CURRENT RESEARCH IN LAND, WATER, AND AGROECOSYSTEMS: ASABE JOURNALS 2017 YEAR IN REVIEW

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Invited Review

ABSTRACT. *This article highlights current research into land and water resources, agroecosystems, and agricultural production systems published by the Natural Resources and Environmental Systems (NRES) community of ASABE journals (Transactions of the ASABE and Applied Engineering in Agriculture) in 2017. Context, scope, and key results of the published articles are reviewed and perhaps more importantly areas for increased research attention are recommended. This article describes experimental and modeling advances in hydrology, agroecosystems, climate change effects, soil erosion, agricultural irrigation, agricultural drainage, forest resource management, livestock systems, natural treatment systems, international water issues, and water quality topic areas. Three special collections were published (International Watershed Technology, Crop Modeling and Decision Support for Optimizing Use of Limited Water, and Advances in Drainage). Other focal areas included 14 articles relating to livestock waste management, 13 concerning irrigated agricultural systems, 8 addressing climate change effects on land, water, and agroecosystems, and 16 on various aspects of soil erosion measurement and modeling. Building on the articles reviewed from 2017 and toward a vision of future agroecosystems research, the NRES community of ASABE journals strives to expand its role in making new knowledge accessible to sustain agricultural and natural systems in a changing world. With this goal in mind, recommendations for future research needs are proposed with an emphasis on increased application of remote sensing data to agroecosystems research, improved assessment of agroecosystem resiliency and vulnerability to land and climate change, development of integrated models of agroecosystem services, meeting stubborn water management challenges in agricultural production systems, and focusing on publishing fully reproducible model results.*

Keywords. *Agriculture, Climate change, Composting, Crop models, Crop water use, Crop yield, Drainage, Drought, Environment, Field experimentation, Food, Forest, Greenhouse gas emissions, Hydrologic modeling, Hydrology, Irrigation, Livestock, Manure management, Modeling, Natural resource, Soil erosion, Wastewater treatment, Watershed, Water quality, Water use.*

Sustainability of land, water, and agroecosystem resources is the central challenge of this generation of natural resources, agricultural, and environmental scientists and engineers. Global challenges include food and water security; water use, availability, and quality; the food, energy, water systems nexus; agroecosystem sustainability; and greenhouse gas emissions. All demand urgent attention by the international research community, especially in the context of growing human populations, non-stationary climate, and limited land and water resources. Research into new understanding of and adaptable solutions to these challenges at local to global scales is needed. The Natural Resources and Environmental Systems (NRES) com-

munity of the American Society of Agricultural and Biological Engineers (ASABE) publishes leading research addressing these and other issues faced by local communities and our global society, as we seek sustainability with finite land, water, and agroecosystem resources.

In 2017, 76 articles were published in *Transactions of the ASABE* and 22 in *Applied Engineering in Agriculture* by 379 authors across all topic areas of the NRES community. Three special collections were published: 6 articles in *International Watershed Technology III* (Tollner and Douglas-Mankin, 2017), 15 articles in *Crop Modeling and Decision Support for Optimizing Use of Limited Water* (Kisekka et al., 2017), and 14 articles in *Advances in Drainage* (Strock et al., 2018; 4 articles published in *Applied Engineering in Agriculture*, 2017, and reviewed herein, and the remaining 10 articles published in *Transactions of the ASABE*, 2018). Other focal research areas included 14 articles on livestock waste management, 13 on irrigated agricultural systems, 8 on climate change effects on land and water resources, and 16 on various aspects of soil erosion measurement and modeling.

The present article highlights the research published by ASABE's NRES community in 2017 and describes the context, scope, and key results for each study. The studies are

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organized by topic area and cross-referenced when appropriate. Finally, future research needs are discussed to extend the current body of knowledge toward a more comprehensive scientific and engineering research basis for sustainability of land, water, and agroecosystems.

HYDROLOGY

HYDROLOGIC MODELING

Numerous modeling studies published in 2017 (table 1) expanded ASABE's extensive publication history in watershed and field-scale hydrologic and water quality modeling (e.g., Muñoz-Carpena et al., 2006; Douglas-Mankin et al., 2010; Tuppad et al., 2011; Moriasi et al., 2012, 2015; Harmel et al., 2018). Many studies applied hydrologic and water quality models to simulate specific constituents (e.g., soil erosion, water quality) or support specific objectives (e.g., climate change effects, drought quantification, forest resource management) and are discussed throughout this review. Two studies were not tied to specific models but rather advanced hydrologic modeling research more broadly. Barnhart et al. (2017) introduced a multi-objective evolutionary sensitivity handling system (MOESHA) and demonstrated that, while computationally expensive, it can differentiate between impactful and non-impactful parameters, assess parameter uncertainty, and achieve excellent calibration results. Linhoss et al. (2017) demonstrated the importance of using multiple objective functions and selecting the prior probability distribution function (PDF) to represent parameter uncertainty for model sensitivity and uncertainty analyses; they found that the choice of objective functions and prior PDFs impacted the ranking of important parameters and inputs in the Mississippi Irrigation Scheduling Tool (MIST).

HYDROLOGIC MONITORING

A set of 12 field-scale (15 m wide, 27 m long) lysimeters were constructed in central Pennsylvania with earthen berms to isolate and collect overland flows and with subsurface tile drains to collect shallow lateral flows (Duncan et al., 2017).

Clear patterns were observed in surface and subsurface flows, but the observed variability may have resulted from bypass flow. This study illustrated both the opportunities and limitations of field-scale lysimeter research.

AGROECOSYSTEMS

EVAPOTRANSPIRATION AND SOIL MOISTURE

In an introduction to a collection of 12 studies on evapotranspiration (ET), Amatya et al. (2016) identify several areas for future research, including enhancement of thermal remote sensing-based technology for regional and global modeling and better characterization of the complex ecohydrological soil-vegetation-atmosphere feedbacks of ET to improve understanding of crop water use dynamics and response to changing climate; several 2017 articles address these issues. Remote sensing ET estimates using METRIC demonstrated the potential to use irrigation to increase crop ET as a flood-mitigation strategy (Büyükcangaz et al., 2017). Other simulation studies of crop ET are discussed in the sections on crop modeling (DeJonge and Thorp, 2017; Marek et al., 2017) and climate change effects (Mishra et al., 2017; Tatsumi, 2017).

CROP YIELDS AND WATER USE

Spatial and temporal variability of corn and soybean production was assessed at the county-scale in the U.S. Great Plains (Kukul and Irmak, 2017). Increasing trends were found for grain yield, precipitation use efficiency, and crop water productivity; interannual variations indicated opportunities for production system improvements. Zhao et al. (2017) found that available water-holding capacity (AWC) was an effective metric for delineating zones for variable-rate irrigation, and that differences in AWC influenced corn and winter wheat yields and water productivity in an alluvial flood plain in China. Alfalfa yield and crop water-use efficiency in a semi-arid region of China had greater response to irrigation application prior to the first cutting and progressively less response to applications prior to second and third cuttings (Li, M. et al., 2017); irrigation also affected relative

Table 1. Summary of modeling research published in 2017 and discussed herein. The hydrologic and water quality modeling category includes water, sediment, nutrient, and pesticide fate and transport at field to watershed scales. The crop modeling category includes studies simulating crop growth or yield, either as stand-alone models or as submodels within hydrologic and water quality models.

Category	Model	Reference
Hydrologic and water quality modeling	AnnAGNPS	Yasarer et al., 2017
	APEX	Van Liew et al., 2017
	REMM	Tilak et al., 2017
	RHEM	Al-Hamdan et al., 2017; Lisenbee et al., 2017
	SWAT	Lee, S. et al., 2017; McDaniel et al., 2017a, 2017b, 2017c; Mittelstet et al., 2017; Muenich et al., 2017; Renkenberger et al., 2017; Wallace et al., 2017
	USLE and WEPP	Lang et al., 2017; Svendsen et al., 2017; Wu et al., 2017
	WEPP and USLE	Grace III, 2017; Lang et al., 2017; Lisenbee et al., 2017; Srivastava et al., 2017; Wang, L. et al., 2017; Wu et al., 2017
Crop modeling	APSIM	Araya et al., 2017; Whitbread et al., 2017
	AquaCrop	Espadafor et al., 2017; Linker and Kisekka, 2017; Wibowo et al., 2017
	DSSAT-CSM-CERES-Beet	Anar et al., 2017
	DSSAT-CSM-CERES-Maize	DeJonge and Thorp, 2017; Fang et al., 2017a, 2017b; Joshi et al., 2017; Linker and Kisekka, 2017; Marek et al., 2017; Sharda et al., 2017
	DSSAT-CSM-CERES-Wheat	Adhikari et al., 2017; DeJonge and Thorp, 2017; Fang et al., 2017a
	DSSAT-CSM-CROPGRO-Cotton	Adhikari et al., 2017; Thorp et al., 2017
	EPIC	Rasche and Taylor, 2017; Tatsumi, 2017
	RZWQM	Anar et al., 2017; Fang et al., 2017a, 2017b; Linker and Kisekka, 2017; Liu et al., 2017
	SWAT	Feng et al., 2017

feed value but not crude protein.

In a soilless culture with low water-holding capacity, water must be applied frequently and precisely. A low-cost irrigation control system, developed and tested for use with soilless culture systems on commercial farms, was found to accurately control irrigation amount and timing while also matching a target leaching fraction (Rodríguez et al., 2017).

DROUGHT QUANTIFICATION

A crop-specific, weekly drought index was developed from five factors: 35-day total precipitation relative to the site normal, temperature and soil moisture stresses using crop-specific thresholds, transpiration using actual relative to daily maximum ET, and cumulative biomass production relative to the site normal (McDaniel et al., 2017a). The introduced drought index, populated with climate data and SWAT-simulated biomass production, soil moisture, and ET for cotton in western Texas, was found to be a good indicator of soil-moisture-related yield (McDaniel et al., 2017b). The drought index was then tested using short-term (two-week) weather forecasts compared to actual data and found to have satisfactory performance (McDaniel et al., 2017c), indicating potential for informing agricultural water management decision-making, such as irrigation timing.

CROP MODELING

Crop models play an important role in optimizing agricultural water use to meet the challenges of changing weather and climate, increasing population, and depleting groundwater. The crop models assessed, applied, or enhanced in 2017 are summarized in table 1. DSSAT-CERES-Maize was found to adequately simulate corn leaf area index (LAI), ET, soil moisture, and yield response for two drought-tolerant corn hybrids in Texas for fully irrigated treatments but was less reliable for limited irrigation treatments (Marek et al., 2017). In eastern Canada, Joshi et al. (2017) found that DSSAT-CERES-Maize adequately simulated corn and biomass yield, LAI, and soil organic C but not soil moisture or soil nitrate in continuous corn under conventional tillage, reduced tillage, and no tillage with two levels of residue management.

Timing of irrigation was critical for increasing wheat yields in Kansas (Araya et al., 2017); the researchers used a validated APSIM model to demonstrate that a limited irrigation application of 100 mm applied at booting and heading provided the highest water use efficiency as well as the greatest increases in yield compared to rainfed (dryland) production. A modification of SWAT to allow simulation of maximum annual LAI (instead of a static value) during establishment of switchgrass and *Miscanthus* perennial grasses resulted in more realistic simulation of LAI values and biomass yields (Feng et al., 2017). A new generic pest submodel was developed for EPIC that simulated pest pressure (for insects, fungi, and weeds), pesticide application, and crop response (Rasche and Taylor, 2017); test cases using cotton, maize, potatoes, soybeans, and wheat crops resulted in reasonable comparisons between simulated and reported mean and spatial distributions of pesticide application rates.

Fourteen articles from the ASABE 2016 Annual International Meeting comprised the Crop Modeling and Decision

Support for Optimizing Use of Limited Water collection, as introduced and reviewed by Kisekka et al. (2017) and highlighted here. One study developed a new dual-crop-coefficient approach to simulate the effects of both soil water and basal crop response on ET (DeJonge and Thorp, 2017), and a second study successfully adapted the improved model for real-world, *in situ* water management (Thorp et al., 2017). Several other studies applied crop models for irrigation scheduling, including an optimization of wheat and maize irrigation scheduling in China (Fang et al., 2017a), a novel model-based optimization of deficit irrigation in the U.S. High Plains (Linker and Kisekka, 2017), a schedule that used a water-stress factor to trigger irrigation, leading to water conservation and increased yields (Liu et al., 2017), and an assessment of supplemental irrigation in the Mississippi Delta (Tang et al., 2018). Two studies assessed crop model development and parameterization: Espadafor et al. (2017) used high-quality lysimeter yield and ET data from California to enhance AquaCrop model parameterization for dry beans, and Anar et al. (2017) parameterized, calibrated, and validated the CERES model for sugarbeet. Important improvements to crop coefficients and algorithms were made to reflect water, nutrient, and biomass-yield interactions for a new maize hybrid (Fang et al., 2017b). Two studies used crop models for soil and water management: one demonstrated no reduction in cotton yield or soil water from a winter-wheat cover crop in Texas (Adhikari et al., 2017), and another demonstrated enhanced simulation of soil-water storage and wheat yields using field-based, rather than lab-based, estimates of crop lower-limit and drained upper-limit in low-rainfall cropping systems of southern Australia (Whitbread et al., 2017). A modeling analysis of irrigated corn production in Kansas found that risk-averse irrigation strategies were sensitive to well capacity and soil type and may substantially increase total water use (Wibowo et al., 2017). Two regional studies using crop models to assess climate change effects (Sharda et al., 2017; Tatsumi, 2017) are discussed in the next section.

CLIMATE CHANGE EFFECTS ON LAND, WATER, AND AGROECOSYSTEMS

Projected climate change is expected to negatively affect food production and water resource availability and quality, and innovative strategies are needed to mitigate those adverse impacts (Chaubey et al., 2016). Climate change effects and mitigation strategies were each assessed by several studies in 2017.

ASSESSMENT OF CLIMATE CHANGE EFFECTS

Climate change effects were assessed in five studies. Wallace et al. (2017) found that future climate resulted in significant 9% to 22% decreases in surface flow, significant 20% to 26% increases in subsurface tile flow, significant (but small) increases in sediment, and no significant differences in atrazine, soluble N, total N, and total P losses among the four subwatersheds simulated by using SWAT in Indiana, as well as no evidence of impact from subwatershed size. Mishra et al. (2017) projected an increased frequency,

severity, and spatial extent of droughts in Alabama and Georgia for future climates on the basis of changes to a standardized precipitation index and a standardized precipitation-ET index. Using the EPIC crop model, Tatsumi (2017) found shortened growing season, decreased water use efficiency, increased ET, and reduced corn yield in almost all regions of the U.S., despite the potential positive yield effect from rising CO₂. Kukal and Irmak (2017) demonstrated the long-term (32-year) response of corn and soybean to historical climate in the U.S. Great Plains on the basis of yield, precipitation use efficiency, and crop water productivity, whereas Sharda et al. (2017) demonstrated that both soil and climate variability in Alabama are important factors to consider in crop-climate impact studies.

ASSESSMENT OF CLIMATE CHANGE MITIGATION

Mitigation of climate effects was assessed in three studies. A study in the Coastal Plain of the Chesapeake Bay watershed found that SWAT-simulated nitrate loads increased for future climate, but identified six winter cover crop implementation scenarios that have various levels of effectiveness in mitigating nitrate loads (Lee, S. et al., 2017). Renkenberger et al. (2017) applied SWAT in a Maryland watershed and demonstrated that implementations of best management practices (BMPs) designed to meet total maximum daily load (TMDL) targets for current climates would not meet targets in future climates. Yasarer et al. (2017) concluded, using AnnAGNPS in a Mississippi watershed, that sediment and nutrient loads would be expected to increase by 9% to 12% with future climate but that no-till and cover-crop conservation practices would decrease loads by 20% to 75%.

SOIL EROSION

Soil erosion is a serious, continuing environmental and economic problem of global proportions (Flanagan et al., 2013). One study published in 2017 assessed the wind erosion effects of crop residues and found that the abrasion energy of saltating sand particles was significantly decreased with increasing vegetation density (Gonzales et al., 2017). The remaining articles on soil erosion focused on erosion by water.

MODELING SOIL EROSION AND TRANSPORT

Several modeling studies of soil erosion were published (table 1). Mittelstet et al. (2017) developed several improvements to the SWAT streambank erosion routine and found the greatest improvement from replacing the empirical effective shear stress equation with a process-based equation. Other studies assessed sediment-yield effects at a range of watershed scales using various models, including AnnAGNPS (Yasarer et al., 2017), APEX (Van Liew et al., 2017), SWAT (Renkenberger et al., 2017; Wallace et al., 2017), and WEPP (Wang, L. et al., 2017).

Methods to develop the erodibility parameter in erosion models were assessed in several studies. Parameters were developed for soil erodibility before and after disturbance by rangeland fire or tree encroachment in RHEM (Al-Hamdan et al., 2017). Parameters were also developed for soil erodibility

under native tallgrass prairie and encroaching eastern red cedar using the Jet Erosion Test method compared to standard methods in WEPP and RHEM (Lisenbee et al., 2017). USLE soil erodibility (*K*) factors were experimentally determined for four soils in Indiana, Missouri, South Dakota, and Vermont, and substantial differences were found among assessments made at dry, pre-wetted then drained, and pre-wetted and saturated conditions (Wu et al., 2017).

MEASURING SOIL EROSION

Several experimental studies of soil erosion were published. A new, low-cost method was developed to estimate raindrop kinetic energy, an important factor affecting soil erosion, and an exponential relationship between rainfall kinetic energy and intensity was derived using experimental data from northwest China (Wang, J. et al., 2017). In a study of soil erodibility in a Kansas crop field having claypan soils, an area with higher crop yield showed an order of magnitude lower critical shear stress (assessed by an erosion function apparatus) than an area having lower crop yield, which was concluded to reveal the extent of historical erosion within the field (Tucker-Kulesza et al., 2017). A study of sediment removal by four surface inlets (that drain ponded agricultural field runoff) found reductions of as much as 66% for sediment concentration and 23% for sediment load compared to the standard Hickenbottom inlet (Li, S. et al., 2017). Soil erosion from forest roads was studied by Grace III (2017) and Lang et al. (2017), as described in the Forest Resource Management section. Svendsen et al. (2017) developed a system for tracking military vehicle movements, assessing vegetation disturbance, and translating that information into changes in USLE C factor.

AGRICULTURAL IRRIGATION

Global food and water challenges require continued research and development in irrigation engineering and science (Lamm et al., 2016). Dukes et al. (2012) presented seven challenges for irrigation research in this decade:

- Profitable production with declining water supplies.
- Further integration of sensor-based data for real-time autonomous or semi-autonomous management.
- Competition for limited water resources between agriculture and other sectors.
- Impact of declining investment in irrigation research.
- Energy cost and the influence on irrigation type and management.
- Environmental impacts of irrigation.
- Using alternative water sources or degraded water for irrigation.

Collections of irrigation research introduced by Dukes et al. (2012) and Lamm et al. (2016) presented 30 articles on a variety of these topics. In 2017, continuing research was presented on many of these issues, spanning subsurface drip (Lamm and Puig-Bargués, 2017; Lamm and Rogers, 2017), microirrigation (Ju et al., 2017), center pivot (Brar et al., 2017), lateral move (Nörenberg et al., 2017), and surface furrow (Pringle et al., 2017; Bautista and Schlegel, 2017a, 2017b) irrigation systems.

SUBSURFACE DRIP IRRIGATION

Subsurface drip irrigation (SDI) system longevity was characterized by testing emitter uniformity on driplines excavated after 27 seasons (26.5 years) and found flow rates within 5% of original measured values, providing important data for planning SDI amortized costs (Lamm and Rogers, 2017). Another study on SDI systems provided simple, alternative guidelines to the Hazen-Williams equation for sizing SDI flushline diameters (Lamm and Puig-Bargués, 2017). A simple, adaptable analytical approach also was developed and tested for sizing the length of microirrigation laterals on uniformly sloping grounds (Ju et al., 2017).

SURFACE AND SPRINKLER IRRIGATION

Research on surface and sprinkler irrigation focused on various aspects of system uniformity and efficiency. Residual plant-available soil water (2.4 m depth) after harvest and prior to planting across western Kansas was greater in irrigated corn than in dryland wheat fields; interestingly, irrigated corn had small (8% to 22%) differences between regions and years but large (183% to 722%) differences among producers within a region, suggesting that producers could better utilize science-based methods in irrigation scheduling (Lamm et al., 2017). Spatial variability of field capacity and root zone available water capacity in central Nebraska was adequately characterized by identifying a suitable predictor variable (Lo et al., 2017); for the study field, use of elevation, selected on the basis of site-specific knowledge and data, as the predictor variable provided better predictions than deep-soil apparent electrical conductivity. In the Mississippi Delta, furrow-irrigated corn yields and net returns were sensitive to drought stress during tasseling, silking, and pollination, on the basis of measured soil water potential and soil water deficit for multiple irrigation initiation timings on deep silty clay loam soils (Pringle et al., 2017). Bautista and Schlegel developed (2017a) and tested (2017b) software for estimating infiltration and hydraulic resistance parameters in surface furrow irrigation systems, with important benefits for modeling application uniformity. A study of center-pivot irrigation systems in ten Nebraska counties found that energy conservation using variable-frequency drive technology was dependent on elevation difference within the field (Brar et al., 2017); however, the payback period for these systems generally exceeded their economic life. In China's Sanjiang Plain, a geostatistical analysis identified several climate and irrigation system factors that were important to improving irrigation water use efficiency (Fu et al., 2017). Field tests in Rio Grande de Sul, Brazil, were used to develop polynomial equations for estimating lateral-move irrigation system uniformity response to wind speed (Nörenberg et al., 2017). An inventory of on-farm irrigation reservoirs was conducted using remote sensing and on-site inspections as part of a broader effort to assess the current state of water resources in two vulnerable alluvial aquifers in Arkansas (Yaeger et al., 2017).

AGRICULTURAL DRAINAGE

Surface and subsurface drainage systems remove excess

water from the root zone and have enabled agricultural production on 194 Mha of land globally (Strock et al., 2018). Several studies published in 2017 contribute knowledge on the effects of agricultural drainage. A study in Indiana found that controlled drainage increased water table recession time compared to paired free-drained fields over the nine-year study, indicating that lowering the subsurface drainage outlet before storms could reduce the time at detrimentally high water table levels (Saadat et al., 2017). Skaggs (2017) proposed three key coefficients to quantify and compare hydraulics of drainage systems across sites, soils, and geographic locations: steady subsurface drainage rate, drainage intensity, and drainage coefficient. Jabro et al. (2017) demonstrated that a new automated passive capillary lysimeter accurately monitored real-time drainage water fluxes in the vadose zone over the four-year study period.

A study of drainage and subirrigation systems over 14 years in Missouri found that soybean yields varied with tile spacing and position relative to tile lines, and that narrower tile spacings were more important for reducing yield variability in low-yielding field areas than in high-yielding areas (Nelson, 2017). Subirrigation was more effective in delivering water to the crop in eastern North Dakota and west-central Minnesota but was less uniform than typical sprinkler and surface-irrigation systems over the two-year evaluation period (Jia et al., 2017).

A field assessment found that the specific electrical conductivity of drainage water in Iowa was not significantly different between growing and non-growing seasons, but it was lower for the soybean year of a corn-soybean rotation than for the corn year of the rotation and for continuous corn or prairie plots; HCO_3^- , Ca^{2+} , nitrate, and Mg^{2+} accounted for 97% of the bulk electrical conductivity (Zimmerman and Kaleita, 2017b). Additional work by Zimmerman and Kaleita (2017a) found greater concentrations of HCO_3^- , Ca^{2+} , and Mg^{2+} during the post-growing season, greater concentrations of nitrate and Cl^- during the growing season, and other interesting relationships among parameters. Dryland barley production in Saskatchewan increased 8-fold and salinity was substantially reduced following installation of a subsurface drainage system enhanced with low-intensity subsurface irrigation and surface roughness barriers to trap snow (Steppuhn and McArthur, 2017). In preparation for future field research on carbon-based, denitrification bioreactors designed to treat intercepted tile drainage in Iowa, Hoover et al. (2017) characterized the hydraulic characteristics of nine pilot-scale bioreactors; they found that the dispersion index was indicative of plug flow, with a residence time of 2.1 h and hydraulic efficiency of 0.78 (indicative of little short-circuiting).

FOREST RESOURCE MANAGEMENT

Improved understanding of forest hydrologic and erosion processes is critical for sustainable resource management and to protect the quantity and quality of about 80% of U.S. freshwater resources (Amatya et al., 2011). Research published in 2017 continued to advance the understanding of forest hydrologic and erosion processes. Srivastava et al.

(2017) incorporated nonlinear algorithms into WEPP for simulating groundwater baseflow and found improved model performance in simulating daily streamflow volumes and hydrograph recessions in a forested, snowmelt-dominated western Washington watershed. Lang et al. (2017) found that WEPP better simulated soil erosion from 37 forest haul-road stream crossings in Virginia than USLE or RUSLE2, but the time, effort, data, and expertise needed to parameterize and apply WEPP made it impractical to use directly as a forest management tool. Grace III (2017) also studied forest road erosion from 156 runoff-generating events at nine sites in the Appalachian Mountains and found that WEPP adequately simulated sediment yield from the road sections but performed poorly in simulating surface runoff. Muwamba et al. (2017) found that intercropping the bioenergy crop switchgrass into loblolly pine in North Carolina significantly reduced nitrate and phosphate concentrations and phosphorus loads in surface runoff.

LIVESTOCK SYSTEMS

LAND APPLICATION OF LIVESTOCK MANURE

Increasing physical separation of crop and livestock production challenges the sustainable distribution of manure nutrients, but county-level analyses in Iowa showed that all but a few counties maintain sufficient cropland capacity to utilize locally produced manure nutrients (Andersen and Pepple, 2017). Nutrient sampling from dairy lagoons in Idaho revealed seasonally higher N and lower P, K, total solids, and volatile solids in spring than in fall, and higher concentrations of N, total solids, volatile solids, and chemical oxygen demand (COD) from freestall dairies than from dry-lot dairies, but no influence of dairy size (Leytem et al., 2017). Land application methods and timing also affect runoff water quality; loads of dissolved P, total P, and ammonium-N were significantly less after six weeks than at one to three days after application, and loads of dissolved P and total P were less for injection than for broadcast application (Schuster et al., 2017). A setback distance of 12.2 m on no-till cropland in Nebraska with 7.7 Mg ha⁻¹ residue and 5% slope was found to reduce runoff concentrations of N, dissolved P, and K, among other constituents, to background levels (Gilley et al., 2017). Biochar added to horse manure or municipal biosolids at 5% to 8% (wet basis) improved runoff quality but had significant covariation with runoff curve number (CN) for some parameters (Williams and Edwards, 2017).

EMISSIONS FROM LIVESTOCK SYSTEMS

Nitrous oxide (NO₂) is a potent greenhouse gas (almost 300 times greater than CO₂) with long atmospheric lifetime (>100 years). Emissions from two beef feedlots in Texas were positively related to manure moisture content, temperature, and nitrate concentrations ($p < 0.01$) and negatively related to organic matter, ammonium, dissolved C, and dissolved N concentrations ($p < 0.05$) (Waldrip et al., 2017); NO₂ emission predictions based on empirical models developed from these data accurately simulated observed emissions. The traditional non-flow-through chamber methods applied by Waldrip et al. (2017) are labor- and time-inten-

sive; Parker et al. (2017) developed and tested new methods using several configurations of a recirculating-flow-through, non-steady-state chamber and produced rapid, precise, and repeatable results. Understanding of NO₂ emissions begins with accurate estimation of N excretion; Martin et al. (2017) characterized the relationship between age and N excretion as a function of feed consumption and retention for squab broiler, broiler, and roaster chickens and used these relationships to estimate annual and peak daily N excretion rates in a variety of production operations. Storage of manure increases operational flexibility for manure applications but also can increase greenhouse gas emissions; Holly and Larson (2017) tested several commercial manure additives and biochar, both with and without aeration, and found that none of the studied treatments reduced manure solids or N emissions.

COMPOSTING AND CARCASS BURIAL

A process-based model designed to simulate environmental conditions and changes in C and N within cattle manure compost windrows was developed and tested (Bonifacio et al., 2017a, 2017b); model agreement with turned-windrow C and N losses was within 0% to 2% after 99 and 188 days, but less agreement was found with static-windrow losses (within 5% for C and 12% for N after 99 days). Mature compost media used to filter odorous gas emissions from an aerated compost pile of swine manure and chopped cornstalks removed about 98% of the ammonia, which increased the N content of the biofilter media by 9% after four weeks of operation (Tao et al., 2017). In-vessel, aerated, turned composting reduced aqueously extractable estrogens to undetectable levels in three of four municipal biosolid samples, but estrogenicity increased >6.5-fold after the first six days in an aqueous extract generated with the remaining sample (Hammett et al., 2017). Measurements beneath and surrounding two carcass burial sites in Saskatchewan at 7 and 60 years post-burial found vertical contaminant movement limited to 1 to 2 m, indicating that burial site-selection characteristics appropriately identified sites with low potential for leachate transport (Pratt and Fonstad, 2017).

NATURAL TREATMENT SYSTEMS

Packed-bed, recirculating-filter bioreactors used to treat residential septic tank wastewater removed 94% of influent ibuprofen, 84% of naproxen, and 83% of triclosan (Perez et al., 2017); the researchers also found that 98.6% to 99.9% of the organic compound removal was by biodegradation. Colloidal particles from potato farm wastewater were effectively removed by coagulation with two polymers, alum, and ferric chloride; larger volumes of less-expensive alum were needed to achieve target total suspended solids (TSS) levels, and polymers did not require additional chemicals to increase pH to biologically neutral levels (Bosak et al., 2017).

INTERNATIONAL WATER ISSUES

Water availability is a global issue with local causes and effects. Limitations in local and regional water availability

result from factors including overdevelopment, harsh environments, severe aridity, saline water encroachment, technological limitations, and climate variability and change. A study of opportunities and challenges facing treated wastewater reuse found that current natural treatment facilities in the West Bank and secondary treatment technologies in Tunisia could support safe agricultural reuse, but insufficient demand limited utilization of the massive investment in producing high-quality treated wastewaters in Qatar (Dare et al., 2017).

Many tools and technologies for sustainable watershed resource management are relevant to both developing and developed countries. A collection of five articles from the fifth biennial ASABE 21st Century Watershed Technology conference in 2016 highlighted important research with the theme of tools and techniques for sustainability (Tollner and Douglas-Mankin, 2017). A novel fog-catcher system was studied and found to meet a portion (5%) of the agricultural irrigation water need in water-deficient Andean communities in Ecuador (Carrera-Villacrés et al., 2017). Another study in Ecuador, also with regional applicability, focused on developing both GIS and multi-criteria based methods to map areas suitable for coffee production, concluding that 50% of the study area was at least moderately suitable (Ochoa et al., 2017). A new shellfish sanitation model, Mermaid, was demonstrated to be an improvement over the national standard Direct Rule method in making shellfish harvest management decisions that maintain bacterial food safety (Conte and Ahmadi, 2017). Two articles applied the SWAT model to assess the effects of winter cover crops on nitrate loads under future climate conditions in the Chesapeake Bay watershed (Lee, S. et al., 2017) and to support pay-for-performance conservation planning in southeastern Michigan (Muenich et al., 2017).

WATER QUALITY

While many water quality studies were discussed in other sections, e.g., agricultural drainage (Steppuhn and McArthur, 2017; Zimmerman and Kaleita, 2017a, 2017b), crop modeling (Fang et al., 2017b), climate change (Lee, S. et al., 2017; Renkenberger et al., 2017; Wallace et al., 2017; Yasarer et al., 2017), land application of livestock waste (Gilley et al., 2017; Schuster et al., 2017; Williams and Edwards, 2017), forest resource management (Muwamba et al., 2017), and international watershed technology (Conte and Ahmadi, 2017; Lee, S. et al., 2017; Muenich et al., 2017), additional studies addressed nutrient transport and water quality modeling.

NUTRIENT TRANSPORT

Total P, dissolved reactive P (DRP), Al, and Fe concentrations and loads in runoff over an 11-year study period were detailed in a rotationally grazed pasture site in Georgia (Endale et al., 2017); DRP accounted for 80% of the total P concentrations and loads, and cattle presence increased concentrations but not loads for DRP and total P, among other results. Heeren et al. (2017) found that flow through macropores and gravel outcrops can allow even a highly

sorbing solute to reach alluvial aquifers by studying movement of P (highly sorptive), Rhodamine WT (slightly sorptive), and Cl⁻ (conservative) solutes through silt loam floodplain soils in hay and pasture in northeastern Oklahoma and northwestern Arkansas. Down-furrow movement of nalidixic acid-resistant *E. coli* was reduced by 50% compared to furrows with no treatment by treating clay soil furrows with alum and grain-dust waste (Abu-Ashour and Al-Hmoud, 2017). A rapid colorimetric method for determining in-field plant-available soil P had correlations >70% with laboratory test results for four regions in South Korea, and regional differences became non-significant when moisture content and electrical conductivity were included in the multiple regression analysis (Lee, S. Y. et al., 2017).

WATER QUALITY MODELING

Several water quality modeling studies were published in 2017 (table 1). A riparian buffer site in North Carolina was the first study to calibrate and validate REMM for plant N uptake, denitrification, and field-edge N reductions under conditions of groundwater dilution (Tilak et al., 2017). Van Liew et al. (2017) compared APEX results for streamflow, sediment, N, and P simulation over a wide range of conditions (including forest, pasture, and crop) at ten USDA Agricultural Research Service watersheds; they found that the APEX model frequently achieved satisfactory performance when fully calibrated, but it rarely provided satisfactory performance when validating the model for different time periods or watersheds. The WEPP-WQ model was enhanced by adding a new overland-flow element for simulating hydrology, soil erosion, and water quality at the hillslope scale and was tested using data from Indiana and Georgia (Wang, L. et al., 2017).

FUTURE RESEARCH NEEDS

The NRES community of ASABE journals strives to make new knowledge accessible to sustain agricultural and natural systems in a changing world. The articles published in 2017 make strides toward that goal, but much more research is needed. Our world is rapidly changing; the past few decades have seen unparalleled changes in the magnitude and distribution of human populations, climate, land resources, and water supplies. At the same time, advances in information technology are allowing collection and distribution of data and knowledge at unprecedented scales and rates. To adapt to our changing world and mitigate adverse effects, researchers are challenged to harness these revolutionary advances in technology to provide new knowledge to enhance the sustainability of agroecosystems while optimizing agroecosystem goods and services. Several areas deserve immediate and sustained research to sustain agricultural and natural systems in a changing world.

REMOTE SENSING OF AGROECOSYSTEMS

This review highlighted the use of remote sensing data in only two studies: one to estimate ET using thermal satellite imagery (Büyükcangaz et al., 2017) and the other to inventory irrigation reservoirs (Yaeger et al., 2017). Clearly, many

more opportunities exist to harness multispectral data from unmanned aerial systems (UASs) and satellite imagery to revolutionize agricultural and natural systems research. Researchers are challenged to increasingly apply remotely sensed data to enhance understanding of spatiotemporal distributions and trends of soil moisture, crop stress, vegetation patterns, land use change, ephemeral gully erosion, stream aggradation and degradation, alluvial channel geomorphological change, pond/lake sedimentation, water quality, pollution plumes, snowpack accumulation, cropland and forest canopy structure, C dynamics, land resource characteristics, and numerous other agroecosystem properties and processes. UASs should have an increased role in data collection with advances in sensor types, resolution, cost, and weight; improvements in image processing; and customization in scale and frequency of fly-overs to meet specific research objectives. Recent technologies, such as structure-from-motion (e.g., Westoby et al., 2012), provide high-resolution data from low-cost UAS platforms that have yet to be fully utilized in agroecosystems research.

AGROECOSYSTEM RESILIENCY AND VULNERABILITY TO CHANGES IN LAND AND CLIMATE

Additional research is needed to understand, quantify, and simulate agroecosystem response to ongoing and future changes in land and climate. This review cited many studies that both filled and highlighted research gaps in quantifying and modeling individual soil and crop responses to variable environmental forcings across diverse climatic regions. However, researchers must better quantify the inherent uncertainty in forcings and system response, define the risk of adverse results, and better understand the adaptations and mitigations possible to develop comprehensive vulnerability assessments as well as robust strategies and recommendations for sustaining agroecosystems. Critical challenges include:

- Quantifying agroecosystem response to changing climate, including:
 - Direct responses: temporal and spatial changes to precipitation, ET, soil water, crop yield, and agroecosystem services as well as longer-term issues of drought, pest and disease infestations, and agroecosystem regime shifts.
 - Indirect responses: collateral influences of climate change on snowpack and snowmelt magnitude and timing as irrigation source water, trade-offs between surface water and groundwater irrigation sources, and increasing reliance on lower-quality groundwater sources.
- Including crop adaptations (plant breeding, new hybrids, new crops) in relevant models and identifying likely crop shifts considering phenotypic balance (or plasticity) with new local climate.
- Enhancing the knowledge base related to land use adaptations and mitigations, including croplands and grasslands for C sequestration, emissions from livestock systems, and food-energy-water effects of shifts from food to bioenergy cropping systems and from traditional to enhanced conservation systems.

INTEGRATED MODELS OF AGROECOSYSTEM SERVICES

The studies of agroecosystem response to change highlighted in this review typically focused on assessing the effects on crop yields and water quality. Limiting the scope of research to this critical, yet narrow, set of system responses perpetuates a limited view of the goods and services provided by agroecosystems. To provide robust assessments and projections of land resource responses to climate, management, and other stressors, more robust models are needed to incorporate the important interactions, feedbacks, and synergies within the system. Models are needed that adequately capture important goods and services provided by the crops within the agroecosystem boundary as well as important soil-water-air exchanges, interactions with and feedback from wildlife and beneficial insects, and other factors important for robust vulnerability assessments, as discussed in the previous section. Importantly, to fully inform decision-makers, agroecological modelers need to incorporate relevant socio-economic approaches into their integrated systems models.

WATER MANAGEMENT IN AGRICULTURAL PRODUCTION SYSTEMS

The seven challenges for future agricultural irrigation research presented by Dukes et al. (2012) remain relevant today. These challenges stress the need to enhance research that integrates sensor-based data and management technologies toward achieving sustainability goals of maintaining agroecosystem services (increased production, reduced environmental impacts) while addressing water scarcity at technological (developing alternative water sources, reducing energy costs) and societal (inter-sector competition for water) levels. An excerpt from the recent ASABE drainage collection (Strock et al., 2018) captures the grand challenge for agricultural drainage research as an integrated agroecological and socio-economic issue:

“Perhaps the greatest challenge for drainage system design and management is to reduce downstream impacts due to losses of N and P in drainage outflows. ... As with many water quality issues, the basic problem is that the benefits of applying measures to reduce nutrient losses and improve drainage water quality would be enjoyed and appreciated by society at large, but the costs of applying the practices to provide these benefits would be borne by the producers. Future research must consider drainage system design and management, agronomic management practices, and the role of government and market forces in implementing technical solutions at the scale needed to make a measurable impact. Future emphasis on management of drainage systems should focus on achieving an acceptable balance between agricultural productivity, conservation, and environmental quality.”

REPRODUCIBLE MODEL RESULTS

This review highlights the extensive efforts underway in modeling agroecosystems. Optimal research efficiency and effectiveness at the global scale can only be achieved with full transparency and reproducibility of published model re-

sults, allowing researchers to build upon, rather than re-invent, each other's progress. Publication of fully reproducible model results implies providing access to all files and executable code needed to reproduce the modeling research (Saraswat et al., 2015). This will require substantial effort and investment from journals, agencies, and researchers to develop and maintain accessible, quality-assured archives of data, metadata, and model code. Full model reproducibility has numerous benefits as well as some concerns (Saraswat et al., 2015) and will require consistent methods of model calibration, evaluation, and communication (Harmel et al., 2014; Moriasi et al., 2015). Ultimately, however, reproducibility will increase modeling credibility and peer-review quality (Douglas-Mankin et al., 2010; Harmel et al., 2018) and enhance the rate of research progress toward achieving sustainable agricultural and natural systems in a changing world.

CONCLUDING REMARKS

The NRES community of ASABE journals, *Transactions of the ASABE* and *Applied Engineering in Agriculture*, published 98 articles in 2017 covering a broad range of issues in land, water, and agroecosystems research. Experimental and modeling advances were described in hydrology, agroecosystems, climate change effects, soil erosion, irrigation, drainage, forest resource management, livestock systems, natural treatment systems, international water issues, and water quality topic areas. Future research should focus on understanding the processes within and interactions among land, water, and agroecosystems in greater complexity, simulating system processes and interactions with more robust and defensible modeling approaches, and addressing the needs of decision-makers as they affect the sustainability of agroecosystems at local to global scales. Finally, research should make full use of the revolutionary opportunities from remote-sensing data collection and apply these data to enhance understanding of complex land, water, and agroecosystem dynamics.

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