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Developing a data-sharing system for geospatial research: A case study on the Joint Research Assist System (JoRAS)*

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Abstract

This study demonstrates a framework for joint research at a university research center that supports research in the geospatial information sciences. Here we examine the improvements in an Internet-based spatial data infrastructure and data-sharing system through its long-term operation. In the original system for this framework (the Spatial Data Infrastructure System or SDIS), the purpose was to make accessing spatial data easier for academic researchers. However, after ten years of service, it was still experiencing challenges, such as increased human costs and inconveniences from its operation, which were no longer negligible. In response, the system was rebuilt in 2010 as a new Joint Research Assist System (JoRAS) by reviewing and changing its design to address the challenges. Two years after the establishment of the JoRAS, its effectiveness and the emerging challenges demanded further improvements. This study summarizes the challenges of the former SDIS and the improvements made to transform it into the new JoRAS. The user statistics and its interpretations are then presented. This

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case study provides a guide to scientists and practitioners who are designing similar systems.

Keywords: Spatial data infrastructure, academic, joint research, data sharing

1. INTRODUCTION

Reliable spatial data infrastructures, i.e. platforms for distributing spatial data, are not only important for social infrastructure, but they are also critical for academic research in the geospatial information sciences (van Loenen and Onsrud, 2004; Masser, 2011). For academic research, the spatial data infrastructure and data sharing promote cooperation among individual research projects to enhance interdisciplinary research, where the role of the university is also essential regarding education (Deng and Di, 2009; Ramos and Ferreira, 2015).

Spatial data infrastructures have been developed in many countries and their challenges have been widely discussed (Maguire et al., 2005; Goodchild et al., 2007; Masser, 2011). For instance, to enhance sharing and public access to the environmental spatial information among public sector organizations across Europe, the Infrastructure for Spatial Information in the European Community (INSPIRE) was planned in 2007 and is expected to be in use by 2019/2020 (Bernad et al., 2005; Harvey, 2011). The University NAVSTAR Consortium (UNAVCO) is a non-profit university-governed consortium that has provided physical geospatial data, including geodesy and satellite imagery (Miller, 2013), while the National Center for Airborne Laser Mapping (NCALM) and OpenTopography have provided high-resolution topographic data (Carter et al., 2007; Crosby et al., 2011).

In Japan, the importance of establishing a national spatial data infrastructure has been mentioned since the 1990s (Iri, 1998). Large-scale examples include the Data Integration & Analysis System (DIAS) by the Earth Observation Data Integration & Fusion Research Initiative (Shibasaki, 2007; Kinutani et al., 2010) and the Global Observation Grid (GEO Grid) by the National Institute of Advanced Industrial Science and Technology (Nakamura et al., 2005). More recently, the increased necessity for spatial data sharing as open data has become crucial (Sekimoto and Seto, 2013).

Along with this background, the Center for Spatial Information Science (CSIS) at The University of Tokyo, an official joint usage/research center recognized by the Japanese government, has developed an extensive spatial data infrastructure (Sadahiro et al., 2001; Arikawa and Sagara, 2001; Okabe et al., 2002; Takahashi et al., 2004). This study provides an overall review of the framework for sharing a spatial data platform with academic researchers, which demonstrates the development of old and new interface systems. While the details for the improvement of the new system have been described by Fujita et al. (in press), here, we describe the problems that emerged during the long-term (10 years) operation of the old system followed by a demonstration of the improved features in the new system. We present the use statistics for both systems (i.e. the number of users and projects) as a timeline, as well as the latest use situation for the new system (after three years since its launch), which includes the types of data and the geographical distribution of the users and projects. We also discuss further issues that could be improved. As a whole, we demonstrate the key knowledge of the system's life cycle as a spatial data infrastructure, including its development, operation and its renovation, which were accomplished by examining its long-term operation over a decade.

2. SPATIAL DATA PLATFORM FOR RESEARCH AT CSIS

2.1. Framework for the Spatial Data Platform for Research (Data Platform) and Joint Research

The CSIS provides spatial data and services through its spatial data platform for research (Data Platform). It supports spatial information science research by inviting and conducting joint research using spatial data (Joint Research) and by providing access to the Data Platform to participating researchers (Users).

Research in spatial information science requires various spatial data, but gathering a large amount of various spatial data is often difficult for private facilities/researchers. Therefore, the CSIS is providing the Data Platform, which is comprised of a large amount of various spatial data that is a free service basically for academic research purposes, where Users must apply for a Joint Research project with the CSIS. The CSIS's National Joint Research Examination Committee (Review Committee), which includes extra-university academic experts, evaluates a Joint Research project for the appropriate sharing of the proprietary data among researchers. When the Review Committee approves an application, the Users are registered as CSIS joint researchers and are granted permission to use the spatial information and services for the approved research project.

At the beginning of the CSIS framework (December 1998), the spatial data in the Data Platform was relatively large in size and the datasets were copied onto portable media (such as CDs) to be mailed to the joint researchers through postal services. However, as the Data Platform grew, there was an apparent need to improve the data-sharing process. The Spatial Data Infrastructure System (SDIS) was launched in April 2000 (Sadahiro et al., 2001), which enabled data transfer over the Internet. However, processes including project applications and deliberations were based on email communications. As the number of Users increased, the personnel costs for its operation by CSIS administrators (Administrators) had increased and the convenience offered to the system's Users had declined. The system was therefore rebuilt as the Joint Research Assist System (JoRAS) in May 2010, which allowed the entire process to occur online, including research project application, deliberation, approval and data download.

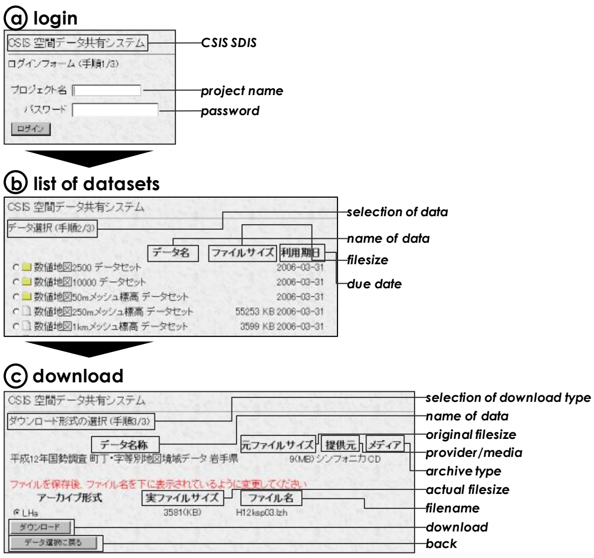
2.2. Previous system: The Spatial Data Infrastructure System (SDIS) was used from 2000-2009

2.2.1. Development of the SDIS

Research related to spatial information science combines a variety of spatial data in numerous formats through a multifaceted structure. However, before the establishment of the SDIS, the ability to instantly identify the formats or locations of the spatial data, when required by researchers, was not available. Also, even when the desired spatial data existed, the data formats, projection methods and the spatial aggregation units varied depending on the specific data, which resulted in labor-intensive conversions (Sadahiro, 2001). The SDIS, which is comprised of a catalog system and a data-sharing system, was then developed to offer 34 datasets that contained about 4000 files. When the SDIS was developed, the priorities for the distribution of spatial information involved providing metadata that conformed to geographic information standards. The spatial information catalog system was designed as a generic application to create a clearinghouse that provides the standard geographical information metadata (ISO/TC211) and spatial- and text-based searching facilities, whereas the spatial information-sharing system was developed to distribute CSIS-owned data.

The basic data-use procedures for the SDIS starts with the search for spatial data using a spatial search function or data lists in the catalog system. Users then submit a research project application, by email that includes the research objectives, member identifications and lists of desired data to be accessed. Administrators send the application email to the Review Committee. Upon their approval of the application, the Administrators contact the Users by email. The Users then send a contract regarding acceptable use practices to the applicant using the postal mail, which is followed by the Users receiving accounts and passwords for each project from the Administrators by mail. The Users can finally log in to SDIS's data download system to find the list of available data (Figure 1).

Figure 1: Screenshots from the SDIS. Each step for accessing the data is shown. Italic letters are the translations of Japanese terms. (a) The login menu requires the project name and password. (b) The list of datasets available to the project includes the data name, file size and the time limit for accessing the data. (c) The download menu for the selected data file.



2.2.2. Problematic issues with the SDIS

The SDIS ran for nearly ten years. During this time, 503 researchers used it for 381 research projects. The SDIS achieved its objective of supporting researchers in their use of spatial information. However, challenging issues have also emerged in the SDIS, which can be viewed from an Administrator's or a User's perspective.

From an Administrator's perspective, three issues were raised. First, project management and User costs have significantly increased. Whereas the SDIS had the data search functionality, but it did not have a function for the online management of research projects or for Users. Information for each project, including the data download rights, passwords and the participants on each project, had to be individually added, updated and deleted in the SDIS database using a generic application (Microsoft Access). The use procedures – including new applications, adding data, adding members, project continuation, the resetting of passwords and the submission of reports – relied on the records and the email correspondence (partially by postal mail) of staff members. Furthermore, the diminished number of management staff (from eight to three) made each individual’s load heavier.

Second, costs for spatial data and metadata management increased. Administrators had to directly edit the database to add new data and new versions of existing data with the appropriate metadata following the geographical information standards, which used a generic spreadsheet application.

Third, security problems emerged. The account names and passwords that are required to download data were shared among project members because they were set on a research project basis. However, sharing passwords likely leads to leaks and must be avoided. Furthermore, there was a risk of human error because Administrators managed passwords and downloading rights directly in the database.

From a User’s perspective, two issues emerged. First, management costs for various applications and projects were high. The series of application steps by email and postal services required a wide range of labor. Moreover, the Users must send confidentiality agreements by postal mail, which resulted in the passage of several weeks before they received approval to download data. Also, the Users needed to ascertain what data they could use for a project because data use rights were determined on a research project basis. This particularly increased the burden of Users who participated in multiple projects with hundreds of datasets.

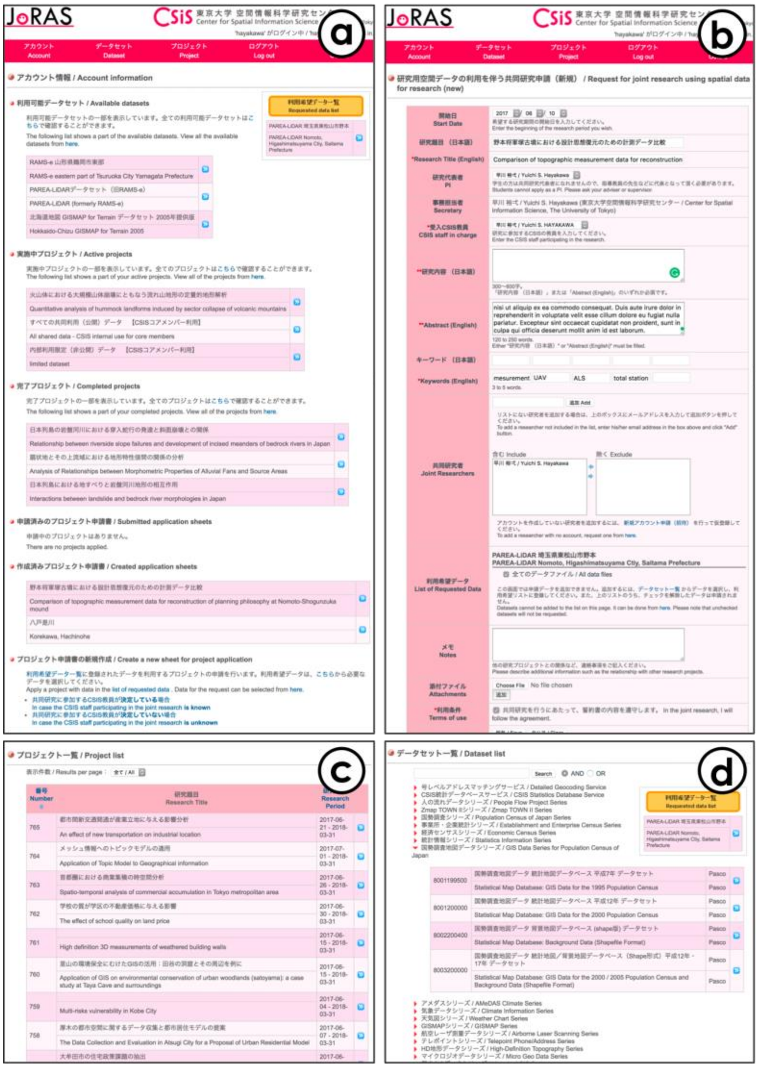
Another issue was with the spatial data search and the download convenience. The search methods for the spatial data in the SDIS required either a spatial search using a map or selection from a list of datasets in its catalog system. The number of datasets in 2009 exceeded 350; however, based on the access log, few Users used the spatial search function. Regarding the download convenience, due to the limitations with the Internet speeds at the time, Users had to download a large number of files that were split into smaller sizes of about 10 MB.

2.3. Successor system: The Joint Research Assist System (JoRAS) has been used since 2010

2.3.1. Development of JoRAS

The successor, the Joint Research Assist System (JoRAS), was developed and released in April 2010 to solve the problems associated with the previous SDIS as noted above. The JoRAS is a web application with enhanced research project management functionality, which had been a particularly significant challenge when using the SDIS.

Figure 2: Screenshots of the main displays in the JoRAS. (a) The account page. Lists of available datasets, active and completed projects and application sheets linked to the account are shown. (b) The application form for a new research project. (c) A list of projects. (d) A list of datasets.



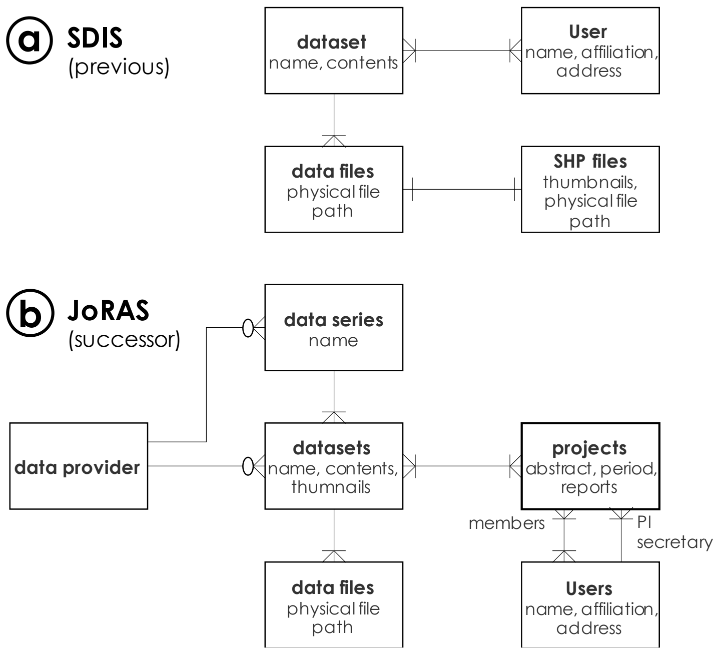
The fully public functions can be used by all the system users, including those without a User account, such as browsing the overviews and keyword searches for spatial data lists and individual spatial datasets, browsing the overviews and keyword searches for research project lists and individual research projects and new User account registrations. Users with registered accounts can then apply for a new research project, modify the information in a User's current projects and download the permitted data.

Administrators have the basic ability to edit all the information in the system. Administrators can manage research project application procedures and system operations including dataset information, data series registration and the editing of automatically sent emails.

2.3.2. System features

In the new, PHP-based system or the JoRAS, all the research project information is stored in an SQL database, where the system successfully reduced the substantial efforts of the Users and Administrators compared to the old SDIS system.

Figure 3: Data models for the previous SDIS and the new JoRAS. (a) In the SDIS, a User could access the dataset, where individual data files were associated with and were mostly provided as shapefiles (SHP). (b) In the JoRAS, Users are associated with a project, to which the available datasets are linked. Data series are the higher groups for the datasets with links to their providers. Individual data files are regarded as subsets of datasets in the same way as with the SDIS.



A main feature of the JoRAS is the addition of the project" to the data model (Figure 3). In the previous SDIS, datasets and User(s) were linked, which requiried the Administrator to maintain the link outside of the system (Figure 3a). In contrast, the JoRAS employs a data model that has two stages: linking datasets to projects and projects to Users (Figure 3b). This model allows Users that participate in multiple projects to use all the data from any of their projects. Also, confirmation and management of the available data and the Users for each project became easier with the ability to manage project information including objectives, period, members, the data to be used, the results and the outcomes.

The JoRAS also introduced the concept of the "data series," which is a bundle of related datasets. This enables hierarchical searches of datasets.

Unlike the previous SDIS, User accounts and passwords have been issued to individuals using the JoRAS. This allows Users to manage their multiple research projects with one User account, which eliminated the need for password sharing among project members. Also, it confirms User authentication and service use rights accessed from outside the system (single sign-on function), which enables Users to access numerous CSIS services with a single User account and password.

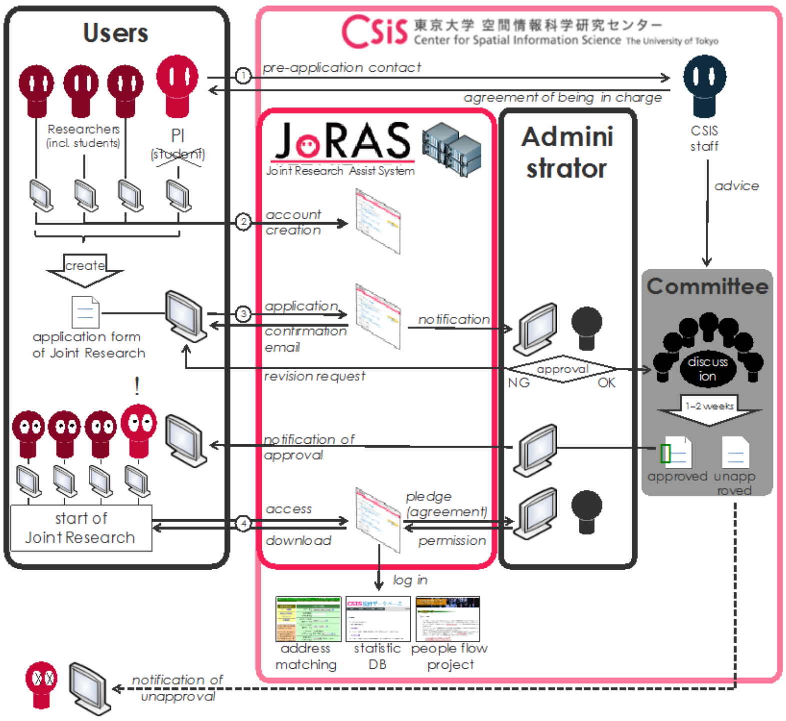
For research projects, two special User roles were created – Representative and Administrative Users – that are authorized to apply for modifications to the project participants or data. The JoRAS has an online application function that allows these privileged Users to perform a variety of online applications, which is much faster than the paper-based ones. Unlike the manual assessment in the previous SDIS, datasets and User(s) are automatically linked in the JoRAS upon application approval.

Administrators can browse and modify all the registered projects and data from the Administrator's web interface. To avoid manual monitoring of the progress, the system automatically sends a notification email to the Administrator when necessary and the required confirmation or task can be immediately performed using the URL contained in the email. Furthermore, the metadata for numerous datasets can be registered in batches, which reduces the cost and the number of human errors involved with registering or editing metadata for large numbers of spatial data files.

2.3.3. Operation of the JoRAS

In the JoRAS, Users can seamlessly perform all the important procedures related to their joint CSIS research. This functionality significantly reduced the Administrator's tasks as indicated by the reduction of the time period for the application procedures (Fujita et al., in press). Figure 4 illustrates the entire flow of the application, deliberation and approval of the online procedures for the JoRAS. First, the representative User of a joint research project starts the joint research project application. The first instance (1) in Figure 4, where a User contacts a CSIS staff in advance, is not mandatory. If a staff member has not been pre-selected, the joint research representative is required to submit his or her resume. At the second instance (2), every User is required to have an active JoRAS account before creating a joint research application.

Figure 4: Flow diagram for the project application, deliberation and the data utilization procedure.



Users prepare the title, abstract, keywords and a list of the desired spatial data required for the joint research, which they enter in the JoRAS window (Figure 2b). After confirming the terms and conditions, the application is registered in the system and submitted to the Administrators (3).

When a User submits an application, an email notification is automatically sent to the Administrator. Upon receipt, the Administrator examines the contents of the application and returns, to the User, any necessary application corrections. The approved application is then forwarded to the Review Committee, where the deliberation begins. More than one week after the conclusion of the deliberation, an approval notification is sent by the Administrator to the User. Upon approval, the joint research begins and the User can access the approved data and services (4). Before using of the data, the Users are required to create and submit a pledge agreement (contract) through the JoRAS, which states that they will observe the Rules for Joint Research. Users can also request modifications to their research project content, i.e. adding or removing members and data, by following the same procedure used for a new application.

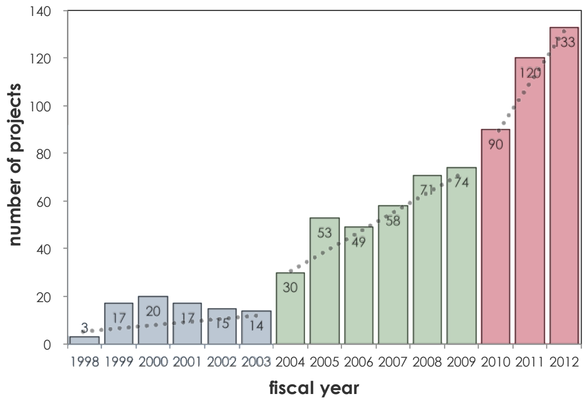
3. USE STATISTICS RELATED TO THE JOINT RESEARCH

In this section, we present the use statistics for joint research projects and data. Hereafter, the annual period is based on Japan's fiscal year, which ranges from April to March. First, we review the temporal changes in the registered projects and Users during the 15-year period from 1998 to 2012. Next, the latest status (as of 2012) of the registered spatial data is summarized. The spatial distribution of the Users, as well as the study areas of projects, are then examined.

3.1. Temporal changes in research projects and researchers

Figure 5 shows the changes in the number of adopted joint research projects from 1998–2012, where the total average annual increase was 29%. These changes can be roughly divided into three periods. During the first period (from 1998–2003), the number of projects did not exceed 20. The second period (from 2004–2009) showed a rate increase of 8.8 projects per year, while the total number of projects more than doubled. During the third period (from 2010–2012), which was after the JoRAS was launched, the number of projects further increased at a rate of 21.5 projects per year, which exceeded 100 projects after 2011.

Figure 5: The number of adopted joint research projects from 1998 to 2012. The annual period is based on the Japanese fiscal year. Dashed lines indicate the linear regression for each of the three time periods (1998–2003 in blue, 2004–2009 in green and 2010–2012 in red).



The average duration of a joint research project was 14 months. Out of the 470 projects, 65% lasted one year or less, which indicates that the majority of projects were conducted within one year (Figure 6).

Figure 6: Duration of joint research projects.

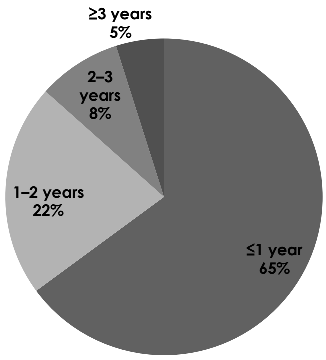
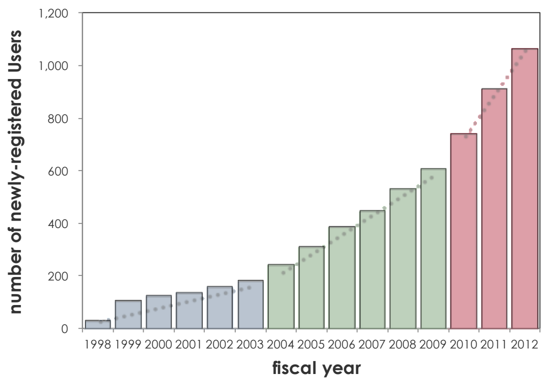


Figure 7 shows the temporal changes in the registered Users. The number of registered Users increased because the Users were rarely deregistered, while projects often ended within a couple of years. The trend of increasing Users can also be divided into three periods like with the research projects, but the differences in the trends are not as clear as those for the projects (Figure 5). This is due to the variations in the number of researchers and the continuity of their projects.

Figure 7: Temporal changes in the cumulative number of joint research Users. Dashed lines indicate trends for the registered Users for each period (1998–2003 in blue, 2004–2009 in green and 2010–2012 in red).



As of 2012, the total number of registered Users was 1,007. Users affiliated with universities and public institutes comprised 90% of the total because a large proportion of the datasets in the JoRAS were only provided to academic users. However, the JoRAS also includes some data that can be used by non-academic institutions. The remaining Users (9%) were from private companies that are allowed to use this data. The number of overseas researchers was small (2%) because the JoRAS interface is only available in Japanese at the time of 2012.

3.2. Statistics for the registered spatial data

Table 1 summarizes the use of the data series offered in the JoRAS as of 2012. Within each data series, the datasets are organized by data type, year and region. The data files are subsets of datasets sorted into actual files. The services linked to the joint research framework (Detailed Address Matching (Geocoding) Service and CSIS Statistics Database) are also shown.

Table 1: Summary of the use for the data series offered in 2012, which are sorted by the number of uses except for the miscellaneous datasets that comprise individual datasets that were not offered in specific data series. "Rank" is based on the number of uses per dataset.

data series	data provier	number of datasets	number of data files	data files /dataset	number of use	number of use per dataset	rank
ZmapTownIISeries	ZENRIN, Co.	141	462	3.3	5,388	38.2	4
National Sensus Series	Sinfonica	125	6,758	54.1	4,382	35.1	6
Office/Company Statistics Series	Sinfonica	49	3,531	72.1	1,626	33.2	7
Statistics Information Series	Sinfonica	26	635	24.4	866	33.3	7
AMEDAS Series	Japan Meteorological Agency	31	532	17.2	768	24.8	10
People Flow Data Series	CSIS	16	16	1.0	559	34.9	6
Climate Data Series	Japan Meteorological Agency	15	421	28.1	396	26.4	9
RAMS-e Series	Kokusai-Kogyo Co.	10	15	1.5	277	27.7	8
National Sensus Maps Series	Pasco, Co.	4	322	80.5	252	63.0	3
Weather Chart Series	Japan Meteorological Agency	10	987	98.7	240	24.0	11
GISMAP Series	Hokkaido-Chizu Co.	6	1,063	177.2	216	36.0	5
TelePoint Series	ZENRIN, Co.	2	96	48.0	161	80.5	2
Detailed Address Matching Service	CSIS	1	1	1.0	96	96.0	1
CSIS Statistics Databasee Service	Sinfonica / Research Institute of Economy, Trade and Industry	50	2,304	46.1	74	1.5	12
(no series)	other companies or researchers	17	112	6.6	728	42.8	
total		503	17,255	34.3	16,029	31.9	

The average number of data files per dataset was 34.3 and varyied from 1 to 177.2. The largest number of data files was for the GISMAP Series, which is map data comprised of large datasets containing both ground objects and topography. The data files were separated into smaller pieces because this data series had also been provided in the previous SDIS, where a large data size was problematic for sharing.

The use frequency of the data series is defined as the number of uses normalized by the number of datasets (the last two columns in Table 1). Except for the Address Matching Service, the most frequently used data series were the telepoint series (telephone directory data with the associated location information) followed by the data series for the census maps. Vector map data for buildings and roads (ZmapTown II and GISMAP) came next. The other data series showed less variation with a use frequency of 25–35. The top-ranked data pertained to the human and social sciences, where the data was assumed to be used for geospatial analyses in fields that include urban engineering. In contrast, the fraction of natural science studies using joint research seemed relatively small, where a lower use frequency was observed for environmental (climatic and geomorphological) datasets such as the AMEDAS (Japanese meteorological records), weather charts and the RAMS-e (airborne laser scanning).

3.3. Spatial distribution of researchers and study areas

Figure 8 shows the distribution of researchers and their affiliated institutions (as of 2012). Most of the affiliated institutions are concentrated in the Tokyo metropolitan area, followed by the greater metropolitan areas of Kinki (the western area around Osaka) and Chubu (the central area around Nagoya).

Figure 8: Spatial distribution of the joint researchers and their affiliated institutions by prefecture.

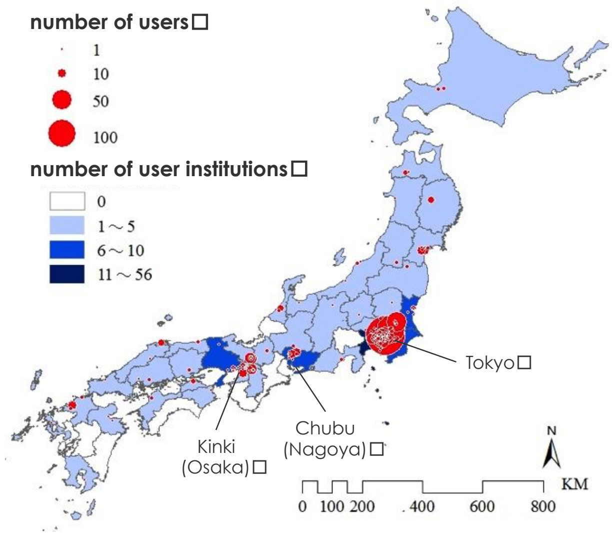
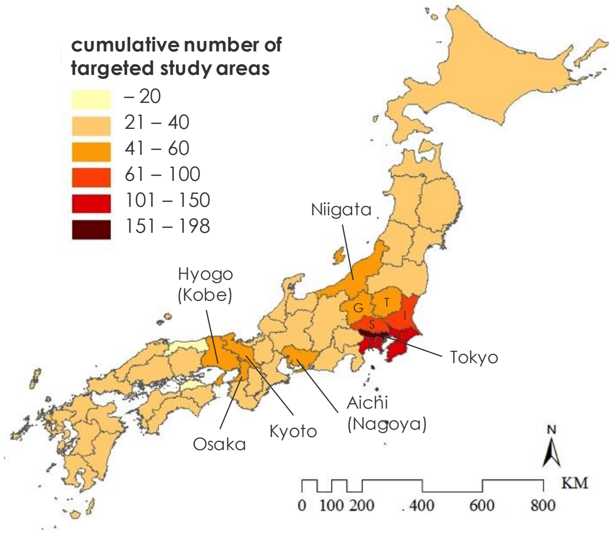


Figure 9 shows the total number of study areas per prefecture for 359 research projects, where the JoRAS provides a clear indication of their study areas as of 2012. The Tokyo metropolitan area was the most frequent subject of study, including the surrounding prefectures of Saitama, Chiba, Kanagawa, Ibaraki, Tochigi and Gunma. This was followed by the greater metropolitan area of Kinki (containing the Osaka, Kyoto Hyogo Prefectures) and Chubu (containing the Aichi Prefecture). The Niigata Prefecture also showed a relatively high frequency, although it is not included in any of the greater metropolitan areas. This may indicate some specific local interest by researchers in the other regions.

Figure 9: Spatial distribution of the study areas divided by prefectures. In cases where multiple prefectures were involved in a joint project, they were counted repeatedly for each prefecture. Names in parentheses indicates the major city in that prefecture. S: Saitama, C: Chiba, K: Kanagawa, I: Ibaraki, T: Tochigi and G: Gunma Prefectures.



4. DISCUSSION AND CONCLUSIONS

4.1. Interpretation of the use statistics

The above presentations only showed the temporal changes in the use statistics in the previous and new systems (the SDIS and the JoRAS respectively). In regards to the latest use status for the JoRAS, it was challenging to determine the precise extent of the effects of the JoRAS, such as for interviews and the evaluation of other factors, which are certainly future issues to be addressed. Nevertheless, the rapid increase in the number of projects and Users after the system's replacement is the apparent main outcome (Figures 5 and 7). It should also be noted that the increase over time in the number of joint research projects and Users is supported by a decreased number of Administrators. The fact that fewer Administrators have operated the system without significant problems is another important outcome for the JoRAS.

The use statistics for the spatial data registered in the JoRAS suggests that the needs for human and social sciences are apparently higher than that for pure natural sciences (Table 1). This may be derived from the fact that the majority of geospatial science is from human geography rather than from physical geography

(Longley, 2000). Another potential factor is that spatial data related to the natural sciences has already been well managed, while those of human and social sciences are less organized and distributed (Asami and Shibayama, 2012), which led to the increased use of well-organized datasets in the JoRAS. In any case, further assessments would be necessary to find the needs of both social and natural sciences and to expand the spatial database accordingly.

4.2. Spatial characteristics of the Users and their projects

The spatial distribution of the Users showed a strong aggregation in some metropolitan areas (Figure 8). This makes sense because major universities and research institutes are densely populated in these areas. There should be, however, further scope to increase the number of Users in other suburban areas by promoting the joint research framework at non-major universities and institutes in areas other than the metropolitan areas.

In this study, we assessed the targeted study areas that use joint research projects according to their prefectures, which also showed a bias in the metropolitan areas (Figure 9). However, unlike in the case of the Users, a high frequency of the study area in a rural area (the Niigata Prefecture) was observed and suggests the potential for the further increase of joint research in suburban areas. Also, the geographic registration of research projects (geotagging) is expected to provide more precise and comprehensive information on the spatial distribution and patterns of joint research. For instance, spatial relationships between the study area and the researchers' affiliated locations could be explored after the projects are precisely geotagged.

4.3. Future issues in the system development

An important prospect for the future of the JoRAS is the improvement of an English translation of the system. This is essential for boosting international joint research. As of 2017, the system provides both Japanese and English descriptions in its interface, but switching the available language on the same interface would work better for the Users. Furthermore, translations for many Japanese instruction manuals for individual data are desired.

On-demand summary export and visualization of the use statistics for Users, projects and data are other potential functions that could be implemented. These features are particularly useful for presenting the data use performance for the data providers that are interested in how their data are utilized in research and for other researchers potentially interested in geospatial studies.

The capability of data registration by researchers is another issue that could leverage the more widespread use of spatial datasets. Spatial datasets that are created by researchers are often owned individually and have fewer opportunities to be provided to academic societies. The issue of open access to data produced by publicly funded research has widely been discussed (e.g., Grove, 2013), but the distribution of open-access geospatial data is still a challenging issue in Japan (Seto and Sekimoto, 2015). Therefore, the function of data registration in the framework of the JoRAS would promote the use of such User-based data, which could also drive the stream of open data and open science (Oguchi et al., 2015).

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