

Article

Managing Agricultural Water Resources in the Southern Region: Perspectives of Crop Growers

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Abstract: The sustainability of agricultural commodities produced in the Southern U.S. under irrigation is increasingly at risk due to erratic rainfall patterns, inadequate water supplies and compromised water quality. This study assessed the needs of crop growers in the United States Department of Agriculture (USDA) Southern Region. The purpose was to identify growers' critical water resource management concerns to identify research priorities from the perspective of growers in this region. To obtain this information, a questionnaire was developed and distributed to growers throughout the Southern Region in 2020. The final sample included 111 crop (row and specialty) production growers from the Southern Region. Overall, respondents named the water available to irrigate as the greatest water resource management priority. Within all the water availability priorities asked, respondents' first choice was declining water supply in the future. Declining water supply and the cost of irrigating presently were the next most frequently named water availability priorities. Growers named both increasing the efficiency of irrigation and development of farming practices to improve soil moisture retention as the primary and secondary focus of future irrigation research, respectively. These results will aid in strengthening existing and developing new initiatives for water research and Extension in this region.

Keywords: agricultural water resource management; irrigation; needs assessment; crop growers; Southern Region; water availability; water quality



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1. Introduction

The effective management of water resources is critical to successful crop production in the future. As climate change persists, extreme weather events will increase in frequency and severity [1]. The resulting increased flooding, drought and destruction will cause greater economic uncertainty about projected yields and ultimately livelihoods for growers. Climate change-initiated increases in rainfall variability and extremes of both drought and excessive precipitation will continue [2–7]. Unpredictable and variable rainfall has a downstream effect on other components in the food production system because decreases in crop yields lead to problems in food processing and distribution, ultimately creating challenges in achieving food security [2–5,8]. The rising pressure of water availability,

amplified by a drastic increase in population, requires more agriculture and potable water to support production [1,7,9,10]. Issues associated with climate change also threaten the quality of water for irrigation. Excessive water can introduce agrichemicals and biological threats to water sources, including those used for crop production or public consumption, via surface runoff [3,8,11]. Therefore, agricultural water resource management requires a systems perspective in which the availability and quality of water for irrigation are inextricably linked [1,12]. The strain on water resources from increased irrigation and the threat to water availability and quality, paired with the increased demand for food and rising operating costs (e.g., fuel, fertilizer, labor), are complex challenges that compromise sustainable crop production. Engagement with farmers in the prioritization of future research for agricultural water resource management is critical to ensure sustainability and respond effectively to the dynamic pressures that climate change presents [6,13,14].

We conducted a study to assess growers' needs about the quality and availability of water for irrigation using an on-line questionnaire (see Supplementary Material S1 for the complete questionnaire instrument) to collect data to identify future research priorities from the perspective of growers. The overall goal of our work was to determine the kinds of research needed to meet the critical needs of farmers regarding the quality and quantity of water for irrigation. The specific objective of this study was to identify research priorities based on growers' perceptions of current and future trends in water use and resulting water management priorities. Many factors demonstrate the need for further investigation of the quantity and quality of water available for irrigation in the Southern Region of the U.S. The recent drastic population and temperature increases across the region led to increased water withdrawals and, ultimately, conflict and litigation over finite water resources [7,15]. The region is an important area of agricultural production in the U.S. Many agronomic crops grown in the Southern Region have a high water demand, such as corn, soybeans, cotton and peanuts. Of the top ten vegetable sales states, three are in the Southern Region: Florida, Georgia and North Carolina. Florida is second only to California in both vegetable sales and harvested acres of fresh market vegetables [16]. There were substantial increases in irrigated acreage from 2007 to 2012 in four Southern Region states: Arkansas, Louisiana, Mississippi and Georgia [17]. According to the 2017 Census of Agriculture, two of the five states responsible for half of the total irrigated acreage in the U.S. were in the Southern Region: Arkansas and Texas [18].

The characteristics of farming (e.g., acreage, climate, crops grown) are fundamentally different in Puerto Rico (PR) and the U.S. Virgin Islands (USVI) compared to the mainland states of the Southern Region. As such, PR and the USVI have agricultural water resource management barriers and needs unique to the region. The full extent of the challenges facing growers in PR and the USVI remains unknown because the data are not nearly as abundant or available in contrast to the conterminous U.S. For example, 19 years after U.S. drought monitoring began, the USVI were finally included in 2019 [19]. Drought persists in both PR and the USVI, which reduces soil moisture retention and results in soil cracking [20]. Erratic rainfall variability from climate change will impact island nations disproportionately due to their heavy reliance on rainfed agriculture. The historic exclusion of the territories presents a need for data collection that will contribute meaningfully to sustainable agriculture and food systems in the territories and extend throughout the Southern Region. Our specific contribution is to inform further exploration of innovative water management strategies for the Southern Region in the face of climate change. The novelty of this study lies within the design of the sampling protocols, instrumentation, data collection and regional focus on managing water resources for agriculture.

2. Methods

2.1. Instrument

The geographic focus of this study is the USDA-defined Southern Region. The Southern Region includes the following states and territories: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, Puerto Rico (PR),

South Carolina, Tennessee, Texas, Virginia and the U.S. Virgin Islands (USVI). Through the needs assessment, we aimed to identify the most critical issues related to water resource management from the farmers' perspective. The purpose of identifying farmers' needs in the questionnaire was to inform the design of future research and programming that enhances the sustainability of water resource management in the agricultural systems of the Southern Region. We divided the questionnaire into two key sections: one about water availability for irrigation and the other about the quality of the available water. In the questionnaire, we asked about demographics, basic characteristics of the farming operation, irrigation practices, sources of water, water resource management practices, factors that affect decisions about water resource management, priorities for research about water resource management and sources of information used to make water resource management decisions. We developed the questions drawing from Dillman's survey design method [21].

We used a drill down approach where the respondent first responded to larger scale or more critical concepts and then selected more detailed responses within each concept. We define drill down in the context of this questionnaire to first asking the respondent to identify broad categories of water resource management priorities from a list. In the next step, respondents answered questions that addressed specific aspects of water resource use and management within each of the broad categories identified in step 1. We first asked growers to select the two most important of five priorities with regard to irrigation needs. In step 2, the respondent rank ordered several factors within each of the priorities selected in step 1. For example, if one priority was "declining water supply", the questionnaire then displayed a list of factors that could affect declining water supply and the respondent rank ordered those items with regard to the importance of these more specific factors. We included the same series of questions for conditions at the present time and in the future. Then, we repeated the process for water quality.

We used a two-step process to test the questionnaire. Step 1 was a cognitive test to address problems in instrument content, including wording, order, omissions and relevance of the questions. The objective was to ensure that the questions comprised all the information needed and were easily understood by the participant. We completed the cognitive test by telephone or e-mail. We called and e-mailed ten growers who have extensive experience in water resource management in the Southern Region, as identified by faculty members, and those who have the requisite expertise in the land grant universities in the Southern Region. We made major revisions to the instrument after this test including asking the same questions for conditions at the present time and in the future.

Step 2 was a pilot test of the instrument to identify and address potential problems in implementation. We addressed any barriers to understanding that emerged with a wider group of respondents, such as response format, wording and length. We made minimal revisions to the questionnaire after this test.

2.2. Sample

The sample selection of growers was based on the counties in each state with the highest irrigated acreage reported in the 2017 Census of Agriculture [22]. Figure 1 shows the irrigated acreage for the Southern Region states. The growers targeted for the sample were those actively engaged in water resource management issues. Extension personnel in the ten counties with the most irrigated acreage of the Southern Region states identified these growers. Members of the Southern Extension and Research Activity (SERA) 43 committee assisted us in connecting with the Extension personnel. SERA 43 is a trans-disciplinary collaboration of teaching and research faculty and Extension personnel at land grant universities throughout the Southern Region, working to strengthen relationships with stakeholders and advance research progress in the realms of water resource management and ecosystem services using a social-ecological systems approach [23]. We drew a purposive sample of growers involved in water resource management issues for two reasons. First, purposive sampling likely improved the response rate. Second, we

sought information from growers who are most concerned and knowledgeable about water resource management issues.

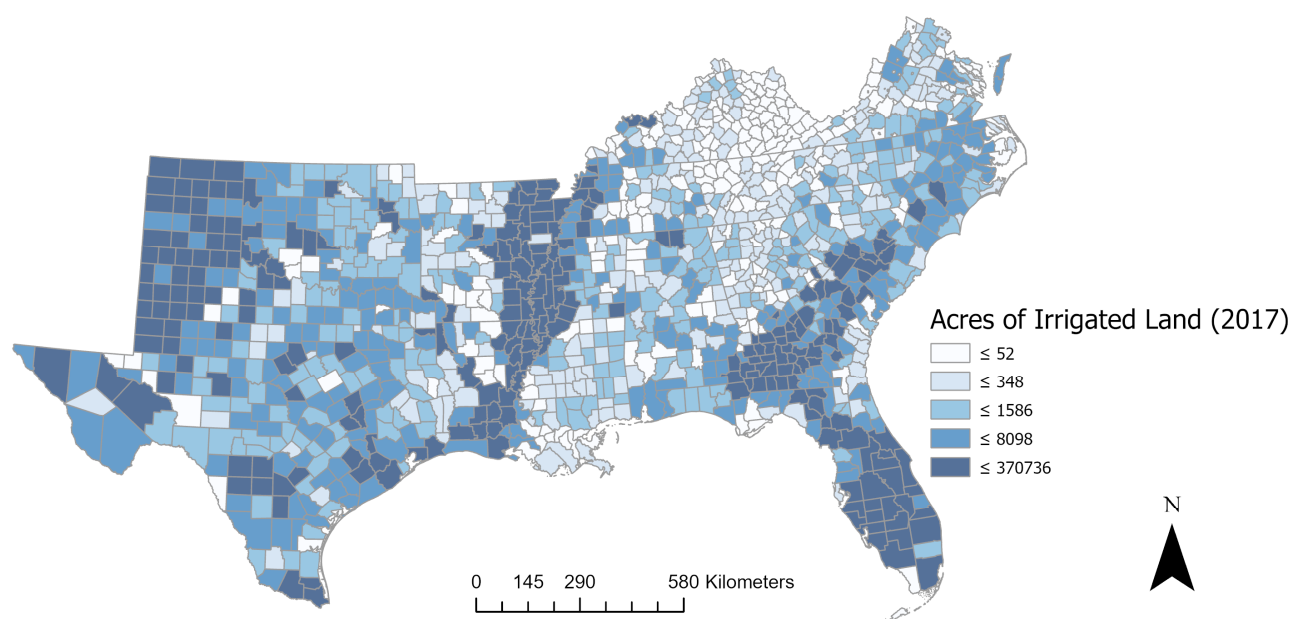


Figure 1. Quantile map of irrigated acreage in the conterminous U.S. Southern Region states by county from the 2017 Census of Agriculture.

We used a two-stage referral sampling approach to identify potential participants.

Stage 1: We requested that Extension personnel identify 10 crop production farmers in each of the 10 counties with the highest irrigated acreage to respond to the questionnaire (100 farmers in total). However, some Extension personnel said that irrigated acreage was not the only important trait relevant to selecting participants for this study because irrigated acreage includes pasture and forage crops in some counties. In these cases, we asked Extension personnel to identify 10 counties in their state based on water use for irrigation in crop production and to identify crop producers that they consider knowledgeable, informed and concerned about local water use and management.

Stage 2: We sent the questionnaire link associated with this protocol to the Extension personnel that identified the list of growers. The Extension personnel then either distributed the questionnaire link to the growers they identified as potential respondents or provided the list of potential respondents to us to handle the questionnaire distribution.

The sampling protocol was different for the territories in the Southern Region, PR and the USVI. Irrigated acreage data for PR and the USVI were not available from the 2017 Census of Agriculture at the time we distributed the questionnaire. Therefore, we relied heavily on collaboration from our colleagues at Universidad de Puerto Rico (UPR), University of the Virgin Islands (UVI) Cooperative Extension and the U.S. Virgin Islands Department of Agriculture (VIDA) to construct a representative sampling protocol. Our colleagues from the USVI provided us with a master list of registered farmers and we selected 100 randomly from this list to send the questionnaire. Irrigated acreage data from the 2017 Census of Agriculture for PR became available during questionnaire distribution, but we were not able to complete the distribution of the questionnaire due to the threats associated with the COVID-19 pandemic. The distribution of the questionnaire coincided with the onset of the pandemic, which generated unforeseen circumstances. As a result, we adapted our original sampling protocol before resuming distribution of the questionnaire.

2.3. Data Analysis

This study mapped county-level irrigation data for the Southern Region from the 2017 Census of Agriculture using ESRI ArcGIS Pro v2.7.0. We designed the questionnaire instru-

ment, collected responses and generated the data using Qualtrics in 2020. We imported our Qualtrics data into IBM SPSS Statistics 20 to conduct the descriptive analyses reported in this study.

3. Results

We report all results separately for the conterminous states in the Southern Region ($n = 85$) and the U.S. Virgin Islands ($n = 25$) because the sampling procedures in the two areas differed due to the differences discussed earlier. The differences that led us to sample the two sub-regions differently are reflected in the characteristics of the farm population and of the farming operations. Table 1 shows the geographic distribution of respondents for the entire sample ($n = 111$).

Table 1. Geographic distribution of full sample ($n = 111$).

State or Territory	County or Parish	Frequency	Percent
Alabama	Total	6	5.4
	Dallas	1	0.9
	Madison	1	0.9
	Talladega	1	0.9
	Did not say	3	2.7
Arkansas	Total	4	3.6
	Lonoke/Jefferson	1	0.9
	Lonoke/Pulaski	2	1.8
	Did not say	1	0.9
Florida	Total	2	1.8
	Manatee	1	0.9
	Did not say	1	0.9
Georgia	Total	7	6.3
	Jefferson	2	1.8
	Jefferson/Burke/Glascock	1	0.9
	Mitchell	3	2.7
	Did not say	1	0.9
Kentucky	Total	2	1.8
	Calloway	1	0.9
	Did not say	1	0.9
Louisiana	Total	8	7.2
	East Carroll	2	1.8
	East Carroll/West Carroll	1	0.9
	Madison	1	0.9
	Morehouse	1	0.9
	Vermilion	1	0.9
	Did not say	2	1.8
Mississippi	Total	19	17.1
	Bolivar	3	2.7
	Leflore	6	5.4
	Issaquena	1	0.9
	Sharkey/Issaquena	2	1.8
	Sunflower	1	0.9
	Sunflower/Bolivar	1	0.9
	Warren/Issaquena	1	0.9
	Did not say	4	3.6
Oklahoma	Total	2	1.8
	Texas	1	0.9
	Texas/Cimarron	1	0.9

Table 1. Cont.

State or Territory	County or Parish	Frequency	Percent
South Carolina	Total	21	18.9
	Aiken	1	0.9
	Calhoun	4	3.6
	Calhoun/Orangeburg	2	1.8
	Clarendon/Sumter	1	0.9
	Edgefield	1	0.9
	Lexington	1	0.9
	Orangeburg	5	4.5
	Orangeburg/Dorchester	1	0.9
	Did not say	5	4.5
Tennessee	Total	2	1.8
	Fayette	1	0.9
	Lake/Fulton	1	0.9
Texas	Total	11	9.9
	Dallam/Hartley	2	1.8
	Hidalgo	2	1.8
	Lamb	2	1.8
	Moore/Sherman	1	0.9
	Did not say	4	3.6
Virginia	Total	1	0.9
	Southampton	1	0.9
U.S. Virgin Islands	Total	25	22.5
Did not say	Total	1	0.9

3.1. Conterminous U.S.

Most respondents were in South Carolina ($n = 21$), with Mississippi closely following ($n = 19$). There were respondents from every Southern Region state except North Carolina. Most respondents were white ($n = 59$), male ($n = 60$), between the ages of 35–49 ($n = 35$) and had farmed 10–39 years ($n = 47$). A large majority of respondents ran conventional farming operations ($n = 79$). Most operations were family-owned ($n = 55$) or managed by lessees ($n = 22$).

A majority of respondents named groundwater ($n = 70$) as their primary water source for irrigation. Figure 2 shows the irrigated acreage reported by respondents. Almost 33% of farms irrigated 1000–3499 acres, with 0–499 acres a close second at 24%. Table 2 shows the primary irrigation method. Most respondents used center pivot as their primary irrigation method ($n = 41$), and flood or furrow irrigation was the next most commonly used method ($n = 28$). Over 75% of respondents grew grains, oilseeds, dry beans or dry peas and nearly half grew cotton or cottonseed. Nearly three-fourths (72%) of respondents said corn was the source of greatest demand for water on their operation, 41% said soybeans and 38% said cotton and cottonseed are the crops that require the most water.

Table 2. Primary irrigation method for conterminous U.S. respondents ($n = 85$).

Variables	Frequency	Percent
Flood or furrow	28	32.9
Drip	5	5.9
Center pivot	41	48.2
Traveling sprinkler	1	1.2
Overhead sprinkler	4	4.7
Spray with riser	1	1.2
Did not say	5	5.9

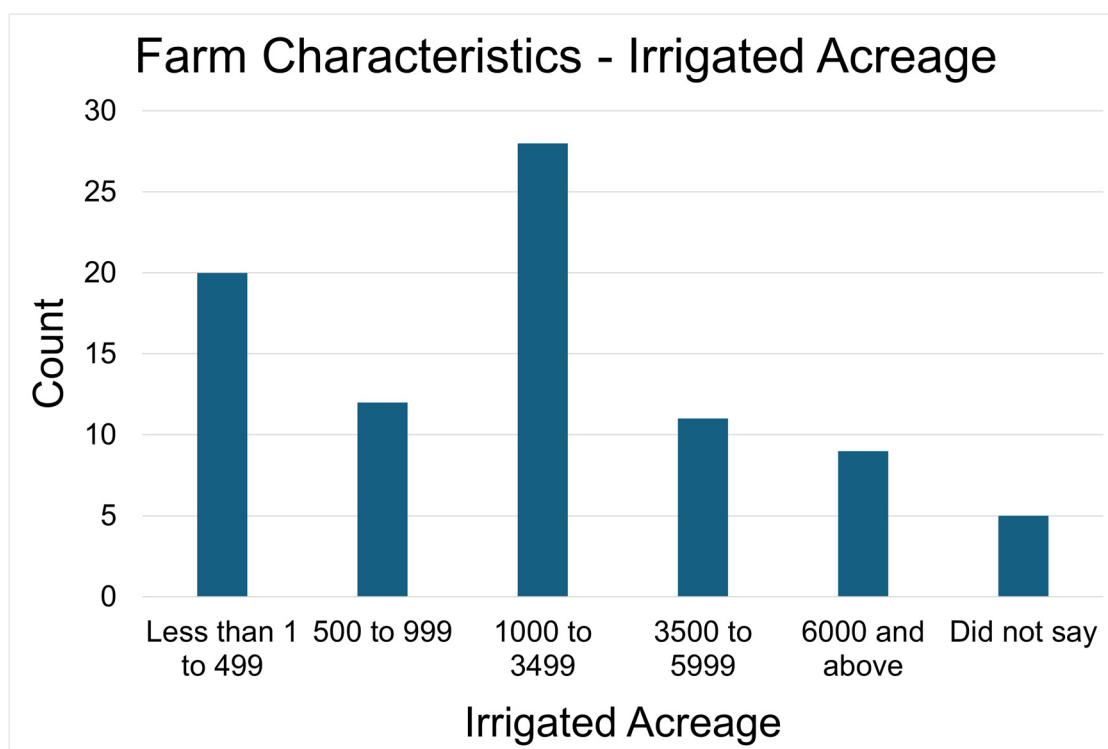


Figure 2. Irrigated acreage from respondents in the U.S. Southern Region states.

Respondents named water available for irrigation as the greatest water resource management priority. Among all the water availability priorities listed in the questionnaire, respondents' most frequently identified threat to water availability was regulations that affect the choices they can make about water use on their farm in the future. Declining water supply in the future was the next most frequently named overall water availability priority. When responding to items about priorities to address the quality of available irrigation water, two choices were identified by the same number of respondents: industrial pollutants coming into their farming operations and changes in the soil profile. Respondents' second most common choice was saltwater intrusion.

Overall, respondents chose increasing efficiency of irrigation as the first choice for future irrigation research. Development of farming practices to improve soil moisture retention and reducing crop demand for water through breeding were tied for second place. When asked about the importance of potential climate variability on their ability to manage irrigation, most respondents said this factor was very important or did not rank its importance. Respondents named time spent as the most burdensome aspect of regulatory compliance at all scales (e.g., regional, state, federal) while expenditures on compliance was the least burdensome. Respondents named test results as the most critically important source of information in their decisions about water management. Other regional and federal natural resource and environmental agencies (those outside of Cooperative Extension Service and Soil and Water Conservation Service) were not at all important.

3.2. U.S. Virgin Islands

Table 3 shows the geographic distribution of the respondents from the U.S. Virgin Islands. Most of the respondents were in St. Croix ($n = 10$) and there were no respondents from St. John. Most USVI respondents were Black or African American ($n = 6$), female ($n = 9$), 35 to 49 years old ($n = 7$) and had farmed for 24 years or less ($n = 14$).

A little over half of the respondents used rainfall as their primary source of water and 40% used groundwater for irrigation. Most of the USVI respondents used organic practices on their farming operation but were not certified organic ($n = 17$). Most USVI respondents were from family-owned operations ($n = 14$). Over 80% of respondents irrigated nine

acres or less (Table 4). Most respondents of the USVI used drip as their primary irrigation method ($n = 14$) (Table 5). Over 75% of respondents grew crops included in the overall category of vegetables, melons, potatoes and sweet potatoes. Over 60% grew fruit, tree nuts and berries. Leafy greens and fruit (both 36%) were tied for the crops requiring the most irrigation, with watermelon (28%), followed by salad greens and cucumbers (both 24%).

Table 3. Geographic distribution of USVI respondents by island ($n = 25$).

Variables	Frequency	Percent
St. Croix	10	40.0
St. John	0	0.0
St. Thomas	3	12.0
Did not say	12	48.0

Table 4. Irrigated acreage for USVI respondents.

Variables	Frequency	Percent
Less than 1 acre	6	24.0
1–9 acres	15	60.0
10+ acres	2	8.0
Did not say	2	8.0

Table 5. Primary irrigation method for USVI respondents.

Variables	Frequency	Percent
Flood or furrow	1	4.0
Drip	14	56.0
Traveling gun	3	12.0
Spray with riser	3	12.0
Did not say	4	16.0

Respondents named water available for irrigation as the greatest water resource management priority overall. Declining water supply in the future was the most important water availability priority. Declining water supply at the present time and the cost of irrigating at the present time were tied for second. Respondents' primary area needing more research to ensure water quality included biological threats and sedimentation. The next most important priorities for irrigation water quality were industrial pollutants, sediments and materials clogging irrigation systems, saltwater intrusion and changes in the soil profile.

Respondents equally chose both increasing efficiency of irrigation and development of farming practices to improve soil moisture retention as their first choice for the focus of future irrigation research. When asked about the importance of potential climate variability on their ability to manage irrigation, most respondents chose the "very important" category. Respondents said fiscal expenditures were the most burdensome aspect of regulatory compliance at all scales (e.g., regional, state, federal) while expenditures of time were the least burdensome. Respondents named soil and water conservation service as the most critically important source of information in their decisions about water management. Other state, local, regional and federal natural resource and environmental agencies were less important sources of information overall.

3.3. Selected Responses by Sample

The tables below show the highest frequencies of selected responses from each sample. Table 6 shows the selected responses for respondents from the conterminous U.S. and Table 7 shows the selected responses from USVI. The majority demographic characteristics

for the conterminous U.S. were White (69.4%) and male (70.6%). In contrast, most of the USVI respondents were Black or African American (24%) and female (36%). Both samples had the majority of respondents in the 35–49 years old age range (41.2% in U.S. states and 28% in USVI) and from family-owned operations (64.7% in U.S. states and 56% in USVI). Most respondents from the U.S. states were from conventional operations (92.9%) while most USVI respondents implemented organic practices on their operations but were not certified (68%). Groundwater was the main source of water for irrigation in the states (82.4%), while the USVI relied primarily on rainfall (52%). There are completely different scales of farming happening among the two samples. Most conterminous U.S. respondents had 1000–3499 acres under irrigation (34.1%) while most USVI respondents had 9 acres or less under irrigation (84%). Center pivot was the primary irrigation method for the (48.2%), while growers in the USVI used drip (56%) for the most part. Both samples grew different types of crops. Grains, oilseeds, dry beans or dry peas were the primary crops grown in the U.S. states (69.4%), and corn (71.8%) had the highest demand for water. Leafy greens and fruit (both 32%) had the highest demand for water and vegetables, melons, potatoes and sweet potatoes were the primary crops grown in the USVI (76%).

Table 6. Selected majority responses from conterminous U.S. participants.

Selected Response	Frequency	Percent of Conterminous U.S. Sample
White	59	69.4
Male	60	70.6
35–49 years old	35	41.2
Conventional operation type	79	92.9
Family-owned ownership type	55	64.7
Groundwater is the primary irrigation water source	70	82.4
1000–3499 acres under irrigation	29	34.1
Center pivot is the primary irrigation method	41	48.2
Grains, oilseeds, dry beans or dry peas are the primary crops grown	59	69.4
Corn has the greatest demand for water	61	71.8

Table 7. Selected majority responses from USVI participants.

Selected Response	Frequency	Percent of USVI Sample
Black or African American	6	24.0
Female	9	36.0
35–49 years old	7	28.0
Organic practices, but not certified operation type	17	68.0
Family-owned ownership type	14	56.0
Rainfall is the primary irrigation water source	13	52.0
9 acres or less under irrigation	21	84.0
Drip is the primary irrigation method	14	56.0
Vegetables, melons, potatoes and sweet potatoes are the primary crops grown	19	76.0
Fruit (32%) and leafy greens (32%) have the greatest demand for water	16	64.0

3.4. Summative Water Resource Management Concerns by Sample

There were key similarities and distinctions among both samples regarding the summative concerns reported by the respondents. Additionally, both the U.S. states and USVI named increasing the efficiency of irrigation as the top priority for future irrigation research and the USVI equally named development of farming practices to improve soil moisture retention as their first choice. The conterminous U.S. named regulations that affect the choices they can make about water use on their farm in the future as a top concern. The USVI respondents named declining water supply in the future as their most important

water availability priority. Regarding water quality, respondents from the U.S. states named both industrial pollutants coming into their farming operations and changes in the soil profile as their top priorities. Respondents from the USVI named both biological threats and sedimentation as their top water quality priorities. When asked what the most burdensome aspect of regulatory compliance was, the U.S. states named time spent and the USVI named fiscal expenditures. Test results were named by the U.S. states as the most critically important source of information in their decisions about water management while the USVI named soil and water conservation service. Overall, respondents from both the U.S. states and USVI named the water available to irrigate as the greatest water resource management priority.

4. Discussion

Looking ahead, water resource management research and practice needs to innovate in response to the increasing global population and finite water resources. Overall, farmers in the Southern Region across different water resource management methods, geographies and crop production systems prioritized water availability over quality and named increasing irrigation efficiency as their top priority for future research. A common solution to water availability concerns in crop production has been to improve irrigation efficiency. This is not always an actionable path [12] and can ultimately accelerate the problem because improved efficiency does not necessarily yield a decrease in resource consumption [10,24]. Specific recommendations to reduce water use on farm and the effects of reduced water vary depending on the irrigation method, geographic location and the crops grown [25]. Many climatic types and considerable variability within each type are represented throughout different geographies in the Southern Region. Contextually specific characteristics such as temperature, rainfall variability, groundwater resources and surface water resources call for tailored agricultural water resource management research to ensure sustainable food systems. For example, the USVI are particularly unique to the mainland states of the Southern Region due to the nature of its water resources, the types of crops grown, its size and scale of farming. Despite these fundamental differences that drive water resource management, crop producers throughout the Southern Region are most concerned about the availability of water resources for irrigation and increasing the efficiency of irrigation. A transdisciplinary, including biophysical, economic and social, approach to the cascading challenges, opportunities and tradeoffs associated with agricultural water resource management allows for more depth and breadth in understanding the underlying issues [1,6,7,11]. Understanding the priorities of farmers can effectively enhance future water resource management research and Extension programming for innovating crop production in the face of both climate change and an increasing global population.

Reducing water use while increasing production is a tremendous challenge faced by farmers worldwide. Ensuring sustainability of water resources is of paramount importance to global food security. The knowledge that farmers in the Southern Region want future research to prioritize increasing the efficiency of irrigation when that may not be sustainable, inherently presents a challenge in using a transdisciplinary approach to future water resource management research design and Extension programming. Framing the circular economy approach as a potential solution to this apparent mismatch of what farmers prioritize and what is happening to water resources in a biophysical sense has potential merit in the Southern Region context. A circular economy, or closed loop system, refers to the concept of maintaining the use and value of resources in the economy for the duration of that resource's existence [26]. In the true circular economy, nothing remains unused and there are no waste products. This approach to management can improve agricultural sustainability by limiting leaching and runoff, being less reliant on fertilizers and resulting in more profit, ultimately. The circular economy approach offers agricultural management concepts that are useful in theory, but closing the loop is not always practically possible because there will always be some waste associated with production. Composting is an example of reusing food waste for food production, although the decomposition process

releases greenhouse gases. Also, the circular economy approach is just one example of what future water resource management research and practice can draw from. Other water management areas of research offer actionable paths to practical sustainability, such as rainwater harvesting. Context is essential to driving the actionable directions forward.

Extension represents a significant source of information about water conservation and irrigation practices for growers, although there is considerable variance regarding the extent to which growers access this kind of information from Extension. The success of Extension efforts in this area does vary across geographic contexts, where the strain on water resources could present a more imminent need for growers to adopt water conservation practices. Extension's inconsistent success in guiding growers to adopt more efficient irrigation practices could be explained in part by the delivery method used. Historically, Extension programs were delivered via lectures, field days, information sheets and demonstrations of a practice [27]. Following program delivery, the typical next step for growers once they have determined the benefits outweigh the costs of a given practice is conducting on-farm trials of that practice as a final evaluation. Trials have their pitfalls, however, which are related to: the trial's ease of being observed, the length of time the trial requires, how complex the practice is, the cost associated with doing the trial, the possibility the trial might fail and various issues regarding implementation. Growers may never reach this trial stage, however, if they are not comfortable taking on the financial risk to implement a trial on their operation. Efficiency competitions were developed to create Extension programming with more impact [27]. This novel approach to Extension programming engaged growers, agricultural service providers, researchers, Extension and other agricultural producer stakeholders in finding efficient water management solutions. These competitions represent a departure from the historically inadequate Extension information delivery methods to emphasize experiential learning and networking across the various agricultural production stakeholder types. This approach worked better than historical Extension programming for the ultimate purpose of efficient water management adoption because of the community development and experiential learning aspects [27]. The focus of future Extension delivery methods for irrigation water management technologies should capitalize on these aspects.

Identifying the needs and concerns of growers is a first step in developing robust solutions to the existing problems in water management and to identify the problems that are likely to arise. Evidence suggests that including the end users of research empowers those voices rather than creating more inequities [28]. The agricultural practices employed on operations are directly related to the funding, resources and capacity available to farmers. For example, we found that respondents in the mainland states were most concerned about regulations to come, while USVI growers were most concerned about the cost of irrigating. Equity issues also presented themselves in the design phase of this study regarding data availability in the territories. The ability to adopt technologies that can help with addressing fundamental sustainability challenges are particularly compromised in the territories due to a lack of available evidence. Gender is a potentially important equity factor regarding agricultural production in the USVI. Recently, farmers from the USVI reported overall societal disregard for women, and women farmers carry a social stigma [29]. We found that most respondents who reported sex in the USVI sample were female, but most respondents chose not to report sex. The continued drawdown of water resources over time and increasing unpredictability in rainfall affecting all farmers across the Southern Region could be disproportionately distressing female farmers in the USVI when considering the social conditions that affect their well-being. Equity in agricultural production looks different across the various geographies represented in the Southern Region. Future research and Extension must consider place-based equity factors in addition to the agricultural practices specific to the geographic location (e.g., irrigation, crops grown) when engaging and communicating with agricultural producers, stakeholders along the supply and value chains and society at large.

5. Conclusions

Overall, farmers in the Southern Region prioritize the availability of water over water quality. The concerns of growers in the states were primarily regarding regulations in the future. In the USVI, growers were mostly concerned with the cost of irrigating at the present time. Declining supply in the future was a water availability priority for respondents in the states and in the USVI. Industrial pollutants and changes in the soil profile were the primary water quality concern for growers in the states. Biological threats and sedimentation were the primary water quality concerns for USVI growers. The respondents from both the conterminous U.S. and USVI in the Southern Region named increasing efficiency of irrigation as the focus of future irrigation research. The farmer characteristics were very different between the two samples. We anticipated this outcome since farming is fundamentally different in the territories compared to the conterminous U.S. in the Southern Region. Most USVI respondents were Black or African American, female, 35 to 49 years old and farmed for 24 years or less. Most of the USVI respondents used organic practices on their farming operation but were not certified organic. In contrast, the states used conventional practices for the most part. Both sets of respondents primarily operated family-owned farms. Most operations in the USVI used rainfall as the primary water source for irrigation and drip irrigation. The crops using the most water were also very different for these two groups. Corn, soybeans and cotton were the highest water users in the states while this was true for vegetables and fruit in the USVI. Future research and Extension programming can consider meaningful ways of integrating these key perceptions moving forward, keeping in mind the primary water resource management concerns of growers based on their geographic location. Ultimately, more accurately tailored research and Extension programs to support the states and territories can be developed and implemented to further food security and sustainable food systems throughout the Southern Region.

6. Limitations and Future Directions

This study would benefit from redistributing the questionnaire to growers in the Southern Region. The small sample size limited the types of analyses we could complete. The lack of consistent data availability across the whole Southern Region caused us to design different sampling protocols for the states and territories. There was not representation of all the states and territories in the Southern Region and some geographic areas had more representation than others. Puerto Rico had no representation, unfortunately. The complications presented by the COVID-19 pandemic pressed us to pause the distribution of the questionnaire shortly after starting and change our sampling protocol upon resuming distribution to send the questionnaire link to growers via Extension agents. Additionally, we received feedback during the distribution process that coordinating distribution around standard planting times by state would help increase our response rate. These factors yielded a sample that was not representative. Finally, we acknowledge this approach was limited to those growers with established relationships with Extension personnel.

The results from the USVI show that the territories, PR and the USVI, necessitate a questionnaire instrument tailored to their unique water resource needs. This is due to how different farming is in the territories compared to the states. There is considerably less acreage and distinctive specialty crops not commonly grown in the states. Also, the lack of data availability in the territories dictate a different sampling protocol than the states. A separate study in the territories would allow for the identification of more accurate future research priorities and tailored Extension programming to improve the sustainability of their local food systems and foster food security. A team of researchers and students at UVI are working on several web applications to better understand water use for crop production in the field. Looking ahead, continued efforts for data collection in PR and the USVI should be prioritized to fill the considerable knowledge gaps and move towards an equitable agricultural body of knowledge in the Southern Region.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/w16131841/s1>, S1: questionnaire instrument.

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Data Availability Statement: Data will be available on request from the corresponding author.

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References

1. Picone, C.; Henke, R.; Ruberto, M.; Calligaria, E.; Zucaro, R. A Synthetic Indicator for Sustainability Standards of Water Resources in Agriculture. *Sustainability* **2021**, *13*, 8221. [\[CrossRef\]](#)
2. Amanullah; Khalid, S. Agronomy-Food Security-Climate Change and the Sustainable Development Goals. In *Agronomy—Climate Change & Food Security*, 1st ed.; Amanullah, Ed.; IntechOpen: London, UK, 2020; pp. 1–8. [\[CrossRef\]](#)
3. Corwin, D.L. Climate Change Impacts on Soil Salinity in Agricultural Areas. *Eur. J. Soil Sci.* **2021**, *72*, 842–862. [\[CrossRef\]](#)
4. Gomez-Zavaglia, A.; Mejuto, J.C.; Simal-Gandara, J. Mitigation of Emerging Implications of Climate Change on Food Production Systems. *Food Res. Int.* **2020**, *134*, 109256. [\[CrossRef\]](#) [\[PubMed\]](#)
5. Malhi, G.S.; Kaur, M.; Kaushik, P. Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review. *Sustainability* **2021**, *13*, 1318. [\[CrossRef\]](#)
6. Siirila-Woodburn, E.R.; Rhoades, A.M.; Hatchett, B.J.; Huning, L.S.; Szinai, J.; Tague, C.; Nico, P.S.; Feldman, D.R.; Jones, A.D.; Collins, W.D.; et al. A Low-to-No Snow Future and Its Impacts on Water Resources in the Western United States. *Nat. Rev. Earth Environ.* **2021**, *2*, 800–819. [\[CrossRef\]](#)
7. Sheng, D.; Owen, S.; Lambert, D.M.; English, B.C.; Menard, R.J.; Hughes, D.W.; He-Lambert, L.; Clark, C.D. A Multiregional Input-Output Analysis of Water Withdrawals in the Southeastern United States. *Rev. Reg. Stud.* **2019**, *49*, 323–350. [\[CrossRef\]](#)
8. Godde, C.M.; Mason-D'Croz, D.; Mayberry, D.E.; Thornton, P.K.; Herrero, M. Impacts of Climate Change on the Livestock Food Supply Chain; A Review of the Evidence. *Glob. Food Secur.* **2021**, *28*, 100488. [\[CrossRef\]](#) [\[PubMed\]](#)
9. López-Felices, B.; Aznar-Sánchez, J.A.; Velasco-Muñoz, J.F.; Mesa-Vázquez, E. Farmers' Profiles and Attitudes towards the Implementation of Rainwater Harvesting Systems in Intensive Agriculture. *Int. J. Agric. Sustain.* **2023**, *21*, 2189402. [\[CrossRef\]](#)
10. Maja, M.M.; Ayano, S.F. The Impact of Population Growth on Natural Resources and Farmers' Capacity to Adapt to Climate Change in Low-Income Countries. *Earth Syst. Environ.* **2021**, *5*, 271–283. [\[CrossRef\]](#)
11. Evans, A.E.; Mateo-Sagasta, M.J.; Qadir, E.; Boelee, E.; Ippolito, A. Agricultural Water Pollution: Key Knowledge Gaps and Research Needs. *Curr. Opin. Environ. Sustain.* **2019**, *36*, 20–27. [\[CrossRef\]](#)
12. Dalla Fontana, M.; Wahl, D.; Moreira, F.d.A.; Offermans, A.; Ness, B.; Malheiros, T.F.; Di Giulio, G.M. The Five Ws of the Water-Energy-Food Nexus: A Reflexive Approach to Enable the Production of Actionable Knowledge. *Front. Water* **2021**, *3*, 729722. [\[CrossRef\]](#)
13. Friedrichsen, C.N.; Hagen-Zakarison, S.; Friesen, M.L.; McFarland, C.R.; Tao, H.; Wulffhorst, J.D. Soil Health and Well-Being: Redefining Soil Health Based upon a Plurality of Values. *Soil Secur.* **2021**, *2*, 100004. [\[CrossRef\]](#)
14. Velasco-Muñoz, J.F.; Aznar-Sánchez, J.A.; López-Felices, B.; Balacco, G. Adopting Sustainable Water Management Practices in Agriculture Based on Stakeholder Preferences. *Agric. Econ.* **2022**, *68*, 317–326. [\[CrossRef\]](#)

15. Manganiello, C. The “Water Wars” and Opportunities for Change. Chattahoochee Riverkeeper. 2021. Available online: <https://chattahoochee.org/case-study/tri-state-water-conflict/> (accessed on 6 October 2021).
16. United States Department of Agriculture. 2017 Census of Agriculture Highlights—Vegetable Production. 2019. Available online: https://www.nass.usda.gov/Publications/Highlights/2019/2017Census_Vegetable_Production.pdf (accessed on 11 October 2019).
17. United States Department of Agriculture. Irrigation & Water Use. 2019. Available online: <https://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/> (accessed on 19 March 2020).
18. United States Department of Agriculture. 2017 Census of Agriculture Highlights—Irrigation and Water Management. 2019. Available online: https://www.nass.usda.gov/Publications/Highlights/2019/2017Census_Irrigation_and_WaterManagement.pdf (accessed on 19 March 2020).
19. National Drought Mitigation Center. U.S. Drought Monitor Now Includes U.S. Virgin Islands. 2019. Available online: <https://drought.unl.edu/Publications/News.aspx?id=342> (accessed on 4 May 2020).
20. National Integrated Drought Information System. Drought Update for Puerto Rico and the U.S. Virgin Islands. 2021. Available online: <https://www.drought.gov/drought-status-updates/drought-update-puerto-rico-and-us-virgin-islands-0> (accessed on 4 May 2021).
21. Dillman, D.A.; Smyth, J.D.; Christian, L.M. *Internet, Phone, Mail, and Mixed-Mode Surveys*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2014.
22. U.S. Department of Agriculture National Agricultural Statistics Service. Census of Agriculture 2017 Census Volume 1, Chapter 2: County Level. 2020. Available online: https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_County_Level/ (accessed on 2 February 2020).
23. SERA43. SERA43 Research, Extension & Education Water Resource Management Programs through the Land Grant University System. 2016. Available online: <http://sera43.soil.ncsu.edu/index.html> (accessed on 15 January 2020).
24. York, R.; McGee, J.A. Understanding The Jevons Paradox. *Environ. Sociol.* **2016**, *2*, 77–87. [CrossRef]
25. Nian, Y.; Huang, Q.; Kovacs, K.F.; Henry, C.; Krutz, J. Water Management Practices: Use Patters, Related Factors and Correlations with Irrigated Acres. *Trans. ASABE* **2020**, *56*, e2019WR025360. [CrossRef]
26. Merli, R.; Preziosi, M.; Acampora, A. How Do Scholars Approach the Circular Economy? A Systematic Literature Review. *J. Clean. Prod.* **2018**, *178*, 703–722. [CrossRef]
27. Rudnick, D.R.; Stockton, M.; Taghvaeian, S.; Warren, J.; Dukes, M.D.; Kremen, A.; Henry, C.G.; Aguilar, J.; Ortiz, B.; Andales, A.; et al. Innovative Extension Methods in the U.S. to Promote Irrigation Water Management. *Trans. ASABE* **2020**, *63*, 1549–1558. [CrossRef]
28. Raja, S.; Morgan, K.; Hall, E. Planning for Equitable Urban and Regional Food Systems. *Built Environ.* **2017**, *43*, 309–314. [CrossRef]
29. Iowa State University Food Systems Team. Virgin Islands Community Food Systems Assessment. 2020. Available online: https://www.extension.iastate.edu/ffed/wp-content/uploads/2020-Final-USVI-Assessment_red.pdf (accessed on 7 April 2020).

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