Characteristics of high-impact agronomic journals

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Abstract
Agronomy journals form a core part of the process of scholarly communication and scientific research in the agronomic field. Determining the key features of high-impact agronomic journals will be a central component for identifying the disciplinary development in the field of agronomy. In this study, we conducted a bibliometric study to fill this knowledge gap based on 64,703 articles published in 18 main agronomy journals since 1948 derived from the Scopus database. Our main findings were that (a) over 20% of publications in Advances in Agronomy and Agricultural and Forest Meteorology received more than 50 citations; (b) authors from the United States, China, the United Kingdom, Germany, and Australia published the most articles in these journals, comprising 22.4, 11.5, 10.7, 8.7, and 8.0% of the total number of publications, respectively; and (c) journals published in a given country had a greater number of papers published by authors of that country than by authors of other countries. Furthermore, three clusters for these 18 journals were identified that included the topics of agronomy, interactions between agronomy and soil sciences, and interactions between agronomy and plant sciences. The results of this study provide valuable insights regarding the current state of and future development trends in agronomic journals.

1 | INTRODUCTION
Agronomy is defined as the application of various soil and plant sciences to improve field management and crop production (Sumberg, Thompson, & Woodhouse, 2013). Agronomy integrates various scientific disciplines and mainly deals with crop calendars, genotypes, plant populations, fertilizers and manures, irrigation, management of biotic and abiotic stresses, climate and weather impacts on agriculture, and development and validation of cropping and farming systems (Rana & Kumar, 2014). Over the last few decades, agronomic research has increased substantially and changed fundamentally in context due to concerns regarding climate change and food security (Ingram, Gregory, & Izac, 2008; Sumberg et al., 2013). Agronomic research appears to be shifting toward fields that depend on large datasets and specialized technology (Makowski, Nesme, Papy, & Doré, 2014; McCallen et al., 2019). New methods, agricultural models, and software platforms continue to be developed regarding various agronomic applications and goals (Folberth et al., 2019; Maes & Steppe, 2019; Shelia et al., 2019). Additionally, some textual analyses (e.g., automated content analysis, meta-analysis, and bibliometric analysis) have been carried out to synthesize results and to identify trends in agronomic research (Cañas-Guerrero, Mazarrón, Pomerina, Calleja-Peruche, & Díaz-Rubio, 2013; McCallen et al., 2019).

In recent years, bibliometric analysis has been broadly applied as a quantitative analysis method (e.g., Li et al.,
In the field of agronomy, Cañas-Guerrero et al. (2013) checked the status and evolution of agronomic research activity using nearly 88,000 publications. Kane, Rogé, and Snapp (2016) compared the development of research on perennial staple crops. In addition, Velasco-Muñoz, Aznar-Sánchez, Belmonte-Ureña, and López-Serrano (2018) explored water use efficiency in agricultural research based on a Scopus database that included 6,063 articles. There are also some bibliometric studies exploring trends in research and publishing for specific agronomic journals (e.g., Thanuskodi, 2012). Currently, there are 87 journals classified in the subject category of “agronomy” in the Journal Citation Reports (JCR) derived from the Institute for Scientific Information Web of Knowledge. An urgent need remains to carry out more comprehensive studies focused on the bibliometric characteristics of high-impact agronomic journals that will provide information to agronomic researchers regarding the key themes and potential bibliometric metric gaps within these journals.

To this end, the objectives of this study were (a) to use bibliometric analysis to summarize the characteristics of high-impact agronomic journals using the general statistics of academic performance, as well as journal author characteristics; (b) to integrate network analysis and cluster analysis methods to identify citation features between journals and co-occurrence of keywords; and (c) to discover potential research topics by surveying the high-frequency keywords.

2 MATERIALS AND METHODS

Bibliographic data were collected from the Scopus database (Scopus, 2019). The retrieval date was 2 June 2019. The bibliometric metrics in 2019 did not represent the actual situation for the full year of 2019. The 18 first quartile (Q1) agronomic journals (Supplemental Table S1) were selected as research subjects based on their impact factors published in the 2018 edition of JCR. A journal’s quartile ranking was determined by comparing it with other journals in its JCR category:

\[ z = \frac{x}{y} \]

where \( z \) is the percentile rank, \( x \) is the journal rank in its JCR category according to the journal impact factor (IF), and \( y \) is the number of journals in its JCR category. The designations Q1, Q2, Q3, and Q4 were classified by \( 0 < z \leq 0.25 \), \( 0.25 < z \leq 0.5 \), \( 0.5 < z \leq 0.75 \), and \( 0.75 < z \), respectively. Journals ranked in Q1 reflected the top 25% of the distribution of IFs. Some journals have evolved over time such that their titles no longer reflected the primary focus of the journal, and their titles have changed. The former names of these journals were not indexed in this study. As noted by McCallen et al. (2019), Global Change Biology Bioenergy, Industrial Crops and Products, and Theoretical and Applied Genetics contains a large proportion of non-agronomy literature and was excluded from this study. Though listed as a book series, Advances in Agronomy was retained in this analysis. “Crop Journal” was the index name of The Crop Journal in Scopus and is used throughout this article. A total of 64,703 papers (articles or reviews) published from 1948 were obtained (Plant and Soil had the longest period covered by Scopus, from 1948).

Before bibliometric indicators were calculated, data were quality checked, duplications were eliminated, and author name disambiguation (AND) was conducted to avoid systematic errors. The procedure of the AND method used both matching of Scopus Author Identifiers and manual disambiguation of Scopus author profiles (Zhang & Yu, 2020). Some quantitative and qualitative parameters for assessing scientific production and impact for journals and for journal authors were calculated in this study to investigate the characteristics of agronomic journals (Table 1). For journals, numbers of publications, citations, \( h \)-index, self-citing rate, and cited half-life were explored. For journal authors, academic age, author type (corresponding author [CA], first author [FA], and supporting authors [SA]), and authors who had never published in these Q1 journals before (defined as novice authors) were also calculated or identified (Zhang & Yu, 2020). Moreover, bibliographic coupling among journals and co-occurrence of author keywords were studied through network and clustering analysis (Boyack & Klavans, 2010). Two journals were bibliographically coupled if they both cited one or more journals in common (Egghe & Rousseau, 2002). Two or more keywords had the relationships of co-occurrence when they appeared in the same article (Chen, Chen, Wu, Xie, & Li, 2016). The more co-occurrence between two keywords, the closer their relationship was. In bibliometric research, clustering has been used to identify groups of related
### Table 1: General description of the calculation and meaning of the measures for investigating the characteristics of agronomic journals

<table>
<thead>
<tr>
<th>Bibliometric metric</th>
<th>Description and calculation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of publications</td>
<td>The most elementary metric for assessing research production of a particular journal.</td>
<td></td>
</tr>
<tr>
<td>Number of citations</td>
<td>The most elementary metric for assessing research impact of a particular journal.</td>
<td></td>
</tr>
<tr>
<td>$h$-index$^{b}$</td>
<td>A numerical indicator intended to represent both the productivity and the impact of a particular journal. It is defined as the highest number of $h$ papers with at least $h$ citations each. For example, a journal with an $h$-index of 10 has published 10 papers, each of which has been cited at least 10 times.</td>
<td>Hirsch (2005)</td>
</tr>
<tr>
<td>Self-citing rate$^{b}$</td>
<td>Self-citing rate related a journal’s number of self-cited articles to the total number of references the journal gave in one calendar year. Journals with high self-citing rates tend to be more specialized and isolated in the relevant fields that had low visibility. For example, a journal has a self-citing rate of 5% in one year, which means 5% of all the references the journal gave are published by this journal itself.</td>
<td>Clarivate (2019); Rousseau (1999)</td>
</tr>
<tr>
<td>Cited half-life$^{b}$</td>
<td>The median publication year of its articles cited during one calendar year. The cited half-life reflected how a journal’s papers were remembered by the scientific community (i.e., their long-term impact). For example, a journal has a cited half-life of 5 yr in one year, which means that 50% of articles cited by other journals have been published by this journal at least 5 yr.</td>
<td>Bornmann and Marx (2016); Clarivate (2019)</td>
</tr>
<tr>
<td>Distribution of academic age of authors$^{b}$</td>
<td>Academic age of an author means the span in years between the first and the most recent article by that author.</td>
<td></td>
</tr>
<tr>
<td>Distribution of author type$^{b}$</td>
<td>All of the journal authors are classified into three types in terms of ultimate authorship role: corresponding authors who have ever served as the authors for correspondence, first authors who are listed as lead authors but have never served as corresponding authors, and supporting authors (other authors).</td>
<td>Milojevic et al. (2018)</td>
</tr>
<tr>
<td>Percentage of publications by novice authors$^{b}$</td>
<td>Percentage of publications by authors who have never published in the first quartile journals before. For example, a journal having 20% of publications by novice authors in one year means that all of the listed authors from these 20% of articles published by this journal first occurred in these 18 top agronomic journals.</td>
<td>Fire and Guestrin (2019); Sekara et al. (2018)</td>
</tr>
</tbody>
</table>

$^{a}$Metric data directly derived from Scopus.
$^{b}$Metric data calculated by R language based on the Scopus dataset.

### Results and Discussion

#### 3.1 General statistics

Table 2 shows the statistical characteristics of articles published in the 18 top agronomic journals. *Advances in Agronomy, Agronomy for Sustainable Development,* and *Agricultural and Forest Meteorology* had the highest IF of 5.073, 4.503, and 4.039, respectively. Most of the journals had IFs within the range of 2 to 4. *Plant and Soil* had the highest number of publications (15,113) and the highest $h$-index (193). Additionally, a large number of authors (28,588), institutions (7,569), and countries/regions (132) participated in research that was published in *Plant and Soil*. Even though *Advances in Agronomy* began publication in 1949, it had a low number of publications (705) due to its irregular publication frequency. *Crop Journal* has been indexed by Scopus only since 2013 and had the least number of articles (343), participating institutions (432), and countries/regions (45). *Rice* presented similar bibliometric characteristics as observed for *Crop Journal*. The high IFs for *Advances in Agronomy* and *Agronomy for Sustainable Development* were likely a result of their large proportion of review publications (27.8 and 36.1%, respectively). *Rice* and *Crop Journal* also had large proportions of review articles.
### TABLE 2  General bibliometric statistics for papers published in the 18 top agronomic journals

<table>
<thead>
<tr>
<th>Journal title</th>
<th>Abbreviation</th>
<th>IF</th>
<th>SY</th>
<th>TP</th>
<th>MCP</th>
<th>RP</th>
<th>TC/TP</th>
<th>h-index</th>
<th>NA</th>
<th>TA/TP</th>
<th>NI</th>
<th>TI/TP</th>
<th>NCO</th>
<th>TCO/TP</th>
<th>TPG/TP</th>
<th>TR/TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advances in Agronomy</td>
<td>Adv. Agron.</td>
<td>5.073</td>
<td>1949</td>
<td>705</td>
<td>0.20</td>
<td>0.278</td>
<td>59565</td>
<td>84.5</td>
<td>140</td>
<td>1536</td>
<td>2.6</td>
<td>685</td>
<td>1.7</td>
<td>51</td>
<td>1.8</td>
<td>50.3</td>
</tr>
<tr>
<td>Agronomy for Sustainable Development</td>
<td>Agron. Sustainable Dev.</td>
<td>4.503</td>
<td>2005</td>
<td>841</td>
<td>0.37</td>
<td>0.361</td>
<td>24564</td>
<td>29.2</td>
<td>75</td>
<td>3368</td>
<td>5.0</td>
<td>1218</td>
<td>2.4</td>
<td>94</td>
<td>3.0</td>
<td>9.4</td>
</tr>
<tr>
<td>Agricultural and Forest Meteorology</td>
<td>Agric. For. Meteorol.</td>
<td>4.039</td>
<td>1984</td>
<td>4829</td>
<td>0.35</td>
<td>0.006</td>
<td>186572</td>
<td>38.6</td>
<td>163</td>
<td>11896</td>
<td>4.7</td>
<td>4249</td>
<td>2.8</td>
<td>112</td>
<td>2.9</td>
<td>12.9</td>
</tr>
<tr>
<td>Plant and Soil</td>
<td>Plant Soil</td>
<td>3.306</td>
<td>1948</td>
<td>15113</td>
<td>0.21</td>
<td>0.018</td>
<td>451358</td>
<td>29.9</td>
<td>193</td>
<td>28588</td>
<td>3.3</td>
<td>7569</td>
<td>1.8</td>
<td>132</td>
<td>1.9</td>
<td>10.7</td>
</tr>
<tr>
<td>Pest Management Science</td>
<td>Pest Manage. Sci.</td>
<td>3.249</td>
<td>2000</td>
<td>3777</td>
<td>0.25</td>
<td>0.06</td>
<td>73746</td>
<td>19.5</td>
<td>96</td>
<td>12236</td>
<td>4.8</td>
<td>3116</td>
<td>2.2</td>
<td>102</td>
<td>2.5</td>
<td>7.7</td>
</tr>
<tr>
<td>European Journal of Agronomy</td>
<td>Eur. J. Agron.</td>
<td>3.192</td>
<td>1993</td>
<td>1871</td>
<td>0.31</td>
<td>0.019</td>
<td>53743</td>
<td>28.7</td>
<td>93</td>
<td>5632</td>
<td>4.6</td>
<td>2024</td>
<td>2.2</td>
<td>105</td>
<td>2.6</td>
<td>10.4</td>
</tr>
<tr>
<td>Agricultural Water Management</td>
<td>Agric. Water Manage.</td>
<td>3.182</td>
<td>1976</td>
<td>4978</td>
<td>0.30</td>
<td>0.019</td>
<td>114459</td>
<td>23.0</td>
<td>113</td>
<td>12159</td>
<td>4.1</td>
<td>3884</td>
<td>2.2</td>
<td>107</td>
<td>2.3</td>
<td>11.4</td>
</tr>
<tr>
<td>Field Crops Research</td>
<td>Field Crops Res.</td>
<td>3.127</td>
<td>1978</td>
<td>4983</td>
<td>0.35</td>
<td>0.02</td>
<td>151799</td>
<td>30.5</td>
<td>137</td>
<td>12083</td>
<td>4.5</td>
<td>3660</td>
<td>2.3</td>
<td>125</td>
<td>2.5</td>
<td>10.8</td>
</tr>
<tr>
<td>Postharvest Biology and Technology</td>
<td>Postharvest Biol. Technol.</td>
<td>3.112</td>
<td>1991</td>
<td>3748</td>
<td>0.25</td>
<td>0.016</td>
<td>128457</td>
<td>34.3</td>
<td>128</td>
<td>8260</td>
<td>4.4</td>
<td>2527</td>
<td>2.0</td>
<td>80</td>
<td>2.1</td>
<td>8.5</td>
</tr>
<tr>
<td>Rice</td>
<td>Rice</td>
<td>3.039</td>
<td>2008</td>
<td>447</td>
<td>0.34</td>
<td>0.101</td>
<td>7349</td>
<td>16.4</td>
<td>39</td>
<td>2304</td>
<td>7.3</td>
<td>610</td>
<td>3.1</td>
<td>46</td>
<td>3.1</td>
<td>4.2</td>
</tr>
<tr>
<td>Crop Journal</td>
<td>Crop J.</td>
<td>2.658</td>
<td>2013</td>
<td>343</td>
<td>0.24</td>
<td>0.082</td>
<td>2288</td>
<td>6.7</td>
<td>19</td>
<td>1818</td>
<td>6.5</td>
<td>432</td>
<td>2.4</td>
<td>45</td>
<td>2.5</td>
<td>8.9</td>
</tr>
<tr>
<td>Journal of Agronomy and Crop Science</td>
<td>J. Agron. Crop. Sci.</td>
<td>2.571</td>
<td>1973</td>
<td>2211</td>
<td>0.18</td>
<td>0.04</td>
<td>30391</td>
<td>13.7</td>
<td>64</td>
<td>4556</td>
<td>3.3</td>
<td>1519</td>
<td>1.9</td>
<td>90</td>
<td>2.0</td>
<td>8.5</td>
</tr>
<tr>
<td>Plant Pathology</td>
<td>Plant Pathol.</td>
<td>2.303</td>
<td>1952</td>
<td>5927</td>
<td>0.20</td>
<td>0.039</td>
<td>87677</td>
<td>14.8</td>
<td>86</td>
<td>12091</td>
<td>3.4</td>
<td>3349</td>
<td>1.7</td>
<td>125</td>
<td>1.9</td>
<td>6.9</td>
</tr>
<tr>
<td>Archives of Agronomy and Soil Science</td>
<td>Arch. Agron. Soil Sci.</td>
<td>2.254</td>
<td>1962</td>
<td>2444</td>
<td>0.13</td>
<td>0.012</td>
<td>9368</td>
<td>3.8</td>
<td>31</td>
<td>5318</td>
<td>3.2</td>
<td>1953</td>
<td>1.8</td>
<td>93</td>
<td>1.9</td>
<td>12.1</td>
</tr>
<tr>
<td>Journal of Plant Nutrition and Soil Science</td>
<td>J. Plant Nutr. Soil Sci.</td>
<td>2.163</td>
<td>1996</td>
<td>2155</td>
<td>0.29</td>
<td>0.037</td>
<td>40971</td>
<td>19.0</td>
<td>76</td>
<td>5363</td>
<td>3.8</td>
<td>1974</td>
<td>2.1</td>
<td>97</td>
<td>2.2</td>
<td>8.1</td>
</tr>
<tr>
<td>Molecular Breeding</td>
<td>Mol. Breed.</td>
<td>2.077</td>
<td>1995</td>
<td>2551</td>
<td>0.34</td>
<td>0.018</td>
<td>63682</td>
<td>25.0</td>
<td>97</td>
<td>11385</td>
<td>6.5</td>
<td>2658</td>
<td>2.6</td>
<td>87</td>
<td>2.8</td>
<td>8.2</td>
</tr>
<tr>
<td>Weed Science</td>
<td>Weed Sci.</td>
<td>2.044</td>
<td>1973</td>
<td>2573</td>
<td>0.12</td>
<td>0.016</td>
<td>55101</td>
<td>21.4</td>
<td>83</td>
<td>3938</td>
<td>3.6</td>
<td>1283</td>
<td>2.0</td>
<td>63</td>
<td>2.1</td>
<td>7.6</td>
</tr>
<tr>
<td>Crop Protection</td>
<td>Crop Prot.</td>
<td>1.920</td>
<td>1982</td>
<td>5196</td>
<td>0.22</td>
<td>0.042</td>
<td>83201</td>
<td>16.0</td>
<td>87</td>
<td>13307</td>
<td>3.9</td>
<td>3784</td>
<td>2.0</td>
<td>128</td>
<td>2.2</td>
<td>7.1</td>
</tr>
</tbody>
</table>

Note: IF, journal impact factor retrieved from the 2018 edition of Journal Citation Reports; MCP, proportion of international collaboration publications; NA, NI, and NCO, numbers of authors, institutions, and countries/regions after merging duplicates, respectively; RP, proportions of review publications; SY, starting year covering by Scopus; TA/TP, authors per publication; TC, total number of citations; TC/TP, citations per publication; TCO/TP, countries/regions per publication; TI/TP, institutions per publication; TP, total number of publications (articles or reviews); TPG/TP, pages per publication; TR/TP, references per publication.
(10.1 and 8.2%, respectively), which may have led to their increasing academic influence in the early years since their foundation (Uzun, 2017). In contrast, most of the other journals published review articles, which accounted for only about 2% of their total publications.

*Agronomy for Sustainable Development*, *Agricultural and Forest Meteorology*, and *Field Crops Research* had the highest proportions of international collaboration publications (0.37, 0.35, and 0.35, respectively). In contrast, *Weed Science* had the lowest proportion (0.12). Gazni and Ghasemini (2016) indicated that older journals were more international than the newer ones, but research field differences also existed. *Advances in Agronomy* and *Agricultural and Forest Meteorology* also ranked first and second with respect to citations per publication (84.5 and 38.6, respectively). The number of authors, institutions, and countries per publication varied among journals, with values of 2.6, 1.7, and 1.8, respectively, for *Advances in Agronomy* and values of 7.3, 3.1, and 3.1 for *Rice*. Moreover, *Advances in Agronomy* had the largest number of pages (50.3) and references (120.8) per publication, again because *Advances in Agronomy* published a high percentage of review articles and book series by inviting submissions from authors.

Citation frequency distributions for the 18 top agronomic journals can be seen in Figure 1. The proportion of papers that were cited more than 100 times was higher for *Advances in Agronomy* (25.5%) and *Agricultural and Forest Meteorology* (8.2%) than for the other journals. For *Archives of Agronomy and Soil Science*, 91.5% of its total publications were cited fewer than 10 times, and 35.3% of its total publications had not received any citations. This journal is published by Taylor & Francis (some Taylor & Francis journals have not been included in Scopus), and 35.6% of its articles were published in German, perhaps resulting in a slight underestimation of number of citations by Scopus (Hardcastle, 2011). *Crop Journal* also produced a larger proportion of publications (82.5%) that were cited fewer than 10 times. However, this journal began publication in 2013, so it would have been difficult to accumulate large numbers of citations.

The numbers of publications per year increased over time for most of the 18 top agronomic journals (Figure 2a). *Plant and Soil* had the highest number of publications per year, reaching a peak of 538 in 2013. *Advances in Agronomy*, *Plant and Soil*, and *Weed Science* showed higher values (>10) of cited half-life in the most recent 5 yr (2015–2019) (Figure 2b). This meant that even after 10 years 50% of the articles published in these journals were still being cited, indicating the importance and long-term impact of these journals. As a new journal, *Crop Journal* showed the lowest level of cited half-life. In comparison, Davis and Cochran (2015) reported that the mean cited half-life of papers published in the 704 agronomy journals listed in the JCR from 1997 through 2013 was 8.12 yr and growing at a rate of 0.07 yr per annum. *Weed Science* showed the highest self-citing rate (~20%) since 1970 (Figure 2c). This phenomenon could partly explain the high cited half-life of *Weed Science*. The time span was selected as the complete citation information provided by Scopus since 1970. Journals with high self-citing rates usually had shorter periods of publication and were older, had more publications,
received more citations, and were cited more by themselves than low self-citing journals (Tsay, 2006).

3.2 Journal author characteristic analysis

For the 18 top agronomic journals, academic age of authors and author type showed great differences from journal to journal (Figure 3a,b). On the one hand, averaged across the 18 top agronomic journals, most researchers had conducted research for 1 yr (68.6%) or for more than 11 yr (9.9%) (Figure 3a). Researchers who had an academic age of 1 yr were mainly SAs and were authors of only one article. Only Advances in Agronomy and Weed Science had a mean academic age of more than 5 yr (5.97 and 5.16 yr, respectively). Most of the journals that had longer publication years had a larger proportion of researchers who had an academic age of more than 11 yr. Crop Journal and Rice had the lowest mean academic age of 2.01 and 2.15 yr, caused by the shorter length of publication years for those two journals and larger proportion of researchers who had an academic age of 1 yr. On the other hand, Postharvest Biology and Technology had the smallest proportion of CAs (0.9%) and a larger proportion of FAs (30.7%), whereas some journals that had longer publication years had larger proportions of CAs (e.g., Archives of Agronomy and Soil Science, Plant and Soil, and Agricultural and Forest Meteorology). Weed Science and Advances in Agronomy had the largest proportion of CAs (35.9 and 35.4%, respectively). Rice had the largest proportion of SAs (96.3%). Some other new journals (e.g., Crop Journal and Agronomy for Sustainable Development) also had large proportions of SAs. In the most recent decade, Agronomy for Sustainable Development, Archives of Agronomy and Soil Science, and Crop Journal published a larger proportion of publications by novice authors who
had not previously published in the 18 top agronomic journals (Figure 3c). In contrast, Weed Science had the lowest percentage of publications by novice authors. Advances in Agronomy also had a lower percentage of publications by novice authors due to the large proportion of review publications. Sekara et al. (2018) found that an individual of a research team was unlikely to appear as a senior author of a paper published in a high-impact journal if he or she lacked experience in crafting scientific work and had not previously published in one of these journals. Overall, larger proportions of high researchers’ academic age and CAs would lead to a lower percentage of publications by novice authors for agronomy journals.

3.3 National analysis

The publication statistics for the top 20 publication-producing countries/regions in the 18 top agronomic journals are shown in Figure 4. The United States published the most articles in most journals, especially in two American journals, Advances in Agronomy (under the auspices
of the American Society of Agronomy) and Weed Science (under the auspices of the Weed Science Society of America). France and Germany had the highest numbers of publications in their own journals: Agronomy for Sustainable Development (published by the French National Institute for Agriculture, Food, and Environment) and Journal of Plant Nutrition and Soil Science (published by the German Societies of Plant Nutrition and Soil Science). China likewise dominated the publications in the Chinese journal, Crop Journal, published on behalf of the Crop Science Society of China and Institute of Crop Sciences, Chinese Academy of Agricultural Sciences. The majority of research published in the European Journal of Agronomy came from European countries (Cañas-Guerrero et al., 2013). Some major rice-producing countries (e.g., China, Japan, the United States, and the Philippines) contributed most of publications in Rice (Cañas-Guerrero et al., 2013). Liu, Zhang, and Wang (2017) also indicated that China, Japan, and the United States were the most productive countries regarding rice research. The International Rice Research Institute in the Philippines ranked first in research institutions with the most publications and total citations. As the major crop producers, these countries, as well as Australia and India, also published a large number of articles in Field Crops Research. These results also reflected different food and scientific strategies across countries (Arvanitis & Chatelin, 1988).

### 3.4 Journal network analysis

Figure 5 shows the bibliographic coupling network for the 18 top agronomic journals. The time span for this cluster analysis was from 2013 to 2019 because 2013 was the starting year for Crop Journal to be indexed by Scopus. The 18 journals were classified into three clusters according to the journals’ topics, which were focused on agronomy (Cluster 1), interactions between agronomy and soil sciences (Cluster 2), and interactions between agronomy and plant sciences (Cluster 3). A wide range of bibliographic coupling between these journals was represented. Journals in the same cluster were more closely connected. Plant and Soil played a very important academic role and was bibliographically coupled with other journals frequently, especially with Journal of Plant Nutrition and Soil Science, Agricultural and Forest Meteorology, and Field Crops Research. Agricultural and Forest Meteorology, Agricultural Water Management, European Journal of Agronomy, and Field Crops Research were closely linked in their cluster (Cluster 1).

### 3.5 Keyword analysis

The high-frequency keywords found in publications for the 18 top agronomic journals in past three decades are listed...
FIGURE 5  Bibliographic coupling network for the 18 top agronomic journals from 2013 to 2019. Clusters of journals are shown by different colors. Greater numbers of publications in specific journals are shown with larger circles. Greater bibliographic couplings (i.e., the number of references that the two journals had in common) of journals are shown with thicker lines.

in Supplemental Table S2. In general, the research interests of these journals changed with advancing time, and different journals had different research emphases. Some cereal crops, such as "wheat" (1,455), "maize" (1,028), and "rice" (1,228), and "yield" (1,014), were the keywords that occurred most frequently for these 18 journals over the 1989–2019 period, implying that these keywords had become increasingly important.

For journals in Cluster 1, research topics mainly centered on some main crops and their yield, evapotranspiration, and irrigation. The research topics for Agricultural and Forest Meteorology changed during these three decades, and some new keywords emerged in recent years (e.g., "climate change" [131] and "remote sensing" [78]). Moreover, "eddy covariance" and "evapotranspiration" were the highest-frequency keywords. "Eddy covariance" refers to a micro-meteorological method to directly measure net ecosystem exchange, evapotranspiration, and carbon and water fluxes at the ecosystem level (Wilson, Hanson, Baldocchi, & Wullschleger, 2001; Xiao et al., 2013). European Journal of Agronomy and Field Crops Research had highly similar author keyword patterns, which focused on crop yield and nitrogen use. Research reported in Agricultural Water Management focused on addressing questions regarding irrigation and water use in agriculture. Drought stress effects on crop production became a recurring research focus in Journal of Agronomy and Crop Science in the most recent decade.

Research reported in Cluster 2 journals dealt with the benefits of soil fertility to crop growth as a core research issue. Plant and Soil, Archives of Agronomy and Soil Science, and Journal of Plant Nutrition and Soil Science had keywords dealing with soil nutrients and crop rhizosphere in common. Plant rhizosphere describes the key zone of soil nutrient uptake and interactions between plants and soils (Shen et al., 2013). In addition, sustainable agriculture was the most frequently used keyword for Agronomy for Sustainable Development, which integrated multiple areas of science to develop new farming practices for solving issues related to climate change and food production (Lichtfouse et al., 2009). The use of this keyword also revealed the authors’ likely strategy to fit their paper into the journal’s scope. Advances in Agronomy had no clear frequently used keywords.

For journals in Cluster 3, crop resistance to pests, weeds, and diseases was the research focus in Pest Management Science, Plant Pathology, Weed Science, and Crop Protection. Quantitative trait locus mapping was one of the most effective tools used for estimating the locations, numbers, magnitude of phenotypic effects, and modes of gene action of individual determinants that contribute to the inheritance of continuously variable traits (Paterson, 2002). This research area has become the center of research reported in Molecular Breeding and Rice. As expected from the journal title, “rice” was the most frequently used research keyword in Rice. In the period of 2009–2019, Crop Journal conducted research on the main field crops. For Postharvest Biology and Technology, “ethylene” was the most frequently used keyword. Ethylene is a key hormone associated with the ripening process (Zhang, Cheng, Wang, Khan, & Ni, 2017).

To identify the up-to-date research advances in agronomy, the co-occurrence of the top 33 author keywords that occurred more than five times derived from publications cited ≥50 times for the 18 top agronomic journals from 2013 to 2019 are shown in Figure 6. This time span was selected because Crop Journal was first indexed by
Scopus in 2013. The keywords “climate change,” “food security,” “water use efficiency,” “maize,” and “nitrogen” occupied core positions relative to all other keywords, with the strongest connections between them. These 33 keywords were classified into five clusters, which revealed some important research topics: “crop evapotranspiration/water use,” “food security under climate change,” “agricultural drought,” “crop yield potential/gap,” and “crop yield and soil nutrition.” Pereira, Allen, Smith, and Raes (2015) argued for the importance of studying and improving the accuracy of crop evapotranspiration computations for agricultural and other land use types by adjusting evapotranspiration for the impacts of surface mulching, intercropping, sparse vegetation, and soil salinity. Based on a detailed review of research dealing with estimating yield gaps, van Ittersum et al. (2013) recommended a tiered approach with the use of crop growth simulation models and emphasized the importance of accurate agronomic and yield data for calibrating and validating crop models and improving upscaling methods. Bodner, Nakhforoosh, and Kaul (2015) reviewed the main climate, soil, and crop properties and the processes that determine yield and derived corresponding management measures for cropping systems under different drought conditions. In addition, some critical methods and techniques, such as “eddy covariance,” “biochar,” “remote sensing,” and “meta-analysis,” were widely applied in agronomic research (Figure 6). Xiao et al. (2013) synthesized observations from 22 eddy covariance flux sites and indicated annual carbon fluxes, evapotranspiration, and water use efficiency of terrestrial ecosystems exhibited clear latitudinal patterns in China. Alburquerque et al. (2013) verified the effects of biochar on the growth and yield of wheat, combined with different mineral fertilization levels. This study indicated that, at the highest mineral fertilizer rate, addition of biochar enhanced wheat production compared with the use of the mineral fertilizer alone. Remote sensing data could be used to develop empirical models for predicting crop yield and for mapping crop evapotranspiration and drought (e.g., Bolton & Friedl, 2013; Pereira et al., 2015). Moreover, meta-analysis could be used to quantify the effect of agricultural management measures on crop productivity using data obtained from peer-reviewed publications, providing a quantitative systematic review through the application of statistical analysis of the cumulative dataset (Liu et al., 2013; Pittelkow et al., 2015).

3.6 Study limitations and future work

Some limitations should be noted regarding this study. (a) The coverage of Scopus is not comprehensive enough in the field of agriculture because it tends not to include some main agronomy topics of interest for low-income countries (Rafols, Ciarli, & Chavarro, 2015). Furthermore, Scopus provides the SCImago Journal Rank indicator to measure the impact or prestige for journals in the selected year. However, in this study, JI factor and JCR quartiles obtained from the Web of Science Core Collection were still adopted because of the early initial publication year.
(1975) and widespread acceptance of some of the journals in the scientific world (Falagas, Kouranos, Arençibia-Jorge, & Karageorgopoulos, 2008). Consequently, some journals that had good prestige and high SCImago Journal Rank indicator (e.g., *Agronomy Journal* and *Irrigation Science*) were not included in this study. Some data mismatches between Scopus and Web of Science existed due to the different journal coverage and total citations. (b) Although we performed some additional consideration regarding author names during the matching of Scopus Author Identifiers and manual disambiguation, the AND method used in this study may have resulted in errors and caused miscounts on some bibliometric metrics for partial Scopus author profiles (Zhang & Yu, 2020). (c) The determination of author type and academic age may have been misestimated because some authors may have additional publications in journals other than the 18 surveyed in this study (Milojevic, Radicchi, & Walsh, 2018). (d) Some early articles were written in German and French (14, 169, 28, 869, and 199 articles in *Agricultural and Forest Meteorology*, *Plant and Soil*, *Journal of Agronomy and Crop Science*, *Archives of Agronomy and Soil Science*, and *Journal of Plant Nutrition and Soil Science*, respectively) and have non-English citations, which may have resulted in misestimating the self-citing rate, cited half-life, and bibliographic coupling of these journals (Hardcastle, 2011; Liu et al., 2014). Moreover, there were some early articles published in some journals (e.g., *Plant and Soil*) that were not recorded by Scopus with integrated bibliographic information and references, which may have influenced the calculation of self-citing rate, cited half-life, and bibliographic coupling (Hardcastle, 2011).

Some questions were raised by the results of this study. Are there obvious benefits when authors publish their papers in journals under the auspices of their own institutes? Does the cost of publication influence the choice of journals (e.g., *The Crop Journal* and *Rice* are open-access journals)? Furthermore, does self-citing rate have an important effect on other bibliometric metrics of journals? Do novice authors prefer to contribute their scholarly works to new journals? Future research into academic journals should focus on developing methods to obtain accurate bibliometric metrics to avoid these limitations and to answer these questions.

## 4 CONCLUSIONS

In this study we observed that bibliometric characteristics and research keywords for agronomic journals were obviously changing with time. Some similar conclusions were reached by this study and Cañas-Guerrero et al. (2013). For agronomic researchers, bibliometric metrics of journals deserve attention for deciding where to submit a manuscript for publication. Some agronomic journals (e.g., *Crop Journal*) should attract more international manuscripts and increase the publication rate of foreign papers, some journals (e.g., *Weed Science*) should broaden their appeal and offer opportunities to young researchers, and some journals having higher self-citing rates should widen their interested scope of journals. Further understanding and development are needed regarding multidisciplinary and big-data systems (e.g., remote sensing and precision agriculture) in future agronomic research.

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## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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## REFERENCES


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