Title
Research Support Services: Agriculture

Authors
McManus, Alesia
Callahan, Beth
Glennie, Charlotte

Publication Date
2017

Research Support Services: Agriculture

University of California at Davis

Project Team: Beth Callahan, Alesia McManus, Charlotte Glennie

1-13-2017

Table of Contents

Executive Summary

In 2016, members of the University Library Research Support Services team conducted a scholar-oriented study of the research process and support needs of UC Davis's agricultural researchers. This report is intended for those in the University Library, the College of Agriculture and Environmental Sciences (CAES), and the wider academic community who are looking to provide the research support services that agricultural scholars need in order to conduct the most effective and impactful research. The goal of this report is to describe the research processes of agricultural scholars, assess the challenges they face, and identify the opportunities for research support services to help overcome these challenges.

The report is based on data collected from 12 interviews with agricultural researchers at UC Davis. The data were collected as part of a nationwide research project by Ithaka S+R, a not-for-profit service that conducts research to guide libraries, publishers and scholarly societies as they seek to improve research support services for the 21st century[1]. The 12 researchers were identified in a purposive sample designed to capture the diversity of agricultural research at UC Davis. The semi-structured interviews were analyzed using open coding and focused coding, a technique to uncover core themes that emerge from qualitative data.

Based on this research, five thematic areas which describe some key elements of agricultural research at UC Davis were identified.

1. **UC Davis supports a diverse, interdisciplinary research agenda pertaining to many aspects of agricultural production, distribution and consumption.** Researchers take up a variety of research topics, using cutting-edge methods of investigation and analysis both in the lab and in the field. Their research often contributes to the University's land grant mission with the help of UC Davis institutional supports such as the Cooperative Extension, the Agricultural Experiment Stations, the Genome Center, and other specialized centers on campus.
2. **Research data management emerged as a major element of the research process by CAES researchers.** Research data are created or obtained through a variety of sources, including observations, experiments, simulations and reference, as well as derived or compiled from secondary sources. Data are processed and stored primarily through digital means. Most researchers in our sample are confident in their use of relevant quantitative and qualitative analysis techniques, but less confident in digital data sharing practices such as repository submission. Some face difficulties in accessing or compiling multiple kinds of data, but uploading and sharing data were even greater challenges.

1 http://www.sr.ithaka.org/about/

3. **Researchers are engaged in scholarly communication with a local to global audience.** Researchers disseminate their findings in a range of academic publications, including open access publications, as well as non-academic venues when appropriate for reaching their research audience. They use multiple strategies to learn about the work of other scholars in their disciplines. Some researchers have concerns about academia's publication-heavy incentive structure, but remain confident that their own agricultural research is effective and important.
4. **Collaboration plays an important role in fulfilling ambitious research goals.** The value and impacts of agricultural research were often described in terms that align with the core priorities of CAES's Academic and Strategic Plan: sustainable agriculture and food systems; equitable, healthy communities; meeting the challenges of climate change; and ecosystem viability and functionality. Most researchers described working to solve global problems through collaboration, and emphasized the importance of finding expertise in related methods and fields of research to form strong collaborations.
5. **Researchers described challenges specific to agricultural research at UC Davis, as well as challenges facing scholars across disciplines.** The major challenges to agricultural research include the difficulties of growing biological systems and working with natural variability; gaining access to infrastructure; managing personnel; and obtaining adequate, consistent funding for research. The latter challenge was noted to be widespread in academia, but takes on a distinctive character for the discipline because of the funding sources available for agricultural research.

The report describes these five thematic areas in detail: a diverse, interdisciplinary research agenda; research data management; scholarly communication; aspects of collaboration at UC Davis; and research challenges. It concludes with implications of the findings for library services. Significant opportunities for the Library to address agricultural researchers' needs include supporting the research process and promoting collaboration, supporting research data management, and facilitating access to research.

Introduction

This research is part of a larger study by Ithaka S+R and sponsored by the United States Agricultural Information Network. The project seeks to explore the research practices associated with agriculture studies through interviews with agricultural scholars across the United States. Throughout the research process, we were guided by the questions "How do agricultural scholars at UC Davis do their research?" and "What research support services do the researchers use and/or need more of in order to best carry out their work?"

These questions are of particular importance to the University Library because agricultural research, teaching and outreach support the land grant mission of UC Davis. Cooperative Extension was formed in 1914 and is a partnership between the US Department of Agriculture and land grant institutions.

Cooperative Extension, which serves the role of application and outreach, is a "successful model for scientific discovery to be transferred to the end user is through the continuum between campus-based faculty and cooperative extension specialists"[2]. A number of cooperative extension specialists are researchers within the CAES.

Another component of the land grant university is the Agricultural Experiment Station. The mission of the Agricultural Experiment Station (AES) at the University of California, Davis is to "conduct research that encompasses the continuum of fundamental and applied research for the purpose of developing new knowledge and technologies that address specific problems of importance to the people of California. Key to this mission is a broad range of research focused on the discovery of solutions and the development of educational programs that disseminate knowledge and technology to an identified clientele. The AES mission focuses on agricultural, environmental and societal issues that are impacted by, or impact upon, the management of agricultural and natural resource systems"[3].

Study Methodology

The data come from 12 interviews with agricultural researchers at UC Davis. To obtain our sample, we first identified 107 research staff and faculty whose work was described on their individual or departmental websites as agriculture related. The pool of 107 research staff and faculty included researchers from 18 departments: the 15 current departments in the College of Agriculture and Environmental Science[4], as well as the departments of Civil and Environmental Engineering, Chicano/a Studies, and Native American Studies, and an interdisciplinary center on campus housed in the UC College of Agriculture and Natural Resources. We also consulted a panel of subject librarians who work with UC Davis agricultural scholars to ensure our sample reflected the diversity of types of agricultural research at UC Davis. From the list of 107 researchers, we sent invitations to 43 researchers representing 16 of the departments, all position types and career stages. This was a purposive sample designed to capture the range of agricultural research at UC Davis and to represent the University's notable research areas, such as viticulture and enology, ecology, genomics, and plant microbiology. From the initial sample of 43 researchers, we received 13 positive responses and were able to schedule 12 interviews within the study's time frame. The final sample of 12 included 5 tenured faculty, 3 pre-tenured faculty, 2 research staff and 2 Cooperative Extension specialists, representing 10 different departments.

---

2 http://www.caes.ucdavis.edu/outreach/ce

3 http://www.caes.ucdavis.edu/research/aes

4 The 15 current departments of the College of Agriculture and Environmental Science are: Agricultural and Resource Economics; Animal Science; Biological and Agricultural Engineering; Entomology and Nematology; Environmental Science and Policy; Environmental Toxicology; Food Science and Technology; Human Ecology; Land, Air and Water Resources; Nutrition; Plant Pathology; Plant Sciences; Textiles and Clothing; Viticulture and Enology; Wildlife, Fish and Conservation Biology

The interviews were conducted in researchers' offices. The session length varied from 21 minutes to 1 hour and 25 minutes, with an average length of 48:15; all were recorded with permission from the interviewee. The interviewers used a semi-structured interview protocol, wherein 11 questions served as an outline for the interviews[5]. Additional questions were asked to probe for greater detail or clarify researchers' responses.

Interview recordings were transcribed and anonymized to remove names and identifying information. The research team analyzed the interviews using a system of open coding and focused coding. First, all transcripts were coded to identify important topics and themes that emerged within the interviews. Using the code lists developed through open coding, the research team organized a focused code list and re-coded all 12 interviews to standardize the results. We identified five themes as integral to agricultural research at UC Davis: a diverse, interdisciplinary research agenda; research data management; scholarly communication; aspects of collaboration at UC Davis; and research challenges. We then clustered the codes according to these thematic areas. Using the qualitative analysis software Dedoose, we analyzed the code clusters to develop our findings.

Our report also includes a discussion of the implications of our findings for library services. Researchers described several important types of challenges that the library's research support services may be able to address, and these opportunities are considered in the conclusion.

Our findings should not be interpreted as a generalization about all agricultural researchers at UC Davis. It is to be noted that the methodology has important limitations: the sample is purposive rather than random, and offers a relatively small N, characteristics which preclude any conclusions about statistical significance. Instead, the findings are intended to offer guidance to the reader by providing an increased understanding of the challenges that agricultural researchers at UC Davis face that may inform improvements to support and services for agricultural researchers. While not suited to statistical generalization, qualitative methods such as interviews offer more detailed information about how people understand their work, social groups, and societal context. This type of information is more useful for the purposes of our research than statistical conclusions would be.

Findings

1. A Diverse, Interdisciplinary Research Agenda at UC Davis

The UC Davis College of Agriculture and Environmental Sciences (CAES) is a global leader that "produces a better world, healthier lives, and an improved standard of living for everyone by addressing critical issues related to agriculture, food systems, the environment and human and social

5 The interview protocol is included as an appendix to this report.

sciences"[6] through research, education, and outreach. UC Davis is ranked the #1 university in the world for teaching and research in agriculture and forestry[7].

Agricultural research at UC Davis covers many disciplines and research topics. The scholars interviewed for this study research environmental toxicology, genomics, bioinformatics, plant physiology, plant virology, plant interactions with microbes and insects, community ecology, food science, local and regional food systems, nutrition, soil science, agronomy, horticulture, animal science, enology and viticulture, and agricultural economics.

Agriculture research integrates multiple fields of study. In the field of environmental toxicology, researchers look at the effects of toxins on humans, food crops, and the environment. One interviewee studies the effects of pesticides in the food supply. The research has implications for environmental health and public health particularly for medical diseases such as cancer and is of interest to both producers and consumers of agricultural products. Another looks at biological components of natural plants particularly in commodity crops to study food function.

The plant scientists in our study look at better ways to grow crops. For example, one scientist studies crop uptake of carbon dioxide, which impacts crop yield and water use, and another assesses the potential for environmentally sound management practices to decrease the impact of diseases on crop production. Another research approach is community ecology, wherein interactions between plants, microbes and insects are studied to examine soil microbial communities' impact on plant defense and pest insects. At UC Davis, plant sciences and plant biology are two distinct departments in two different colleges. CAES has a Department of Plant Sciences which encompasses research from "lab to field, to forest, rangeland, and beyond"[8] that strives to meet global agricultural, ecological and environmental needs. The College of Biological Sciences (CBS) has a Department of Plant Biology that studies plants as organisms including plant molecular and cellular biology, plant physiology and biophysics, and plant structural and developmental biology. Our study included two researchers from the CAES Department of Plant Sciences.

Animal scientists study both domestic and wild animals in their respective environments. The animal scientist in our sample studies livestock nutrition and greenhouse gas emissions by livestock, thus contributing to research on sustainable animal agriculture.

Agriculture also encompasses food systems research, food science and nutrition. A nutrition researcher described how the discipline benefits agriculture in two ways:

> "Number one: it allows nutrition and public health policymakers to be more informed when making food and diet recommendations, which is the responsibility of the US Department of

---

6 http://www.caes.ucdavis.edu/

7 http://www.caes.ucdavis.edu/about/files/Collegebrochure2014.pdf

8 http://www.plantsciences.ucdavis.edu/plantsciences/

> Agriculture and the National Academy of Sciences. And number two: we primarily study California agricultural crops, such as walnuts, strawberries, dried plums, grapes, and other phytochemicals or plant compounds. And if our data shows favorable effects, it may influence consumer preference and thereby drive California agriculture."

Another researcher who studies community preferences for food systems discussed the implications of food systems research for agriculture:

> "We [the Cooperative Extension] had a competitive grants program, we funded a lot of what has become in some places now food policy councils, but have gone by different kinds of names over time. And so there were groups out there in communities around California, and they're interested in moving the food system in a different direction from the big Ag monoculture industrial Ag direction, kind of broadly."

One researcher in our study is working at the intersection of the environment and agriculture to coordinate projects that bring experts together from different disciplines to study "big, gnarly issues." Another specializes in agricultural economy, a field that researches the "production, distribution, and consumption of food, fiber and energy"[9].

Study participants identified trends that may impact future directions of research in agriculture. One of these trends is genomics or the study of genomes for crops, animals, and microorganisms. A second trend is functional foods, which are foods that may have a positive effect on health naturally or may be modified to produce health benefits[10]. A third trend is the study of the human microbiome, which is the study of "microbial communities that live in and on our bodies and the roles they play in human health and disease"[11].

Agricultural research is interdisciplinary

Several of the study respondents discussed the interdisciplinary nature of agricultural research. This is reflected in the most recent Academic and Strategic Plan (2015) of CAES, "Meeting the Challenges of 21st Century Global Change"[12]. The College identified four core priority themes for "growth and integration with the college" which are further described as "critical transdisciplinary issues":

- Sustainable Agriculture and Food Systems
- Equitable, Healthy Communities

---

9 http://www.caes.ucdavis.edu/research/dept/are

10http://www.mayoclinic.org/healthy-lifestyle/nutrition-and-healthy-eating/expert-answers/functional-foods/faq-20057816

11 https://commonfund.nih.gov/hmp/index

12 http://www.caes.ucdavis.edu/about/academics/plan/files-1/ASPReport_Final_21916.pdf

- Ecosystem Viability and Functionality
- Meeting the Challenges of Climate Change

One objective of the College is to “articulate a coordinated crosscutting structure” to “promote interdepartmental/interdisciplinary connections.” The core themes noted above also emerged in the agricultural scholars’ responses regarding collaboration and research challenges, which will be discussed in upcoming sections of the report findings.

Here is what the researchers said about the interdisciplinary aspect of their work:

> “We use microbial ecology, chemical ecology, plant science… it’s very interdisciplinary.”
>
> “My research is very interdisciplinary, especially the human pathogens of plant part. This has a major implication in human health.”
>
> “My focus is on anything having to do with agriculture and the environment. So, it encompasses a whole lot of different disciplines, actually… It’s all just a mixture of sort of economics, and engineering techniques, we do life cycle assessment methodology, which comes more from an engineering realm; social science and soil science and agronomy and horticulture.”
>
> “We use a lot of current mathematical and statistical methodologies to describe and to represent the system in general. So, it is a more interdisciplinary between mathematical fields, agricultural fields, and I guess environmental fields as well.”
>
> “I’m just amazed with the breadth and diversity of work going on, how much interdisciplinary work is going on, and then that’s not even getting into Plant Sciences and the other Ag and environmental departments in the college…our enterprise is a very diverse one, and agriculture in a way is almost a limiting word.”

The research process

Agricultural researchers at UC Davis study a variety of plant and animal species including humans. Scientists draw on both lab and field methods, often in combination, to study agricultural systems from the molecular level to the ecosystem level. Molecular level research focuses on the study of genomes and genetics, or chemical compounds such as natural antioxidants, floral nectars, and scent compounds. Crop research pertains to commodity crops such as coffee beans, legumes, grapes, almonds, wheat, blueberries, strawberries, pistachios, sweet potatoes, roses and fruit and nut trees. Some research is done at the level of the community or system such as food systems research, community ecology research, and plant-microbial and plant-microbial-insect interactions. The microorganisms studied include both beneficial and pathogenic bacterial species as well as viruses.

Much of the research involves lab and field experiments, and often, the researcher performs both. This may reflect the applied nature of agriculture, in which lab research results are validated by field studies and explanations for field observations may be further studied and tested in the lab. One researcher described it this way:

> "I like the combined approach of using these field surveys plus the more manipulative studies in the lab. And so I think that even if the studies aren't, don't exactly mimic what's in the field, we're testing process, and seeing what the outcomes might be given a certain set of conditions, even if those aren't what we see in the field. And so I think they inform each other, even if neither one is perfect."

Another researcher observed:

> "There are hundreds of thousands of people working on the water use of plants from either a physiological or molecular biological point of view. And I guarantee that none of those will have an impact on agriculture unless they do work in the field."

A third researcher talks about diverse techniques used in doing both field and lab research:

> "We use field surveys, and when we do that, we go out into the field, we collect samples, we do observations, we often bring samples back to the laboratory, and we process them in any number of ways. So, we look at the chemical content of many of the types of samples that we bring back. We also look at the microbial community composition. So, we extract DNA sequence of the full community and basically look, describe that community using sequence data."

Research methods and techniques

Agricultural researchers use a variety of research methods and techniques depending on what they are studying, and we found this to be true for the researchers in our study. Laboratory research utilizes quantitative techniques, *in vivo* experiments (plant or animal), microscopy, chromatography, and molecular biology/omics techniques.

> "I do a lot of cloning, plant transformation, bacterial transformation… we do genetic complementation assays, pathogenesis assays…. And for the '-omics' part we've done several transcriptome analyses, like to identify differentially expressed genes. I've sequenced part of the genomes where we want to know the genetic structure or the genome content of the site that I want to focus on."

> "The lab as a whole we use a lot of molecular biology and biochemistry, and next-generation approaches like the '-omics' kind of approach. We use genetic techniques like mutant analysis. We do physiological measurements on the plants. We use a lot of microbial genetics as well because you want to understand how the pathogen survives on the plant, so we need to know about their genetics and their physiology and basically behavior. We do a lot of microscopy."

One researcher studies nutrition through human feeding trials, and another focuses on qualitative research with human subjects using techniques ranging from surveys, focus groups, interviews, evaluation, participant observation, and comparison studies. The researcher using a community ecology approach incorporates life cycle assessment, some qualitative research, and is “synthesizing existing research from a wide range of different bodies of literature”.

We found that researchers often design new experimental techniques and methods as well as equipment. In our study, researchers described developing diagnostic molecular probes, designing new methods for quantifying livestock emissions, and even building unique machines to take sophisticated measurements.

> “I find that almost entirely the things I want to do, the questions I want to answer, can’t be answered with machines I can buy, so to some extent a lot of the work I do is building machines.”

Agricultural research supports the UC Davis land grant mission

The land grant mission translates to research that is both relevant to basic scientific research and often applied in the service of the needs of producers, consumers and the general public. A plant physiologist comments on studying the physiological rather than the farm level:

> “that fits nicely within any other part of academia, I mean it could also be biological sciences except I do it on agricultural plants … and I think one key thing would be to say that I almost entirely work in the field because it’s appropriate to do that for agriculture. So, my research is quite field directed… but it’s very much basic research with a view to application”.

Another researcher provides this description of the relationship between applied and basic research in their work:

> “I am trying to solve the problem, if disease is a problem, trying to make the plants resistant to the disease. We try to make chemical treatments more effective against the disease. This is from my practical point of view. From my fundamental biology question point of view, I am interested in understanding how organisms from different kingdoms communicate with each other. So, plants, microorganisms, and how did two parties evolve closely to each other.”

This researcher has a dual role in performing both academic and non-academic research:

> “The unit is commercial, but my position is kind of unique too. Part of my responsibility is to provide service to this unit… And that service is to monitor the health status of the plants here, to make sure if a plant, we produce a healthy plant, that will stay healthy in our collection, so that in years we can provide the growers with healthy material. And also, the other function that I have here is to develop new molecular methodologies for the detection of viruses.”

Research Support on Campus

Researchers described campus research support in favorable terms.

> "I feel like I can do anything that I'm able to, because of the environment, because I'm at a very good university; I think that that's very conducive for high-quality research. So my projects really depend on my ability to come up with good projects."

> "I think UC Davis is a great place to be a scholar. And that's the environment. In my discipline, we have, some of my colleagues like to say we're one of the top 3 programs in the world. I think we're the top program in the world. And so just the standard of what's normal is really great."

During the interviews, several aspects of research support were discussed in more detail including access to specialized research centers on campus such as the Genome Center, which was mentioned most frequently as a center on campus that was for important for agricultural research. Researchers described making use of the Genome Center's core facilities, particularly DNA technologies, bioinformatics and metabolomics, for sequencing services, and for management and analysis of large data sets. One respondent suggested that "it would be great for the library to be thinking about working with the Genome Center because it interfaces with them [the library]" in the area of research data management. The library could support compliance by promoting awareness of data sharing and access policy of key funding agencies and helping to organize the data (e.g. basic headers needed).

Library services, such as interlibrary loan, remote access and help with citation alerts, were also mentioned as important in supporting access to the research literature. Further details are in the section of the report on implications for library services.

2. Research Data Management

Research data management (RDM) emerged as a major element of the research process by CAES researchers. Research data is "data that are collected, observed, or created, for purposes of analysis to produce original research results"[13]. In this section of the report, we'll discuss data sources, storage, analysis and sharing as well as some of the data management challenges described by researchers. These findings are relevant to services provided by the UC Davis Library Data and Digital Scholarship department[14], which helps with the design of sustainable data storage strategies, the analysis and visualization of data, and the management and organization of data in the planning, collection, description, discovery, dissemination and preservation stages of the data lifecycle. Well-managed data is more discoverable, available, and re-usable, so it is no surprise that data management emerged as a core theme and also a source of opportunity for library support services.

Generating data

According to the UK Archive model, in the first phase of the research data lifecycle[15], researchers locate relevant existing data, and/or collect and capture it. Research data can be observational,

---

13 http://www.bu.edu/datamanagement/background/whatisdata/

14 https://www.library.ucdavis.edu/dept/digitalscholarship/

experimental, simulated, derived or compiled, as well as reference data; our researchers generate and use all of these types of data. Observational data are data collected in real-time, including data from interviews and focus groups, sample data, and environmental and meteorological data from the field. The qualitative researchers gather data from interviews, focus groups, collected documents, and secondary data about regions, organizations, or industries. Experimental data are collected from laboratories or the field. Examples of experimental data include physiological measurements, chemical activity, chemical composition data, sequence data, and environmental data.

A researcher who collects both observational and experimental data describes the work in the following way:

> "We use field surveys, and when we do that we go out into the field, we collect samples, we do observations, we often bring samples back to the laboratory, and we process them in any number of ways…we do lots of experiments in the lab, where we either compete microbes against each other, or we look at their effects on different media types – so how did they change these media? We look at effects of microbes on insect pests or pollinators."

Simulated data comes from test models, and researchers do biophysical, environmental and economic modeling. For example, within the California wine industry, there are seventeen crush districts that process harvested grapes. The state reports the amount of grapes crushed by the ton and one of the researchers models this data:

> "They get the price of that ton, and they measure the sugar content of the grapes, and they measure other chemical properties at the time of crushing. And so these data are available at the level of the individual lot, or aggregated up to annual totals for individual varieties, of which there are many. So really it's very detailed data on production that we can use to build out models from there, looking at the effects of particular pest problems, or new varieties, or things like that."

Many of our researchers reuse published and curated datasets. Some examples are human epidemiology data, NCBI GenBank, soil maps, survey data (Census, American Community Survey, Nutrition and Health Examination survey), proprietary data (e.g. Guidestar), and collaborator datasets (such as records from the local Russell Ranch Agricultural Experiment Station).

All of these data come in varying sizes and different formats, which necessitates considerations for organizing the data. The epidemiology data, for example, "is usually coming … as a de-identified matrix that's about 3,000 by a couple hundred," while the sequence data can be "something like 3 million by some smaller number." Several respondents describe working with one or more data formats within the same study. One mentions "We have quantitative, qualitative data; we have live imaging that we need to analyze, like micrographs." Another respondent generates sequence data, uses spreadsheets for recording field observations, and collects chromatography data from field

15 http://www.data-archive.ac.uk/create-manage/life-cycle

samples to obtain “concentration data or the amount of a chemical in a sample.” Another researcher has interview data, field observations, and secondary community-level data.

Processing data

Once the data are generated and captured, researchers process the data. Processing data can encompass any or all of the steps involved with entering data and recording data. These include checking, validating, and cleaning the data; anonymizing the data; describing the data; and managing and storing the data.

One researcher was initially concerned with having server space to be able to safely file share, but as the research evolved, opted to use the fee-for-service data hosting and processing provided by the campus Genome Center.

> “You know they have servers with processing, and so I just kind of buy it with the whole package, and so that way the data gets dumped out there, I pay someone to process and align it to a genome, and do a number of these things that I feel are trivial for someone who does them routinely but would cost me a lot of time to pay a graduate student to learn how to do that.”

Similar to the need for assistance in processing quantitative data, qualitative researchers may encounter challenges integrating and processing data. One researcher in our study, who does primarily qualitative research in which interviews are transcribed, now has a “database of over 2,000 interviews with local people all over California.”

Two of the researchers in our study discussed checking, validating and cleaning data. The first researcher has a server where data is stored and analyzed by the graduate students and staff research associates in the lab group. They have to examine the data because “it’s not 100% accurate all the time. And that has to do with just the integrity of collecting the data on the machines. The operator may have an error… So before we can just automatically put it into our data set, we have to screen and filter it.” The second researcher generates data on the “abundance of things like RNA, DNA, proteins like hormones, lipids, all sorts of things like this, and so these can often have nuisance data structure shapes that you have to reshape to do real analysis with.”

This researcher discussed in detail how the data is prepared for storage and analysis including description of the data.

> “I just got back a data set from the Genome Center…So we take that, back up a copy of the raw data, then we also use different scripts and packages that people have put together, and compile those bioinformatics scripts and save that, and then we have basically final data files where we cluster the raw sequences – we basically trim them, cluster them into similar sequences, and assign an identity to them. So we have both the raw data, and then the processed data, and then the metadata. So it turns out there are a lot of different data types.”

Many of the researchers described how they store their data for processing and analysis including the use of spreadsheets, databases, paid hosting, and lab-based servers. One researcher keeps paper copies of collected documents referred to as a "super document…I actually made a copy of everything, and I keep this in the bag," reflecting an analog method of storage.

As mentioned earlier, processing data has many aspects such as checking, validating, and cleaning the data; anonymizing the data; describing the data; and managing and storing the data. Processing data can be complicated and labor-intensive, so researchers appreciate data processing services that save them time and expand their capacity for analysis.

Analyzing data

In this phase of the research data management lifecycle, researchers interpret and make inferences about the processed data for their research outputs. This section gives examples of data analysis from a variety of research projects to illustrate how agricultural researchers currently analyze their data.

One researcher describes using representative samples of environmental data to estimate agricultural inputs and pollutant emissions statewide. In another example, the agricultural economist talked about the growing importance of econometrics, the statistical analysis of economic data, in which it's important to standardize units and methods so the data can be compared other data.

Sometimes researchers are working with large data sets. An almond research project uses as many as two hundred sensors per tree with measurements being taken every five seconds. "Multiply that out, it's gigabytes worth of data, but we then analyze it down to much smaller data sets. So the output, the final product is much simpler than that huge [data set]."

After completing a series of qualitative research projects, a researcher recognized a new "class of stories" apparent in some interviews, which the researcher called "workaround stories." The researcher has begun to analyze those stories with regards to the implications for public policy:

> "To kind of think about what they [workaround stories] tell us about the policy process, how they might be used to backward map up to public policy or regulatory mechanisms to change what they're having to work around down here, so that they don't have to work around it….or just to recognize that workarounds are in some sense inevitable in a system….and so workarounds are part of the craft of public administration – knowing when to do it, when not to do it, what's, what would be a legitimate workaround vs. what's just breaking the rules to gain some advantage."

Both quantitative software (e.g. SPSS) and qualitative software are used in data analysis. One researcher notes that "while it takes ten minutes for my computer to run the biggest math that I do, there's no program out there that runs the analysis for me. So I have to write a program to calculate all these things. And, it takes me months to figure out the program." Another researcher, who compiled the database of over 2,000 interviews, uses qualitative analysis software "depending on the scope or the scale of the project" and also shared some thoughts about analyzing the corpus of transcripts.

> "The one interesting conversation I've had of the sort of big data variety has been about the fact that we've got these 2,000 interviews, and what if that was all, really was one big database? I mean those are, it's a compilation of 8 or 9 different studies over time. And if you treat it as one big thing, and you had these more sophisticated linguistic-oriented data search capacities through the data or whatever, what could you learn?"

Knowledge of bioinformatics is needed for the analysis of genomic data. One researcher who uses the UC Davis Genome Center utilizes the center's a fee-for-service bioinformatics service to clean up their data and for preliminary analysis. Two researchers mentioned using data retrieved from the National Center for Biotechnology Information (NCBI) GenBank database to supplement their collected data for analysis. For example, one project on a species of berries lacked data on other similar species. So the researcher "went to NCBI and got the data that were there from other studies and did the meta-analysis to confirm or at least to validate what was the observation of our system."

Sharing data

Data management and sharing have become prevalent in science as funding agencies and journal publications have implemented requirements to do so. The amount of digital data has grown rapidly, to the benefit of research, but the data are easily corruptible if not managed well. Data sharing also promotes the ability to reproduce and confirm research results which protects the integrity of scientific research. One means of sharing and protecting data is to upload or deposit data to a publicly accessible data repository (e.g. NCBI GenBank and Dryad) to ensure the data remains available and discoverable[16].

All study respondents were asked if they had deposited data or final research products in a repository and, if so, which ones and why; and, if not, why not (see Figure 1). We found generally that while most of the researchers are sharing their data, they have a limited understanding of data sharing practices. Within the sample, we determined that seven researchers had a limited understanding of how repositories worked and/or did not use them.

Of the researchers that have shared their data via a repository, NCBI's GenBank was cited most frequently. Other repositories mentioned were Dryad, clinicaltrials.gov, and NASC, an *Arabidopsis* stock center[17].

---

16 Briney, Kristin (2015). Data Management for Researchers: Organize, maintain and share your data for research success. Retrieved from http://www.eblib.com

17 http://arabidopsis.info/InfoPages?template=about_nasc;web_section=germplasm

One researcher who deposits their data when required does not think making the raw data available publicly is useful because:

> "If it's really raw data, it doesn't make sense to have it publicly available…And if you really process them, it's going to be publication data that everybody could have access to."

Two researchers used university-based websites to expose their data. Another researcher shares data internally within a group of international collaborators but the project team itself does not share these data publicly. The project's funders and also the project's publication outlets do not have data sharing requirement at this time.

Of the seven researchers who said they shared data, all mentioned they do so because it is either required by the grant funder or because it is required for publication. Two of these researchers also emphasized that sharing data is beneficial for the scientific community.

> "Data sharing in genomics is key for the success of the entire community. I tried to do that, to submit data early on to a public database."

Another researcher shares data when required for publication but expressed interest in making data from a specialized center on campus available:

> "I'm at the __________________, and have been working for a year or two to organize some data on ____ and make it available. And it's been a long project, but that's just as a service."

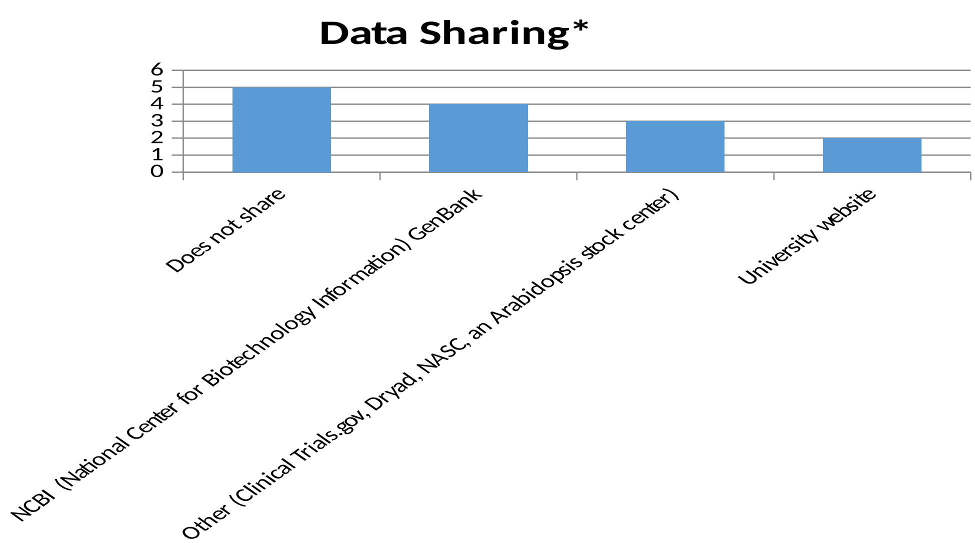

Figure 1: Data Sharing * Note: Two researchers in our study share data both through NCBI and one other repository. For this reason the total represented in this table is greater than 12.

Data management challenges

The researchers identified several obstacles to accessing, using and sharing their data including:

1. Readily available sources of data

> "I think in terms of getting access to some of the community-level data, that's a challenge sometimes, of getting data that's up to date and all, a lot of that just has to do with how frequently it's collected and distributed. And so there's a time-lag with all of that. But you'd think as automatic as a lot of that data is, that somebody could go somewhere and, have a menu: 'here's what I want to know' and push the button, and spits it [the community level data] out. I don't know that anything quite like that exists."

> "'I've found that talking to people who have experience at these sites can be more helpful, especially to access unpublished data or data sets that you can't access online."

2. Compiling and analyzing many different kinds of data

> "There's challenges about just the compiling of the different kinds of data....We're going to have a mass of different kinds of data. How do you compile that, store that, and then analyze that? It becomes a challenge of data management."

> "This whole big data thing now and that is a whole new area of figuring out... I think the challenge is setting up the information processing infrastructure, all the software mechanisms for dealing with all the data coming in and then actually getting something useful out of it."

3. Following compliance guidelines and procedures for uploading data

One researcher finds it difficult to understand the compliance language:

> "When I read about the requirements from the NIH and from journals about depositing my data, I don't really understand the compliance language and, it can vary per ...Elsevier versus some other publishing house, and per funder...I have a problem with figuring out the compliance, and it's a huge waste of intellectual resource to not centralize that."

Another researcher who uses the UC Davis Health System Clinical and Translational Science Center (CTSC) described the process as a "hassle" because a form is required to get the campus ID number. The researcher said "All I want is the campus ID number to post my new study on clinicaltrials.gov".

4. Anonymizing data

Two researchers expressed concerns about how to share data but keep identities confidential if needed.

> "Being a public institution we should be very in favor of the open-access thing for all our data. But, as you know, there's the whole IRB aspect to that. And insofar as we're collecting data from specific farms or specific processing operations, we can't put that out there."

In order to better serve agricultural researchers, it will be important for the UC Davis Library to learn more about these challenges and address these barriers since researchers are generally in favor of sharing data.

3. Scholarly Communication

Dissemination of Research Results

This section focuses on final research results disseminated primarily through journal publication, conference presentations, as well as other means of distribution depending on the research audience. Dissemination and sharing of research data, including use of repositories, was discussed in the Research Data Management section.

Dissemination of research products via traditional scholarly communication channels

Disciplinary and interdisciplinary journals continue to be the primary means of publishing research results. The researchers in our study described publishing in a wide range of fields including toxicology, public health, endocrinology, genetics, cancer research, plant physiology, public administration, plant pathology, virology, animal science, nutrition, phytochemical, ecology, and agricultural economics. They mentioned a number of disciplinary *focused* journals by title: *Plant*, *Cell and Environment*, I*nternational Journal of Plant and Environment*, *Crop Science*, *Journal of Agricultural and Food Chemistry*, *Plant Physiology*, *Phytopathology*, *Community Development*, *Agriculture and Human Values*, *Journal of Agriculture*, *Food Systems*, *and Community Development*, *Journal of General Virology*, *Proceedings of the National Academy of Sciences (PNAS)*, *Agroforestry Systems*, *Renewable Agriculture and Food Systems*, *Journal of Dairy Science*, *Journal of Animal Science*, *Animal: the international journal of animal biosciences*, *Global Change Biology*, and *American Journal of Agricultural Economics*.

Societies play an important role in disseminating research and many the journals mentioned are society and association journals [See Table 1].

Table 1 Association and Society Journals by Title

Journal Title	**Society/Association Name**
Agriculture and Human Values	Agriculture, Food, and Human Values Society
American Journal of Agricultural	Agricultural and Applied Economics Association

Economics	
American Journal of Evaluation	American Evaluation Association
Animal	British Society of Animal Science
Community Development	Community Development Society
Crop Science	Crop Science Society of America
International Journal of Plant and Environment	International Society of Environmental Botanists
Journal of Agricultural and Food Chemistry	American Chemical Society
Journal of Animal Science	American Society of Animal Science
Journal of Dairy Science	American Dairy Science Association
Journal of General Virology	Microbiology Society
Nonprofit and Voluntary Sector Quarterly	ARNOVA: Association for Research on Nonprofit Organizations and Voluntary Action
Plant Physiology	American Society of Plant Biologists
Phytopathology and *Plant Disease*	American Phytopathology Society

Other types of journals that the researchers published in include nonprofit journals and methodological journals. Three examples are *Nonprofit and Voluntary Sector Quarterly* from ARNOVA, *American Journal of Evaluation*, and *Journal of Biological Methods* (an open access journal).

Researchers select which journals to publish in based on a variety of factors including scope of the journal, editor of the journal, impact factor, journal quality, whether or not it is a society journal, audience for the journal, and desired research impact. One researcher said "I work so hard on making sure that my experimental work is relevant to the human health condition" because publishing in public health, a broader field than the researcher's disciplinary specialization, "elevates its impact."

In choosing which journals to publish in, interviewees also mentioned "whether the research fits in that journal" and "whether the editor is the perfect person to review this subject." Another researcher referred to the "mission to produce knowledge," and said that because they focused on basic research and foundational products, they only publish in peer reviewed publications. Still another researcher does not look at the journal's impact factor "because it's very biased" and instead chooses journals based on editorial boards and outcomes of reviews. This researcher also mentioned publishing in the "well-respected" journals of the societies of which the researcher is a member. Since agricultural research is closely tied to the University's land grant mission, the audience for the research is an important determinant of where the research is published. One researcher talked about publishing research on issues relevant to growers, or commodity farmers:

> "Sometimes we do publish in the grower journals, like *California Agriculture*. Because if really, I have something that I want specifically the growers and the nurseries to know about, I go to some of those agricultural journals to have that audience. That audience usually does not go to scientific journals to look. And I have done many, many publications in *California Agriculture*, because I know it has a broader, non-technical type of audience."

One researcher discussed the disparity in impact factor for journals which publish basic research and those that publish agricultural or applied research. The example given was the *International Journal of Plant and Environment*, which has a much higher impact factor than *Crop Science*, "and yet *Crop Science* is probably one of the top journals in the agricultural field. How can it be 1.5 [impact factor] as a top journal? A respected journal?... impact factor is a bit silly in this context." A Cooperative Extension specialist commented, "I've never had the same pressure to think about top-tier journals" and has published research where it will "get read and used and influence people."

Three researchers mentioned that they made an effort to publish in open access publications, with one mentioning the caveat of "when I can afford it." Some society journals charge a flat fee for online publication but then the journal is also open access to you if you are a member of the society. One researcher posts research publications to a personal website and uploads articles to ResearchGate and academia.edu so they are more accessible, and because they have "heard that it can increase your citation rate." Another researcher is a fellow of a research center at another university, so the researcher's relevant publications are available on that university's website. A researcher observed that industry collaborators may also have a desire for research they participate in to be made widely available; one industry board gave the researcher money to publish in an open access journal.

Another interesting example is industry serving as a publisher or aggregator to maintain research on particular topic of interest to the industry. One of our respondents sent already published, peer-reviewed papers to the company funding the research since the company is “trying to put together this whole database on sustainability for the particular types of products and the crops that they depend on.” It’s wasn’t clear whether or not this database is available to the public.

Research results are also disseminated via monographs or books, and conferences proceedings. Monographs enable researchers to synthesize and consolidate knowledge in a particular research area. Four researchers mentioned having written a monograph or monograph chapters and one of them said that writing monograph chapters and editing monographs “gives you a chance to keep up with what’s going on.” Conferences play a key role in presenting research findings to interested and relevant peer communities with a discipline, and three researchers indicated that they present their research results at conferences.

Dissemination of research products via non-traditional communication channels

Beyond the traditional academic communication vehicles of journal articles, conference presentations and monographs, a variety of non-traditional research products can appeal to different audiences depending on the stakeholders’ interests—for example, farmers, funding agencies and policy makers. In our study, researchers described publishing research briefs, evaluation reports and legislative briefings, further demonstrating the land grant mission through outreach to relevant stakeholders. Some UC Davis researchers who are reaching out to stakeholders produce “less academic products” that are “synthesized reports that are more easily digestible without a lot of technical terminology that are often targeted for a specific audience, like the policymaker audience vs. the growers and the grower organizations.” These researchers try to be “rigorous about keeping things up to date as far as finding interesting ways to portray research findings, through graphics… and 2-page handouts… for non-academic partners, nonprofit organizations and grower organizations and policy people and state agency people.” One researcher who led a statewide assessment project said that “because it’s so big and kind of contentious, we’re going to do a legislative briefing. A UC person who sits in Sacramento to help do these kind of government relations things is helping us set up a particular one-hour panel session where it’s going to be just about the project and all the legislative aids come to that.”

Strategies for Keeping Up with Disciplinary Trends

The scientific method “is the principles and procedures for the systematic pursuit of knowledge”[18]. It is an ongoing process wherein hypotheses are tested by experiments and data are collected in a

18 https://www.merriam-webster.com/dictionary/scientific%20method

reproducible manner. The results of experiments are published so conclusions can be retested. Therefore, staying abreast of current trends and experimental results in one's scientific field of inquiry is vital to a researcher's success as scientist. One of our research questions (see Appendix) was "How do you keep up with trends in your field more broadly?" with the follow up question of "Does this method work well for you?" Respondents were able to clearly articulate how they keep up with trends by describing a variety of strategies or methods for doing so. Researchers also reflected on the value of keeping up with trends in their field as well as the ease or difficulty of keeping up.

Seven researchers expressed difficulties with keeping up with the literature and trends in their field(s); the difficulties mentioned include the timing, amount, and accessibility of information. For instance, one researcher mentioned the difficulty staying current with cutting-edge lab methods because the information is often out-of-date by the time it's published. However, because they need vetted analytical methods, the researcher has found that it's still better to rely on the published literature since those methods are reviewed. Another researcher discussed the challenges with keeping current in their discipline "because it's an exploding field and every week there is at least a dozen articles, some reviews, some primary literature, hitting my variables and keywords." This challenge was echoed by someone who characterized their strategies as "I basically do nothing other than scan a few titles every week". Other researchers talked about the challenge of keeping up in terms of the accessibility of the information. One researcher observed that:

> "There seems to be a lot of information that's passed down that's not necessarily in the literature. So as a new person in agriculture, it's sort of difficult to get some of that inherited knowledge. And so maybe that's a challenge for the field, sort of translating that into something that's more accessible."

Another researcher said something similar:

> "People will publish a lot of reports and white papers, and those aren't archived in the same way. And I feel like they're not quite as accessible, although maybe just through different routes, and there are ways that I don't look for literature."

These statements reflect the finding that agricultural information is often published in non-traditional ways to meet the needs of stakeholders outside of academia such as growers, consumers, federal and state agencies, and policy-makers.

Some researchers said that it was challenging knowing how to keep up, because of the breadth of research projects they may be working on or the interdisciplinary nature of their research. One researcher stated, "My problem now in this job is that it's so wide ranging that I'm having a really hard time…. I don't even know how to keep up with literature anymore or what that even means for my job. It's so many different fields."

While researchers reported some challenges keeping up with trends, they were able to employ successful strategies staying on top of the literature. These successful strategies, shown in Figure 2, include peer contact, screening, scanning or reading the literature, keyword and topical searches, cited reference searching, reading review articles, email alerts, conferences, and Twitter and are further described below.

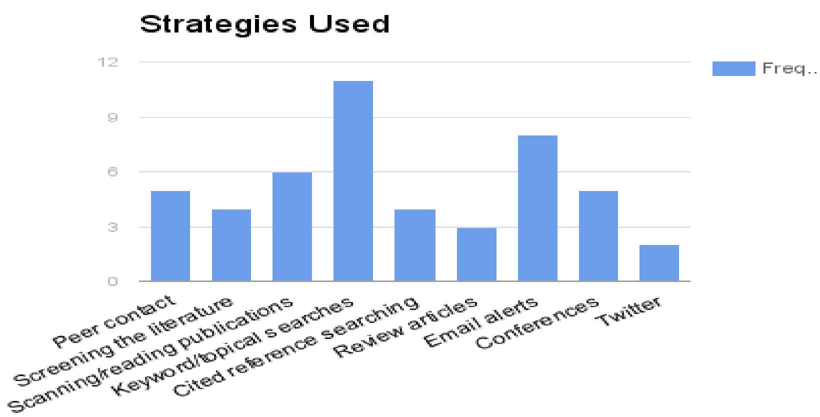

Figure 2: Successful strategies used to keep up with disciplinary trends

Crane (1972) describes a communication network of researchers or "invisible college" that "links groups of collaborators" enabling them to "monitor the rapidly changing research 'front'" and "to keep up with new findings"[19]. In our study, five researchers relied on peers or collaborators to identify relevant research. They referred to finding experts, relying on a network of colleagues, and talking to colleagues that have "a lot of experience in the field in this area." A related strategy is conference attendance. Seven researchers mentioned the value of going to conferences especially for learning about unpublished research.

Researchers primarily read professional and/or peer reviewed journals and newsletters. They also talked about screening, scanning and reading the literature, including reading the news to see implications of the research. A researcher that reads news sources (e.g. newspapers or popular periodicals) does so to "see the implications of my research, if it's useful." Another researcher mentioned reading newsletters, such as the one produced by the John Muir Institute of the Environment, which "often links to more …news articles about agriculture and environmental topics, but that leads me to thinking about topics I need to read about." Another said "sometimes I'll read something that leads me to a newsy article, but it may mention …'some researcher did this x y z work' and then I can look up that researcher online and see if they have anything on their website about this particular project."

19 Crane, D. (1972). *"Invisible colleges: diffusion of knowledge in scientific communities"*. Chicago, IL: University of Chicago Press.

Eleven of the researchers we interviewed discussed keyword and/or topic searching as a primary means of keeping up with the literature; this includes setting up regular keyword alerts. Alerts, a form of current awareness, are created by saving searches in databases and journal publications. Receiving citations via email was mentioned by eight of the respondents. They value the immediacy and ease of receiving the information "directly to the desktop." In addition to keyword or topic alerts, they also receive table of contents alerts from journals they read most. Each researcher determines the frequency and method of getting the alerts. Table 2 lists the databases used by our respondents most frequently for one-time searches or ongoing keyword alerts.

Table 2: Resources used most frequently for literature searches

Resource Name	**Number of time a resource was mentioned**
Web of Science*	5
Google Scholar	4
PubMed	3
NCBI databases (not including PubMed)	2
Agricola	1
CAB Abstracts	1
Scopus	1
Google	1
Wikipedia	1

*One respondent said they used ISI, which used to own Web of Science, so it was counted as a reference to Web of Science.

Sometimes researchers delegate literature searching to graduate students and other research staff, such as post-doctoral researchers, which is important to keep in mind in terms of library services for graduate students and research staff. These groups may benefit from outreach regarding strategies and approaches for effective searching.

Four researchers look at cited references as a strategy for keeping up with trends. One examines cited references in of Google Scholar and Web of Science, while the others use cited references in review articles and papers recommended by peers. One researcher said that they "look up what certain authors are citing, and do the forward and reverse searching....and look for review articles to see what they are citing." Another person said that typically they "take the most recent journal article that best reviews from the last year in that field, and start going back into the references and cites. And…slowly accumulate out of a hundred papers, ten papers that are really key."

Two researchers mentioned Twitter as a useful means to see what authors and journals were publishing. They found following journals on Twitter more useful than getting emailed the table of contents, because journals tweet each new paper as it's published. They also follow peers that they trust to see what papers they retweet. One of the researchers described this method of keeping up as "post-peer review ranking." Another said "I've been finding that more real-time information is more helpful so following people's Twitter feeds is a good way to keep up on what other people are looking at."

The Role of Publication in Peer Review and Promotion

As noted in the previous section, the publication of scientific research results is vital to the iterative nature of the scientific method. Researchers in our study frequently noted the centrality of publication to their professional success and career advancement. Eight respondents referred to the value of publishing work considered to be high enough quality for top-tier journals. Five respondents referred to the value of publishing a substantial number of articles. While the researchers in our study acknowledged this incentive structure is standard to academia, several pointed out tensions arising from the strong emphasis on article publication.

On tension occurs because agricultural journals tend to have lower impact factors than other disciplinary journals. Traditional journals are still the medium of choice for many researchers, and for respondents in our study, the emphasis on journal quality may present a challenge to achieving promotion and tenure. One researcher observed that agricultural journals tend to have lower impact factors (one measure of journal quality) overall compared to other journals. Therefore, the use of impact factor to assess an agricultural researcher's record of publication could potentially affect the outcome of the peer review process. This researcher noted that their department was subdivided such that agricultural researchers review each other's work:

> "If I'm not an agricultural person, they might be a bit more discerning about impact factor… but it kind of works anyway, because the agricultural people vote on the packages of the agricultural people."

It seems that because of this structure, agricultural researchers are not penalized for publishing in the standard journals for an agricultural audience, such as *Crop Science*, which are respected but do not have as high an impact factor as the primary journals for other disciplines.

Another tension arises for researchers when their target audience does not typically read academic journals. Four researchers in our study mentioned alternative publications, such as white papers, non-technical reports, and genome announcements, as more effective means of communicating some of their findings. One Extension Specialist described producing legislative briefings and white papers:

> "We really try very much to reach out to stakeholders and so we [sometimes] produce less academic products than some of our straight faculty colleagues do. So it's different: synthesized reports that are more easily digestible without a lot of technical terminology."

Three of the researchers in our study who target non-academic audiences have the title of Extension Specialist or Research Scientist. Two of them noted that academic publication is not given as much emphasis weight for researchers in their position as it is for faculty researchers, so they feel empowered to publish whatever types of research products are best suited to their audience.

These discussions suggest that UC Davis and its departments have largely organized the incentive structures for researchers in ways that live up to the Land Grant Mission. The best ways to publish agricultural research are often via lower-impact journals or non-academic publications, practices which deviate from what is standard to academia. Still, agricultural researchers in our study feel that proceeding with agricultural research, and publishing their findings in the ways most appropriate for their work, will not hinder their career advancement.

While most researchers did not describe being hindered in their own work because of the incentive structures relating to publication, they did note general drawbacks to the heavy emphasis on number of publications. Five researchers described problems with the high volume of publication occurring in their discipline, either because some of the work being published is of poor quality, or because the amount of new material being produced is unmanageable. In the words of one researcher,

> "It's a global phenomenon – people are pushed to do too many things… we're rewarded, I think, for the numbers of things we publish, in a way that encourages people to do more things … and not doing them as well."

As another researcher described the issue this way:

> "I think there's too much information; like people are publishing so much right now that it's really difficult to keep up with it, to be able to sort of follow it. And there's a lot of science that's not being vetted properly."

These researchers used methods, described in section on strategies for keeping up with disciplinary trends, to sift through the enormous volume of peer-reviewed literature and find the works that would be most valuable for informing their own contributions.

Other problems arising from the emphasis on publication relate to challenges of collaboration. One researcher described how large, cross-disciplinary collaborations can produce excellent research with broad implications, but this kind of work is more difficult to publish because it leads to authorship disputes:

> “That’s the kind of stuff that they publish in Nature Medicine, that they publish in like the really high big-name fancy ones… basically, if you chose to not do that, then more people get to be first author and more people get to be last author… so then you have to have a working relationship with people where they’re willing to step aside… and it’s not an easy thing and I’ve never pulled it off before, because there’s always at least one person who’s like, no I think I should be… and everyone else is like, well I’d rather not do it then because you don’t deserve this.”

Another researcher, whose work involves bringing scholars together on large, interdisciplinary review projects, observed that:

> ”Getting the attention of different people, even our own colleagues, is very difficult for that type of work, because it’s not like the original research that’s going to get their name big in the publishing world.”

This researcher explained that the challenge related to attracting experts can significantly lengthen the project timeline, and that their team had worked to motivate critical collaborators by producing smaller “off-takes of some of the pieces of analysis” that could be published as more traditional journal articles. For these researchers, the general trend toward producing as many publications as possible, in the best peer-reviewed journals possible, in some ways hinders the actual scholarly endeavor.

Open Access Publication

Overall, the researchers expressed a strong commitment to communicating their research findings broadly, to target audiences outside their home discipline or to the general public. Two researchers said that making their findings more widely available, via repositories or open access publication, has benefits for the research community as a whole and also for the publishing scholar.

> “It’s very expensive to publish in open access journals, but the visibility they have right now, when you search articles on Google, it’s fantastic… The journals are dying, because they just never come up in the searches.”

These two researchers, along with others, suggested that the traditional model for journal publication is becoming outdated. Publication in journals that are only accessible to paying subscribers will not fulfill all of the potential benefits that could be achieved through broader access. As one researcher stated,

> “I think that the reviewing process has challenges… having this information available to taxpayers or people that have paid for this research is really important. So some way of making it accessible while also allowing it to be organized in a reasonable system will be a challenge.”

In total, four researchers indicated they value open access publication and would like to publish their work through such channels. However, three reported that the expense of open access publication was often too high for them to afford. Two of the researchers described methods for reducing the cost or obtaining funding for open access research, but none of the researchers mentioned the UC Davis University Library’s Open Access Fund. By doing more to advertise its Open Access Fund, the Library may be able to better provide researchers with the funds needed to publish in open access publications—a needed service with benefits to individual researchers, the academic community and the wider public.

4. Aspects of Research Collaboration at UC Davis

Research Value and Impact

Every one of the researchers interviewed for this study articulated the value of their research in terms of broader social or environmental goals, though the interview protocol did not even include questions about research value. Interestingly, these descriptions fell into a set of categories similar to the CAES Academic and Strategic Plan, Meeting the Challenges of 21st Century Global Change[20]. In our analysis of the interviews, we identified research impacts related to "sustainability" (including greater efficiency in agriculture), "environmental impacts of agriculture," "policy analysis and implications," "public health implications," and "climate change." These categories that emerge from our study align with the four core priority themes articulated in the Academic and Strategic Plan: Sustainable Agriculture and Food Systems; Equitable, Healthy Communities; Meeting the Challenges of Climate Change; and Ecosystem Viability and Functionality. This would seem to confirm that CAES researchers are addressing the College's strategic priorities.

Sustainable Agriculture and Food Systems

The categories we developed relating to 'sustainability' and 'environmental impacts of agriculture' reflect efforts to study diseases, pathogens and pests that reduce crop yield, to find management practices that minimize pesticide use and other pollution, and to assess the effectiveness of policies designed to improve food systems or reduce pollution. These efforts align with the College's goal of promoting sustainable agriculture to "ensure secure, safe, high quality and healthful food for the world's population without negative social and environmental impacts."

Seven of the researchers described how their work related to sustainability and mitigating the environmental impacts of agriculture.

> "So the biggest challenge will be increased production with a minimum impact on the environment. And that's if everyone does a little part on that, we will continue improving. And that's why I like to use genetics… to improve crops, because that's environmentally sound."

In the words of a plant physiologist:

> "At the most broad level, we have to produce more food with less resources, or the same resources. It's a huge problem, and it's something I'm directly working towards."

Whether researchers study an entire ecosystem, a single agricultural species, or a specific biological mechanism, they are conscious of how their work contributes to the broad goal of sustainable agriculture and food systems. Researchers consider this goal to be very important, and work to produce knowledge that will improve agricultural production in a variety of ways.

20 http://www.caes.ucdavis.edu/about/academics/plan/files-1/ASPReport_Final_21916.pdf

Equitable, Healthy Communities

The categories developed relating to “policy analysis and implications” and “public health implications” reflect efforts to document the environmental and health impacts of agriculture, provide regulators and policymakers with information about aggregate effects and best practices, and study the health effects of particular plant compounds. These efforts address the College’s goal to “inform sustainable development, vibrant communities, and provide solutions for equitable access to food and nutrition at the individual, community, societal, and global scales.”

Seven researchers made explicit reference either to their work’s policy implications in the areas of equity and health, or to how their work relates to public health (such as relationships between pesticide exposure and health outcomes, or agricultural practices that reduce the prevalence of human pathogens). A researcher from the nutrition department explained their work this way:

> “It allows nutrition and public health policymakers to be more informed when making food and diet recommendations, which is the responsibility of the US Department of Agriculture and the National Academy of Sciences.”

A Cooperative Extension specialist described how a collaborative project in which they participated integrated a wide range of disciplines to meet this goal:

> “It’s supposed to be a very holistic approach… not just from the biophysical, but what about the health impacts, and what are the farming practices that could change the situation, what are the policies, the whole policy analysis.”

Overall, researchers expressed strong awareness of how their work related to human health, inequality, and agricultural policy making. Again, the researchers clearly value the goal of creating equitable, healthy communities and work to produce knowledge toward this goal.

Meeting the Challenges of Climate Change

The category developed relating to “climate change or drought” reflects the understanding of the effect that climate change is having on agriculture and agricultural research. Five researchers identified climate change as one of the major challenges that the discipline of agriculture will need to address, which fits with the College’s core theme that “the impacts of climate change on agriculture will significantly impact the world’s ability to feed itself.”

Highlighting the challenge that climate change poses to agricultural research specifically, one researcher noted,

> “I think that the challenge to Ag research in general will be the high variability in climate. I think that scientists need reproducibility, and it’s really hard to do fieldwork, and, if one season to the next is so highly variable because that’s the nature of our climate, how are they going to [achieve consistency]?”

Another researcher, who focuses on plant-microbe interactions, described the importance of their work in terms of climate change:

> "Changing climate can cause a shift in the environmental distributions of pathogens and introduction of exotic pests that would not adapt before and now they are."

In addition to pest management, the researchers interviewed study the effects of climate change on water systems and on crop quality. Thus climate change is both a challenge for experimental design for many projects, and a variable of study for some agricultural research.

Ecosystem Viability and Functionality

Less evident from our interviews was an emphasis on the College's core theme of Ecosystem Viability and Functionality, which focuses on "ecosystem services, such as provision of clean air and water, fisheries and forest products, carbon sequestration and climate regulation." This type of research is probably under-represented because our sample of researchers did not include researchers from the departments of Land, Air and Water Resources or Wildlife, Fish and Conservation Biology, which in addition to Environmental Sciences and Policy, have researchers who are likely to conduct research projects specifically aimed at improving ecological health.

However, two researchers in our sample did articulate the value of their research in terms of a holistic approach to healthier agro-ecological communities:

> "The research in my lab is focused on plant interaction with microbes… we try to understand how these interactions happen at the molecular level. So we study the plant responses to these microbes and how these bacteria are able to colonize the plants…. in the big picture of this research, we are trying to find better ways to grow our crops, and we want to have environmentally sound management to decrease the impact of diseases on crop production."

An entomologist describes their research this way:

> "The work we do here in the lab is focused on interactions between plants, microbial communities, and insects. We take a community ecology approach and look at basically interactions that involve three of those partners… so looking at for example the effects of soil microbial communities on plant defense, and pest insects."

While not explicitly framed in terms of ecological viability and functionality, this research builds understanding of the ecological systems involved in plant growth, which may be used to promote ecologically sound agricultural management practices.

Sharing Resources to Address Global Problems

Beyond articulating their research value in terms of broader social and environmental goals, three researchers highlighted the importance of collaboration for addressing these goals. The researchers see themselves as part of a larger global mission to tackle the world's pressing problems and to meet the College's goals.

> "The big challenges we face – climate change, inequality, even as a social challenge that is intricately part of thinking about food systems and agriculture – those challenges are going to take a very integrated, integral, holistic systems-thinking kinds of work"

Researchers described the value of broad international collaborations in order to understand things at the global level. Two researchers described their current international collaborations; one analyzes data provided by an international group of collaborators, and the other works with counterparts in other countries to synthesize their national-level analyses into a more complete picture:

> "People… are working in closely related areas, and you could actually come together and have a pool of people working on those areas with bigger data to address similar problems…So recently we put together a global network that is doing this kind of work, and that we are getting data from internationally, and using that data to develop models that are much more robust than the data we would have access to normally."

> "You can do an economic history of a particular place, but the comparative history is more informative, because these places are interacting with one another, or they have things in common, or things that are surprisingly different. So this is the thing of globalization, but the long history, there are multiple waves of globalization."

One Cooperative Extension specialist said that the effort to form cross-disciplinary collaborations to address larger problems is one of their most important responsibilities:

> "The role of our institute is to bring a lot of different disciplines to bear on these big, gnarly issues…I kind of sit at that midpoint where I know enough about a lot of different disciplines… so I know which experts in the academy to bring together on the teams that we create to work on these projects."

All of these researchers felt that their own work is more powerful, in terms of the significance of their conclusions, when they involve a diverse research team. Researchers feel they are better able to address the large problems confronting agriculture in the 21st century when they work in close collaboration with a larger research team or community.

Collaborators

Collaboration was a common theme across the interviews, with nine researchers describing some form of collaboration as important to their own work. Collaborators come from different organizations, such as UC Davis, other research institutions, or industry organizations, depending on what skills or assets the researcher is seeking from collaboration.

Researchers in our study sometimes formed collaborations by networking at conferences with other researchers in their field, either approaching other scholars with similar interests or being approached in turn:

> "The speaker may talk about a new project they have that hasn't been published, and you can get some clue [about] what they are doing. And if it's something that you're interested in, or you

> are doing too, you can communicate and say 'Hey I'm doing this same thing. Do you want to join or work together?'"

Industry collaborations were sometimes formed through networking as well. One researcher who has developed a professional network among regional industry groups described how they develop research questions:

> "It could be through networking, and people basically coming up and saying, 'look, you know, we are interested in doing this and this and that. Could we do a joint project, and to look at this?' and then we do that."

Our researchers are able to expand the scope of their projects by collaborating. Collaborators were valued for their expertise in specific subject areas or methodologies, or for their access to necessary tools, data sets, or social networks. Asked at the end of the interview if there was anything else relevant to agricultural research, one respondent said:

> "I would also emphasize the importance of collaborators, and their knowledge about certain systems, that can be really important."

Two researchers described the UC Cooperative Extension specialists as particularly valuable collaborators for outreach to target groups such as growers:

> "We have a number of our local Cooperative Extension advisers, who are actually already working with [the group we wanted to study]. And so we put a call to see among those, who would be interested in being part of a study. And so then we had some willing volunteers who could be the people who would help us identify key informants in the community."

Many of the researchers in our study considered collaboration to be an important element of their research process, from the point of developing a research question to the collection and analysis of data. Collaboration facilitates larger and more sophisticated studies, helping advance UC Davis agricultural research toward the goals of the CAES Strategic Plan.

Finding Expertise

Freeman et. al. (2014)[21] found that one of the main reasons for collaboration is to "combine the specialized knowledge and skills" of collaborators. Four of the researchers in our study noted that finding the right people to consult or with which to collaborate can be a challenge. Two of these researchers described the Cooperative Extension network and Agricultural Experiment Station as particularly helpful resources for finding relevant expertise. The University of California of Agriculture and Natural Resources (ANR), which is the University of California system's home of the statewide Cooperative Extension service and the Agricultural Experiment Station, has a directory which is

21 Freeman, R, Ganguli, I, & Murciano-Goroff, R. (2014) Why and wherefore of increased scientific collaboration. In A. Jaffe & B. Jones (Eds.), The Changing frontier: rethinking scientific innovation and policy (pp. 17-48). Chicago, IL; University of Chicago Press.

searchable by commodity; one of the researchers often finds "the right colleagues through that [directory]."

The other two researchers felt that additional resources to organize information about expertise would greatly support their research. Because these researchers conduct highly interdisciplinary work, they struggle to familiarize themselves with entire disciplines or new topic areas quickly and efficiently.

> "Thinking back to the challenge of entering new fields… if there were navigator people that you could pick up the phone, say, 'I've found myself over here, lost, tell me where to go.' Somehow, or who should I be reading, or whatever, the boundary navigator people, the brokers. I think, if we had more of those people around, it'd be easier on everybody to move back and forth."

Additional resources to help locate expertise on campus would benefit the researcher's projects and free up their time for other research needs. At the end of this report, we discuss how the library may be able to facilitate and promote connections among researchers to support the collaborative research process

5. Research Challenges

One of the study questions (see Appendix) asked about future challenges, specifically what did researchers see as challenges for the broader field of agriculture; this section of the report describes researchers' responses to this question. While addressing these challenges is beyond the scope of the library, it is interesting to note the wider institutional factors that affect the research process.

Difficulty of working with live organic material

The inherent difficulty of working with live organic material was the most common challenge researchers described, mentioned in eight of the interviews. It is a challenge for a variety of reasons which are highlighted by the following examples. In some cases, biological timelines dictate a long timeline for the research process:

> "The other challenge is that I work with a perennial crop with one harvest a year, so sometimes things have a vintage that doesn't work and you have to wait."

> "From the beginning when I started here, the detection method that we had was really basic, and we were inoculating some of the plants that were susceptible to some of the viruses. And then after waiting for a year or two years, [we were finally able] to look at the symptoms."

Another researcher described a project that was ultimately unsuccessful because of variability:

> "Every time we did the experiment, the outcome changed and we never could understand why that happened, and there was no sort of pattern in those data, and sometimes we just couldn't get the species of microorganisms to grow, and so we ultimately had to abandon that idea, because it was so inconsistent."

The variability of live organic material is sometimes problematic for research, yet technological advances have produced methods such as genetics and precision agriculture that can compensate for some forms of variability. In these cases, the challenges caused by natural variability serve as an opportunity for researchers to develop technological solutions. One researcher described a potential application of genetics to compensate for natural variability in human dietary needs:

> "Nothing works the same for everybody. So there's individual variation. So rather than, like how it is now in nutrition, you say well just eat five servings a day of fruits and vegetables. Well, maybe you need seven, based on your history or your genetics….so I think the future is how to split it out based on our genetics, or genetic expression, of 'you need this' or 'I can optimize a nutrition plan for you that's different from the nutrition plan for person x, y, or z.'"

Describing the potential of precision agriculture to address issues of natural variability, one researcher said:

> "You can have remote sensors that are either above canopy, like cameras that look at the rows of your vines, so you may have satellites or cameras attached to balloons … and what they record depends on the type of crop. It may record how much biomass the crop is developing, and, or how yellow is that biomass, and indication of nutrient deficiencies or water deficiencies, disease presence. It all goes back to the principle of precision agriculture that you have variability in your field and you apply your inputs where it's needed, and so you monitor at the plant level or the batch level."

Viewed in this way, the natural variability of organic systems is both a challenge for agricultural researchers and an opportunity for them, through genetics and precision agriculture, to make significant positive impacts on human health and the environment.

Sufficient infrastructure

Researchers in our study shared examples of infrastructure issues that impacted their research. For instance, technology and facilities are critical to the research process. Most of the researchers using lab methods, such as microbiology, genomics and chromatography, were satisfied that they had all the tools they needed. However, two of the researchers, who conduct field experiments, described access to facilities and equipment as a main challenge to their researcher process.

Another aspect of research infrastructure is availability of and funding for trained research personnel. Overall, five researchers mentioned personnel as one of their main challenges. The difficulties relating to personnel usually derived from their funding requirements and the time needed to train personnel:

> "The challenging thing is for example if I have 2 or 3 employees that I'm supporting here to do the research for me, if the next year I don't get the money… what am I going to do? I have to lay them off… And if I get it next year I have to bring somebody [new] here, that takes another 2, 3 months to train them, bring them up to date."

> "You're not allowed…to hire someone before you have money in hand, and then as soon as the project begins, your funder expects you to have a progress report 12 months later…. and so nobody acknowledges that there's any allowable time for recruiting, and so I feel like if a grant happens to land after graduate students have finished their rotations and chosen their labs, then I have to wait 6 months for the next set of graduate students even to show up."

Some researchers hoped for changes in university policy and procedure that would increase the consistent availability of research staff, with their funding less contingent on the researcher's current grants.

When asked how they mitigated challenges they faced, or what they thought could be done to address them, the researchers had several common responses. Five researchers in our study referred to persistence or workarounds:

> I: When you have a study that's ongoing, and you're taking measurements at regular intervals, how do you work around one of those technical problems?
>
> R: Well, here it's a mechanical type thing, then you may end up repeating the part of the study, or [if it's a small enough problem] you can just claim it as 'missing data.'
>
> "When we design primers and probes for the detection, all that is really found is exactly the [target] genome, but when we use it sometimes it doesn't work. So we have to really go back and study and try different primers and somehow see what's going on and why it didn't work."

Other researchers overcame challenges through the development of new techniques or research methods that would address the problem:

> "There are always issues with very small sample sizes. And so then there's sometimes a challenge in quantifying the particular compounds of interest. But then you develop scaled methods, and that's what we did in this case, to look at those very small quantities."
>
> "[Life cycle assessment is] challenging in agriculture, because life cycle assessment arose more in an industrial context, where things are not so variable like they are in agriculture where every farm is a little different or very different… But [my collaborator] has developed some kind of new techniques even within life cycle assessment to take account of some of the uniqueness of agriculture."

Another strategy for addressing challenges was peer contact: asking colleagues for advice and suggestions, or networking with colleagues and stakeholders who can sometimes provide crucial support. The two Extension Specialists noted that their relationships with farm advisers and public stakeholders made it easier to find key informants and get information out to the right audience. As noted in the previous sections of the report, collaboration and peer contact is fundamental to the research process.

Research Funding

The researchers identified research funding via grants as one of their most critical research support needs. Funding is used to hire additional research staff and graduate students who aid in data collection, analysis and reporting, pay for data services like sequencing, data storage and bioinformatics (analysis of biological data), publish in open access journals (e.g. pay article processing charges) , and attend conferences and meetings to keep up with the discipline.

Almost all researchers identified access to funding as an important challenge for their research, and three also described how funding limitations are affecting the discipline of agriculture more broadly. The researchers in our study perceive that priorities for academic funders, such as federal grant programs and philanthropic organizations, have shifted toward other disciplines outside of agriculture. This shift has left less funding to be allocated to agricultural research. Three researchers felt that more grant money was available for basic research or specific applications like public health, while grants for applied agricultural research have become extremely competitive.

> "I've found funding, it hasn't been that much of a problem, but in the long term, I think the basic plant biologists are getting lots of money, and the agricultural scientists are in a bit of a gap … It can be difficult to get money, which is surprising."

> "What's happening is funding for agricultural science is drifting away from the farm towards other issues like obesity, or the environment, or animal welfare. Or all those things that may be good things, but they're away from the traditional agenda. So agricultural science is changed."

Because researchers require funding for assistance and support services in the research process, as well as scholarly communications such as open access publication and conference attendance, the limited availability of funds poses a significant challenge for agricultural researchers.

Funding sources

Researchers in our study reported securing funding through federal grants, industry or commodity organization grants, state agencies and nonprofit organizations. The most common funding source among our respondents was industry or commodity grants, which currently fund five of the researchers. Federal grants also represent a frequent source, currently funding four of the researchers.

Several researchers noted significant differences between the scope and nature of projects funded by federal grants and those funded by industry groups. Four researchers described federal grants as extremely competitive and therefore difficult to secure, but as overall more desirable than other funding sources because they last for a longer time period and can be used for broader projects.

> "Give me a big 5-year NIH grant…. it allows a length of time for more in-depth studies compared to my current model, which is I get a grant, I do a project. I have no way to predict if I'll be able to do a second project on that topic until I finish the first project and do a publication, so the funding source can see that I do the work. And then it takes another six to twelve months to apply for that second grant. And in the meantime, there's this gap. So what's going on? …. With an NIH grant, you have 5 years."

In addition to facilitating more ambitious projects, federal grants are also thought to provide the researcher more latitude in what to study, while industry grants are more narrowly focused on a particular commodity.

> "[With an industry grant] you're working more on the highly applicable and you're working with problems that they have. It might not be your interest in doing some of the work, because the basic kind of work that you want to do will not be funded by industry. Because industry wants something that is immediately applicable."

Respondent researchers who are not currently funded by federal grants are still working on projects they find meaningful, but they have had to tailor their proposals more closely to their funders' priorities. For example, an industry board may only fund studies on a particular plant species, and so the researcher must find a way to ask their own questions using that plant species.

Senior researchers observed that in the past, funding was easier to obtain and was not as constrained by bureaucratic requirements or stipulated research topics. Two researchers expressed frustration over the amount of time involved in meeting the increasingly bureaucratic requirements for funded projects.

> "In the agricultural research system, we've got donors giving people money for particular purposes. And so there's really a lot more burdens, lots more limits on creativity, lots more paperwork, lots less out."

Other researchers pointed out a potential conflict of interest between the public good and the increasing reliance on industry and commodity organization funding. One researcher drew a parallel between conflict of interest in medical research and agricultural research, observing that the field of medicine has done a good job of addressing conflict of interest between health care providers and pharmaceutical companies, while the field of agriculture has room to improve:

> "For the field of agriculture, I think you know one of the challenges is are you working for the producers or the consumers, and how does that, um, work with conflict of interest? I feel like the field of medicine has done a really good job harping down on conflict of interest… and people have realized that is not acceptable, it's not ethical, and it's not allowed, and there's a lot of clear disclosure on who funded what work in that way. And I don't feel that precedent is in place for agriculture."

Some of the researchers noted that funding could influence the direction of research, and funding availability will remain an important consideration for agricultural researchers. Despite the frequent mention of funding constraints, however, the researchers in our study are finding funds to do work they find interesting and important. All of the researchers in our study articulated how their own work contributes to progress on critical challenges like developing sustainable agriculture, addressing climate change, and ensuring healthy communities.

Implications for Library Services

How can these findings inform enhancements in library services? Library services are used by five of the researchers. These researchers had consulted with a subject librarian; accessed publications using the VPN (virtual private network) client to access library resources from off campus; used interlibrary loan services; employed Endnote citation management software; and used materials found in Special Collections. Comments about these services led to the consideration of areas of opportunity for the library to address unmet needs of researchers.

Opportunities / Unmet Needs

Supporting the research process and promoting collaboration

One research challenge that emerged in our study is finding expertise. Researchers mentioned that it is sometimes difficult to identify peers to consult and collaborate with on campus or externally. A related need they expressed, especially researchers with broad research and/or interdisciplinary research agendas, is the difficulty of learning about or understanding new areas of knowledge. While most of the researchers use the literature and reach out to peers to keep up with research trends, they also expressed a need for someone to help them identify experts who could guide them in these new areas of knowledge.

> "So I guess from that standpoint, things that people are doing, we've been talking about that here ...to do a better job of identifying the expertise within our...faculty on different topics. And I think there's a lot more possible there than we're doing right now, you know, to kind of make that easier both for internal people and for the public to get access to.... "

This researcher was interested in identifying external expertise:

> "One thing that would be neat is if we could figure out who are the important thought leaders on a particular topic whether in California or the nation. If you could have a sense who are the people we need to reach out to when we're framing our research and thinking about the products, the communication coming out of it, or who be the most valuable people to reach out to because they affect the opinions of a lot of other people? ... You're never sure if you've reached everybody, or is there some key population that we've totally forgotten. So some tool like that could be really good."

One of the respondents reflected on the challenge of getting up to speed in a new area of research and potential qualities of service that could help researchers in this situation.

> "I think is a huge, huge challenge to think about, and in some ways it requires maybe people who do have these sorts of expertise in learning, and in information exchange, and thinking in systems."

Organized information about experts on campus would also help researchers to collaborate on projects when others are doing similar work. One researcher who frequently conducts surveys noted that a clearinghouse of recent and upcoming surveys could be beneficial:

> "Lots of us are doing surveys and we're not always all aware of what each other is doing in that regard. And maybe somebody's gotten data that's pretty close to what we need, or maybe they're about to send out a survey and if they just add a couple questions [it could save us time on data collection]".

Subject librarians are often familiar with the current projects and areas of expertise of the researchers in the departments they serve. As the campus develops tools to aggregate information about research for easy discovery, subject librarians can assist in gathering and organizing this information and ensuring experts are able to connect with each other. Part of this effort could be to conduct research on faculty workflows so we can understand how to build services to support researchers in the various stages of their research. The methodology used in this study could be used to perform additional qualitative research studies to enrich the information in the academic profiles. In addition, the Library is currently re-envisioning space use by campus libraries. We are giving consideration to how we could provide spaces and events for researchers to connect with each other.

Exploring these ideas further may help facilitate the large interdisciplinary projects that are critical to the CAES goals, or at least alleviate some of the strain that researchers feel when they find themselves crossing disciplinary boundaries.

Supporting research data management

One of the main findings in the research data management section of the report is that seven of the interviewees had a limited understanding of how repositories worked and/or did not use them. This is an opportunity for the Library's Data and Digital Scholarship and Research Support Services departments to familiarize agricultural researchers with relevant data management policies and best practices. Experts in the library can also support researchers by helping them more effectively access and organize information about research trends or promoting our data management services, which provides support and advice for managing their data. The Library's expertise in organizing information was acknowledged by one researcher who would like to see the Library partner with the Genome Center to help with organizing data for major grant funders and "to shape the data for that compliance." For example:

> "The library has someone who can tell you what is the basic headers that you need to have, or you know, at least for some of the big funders like NIH, NSF; there's probably like a top five of funders on campus. And then to say if you don't know how to do this yourself, there are people you can pay at the Genome Center who will do it for you."

Another researcher expressed a need for assistance with finding and shaping social sciences data at the community level.

> "You'd think as automatic as a lot of that data is, that somebody could go somewhere and, you know, have a menu: 'here's what I want to know' and push the button, and spits it out."

A researcher in a data intensive field talked about the need to help students "understand the difference between Wikipedia and real data." To be data literate, students must be able to "effectively access, handle and use data" and data literacy can be defined as the "component of information literacy that enables individuals to access, interpret, critical assess, manage, handle and ethically use data"[22]. The Data Information Literacy (DIL) project, funded by the Institute of Museum and Library Services (IMLS), "investigated the data information literacy needs of e-scientists" and resulted in the creation of a DIL guide to developing data information literacy programs for graduate students[23]. The Library should consider incorporating data information literacy learning outcomes into its instructional program.

Facilitating access to research

Researchers conveyed challenges both in keeping up with the literature and in accessing and obtaining articles and other publications of interest. One researcher reflected that the current solution "works and therefore it's adequate given the amount of effort I put into it…but I think with more effort I could probably do a much better job, and I know that there are better solutions out there." Table 2 in the section of the report "Strategies for Keeping Up with Disciplinary Trends" shows the relatively small number of databases that the respondents mentioned using. One researcher acknowledged that there are "more advanced platforms out there," referring to our subscription databases, that the researcher has not used much or at all. Other researchers talked about challenges in obtaining immediate access to articles. For example, one researcher, who uses citation alerts, cannot always access an article of interest immediately. In this case, it's often because some of the journal publications have embargoes, so the researcher keeps tabs open on the computer that link to the articles, and then periodically checks to see if the article has become available yet.

Subject librarians, because of their liaison work with departments, are well positioned to consult individually with researchers to learn about their strategies for keeping up with the literature and offer suggestions and ideas for effective and efficient use of the researcher's' time. For example, because librarians are familiar with a variety of relevant subject databases and because they know how to develop good search strategies, they can help researchers set up keyword searches in the most appropriate databases. At least one researcher mentioned the library as a resource in this regard saying, "I often think I need to make the time to go over to the library, I need more advice on how to deal with my situation and my challenges, especially with the literature, of how to find those key things in these wide ranges, when I need them."

Another researcher shared that a major stumbling block is requesting articles via the library's Interlibrary Loan (ILL) service[24]: "I can get abstracts, almost every single abstract, but then from there, if I want to see the entire article… sometime I can get it…. not every single time." This researcher knows about ILL but doesn't remember their login information to request the article. Rather than contacting the library for assistance, the researcher has apparently stopped using the service. When

22 Calzada Prado, J., & Marzal, M. Á. (2013). Incorporating Data Literacy into Information Literacy Programs: Core Competencies and Contents. *Libri: International Journal of Libraries & Information Services*, *63*(2), 123-134. doi:10.1515/libri-2013-0010

23 http://www.datainfolit.org/

24 https://www.library.ucdavis.edu/dept/ill/

library service staff become aware of problems with use of the library's website, we should make note of them in a centralized place. This would help us to identify patterns of difficulty and enable us to engage in usability studies, in order to assess the barriers and to make improvements.

Two of the researches use Twitter to keep up with the literature. Discussing articles via social media such as Twitter, blogs and Facebook is a type of altmetric that can be seen to "capture the potential impact of a paper"[25]. Altmetrics are a developing area of non-traditional metrics for use in scholarly publishing. Study respondents considered impact when determining where to disseminate their research results. By becoming more familiar with the use of these metrics, subject librarians can help researchers think about how to promote and share their research findings. One way of doing this is to have librarians in Research Support Services develop workshops and other resources on understanding research impact, similar to this resource on Measuring Research Impact[26] created by librarians at North Carolina State University. We could also develop strategies for how to use Twitter and other tools ourselves as one means to understand what research is important to our scholars. For example, we can follow individual researchers, academic departments, and research centers via social media to increase our knowledge about current research trends in this emerging knowledge sharing environment.

One researcher talked about having a mobile interface that would make it easy to discover, read, and share literature with peers and mentioned Browzine, which the library recently has trialed. Browzine facilitates mobile browsing, discovery and sharing of the content in the Library's academic journal subscriptions.

> "But my dream is to have Twitter, Scoop-It, and a library browser linked altogether, so I have technically on the shelf, the stuff I want to read."

If the Library's trial results are inconclusive, we should consider being more proactive in demonstrating this tool to individual faculty members to see if this type of mobile interface enhance access to the Library's journal content.

Two researchers would like to use Endnote more effectively.

> "I wish I knew how to use Endnote more than the 5% of the power I know how to use."

The Library offers both introductory and advanced workshops on Endnote, but we ask that attendees come to the library. One thing we heard over and over in the responses was lack of time, so faculty may not want to attend a workshop outside of their building. Perhaps we need to offer and promote clinics for individual faculty or departmental groups at their location depending on learning preferences.

---

25 https://en.wikipedia.org/wiki/Altmetrics

26 http://www.lib.ncsu.edu/do/research-impact

Conclusion

The University of California Davis University Library chose to participate in this national study of agricultural scholars to learn more about how agricultural research is conducted on our campus. The study helped us gain insight into the nature of agricultural research on campus including the research process, research data management practices, scholarly communication patterns, preferences for collaboration, and research support and funding challenges.

Key Findings

The findings were derived from a review and analysis of transcripts from semi-structured interviews with twelve researchers in CAES. The researches were selected using a purposive sample designed to gather input from a variety of disciplines; from researchers with different roles within the College (e.g. faculty, Cooperative Extension, professional researchers) and from both pre- and post-tenured faculty. Open and focused coding of the qualitative data led to the identification of five major themes which we've described in this report using a narrative structure with embedded quotes and excerpts from the interviews.

The key findings are:

1. **UC Davis supports a diverse, interdisciplinary research agenda pertaining to many aspects of agricultural production, distribution and consumption.** Researchers take up a variety of research topics, using cutting-edge methods both in the lab and in the field. Their research often contributes to the University's land grant mission with the help of UC Davis institutional supports such as the Cooperative Extension, the Agricultural Experiment Stations, the Genome Center, and other specialized centers on campus.
2. **Research data management emerged as a major element of the research process by CAES researchers.** Research data is created or obtained through a variety of sources, including observational, experimental, simulation and reference data, as well as data derived or compiled from secondary sources. Data are processed and stored primarily through digital means. Most researchers in our sample are confident in their use of relevant quantitative and qualitative analysis techniques, but less confident in digital data sharing practices such as repository submission. Some face challenges in accessing or compiling multiple kinds of data, but uploading and sharing data were more often described as challenges.
3. **Researchers are engaged in scholarly communication with a local to global audience.** Researchers disseminate their findings in a range of academic publications, including open access publications, as well as non-academic venues when appropriate for reaching their research audience. They use multiple strategies to learn about the work of other scholars in their disciplines. Some researchers have concerns about academia's publication-heavy incentive structure, but most remain confident that their own agricultural research is effective and important.

4. **Collaboration plays an important role in fulfilling ambitious research goals.** The value and impacts of agricultural research were often described in terms that align with the core priorities of CAES's Academic and Strategic Plan: sustainable agriculture and food systems; equitable, healthy communities; meeting the challenges of climate change; and ecosystem viability and functionality. Most researchers described working to solve global problems through collaboration, and emphasized the importance of finding expertise to form strong collaborations.
5. **Researchers described challenges specific to agricultural research, as well as challenges facing scholars across disciplines.** The main challenges to agricultural research include the difficulties of growing biological systems and working with natural variability; gaining access to adequate facilities and equipment; managing personnel; and obtaining adequate, consistent funding for research. The latter challenge was noted to be widespread in academia, but takes on a distinctive character for the discipline because of the funding sources available for agricultural research.

Opportunities for the Library

In addition to discussing these findings in more depth, we considered how the library might address the opportunities and unmet needs that were uncovered during the research. These opportunities include providing more effective support for the research process by facilitating collaboration among researchers. We could help to provide organized information about experts on campus and collaboration spaces in the library. Another opportunity is to leverage the expertise of the Library's Data and Digital Scholarship department in partnership with subject librarians in Research Support Services to familiarize agricultural researchers with relevant data management policies and best practices. The Library's instruction program could also develop data literacy learning outcomes for both undergraduate and graduate students. Lastly, subject librarians, because of their liaison work with departments, are well-positioned to work individually with researchers to learn about their strategies for keeping up with research trends and their scholarly communication patterns and preferences. This knowledge could enable us to optimize use of the researcher's time, facilitate their access to the research literature, and enhance the impact of their research. We also hope that this study methodology, with some adjustments, could be used to interview researchers in other programs and disciplines to further inform library services and collection needs.

Appendix
Interview Protocol
Research Support Services – Agriculture

Research Focus

1. Describe your current research focus and how this focus is situated within the broader agriculture discipline and the academy more broadly. [*Probe for whether or not they see themselves as located firmly within agriculture as a discipline or located across/between disciplines*.]

Research methods

2. What research methods [*techniques*] do you currently use to conduct your research?

3. What kinds of data does your research typically elicit [*generate*]?

4. How do you locate the primary and/or secondary source materials you use in your research? [*What kinds of data do you use in your research?*]

5. Think back to a past or ongoing research project where you faced challenges in the process of conducting the research.
    a. Describe these challenges
    b. What could have been done to mitigate these challenges [*by the researcher, or by others*]?

6. How do you keep up with trends in your field more broadly? [*Does this method work well for you*?]

Dissemination Practices

7. Where do you typically publish your research in terms of the kinds of publications and disciplines? How do your publishing practices relate to those typical to your discipline? [*How do you share your research*?]

8. Have you ever deposited your data or final research products in a repository?
    a. If so, which repositories and what have been your motivations for depositing?

    b. If no, why not?

Future and State of the Field

9. What future challenges and opportunities do you see for the broader field of agriculture?

10. If I gave you a magic wand that could help you with your research and publication process – what would you ask it to do?

Follow-up

11. Is there anything else about your experiences as a scholar of agriculture and/or the agriculture discipline that you think it is important for me to know that was not covered in the previous questions?