Promoting Open-Source Resources Based Spatial Science Education In Developing Countries

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Abstract

Conducting satellite remote sensing and GIS (Geographic Information Systems) based research and higher education opportunities in developing countries have been limited due to high data, software, and hardware costs until 2000 [6]. During the early era, computers at universities, remote sensing and GIS software were rare, and satellite imagery was expensive. Since 2000, through the internet and electronic media expansion, the world has started to recognise the imbalance in scientific development among developed and developing nations. A UNESCO report indicated that revolutionary scientific development in the 1990s did not spread worldwide due to income disparities [7]. This imbalance has opened a new concept for software, "open source". In 1996, the University of Leeds initiated a project to introduce a Java-based GIS library to help various GIS applications [1]. Today, QGIS (Quantum GIS), founded as a volunteer-driven project in 2002, leads the professional open source GIS applications which are supported by GRASS (Geographic Resource Analysis Support System) and several other entities (Jeffry, el. at, 2021). In remote sensing, NASA, European Spacey Agency [2], and JMA (Japan Meteorological Agency) [8] introduced free data and software. The present study discussed open source GIS and remote Sensing software and how they can open gates for education and research in the developing world without costly commercial GIS software. A case study has been conducted using Sentinel 2 satellite data covering a selected area in Sri Lanka to demonstrate the functionality of open source data, software, and low-cost computer hardware. The case study shows the potentiality of expanding professional-level GIS and remote sensing into the developing world.

Keywords*: Open source data, QGIS, SNAP, Remote sensing, GIS, developing countries*

1. The background

Landsat MSS, launched in 1972, became the pioneer of satellite observation of the global environment (USGS) [14] by writing the birth of detailed digital information on the earth's surface. Satellite remote sensing and GIS (Geographic Information Systems) based research became valuable and efficient research components with the invention of the digital computer in the early 1990s. The higher education sector in developed nations is the first user who got the opportunity to use these extensive research tools. Initially, the Landsat MSS image price was below $200, but became in the range of $3000-$4000 between 1983-1998 due to the high demand [15].

In the 1995 study, the authors investigated GIS and remote sensing education at randomly selected 26 universities worldwide, and responses from 14 universities were received by post [6]. The survey revealed the sharp differences between developed and developing countries in applying remote sensing and GIS in the higher education sector. Geography departments in two leading universities in Sri Lanka and Ethiopia had less than $2000 as their annual income in 1993. Attendance for international conferences in remote sensing and GIS also showed this gap between the two worlds. The participation patterns of the IGARSS, 1993, in Tokyo had only 55 participants from developing countries compared to 288 participants from developed countries [6]. The high cost of data, lack of software and high price, and expensive hardware were bottlenecks that blocked these technologies from flowing into developing countries until 2000.

In 1994, the Open Geospatial Consortium was established as a volunteer organisation to set GIS and related spatial sciences standards [11]. A new wave of voluntary academic resource creation appeared with improvements in computer capabilities and decreased prices. The evolution of freely accessible spatial data and software created a revolutionary improvement in GIS applications worldwide. The prime scope of this study is to discuss some of the open source data and software in the field of GIS to encourage users in developing countries to use them as a rich alternative to costly commercial software.

2. Open Source GIS resources

The simplest definition for free "open source" is the openness in content that any user can adjust and improve. Free computer software was developed in the 1980s to replace proprietary software under expensive and restrictive licensing terms. Richard Stallman, a pioneer behind the movement, introduced the GNU operating system to develop free software. Since then, Linux (1991), Python (1991), and Open Office (2000) [10] paved the path to Various other open source projects, including many GIS packages. Quantum GIS (QGIS) is today's leading open source GIS software, invented by Gary Sherman in 2002 [9],[5]. Several other GIS software is available; however, QGIS had 2.7 million users in 2021 after the world's leading commercial GIS software ArcGIS Pro [3].

Open source spatial data and GIS software are interlinked components and can be accessed by any user worldwide. USCS Library Notes (2023) listed several open source GIS software and datasets, including QGIS, DIVA-GIS, and Natural Earth Data. These open source spatial data resources contain raster (pixel-based data) and vector (points, lines, and polygons) data covering from local to global scale. Apart from the education sector, other organisations related to natural disasters such as floods, bushfires, and storm damage access open source data which are updated regularly.

2.1. Raster data

The popularity among scientists to use satellite imagery has increased in recent years with free access to many satellite data sources. These data became free of charge, and users can obtain data after registering to the respective system [12]**.** Users can obtain several major satellite data products for GIS and remote sensing studies without fee, including Landsat, MODIS, Himawari, and Sentinel. In this study, only two of these available satellite data types are discussed. However, through QGIS and SNAP, applying all this data in research and mapping projects is possible. Users can seek support from free tutorial sites, guidelines, and demonstration videos through the web.

2.1,1. NASA MODIS mission

NASA's MODIS Aqua and Terra satellite mission is one of these key satellite missions at the global scale and releases data daily (MODIS, 2023). MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (originally known as EOS AM-1) and Aqua (originally known as EOS PM-1) satellites.

Figure 1 presents bushfire devastated forest cover in New South Wales, Australia, detected by NASA MODIS 250m imagery. MODIS acquires data at three spatial resolutions, 250m, 500m, and 1,000m (MODIS, 2023). Terra MODIS and Aqua MODIS view the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands or groups of wavelengths between 0.405 and 14.385 µm. Monitoring large areas can be effectively conducted with 250m spatial resolution MODIS data to identify possible risk areas, developments and damage that occurred by natural disasters.

2.1. 2. Himawari-8 and 9 satellite data

The Himawari mission is the new generation geostationary JMA meteorological satellite mission data. This is a joint project between JMA and WMO (World Meteorological Organization) to provide real-time weather satellite data to several East Asian, South Asian, and Western Pacific Region countries (WMO, 2016). Presently, Himawari-9 is in full operation, and Himawari-8 uses as a backup mission. With the enhanced 16-band (channel) observation capability, Himawari data can be used in weather forecasting, climate monitoring, disaster risk reduction and safe transportation. Apart from these two missions, NASA's Landsat mission and ESA's (European Space Agency) Sentinel mission provide free data. The Suttle Radar Topography Mission (STRM DEM) is another precious raster data resource essential to identify possible flood directions and their volume according to land surface conditions (NASA, 2023) (Figure 2.).

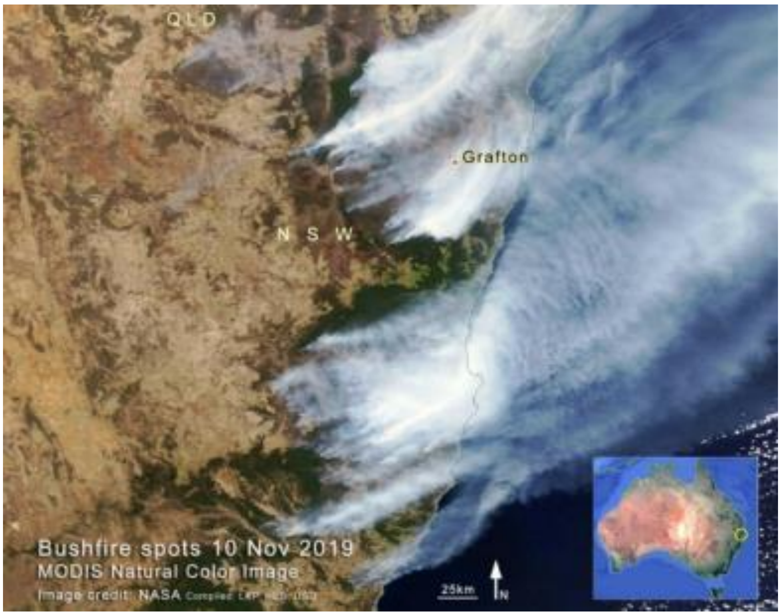

Figure 1. The application of MODIS images has a potential to use in natural disaster monitoring.

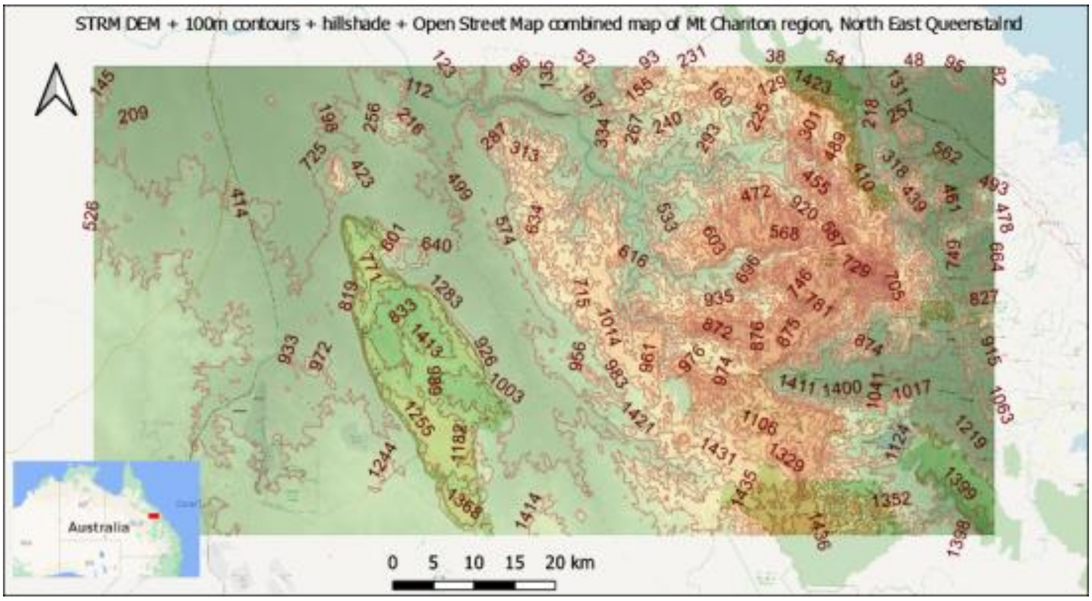

Figure 2. This map combines STRM DEM (Digital Elevation Model) data, Open Street map, 100m contours, and the hillshade effect. Elevation ranges from red (high) to green (low).

2.3. Vector data

Vector data represents the major spatial data type in GIS, consisting of points, lines, and polygons. Among prominent spatial data providers, Google provides great raster and vector data platforms for displaying topic-specific information (Google Maps, 2023). OpenStreetMap is another widely popular open source vector database that covers the entire world (openstreetmap, 2023) and provides data in GIS-friendly shapefiles format. Natural Earth data and DIVA are popular open source data resources among cartographers (Natural Earth, 2023; DIVA, 2023).

3. The case study

Conducting satellite remote sensing and GIS-based research and higher education opportunities in developing countries have been limited due to the barriers of high cost for data, software, and hardware till the year 2000 [6]. The expansion of open source data and software has opened doors for any user worldwide to conduct GIS and mapping research. The case study aims to demonstrate the capability of intensive application of freely available Sentinel 2 satellite data for intermediate to advanced GIS and remote sensing users. This study used Sentinel 2 satellite data to classify land use land cover types in one of the developing countries in Asia, Sri Lanka. Please read remote sensing documents published by leading scientific organisations, including USGS, NASA, Sentinel Online, and Natural Resources Canada.

3.1. Data and Methodology

From Copernicus Open Access Hub, the user can download Sentinel satellite data [13]. The present study used Sentinel-2, level 2A satellite data acquired on January 22, 2022. Sri Lanka is a tropical country, and the vegetation cover has an unchanged greenery which depends on rainfall and crop calendar variations. However, according to the 1991-2020 average data, after Oct-Dec heavy rainfall, a relatively less clouded sky can be expected in January [4]. The classification utilised high-resolution Google Earth images to collect ground truth data and assess the final accuracy. The image was classified using two classification algorithms (Figure 3).

3.2. Support Vector Machine (SVM)

The supervised classifications using the SVM algorithm in the open-source Orfeo Toolbox (OTB) software. The algorithms implemented in OTB were applied in this work through QGIS software. The OTB version used was 8.1.0 and interfaced with QGIS 3.22. With the SVM, we used a linear kernel type with a model type based on a C value equal to one. For the classifications, 50 percent of the field samples were used as training data and 50 percent for validation.

3.3. Random Forest classifier (RF)

For this study, Sentinel-2 imagery was processed using ESA SNAP version 9.0.0 software developed by ESA. Sentinel-2 imagery-corrected 10m spectral bands were used in this classification. For the RF model, defining two important adjustable parameters was necessary. The first denotes the number of predictors tested at each decision tree node split (mtry), and the second illustrates the number of decision trees runs at each iteration (ntree). In this study, the RF model was optimised, and the model accuracy was maximised using these two primary parameters, set as mtry 3200 and ntree 50.

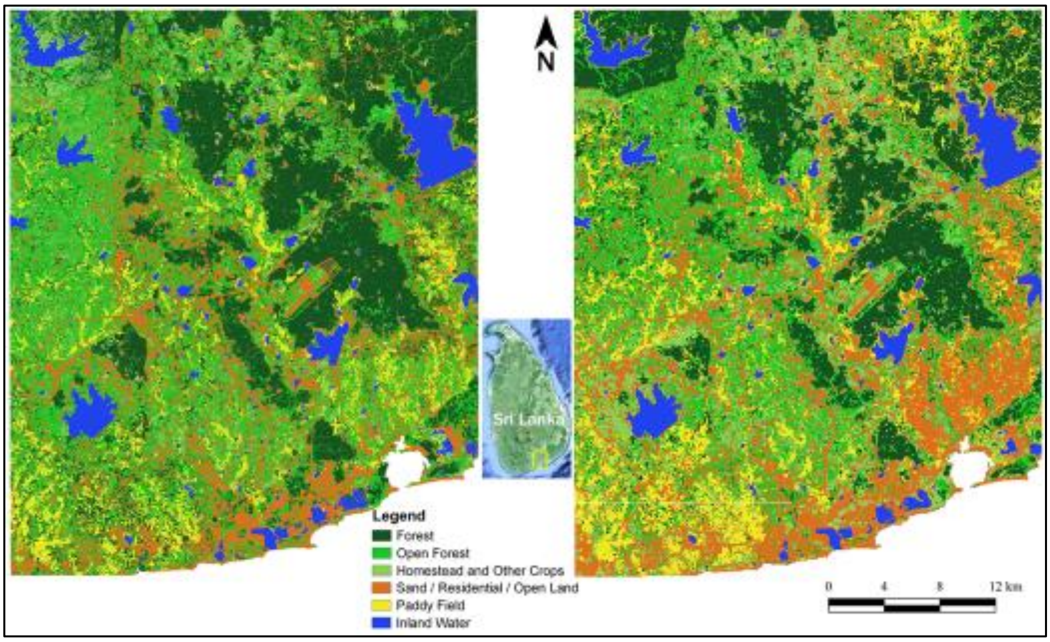

Figure 3. Classified Sentinel 2 image of the study area by SVM (left) and RF (right) methods using SNAP software.

3.4. Accuracy Assessment

For accuracy assessment, 61 ground truth data pixels were randomly selected. Confusion matrix for RF and SVM classifications were developed, including user's (UA) and producer's (PA) accuracies. The overall accuracy of the SVM method was 88.52%, while RF was recorded as 91.80%, indicating the slightly higher accuracy obtained by the RF method. Producing a land use/land cover map with satellite imagery is a goal of medium to advance level users in remote sensing technology.

4. Conclusion

A UNESCO report indicated that revolutionary scientific development in the 1990s did not spread worldwide due to income disparities [7]. This imbalance has opened a new concept for software, "open source". Since 2000, a range of open source software and spatial data has become accessible to any user of the world without restrictions. QGIS is the leading GGIS software in this field, and Open Street Map and Google Maps are among popular open source data. NASA's Landsat and MODIS, ESA's Sentinel and JMA’s Himawari missions are leading providers of free satellite data. A case study has demonstrated the capability of successfully applying free data and software for advance level mapping. The study used Sentinel 2 satellite data covering a selected area in Sri Lanka and shows the potentiality of expanding professional-level GIS and remote sensing into the developing world.

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