Final Report: Research Practices and Support Needs of Scholars in the Field of Agriculture at Cornell University

Introduction

Overview of Report

This report presents the findings of a qualitative assessment of the research practices of agricultural faculty and research staff in Cornell University's College of Agriculture and Life Sciences. This work was carried out as part of a larger project led by Ithaka S&R, conducted at numerous land grant institutions nationwide. The aim was to examine various aspects of the research life and process of faculty and research staff in the agriculture discipline, with the goal of elucidating resource and information needs and possible points of entry for library services.

Agriculture is a diverse and interdisciplinary field. Faculty self-identifying as 'agricultural researchers' can range from molecular geneticists to plant breeders to social scientists like economists. Often, agricultural researchers in institutions of higher education are based at land grant universities and affiliated with extension services to bridge scientific research and farming practices. These unique attributes of the discipline shape the ways in which researchers collaborate, seek information, disseminate their work and carry out their research.

This report highlights five themes that emerged from interviews with agricultural researchers at Cornell: engaging stakeholders to change practice, interdisciplinarity and collaboration, the impact of changing technology on agricultural research, the implications of the information age on the inputs of research, and similar implications for research output and dissemination. With each theme, we discuss the ways in which these trends impact research practices and call attention to potential roles for librarians and library services in addressing changing needs and emerging challenges.

The Field of Agriculture at Cornell

The College of Agriculture and Life Sciences (CALS) at Cornell is comprised of 15 academic departments including two schools: the Dyson School of Applied Economics and Management and the School of Integrative Plant Science. There are over 300 faculty in CALS, over 3300 undergraduates and around 880 graduate students.

Agricultural research at Cornell encompasses a broad range of life and social sciences, with a particularly strong focus on both New York agriculture and agriculture in developing regions around the world. Strong research programs exist in agricultural economics, food science, including enology and viticulture, integrative plant science, animal science and development sociology. The agricultural economics program covers topics such as agricultural markets and trade, agricultural development, and production economics. The highly ranked enology and viticulture program covers a wide range of research areas related to the growth, production and marketing of fruit crops, with a focus on the grape and wine industries. Faculty in the integrative plant sciences address the science of crop production at local, regional and global scales. The animal science

department is particularly strong in food animal production, with a focus on dairy science. Finally, several faculty in development sociology focus on sustainable agricultural development, food systems and related health and nutrition topics, largely focused on rural areas and developing countries.

All of the agriculture-related research and departments emphasize a connection to cooperative extension, and many faculty have strong ties to extension programs serving New York State.

Research Methodology

Fourteen semi-structured interviews were carried out by four librarians based at Albert R. Mann Library. Each interview was conducted by a single librarian. Interviewees were recruited by directly contacting faculty with known connections to the library, in an effort to increase the likelihood of willing participation. Interviews were carried out at the office of the researcher, recorded, and subsequently transcribed. Interviewees were asked to sign an informed consent form prior to the interview, in accordance with Institutional Review Board requirements.

Interview transcriptions were coded and analyzed with the guidance and methodology provided by Ithaka S&R. All interviews were initially coded by at least two of five librarians (the four interviewers and one additional coder). After initial coding, codes were grouped and themes identified based on discussion and consensus. All interviews were then re-coded for each of five themes. The findings around these five themes are discussed below.

Findings

Engaging Stakeholders to Change Practice

Nearly all of the agricultural researchers we interviewed are strongly motivated by a desire to change agricultural practice—that is, to have their research improve the work of farmers and farming. Unlike their counterparts in the pure sciences, who are firmly situated in academia, agricultural researchers straddle the divide between the academy and the 'real world'. This motivation defines many aspects of their research practices, including the collaborations and relationships in which they invest, their interactions with information, how they disseminate their research findings, and their self-perceptions as educators both within and outside of the university.

As applied researchers seeking to change agricultural practice, many of the interviewees actively engage with farmers. Reaching farmers with research findings and facilitating change in farming practices were frequently mentioned activities. This was particularly true of the several researchers we interviewed who hold extension appointments, whose focus is New York state agricultural workers and industry. Likewise, researchers working in an international setting are also involved with farmers and with translating research findings to more effective, sustainable farming practices;

however, they face unique challenges to this process, such as cultural and political barriers and language.

Relationships with farmers not only provide a conduit for translating research findings to practice, but also are critical for informing research direction and development. For this reason, extension publications and trade journals were mentioned as important forms of literature, on par with academic journals. Thus, libraries serving these populations should prioritize the collection and accessibility of this type of literature.

Because agricultural researchers aim to influence agricultural practice, their research dissemination methods are often dictated by the importance of reaching practitioners (i.e., farmers, policy-makers, etc.) as well as scholars. Thus, communication methods are unique and varied. In addition to scholarly journals, researchers publish in extension publications, newsletters, and trade journals. They make use of novel communication platforms including YouTube videos and blogs. One international researcher working with illiterate populations in a developing country mentioned the use of illustrated materials and theater to convey information related to agricultural practice.

Traditional academic publishing was also viewed as important. However, there was a friction between the unequal value placed by administrators on publishing in academic journals versus other forms of publication. Most researchers appreciated the importance of publishing both for an academic audience as well as a practitioner audience. In reference to a particular project, one researcher stated, “My ultimate goal…is not to generate academic publications necessarily, but to generate articles that explain concepts that have data to back them up and that are aimed at producers and the practices that they use.” Another reflected, “I think it’s essential that you have to inform other people in your field about what you’re doing, and what results you’ve gotten…. But it’s not going to have an impact on that farmer.”

When asked about challenges in the agriculture field, many researchers invoked the importance of public opinion and scientific literacy. In particular, the disconnect between people and agriculture was viewed as an important barrier to progress. Despite this, few researchers mentioned involvement in professional activities to bridge this divide. This could present an opportunity for the library to serve as a liaison between researchers and the public, holding events or engaging in public outreach to educate and inform.

The focus on applied research also has significant implications for teaching and learning. Most of the researchers interviewed were also teaching faculty, and several discussed the ways in which real world applications to research impact their pedagogical approach. They placed value on teaching students not just to be successful researchers, but also to engage with the world around them as agents of change. Activities such as internships and study abroad were mentioned as important components of the curriculum.

There were frequent reflections about the applied and complex nature of agriculture,

which demands a multi-disciplinary approach, both in terms of research and in terms of stakeholder engagement. Often mentioned as an obstacle to progress in agriculture were barriers between scientists, farmers, economists, politicians and the public. One researcher stated, "…anything we do on the production practices end of things, [requires that we] work hand-in-hand with the economists and social sciences…. That's been a challenge for some people too because you tend to speak different languages and think differently."

Overall, the researchers interviewed seemed to draw their inspiration from a desire to contribute to solving large global problems, like climate change and food security, and impacting the lives and livelihoods of farmers in a positive way. Libraries serving these researchers should think creatively of how to help amplify the impact of academic research and remove barriers that slow this process of change. Leveraging information technology to deliver spatially and temporally relevant data to farmers, assisting in rapid evidence synthesis to help deliver timely recommendations to practitioners, or negotiating affordable access to scientific research for farmers without an institutional affiliation are just a few ways libraries could help researchers contribute to changing agricultural practice.

Collaboration and Interdisciplinary Research

All of our interviews made clear that the complex nature of agriculture demands a multi-disciplinary approach that draws on expertise from a range of disciplines, including the plant sciences, development sociology and economics. At Cornell, organizational changes within the College of Agriculture and Life Sciences encourage the perpetuation of interdisciplinary collaborations. Many of the researchers that we interviewed hail from one of five disciplines that comprise the newly created School of Integrative Plant Sciences at Cornell, a structural collocation at the administrative level intended to drive the very collaboration needed to tackle some of the most pressing issues of our time. Indeed, one challenge referenced in several interviews is the 'Food for 9 Billion' challenge, a collective effort among diverse specialists to increase food production for a projected global population of 9 billion by the year 2050. Meeting such challenges requires a systems approach - with soil chemists working alongside plant pathologists and social scientists working alongside plant breeders.

A variety of stakeholders outside the academy play equally crucial roles, including farmers, policy-makers, consumers and extension agents. While it is important for agricultural researchers to reach these stakeholders with their research findings, these stakeholders also offer a range of skills and expertise beneficial to the research, such as field plot access and data management acumen. The liaison librarian is in a unique position to bridge the gap between the various constituents while providing training in basic tools, such as citation and content management software, that facilitate the sharing of information between multiple parties. One of the researchers had difficulty with using Mendeley to gather and share references for a large grant-funded international non-governmental organization (INGO) project, and another lamented the slow progress of delivery of information directly to smallholder farmers for day-to-day

decision making. Libraries can play a role in the set up and continuation of these types of information projects.

In terms of collaboration, another potential role for the librarian is helping researchers at the beginning stages of a project when collaborators must be identified. Some researchers found collaborators through chance conversations and personal networks; however, liaison librarians are uniquely positioned to hear about and facilitate cross-collaboration. If facilitated appropriately, collaborations between researchers and farmers should be mutually beneficial. Several researchers expressed trepidation about encroaching on a farmer's time, especially when a treatment – such as a new type of pest suppressant – is applied with unknown effect. As one researcher noted, "It's challenging to find good farmer collaborators and we certainly get a lot out of it and we hope, that if everything works well, that the farmers also get something out of the interaction as well." When yields are reduced or production quality decreases, the effect may strain the relationship if not handled well. One researcher that we spoke to explained the importance of reimbursing for lost income due to failed field trials in order to maintain goodwill for future collaborations. Of course when trials are successful, the short pipeline from research to practice is pleasing to both researcher and farmer alike.

At Cornell, like most large research universities, there are physical, administrative and mental divides between researchers and departments. A researcher in rural development complained about the difficulty and expense of international communication for larger or more critical events. "If I need to be able to have a conversation - and it's partly our end and it's partly their end, right - but a conversation with five people in five different continents. You can do that on Skype for a planning meeting, that's fine, but if you want to have a real workshop or a dissertation defense or something, you have to rent out the communications room and pay $500 to have somebody come and set it up for you. So somehow, if there were communication stations where we could more easily connect." Libraries could help bridge those divides, starting with something as simple as equipping conference rooms for distance communication and offering those to faculty.

Even more importantly, the library can serve as a site for researchers to gather and exchange ideas. One professor who wanted universities to think more creatively about encouraging idea generation and collaboration amongst researchers suggested tearing down and rebuilding his older, windowless building. "I think to have the physical environment that is organized in a way that it promotes these human to human but also these chance encounters to be creative is very important," he said. "If you look at this building, for instance, this is probably the building that allows the least amount of creativity . . .You don't have any interaction with anybody else. You don't see anyone. So it's an intellectual dead zone. . .So what we need is spaces where faculty and students can interact and, obviously, that are conducive to healthy work environment…I could see centers of excellence where a sociologist, a physical scientist…all work together all day. They come together for two or three years and then they rotate out. Now you get this constant exposure to other ideas. The physical space is very important for that. I wish we would be more creative in organizing a university than putting us into

windowless rooms where we never meet anyone else." As libraries renovate and reorganize, adding this type of research commons for faculty is a natural fit for libraries as the intellectual heart of campus. Furthermore, adding programming that encourages interdisciplinary conversation and collaboration on top of enhanced research consultation and data management and visualization services would position the library as a key resource for faculty collaboration and networking.

Finally, the library can also play an important role at the end stages of a research project, when appropriate avenues must be identified for sharing advances with external groups. When asked if their research output had been deposited in digital repositories (either affiliated with their institution or elsewhere), many interviewees quickly recognized the importance of such a practice despite very few having deposited their data in the past. Sharing previously collected data, especially if others can then find new uses for the data, is appealing to many researchers that value collaboration, transparency and data sharing. To facilitate such practices, libraries can continue and increase provision of research data management services. In addition, networking tools maintained by the library could play an important role. As one researcher noted, "I do think that a certain amount of networking is required in order to build collaboration, but whether or not collaborations happen really are partly a function of your reputation, reputation over time." Digital archives of a researcher's output can contribute to one's reputation within the research community, a very real value proposition for faculty that the library could assist with.

As the issues facing agricultural researchers grow increasingly complex and technologies like precision sampling and GPS mapping become more pervasive to many disciplines, the future of the field continues to look necessarily interdisciplinary and collaborative, a point that will be explored in further detail in later sections of this report. Additionally, as budgets narrow and grant competition stiffens, collaboration becomes about self-protection too, as grant proposals with an enhanced scope and greater breadth in the proposed contribution seem more likely to be funded. The School of Integrative Plant Sciences at Cornell and the New York Agriculture Experiment Station, a satellite campus of Cornell, are two examples where agriculture scholars have been situated to work alongside colleagues in related but different departments. As resources become tighter, and such collaborative units increase in prevalence, librarians should look to situate themselves within such units for greater impact.

Impact of Changing Technology on Agricultural Research

Not surprisingly, faculty working in an applied field like agriculture rely heavily on modern technologies of one sort or another, and the Cornell scientists we interviewed in both the life and social sciences listed the many and various tools they used and how they were changing the ways they worked. The big topics were near-science fiction technologies like remote imaging drones, hyper spectral cameras, plastics for sheltering field crops from ultraviolet radiation, and precision agriculture systems relying on satellite data. But there were also accolades for more everyday (but still very important) productivity technologies like iPads, Zotero and Dropbox.

The plant scientists were especially enthusiastic about how new technologies were improving their work and their ability to collect data from the field and the lab; one crop breeder spoke about how genetic technology had made sequencing and modelling so much cheaper and easier. "For twenty dollars I can tell you if that variety is going to yield as well as or better than my current varieties, and I think that is just the most amazing technology I've ever seen in my life."

It was this same group of scientists, however, who noted the challenges created by these new technologies, a challenge that could be summarized as something like "more data doesn't mean more knowledge, necessarily." This was a theme that came up over and over again.

For example, several researchers made specific reference to precision agriculture as one of the newer technologies holding great promise but also presenting equally great challenges. One noted "the big challenge with that is, yes, it's possible to collect a lot of information and make some nice maps that show the spatial variability of whatever it is you're measuring. It's a little more challenging to say, okay, well, what do you do with that information, and how do you reduce it to a level that you can really understand and work with." Another drew parallels between the disappointingly slow process of applying the results from genetic technologies and what will likely happen with precision agriculture. "We know what all the genes are in the human genome and we haven't conquered all these diseases and everything we said we were going to because we know the script, we know the alphabet, that's only the first step. Now to try to decipher what it means and all the rest of it. And precision ag is going to be the same."

Related challenges of these new technologies are that they are expensive and difficult to master. Several faculty members talked about the collaboration bred by the necessity of relying on a colleague's grant-funded piece of equipment they had in their lab. A few also mentioned the collaboration bred by the necessity of relying on others' expertise in using that equipment, such as the Cornell faculty member whose former graduate student, now faculty at another university, utilized advanced spectral technologies in his lab, and how she would turn to him for his knowledge of this technology. Noting this relationship, she said, "What I need to do is just build my network to encompass the expertise." This was a sentiment echoed by many of the other faculty, and more than one, when asked about a magic wand, wished for a greater facility with the technologies they were growing increasingly reliant on for their work. "There are awesome, thrilling possibilities in low and high tech," noted one researcher, "…if you could just change me with your magic wand and make me smarter."

Where might the library play a role in supporting faculty with their technology needs and frustrations? Many are beyond our power—one faculty member, for example, had an expensive piece of equipment he couldn't unpack because the building he was currently in didn't have the sprinkler system necessary for its use. But there are

clearly some other areas where the library could help out. GIS support, for example, remains a strong and growing need—both in accessing the spatial data and in using the software to geocode that data.

Another growing area of need, mentioned by several researchers, was for help visualizing information and scholarly networks. One researcher, noting how interdisciplinary their work was, wished to "visualize some nice network analysis when people work on these different subjects….and then it would be nice if there were a sense of these are the journals that exist, these lit up ones are ones we have, is there anything that we should have that we don't? These are the concepts that people are highlighting as being au courant or something. These are the meetings that occur around each of these themes, just so that you can enter this, and if you grab this ball from this network." This is a technology that does currently exist in basic form—the VIVO system developed here at Cornell—and the second generation of VIVO, called Scholars@Cornell, is already in the works and holds great promise to create this desired-for visualization of the complex networks of scholarship in agriculture.

And last but not least, there are the many opportunities (and challenges) for libraries in helping researchers with "the big data problem," as one faculty member referred to it. The drones flying over fields and the hand held spectral cameras in the fields are all producing terabytes of data, and there's more on the way. Most agriculture researchers are involved in computationally intensive research, and this is an area where the library could play a vital role. Most university libraries have some sort of data management support, and this will grow increasingly important as the amount and complexity of data increases. Repositories and other data storage locations will be vital (as mentioned before, most Cornell researchers interviewed did not seem to regularly deposit their data anywhere), as will helping the researchers comply with data management requirements from funders and publishers.

Research in the Information Age--Inputs

The iterative nature of the research cycle and the breadth of agriculture as a discipline push agricultural researchers to rely on a variety of rapidly changing tools and strategies to manage the many inputs for their research processes: the research questions they formulate, the methodologies they choose, the range of literature in their field they must consult and keep up with, and the information they have to manage.

A common thread in all the interviews was how much their research questions are informed by real world applied contexts and conversations with colleagues and stakeholders. An extension researcher described a project born out of a debate between farmers and seed salespeople at a meeting and another noted that, "we do a phone call with the...researchers around the Northeastern United States and...talk about what we're seeing and what's coming up and offer suggestions - has anyone done any research on this? And someone might say, 'Oh, no, I'll start an experiment and do that'." When asked what he would change about the research process, a professor in soil science wanted universities, "to be more creative about...how ideas are born. And

they're not born by me staring at a screen. In the rarest of cases, are they born that way. They are usually born through interactions, through discussions, through accidents..."

Besides basic research that arises out of questions from the field and talking with colleagues, projects also come from trying to understand and solve problems for farmers on the ground. One field-based cropping systems researcher said, "a lot of times we use data to justify grant proposals that we're working on and . . . we can say we have so much support for this particular project. We've been in touch with our stakeholders and this is what they want to see. A lot of times we'll have an idea. We'll hear a couple of people talk about this or it will be an idea that we've been working on for a while and we'll try to build support or gauge the support for that. So it is to a degree somewhat circular, like okay, well, do we start with the idea then try to find support or do we just blindly look for support for different things and then apply it to the research that we're going to do in the future."

The library and the literature in these applied science cases are often not their starting point. An extension associate said, "I don't think I start out - with respect to libraries - I don't start out going to the literature; I start out with the questions that come up in the industry. Then you have the tools - discussions with colleagues, the seminars that give you ideas, visiting scientists, whatever, and then after that you just sort of go to the literature and you develop your proposals or whatever. That's the way ideas make it into projects, and the projects make their way into practices, I guess."

Agricultural researchers use an enormous variety of research methodologies. Besides the very common classic experimental design work in field, greenhouse and growth chamber studies, they also use methods like lab research (wet chemistry methods using balances, pH meters, and conductivity meters; microscopy; x-ray, infrared, and UV-vis spectroscopy; bioinformatic and genomic methods), soil sampling and analysis, disease surveys, remote sensing, special and process-based modelling, interviews, participant observation, surveys, historical research, experimental design and evaluation studies in social sciences like economics, and participatory methods like workshops and mapping exercises.

When it comes to locating primary sources, the researchers we interviewed most often collected their own data. However, researchers in the social sciences also consulted archival and other primary historical sources. Talking to colleagues or stakeholders in the field also played a significant role for some. For empirical literature, on the other hand, Google and Google Scholar are the resources most often searched first, though researchers often indicated their awareness that it might not be the best source and that ultimately access to the literature comes from the library. One researcher said, "So when I'm doing like a literature review I do it a certain way. I wind up using Google Scholar quite a bit and I know other people use [Web of] Science and other tools, but for me I feel like I can find things easier with Google Scholar. So when I'm on campus I can access PDFs very easily that way because of the library subscriptions to all the journals; it's very easy to have access to them. When I'm at home I would just log into my Cornell

account and then through the library I can access anything I would need. I really like Google Scholar." A couple of researchers did eschew Google Scholar, since they found the library's single search portal and databases more useful.

Web of Science was most frequently mentioned by researchers for its citation features (though some complained about its ease of use). Other researchers, though they did not mention Web of Science, also indicated that citation chaining was a way they found additional or key resources. "Whether it's ISI or Google Scholar, it's just brilliant. If you know an authoritative article from ten years ago, five years ago, you go to that one and then you look who cited that article. Then you pretty much know anybody who knows the field should have cited this article. You then know all the recent ones."

For other individual library resources and databases, the library's catalog and single search portal, AGRICOLA and CAB Abstracts were mentioned. However, one researcher said that "when you're doing interdisciplinary research, those more particular search engines are not useful." Trade journals and industry sources, experiment station bulletins, and even popular press (both local campus sources and national news) also played a part, particularly in extension researchers' information gathering.

For primary data, the interviewees generated an incredible variety of data types, including: quantitative and qualitative data from the field and greenhouse (measurements of yield, growth, size, weight, soil characteristics, microbiological processes; population counts; quality evaluations; genetic/genomic data; measurements of nitrogen, sugar, and protein content and experimental data on the effects of various treatments); climate models; epidemiological data; solution chemistry/chemical composition and spectroscopy data; sensor data; satellite photos and geospatial/GIS data; plant samples; survey data (e.g. farmer surveys, disease surveys of plants); economic data (market consumption, prices, income, etc.); demographic data; transcripts and field notes from interviews; grey literature from NGOs (pamphlets, handouts; workshop manuals, etc); and print and electronic copies of archival and historical materials (journals, diaries, narratives, and historical materials from national and international archives). Some researchers dealing with genomic studies, watershed scale longitudinal data, sensor data or satellite imagery were dealing with collecting and managing massive datasets, though not all researchers had big data.

In terms of secondary data, the USDA Economics, Statistics, and Market Information System (ESMIS) portal (supported by Mann Library) was mentioned, as well as FAOSTAT and Global Trade App (a fee-based resource accessed not through the library but through a company affiliation). Other sources mentioned include Triticeae Toolbox, National Research Conservation Service (NRCS) GIS maps, supplemental data published in journals, and data requested from other researchers and companies. A couple of researchers mentioned difficulties in getting data from other researchers or institutions, either at all or in a format that was useful to them (e.g. at the state vs. county level; recently updated, or of high enough quality).

In terms of current awareness and keeping up with developments in their field,

researchers reported using a variety of methods, including conferences; talking with other colleagues, farmers or people in industry; journal alerts and reading tables of contents (and in some cases, their positions as writers in and/or editors of journals, books, newsletters, or special issues); literature searches for papers they are writing or just in time information; or industry and popular press.

Conferences and professional meetings are the most common ways researchers keep up, and most have a few core local, national, and/or international conferences they attend. One cropping systems researcher said, “conferences, workshops, that’s I think really where cutting edge research is being presented and so I feel like I’m missing out when I don’t go to a big conference, especially if I’ve been going for a number of years. So yeah; face-to-face interactions, networking.” In some cases, researchers indicated that conferences and even just talking to people in their field were the main way they kept track of new developments in their field, even more than the journal literature. That same researcher said, “you can go into a journal homepage and see what’s ahead of print, but even by that time that’s somewhat dated. And if you really want to be right at the forefront then going and interacting with people before they have submitted their papers and seeing where they’re headed with different research. That’s really a good way to stay current. Talking with farmers, talking with their stakeholders, seed sales people.”

Journal alerts, reading tables of contents and keeping up with the literature in various ad hoc ways are still key components of many researchers’ current awareness systems. Formal alerting systems were sometimes used, though the volume of information and the lack of time to read it were challenges several people mentioned. A few researchers noted that they get alerts or forwards of papers only when people in their network send them to them, or mentioned tools like ResearchGate for automatically keeping up with people in their circles.

Literature searching was mentioned as part of this process of staying current, but only in certain contexts and with its own challenges. One researcher said, “there’s tens of thousands of articles. There’s no way you can read these and find the five relevant articles for you, or stay on top of it. Some people have alerts and they get emails. I already get too many emails. And I don’t find the time once a week or once a month to go through everything that has been published in that month. I just don’t seem to find the time or the patience.” Another said, “I used to...subscribe to current contents…[but] I just find now that rather than accumulating this extraordinary database, it’s easier just to do the search that you need to when you need to do it.”

A couple of researchers also mentioned catching up via literature searches only when they were doing their own papers or checking on their graduate students’ work, a method they seemed to regard as backwards but an adequate way of satisficing. “You can’t write a paper if you haven’t either done a 360 around your topic,” noted one faculty member, “so that’s kind of the chance to reacquaint oneself with what you should have known at the beginning all throughout this time.” Another said, “It would take me two or three days every month to just browse the abstract[s] of everything that been published

and stuff that's interesting. It's probably not even possible. So I typically then go through the literature and do these kind of searches when I write a proposal or a paper."

For analyzing and managing their information, researchers mentioned a range of tools such as STATA, SPSS, Atlas.ti, epi info, Excel, homegrown databases, Dropbox, Zotero, Mendeley and Devon Think Pro; many seemed to struggle with finding and using tools that met their needs (particularly for data and sharing of materials). One interviewee had issues with both Zotero and Mendeley for the kind of group citation and paper sharing they wished to do; a few researchers with big genomic data needed more help with databases (and one was contributing to the Gates-funded GOBII project to address this); and a social science researcher wanted to share the unused interview transcripts and copies of archival material she had (some sitting in print in boxes in her office).

The researchers we spoke to encountered a number of challenges in these initial pre-publication stages of the research process that libraries are not equipped to address, including a lack of time, staffing and funding, issues with research design, environmental and labor-related challenges of fieldwork, and in general the complexity and interdisciplinary nature of modern agricultural research. However, there are key areas where librarians can make (and are making) a difference. The library is already doing some of these things, like: providing access to the literature (both locally and internationally, as Mann Library does with TEEAL (http://www.teeal.org/), Agriknowledge (https://www.agriknowledge.org/), and other Research4Life programs (http://www.research4life.org/)); collecting and preserving extension knowledge and researcher papers (including unpublished material); and providing reference, citation and research data management and GIS support. Even areas that might seem to be outside the library's area of expertise—like statistical methodologies and software—present opportunities for either developing in-house expertise or partnering with campus groups who are the experts (for example, Mann hosts drop-in statistical consulting in its consultation area, staffed by the Cornell Institute of Social and Economic Research and the Cornell Statistical Consulting Unit). Many of these researchers already recognize the value and explicitly praised the library in this regard. However, there clearly remain opportunities for more in-depth support and information and data literacy. The keys seem to be determining researchers' needs in these areas, making them more aware of the services and expertise the library does provide and, critically, making it as easy as possible to access all of this at the point and level they need them.

In general, faculty awareness of the library as a source for help beyond collections for themselves seemed limited. While a couple of respondents specifically mentioned using and valuing instruction for their students in information literacy, many had not been into the library itself for some time, having accessed the literature on their desktops. They did repeatedly express the need for help, especially when they were entering a new area and wanted assistance in orienting themselves and finding the right resources and search strategies, looking for specialized resources like archival collections, or were stuck in finding particular information or getting it in the format they needed. However, most didn't mention the library as a possible source for that help or only did in hindsight.

One did say, “Occasionally I will go to the reference desk, but mostly I go there when I have a citation and I can’t find it. I don’t think I have gone and asked for a consultation just because generally I think I know the literature better about this subject than they do, and it’s just a waste of both of our times, right? But sometimes I think I get some place - and I’ve gone over a couple of times and said, ‘What do you think? Where should I go?’” The others figured things out on their own or simply expressed a general desire for help, unconnected to the library in particular. A plant breeding professor wanted to “be able to find information beyond...Google Scholar and having some more targeted support with like, okay, we’re starting a project on this. I can do my literature review, I’m going to miss a lot with the way that I do it, what other pieces of information should we be thinking about and be accessing? So if there is some support, some tools related to that, I think that would be really helpful.” A researcher who hadn’t sought help said, “I would love to. I think that would be fantastic. I think it would be really nice to know when it would be appropriate to reach out to a librarian and when it would just seem like we’re being lazy.” There are clearly opportunities for the library to be more involved in researchers’ process here.

Research in the Information Age--Outputs

As has been mentioned, agricultural researchers communicate the results of their research using a multi-faceted approach so as to reach multiple audiences at varying levels of expertise. Researchers acknowledge that it is critical to report the results of their work in the peer reviewed journal literature to document their work for the scientific community, while also arguing that making an impact at the farm level or policy level--whether local, state, national or international—necessitates that applied research results be communicated through a variety of other media, like extension newsletters, farm field days, policy briefs, news media and meeting presentations.

Traditional journal publishing is essential for agricultural researchers to establish themselves in their research communities and communicate the results of their work to their peer researchers. Agricultural researchers interviewed expressed a desire to publish in the top tier journals, but often found that their work was not accepted for publication. One researcher commented, “the Holy Grail is to go towards *Nature* and *Science*. We try every year, sometimes we are lucky and most of the time we’re not lucky.” Another researcher commented, “I have been able to publish in higher ranking journals than most of my colleagues. I think there’s a technique to that. And not just the quality of the research.”

The goal for all of the researchers interviewed was to get their work published in the best journals possible, but also the journals that are most likely to be read by their intended audience. Many of the interviewees named the key journals that members of their research community read, and they knew that publishing in those journals would reach their desired audience. They lamented the struggle between the lower impact factor of some of the key journals in their fields where they reach their desired audience--sometimes a small specialized group--and the pressure to publish in high impact journals. “I’m strongly opposed to impact factors as a measure of journal

quality," commented one researcher. "My philosophy has always been to choose those journals that I know people of my discipline read." Some researchers also expressed a specific interest in publishing in open access journals, and some said they had. Several researchers expressed a preference for society journals, where they were members, while a few commented on publishing in broader interdisciplinary journals because their work in areas like sustainability and food security crossed multiple fields. Sometimes researchers find they are able to publish in journals from related disciplines, and other times their articles are rejected as out of scope.

In an applied discipline like agriculture, one of the true measures of success for researchers is to see the results of their research implemented at the farm or policy level, and several researchers expressed frustration with the time it takes to get an article published, impacting their ability to get the word out to the wider community. One commented, "the amount of time it takes from when you submit something to when it's actually published can be three years…the problem with that is most of the impact of that is not going to be in the journal, it's going to be in talking with the press and getting this out. The press doesn't want to hear anything until the study's been published. So you say, I have all these results. Is it published? Not yet, we haven't. Talk to me when it's published. And then it's old, especially if it's on a policy." Another researcher commented, "sometimes I'll go with a lesser journal that I know will publish it fast, and there won't be a lot of revisions." Other interviewees expressed frustration at the slowness of the review process, where articles have been rejected before review after sitting with the publisher for six weeks. Others had work rejected because the work was not broadly applicable, but only applicable to the Northeast. In those cases regional journals, newsletters and trade publications offered possible alternative outlets for these research results.

Conferences (and their proceedings) were repeatedly mentioned as key places for not just keeping up, but also sharing the results of research. From an outreach and extension perspective, speaking at meetings is seen as an important way to get the word out about new research. "My outreach is sort of broad because I have an extension responsibility as well, so a lot of my time is spent taking the research, things we've learned and speaking at conferences and newsletter articles and little web-based publications," commented one researcher.

As has been noted, reaching the farm audience and the public is a priority for agricultural research; to accomplish this, researchers at Cornell present their work in lay terms in extension and trade publications. Some departments have their own newsletters which used to be mailed out in print, but are now published online, while others have discontinued their own newsletters and instead place articles in newsletters produced by other organizations, including societies' and growers' associations. They also try to get the media to cover their discoveries. "You don't have impact from publishing in journals…using the media is the best way to have impact," one researcher said. An added challenge for some international agricultural researchers is that some

farmers in the developing world can't read or write. Alternative methods for getting information out to them must be used, like the aforementioned illustrated materials and theater. And finally, a type of hybrid publication was discussed by one researcher. "APS (American Phytopathological Society) has been a leader in something called plant disease management reports. It's part of the Plant Management Network. But it's a great venue to publish a lot of our efficacy trials for looking at how different corn varieties performed or how different fungicides performed. It's a great place to get some of those things out. The researcher went on to explain, "actually you're…restricted to a data table, a paragraph of materials and methods, and a paragraph of results and discussion. It's a mini publication, but very powerful for what you need."

Field days and meetings were also mentioned as important ways for researchers to share the results of their research with the wider ag community. One researcher estimated that "I probably write 12 to 14 extension news articles per year, [and do] 20 to 25 winter workshops, three or four field days." The combination of in-person outreach events and news articles was mentioned by several researchers with research-extension appointments.

Social media tools, on the other hand, were only mentioned by a few of the researchers. One stated that after publishing results in a journal, "Now maybe some of these social media things, Twitter, and Facebook, and LinkedIn" can be used to help distribute information. "We never had this available to us when I was a graduate student." ResearchGate was also mentioned as a way to connect with colleagues doing similar work. By entering information on the platform, one researcher mentioned that he gets alerts about what colleagues are doing in similar areas.

In the library community, librarians are expanding their skill sets to assist with sharing and depositing data, and there is much discussion about open data; among researchers interviewed, however, sharing research data is just beginning to get a foothold. Many of our researchers said that they were hearing about new requirements or initiatives to share data, whether from sponsoring agencies or journals, but many interviewees were not clear on exactly what the best strategy might be or what was required, and had not yet deposited their data in a repository. One commented, "With the high profile journals everything is included as supplemental material and so you can see the raw data. You can reanalyze it and I think for transparency, for the scientific process that's really important, and that's a great model."

Cornell's eCommons institutional repository was used by some researchers to store and share data, and others were considering it. For example, one researcher commented, "a lot of times with my students I'm very happy if they can summarize their data, provide a folder that has all the information in it with appropriate [meta]data so that we can go back and track down anything that we would ever want to, but I can see opportunities for that too. Instead of being placed on a departmental hard drive or shared folder, just being placed into eCommons so that not only I can access it or other people in the lab, but other people beyond our group can access it."

Interviewees also mentioned informal data sharing arrangements. “There are journals that I’ve published in that I signed a form that said, if anybody wants your data, you have to give it to them. But I don’t think I ever submitted to that journal that data. I think they didn’t want to have it in a repository,” said one. Another commented on sharing data to use for teaching purposes, where a professor in another university asked for data that students could use for a class project, which he was happy to share.

Several researchers mentioned that their data would not be all that useful in different agro-ecological zones and thus questioned the value of depositing it. One researcher stated, “there is some information, some repository data that the pathologists [create and use], entomology issues on pesticide efficacy, and that’s generally if a pesticide works in one place it’s probably going to work in another place, even though the growing system is a little bit different. But in terms of our performance and fertility practices and all that, it just varies too much from location to location.” Others mentioned the tremendous loss of data that occurs when faculty retire, and years of research data is simply gone, suggesting that data repositories could address this problem.

One researcher suggested that there still seems to be a lingering tradition of holding data close. “I think perhaps it’s just tradition or it’s a thing of the past where people have held their data somewhat closely, and people always talk about, ‘Well, I might publish something else related to that dataset down the road.’ I sort of understand those arguments but I also think that it would be really nice if people were just more transparent, but I am certainly not one to criticize doing that; I don’t typically do that or haven’t done it.” And a similar comment came from another researcher, “In everything I’ve done…and I’ve done hundreds and hundreds of studies, [I] have the attitude that if anybody ever wants the data, I’ll give it to them. There are people that try and keep it proprietary or whatever. Maybe not everything. There might have been some primary data, but I would probably share it with other researchers because I’m pretty open to that. I’m not going to be going back and using that data for publishing or whatever.” But generally the researchers interviewed were supportive of the idea of sharing data through depositing it in a repository. One said, “So that could be very useful, and certainly more useful than having it sit around so that only you see it and it collects dust. But I think we can even take a further step and provide the background material, information, the data that is associated with a summarized journal article and put that in a place where it becomes accessible to other people.”

Agricultural research was described by one researcher as a continuum, linking research and practice. “You do research, [and] you then have to make sure those good results get adopted by farmers otherwise you’re not really making any impact, are you. So the impact comes when farmers adopt it, change their practices, and improve their productivity in a reasonable or sustainable manner.” Regarding this linking of research and practice, we saw two general themes related to research output across the interviews: 1. all researchers are committed to sharing their work through multiple

forms of publication in order to reach both the research and practitioner audiences, and 2. they are moving towards a trend of depositing research data for reuse. Both of these are seen as being in the interest of making the greatest impact on the world's food systems and the need to feed a growing population.

Perhaps one of the biggest takeaways for the library regarding research outputs is that there is a lot we can do to make the sharing of research data easier. As has been noted in other sections, big data is a growing issue for faculty, and they will need support in understanding and compliance with the requirements for data sharing. This would also mean increasing faculty awareness of repositories like eCommons, and making it easier for them to use. Another potential area for library support for research outputs is helping faculty navigate the increasingly complex world of research impact; this could include everything from marketing ORCID ids to providing assistance for researchers measuring and tracking their research impact using tools such as Publish or Perish and Web of Science citation tools. Cornell has created an excellent guide on the subject at http://guides.library.cornell.edu/impact, but there is much additional work to be done helping faculty truly understand all of this.

Final Thoughts

These interviews, conducted across Cornell's College of Agriculture and Life Sciences, offer a number of valuable insights into the research practices of a group of agricultural faculty circa 2016 and into the many possible points of entry for the library to provide needed support and services. The field is (and will continue to be) by its nature diverse, interdisciplinary and collaborative, and its practitioners are driven by a desire to improve agricultural practices and to feed the estimated 9 billion people who will soon call this planet home. They seek to present their research in scholarly journals and at conferences, but are also compelled to share those scientific insights in lay terms for the many stakeholders in the field—including farmers, policy makers, and extension specialists—in non-scholarly venues such as newsletters, extension publications, social media and field days. They also see these outside stakeholders as essential partners in determining the nature and direction of their research. And while technology offers them new and better ways of capturing and manipulating data in the field and in the lab, it also creates a constant need to maintain expertise in these technologies and somehow manage the growing amount of data produced. Clearly, there are many exciting opportunities in this field right now, but with those opportunities come a number of challenges and pain points for the faculty.

Of course, many of the researchers' challenges are outside the library's ability to render assistance; certainly issues related to money, staffing or regulations are outside our purview. However, as noted throughout this report, there are many areas where the library can play a strategic role in helping agricultural faculty overcome the hurdles they face in their research. Every major theme we identify—engaging stakeholders to change practice, interdisciplinarity and collaboration, the impact of changing technology

on agricultural research, the implications of the information age on the inputs of research and on research output and dissemination—has places where the library can and should play a strong (and growing) role. From data management and information visualization to fostering spaces and programs for networking to data and citation management support, the agricultural librarian has many opportunities to help. We hope that this report provides a blueprint for the library and the College of Agriculture and Life Sciences to foster a mutually beneficial relationship between librarians and researchers in the quest to improve agricultural practices and feed a growing planet.

Appendix: Semi-Structured Interview Guide

Research focus
1. Describe your current research focus and how this focus is situated within the broader agriculture discipline and the academy more broadly.

Research methods
1. What research methods do you currently use to conduct your research?

2. What kinds of data does your research typically elicit?

3. How do you locate the primary and/or secondary source materials you use in your research?

4. 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?
5. How do you keep up with trends in your field more broadly?

Dissemination Practices
1. 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?

2. Have you ever deposited your data or final research products in a repository?

    a. If so, which repositories and what has been your motivations for depositing? (i.e. required, for sharing, investment in open access principles)

    b. If no, why not?

Future and State of the Field
1. What future challenges and opportunities do you see for the broader field of agriculture?

2. 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/orthe agriculture discipline that you think it is important for me to know that was not covered in the previous questions?