Publishing Agricultural Data from the Morrow Plots

The Value and Logistics of Preserving a Long-Term Research Experiment

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Abstract – The Morrow Plots at the University of Illinois Urbana-Champaign are the longest-running continuous experimental agricultural fields in the Americas. At iPres 2022 we reported on work to curate, preserve, and visualize planting, treatment, and yield data collected from the plots' nearly 150-year history. This paper provides an update on these efforts over the past year and, with special emphasis on the data's scientific and cultural value, discusses the importance of collaborative and interdisciplinary work within the Morrow Plots stakeholder community to publish the dataset, and identify necessary next steps.

Keywords – data, agriculture, archives, curation, collaboration

Conference Topics – We're all in this together

I. Introduction

The Morrow Plots, located at the University of Illinois Urbana-Champaign, are a set of well-known experimental agricultural fields noted for both their scientific and cultural importance. The plots are the site of a long-term research experiment (LTRE) to test the effects of crop rotation and were established in 1876, making them nearly as old as the university itself. The plots are of such significance that the university's College of Agricultural, Consumer and Environmental Sciences (ACES) is planning a sesquicentennial event in 2026. In preparation for this celebration, the authors became interested in enabling greater access to various materials pertaining to the plots, including the data resulting from this LTRE right in the heart of our campus.

Various kinds of experimental data have been collected from the plots in their long history, but there had not been an attempt to consolidate the data into a single, cohesive, well-documented dataset that could be publicly shared and used by others. At iPres 2022, we reported on our early efforts to establish the "Morrow Plots Data Curation Working Group," a cross-unit collaboration involving the College of ACES, the University Library, and the University Archives [1]. In this paper we describe an update on the group's progress since last year including the recent assembly and publication of a planting, treatment, and yield dataset, which was made possible by blending data and preservation

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expertise with deep disciplinary engagement and knowledge. We describe the various stakeholders involved, their interests in this project, and the data release process, including our efforts to engage stakeholders throughout.

A. A Brief History of Change

In 1876, Professor Manly Miles broke ground on "Rotation Experiment 23" which would later become known as "The Morrow Plots" to test growing conditions for corn, Illinois' most important crop. Every year since, agricultural researchers have planted these plots, located just off the Main Quad, with a combination of corn and other common local crops like oats and clover. Plot divisions allow for comparisons between soil fertility treatments and crop rotation schedules. Over time, the plots have been divided and subdivided as new treatments (for fertility input specifically) were introduced. Although the experiment has continued uninterrupted for over a century, change has been a constant from the beginning.

Shortly after the launch of the experiment, Professor Miles left his post at the University of Illinois. George Espy Morrow, the experiment's namesake, then assumed responsibility in the fall of 1876, only a few months after the beginning of the work earlier that spring. While little is known about the details of this first hand-off, it was by all accounts swift with the termination of Manly Miles' contract in June of 1876 [2] [3]. This turnover of the experiment's leadership would be the first of many in its nearly 150-year history. Since the formation of the Morrow Plots Data Curation Working Group in 2018, stewardship of the plots has changed hands between three different parties. The Morrow Plots are now overseen by the laboratory of Professor Andrew Margenot, current chair of the Morrow Plots Steering Committee (and a co-author of this article).

Each time the Morrow Plots experiment transitioned to a new steward, there was much to be considered as a part of the switch. From the fundamental understanding of the details of the experiment and the nature of its importance, to the recordkeeping and data storage practices employed to ensure the longevity of the experiment's value. These challenges have been repeatedly brought home to us as members of the Morrow Plots Data Curation Working Group. In addition to changes in plot management over time, within the relatively short history of this working group, there have been major changes to administration in our respective colleges as well as changes in working group membership itself as people transitioned on or off the working group in keeping with different roles or jobs. Thus, we recognized early on that stakeholder awareness and engagement would require perpetual attention.

II. STAKEHOLDERS

Given the Morrow Plots' prominence (physically, historically, and culturally), multiple units at the University of Illinois have an interest in the plots, their history, and their associated data (Fig. 1); in particular, the College of ACES and its Department of Crop Sciences, as well as the Library, the Archives, the Funk ACES Library, and the Research Data Service. Individuals within each of these units also have their own lens for considering the value of anything associated with the plots. For example, researchers from Crop Sciences take an active interest in using the plots for research purposes [4], while archivists are interested in ensuring that this important landmark continues to be represented in the history of the university and that data from the plots are preserved and made available for historical and scientific research use [5] [1]. For life sciences librarians, the Morrow Plots are an important facet of collection management, instruction, and research assistance at the University of Illinois [1].

Additionally, communications groups at the college, library, and even university-level are interested in the plots for their ability to demonstrate the value of agricultural research, convey the impact of the university's history, and connect with the public, including hundreds of thousands of alumni, who remember the plots as one of the university's most famous landmarks. Preserving evidence and data from the Morrow Plots and sharing these materials with local communities and the general public is critical to the University of Illinois' role as a land-grant institution.[1] The plots are important not

[1] Land-grant institutions are public colleges established by the Morrill Act of 1862, the first federal investment in higher education in the U.S.: https://www.archives.gov/milestone-documents/morrill-act.

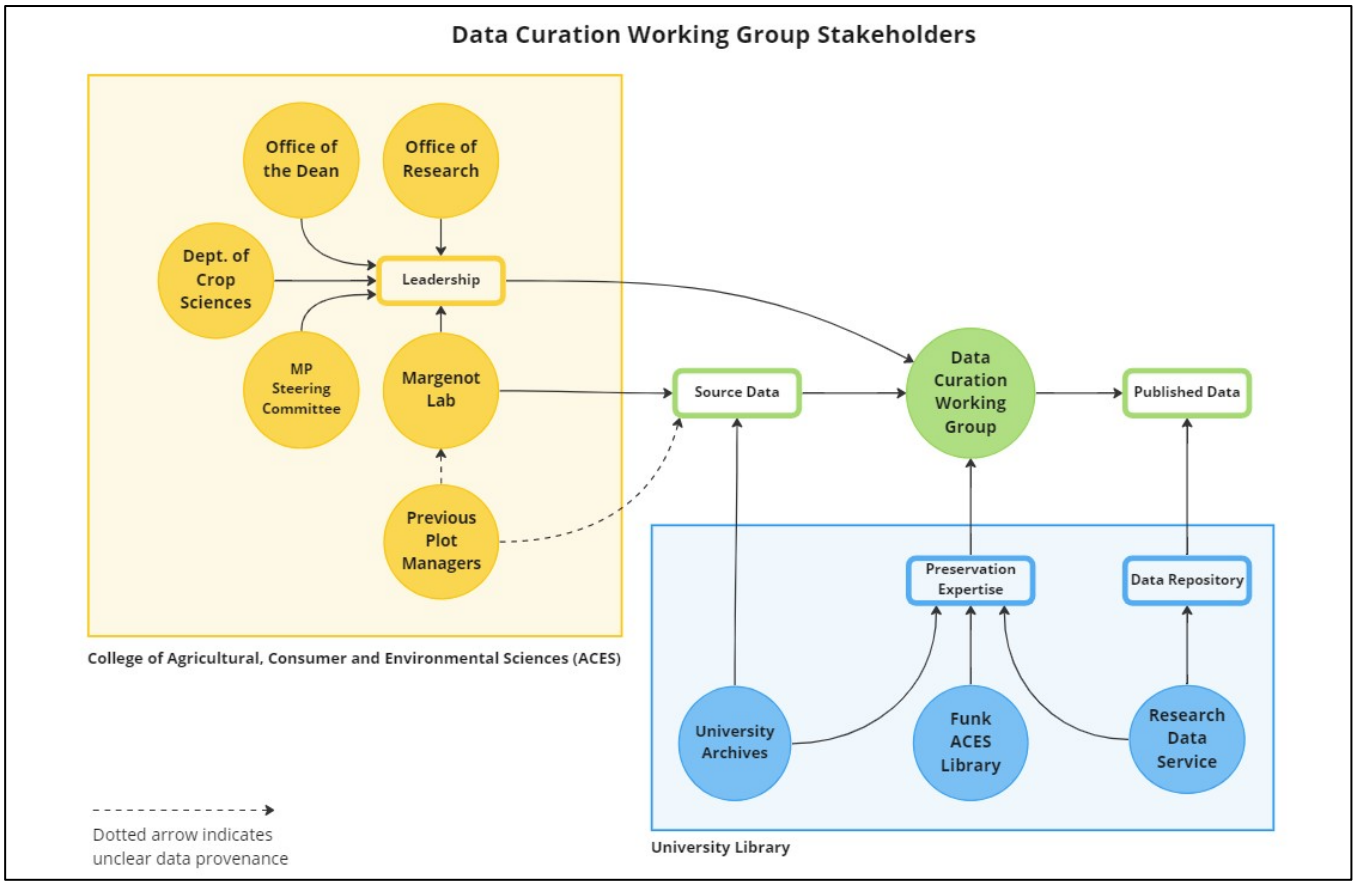

Fig. 1, Data Curation Working Group Stakeholders diagram.

only for agricultural and university history [6], but also for the advancement of agriculture in the state of Illinois and beyond [7]. Bearing in mind this broad array of stakeholders is important when curating and creating access to the plots' data and engaging university and external communities in the history and results of this long-term agricultural experiment.

III. Value Perspectives

A. Agricultural Research

LTREs are few and far between in the agricultural world. These are not necessarily synonymous with agricultural experiments, as there can be LTREs that are ecological in nature (e.g., carbon-enrichment experiments), as evidenced by the National Ecological Observatory Network (NEON) funded by the U.S. National Science Foundation [8]. The U.S. Department of Agriculture funds an 18-site network of long-term agroecosystem research experiments [9], established at the turn of the twentieth century after a crescendo of calls for well-designed, at-scale and intentional long-term evaluation of agroecosystems (LTAR) in the U.S. [10] [11]. However, these federally funded twenty-first century efforts are distinct from and relatively much younger than historical LTREs such as the Morrow Plots. A cluster of these historical LTREs were established with the advent of the land-grant institutions in the late 1800s, several of which continue today as some of the oldest LTREs in the world. In addition to the Morrow Plots – the eldest sibling (1876) - there are the Sanborn Fields at University of Missouri (1888), Magruder Plots at Oklahoma State University (1892), and the Cullars Rotation at Auburn University (1911) [12].

LTREs offer unique insights to the sustainability of agriculture. For example, the oldest continuous agricultural experiment in Rothamsted, United Kingdom, has produced multiple and invaluable insights to the effects of agricultural management practices on soil functions and crop productivity [13]. LTREs offer direct observations of how soils change at timescales beyond typical funding cycles (e.g., 5 years), thereby offering insight to sustainability – inherently a timescale function – at scales not usually assessed. In the case of centennial-scale LTREs, the information gained spans the careers of multiple scientists. Emergent agroecosystem processes and

properties can also be captured by LTREs, because some functions of cropping systems only manifest at multidecadal timescales. For example, changes in soil organic matter or yield stability emerge at timescales that exceed most experimental durations of 5-10 years [14] [15]. Finally, the longitudinal data offered by LTREs, especially in conjunction with auxiliary data (e.g., weather), enables model calibration and validation at a scale that enables backcasting and forecasting at longer time ranges and with higher confidence.

Some have questioned the utility of LTREs such as the Morrow Plots [16] and even Rothamsted [17]. Classic arguments for the constraints of LTREs include:

- Small plot size: as a result of subdividing the already relatively small crop rotation plots into fertility input treatments, the 24 distinctly managed plots that currently make up the Morrow Plots are less than 0.01 ha in area. Small plot size means that observations such as yield may be prone to variability or random effects that decrease sensitivity to treatment effects (e.g., drought) or make a given plot more susceptible to data loss (e.g., rodent damage).
- Replication: preferably randomized, replication is key to enable statistical analyses of response variables. However, the Morrow Plots do not have strict replication of treatments, precluding analysis of variance (ANOVA) for replicated block or complete block designs [16]. On the other hand, longitudinal studies are still enabled [18], as well as approaches such as exploratory factor analyses and multivariate analyses that enable detecting signals in non-replicated treatment plots over time [19].
- Context-dependence: from soil type to climate conditions to geographic region, the insights of a given LTRE will be limited in inference space. This is an issue for any field experiment, which is why a network of LTREs such as the USDA-funded LTAR is essential [9].
- Changes in treatments over time: as with any long-term experiment, changes must be made to treatments to keep pace with current practices, including: crop cultivars (e.g., modern hybrid) or even species (e.g., Morrow Plots switched rotation from oats to soybean to reflect recession of animal draft power by mid-1900s), fertilization approaches (e.g., rates, sources), planting densities, tillage, and pest management. However, strict adherence to the original treatments of any long-term experiment will rapidly make the experiment obsolete (e.g., use of bone meal as a fertility source and open-pollinated maize varieties in the Morrow Plots). For this reason, LTREs around the world have kept pace with changes in specific agricultural practices while maintaining the overall concept of a treatment (e.g., "high fertility input" treatments changing sources and rates over time). In fact, updating treatments to reflect contemporary changes helps identify how advancements in agricultural technologies such as hybrids or fertilization have impacted yields and agroecosystem properties such as soil organic matter content [16] [18] – serving as a living record of such changes.

As with any experiment, there are limitations that must be gauged with benefits for scientific insights. Despite the general and specific limitations, the Morrow Plots still offer unparalleled insights to the long-term impacts of crop rotation and fertility management by virtue of its sesquicentennial duration and the archiving of soils sampled since 1904, including soil organic matter [16], microbiological community composition [19] [20], yields [16] [18] and even soil formation [21] and mineralogy [22] [23]. Additionally, the experiment and its soil archive enable evaluation of non-agricultural biogeochemical processes, such as lead deposition from coal combustion in the early 1900s [24]. A comprehensive description of layout and history of the treatments, site conditions, and yields have been extensively reported elsewhere [18].

Beyond these trade-offs in scientific value, logistical constraints to LTREs include the resources needed to continue experiments. Here, the Morrow Plots are unique in that they have enjoyed strong support from the University of Illinois, no doubt in part from their high visibility as a centrally located and national historical monument site as of 1968 [6] on the campus of the state land-grant university. The relatively small size of the Morrow Plots – a key

disadvantage for its research applications – also incurs a lower maintenance cost. In contrast, a large-scale LTRE such as the University of California Davis Century Experiment (e.g., 1 acre replicate treatments) has high costs of operation, which contributed to the early demise of this hundred-year LTRE in year thirty-three [25].

B. College of Agricultural, Consumer and Environmental Sciences

The University of Illinois has a long history of agricultural education and research, especially related to agricultural experiments. An Agriculture Department was among the university's initial units, and a College of Agriculture was established ten years later in 1877 [26]. Following the Hatch Act of 1887, an Agricultural Experiment Station was established at the University of Illinois to oversee the management of several ongoing and new experiments [27]. Originally known as "Experiment 23," the Morrow Plots was one of these experiments but focused specifically on the effects of crop rotation [28]. Today, it is the second longest-running agricultural experiment in the world, following experiments at Rothamsted, but to the University of Illinois it also holds relevance as a long-term experiment that has roots in ACES's early history and the founding of the university as a land-grant institution.

A search of scholarly outputs that either name or cite research from the Morrow Plots since 2019 returns over one hundred entries, and in varied disciplines from soil science and agronomy to journalism and poetry. The results are not just U.S. or North America centric. Citations and mentions from Europe, South America, East Asia, the Middle East and Africa are also represented. This international scholarly and scientific profile holds significant importance to the University of Illinois and the College of ACES. Because of this reach, the preservation and presentation of the outputs from this LTRE are extremely valuable. In addition to the scholarly impact, the Morrow Plots hold a specific historical and cultural significance to the university community. The "hope that hunger and privation are not the inevitable fate of man," noted in the proceedings of the plots' initiation as a registered National Historic Landmark in 1968 underlines not only the scientific value of the experiment but the aspiration that through scientific research and collaboration we can best the worst challenges of our time [29].

C. University Archives

As the official repository for the University of Illinois, the University Archives has a mandate to broadly document the history and activities of the university. The Archives aims to preserve and make available for research use records and personal papers that capture various facets of life on campus including students' experiences, the work and contributions of faculty, alumni, and staff, and decisions of university administration. As a part of this mandate, the Archives has routinely transferred and preserved records from the University of Illinois' science units and programs. A significant part of the University of Illinois' early history and curricula was focused on agriculture [30], which is due in part to being one of the land-grant institutions that came out of the Morrill Land Grant Acts in the nineteenth century [31].

The University Archives maintains records that shed light on the university's agricultural history as well as the plots' long history as an initial experiment, but also its changing hands over time (and university politics surrounding its significance). The vast majority of the Archives' materials pertaining to the plots are administrative records, and the Archives has a dearth of materials documenting its scientific significance, especially in the form of historical data.[2] In 2019, however, the Department of Crop Sciences transferred a notebook to the Archives containing rotation and yield data spanning from 1876 through 1913, which was subsequently digitized [32]. While this notebook is a significant acquisition that fills this gap in the Archives' holdings, and the Morrow Plots Data Curation Working Group has identified overlapping and later yield data [1], we hope to locate, preserve, and make available other extant data for both historical and scientific research use.[3]

[2] See the Morrow Plots LibGuide for a list of records from the University Archives, https://guides.library.illinois.edu/Natural_and_Applied_Sciences_Archives/Morrow_Plots.

[3] The University Archives has photographic evidence of other notebooks which exist that possibly have additional data. See Agriculture, Consumer, and Environmental Sciences Photograph

Preserving and making available data from the Morrow Plots helps make the case for access to historical data more generally, especially given the long engagement from the scientific community with the plots (as noted above). There are myriad reasons why ensuring broad and public access to historical data (especially longitudinal data) has great benefit to current science as well as to other stakeholders who have historical, administrative, and general interests including research on climate change and ecological shifts over time (e.g., Climate Data Online). Increasingly, researchers are seeking to identify and reuse historical (analog) data, but finding such data in the first place may be difficult [33]. One challenge is that it is not immediately evident where researchers can look for historical data. For example, academic archives in particular have not been actively engaged in curating and preserving data, let alone historical data [34]. The efforts of the Morrow Plots Data Curation Working Group speak to the need to create access to and ensure the archival preservation of historical data, but also underscore the ways in which such a project benefits from collaboration and engagement with a multitude of stakeholders. From an archival perspective, this helps emphasize the need for more historical data to be identified, transferred to an archive or a disciplinary repository, and thoughtfully and carefully curated for public use. Archives have a vital role in this space, especially bearing in mind the value of historical data when appraising scientific records while also enhancing access to historical data already held in their collections. At a land-grant institution like the University of Illinois, ensuring public access to such data helps foster greater engagement with the university's scientific heritage while recognizing other potential and future stakeholders across the State of Illinois and beyond.

D. Research Data Service

As one of the stakeholders in the Morrow Plots Data Curation Working Group, the Research Data Service (RDS) provides campus researchers with the expertise, resources, and infrastructure necessary to responsibly manage and steward data. Housed within the Library and serving the entire campus research community, the RDS provides workshops and guest lectures on data management best practices, reviews the data management plans typically required with grant applications, consults with researchers and labs on policies and procedures, and operates the Illinois Data Bank, an open-access institutional repository for research data and its associated documentation and code.

By aggregating, cleaning, and documenting the plots data, the RDS gained invaluable experience from the process leading up to publication. The experience of curating a historical dataset from a LTRE and navigating the interests of the wide variety of stakeholders involved, prepares us for consultations on datasets and data management plans from other longitudinal projects. This experience can be applied not only within the Illinois research community, but also in the wider Data Curation Network, a national network of data repositories and memory institutions to which the university belongs.

The content of the dataset has clear value to agricultural researchers, but the form of the dataset has value to other researchers as well. In preparing the dataset for publication, great care was taken to clean and format the data according to the Tidy data specifications for improved clarity and interoperability [35]. In the interests of open science, the dataset was also meticulously documented, and the cleaning process recorded both in the codebook published alongside the data and in a GitHub repository containing all of the R code used in the process [36]. The RDS can point to these as a model for data producers in a wide range of fields.

The dataset also lends itself well to educational use. At just over 3,000 rows, the table is easy to open and navigate without special skills or software, and since much of it was manually recorded, it's highly human readable. Additionally, the concepts of planting, fertilization, and yield are easily understandable without background knowledge. Lessons about data management and the associated tools and software require sample datasets. The Morrow Plots data would not only be easy to integrate into the classroom for the reasons listed above, it would also give students opportunities to learn not just about data but also about history and preservation. Finally, exposing the data to a wider

File (Born Digital Records), Record Series 8/1/57, University Archives, https://digital.library.illinois.edu/items/81c58e60-57f3-0134-1dc2-0050569601ca-6.

audience, including students, opens the door to imaginative reuse.

IV. Logistics

A. Publishing the Planting, Treatment, and Yield Dataset

Recent work undertaken by the Morrow Plots Data Curation Working Group included compiling planting, treatment, and yield data covering 1888 to 2021 from three sources: 1) an internal tracking spreadsheet, 2) published yield tables, and 3) an archival notebook. The tracking spreadsheet kept by farm managers provided crop data for 1955 to 2021. As the most detailed of the three sources, the tracking spreadsheet provided the majority of the variables and the basic structure of the compiled dataset. The dataset was extended backward in time with the help of yield tables covering 1888 to 1954 previously published in a 1982 University of Illinois Agricultural Experiment Station Bulletin [21]. The yield table data was highly condensed for print publication, but once teased out, covered many of the same variables in the tracker. It did not, however, include the specific planting dates or the particular crop varieties for those years. As much as possible, these two variables were supplemented by the third source, the handwritten notebook in the University Archives covering 1876 to 1913 [32].

Data from all three sources was imported into RStudio to be cleaned and compiled. Summaries, spot checks, and exploratory data visualizations were used throughout the process to ensure data integrity. The R code used to clean, combine, and format the dataset is publicly available in R Markdown format on GitHub [36]. For more information on the cleaning process, please see our iPres 2022 publication [1]. The working group opted for the Tidy data format for tabular data employing one column per variable and one observation per row [35]. One of the benefits of the Tidy format is that it takes implied information (e.g., color coded text in the Yield variable to designate crop damage) and makes it explicit (e.g., the addition of a separate Damage variable), allowing the dataset to be converted to other formats without data loss. The Tidy format is highly machine readable, making it easier to combine with other datasets. We successfully tested this by linking the compiled data to a fourth dataset, an inventory of soil samples periodically taken from the plots starting in 1904. The result is a TRUE/FALSE variable noting whether a soil sample exists for the corresponding plot and year. The Margenot Laboratory is working to make more information about the soil samples publicly available, and we may be able to provide more detail in future versions of the dataset.

The Illinois Data Bank was a natural fit for publishing the aggregated Morrow Plots dataset where it will be both carefully preserved and freely available to the public. All Illinois Data Bank datasets are assigned a digital object identifier (DOI) registered with DataCite along with additional metadata following the DataCite Metadata Schema for improved discoverability [37]. The completed dataset is published in CSV format along with an extensive codebook [5], making the dataset FAIR (findable, accessible, interoperable, and reusable) [38]. The Illinois Data Bank retains published datasets for a minimum of 5 years and after that as long as the data remains relevant. Given the enduring value of the Morrow Plots experiment and our deliberate decision to share the dataset in preservable formats, we can expect the data to remain in the repository's collection indefinitely.

B. Administrative Approval

Although the Morrow Plots Data Curation Working Group formed with hopes of gathering and sharing data from the Morrow Plots, the first phase was exploratory. It was not clear exactly what outcomes might result, let alone how those outcomes might be distributed and under what conditions. Until viable outcomes could be articulated, it was difficult to imagine, let alone seek approval for, such details. Additionally, there was no formal charge for the group. While the group's work progressed and the aggregate dataset came together, informal conversations were happening with researchers within ACES (via the Morrow Plots Steering Committee) and the then-manager of the plots. Periodic updates were also given to administration in both ACES and the Library. However, an informal conversation is, by definition, unofficial, and once we were ready to release the dataset to the public, it became necessary to make it very clear to leadership exactly what we hoped to do. A misstep at this stage could result in surprised, possibly alarmed, or even angered administrators. Therefore, we opted for a synchronized strategy to update our respective administrators in ACES and the Library and get approval prior to releasing the

data. Since there are multiple draws on an administrator's attention, we made sure our communications were clear, concise, and decision-ready. We waited until we had a completed draft dataset ready for previewing in the Illinois Data Bank so that administrators could evaluate exactly what would be shared. In communications we also highlighted the three trickiest aspects of publishing the dataset: authorship (especially given the many hands that touched the data over the years), licensing, and the potential for negative impacts since, after almost 150 years of data collection, there are gaps in some variables. We encouraged review, offered to meet to discuss, and finally listed the individual administrators being contacted in the other unit so that it was clear who was being consulted. We received swift approval from the Dean of the Libraries while the Dean of ACES first consulted with others in the college. We retained this email correspondence to document the decision.

V. Conclusion

With the initial work of collecting, documenting, publishing, and preserving the Morrow Plots planting, treatment, and yield dataset completed, the working group looks to the future with plans to communicate its availability, develop new resources and relationships for its use as an educational tool, and to celebrate the legacy and impact of the experiment with the stakeholders of the Morrow Plots in a sesquicentennial symposium in 2026. Additionally, efforts are ongoing to uncover and include more data and context materials to enrich the existing data. The working group will also document best practices for curating and preserving Morrow Plots data to ensure long-term stability of the data, especially as the stewardship of the Morrow Plots transitions over time.

Like the initial work, these next steps will require a variety of perspectives and expertise to be successful. No individual or single unit could achieve these outcomes. As working group members, we will continue collaborating and engaging others to further preserve, disseminate and enhance the Morrow Plots data. By coming together, the group members are contributing significantly to preserving and celebrating university history, enabling agricultural research, and improving data education.

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