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EXPLORING REMOTE SENSING TRENDS AND OPPORTUNITIES: GOOGLE EARTH ENGINE APPLICATION ON URBAN GREEN AREAS

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Abstract: *During the last few decades, remote sensing and satellite earth observation have experienced a rather impressive escalated advancement. As a result, large amount of geospatial information that derived from orbiting platforms became publicly available and organized databases, carrying exabytes of information, were created. Those databases became the core of elaborated systems, that contribute to the understanding and hierarchy of several phenomena, that dominate entire human artificial environments, thus aiming in finding answers to complex contemporary problems. Google Earth Engine (GEE) is a relatively new addition to this set of software platforms, that are designed to freely handle and process big geospatial data. GEE is an online web environment, driven mostly by Java applets. The platform is producing key results, by running any relative code, produced by any remote user.*

The main objective of the present study, is to demonstrate the provided enhanced opportunities for detecting environmental problems, using Google Earth Engine. Urban green areas particularly, hold a vital role in the regulation for optimum environmental conditions, concerning the urban residents as well as the sustainability of existing ecosystems within them. In the current study, recent publications concerning urban green areas were collected and an up to date literature review has formed. The publications review provides some collective knowledge about the trends, concerning the ongoing research, along with the use of GEE focusing in urban green areas evolution and its constant depiction. It should be mentioned that the study was concluded by the collected user query requests, that were gathered during the current year last month, in the GEE Group Developers board. The origin of the users, the nature of their requests and their research aspects are forming the future shape of GEE. Central local governments and several European Union Environmental Institutions could emphasize in practical solutions, regarding environmental distortions and interventions, by extending the practical benefits of platform like GEE.

1. Introduction

During the last forty years, practices of Remote Sensing (RS) have experienced continuous developments and diversifications. Nowadays, the result of such elaborations, gave birth to revolutionary scientific fields and new abilities of the present RS systems, which are considered as one of the founding wheels, resulting in driving the innovation and investment into the future. Remote Sensing is lately transformed in Earth Observation (EO), a larger pool of applications, attracting financial interest. The ability of accessing high resolution satellite data became the essential tool for analyzing various aspects of human interaction with land, water and vegetation (Sajjad&Kumar, 2019). There are several types of sensors equipped by remote sensing satellites, according to their specific targeting purposes (land types, surface elevation etc.). As a result, global scale observation and data processing with different spatial and temporal characteristics were used, originating optimum decisions, in order to mend complicated problems, concerning natural or human-made environments.
As with any modern technology, Remote Sensing is influenced by advances in scientific fields and the uprising human needs concern. These advances offered capabilities, potentially able to transform any kind of information. The specific trend, that affects Remote Sensing, results in the need for continuously collecting Earth Observation data, with the best high spatial resolution from multiple sensors, available via Internet, with the most affordable way. This means that huge amounts of remote sensing data requires changes to be made, concerning the traditional ways of storing, processing and free distribution.

The aim of this paper is to present current trends and opportunities of Remote Sensing as well as to evaluate Google Earth Engine (GEE), as an online web environment, that transforms open information into ready for use datasets.

Notably, the current paper is organized into four main sections. First, a brief review of Remote Sensing current trends is exposed. Secondly, the management of geospatial big data and the way of dealing with them, using the GEE platform is described. A description of its basic function follows. Subsequently, in the third part, a review of the corresponding scientific literature is presented and as well as bibliometric analysis concerning urban green spaces with GEE. In the last part, one, could find conclusions, extracted solely from this research paper.

2. Remote Sensing Technology: Usage and Trends

2.1 Current state of trends in Remote Sensing Technology

In the last decade big amounts of remote sensing data, fundamentally alters the existing storage needs, analysis and the traditional ways of processing. The availability through Internet and the simple use of them, functioned a major role in the configuration of existing trends, concerning remote sensing industry.

Current dynamic and demanding information environments, combined with complex geospatial data formats and big amount of related data, irrevocably lead professionals and RS experts, to create new data models, strategies and platforms that are cost effective and time consuming. At the same time, continuous capture and re-capture of satellite data from multiple sensors, that could be used many times over from various expert users and not only, transform the approach of managing geospatial big data (Koswatte & McDougall, 2018). Consequently, one of the future challenges will be the exploitation of these data, using specialized processing methods, such as cloud-based computing approach. Google Earth Engine is a representative example of such a platform.

Remote sensing technology is an extremely significant tool, essential for observing Earth's surface and mapping land cover changes, in order to manage and predict emergency cases, such as forest fires and floods. Merging data from various satellites and sensors result in a very useful technique, to acquire better and more accurate information.

There are four main categories of satellites according to their spatial resolution: Low resolution sources (pixels larger than 30 meters) that are used to monitor the environment and the global changes occurring in natural resources, by the use of satellites such as LANDSAT, MODIS, TERRA etc. Medium resolution sources (pixels between 5 and 30 meters) that are applied for monitoring areas or phenomena in daily basis, by the exploitation of satellites such as SPOT, Rapid Eye, IRS etc... High resolution sources (pixels between 1 and 5 meters) that are utilized to urban studies, through satellites such as THEOS, Dove, Aist–2D, Resurs -P etc. Very high resolution sources (pixels under 1 meter) that are adopted for precision agriculture applications, cadastral mapping and urban planning with satellites, such as Ikonos, QuickBird, WorldView, Kanopus – V etc..

Nowadays, the problem of consecutive land cover changes and especially of habitat changes inside cities, shows the extreme importance of high spatial resolution satellite imagery for monitoring them. Thus, pivotal role is owned by the unmanned aerial vehicles (UAVs). They are used for monitoring and collecting near and real-time data, for small areas where the scale doesn't matter, with a more affordable way, than any other regular aerial and not only survey (Sajjad&Kumar, 2019). However, the newest add in the remote sensing field is the airborne laser ranging (LIDAR) technology. Airborne LIDAR is the rising geospatial tool that gives us the opportunity to generate direct 3D urban landscape models, at the resolution of up to a few centimeters (Shan & Hussain, 2010). Not to mention that, aerial LIDAR data quickly became an attractive mapping solution. Looking ahead and focusing in an extend of just a few years; professionals will try to find more affordable ways to deliver data, according to any individual researcher need. This trend will influence both professionals and LIDAR experts, resulting them to be able to provide them with the best sensor technology, either for low or high altitude aerial sensors, depending on each specific project and its budget.

2.2 Remote sensing data, software, drones and portable devices

Remote Sensing scientific research, the gathering of satellite data and the massive acquiring of real-world applications have experienced a fundamental worldwide explosion, that has occurred in the last ten years. The everyday increased demand of geospatial data as well as the global need to discover new methodologies and applicable solutions, to natural or man-made environments, forced both scientists and experts around the world, to incorporate in the vast Remote Sensing domain utilizing innovative and efficient technological tools. The most representative among them, became the UAVs and the smart-phones, equipped with adequate software.

The huge growth of the Remote Sensing field, being a real obstacle in its use for almost every world-wide user, can be faced through three main domains.

The optimum choice for end-user needs is adequate satellite images according to their suitable qualities. It is well-known across the Remote – Sensing community, that the number of remote sensing earth observation satellites nowadays exceed six hundred and fifty.

Always taking into consideration, the type of the chosen satellite images, for either private or public projects to be implemented, it is necessary to use the most convenient and efficient software, in order to reach the final and desired target. A plethora of such software exists and some of them are remote sensing and GIS specialized, at the same time. The most known are presented in the following table (Table 1).

Table 1. Most known Remote Sensing Software Packages

Software:
Geomatica, PCI Geomatics
SAGA GIS (Open Source)
ERDAS IMAGINE
ENVI
Google Earth Engine
GRASS GIS
Orfeo toolbox (Open Source)
IDRISI
ECognition
ArcGIS
SNAP

Nowadays the “value for money” rule seems to govern our professional life and not only. The same applies to the Remote Sensing Community. Due to the increasing cost of almost everything, a powerful and almost global trend in the remote sensing community appeared; the disposition of freely available satellite data, as well as medium spatial resolution satellite images, sometimes even of high spatial resolution in addition to the use of freeware, comparable in quality to commercial well-known ones.

Representative examples for free distributed satellite images, according to the Earth Observing System (EOS), presented in the Table 2.

Table 2. Most known sites with satellite images for Earth Observation

Sites with satellite data for Earth Observation
USGS Earth Explorer
LandViewer
Copernicus Open Access Hub
Sentinel Hub
NASA Earthdata Search
Remote Pixel
INPE Image Catalog

Similarly, representative examples for the open source remote sensing software packages are presented in the Table 3.

Table 3. Open source remote sensing software packages

Open Source remote sensing Software Packages
The Sentinel Toolbox
QGIS Semi-automatic Classification Plugin (SCP)
SAGA GIS: System for Automated Geoscientific Analyses
ORFEO Toolbox (OTB): Optical and Radar Federated Earth Observation
GRASS: Geographic Resources Analysis Support System
PolSARPro
Opticks
OSSIM: Open Source Software Image Map
InterImage
ILWIS: Integrated Land and Water Information System
gvSIG
Whitebox GAT
E-foto

Another big deal to face up is the explosive use of drones in the last years.

First, we pose the following statement in question: Do UAVs (Drones) and satellites supplement each other or act in a contrary way?

Taking into consideration, the difference in spatial resolution between satellite and drone images, the different temporal resolution, setting drones in a rather advantageous position, the field of view the satellites can cover despite the existing weather conditions, such as cloudy days, that still are not an obstacle concerning drone use, although bad weather conditions can even destroy them. Finally, considering the limited drone flight range, one can vaguely conclude that drones and satellites supplement each other.

It's worth to mention a study comparing the utility of drone images (DJI-Phantom-2 with SJ4000 RGB and IR cameras, spatial resolution: 5cm) and satellite images (Pleiades-1B, spatial resolution: 50cm), for mangrove mapping. According to the researchers who implemented this study, image classification techniques seemed to be more accurate for drone than for satellite images, although the processing time was at least ten times longer for the drone than for the satellite image.

The outstanding evolution concerning the use of cell phones in the last decades didn't exclude some remote sensing applications.

Nowadays, although cell-phones are far from reaching laptop capacity, there are applications, that even if they are not equivalent to a computer software, they are at least similar.

Dr Karen Anderson, Associate Professor of Remote Sensing in the University of Exeter and leader of a cell-phone (used as sensor) scientific project said:

"Currently the sensors on mobile phones harvest data about their users and send this information to third parties. We wanted to start using those data for beneficial purposes, such as community-led mapping."

In another project entitled "Sensors for ANDROID in embedded systems", which was achieved in the "Department of Information Engineering, University of Brescia, in Italy, a framework was created, which allows the Android developers to handle the remote resources (i.e. sensors and actuators) via the Bluetooth 4.0-4.1 technology with the same approach to the embedded resources

A third application is entitled "Development of Android Smart Phone App for Analysis of Remote Sensing Images". The purpose of this study is to develop an Android smartphone app, that provides analysis capabilities of remote sensing images, by using mobile browsing open sources of gvSIG, open source remote sensing software of OTB and open source DBMS of Open source Relational Database PostgreSQL. In this app, five kinds of remote sensing algorithms for filtering, segmentation, or classification are implemented, and the processed results are also stored and managed in image database, for any user to retrieve.

2.3 Big Earth Data a rising trend in Remote Sensing Industry

Managing and processing of Big Earth Data is the main recent trend in satellite Earth Observation. The ever-increasing volume, variety and velocity of satellite data (Sudmanns et al., 2018), whether they are near real-time or from previous years, faces the need to correlate information, between what happened in the past and what will come to be in the future. During the last ten years, Earth Observation Big Data gained worldwide attention, not only by commercial organizations and governments, but also from researchers, Big Data experts and individual users on Remote Sensing technology (Koswatte&Mcdougall, 2018).

Free for all, open to the public, a continuous flow of information and a steady policy concerning Landsat and Sentinel data, create new challenges for Big Earth Observation data. Thus the question, how to make the best use of Big Data, in terms of generating information useful for everyone to access. Nowadays, the European Programme “Copernicus” is one of the key drivers for the expansion of EO data and its truly free distribution, for everyone to exploit. The Copernicus Sentinel-2 satellites collect more data, than any other comparable initiative, past or present (Sudmanns et al., 2018).

The big data environment presents a range of challenges for the management of geospatial data, that determine trends of Earth Big Data. To address these challenges, experts are making efforts, to develop computing platforms and algorithms, that can effectively store and manage those huge and increasing amounts of geospatial data. Still, cloud storage technologies are lower in cost and seem to be the best possible solution, for storing and processing data in cloud storage platforms anywhere and anytime, as well as to perform spatial analysis on demand. MapReduce pattern for parallel processing seems to be superficial for handling large-scale and demanding Big Earth Data (Sidhu et al., 2018).

It is worth to mention that, constant flow of high-resolution satellite imagery data requires artificial intelligence (AI) processing, that efficiently performs real-time processing and analysis. Artificial intelligence systems would be a useful tool in automated analysis of large data sets (Koswatte & Mcdougall, 2018). One of the main challenges of machine learning for mapping industries is to develop systems that periodically analyze satellite data, to identify temporal changes and correct errors in geospatial data sets.

Trends and challenges may arise with the daily use of big EO data, including questions concerning data storage, as well as processes and methods, that are both easier and time consuming. These of course are just some of the questions, which we will be challenged to change, periodically alter, manifest and resolve anytime, according to the impact the increased flow the amount of satellite data has to offer to us.

3. Google Earth Engine (GEE) the upcoming global remote sensing tool

3.1 GEE Cloud Platform in the processing of geospatial data

Nowadays, there is a wide variety of software libraries (TerraLib, Hadoop, Geospark etc.) that have been developed to process geospatial data from different resources (USGC, NOAA etc.). Since the dawn of the new millennia, Google Inc. has played a pivotal role in the information community, which is furthermore proved by the evolving role of Google Earth, a publicly accessible software, for processing remotely sensed data.

Google Earth Engine (GEE) is a cloud-computing platform, which evolved into a remote sensing tool for everybody to study and research. GEE written in Java, containing the necessary Java templates and being the bridge between the data source and the analysis process, includes petabytes of data, that are freely available and ready for use, created in cooperation with research Institutes - such as the University of Maryland. Geospatial datasets of GEE include satellite data and aerial imaging from a considerable number of frequencies of the electromagnetic spectrum, climate forecasts, land cover, environmental, geophysical and socioeconomic datasets. These datasets can be used in a variety of fields, such as global forest change, crop yield estimation, urban and flood mapping (Gorelick et al., 2017).

There are no restrictions for using this platform, except from having a Gmail account, enabling users to start programming. GEE uses Java, as a programming language, but there is an option for Python. Processing satellite data, depends on each user individual programming ability and the Internet connection quality. Therefore, general public can easily use it, in contrast with known specialized remote sensing software such as, Environment for Visualizing Images (ENVI) and Earth Resources Data Analysis System (ERDAS) Imagine (Kumar & Mutanga, 2018).

Following the trends of technology and remote sensing, Google Inc. evolved furthermore this platform, thus allowing users to process data in rural areas, via mobile devices (Venturino et al., 2014).

3.2 Earth Engine Developers Groups

Earth Engine Developers Group is an online developing community, which is officially supported by Google. The GEE Developers Group is a forum for asking and answering technical questions, related to GEE with active members from all over the world. Those members have the chance to discuss features of this platform and pose useful proposals among them, that can be helpful for each other. The main advantage of this Group is that its members can share their scripts openly, within their respective directories, in order to solve code running problems.

3.3 Materials and Methods for our study case

"Harzing's Publish or Perish" (HPoP) is a software program, that analyzes academic citations by using Google Scholar, Microsoft Academic Search, Scopus, Web Science etc., granting this way the chance for every user, to make research complex queries and extract bibliometric results and statistics. The aim of bibliometric analysis here, is to show the way GEE platform is used, both as a tool for calculating urban indices, as well as to pinpoint the arising problems encountered by the users. The reference time period was the elapsed year of 2019.

In our research, Google Scholar via HPoP is used to locate publications, using a select combination of keywords and logical operators. The final expression was like: "Google Earth Engine" AND ("urban green space" OR "urban green areas" OR "urban trees" OR "urban forest" OR "urban green"). The search has included the body of the articles, excluding the references section. A database was formed following this procedure, including all articles that derived from the aggregation. Microsoft Excel software was used to exclude duplicates, perform cross tabulation and calculate the frequencies within data. Conference papers, books and book chapters, reports and thesis were included in the database. An effort was undertaken to summarize as many aspects of the stored records as feasibly possible, resulting into more generalized conclusions. The related to GEE articles were checked out, by their thematic content, their data satellite sources (Landsat series, Sentinel etc.), the areas of interest in case studies and the used spectral indices.

In order the queries to be studied by members during a selected month period, a database has been created, using the GEE Developers Group queries. The main idea was to document the arising issues and announcements, that were addressed to the GEE board and thus, to record the users' experience and the resulting vulnerabilities. Developers usually react to users complains and remarks. Future platform developments are the results of current problem reports. Gathered queries were summarized, using the gender of each submitter, the data source satellite system, the spectral indices and the type of query (technical problem, error in code error, announcement and proposal from members) as examined features.

Statistics were corresponding to one-year period (until October 2019) for the literature review and for one month (October 2019) for the GEE Group board queries.

4. Results

4.1 Trends from GEE literature review on Urban Green

The distribution of frequencies concerning the gathered research papers, by their thematic content is as illustrated as in Fig. 1. Generally, papers could be classified as "Case Studies" or as "Theory content". Still, another yet not small, percentage group belongs to those that had no other information, concerning their content, other than the publication title and the names of the authors. Having an objective difficulty to classify those cases, a third class was formed under the characterization "Undefined".

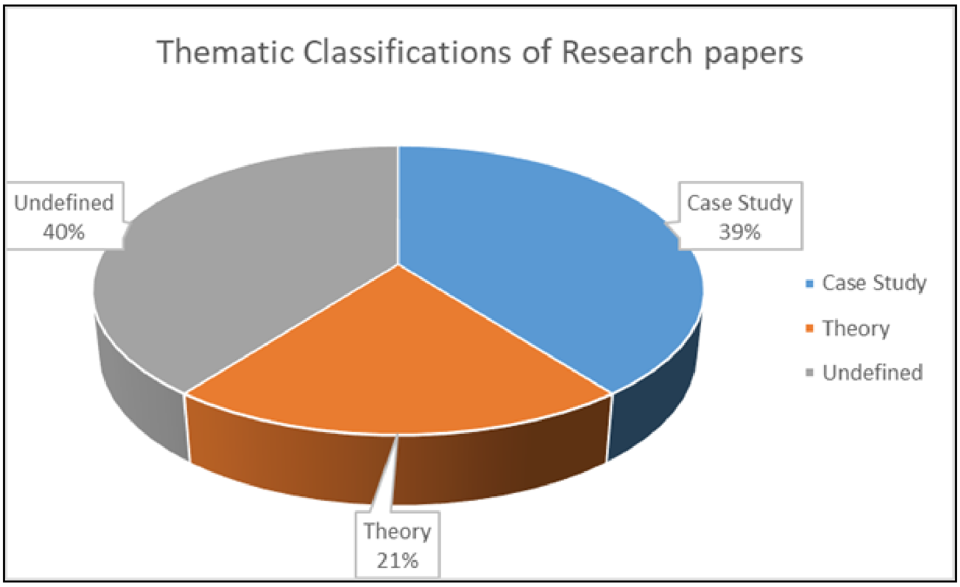

Fig. 1. Pie-chart of the frequency distribution of different thematic contents

“Case Study” was the class that had the most complete set of records in the database. Thus, only this group was used to produce the summarizing reports for the rest of the analysis.

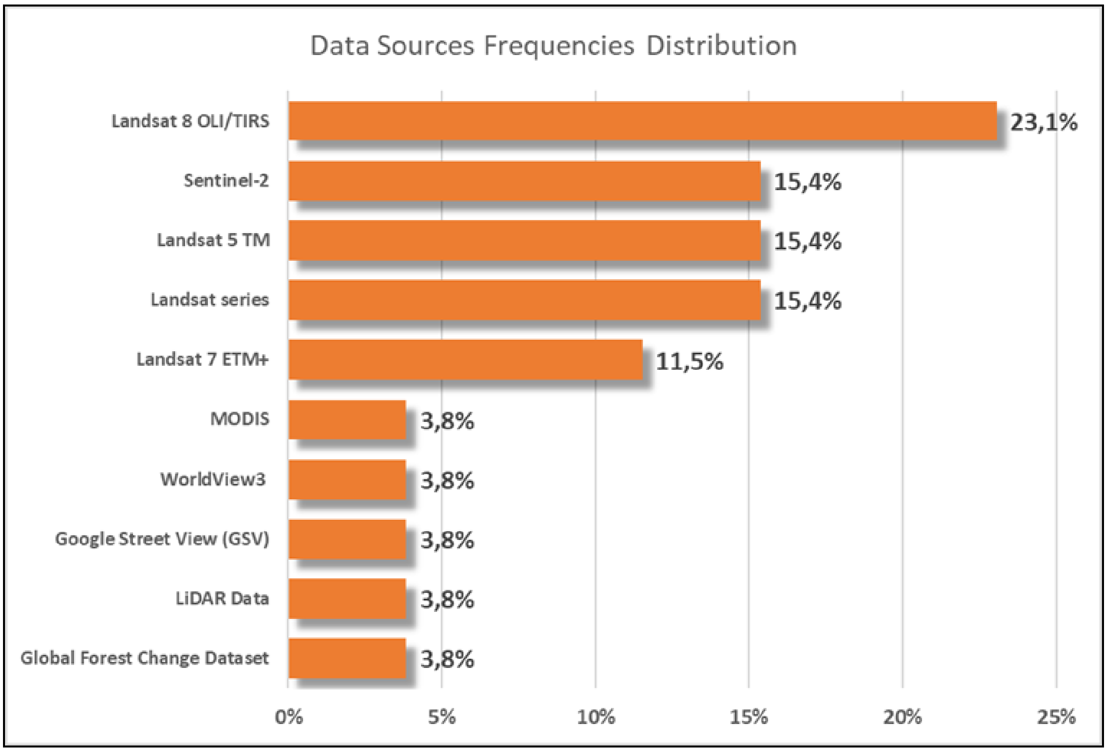

Fig. 2. The distribution of satellite sensors frequencies preferences in database

The preference in data sources used in case studies into research papers is illustrated in Fig. 2. The free access data of Landsat and Sentinel series sensors come first in reference.

Respectively, the geographical allocation of the study areas is illustrated in Fig. 3 and they are located mainly in Asia (about 50 %). This may arise by the fact that this continent is overpopulated and there is a great number of research institutes producing huge amounts of publications.

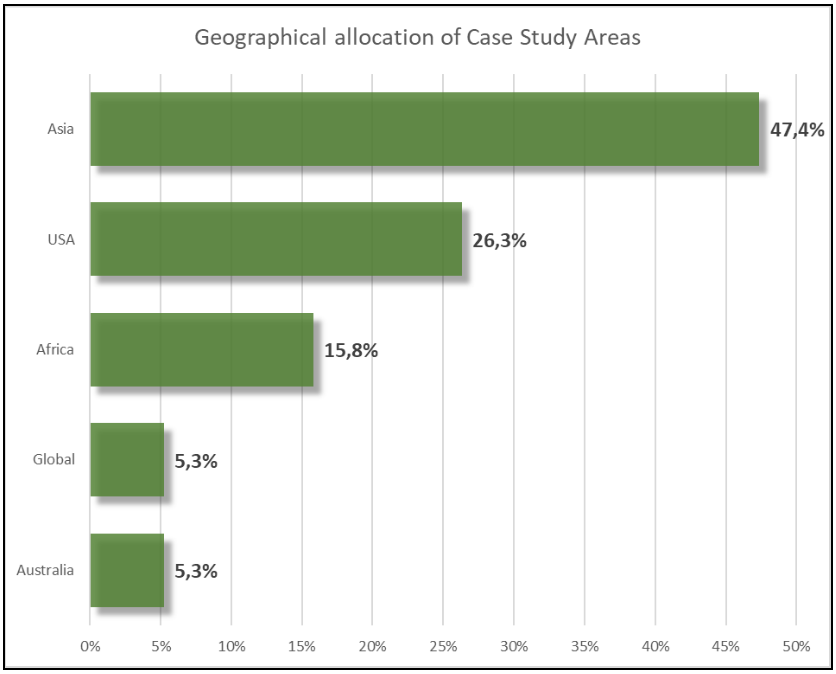

Fig. 3. Relative frequency distribution of the geographical allocation of case studies

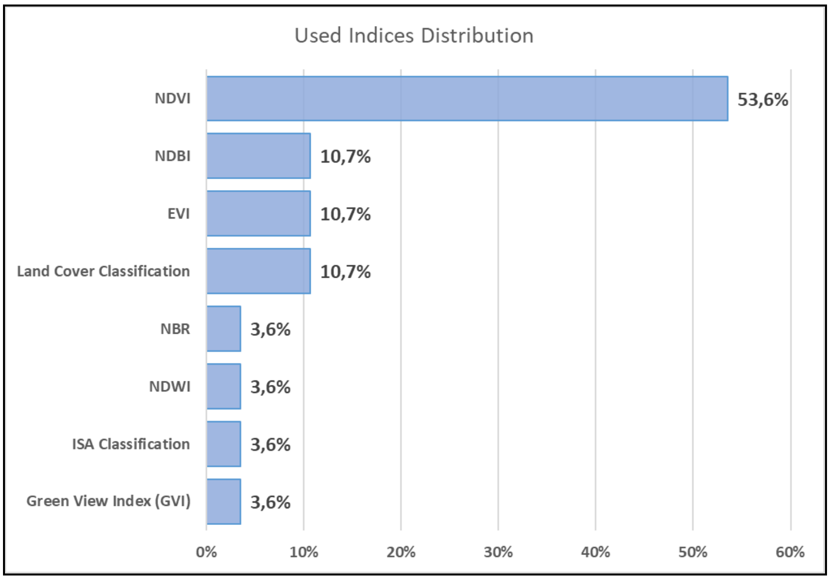

Fig. 4. Frequency distribution of indices used in publications

Finally, Fig. 4 illustrates the corresponding distribution of indices used in research of urban green areas. NDVI represents about the 50 % of occurrences, in publication denoting, established scientific value and the general recognition of its use.

A general evaluation on this brief report of findings may conclude the following: Case Study research papers have a 2:1 ratio of frequency, over theoretical oriented publications. Landsat and Sentinel sensors are primarily preferable in case study types of research. Most frequently mentioned study areas are allocated in Asia. The most commonly used index in research publication concerning urban green areas, by using satellite remote sensing data is NDVI.

4.2 Trends from GEE Group

Calculating the evolution of GEE trends is not an easy task. The platform is under constant development, thus thousands of lines of code written in the near past to be ineffective, erroneous and in need of close review and update. For the purposes of the present approach, an effort was done, to locate common characteristics among the queries of the GEE Board of users and summarize them.

Table 4. Distribution of queries addressing users' gender

Gender	Frequency
Female	34
Male	178
Total	**212**

The distribution of users' gender areas in Table 1. Males appear to be five times more frequent than females. Without any conclusive meaning, this ratio maybe useful for comparison with future estimations.

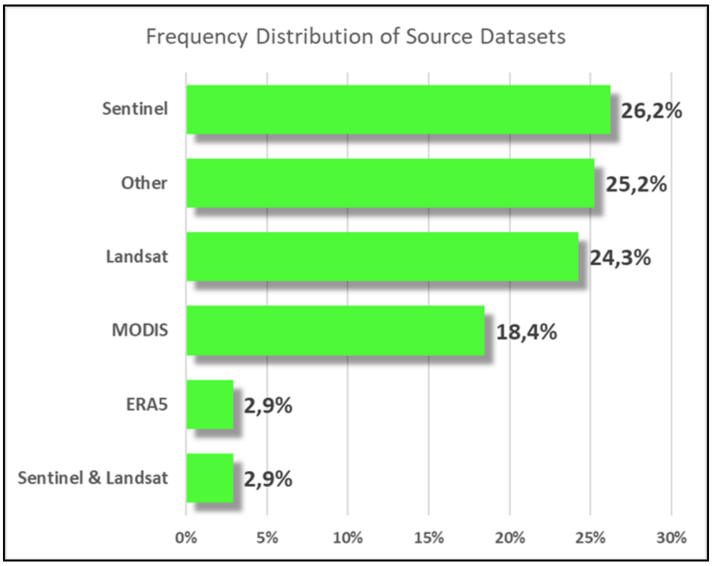

Fig. 5. Users' referenced Data Sources frequencies distribution

Frequency distribution of the mentioned in the queries data sources appear in Fig. 5. The general picture is a little different than that illustrated in Fig. 2. As it appears, users begin to prefer the use of Sentinel data, in contrast to distribution of Fig. 2. Two of the reasons that this is observed is the better provided resolution by Sentinel and the lack of need for atmospheric correction.

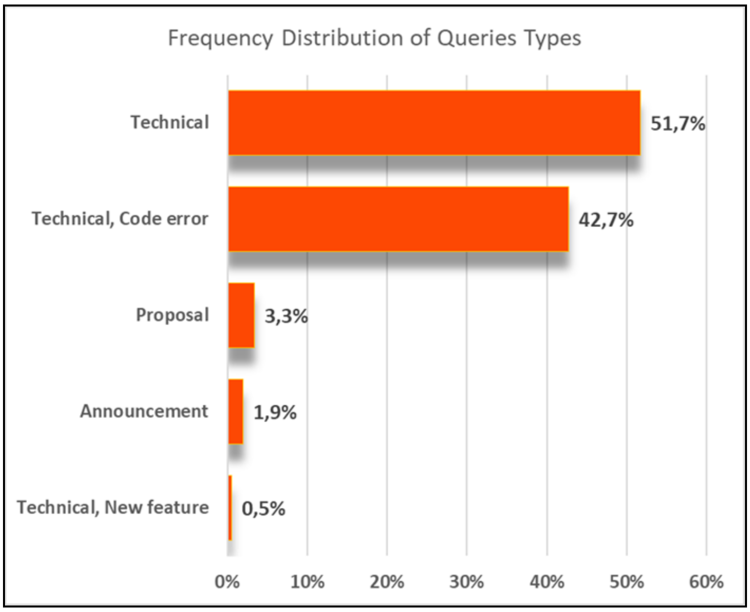

Fig. 6. Types of queries frequency distribution

One very useful aspect would be to identify and classify the types of queries, that participate in that aggregation. The most frequent types are obviously “Technical questions” and “Code error” questions. The difference between those two types is the preciseness. “Technical queries” address a more general question. “How can I calculate NDVI index“ for example. The question is more general and does not specify. “Code errors”, on the other hand, address specific questions, on part of erroneous code. Most of the time, users with such queries, deposit their piece of code asking for more clarifications.

Finally, the distribution of index reference frequencies was calculated and it is illustrated in Fig. 7. NDVI is again the most popular index by far.

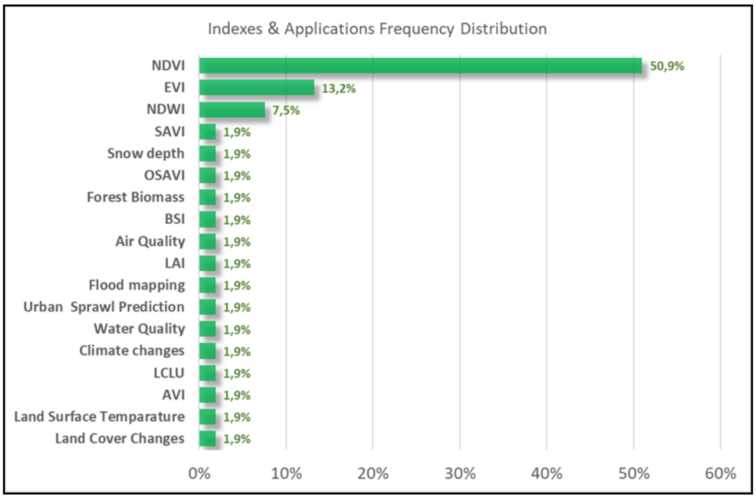

Fig. 7. The frequencies distribution of index references

5. Discussion

Due to the increasing cost of well-known, word-wide geoprocessing software, the vast use of it, for a big part of users, experts or not, scientific or professionals, is a real obstacle. On the other hand, the importantly high number of Earths observing satellites and the corresponding satellite images, offer a variety of choices, according to the end user targets and needs. The ideal combination of processing low, or without cost at all, software and, if possible, the same for the corresponding satellite images, limits the provided choices to just a few ones. It seems that GEE is among the optimum choices for geoprocessing satellite and various geo-data.

Every remote sensing software program has its own prons, cons and future challenges. Thus, over time, many new approaches to processing GEE platform will develop to make it more efficient in handling satellite data (Sidhu et al., 2018). The main advantage of this platform, which was highlighted not only by researchers but by RS experts as well, is that it focuses on the provided opportunities, including storage capacity and processed data usage. It gives the opportunity for accessibility to more than 40 years of free historical imagery and scientific data sets, in order to develop large-scale and long-term monitoring applications for Earth’s environmental problems and resources (Kumar & Mutanga, 2018).

Due to the explosion of information and satellite data, GEE platform faces some interesting challenges, for the immediate future. Client server programming is the main goal of Earth Engine, but also one of the future’s challenge. GEE must work out to make quantities of data more easier to be processed (Gorelick et al., 2017).

6. Conclusion

Open source Earth observation platforms and computing resources are a remarkable way to make the field of remote sensing essential for spatial data analysis. Free of charge satellite images can be downloaded and used in various applications, upon the corresponding field like forestry, agriculture, urban environment etc. An important part of world-wide users today uses free remote sensing and GIS software like SNAP, ILWIS, QGIS etc., in order to analyze suitable satellite images, that are downloaded from international scientific reliable sites, like USGS, LandViewer, Copernicus Open Access Hub, Sentinel Hub, NASA Earthdata Search, etc. with low cost or even without any at all. Drone images seem to be complementary to satellite ones, providing better spatial and temporal resolution, although having some restrictions (weather conditions, flight range). Cell phone remote sensing applications, while being extremely useful for everybody have not yet reach an acceptable level of image registration and processing, due to their limited capacities.

This research investigated the uptake and usage of the Google Earth Engine (GEE) platform, in calculating urban green areas, mainly in terms of the datasets used, most used indices and the features of members that questioned in Developers Group.

One of the main goals of GEE is to become an evolving cloud computing remote sensing tool, that is accessible and easy to use by everyone, with substantial opportunities for Earth observation and geospatial applications.

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