 1 Long term agroecosystem research (LTAR) sites—Descriptive and data access information

Site name (link to site page)	LTAR site name & location Type	Location	Year site established	Area (km <sup>2</sup> )	Climate <sup>a</sup>	Access <sup>b</sup>	Network Affiliation <sup>d</sup>	Bibliographies
Archbold-University of Florida	ABS-UF BS	Lake Placid, FL; Venus, FL; Ona, FL	1941	102	Humid-subtropical	<a href="https://www.archbold-station.org/html/datapub/data/dataovr.html">https://www.archbold-station.org/html/datapub/data/dataovr.html</a>	AmeriFlux, GLEON, NutNet, USCRN, Phenocam	Short bibliography Long bibliography
Central Mississippi River Basin	CMRB LTEW	Columbia, MO (Goodwater Creek Experimental Watershed)	1971	490	Humid-subtropical	STEWARDS <sup>c</sup>	CEAP, SCAN, Phenocam	Long bibliography
Central Plains Experimental Range	CPERER	Nunn, CO	1937	62.8	Cold semi-arid	<a href="https://data.nal.usda.gov/long-term-agroecosystem-research">https://data.nal.usda.gov/long-term-agroecosystem-research</a>	LTER, NEON, GRACEnet, NADP, NutNet, SCAN, Phenocam WERN	Long bibliography
Eastern Corn Belt	ECB ARSU & MTEW	Columbus, OH	1974	N/A	Hot-summer humid-continental	STEWARDS	CEAP, GRACEnet	Short bibliography Long bibliography
Great Basin	GB LTEW	Boise, ID	1961	239	Cold semi-arid	<a href="https://data.nal.usda.gov/long-term-agroecosystem-research">https://data.nal.usda.gov/long-term-agroecosystem-research</a>	CEAP, CZO, NADP, SCAN, Phenocam, WERN	Short and long bibliographies
Gulf Atlantic Coastal Plain	GACP LTEW	Tifton, Georgia; (Little River Experimental Watershed)	1965	334	Humid-subtropical	STEWARDS	CEAP, NADP, SCAN, Phenocam	Short and long bibliographies
Jornada Experimental Range	JER ER	Las Cruces, NM; Monticello, UT (TNC Dugout Ranch)	1912	780	Hot semi-arid	<a href="https://jornada.nmsu.edu/data-catalogs">https://jornada.nmsu.edu/data-catalogs</a>	CEAP, COSMOS, LTER, NEON, SCAN, UV-B MRP, USCRN, WNB, Phenocam, WERN, MRP	Short bibliography Long bibliography
Kellogg Biological Station	KBS BS	Hickory Corners, MI	1987	16	Warm-summer humid continental	<a href="https://lter.kbs.msu.edu/datatables">https://lter.kbs.msu.edu/datatables</a>	LTER, AmeriFlux, NADP, NutNet, Phenocam WERN	Short bibliography Long bibliography
Lower Chesapeake Bay	LCB MTEW	Beltsville, MD, Eastern Shore, MD/DE (LCB Choptank Section)	1910	2600	Humid-subtropical	STEWARDS	CASNet, AmeriFlux, CEAP, COSMOS, EOS, NADP, GRACEnet, SCAN, UV-B MRP, Phenocam	Short bibliography Long bibliography
Lower Mississippi River Basin	LMRB LTEW	Oxford, MS	1981	21.3	Humid-subtropical	STEWARDS	COSMOS, CEAP, SURFRAD, SCAN	Long bibliography
Northern Plains	NP ER	Mandan, ND (Northern Great Plains Research Laboratory)	1912	9.7	Semi-arid continental	<a href="https://data.nal.usda.gov/long-term-agroecosystem-research">https://data.nal.usda.gov/long-term-agroecosystem-research</a>	NEON, CEAP, GRACEnet, REAP, SCAN, Phenocam, WERN	Short and long bibliographies



TABLE 1 (Continued)

Site name (link to site page)	LTAR site name & location Type	Location	Year site established	Area (km <sup>2</sup> )	Climate <sup>a</sup>	Access <sup>b</sup>	Network Affiliation <sup>d</sup>	Bibliographies
Platte River/High Plains Aquifer	PRHPA ARSU	Lincoln, NE	1912	16 500	Hot-summer humid continental	<a href="https://prhpa.unl.edu">https://prhpa.unl.edu</a>	AmeriFlux, GRACEnet, REAP, SCAN, Phenocam	Short bibliography Long bibliography
R.J. Cook Agronomy Farm	CAF ARSU & MTEW	Pullman, WA	1999	0.57	Warm-summer mediterranean	<a href="https://meta.cafttar.org/catalog">https://meta.cafttar.org/catalog</a>	7 LTAP, GRACEnet, REAP, NADP, SCAN, Phenocam, WERN	Short bibliography Long bibliography
Southern Plains	SP LTEW & MTEW	El Reno, OK (Little Washita River/Fort Cobb Reservoir Experimental Watersheds)	1946 1959	1423	Humid-subtropical	STEWARDS	CEAP, COSMOS, SCAN, Phenocam, WERN	Short bibliography Long bibliography
Texas Gulf	TG LTEW	Temple, TX	1937	3.5	Humid-subtropical	STEWARDS	CEAP, GRACEnet, NutNet, LTBE, SCAN, Phenocam	Long bibliography
Upper Chesapeake Bay	UCB LTEW	University Park, PA (Upper Chesapeake Bay Experimental Watersheds)	1968	1127	Warm-summer humid continental	STEWARDS	CEAP, GRACEnet, SCAN, Phenocam	Short bibliography
Upper Mississippi River Basin	UMRB MTEW & ARSU	Ames, IA (Upper Miss. River Basin Exper. Watersheds); Rosemount, MN (ARS St. Paul); Platteville, WI (Univ. of Wisconsin- Platteville, Pioneer Farm); Morris, MN (UMRB Swan Lake Research Farm)	1992	6200	Hot-summer humid continental	STEWARDS	AmeriFlux, CEAP, GRACEnet, SCAN, Phenocam	Short and long bibliographies
Walnut Gulch Experimental Watershed	Walnut Gulch LTEW	Tombstone, AZ (Walnut Gulch Experimental Watershed); Green Valley, AZ (Santa Rita Experimental Range)	1953	150	Hot desert	<a href="https://www.tucson.ars.ag.gov/dap/">https://www.tucson.ars.ag.gov/dap/</a>	AmeriFlux, CEAP, COSMOS, EOS, GRACEnet, SCAN	Short bibliography Long bibliography

Abbreviations: ARSU, ARS/University partnership; BS, biological station; ER, experimental range; LTEW, long-term ARS experimental watersheds; MTEW, medium-term ARS experimental watersheds.

<sup>a</sup>All sites measure standard meteorologic variables.

<sup>b</sup>All LTAR data will eventually be accessible at: <https://data.nal.usda.gov/long-term-agroecosystem-research>.

<sup>c</sup><https://data.nal.usda.gov/dataset/stewards-data-delivery-application-usdaars-conservation-effects-assessment-project>.

<sup>d</sup>For network names and abbreviations see list of acronyms in supporting information (Data S1).

**TABLE 2** Additional information on LTAR network sites and selected research accomplishments

LTAR site	Overview or special issue introduction paper	Basic hydrometeorologic data collection <sup>a</sup>				Selected major hydrologic research accomplishments
		Discharge	Sediment	Water quality <sup>b</sup>	Other <sup>c</sup>	
Archbold–Univ. of Florida	Swain et al. (2013)	X	X	1	1,4	<ul style="list-style-type: none"> <li>On ranges, implemented payments for water and ecosystem services on over &gt;25 000 ac that cleanse and slow the flow of water downstream to the everglades</li> <li>Developed stewardship guidance for compatible grazing management to maintain ecosystem services from wetlands embedded in ranchlands</li> <li>Pasture fertilization methods used to develop state water quality regulations</li> </ul> (Bohlen et al., 2009; Bohlen & Villapando, 2011; Boughton et al., 2019; Capece et al., 2007; Chamberlain et al., 2017; Gomez-Casanovas et al., 2020; Jansen et al., 2019; Silveira et al., 2011; Sonnier et al., 2018; Zielinski et al., 2006)
Central Mississippi River Basin	Sadler et al. (2015)	X	X	1,3	4	<ul style="list-style-type: none"> <li>Shallow claypan hydrologic processes</li> <li>Assessment and prediction of conservation practice effects on surface WQ</li> </ul> (Wendt et al., 1986; Hjelmfelt & Wang, 1994; Blanco-Canqui et al., 2017; Lerch et al., 2005; 2011; Kitchen et al., 2015; Al-Qudah et al., 2016; Baffaut et al., 2015, 2020)
Central Plains Experimental Range (CPER)	Raynor et al. (2020)	X			1,4	<ul style="list-style-type: none"> <li>Temporal hierarchical approaches using PDO, ENSO, and local-scale precipitation can enhance decision-making for rangeland stocking density</li> <li>Rangeland productivity sensitive to topographic position as well as precipitation pattern &amp; amount In a warm phase PDO stocking rates can be increased: conversely during cold-phase PDO, ENSO and prior fall–winter precipitation can help predict when stocking should be reduced</li> </ul> (Augustine et al., 2020; Faust et al., 2021; Hoover et al., 2020, 2021; Petrie et al., 2018; Wilcox et al., 2021; Wilmer et al., 2018)
Eastern Corn Belt	King et al. (2008); Williams et al. (2016)	X		1,3		<ul style="list-style-type: none"> <li>Impacts of conservation practices and programs on water quality</li> <li>Quantified the role of tile drainage in hydrology and</li> </ul>

TABLE 2 (Continued)

LTAR site	Overview or special issue introduction paper	Basic hydrometeorologic data collection <sup>a</sup>				Selected major hydrologic research accomplishments
		Discharge	Sediment	Water quality <sup>b</sup>	Other <sup>c</sup>	
Great Basin	Slaughter et al. (2001)	X	X	1,2	1,2,3,4	<p>water quality - assessing the processes associated with tile drainage (Hanrahan et al., 2021; King et al., 2008, 2012, 2014, 2015, 2016, 2018; Nazari et al., 2020; Shedekar et al., 2020; Williams et al., 2015, 2016, 2018)</p> <ul style="list-style-type: none"> <li>• Snow, freeze/thaw, and snow dominated water supply</li> <li>• Effects of fire and conservation practices on rangeland runoff and erosion (Kormos et al., 2018; Marks et al., 2013; Pierson et al., 2011; Pierson &amp; Williams, 2016; Williams et al., 2019; Winstral et al., 2013)</li> </ul>
Gulf Atlantic Coastal Plain	Bosch et al. (2007)	X	X	1,2,3	1,3,4	<ul style="list-style-type: none"> <li>• Coastal plain hydrological processes</li> <li>• Assessment, prediction, and remediation of nutrient, agrochemical, and animal waste impacts on surface and groundwater (Bosch et al., 2007; 2017; Hubbard et al., 2004; Lowrance et al., 1985, 2000; Lowrance &amp; Sheridan, 2005)</li> </ul>
Jornada Experimental Range	Havstad et al. (2006)	X			1	<ul style="list-style-type: none"> <li>• Role of ecohydrological processes in vegetation patchiness and restoration</li> <li>• Soil water dynamics and its relationships to desert vegetation</li> <li>• Effects of woody plant encroachment and extreme weather events on ecohydrology and groundwater recharge in desert watersheds</li> <li>• Unmanned aerial vehicle applications for hydrology research (Duniway et al., 2010, 2018; Rango et al., 2006; Schreiner-McGraw et al., 2019, 2020; Vivoni et al., 2014; Wainwright et al., 2002)</li> </ul>
Kellogg Biological Station	Robertson and Hamilton (2015)			1	3,4	<ul style="list-style-type: none"> <li>• Evapotranspiration and bioenergy crops</li> <li>• Nitrate leaching in long-term cropping systems</li> <li>• Groundwater irrigation greenhouse gas emissions (Abraha et al., 2016; Hamilton et al., 2018; McGill et al., 2018; Syswerda et al., 2012)</li> </ul>

(Continues)

TABLE 2 (Continued)

LTAR site	Overview or special issue introduction paper	Basic hydrometeorologic data collection <sup>a</sup>				Selected major hydrologic research accomplishments
		Discharge	Sediment	Water quality <sup>b</sup>	Other <sup>c</sup>	
Lower Cheaseapeake Bay	McCarty et al. (2014)	X	X	1	4	<ul style="list-style-type: none"> <li>• Impacts of conservation practices on water quality</li> <li>• Test bed for assessment of remote sensing approaches for monitoring winter cover crops, residue management and wetland ecosystem function. Test bed for development of a novel transient groundwater tracer for measurement of watershed lag time.</li> </ul> (Du et al., 2020; Hively et al., 2020; Lee et al., 2020; McCarty et al., 2014; Plummer et al., 2020)
Lower Mississippi River Basin	Langendoen et al. (2009)	X	X	1	4	<ul style="list-style-type: none"> <li>• Stream instabilities and sediment yield responses</li> <li>• Aquatic habitat improvement by instream structural stabilization measures</li> </ul> (Murphey & Grissinger, 1985; Shields et al., 1995, 1998)
Northern Plains	Liebig, Archer, Hendrickson, et al. (2014); Sanderson et al. (2015)	X			1,3	<ul style="list-style-type: none"> <li>• Impacts of conservation practices on crop, forage, and livestock production and economics</li> <li>• Soil characteristics, greenhouse gas flux, water use</li> <li>• Within field water quality measured through using rainfall simulation</li> </ul> (Archer et al., 2020; Halvorson et al., 2016, 2019; Liebig et al., 2019; Liebig, Archer, & Tanaka, 2014; Nouwakpo et al., 2019; Reeves et al., 2014; Sanderson et al., 2015)
Platte River/High Plains Aquifer	—	X			1,3,4	<ul style="list-style-type: none"> <li>• Infiltration did not increase with increased soil carbon associated with no-till</li> <li>• Remote sensing assessment on crop water use</li> </ul> (Aragon et al., 2021; Blanco-Canqui et al., 2017)
R.J. Cook Agronomy Farm	—	X		1,2	1,4	<ul style="list-style-type: none"> <li>• Groundwater recharge in basalt aquifer in the Palouse</li> <li>• Hydrologic flow paths are a major determinant of BMP effectiveness</li> <li>• Soil water storage at different locations and times can be assessed knowing the average soil water of the locations</li> </ul> (Dijksma et al., 2011; Gasch et al., 2015; Ibrahim & Huggins, 2011; Kelley et al., 2017; Rittenburg et al., 2015)



TABLE 2 (Continued)

LTAR site	Overview or special issue introduction paper	Basic hydrometeorologic data collection <sup>a</sup>				Selected major hydrologic research accomplishments
		Discharge	Sediment	Water quality <sup>b</sup>	Other <sup>c</sup>	
Southern Plains	Steiner et al. (2014)	X	X	1	1,3,4	<ul style="list-style-type: none"> <li>Assessment of overall impacts of flood control and watershed protection programs</li> <li>Quantified effects of projected climate change on soil erosion, surface water resources and impoundments on water quality and ecosystems</li> </ul> (Garbrecht & Starks, 2009; Moriasi et al., 2018; Schoof et al., 1987; Van Liew et al., 2003)
Texas Gulf	Harmel et al. (2014)	X	X	1,3	4	<ul style="list-style-type: none"> <li>Quantified the effects of conservation practices on runoff, erosion &amp; water quality</li> <li>Hydrologic processes of heavy clay soils—cracking, shrink, swelling</li> </ul> (Harmel et al., 2004, 2006, 2013; Smith et al., 2019, 2020; Wagner et al., 2012; Baird, 1948; Kishne et al., 2014)
Upper Chesapeake Bay	Bryant et al. (2011)	X	X	1	4	<ul style="list-style-type: none"> <li>Overcoming historical P imbalance and legacy impacts</li> <li>Identifying critical sources of P export from watersheds</li> </ul> (Buda et al., 2013; Flaten et al., 2019; Kleinman, 2017; Liu et al., 2017; McDowell & Sharpley, 2001; Miller et al., 2018; Smith et al., 2019; Veith et al., 2020)
Upper Mississippi River Basin	Hatfield et al. (1999); Kaspar et al. (2012)	X	X	1,2,3	1,3,4	<ul style="list-style-type: none"> <li>Impacts of conservation practices and programs on water quality</li> <li>Established the role of cover crops for decreasing nitrate losses in subsurface tile drainage</li> <li>Nitrate leaching losses from corn are lower in living mulch systems than in conventional corn</li> <li>Infiltration rates are much higher in living mulch systems compared to conventional corn</li> <li>Developed solar powered electro dialysis system for recycling nitrate from contaminated water</li> </ul> (Baker et al., 2021; Basche et al., 2016; Gamble et al., 2018; Kaspar et al., 2007; Ochsner et al., 2018)
Walnut Gulch	Moran et al. (2008)	X	X		1,3	<ul style="list-style-type: none"> <li>Semiarid and monsoon influenced precipitation, runoff, and erosion</li> <li>Influent (ephemeral) hydrologic processes and instrumentation</li> </ul>

(Continues)

TABLE 2 (Continued)

LTAR site	Overview or special issue introduction paper	Basic hydrometeorologic data collection <sup>a</sup>			Selected major hydrologic research accomplishments
		Discharge	Sediment	Water quality <sup>b</sup>	
					(Goodrich et al., 1997; Osborn et al., 1980; Paige et al., 2003; Polyakov et al., 2010; Renard et al., 2008; Smith et al., 1982)

<sup>a</sup>All sites measure standard meteorologic variables.

<sup>b</sup>Water quality: 1 = Nutrient, 2 = Temperature, 3 = Pesticides, 4 = Pathogens.

<sup>c</sup>Other: 1 = H<sub>2</sub>O & CO<sub>2</sub> Fluxes, 2 = Snow, 3 = Remote Sensing, 4 = Groundwater.

available to watershed scientists, including data from the ARS Experimental Watershed Network. At present, a contact for collaboration with LTAR is co-author T. Tsegaye (teferi.tsegaye@usda.gov).

#### 4 | MAJOR ACCOMPLISHMENTS FROM THE ARS LTAR EXPERIMENTAL WATERSHED SITES

The accomplishments listed below employed the knowledge base of watershed processes and observations acquired from long-term research in one or more of the ARS LTAR Experimental Watershed network locations. Observations from the network were also used to develop and verify conservation methods, numerous simulation models, and many remotely sensed retrieval algorithms. They benefit both hydrologic professionals and society (Goodrich et al., 2021).

- Development, experimentation, and quantification of conservation management and practices effects led to rapid global adoption of Conservation Agriculture that markedly reduced erosion and non-point source pollution (Kassam et al., 2015)
- The dominance of channel sediment in many large river systems led to bank erosion models used to design multiple billion-dollar flood reduction and bank stabilization projects (Wilson et al., 2008)
- Mapping crop water use and stress from space using satellite remote sensing (Anderson et al., 2011)
- Rainfall design storm characteristics have been used to design billions of dollars of storm water infrastructure in the Southwest (Osborn & Lane, 1981; Zehr & Myers, 1984)
- Next generation of water supply forecasting tools developed for the mountainous west; forecasting water for agriculture, power generation, and ecosystems valued between \$1B to \$5B/year in California's central valley (Havens et al., 2017)
- Quantification and modelling of riparian ecosystem services in agricultural (Lowrance & Sheridan, 2005)
- Calibrating and validating remotely sensed soil moisture products to compute crop water use and stress used in drought and flood prediction as well as globally for commodities production estimates (Colliander et al., 2017)

The observations from this network could be used to investigate scale issues and many watershed locations contain gauged

subwatersheds that are nested within the overall experimental watershed. Much of the research resulting from the network largely focuses on individual watershed locations. Network observations are ripe for cross-site comparisons and synthesis across hydroclimatic and agricultural production domains such as the recent study of water balances across the network by Baffaut et al. (2020).

#### 5 | OWNERSHIP/FUNDING/CONTRIBUTORS

All data collected as part of LTAR efforts are in the public domain. In the case of active experiments there may be a temporary embargo of a subset of observations relevant to the analysis of that experiment. A document describing LTAR data sharing principles and guidelines is available at: <https://ltar.ars.usda.gov/data/data-guidance/>. Funding for the collection, maintenance, and curation of LTAR data at ARS locations are from Federal appropriations to the USDA-ARS. Readers are referred to the primary web site for each non-ARS LTAR site for additional funding and contributor details (click on LTAR site names in Table 1, column 1. Eventually a Federal appropriation to all non-ARS LTAR sites will be facilitated through specific cooperative agreements from an ARS LTAR location. In some cases, instrumentation to expand collection of various data types (e.g., soil moisture) was provided by projects and grants. The list of persons contributing to the collection, maintenance, and curation of LTAR data is far too large to include herein. Nevertheless, their contributions are very much appreciated.

This software/database is a "United States Government Work" under the terms of the United States Copyright Act. It was written as part of the author's official duties as a United States Government employee and thus cannot be copyrighted. This software/database is freely available to the public for use. The Agricultural Research Service (ARS) and the U.S. Government have not placed any restriction on its use or reproduction. Although all reasonable efforts have been taken to ensure the accuracy and reliability of the software and data, the ARS and the U.S. Government do not and cannot warrant the performance or results which may be obtained by using this software or data. The ARS and the U.S. Government disclaim all warranties, express or implied, including warranties of performance, merchant availability or fitness for any particular purpose.

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## DATA AVAILABILITY STATEMENT

A gateway to the primary web page of each LTAR site can be found at: <https://ltar.ars.usda.gov/> under the “Sites” tab. Contacts for each site are listed on the individual site page. Under the “Data” tab of the same web page, subtabs include an LTAR data overview, data inventory, data dashboard and visualizations, and data access. All LTAR data will eventually be accessible at: <https://data.nal.usda.gov/long-term-agroecosystem-research> (click the LTAR site name and all data in the Ag Data Commons from that site can be accessed). Data will be updated on an on-going basis. Until consolidation of all LTAR data into the Ag Data Commons, some LTAR data may reside on an individual site's website or in another database serving as the gateway for a specific program or project (see Table 1). One such database is STEWARDS (Sustaining the Earth's Watersheds-Agricultural Research Data System). It provides a central data portal for a large percentage of the LTAR ARS-Experimental Watershed Network (ARS-EWN) locations involved in the CEAP (Conservation Effects Assessment Project) effort. The STEWARDS portal is a data delivery system with a geographic information system interface, using space, time, and topic as key fields for searching an extensive database of soil, water, climate, and land management data from multiple long-term research watersheds (Steiner et al., 2008; Steiner, Sadler, Hatfield, et al., 2009; Steiner, Sadler, Wilson, et al., 2009). STEWARDS can be accessed via the Ag Data Commons at: <https://data.nal.usda.gov/dataset/agricultural-collaborative-research-outcomes-system-agcros>.

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