The Status and Patterns of Open Access in Research Output of Most Productive Indian Institutions

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ABSTRACT
Open Access is emerging as an important movement worldwide since last few years, triggered mainly by the high subscription cost of pay walled journals that create barriers in universal dissemination of knowledge reported in those journals. The paywall barriers to access of knowledge has become so problematic that even institutions in the developed countries are not only cancelling subscriptions but also mandating it for their researchers to either publish in open access journals or at least deposit their research papers in Institutional Repositories. The high subscription cost of journals is a more serious issue for developing countries, as it takes away institutional resources that can be used for other productive purposes. India has taken several steps in promoting open access, including release of an open access policy by Ministry of Science and Technology, however, it is not very clear that how effective these initiatives have been. This paper intends to address this issue. It examines published output, indexed in Web of Science, from 100 most productive institutions in India and analyze how much research output coming from them are available in Open Access (OA). The paper further analyzes availability of research papers from these institutions in the popular pirate site Sci-Hub. It is interesting to observe that legal OA percentages are significantly lesser than the Sci-Hub availability for all the institutions, an indication that the existing systems for promoting open access in India are not working efficiently. At the end, the paper also presents statistics about number of papers deposited in three central institutional repositories in India. These statistics provides an indication of the extent to which these repositories have been able to promote open access in India. The paper concludes by pointing to some factors that impede Open Access in India.

Keywords: Open Access, Sci-Hub, Unpaywall, Gold Open Access, Green Open Access, Black Open Access, Institutional Repository.

INTRODUCTION
The increasing subscription cost of journals from large publishing houses is becoming a severe deterrent in universal open access to knowledge. Not only institutions in developing countries are finding it difficult to pay these costs but several institutions in the developed world are also cancelling subscriptions of many journals. Many top Universities in the world are now asking their researchers to publish in open access journals so as to make the knowledge generated accessible, without barriers, to the world. Institutions are creating Institutional Repositories (IRs) to keep copies of papers published by their researchers in different journals. The top funding research organizations of the world are now making it mandatory for their researchers to submit pre- or post-print of their research papers in different repositories, either institutional or disciplinary. Organizations like US National Institutes of Health, US National Science Foundation, Welcome Trust, Bill and Melinda Gates Foundation, the European Commission etc. are some examples. Further, almost all major publishing house are allowing submission of papers that have been earlier submitted as pre-print in repositories.

India has also tried to move towards Open Access, both through efforts at the national level as well as at the institutional level. Open Access culture in India was initiated by Indian physicists back in the early 90s when they started depositing their preprints in arXiv. Later, they were joined by Mathematicians, Computer Scientists, Biologists etc. Since then there have been several initiatives taken, though the
impact was not as expected. Some of these early initiatives include Mirror server for arXiv set up by Institute of Mathematical Sciences (IMSc) at Chennai, the Vidyanidhi Digital Library for electronic thesis and dissertations from the university of Mysore in 2002[1] and EPrints@IISc electronic repository by Indian Institute of Science, Bangalore in 2002.[2] The open access and open educational resources were discussed by the National Knowledge Commission in a report in 2007.[3] In 2009, CSIR headquarters sent a memorandum to all of its 38 laboratories in the country to set up institutional open access repositories, as detailed ahead. The work of Das[4] and Arunachalam and Muthu[5] can be referred to know about initial open access initiatives and projects in India.

The Government of India’s most recent effort in this direction was the release of the Department of Biotechnology (DBT) and Department of Science and Technology (DST) Open Access Policy in 2014.[6] The DBT and DST, the two main research Departments of the Ministry of Science and Technology of Government of India have jointly issued the policy. It states that “since all funds disbursed by the DBT and DST are public funds, it is important that the information and knowledge generated through the use of these funds are made publicly available as soon as possible...”. The fundamental guiding principal of this policy is the fact that public funded research outcomes should be publicly available. The policy also envisaged that open access would allow percolation of cutting-edge research in Higher Education curricula, which in turn will raise the standards of technical and scientific education in the country. Through the policy, institutions were encouraged to setup institutional repositories (IRs) and to deposit all their research outcome in them. A central harvester sciencecentral.in was also created and it was expected that all institutional repositories would eventually link to it. All institutions receiving funds from DBT and DST are expected to mandatorily follow the policy.

In another similar step, the open access mandate[6] has been issued by Council of Scientific and Industrial Research (CSIR) which instructs the setup of interoperable institutional open access repositories at all CSIR laboratories. Through this mandate CSIR took the initiative to “lead the open access movement within the country”. The csircentral.net established by CSIR-URDIP is the central harvester that is expected to link different institutional repositories created by individual CSIR labs. The Indian Council of Agriculture Research (ICAR) has also created an open access policy,[2] which required setting up of open access institutional repository by each ICAR institute. It has also setup a one stop access platform, to provide access to all the agricultural knowledge generated in ICAR, known as Krishikosh.[3] In 2018, the Delhi Declaration on Open Access[3] was signed by a group of academician and open access enthusiasts, which advocated for “the practice of open science” and “adoption of open technologies for the development of models for sharing science and scholarship”. The IndiaRxiv[6] of the Open Science project is the most recent addition to the open access cause. Open Access India has initially launched AgriXiv, a preprints repository for agriculture and allied sciences and then launched IndiaRxiv. However, this preprints repository has only 67 preprints available as on 16th Feb 2020, since its launch in April 2019 and is yet to pick its momentum.

Despite all these initiatives and efforts, India has somehow lagged behind in ensuring open access to its research output. There are no proper estimation of the research emerging from Indian institutions which is in open access. It is in this context that this paper tries to measure the current status of open access in research output from 100 most productive institutions in India. These institutions provide a good estimation of research available in Indian institutions in open access as they together account for about 82% of the total research output from India for the year 2016 as indexed in Web of Science. Papers covered in WoS are regarded as a benchmark of quality by several institutions and there is a general tendency for researchers to access papers that are in this database. To provide another perspective and complement this study, a detailed examination of volume of research papers in various institutional repositories (IR) in India is also examined.

In addition to computing open access levels of research output indexed in Web of Science and in institutional repositories in India, the study also present statistics of availability of these papers in Sci-Hub. Sci-Hub provides a questionable route for access to scientific papers as it ignores copyright clauses to allow users to download papers which are not openly licensed content. Our motive at examining paper availability in SCI-Hub is not an endorsement of this type of database but to underscore that lack of Open Access may lead to these types of behaviors. Apart from this it can lead to legal consequences for readers, authors and institutions to which they are affiliated, if they use this approach.

The paper focusses on three questions:

First, how much scholarly research output from the 100 most productive Indian Institutions is available in legal (such as gold, green and bronze) and black access models?

Second, how much research output is available in open access through IRs in India?

Third, what are the plausible factors that impede open access in India?

**Open Access Types**

There exist multiple forms of open access. Some journals are absolutely free and completely open access, where articles are
freely available to everyone. Then, there are paywalled journals that requires reader to pay before accessing the article. But these journals may also make some articles freely available to everyone, either after payment of an article processing charge or after a particular period from publication date. Open access articles are classified into following main categories based on the levels and types of open access:

**Gold open access:** This refers to an article which is freely available for everyone as it is published in a journal that is open access. Generally, the Directory of Open access Journals (DOAJ) includes qualitative open access journals, after a self-nomination and evaluation process. In this type of open access, copyright is usually retained by the authors.

**Green open access:** This refers to articles which are accessible free of cost as they are uploaded on some repository (either institutional or disciplinary), though they may be published in pay walled journals. However, the reuse rights are restricted in such case and in most of the cases, the articles can be uploaded on such a repository after a certain period of time from their publication in the journal (varying from 6 to 48 months).

**Hybrid open access:** This refers to an article which becomes open access after an article processing charge is paid (along with some agreement with the journal) by the authors or their institution. Such articles are published in closed journals.

**Bronze open access:** This refers to an article which is freely available to read but without a license.

**Black open access:** This refers to an article that is shared on illegal pirate sites, such as Sci-Hub or LibGen. However, this type is not well recognized as open access in the literature.

**Closed access:** This refers to all other articles that are not openly accessible in legal forms. The copyright is with the publisher and readers need to pay to access the paper.

**Related Work**

There exist several previous studies that tried to understand and characterize open access (OA) patterns in research outputs at the international level. Hajjem et al. is one of the earliest studies to have analyzed open access availability of articles and found that OA articles have comparatively more citations than non-OA ones. Bjork et al. through their multiple studies during 2010 to 2017, analyzed the open access patterns in scientific publishing, with varied data. Archambault et al. analyzed the proportion of open access peer-reviewed papers at European and world levels for 2004-2011 and 1996-2013 time periods, respectively. They have shown that several countries, including Brazil, Switzerland, Netherlands, US have more than 50% of the research articles freely available. Piwowar et al. used three different samples of 100K articles each drawn from Web of Science (WoS), CrossRef and Unpaywall for publications from worldwide and found that about 28% the scholarly articles are available in open access. Bosman and Kramer collected data from Web of Science using its oaDOI service and explored open access levels across research fields, languages, countries, institutions, funders and topics and found high variations in open access levels on all these dimensions.

There are, however, very few recent studies on open access levels in publications from India. Among the recent studies, Kumar and Mahesh tried to analyze the Institutional Repositories in India, as a means of providing open access to articles. They analyzed the statistics of submission of papers for about one year and found that submissions to the Institutional Repositories were very low, with some not even getting a single paper deposited in the whole year. They concluded that the Institutional Repositories in India have not really picked up in terms of papers deposited. Another recent article in Nature talked about the newly proposed IndiaRxiv repository, with the caution that the performance of Institutional Repositories in India is not very good. Piryani et al. is another recent study that focused on measuring open access levels for India as a country. They tried to analyze the overall level of open access in Indian research output by taking data from the Web of Science for all publications during 2016. They conclude that the overall open access level in Indian research output is about 24% of the total output, which is less than the world average. Another study by Singh et al. have analyzed Indian research output data in Web of Science for the period 2014-18 and obtained OA evidence from Unpaywall as well as volume of papers available for free download from Sci-Hub. However, both of these previous studies only looked at overall data for India as a county and did not go at the institutional level. Therefore, there is no evidence available about what proportion of research papers from different institutions in India are available as OA. Further, no recent analysis is available about number of papers available in Indian IRs.

**Data and Methodology**

The 100 most productive Indian institutions (including institution systems) account for a total of 62,688 publications out of total 76,530 publications indexed in Web of Science for India for the publication year 2016. This is about 82% of the total research output from India for the year 2016 as indexed in Web of Science. All these 62,688 publication records are then scanned one by one to find out if they are available in open access in some platform.
Thus, the data for analysis in this work is obtained from four sources: (a) Web of Science\(^3\) (WoS) database, (b) Unpaywall\(^9\) portal, (c) Sci-Hub and (d) main IRs in India.

For all the publication records downloaded from WoS, the OA evidence is obtained from the Unpaywall portal through API calls. The data downloading from WoS and OA evidence from the Unpaywall portal was obtained for the first time in July 2019.

The publication record data from WoS was used to make an automated lookup in Sci-Hub website. The crawling was done using a custom Python script to identify which of the DOIs in our WoS data have full text available in Sci-Hub. Thus, for all the 62,688 publication records obtained from the WoS database, the Sci-Hub portal was queried and evidence of availability of full text was recorded.

Further, as was observed by Das and Dutta,\(^{[23]}\) there were 726 open access journals covered by WoS in 2017, which covers 7% of the total open access articles globally, therefore, it is clear that capturing open access output from WoS only would limit any study. It is for this reason, we also tried to look at data in IRs in India as this data complements the study and provides a more informed assessment of institutional research that is in open access from India. Data from the three main central portals and their associated IRs, as explained later, was obtained and analyzed.

The publication records data has been analyzed computationally by writing programs in Python and R. Standard computational methods are used for computing results and generating plots. As stated earlier, the OA evidence was obtained from Unpaywall through an API lookup in the portal. One important point of analysis in the paper is to look at disciplinary variations in open access. For this purpose, each publication record is tagged into one of the 14 broad research disciplines, as proposed in a previous work.\(^{[23]}\) The Web of Science Category (WC) field is used for this tagging. These 14 research disciplines are: Agriculture (AGR), Art and Humanities (AH), Biology (BIO), Chemistry (CHEM), Engineering (ENG), Environment Science (ENV), Geology (GEO), Information Sciences (INF), Material Science (MAR), Mathematics (MAT), Medical Science (MED), Multidisciplinary (MUL), Physics (PHY) and Social Science (SS). The analytical results are presented in different tables and figures.

**Open Access Evidence from Unpaywall**

The 100 Indian institutions covered in this study account for 62,688 publication records. Out of 62,688 publication records, only 14,454 records are in Unpaywall, i.e. found to be available in some form of open access. In percentage terms, only about 23% of the combined output of 100 most productive institutions in India is available in open access.\(^{[23]}\)

The number of open access articles from all these institutions combined contributes about 83.65% of the total number of open access articles for India for the year 2016. When we look at open access categories, we observe that out of the combined output from the 100 institutions, 5,893 records are Gold open access (~41% of total open access articles), 3,844 records are Green open access (~27% of total open access articles) and 2,580 records are Bronze open access (~18% of total open access articles). Thus, the Gold open access type is the most prevalent type of open access.

We tried to see if the open access levels in the combined output of 100 institutions are similar for all disciplines or there are variations in different disciplines. Figure 1 the disciplinary distribution of open access articles in the combined output of the 100 institutions. It can be seen that PHY discipline accounts for the highest proportion (23%) of articles in the total open access articles for all the institutions taken together. This is followed by MED discipline with a 17% share and MUL discipline with a 13% share. Thus, PHY, MED and MUL taken together contribute more than 50% of open access articles in the combined output of the 100 institutions. SS, MAT and (surprisingly) INF disciplines have a very low contribution to open access articles, possibly also because they have less volume of output too. PHY discipline is the most interesting case with only 12.25% contribution in the combined output of the 100 institutions but when it comes to contribution to open access articles, it is much higher at 23%. One possible reason for this could be the existence of the well-known arXiv repository where Physicists are the key contributors.

After looking at the OA levels for combined data of all institutions, we analyzed OA levels at the level of granularity of individual institutions. Table 1 presents the detailed data for all the 100 institutions (including institution systems). It shows the name and location of the institution, number of records it has in Web of Science, number of records that are available in open access and also percentage contribution that this institution makes to total output as well as to total open access articles from India. In order to understand open access levels in each of the institutions in more detail, we categorize institutions in three categories: OA_Low, OA_Med and OA_High corresponding to open access percentage levels of below 25%, between 25 to 45% and above 45%, respectively. It can be observed that out of 100 Institutions, there are 58 Institutions under OA_Low category, 32 Institutions under OA_Med category and 10 under OA_High category. The statistics for these 100 institutions are also plotted in Figure 2 as a scatter plot for an alternative way of visualization and understanding. Here, the x-axis denotes the number of papers.
| S. No. | Institution Name | No. of articles in WoS | Articles with DOI | No. of articles that are OA | OA articles as percentage of total articles | Proportionate Contribution to OA of India | Overall OA % | Institution Systems/ Govt Departments |
|--------|------------------|-----------------------|------------------|---------------------------|-------------------------------------------|------------------------------------------|-----------|----------------------------------|
| 1      | Council of Scientific Industrial Research (CSIR) | 8041 | 5027 | 965 | 19.20 | 5.58 | 20.24 | Institution Systems/ Govt Departments |
| 2      | Indian Council of Agricultural Research (ICAR) | 3774 | 1982 | 588 | 29.67 | 3.40 | 3.40 | Institution Systems/ Govt Departments |
| 3      | Department of Science Technology India (DST) | 2146 | 2053 | 719 | 35.02 | 4.16 | 4.16 | Institution Systems/ Govt Departments |
| 4      | Department of Biotechnology (DBT) | 890 | 825 | 464 | 56.24 | 2.69 | 2.69 | Institution Systems/ Govt Departments |
| 5      | Defence Research Development Organisation (DRDO) | 856 | 821 | 161 | 19.61 | 0.93 | 0.93 | Individual Institutions |
| 6      | Ministry of Earth Sciences (MOES) India | 414 | 356 | 96 | 26.97 | 0.56 | 0.56 | Individual Institutions |
| 7      | Indian Space Research Organisation (ISRO) | 310 | 289 | 63 | 21.80 | 0.36 | 0.36 | Individual Institutions |
| 8      | Indian Council of Medical Research (ICMR), New Delhi | 257 | 235 | 108 | 45.96 | 0.63 | 0.63 | Individual Institutions |
| 1      | Indian Institute of Science, Bangalore (IISc) | 1861 | 1805 | 529 | 29.31 | 3.06 | 3.06 | Individual Institutions |
| 2      | Indian Institute of Technology, Kharagpur | 1666 | 1589 | 206 | 12.96 | 1.19 | 1.19 | Individual Institutions |
| 3      | All India Institute of Medical Sciences (AIIMS), New Delhi | 1621 | 1217 | 474 | 38.95 | 2.74 | 2.74 | Individual Institutions |
| 4      | Bhabha Atomic Research Center (BARC) | 1491 | 1464 | 292 | 19.95 | 1.69 | 1.69 | Individual Institutions |
| 5      | Indian Institute of Technology, Delhi | 1479 | 1423 | 223 | 15.67 | 1.29 | 1.29 | Individual Institutions |
| 6      | Indian Institute of Technology, Bombay | 1412 | 1371 | 288 | 21.01 | 1.67 | 1.67 | Individual Institutions |
| 7      | Indian Institute of Technology, Madras | 1393 | 1363 | 263 | 19.30 | 1.52 | 1.52 | Individual Institutions |
| 8      | University of Delhi (DU) | 1226 | 1141 | 291 | 25.50 | 1.68 | 1.68 | Individual Institutions |
| 9      | Banaras Hindu University, Varanasi (BHU) | 1210 | 1095 | 251 | 22.92 | 1.45 | 1.45 | Individual Institutions |
| 10     | PGIMER Chandigarh | 1197 | 942 | 340 | 36.09 | 1.97 | 1.97 | Individual Institutions |
| 11     | Indian Institute of Technology, Roorkee | 1190 | 1162 | 134 | 11.53 | 0.78 | 0.78 | Individual Institutions |
| 12     | Indian Institute of Technology, Kanpur | 1088 | 1057 | 246 | 23.27 | 1.42 | 1.42 | Individual Institutions |
| 13     | Anna University, Chennai | 1023 | 912 | 156 | 17.11 | 0.90 | 0.90 | Individual Institutions |
| 14     | Jadavpur University, Kolkata | 972 | 923 | 120 | 13.00 | 0.69 | 0.69 | Individual Institutions |
| 15     | Tata Institute of Fundamental Research (TIFR) | 955 | 912 | 663 | 72.70 | 3.84 | 3.84 | Individual Institutions |
| 16     | Vellore Institute of Technology (VIT) | 922 | 854 | 150 | 17.56 | 0.87 | 0.87 | Individual Institutions |
| 17     | Indian Institute of Technology, Guwahati | 888 | 853 | 134 | 15.71 | 0.78 | 0.78 | Individual Institutions |
| 18     | University of Calcutta, Kolkata | 790 | 744 | 160 | 21.51 | 0.93 | 0.93 | Individual Institutions |
| 19     | Manipal University, Karnataka | 786 | 687 | 283 | 41.19 | 1.64 | 1.64 | Individual Institutions |
| 20     | Indian Institute of Technology (ISM Dhanbad) | 746 | 713 | 66 | 9.26 | 0.38 | 0.38 | Individual Institutions |
| 21     | Panjab University, Chandigarh | 682 | 337 | 99 | 23.68 | 0.57 | 0.57 | Individual Institutions |
| 22     | Aligarh Muslim University (AMU) | 625 | 585 | 168 | 28.72 | 0.97 | 0.97 | Individual Institutions |
| 23     | University of Hyderabad, Hyderabad | 613 | 595 | 169 | 28.40 | 0.98 | 0.98 | Individual Institutions |
| 24     | Savitribai Phule Pune University, Pune | 600 | 569 | 183 | 32.16 | 1.06 | 1.06 | Individual Institutions |
| 25     | Jawaharlal Nehru University (JNU), New Delhi | 596 | 545 | 175 | 32.11 | 1.01 | 1.01 | Individual Institutions |
| 26     | National Institute of Technology, Rourkela | 550 | 538 | 71 | 13.20 | 0.41 | 0.41 | Individual Institutions |
| 27     | Birla Institute of Technology and Science, Pilani | 497 | 473 | 104 | 21.99 | 0.60 | 0.60 | Individual Institutions |
| No. | University/Institution                                      | Country/State | OA Factor | OA Index | MOPA  
|-----|----------------------------------------------------------|---------------|------------|----------|--------
| 28  | Indian Institute of Technology (IITBHU) Varanasi         | India         | 491        | 475      | 50     10.53 0.29
| 29  | Tata Memorial Hospital (TMH)                             | India         | 483        | 291      | 105 36.08 0.61
| 30  | Saha Institute of Nuclear Physics, Kolkata               | India         | 468        | 466      | 278 59.66 1.61
| 31  | Thapar University                                        | India         | 465        | 433      | 58 13.39 0.34
| 32  | Christian Medical College Hospital (CMCH), Vellore       | India         | 465        | 376      | 194 51.60 1.12
| 33  | Bharathiar University, Coimbatore                        | India         | 462        | 425      | 63 14.82 0.36
| 34  | Annamalai University, Tamil Nadu                         | India         | 444        | 397      | 76 19.14 0.44
| 35  | Indian Association for the Cultivation of Science (IAACS), Jadavpur | India         | 430        | 422      | 84 19.91 0.49
| 36  | Institute of Chemical Technology (ICT), Mumbai           | India         | 403        | 398      | 37 9.30 0.21
| 37  | National Institute of Mental Health Neurosciences India  | India         | 399        | 330      | 120 36.36 0.69
| 38  | Amity University, NOIDA                                  | India         | 399        | 371      | 84 22.64 0.49
| 39  | Indian Institute of Science Education Research (IISER), Pune | India         | 396        | 384      | 200 52.08 1.16
| 40  | Indian Statistical Institute (ISI) Kolkata               | India         | 395        | 375      | 149 39.73 0.86
| 41  | Sanjay Gandhi Postgraduate Institute of Medical Sciences (SGPGI), Lucknow | India         | 394        | 302      | 102 33.77 0.59
| 42  | Indira Gandhi Centre for Atomic Research (IGCAR), Tamil Nadu | India         | 391        | 386      | 43 11.14 0.25
| 43  | National Institute Technology (NIT), Tiruchirappalli     | India         | 387        | 378      | 37 9.79 0.21
| 44  | Guru Nanak Dev University, Amritsar                      | India         | 387        | 377      | 57 15.12 0.33
| 45  | Jamia Millia Islamia (JMI), Delhi                        | India         | 382        | 366      | 82 22.40 0.47
| 46  | National Institute of Pharmaceutical Education Research (NIPER), Mohali | India         | 372        | 352      | 82 23.30 0.47
| 47  | Visva Bharati University, Burdwan                        | India         | 355        | 345      | 146 42.32 0.84
| 48  | Indian Institute of Engineering Science Technology (IIEST), Shibpur | India         | 341        | 331      | 35 10.57 0.20
| 49  | Shanmugha Arts Science Technology Research Academy (SASTRA), Tamil Nadu | India         | 332        | 314      | 81 25.80 0.47
| 50  | Indian Institute of Technology, Indore                    | India         | 331        | 330      | 98 29.70 0.57
| 51  | Jawaharlal Nehru Center for Advanced Scientific Research (INCASAR) | India         | 326        | 321      | 100 31.15 0.58
| 52  | Indian Institute of Science Education Research (IISER), Kolkata | India         | 320        | 318      | 136 42.77 0.79
| 53  | Bharathidasan University, Tamil Nadu                      | India         | 317        | 300      | 83 27.67 0.48
| 54  | University of Madras, Chennai                            | India         | 317        | 301      | 54 17.94 0.31
| 55  | Osmania University, Telangana                            | India         | 313        | 289      | 47 16.26 0.27
| 56  | National Institute of Science Education Research (NISER) | India         | 307        | 306      | 194 63.40 1.12
| 57  | Sri Venkateswara University, Andhra Pradesh              | India         | 300        | 277      | 59 21.30 0.34
| 58  | Jamia Hamdard University, New Delhi                      | India         | 294        | 275      | 70 25.45 0.41
| 59  | Tezpur University, Assam                                  | India         | 293        | 288      | 42 14.58 0.24
| 60  | Pondicherry University, Pondicherry                      | India         | 292        | 273      | 52 19.05 0.30
| 61  | Indian Institute of Technology, Hyderabad                | India         | 286        | 280      | 68 24.29 0.39
| 62  | Shivaji University, Maharasthara                        | India         | 285        | 275      | 29 10.55 0.17
| Institution                                                                 | OA Count | Total OA Count | Percentage | OA Indexed | OA Count | Total OA Count | Percentage |
|----------------------------------------------------------------------------|----------|----------------|------------|------------|----------|----------------|------------|
| Srichandan et al.                                                        |          |                |            |            |          |                |            |
| Amrita Vishwa Vidyapeetham University, Tamil Nadu                          | 284      | 247            | 60         | 24.29      | 0.35     |                |            |
| King George Medical University (KGMU), Lucknow                             | 272      | 223            | 78         | 34.98      | 0.45     |                |            |
| Indian Institute of Science Education Research (IISER), Bhopal             | 261      | 257            | 125        | 48.64      | 0.72     |                |            |
| Public Health Foundation of India                                          | 257      | 245            | 185        | 75.51      | 1.07     |                |            |
| Visvesvaraya National Institute of Technology (VNIT), Nagpur                | 247      | 236            | 32         | 13.56      | 0.19     |                |            |
| Birla Institute of Technology Mesra                                        | 240      | 229            | 36         | 15.72      | 0.21     |                |            |
| Physical Research Laboratory (PRL), India                                 | 239      | 224            | 147        | 65.63      | 0.85     |                |            |
| University of Allahabad                                                   | 232      | 201            | 31         | 15.42      | 0.18     |                |            |
| Madurai Kamaraj University, Tamil Nadu                                      | 228      | 218            | 31         | 14.22      | 0.18     |                |            |
| Homi Bhabha National Institute, Mumbai                                     | 228      | 228            | 60         | 26.32      | 0.35     |                |            |
| Jawaharlal Institute of Postgraduate Medical Education Research (JIPMER)   | 225      | 205            | 81         | 39.51      | 0.47     |                |            |
| University of Mysore                                                       | 225      | 208            | 57         | 27.40      | 0.33     |                |            |
| University of Kashmir                                                     | 224      | 206            | 45         | 21.84      | 0.26     |                |            |
| Andhra University                                                          | 222      | 198            | 52         | 26.26      | 0.30     |                |            |
| National Institute of Technology (NIT), Durgapur                           | 220      | 214            | 24         | 11.21      | 0.14     |                |            |
| Alagappa University, Tamil Nadu                                            | 218      | 210            | 16         | 7.62       | 0.09     |                |            |
| Maharaja Sayajirao University Baroda                                       | 217      | 212            | 41         | 19.34      | 0.24     |                |            |
| Sardar Vallabhbhai National Institute of Technology (SVNIT)                | 217      | 197            | 30         | 15.23      | 0.17     |                |            |
| Cochin University Science Technology (CUST), Kerala                        | 217      | 196            | 35         | 17.86      | 0.20     |                |            |
| PUNJAB AGRICULTURAL UNIVERSITY                                             | 213      | 162            | 41         | 25.31      | 0.24     |                |            |
| Kalyani University, West Bengal                                            | 213      | 201            | 29         | 14.43      | 0.17     |                |            |

Note: The 100 institutions include 8 institution systems and 92 individual institutions.
is observed as the largest contributor to open access articles from India.

The research discipline is observed to be an important correlate for a higher proportion of open access articles, as it is seen in institutions that work mainly in the area of Physics. Many institutions working in the area of MED and MUL also have relatively higher proportion of articles available in open access. On the other hand, institutions mainly specializing in Engineering and technology areas, in general, have lower proportion of their research output available in open access. The geographical location of an institution is not found to be a differentiating factor for low or high open access. This could be observed by looking at the fact that some institutions located in big cities like Mumbai and Delhi are found to have low open access levels, on the other hand, some institutions located in small towns are found to have higher open access levels.

Papers available in Sci-Hub

We also looked at how many papers from each institution are available as full text for free download in the popular pirate site Sci-Hub. Our argument is that Indian papers if available in legal forms of open access will not promote illegal access, as researchers, more so in developing countries, are constrained by research funding and hence tend to exploit this type of resources (see for example Gresheke).[24] At the same time, it is equally interesting to note that Sci-Hub is also frequently used for paper downloads from both, the developed and developing countries.

Table 2 shows the number and percentages of papers for each institution available for free full-text download from Sci-Hub. It can be observed that, unlike low levels of legal open access forms, here the availability of articles for free download is much higher for all the institutions. The highest value being 99% articles for Institute of Plasma Research and the lowest being 73.5% articles for Tata Memorial Hospital. Majority of the institutions in the 100-institution set, have more than 90% of their papers available for free download from Sci-Hub. This is a huge contrast with the results of legal OA availability percentages. These values show that something is wrong with the legal forms of open access models as they relate to Indian research. Sci-Hub seems to be complementing the low legal OA availability with, on an average, more than 90% of the articles available for free download. Some studies (for example, Singh et al.)[21] Have also found that Sci-Hub seem to complement the availability in different disciplines too, with disciplines having low legal OA levels being preferentially covered in Sci-Hub.
| No. | Institution Name                                      | OA Score | OA Share | Impact Factor |
|-----|-------------------------------------------------------|----------|----------|---------------|
| 13  | Anna University, Chennai                              | 1023     | 912      | 829           | 90.90      | 1.98     |
| 14  | Jadavpur University, Kolkata                          | 972      | 923      | 880           | 95.34      | 2.10     |
| 15  | Tata Institute of Fundamental Research (TIFR)         | 955      | 912      | 864           | 94.74      | 2.06     |
| 16  | Vellore Institute of Technology (VIT)                 | 922      | 854      | 811           | 94.96      | 1.93     |
| 17  | Indian Institute of Technology, Guwahati              | 888      | 853      | 830           | 97.30      | 1.98     |
| 18  | University of Calcutta, Kolkata                       | 790      | 744      | 712           | 95.70      | 1.70     |
| 19  | Manipal University, Karnataka                         | 786      | 687      | 605           | 88.06      | 1.44     |
| 20  | Indian Institute of Technology (ISM Dhanbad)          | 746      | 713      | 686           | 96.21      | 1.64     |
| 21  | Panjab University, Chandigarh                         | 682      | 337      | 312           | 92.58      | 0.74     |
| 22  | Aligarh Muslim University (AMU)                       | 625      | 585      | 546           | 93.33      | 1.30     |
| 23  | University of Hyderabad, Hyderabad                    | 613      | 595      | 568           | 95.46      | 1.35     |
| 24  | Savitribai Phule Pune University, Pune                | 600      | 569      | 545           | 95.78      | 1.30     |
| 25  | Jawaharlal Nehru University (JNU), New Delhi          | 596      | 545      | 530           | 97.25      | 1.26     |
| 26  | National Institute of Technology, Rourkela            | 550      | 538      | 525           | 97.58      | 1.25     |
| 27  | Birla Institute of Technology and Science, Pilani     | 497      | 473      | 451           | 95.35      | 1.08     |
| 28  | Indian Institute of Technology (IITBHU) Varanasi      | 491      | 475      | 459           | 96.63      | 1.09     |
| 29  | Tata Memorial Hospital (TMH)                          | 483      | 291      | 214           | 73.54      | 0.51     |
| 30  | Saha Institute of Nuclear Physics, Kolkata            | 468      | 466      | 456           | 97.85      | 1.09     |
| 31  | Thapar University                                    | 465      | 433      | 400           | 92.38      | 0.95     |
| 32  | Christian Medical College Hospital (CMCH), Vellore    | 465      | 376      | 316           | 84.04      | 0.75     |
| 33  | Bharathiar University, Coimbatore                     | 462      | 425      | 403           | 94.82      | 0.96     |
| 34  | Annamalai University, Tamil Nadu                      | 444      | 397      | 371           | 93.45      | 0.88     |
| 35  | Indian Association for the Cultivation of Science (IACS), Jadavpur | 430      | 422      | 414           | 98.10      | 0.99     |
| 36  | Institute of Chemical Technology (ICT), Mumbai        | 403      | 398      | 385           | 96.73      | 0.92     |
| 37  | National Institute of Mental Health Neurosciences India | 399  | 330      | 250           | 75.76      | 0.60     |
| 38  | Amity University, NOIDA                               | 399      | 371      | 354           | 95.42      | 0.84     |
| 39  | Indian Institute of Science Education Research (IISER), Pune | 396  | 384      | 376           | 97.92      | 0.90     |
| 40  | Indian Statistical Institute (ISI) Kolkata            | 395      | 375      | 359           | 95.73      | 0.86     |
| 41  | Sanjay Gandhi Postgraduate Institute of Medical Sciences (SGPGI), Lucknow | 394  | 302      | 247           | 81.79      | 0.59     |
| 42  | Indira Gandhi Centre for Atomic Research (IGCAR), Tamil Nadu | 391  | 386      | 381           | 98.70      | 0.91     |
| 43  | National Institute of Technology (NITT), Tiruchirappalli | 387  | 378      | 359           | 94.97      | 0.86     |
| 44  | Guru Nanak Dev University, Amritsar                   | 387      | 377      | 361           | 95.76      | 0.86     |
| 45  | Jamia Millia Islamia (JMI), Delhi                     | 382      | 366      | 347           | 94.81      | 0.83     |
| 46  | National Institute of Pharmaceutical Education Research (NIPER), Mohali | 372  | 352      | 327           | 92.90      | 0.78     |
| 47  | Visva Bharati University, Burdwan                     | 355      | 345      | 334           | 96.81      | 0.80     |
| 48  | Indian Institute of Engineering Science Technology (IIEST), Shibpur | 341  | 331      | 323           | 97.58      | 0.77     |
| 49  | Shanmugha Arts Science Technology Research Academy (SASTRA), Tamil Nadu | 332  | 314      | 290           | 92.36      | 0.69     |
| 50  | Indian Institute of Technology, Indore                | 331      | 330      | 326           | 98.79      | 0.78     |
| 51  | Jawaharlal Nehru Center for Advanced Scientific Research (INCASR) | 326  | 321      | 315           | 98.13      | 0.75     |
| 52  | Indian Institute of Science Education Research (IISER), Kolkata | 320  | 318      | 307           | 96.54      | 0.73     |
| 53  | Bharathidasan University, Tamil Nadu                  | 317      | 300      | 291           | 97.00      | 0.69     |
| 54  | University of Madras, Chennai                         | 317      | 301      | 283           | 94.02      | 0.68     |
| 55  | Osmania University, Telangana                         | 313      | 289      | 274           | 94.81      | 0.65     |
| 56  | National Institute of Science Education Research (NISER) | 307  | 306      | 296           | 96.73      | 0.71     |
| 57  | Sri Venkateswara University, Andhra Pradesh           | 300      | 277      | 256           | 92.42      | 0.61     |
Open Access through Institutional Repositories

Various ways have been implemented to promote open access in India by several organizations, including creation of Institutional Repositories. The DST-DBT’s sciencecentral.in,[11] CSIR’s csicentral.net[12] and ICAR’s krishikosh[13] are some of the most prominent central institutional repositories in the country. Various government organization have now made it compulsory for their researchers and scientists to submit their research output in relevant IRs. Different funding bodies are also increasingly promoting the cause of public access to public–funded research. The grant award recipients are being encouraged to submit their research outcomes in relevant IRs. Given these initiatives, IRs can play a major role in providing open access to research articles. We have, therefore, tried to analyze the number of research articles that are accessible by the way of being deposited in prominent India IRs.

The science central. In repository of the DST-DBT is perhaps the largest central IR in India. It provides an aggregate service that collects the full text and metadata of publications from the DST-DBT institutions as well as outcomes of research funded by them. This IR website says “at present there are 17 Institutional Repositories hosted at the science central, while 42 institutional repositories are regularly harvested on the same”. We have conducted a study on the number of articles available through the 24 Institutional repositories that are part of this central repository and found there are total 125,595 publications deposited and available. Table 3 shows the detailed data about number of articles available in each of these 24 repositories. These are very small numbers taking

| Institution Name                                    | Available Articles | Total Available Sci-hub Articles | Percentage |
|-----------------------------------------------------|--------------------|---------------------------------|------------|
| Srichandan, et al.: Patterns of OA in Indian Institutions | 100 Institutions of India (= 41,925) | 205,913 | 49.36 |

1Percentage is calculated with respect to number of articles in WoS having a DOI, i.e. column 4.

2Percentage calculated with respect to total available Sci-hub article count for 100 Institutions of India (≈41,925)

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Table 3: Status of DST-DTB Central Repository (sciencecentral.in).

| S. No. | Name of Institutional Repository | Period of Records | Total Records |
|--------|----------------------------------|-------------------|---------------|
| 1      | IR @ Bharat Immunological and Biologicals Corporation Limited | - | 0 |
| 2      | IR @ Biotechnology Industry Research Assistance Council | - | 0 |
| 3      | IR @ Centre of Innovative and Applied Bioprocessing | 2016 | 2 |
| 4      | IR @ Centre for DNA Fingerprinting and Diagnostics | 1999-2019 | 877 |
| 5      | IR @ Department of Biotechnology | - | 0 |
| 6      | IR @ Department of Science and Technology | 2014-17 | 19 |
| 7      | IR @ Indian Academy of Sciences | 1920-2017 | 98205 |
| 8      | IR @ Institute of Bioresources and Sustainable Development | 2013-14 | 10 |
| 9      | IR @ Institute of Life Sciences | 2014-15 | 10 |
| 10     | IR @ National Agri-Food Biotechnology Institute | 2010-15 | 35 |
| 11     | IR @ National Brain Research Centre | 2003-18 | 437 |
| 12     | IR @ National Centre for Cell Science | 2012-18 | 577 |
| 13     | IR @ National Institute of Animal Biotechnology | 2012-14 | 9 |
| 14     | IR @ National Institute of Biomedical Genomics | 2013-14 | 10 |
| 15     | IR @ National Institute of Immunology | 2014-15 | 10 |
| 16     | IR @ National Institute of Plant Genome Research (NIPGR) | 2013-17 | 772 |
| 17     | IR @ Rajiv Gandhi Centre for Biotechnology | 2011-18 | 599 |
| 18     | IR @ Raman Research Institute Digital Repository | 2005-15 | 5947 |
| 19     | IR @ Regional Centre for Biotechnology | 2010-18 | 117 |
| 20     | IR @ S.N.Bose National Centre for Basic Sciences | 2012-18 | 1684 |
| 21     | IR @ SreeChitraTirunal Institute for Medical Sciences and Technology, Trivandrum | 2012-13 | 1800 |
| 22     | IR @ The Indian Association for the Cultivation of Science | 2010-18 | 7941 |
| 23     | IR @ Translational Health Science and Technology Institute | 2013-14 | 9 |
| 24     | IR @ Indian Institute of Astrophysics | 2004-15 | 6525 |
| 25     | Total Records | 1,25,595 |  

Table 4: Status of CSIR Institutional Repository (csircentral.net).

| S.No | Name of Institutional Repository | Period of Records | Total Records |
|------|----------------------------------|-------------------|---------------|
| 1    | IR@AMPRI: CSIR-Advanced Materials and Processes Research Institute, Bhopal | 2013-14 | 764 |
| 2    | IR@CBRI: CSIR-Central Building Research Institute, Roorkee | 2012-16 | 1078 |
| 3    | IR@CDRI: CSIR-Central Drug Research Institute, Lucknow | 2009-15 | 1070 |
| 4    | IR@CECRI: CSIR-Central Electrochemical Research Institute, Karaikudi | 2012-19 | 2639 |
| 5    | IR@CEERI: CSIR-Central Electronics Engineering Research Institute, Pilani | 2013-17 | 226 |
| 6    | IR@CFTRI: CSIR-Central Food Technological Research Institute, Mysore | 2008-19 | 9031 |
| 7    | IR@CGCRI: CSIR-Central Glass and Ceramic Research Institute, Kolkata | 2011-18 | 3692 |
| 8    | IR@CIMFR: CSIR-Central Institute of Mining and Fuel Research, Dhanbad | 2011-19 | 1894 |

The third major IR is ICAR system’s krishikosh repository which stands for Knowledge based Resources Information Systems Hub for Innovations (KRISHI) in agriculture. It consists of Surveys/Experiments/Observational studies, Geospatial data, Learning resources, Publications etc., as it is the centralized data repository of ICAR. The KRISHI community is divided according to subject division matter (SDM). Some of the subject divisions are Agricultural Education (1285), Agricultural Engineering (364), Agricultural Extension (235), Animal Science (1720), Crop Science (4025), Fisheries (2721), Horticulture Science (3677), Natural Resource Management (4252) etc. The numbers in bracket indicate the number of available resources in the repository. Table 5 the details of number of items available in each of the repositories. The total number of records available till date on all the repositories into account the research output volume of India. In order to arrive an estimate, the total publication count of India in Web of Science could be used. A total of 80,9404 articles are there indexed in Web of Science for India for the said period. If we take this as the complete publication volume of India, the number of publications available in this central repository would be only about 15%. However, since it is quite obvious that all research output from India is not indexed in Web of Science and in fact the actual publication volume would be much higher than that, it can be concluded that articles accessible through this IR will be lesser than even 15% of the total volume.

The csircentral.net IR is the other big central repository. All the IRs of different labs that are part of CSIR system are regularly harvested by this central harvester. We observe that it has about 30 IR’s with a total of about 100,609 articles deposited. Table 4 shows the details of number of articles in each of these 30 IRs. In this case also, taking the Web of Science publication count as volume benchmark for India for the concerned period, it is seen that there are 747,759 papers in Web of Science, out of which less than 13% are available through this IR. Given that in actual practice the total publication volume for India would be much higher than the Web of Science indexed volume, this availability proportion is actually much lesser than 13%.
### Table 5: Status of ICAR Central Repository (krishikosh).

| S. No. | Name of Institutional Repository                                                                 | Total Records |
|-------|------------------------------------------------------------------------------------------------|---------------|
| 1     | ICAR-Agricultural Technology Application Research Institutes of all zones together located at Bengaluru, Hyderabad, Jabalpur, Jodhpur, Kanpur, Kolkata, Ludhiana, Patna, Umiam, Guwahati and Pune. | 235           |
| 2     | ICAR-Central Agroforestry Research Institute                                                                 | 62            |
| 3     | ICAR-Central Arid Zone Research Institute                                                                 | 1947          |
| 4     | ICAR-Central Avian Research Institute                                                                 | 205           |
| 5     | ICAR-Central Citrus Research Institute                                                                 | 87            |
| 6     | ICAR-Central Coastal Agricultural Research Institute                                                                 | 163           |
| 7     | ICAR-Central Inland Fisheries Research Institute                                                                 | 390           |
| 8     | ICAR-Central Institute for Arid Horticulture                                                                 | 489           |
| 9     | ICAR-Central Institute for Cotton Research                                                                 | 113           |
| 10    | ICAR-Central Institute for Post-Harvest Engineering and Technology B4                                                                 | 87            |
| 11    | ICAR-Central Institute for Research on Buffaloes                                                                 | 42            |
| 12    | ICAR-Central Institute for Research on Cattle                                                                 | 30            |
| 13    | ICAR-Central Institute for Research on Cotton Technology                                                                 | 20            |
| 14    | ICAR-Central Institute for Research on Goats                                                                 | 39            |
| 15    | ICAR-Central Institute for Women in Agriculture                                                                 | 366           |
| 16    | ICAR-Central Institute of Agricultural Engineering                                                                 | 148           |
| 17    | ICAR-Central Institute of Brackish water Aquaculture                                                                 | 841           |
| 18    | ICAR-Central Institute of Fisheries Education                                                                 | 35            |
| 19    | ICAR-Central Institute of Fisheries Technology                                                                 | 944           |
| 20    | ICAR-Central Institute of Freshwater Aquaculture                                                                 | 48            |
| 21    | ICAR-Central Institute of Sub-tropical Horticulture                                                                 | 154           |
| 22    | ICAR-Central Institute of Temperate Horticulture                                                                 | 56            |
| 23    | ICAR-Central Island Agricultural Research Institute                                                                 | 87            |
| 24    | ICAR-Central Marine Fisheries Research Institute                                                                 | 1               |
| 25    | ICAR-Central Plantation Crops Research Institute                                                                 | 339           |
| 26    | ICAR-Central Potato Research Institute                                                                 | 970           |
| 27    | ICAR-Central Research Institute for Jute and Allied Fibres                                                                 | 126           |
| 28    | ICAR-Central Research Institute of Dryland Agriculture                                                                 | 594           |
| 29    | ICAR-Central Sheep and Wool Research Institute                                                                 | 11            |
| 30    | ICAR-Central Soil Salinity Research Institute                                                                 | 493           |
| 31    | ICAR-Central Tobacco Research Institute                                                                 | 259           |
| 32    | ICAR-Central Tuber Crops Research Institute                                                                 | 37            |
| 33    | ICAR-Directorate of Cashew Research                                                                 | 19            |
| 34    | ICAR-Directorate of Cold Water Fisheries Research                                                                 | 15            |
| 35    | ICAR-Directorate of Floricultural Research                                                                 | 38            |
| 36    | ICAR-Directorate of Groundnut Research                                                                 | 424           |

**Total Records:** 1,00,609
| Institution                                                                 | OA Articles |
|----------------------------------------------------------------------------|-------------|
| ICAR-National Institute of Animal Nutrition and Physiology                | 239         |
| ICAR-National Institute of Biotic Stress Management                       | 28          |
| ICAR-National Institute of High Security Animal Diseases                  | 107         |
| ICAR-National Institute of Natural Fibre Engineering and Technology (earlier NIRJAFT) | 05         |
| ICAR-National Institute of Veterinary Epidemiology and Disease Informatics| 280         |
| ICAR-National Organic Farming Research Institute                          | 0           |
| ICAR-National Research Centre for Banana                                  | 253         |
| ICAR-National Research Centre for Grapes                                  | 89          |
| ICAR-National Research Centre for Litchi                                  | 81          |
| ICAR-National Research Centre for Pomegranate                             | 05          |
| ICAR-National Research Centre on Camel                                    | 53          |
| ICAR-National Research Centre on Equines                                  | 85          |
| ICAR-National Research Centre on Integrated Farming                       | 0           |
| ICAR-National Research Centre on Meat                                     | 237         |
| ICAR-National Research Centre on Mithun                                   | 112         |
| ICAR-National Research Centre on Orchids                                  | 13          |
| ICAR-National Research Centre on Pig                                      | 18          |
| ICAR-National Research Centre on Seed Spices                             | 45          |
| ICAR-National Research Centre on Yak                                      | 06          |
| ICAR-National Rice Research Institute                                    | 661         |
| ICAR-Project Directorate on Foot and Mouth Disease                        | 17          |
| ICAR-Research Complex for Eastern Region                                  | 31          |
| ICAR-Research Complex for NEH Region                                      | 243         |
| ICAR-Sugarcane Breeding Institute                                         | 07          |
| ICAR-Vivekananda Parvatiya Krishi AnusandhanSansthan                       | 162         |
| Others-Others-AICRP on Pearl Millet Publication                           | 07          |
| Others-Others-Data Inventory                                              | 00          |
| Others-Others-Other                                                        | 00          |
| Others-Others-Publication                                                 | 262         |
| **Total Records**                                                         | **18,486**  |

**Figure 1:** Discipline wise distribution of OA articles for collective data of institutions.
taken together are 18,486, which would again be a very small proportion of Indian research output in the area. The most recent initiative in the repository culture of open access in India is the creation of IndiaRxiv hosted at indiarxiv.org. However, there are only 67 preprints available as on 16th Feb., 2020, almost 10 months after the launch of the repository in April 2019. This repository is thus yet to gain popularity and momentum of deposits.

CONCLUSION

The paper tried to analyze the research output of 100 most productive institutions (including institution systems) in India for the year 2016 and measured the proportion research output available in open access. The study not only provides important observations on the status and pattern of open access in Indian institutions, but also draw attention to some inhibiting factors/constrains that prevents Indian research outputs from being available in open access mode.

Firstly, it is observed that only 23% of the combined output of the 100 institutions in 2016, as indexed in Web of Science, are available in open access. Gold Open access is the most prevalent type followed by Green and Brown open access. The lack of visibility of articles in hybrid open access may have deeper causal reasons. It has now become common for journals to have a hybrid open access model which acts as a revenue source for them. However, the cost of keeping a paper open access in most of the journals that follow this model is exorbitantly high. Institutions in developed economies have articulated policy that allows researchers to exploit this opportunity to keep their papers open access. The window available for Indian researchers to publish in open access mode is much less than those countries where institutional support is given. Thus, the findings of this study have to be seen in this context. Studies clearly point out and unsurprisingly so that a paper that is in open access has more chance for dissemination across the research community and attract higher citations and recall. Thus, a researcher if provided support would exploit it to publish in journals that follow hybrid open access policy.

Secondly, the open access proportions in the 100 most productive institutions are found to vary significantly, ranging from as low as 7% to as high as 75% of the total published papers. TIFR, Saha Institute of Nuclear Physics, NISER, PRL and PHFI are some of the institutions with high percentage of their articles available in open access. The Engineering and Technology institutions, including several IITs are found to have low percentage of their articles available as open access. A more detailed study may highlight the inhibiting factors behind the lower percentage of articles in open access from engineering and technology institutions.

Thirdly, the paper also found disciplinary variations in open access levels, with disciplines like PHY and MED having a higher proportion of articles available as open access. Papers from ENG and INF disciplines are found to have low open access proportion. Institutions in general having higher open access are primarily those that have Physics or Medicine as their major areas of activity. Interestingly, the geographical location of an institution is not found connected to the level of open access availability of research output of the institutions.

Fourthly, the number of papers available in Sci-Hub from all the 100 institutions (including institution systems) is many times higher than those available in legal open access forms. More than 2/3rd of the institutions in the set have higher than 90% of their papers available for free download in Sci-Hub. These results are in a sense an indication of failure of the legal OA models. Results indicate that there are either deterrents to use of legal OA models or possibly some kind of apathy in researchers to use legal OA models (such as depositing papers in institutional or disciplinary repositories).

Lastly, analysis of major Indian IRs show that the proportion of papers deposited in the IRs is very low and IRs as such could not emerge as a significant source of open access availability of research articles. The analysis of the three major repositories: Sciencentral, csicentral and krishikosh suggest that more efforts are needed to promote the IR culture in India. At the same time a lot needs to be done to understand why IRs are not an attractive medium for Indian researchers to disseminate their research in open access. These efforts could not only be limited to funding agencies but all the research institutions should make it mandatory for their researchers to submit their papers (or pre-print or post-print) to concerned IRs. Individual scientists should also be encouraged and incentivized for submitting their papers to IRs. This would not only help other Indian researchers who do not have access to costly journal subscriptions, but also the researchers themselves as their paper would find more citations and use.
It is quite clear from the study that much more needs to be done to promote open access culture in India, including the provision of incentives to researchers and institutions that help promote open availability of research output from Indian institutions. The study opens up new research questions, possibilities for expanding the scope of research and some important lessons.

One important aspect that this paper could not analyze is the amount of research output from India that is deposited in disciplinary repositories like arXiv or in academic social networks (such as ResearchGate). Academic social networks are now increasingly being used by researchers and also indexed by Web search engines. There are some difficulties in accessing these platforms for an automated crawling which prevented us from analyzing data from them. However, we are working on finding solutions to this and hope to look at this aspect as well in future work.

ACKNOWLEDGEMENT

The authors acknowledge the enabling support provided by the DST-NST Mis funded project ‘Design of a Computational Framework for Discipline-wise and Thematic Mapping of Research Performance of Indian Higher Education Institutions (HEIs)’, bearing Grant No. DST/NST Mis/05/04/2019-20 for this work.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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