Panamerican Mathematical Journal
ISSN: 1064-9735
Vol 35 No. 1s (2025)

A Complete Study of Remote Sensing- Sentinel-2 Satellite Data for Land Use / Land Cover (LULC) Analysis

Dr. Ninad More[1], Dr. Ashok Kanthe[2], Dr. Jyoti Gangane[3], Dr. Puja Padiya[4], Dr Sumithra T.V[5]

[1] Assistant Professor, Department of Computer Science and Engineering, Xavier Institute of Engineering, Mumbai University, Mumbai, India. ninad.m@xavier.ac.in

[2]Associate Professor, Department of Computer Engineering, Fr. Conceicao Rodrigues College of Engineering, Mumbai, Maharashtra, India. ashokkanthe@gmail.com.

[3]Professor, Electronics and Telecommunication Engineering, Vishwaniketan's-iMEET, Khalapur, India. jgangane19@gmail.com

[4] Assistant Professor, Department of Computer Engineering, Ramrao Adik Institute of Technology, D Y Patil Deemed to be University, Nerul, Navi Mumbai, India. puja.padiya05@gmail.com

[5] Assistant Professor, Department of Computer Science and Engineering, Ramrao Adik Institute of Technology, D Y Patil Deemed to be University, Nerul, Navi Mumbai, India. sumithratv@rait.ac.in

Article History:

Received: *28-08-2024*

Revised: *10-10-2024*

Accepted: *25-10-2024*

Abstract:

Remote sensing based Satellite collected Images is a complete advanced process of both the automatic detecting observation and overall earth monitoring as well as observing the mainly physical level of characteristics of an area by mainly measuring its reflected and emitted radiation at a distance mainly used from both satellite and aircraft. Special quality cameras collect remotely based sensed images, which help all researchers "sense" things about overall Earth observation. The European Research Space Agency (ESA) and the European (member countries) Union-EU both have equally provided together to specially a very powerful observation of the whole planet surface by simply making the remote sensing based Sentinel type-2 numerous spectral based results. The Sentinel category 2 satellite was successfully launched on June, 23rd 2015 to deliver satellite collection of data and imagery. The sentinel category-1 is the mission of the introductory satellite of Copernicus oriented research project for the artificial satellite based asterism organized by all Europe countries Space Research Agency. The satellite series of Sentinel 1A was successfully produced in the month of April, 03 2014, the same as Sentinel-1B satellite was successfully launched in the month of April, 25 2016. The Sentinel category-2 is the second category of satellite constellation of the All European countries Space Research Program designed mainly for a series of Sentinel missions. The main goal of the Sentinel category-2 satellite series mission is primary provide a very good quality of best pixel-resolution space satellite data / information used mainly for Land surface Cover (LC)/ Land Usage (LU) observation, coastal surface observation, different climate (Cloud) change and natural disaster damage mapping, Natural disaster, Earth Observatory, Forestry, Wildfire Assessment, Humanitarian operations with a best complementing to the other remote sensing satellite series missions mainly as-”LANDSAT”. Therefore, the review of advanced Sentinel type -2 is primary highlighted on these two important parameters: First, The main advantage of the ESA-Sentinel type 2 to different Land surface cover / Land usage classification or monitoring, second, Discovering total overall results of the ESA- Sentinel type-2 satellite data / imagery in various remote sensing based applications (such as the

green-forest monitoring, urban area locality, natural level incident hazard analyze monitoring, coastal monitoring). The complete overall accuracy of data analysis can be improved when the possibility to simply integrate Sentinel type-2 satellite data with additional various types of advanced remotely based satellite observed details. The overall literature review of the Sentinel type-2 also describes a use of advanced remote sensing Sentinel type-2 details which are produced a very high level accuracies (>81 to 85% by using various advanced machine-learning classification algorithms mainly as: Logistic standard Regression, Support based-Vector (classification) Machine-SVM, Decision level of Trees and Random standard forest-RF algorithm. Remaining, other classifier techniques commonly known as Maximum-Likelihood Analysis (MLA) are most commonly used. Although the sentinel type-2 also provides good level of opportunities mainly for Land surface cover-LC / Land usage-LU based on various classification, as well as they have many complex difficulties which added different mismatching with data of Landsat satellite based on OLI-category 8 additionally a gap of various thermal level bands, and different spatial based resolution (pixel) among the various bands of Sentinel type-2 satellite. The Sentinel-2 data has the good quality of probable to significantly present in the direction of land surface coverage with land usage monitoring as well as classification.

Keywords: ESA; Sentinel-Satellite 2; Remote Sensing; Accuracy, LULC Mapping

1. Introduction:

The complete global category of land area is continuously changing by various natural disasters (example. of flooding, earthquake), urban development, agricultural expansion [1], [2], and [3]. These changes of global land have an impact on human daily life, hence it is a very effective and unique earth observation technique that is mainly important for the maintainability with a complete utilization of all natural based resources such as wildlife, forest area, water sources etc.

The main aim of remote sensing based satellite imagery has developed various approaches primarily in monitoring including original natural resources and all human level resources on a complete Earth's ground surface, and the remote sensing based advance technology makes it easily possible to monitor wider earth surfaces [4]. This remote sensing based satellite imagery technique has developed various approaches to simply monitoring the original and natural availability of various resources on the Earth ground surface. Additionally, the remote sensing technique finds it easily observed to cover the wide surfaces of earth [5]. The first remote sensing based satellite was experimented on July, 23rd 1972 which had been designed to monitor a whole ground surface of the earth, the research scientific community had seen numerous various satellites with the different commercial satellites: IKONOS-based satellite, SPOT-based satellite and non-commercial based satellites Sentinel-series and Landsat satellites. These satellites produce various unique types of remotely based sensed observation data which are mainly applied for various applications including wild forest, urban area natural hazard, agriculture and coastal area monitoring. These freely available Landsat satellite based remotely sensed data has been creating a principal importance in accurately monitoring the earth's original available resources and different ecosystem category processes [6,7].

In 2014, the European countries based Space Research Agency (ESA) conducted the advanced Copernicus Research Event, specially launched the level of the first category of satellite of Sentinel type-1A. Also, the Copernicus Programme committee has launched various categories of sentinel satellites such as Sentinels-1, 2, 3 and Sentinel-5. In that, the sentinel-2 constellation is an assembly of

two different remote sensing based satellites including Sentinel type -2A and Sentinel type-2B. The sentinel-2 A had successfully launched on June,23 2015, the first satellite images of Sentinel-2A were just received a few days later after launching of Sentinel-2A [8], and [9] and the remote sensing type sentinel-2B was experimented in the month of March,7 2017. These both the Sentinel-2 satellites have special capabilities to carry on board high Multispectral based Imaging designed Instruments (MSI) with a very high capability of easily recording a total of 13 various wide-swath categories of band levels [9]. The main objectives of the advanced Sentinel type-2A is to mainly provide a very high quality of pixel based resolution images based on the satellite collected data for mainly use in Land surface Cover-LC and Land Usage-LU observation, different climate changes observation, disaster damage monitoring [9], and [10] as well as by simply ensuring consciousness in a complete monitoring the wide Earth's surface observation [8 -11], [12], and [13]. The mostly research scientific communities, different nationalized research government approved agencies and various private research sectors have commonly used remote sensing Sentinel type -2 data for multiple purposes of remote sensing applications, mainly as agricultural level, natural disaster monitoring, urban area development and green forest monitoring, coastal area observation [12 -14] , and [15]. Latest one example, author [16] Bruzzone, et al. cited the Sentinel-2 data as one of the essential applications for mainly land surface use and land surface cover monitoring. As of the start from 1401 to 1500 (15th century) [17], a global Earth's level surface observation has advanced experienced continuous most rapid sudden most changes of earth, which are effective mainly on high agricultural-land surface wide expansion [18], different changes of climate [19] and rapid urban development [20]. These changes need monitoring by one instrument namely as Sentinel-2 to continuously access the observation of earth surface and also inform about the future changes. The sentinel type 2 satellite has provided a very high potential of strengthening existing various categories of policies to easily provide more accurate and exactly timely collected information of land surface use and land usage monitoring [8], and [21]. The sentinel series missions of the all data of can be accessible on path of "Copernicus Open Access Hub" URL: https://scihub.copernicus.eu/. Hence, the sentinel type-2 collected data has a very high level of the all potential capabilities for both land surface use / land cover monitoring on the entire earth's mostly in those all countries whose economic financial based all resources / capabilities for acquiring these remotely based sensed based satellite data are very limited [22].Many researchers, they have studied the remote sensing based sentinel type-2 collected data at the launch of all these sentinel series remote sensing satellites in the year of 2015 [23-24] but it has observed that these research study has not been a complete review research study on the sentinel category 2 satellite for various land surface use / land surface cover monitoring. Hence, therefore the two primary objectives of this complete review study mainly are: 1) Accurately evaluate all the contribution of advanced sentinel type-2 collected data / imagery for particular land surface covering/ land surface usage monitoring and 2) Discover all uses with different possible opportunities of sentinel type-2 satellite collected data / images. At the last stage of the complete study of sentinel series satellites, the best techniques for using remote sensing based Sentinel type-2 collected data are highly recommended.

2. Discussion:

2.1 History of ESA-Copernicus Sentinel Series Programme:

In 1998, the European based Space Research Satellite Program and European members of all countries-EU both have introduced a complete Global level Monitoring for mainly Environment research and Security based (Global-MES) programme, which was finalized the "Copernicus-Programme" in the year of 2014 which are part of the European members countries-Earth's surface observation category programme [13]. In 2014 and 2020, both the European based Space Research Satellite Program and European members of all countries-EU have arranged a research funding scheme and financial support for the Copernicus Programme to increase the various satellites network and to easily launch the latest

advanced remote sensing based satellites [10], and [21]. The "Copernicus Research Programme" has designed three primary goals: Firstly, create also circulate a complete details to truly support European Union-EU worldwide new policies related for research environment domain and security also, Secondly, create a new plan particular for various levels of stockholders, for dialogue also collaboration between providers and users and , Third, to provide a complete legal, full based on financial as well as research institutional based framework for the smoothly and easily conduction of European Space Research Agency (ESA) space satellite series projects. The ESA- Copernicus Research Program has planned for growing a total seven ESA space satellite series operations; (Satellite 1 to 3 and satellite 5 to 6) has developed and satellite-4 is now still under construction. The primary two advanced space satellites under the category of sentinel type-4A and Sentinel type-4B are to be launched in 2024 and 2032 [8] and [9]. Every Sentinel series mission is mainly based on the advanced two satellite designs which produce the data in the minimum feasible time and accurate revisiting completion period [10] and [25]. The ESA- Copernicus Space Sentinel series research program has been experimented by various three important stages: 1) before -step operation (period: 2008–2010), 2) initial -step operation (period: 2011–2013), 3) and a complete operation (period: 2014 and beyond) [25].

Table 1. Study of ESA-Sentinel's series (Sentinel-1 to Sentinel-6) with specifications [9].

Sr. No	Sentinel Series	Launched Year	Specification
1	Sentinel-1 Categories: 1) Sentinel type-1A and 2) Sentinel type-1B	April,3 2014 and April,25 2016	Sentinel -1: All weathers, Radar based Imaging for particularly land and ocean observations.
2	Sentinel-2 Categories: 1) Sentinel type-2A and 2) Sentinel type-2B	June,23 2015 and March,07 2017	Sentinel -2: It provides multispectral high (pixel) resolution data /imagery mainly for land monitoring.
3	Sentinel-3: 1) Sentinel-3A and 2) Sentinel-3B	February,16 2016 and April,25 2018	Sentinel-3: It has a multi-based level of instrument mission to observe sea surface category of topography, temperature of land and sea as well as identify colour complexity of land and ocean with high accuracy and efficiency.
4	Sentinel-4	March,31 2024	Sentinel-4: Used for Atmospheric monitoring.
5	Sentinel-5 Precursor	October,13 2017	Sentinel-5: It provides well-timed information on a multitude of trace levels of aerosols and gases particles that influence mostly atmosphere pollution attributes as well as rapid climate changes.
6	Sentinel-6	November,21 2020	Sentinel-6: It carries a powerful radar based altimeter instrument for specially measuring the height of sea-water level surface used in oceanography research and effect of climate research studies.

a) Sentinel-1 Satellite (Image credit: sentinels.copernicus.eu)

b) Sentinel-2 Remote Sensing Satellite (Image credit edit: ”ESA_Enabling_ Support / Operations”

c) Sentinel-3 Satellite (Image credit: “Esa.int/Applications”)

d) Sentinel-4 Satellite (Image credit: sentinels.copernicus.eu/)

e) Sentinel-5P Satellite (Image credit: “Esa.int/Applications”)

f) Sentinel-6 Satellite (Image credit: ESA / Applications / Navigation)

Fig 1. European Space Agency-(ESA) Sentinel’s Series (a) Sentinel category-1, (b) Sentinel category-2, (c) Sentinel category-3, (d) Sentinel category-4, (e) Sentinel category-5 P and (f) Sentinel category-6

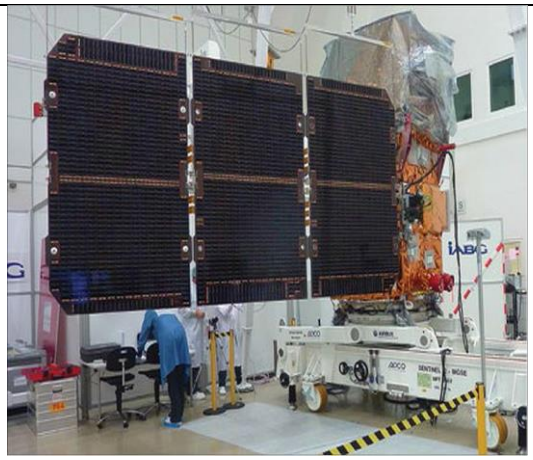
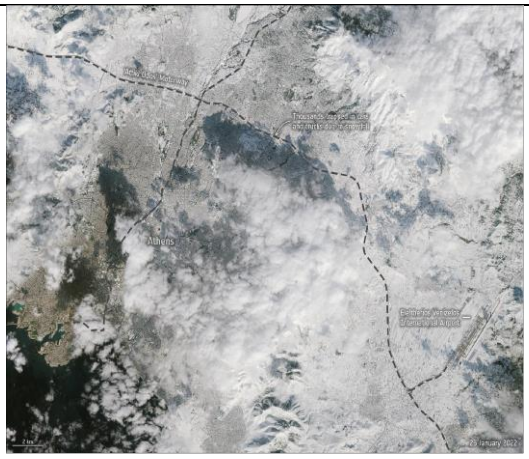
2.2 Overview of Sentinel-2 Mission:

The Sentinel category-2 is an advanced Multispectral based Operational level Imaging (MOI) assignment under an important category of all Global level monitoring for particularly Environment research and a high Security level-GMES scheme. This Sentinel type-2 satellite was designed and implemented by European Space Research Satellite Program and European Commission (EC) on June 23, 2015 for global land observation mainly for land area monitoring and the crops management, forests monitoring, natural disasters data and imagery [25]. The European Space Satellite Research Program has designed the series of remote sensing based Sentinel-2 satellite to take 5 days’ revisit time over land area and surfaces with two Multispectral Instruments (MSI) involved Sentinel Satellite type-2A and Sentinel Satellite type-2B and The orbit at an average height (an altitude level: 785 k.m) and

the Sentinel-2 satellites in the mission allow revisit surveys every five days at the around the middle of a planet (equator) and every minimum 2 to 3 days at mid- level of latitudes region. The main goal of Sentinel type-2 is to accurately monitor global area Land surface Use also Land surface Coverage (LULC) areas at global scales. The other main goal of Sentinel type-2 is match to the various category of overall level satellite research programmes mainly as “SPOT” (from French "Satellite pour l'Observation de la Terre") and the Landsat space-satellite mission for continuous level of monitoring of changing aspects of complete earth’s surface [8], [11-13].

Table 2. Characteristics of Remote Sensing based Sentinel-2A and Sentinel-2B satellite imagery [25]

Sr. No.	**Sentinel-2 Characteristics**	**Description**	
1	Mission type	Earth Observation	
2	Mission Research Funding	ESA States Member	European Union members
3	Prime level contractors of Sentinel-2	Airbus Defence & Space Germany research technology mainly for satellite level	Both Airbus Defence with Space country: France research technology mainly for the instrument level
4	Mission Vehicle:	Vega Rocket	
5	Launch date & End of life date: Sentinel-2A Sentinel-2B	Vega from City: Kourou, District: French Guiana June, 2015	2038
		Vega Rocket from City: Kourou, District: French Guiana March 2017	2038
6	Spatial Resolution	10 m Resolution	
7	Sentinel 2 (Carry Twin Satellites)	SPOT	LANDSAT
8	Sensor / Instruments/ Design Life	Multi spectral instrument (MSI) / 7 Years	High resolution optical imagers
9	Spectral Bands	13	
10	Geographic area coverage	Covered all Land surface and Islands areas	Not covered area of Antarctica
11	Sentinel-2 Service	Very Fast revisit surveys, Timely and Accurate meaningful information	
12	Orbit	Orbit at an average height (an altitude) of 785 km	
13	Orbit swath width	290 km	
14	Sentinel 2 applications	Land surface Use and Land surface Cover Monitoring (LULC)	Agriculture / Forests / Coastal mapping, inland waters, disaster mapping.

15	 **Fig 2.** Sentinel-2 Category A Satellite: Successfully Solar Array Deployment Test (SADT) has been conducted at Centre of IABG-Airbus Defence & Advanced Space Manufacturing, (Picture captured credit by ESA)	 **Fig 3.** Sentinel-2 Category A: Designed the Space-craft at the centre of satellite research integration in the city of Friedrichshafen, Country: Germany (Picture captured credit by "Airbus with DS, "A. Ruttloff")
16	 **Fig 4.** Sentinel-2 satellite has captured this Athens image on January,20 2022 (image 04 captured credit by ESA, the Athens picture simply carries advanced modified level Copernicus Remote Sensing Sentinel based information (2022)	 **Fig 5.** The Sentinel-2 has captured captured this Athens image under snow on January, 25 2022 (image 05 captured credit by ESA, the Athens picture simply carries advanced modified level Copernicus Remote Sensing Sentinel information (2022)

2.2.1 Multispectral Instrument (MSI) integrated with Sentinel-2:

The Sentinel level -2 satellite is a advanced Multispectral based Instrument (MSI) designed mainly for remote sensing satellite based images of complete earth's monitoring along with the high resolution and large swath high level of geometrical performance of the measurements. The Sentinel level-2 advanced Multispectral based Instrument-MSI has (1-13 different spectral levels bands) for measuring overall earth's reflected radiance from easy Visible Infrared also Near level of Infrared (V+NIR) to Short Wave based Infrared (SWIR). The Band-1 (Ultra Blue) with 60 m spatial (pixel) resolution, Band: 2 color is Blue, Band 3 color is Green, Band 4 color is Red with accurate 10m spatial (pixel) resolution, remaining Bands (5 to 8 also 8-A) are Visible and Near Infrared (VNIR) acquired (20,20,20,10,20) m spatial (pixel) resolution, Bands-9 and 10 have shortwave infrared (SWIR) with

60 spatial resolution, bands no.11 to 12 are mainly acquired at 20m spatial (pixel) resolution [9,25]. The level of Visible Infrared and level of Near Infrared (VNIR) simple focal based plane is constructed on the level of monolithic based CMOS detector by using a simple "0.35 μm" CMOS based technology and shortwave infrared (SWIR) simple focal based plane are constructed on advanced Mercury level of Cadmium Telluride (MCT) level detectors category of hybridized based on a CMOS readout circuit design. The Sentinel-2 Multispectral level of Instrument (MSI) is mainly focused on (SSD) Spatial Sampling Distance OF 10m on the ground level and 290 km of Swath which require a great level of view 20.6° and the 13 various spectral bands inside a large spectral domain from mainly 0.4 to 2.4 μm.

Table 3. The Sentinel type-2 Advanced Multispectral based Instrument (MSI) along with 13 various bands [9]:

Sr. No.	Band	Resolution
1	MSI:Three visible bands	Spatial resolution:10 m
2	MSI:One visible band	Resolution: 60 m
3	MSI:Three NIR (Near-Infrared) bands	Resolution: 20 m
4	MSI:Six SWIR (Short Wave Infrared) bands	Resolution: 60 m

Table 4. Sentinel-2 bands and characteristics [9, 25]:

Sr. No.	Band	Pixel size (m) / Resolution	Wavelength (nm)	Description of Bands
1	B1	60m	443 nm	B1-Ultra Blue (Coastal and Aerosol)
2	B2	10m	490 nm	B2-Blue
3	B3	10m	560 nm	B3-Color of Green
4	B4	10m	665 nm	B4-Color of Red
5	B5	20m	705 nm	B5-Visible + Near Infrared (VNIR)
6	B6	20m	740 nm	B6-Visible + Near Infrared (VNIR)
7	B7	20m	783 nm	B7-Visible + Near Infrared (VNIR)
8	B8	10m	842 nm	B8-Visible + Near level of Infrared (VNIR)
9	B8-A	20m	865 nm	B8A-Visible + Near level of Infrared (VNIR)
10	B9	60m	940 nm	B9-Short Wave Infrared (SWIR)
11	B10	60m	1375 nm	B10-Short Wave Infrared (SWIR)
12	B11	20m	1610 nm	B11-Short Wave based of Infrared (SWIR)
13	B12	20m	2190 nm	B12-Short Wave based of Infrared (SWIR)

2.2.2 Important Properties of Satellite Sentinel Type-2 Data:

The acquisitions of sentinel type-2 satellite collected data will provide remote based data continuously to work already performed by SPOT and LANDSAT. The satellite data is planned to be modified by users interested in research areas such as: 1) Spatial Planning and Development 2) Agro-ecological monitoring 3) Water monitoring 4) Wild Forest and vegetation based monitoring 5) Original natural resource monitoring 6) All global agricultural monitoring systems [26]. The continuous acquisition of sentinel -2 data in a given MSI mode is called a "Data Take". The Sentinel-2 is an acquisition of high resolution images from 15000 km. The continued acquisition is a form of "Data Take" that is the base of the consequent product tree. If the data take is assimilated by two different receiving stations, the data take can be divided into different data strips [8]. The Sentinel satellite data process acquisition

along local stations (method of quasi real time based production) can deliver a complete geographical 10 to15 min from sensing quasi real time data services via local stations collaborative with sentinel. The Sentinel mission's concepts for the free data, open data policies as well as different data access concepts may lead to the unique development of "Application Software- APPS" mainly for the general level category of public. The all sentinel data allows the sentinel core ground segment to be acquired systematically, processed and distributed properly. The sentinel satellite data includes various elements for controlling, monitoring as well as observing the sentinel series satellites and for the process of downloading, pre-processing methods and disseminating the sentinel data to all users. They also have appliances particularly for data products mainly monitoring, controlling and data archiving. The advanced Sentinel-2 data product will be easily available to all users in SENTINEL-2 SAFE format including image data in different formats including JPEG2000 formats, metadata, auxiliary data and quality indicators (Example: Defective pixels mask) [27].

2.2.3 Data Products of Sentinel type-2:

The Sentinel type-2 is a product of MSI undergoing different stages including MSI-0 Level product, MSI-1A product, MSI-1B level product, MSI-1C level product and MSI-2A level product of primary level of all processing to exact reach an accurate level so that can be easily available by all general public and common users [9], and [28].

Table 5. Sentinel-2 Data Product Types [9], [28]

Name of the Product	Data Volume	Product Types
Level 1 B	27 MB (Each 25*23 km^2)	The Sentinel -2 Level 1B product is the lowest product level made available to general users.
Level 1 C	500 MB (each 100*100 km^2)	Level-1 C product is available to users
Level 2 A	600 MB (each 100*100 km^2)	Level-2 A product is not available to users.

1) Level-0 Product: Level-0 product is not released to general users. The Level-0 is mainly compressed with raw data in the format of Instrument Source Packet (ISP) [9].

2) Level-1A Product: The Level 1 A product is also not available and released to users also Level-1 A product is mainly acquired by decompressing the Level-0 product raw based images data.

3) Level-1B Product: The Level-1 B product is made available to users and the Level-1 B is the lowest product level. Level-1B product provides radiometric corrected images that highly improve the good quality with accuracy of the satellite based remote-sensing imagery by mainly removing and reducing the various effects of sensor, atmospheric and brightness or illumination factors in Top-level of-Atmosphere (TOA) radiance values and in sensor geometry.

4) Level-1C Product: The product of Level-1C type is primarily "100*100" km based tiles composed in the process of UTM or WG-S84 based projection with an Ortho images format as well as Level-1 C produce the various results by using an advanced Digital based Elevation-Model (DEM) i.e. Digital cartographic dataset to simply project the image in a method of cartographic based coordinates system.

5) Level-2A Product: The product of Level-2 A is associated with a Level-1 C product to provides Bottom level of Atmosphere (BOA) based on reflectance category of images and the Level-2A is also product "100*100" km tiles composed of UTM or WG-S84 based projection with an Ortho images format [9].

2.2.4 Classification of Earth Land surface Usage/ Land surface Covering (LULC) with Sentinel-2 type satellite:

The European (Remote Sensing) Space Research Agency-ESA launch the Remote Sensing based Sentinel type -2 twin satellites carries 13 various spectral bands: Band-04 at 10 m nearest spatial (pixel) resolution, Next 06 spectral band at 20 m based spatial (pixel) resolution. The others remaining 03 bands at level of 60 m based spatial (pixel) resolution [29]. The sentinel type-2 has twin satellites carrying on the continued level of endowment for LANDSAT and SPOT by simply continuing to deliver various categories of imagery / information simply related to constant multi-spectral based attention. The Sentinel type-2 twin satellites are made available with new remote sensing opportunities mainly for earth Land Surface Usage / Land Surface Covering (LULC) classification methods since of the ready accessibility of data, temporal and spectral resolutions. There are various advanced categorization algorithms to simply produce Land Usage level / Land Coverage level (LULC) plans from sentinel type-2 satellite imagery including classification based Random standard forest (RF), K-nearest based neighbour (KNN), Maximum likelihood (ML), Neural-based network (NN), Convolutional advanced neural concept network (CNN) and New Support based vector classification machine (S-Vector Machine) and Bayes [30]. The new Support based vector classification machine (S-Vector Machine) is a mainly supervised category of advanced classification technique mainly designed on the statistical level of learning theory and often mostly provides different unique classification categories of results from highly available spectral related data /information.

2.2.5 Supervised and Unsupervised Classification Methods:

Both unsupervised and supervised classification method using sentinel type-2 data source, imagery from Research Agency of European Satellite Space mission of Sentinel-2 series satellites but the previous research works on remote sensing sentinel-2 satellite information / imagery have been shown the various supervised based classification methods is mostly applied that an unsupervised based classification methods [31]. The main ground behind that most of the classification based algorithms namely Linear regression, logistic based regression, Naive-(statistics) Bayes, kNN (non- parametric category of supervised based learning classifier), Random decision forest, Decision based-Tree, Support Vector Machine-(SVM) have been most probably developed primary on the only supervised based classification level of approach, while the unsupervised level of classification works with a modified level of Iterative based Self level of Organizing Data Analysis advanced Technique Algorithm (m-ISODATA) along with K-mean (standard) clustering technique, Hierarchical cluster analysis (HCA) and Probabilistic clustering [32], and [33]. The supervised classification approach is often used in segmentation by combining applied “Object-based Image Analysis” (OBIA) with Multi-(pixel) resolution Segmentation and the base parameters Scale, Shape and Compactness. The supervised classification approach with the new application of advanced machine-learning based on various classifier techniques and Object-based category of Image Analytics technique (OBIA) has shown the probability by achieving high level of classification accuracy

2.2.6 High Accuracy of Sentinel type-2 series satellite for Land Surface Coverage /Land Surface Usage Mapping:

The advanced sentinel-2 satellite data on the Land surface coverage / land surface usage (LCLU) classifying has reported high accuracies and most of classification achieved above 80 to 85 % accuracies [34], and [35]. Three different machine learning classifiers: 1) the Minimum Distance Classification (MDC), 2) Random- standard Forest (RF) and 3) the advanced Support-Vector Machine (SVM).

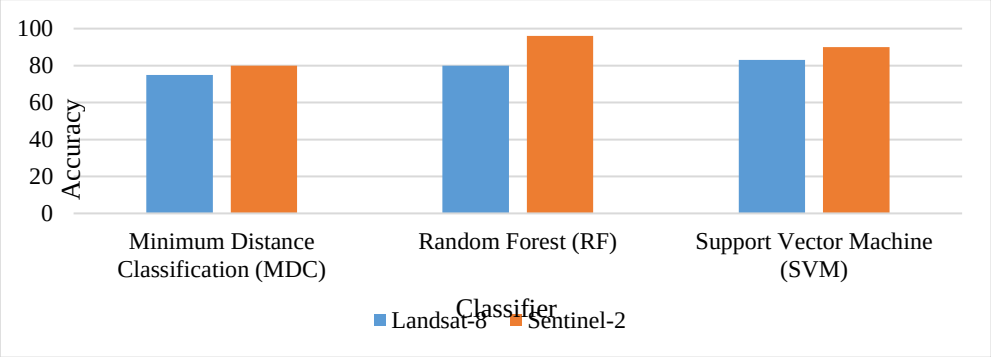


Fig 6. Accuracy of ESA mission of Sentinel-2 Land Surface Usage / Land Surface Coverage (LULC) classification based on three different classifiers (MDC, RF and SVM) from the reviewed studies. Note: RF refers to: Random standard-Forest, Minimum Distance based Classification (MDC) and Advanced Support-Vector Machine (SVM).

According to research study, the Random Forest-RF technique of classification has proved a much better accuracy simply compared to the Minimum Distance based Classification (MDC) and Advanced Support Vector Machine (SVM) classification models. Other methods, Support Vector Machine (SVM) have also proved high classification accuracy. Accuracy of all three classifiers depends on the total number of all training categories with samples as well as total number of different categories of land surface cover classes, pre-processing methods, segmentations and thresholding techniques applied on the images [36,37]. To accurately evaluate a complete performance of Use of land/Cover of land Cover model to utilize two different metrics: 1) Intersection over Union (IoU) mostly also called Jaccard based index 2) F1-score (F1) also called Dice Score.

Accuracy: Calculation of accuracy is as in equation 1.

$$Accuracy\ (A) = \frac{(T\_P+T\_N)}{((T\_P+F\_P+F\_N+T\_N))} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Inter-section over (evaluation metric) Union (IoU) is defined as in equation 2.

$$IoU = \frac{(T\_P)}{((T\_P+F\_P+F\_N))} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Precision (P): The Precision (P) is simply defined as all True_Positives (T_P) divided by combination of all True_Positives (T_P) + all False_Positives (F_P) as in equation 3.

$$Precision\ (P) = \frac{(T\_P)}{((T\_P+F\_P))} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Recall (R): The Recall (R) is simply defined as all True Positives (TP) divided by all True Positives (T_P) + all False Negatives (F_N) as in equation 4.

$$Recall\ (R) = \frac{(T\_P)}{((T\_P+F\_N))} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

F1-Score: The F1-Score (evaluation based metric) is based on the harmonic mean value of the Precision (P) + Recall scores (R). as in equation 5.

$$F1 - Score = \frac{((P)*(R))}{(((P)+(R))\ /\ 2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

The F1-score ranges between (“0“and “1”) where range-1 means the highest accuracy and range -0 means lowest accuracy.

Where True (+) Positive-TP is the based on total number of accurately classified all pixels as target class, False (-) Positive-FP is the based on total number of inaccurately classified all pixels as target defined class, as well as False Negative-FN is simply total number of pixels of target class that were incorrectly classified as another class.

2.2.7 Combination of Sentinel type-2 satellite data with others remotely based sensed collected Data:

The sentinel mission-2 is a primary combined datasets mainly as 1) Synthetic aperture radar system-SAR technology, 2) More accurate Light Detection and high Ranging-LiDAR provide very high level resolution data and 3) Unmanned Aerial vehicle (UAV) images including higher spatial resolution images. The technology of Synthetic Aperture Radar (SAR) may easily acquire various data in four different categories: 1) Stripmap (SM): SAR- Stripmap based imaging mode where the swath of ground is mainly illuminated using a continuous level of sequence of pluses. 2) Interferometric based Wide Swath (IW): The data is simply acquired in various three swaths with the TOPSAR-Terrain Observation with high Progressive Scanning-SAR based imaging technique. 3) Extra Wide level of Swath (EW): The data is mainly acquired in five various swaths with a same TOPSAR [Terrain Observation with high Progressive Scanning SAR] based imaging advanced technique. 4) Wave (WV): Data is primary acquired by using “Vignettes-Small Stripmap (SM) scenes” situated at consistent intervals of 100 km along track. Many research studies, they have reported the simply integration of both the ESA series of “Sentinel-2” data along with “Sentinel-1” data in various remote sensing applications including primary urban area of Land surface Use/ Land surface Cover (LULC) Monitoring, Biomass Assessment and Wetland Mapping [38]. The Sentinel-2 data offers many numbers of advantages when integrated with proper Sentinel type-1 Synthetic Aperture advanced Radar system (S-AR) collected data and these all benefits primary include the enhancement in earth Land surface Use level / Land surface Cover level (LULC) classification based accuracy. The satellite of sentinel type-2 has further successfully integrated with satellite sentinel type-3 data includes (both Topographic area as well as Surface Temperature Data) and all results showed a high level of best accuracy. The combination of Light Detection with Ranging (LiDAR) is mainly based on an active remote sensing based system that mainly uses a laser (emit a very high intensity based light) pulses in the visible spectrum to simply record the different altitude points on the earth and its surface characteristics [39]. The LiDAR has two data types: 1) Topographic LiDAR-that usually uses Near level of Infrared (N-IL) Laser which is easily map with land cover monitoring 2) Second, Bathymetric category of LiDAR- that primary uses water penetrating based green light to normally measure a complete seafloor as well as riverbed elevations [10]. The LiDAR accuracy is usually estimated by calculating the RMSE-Root Mean Square Error. In LiDAR, there are two types of LiDAR accuracies: 1) Absolute LiDAR accuracy (ALA) - Absolute LiDAR accuracy mainly refers to both the vertical accuracy and horizontal accuracy and it’s assessed by comparing LiDAR data with ground control checkpoints. 2) Relative LiDAR accuracy (RLA) - Relative LiDAR accuracy primary used to the internal quality of LiDAR altitude data without using surveyed ground control checkpoints.

3. Various Remote Sensing Based Applications by Using Sentinel Type-2 Satellite for Earth Land Surface Usage / Earth Land Surface Coverage (LULC) Monitoring:

3.1 Forest Monitoring by using Sentinel-2:

In forest monitoring, the ESA based sentinel-2 satellite produces a very powerful implement, the sentinel-2 is useful in various remote sensing applications including mainly wild-forest monitoring, identifying of specific forest areas, discrimination of different wild forest types, monitoring of green areas, mapping of wooden forest [40]. In all these types of forest monitoring, the sentinel- data / imagery are more accurate and useful than LANSAT low spatial resolution images. Forest fire / forest

damage have become more frequently happening in European countries in the last decades and remote sensing satellite imageries offers a very powerful application for forest monitoring / mapping them very accurately and cost effective [26].

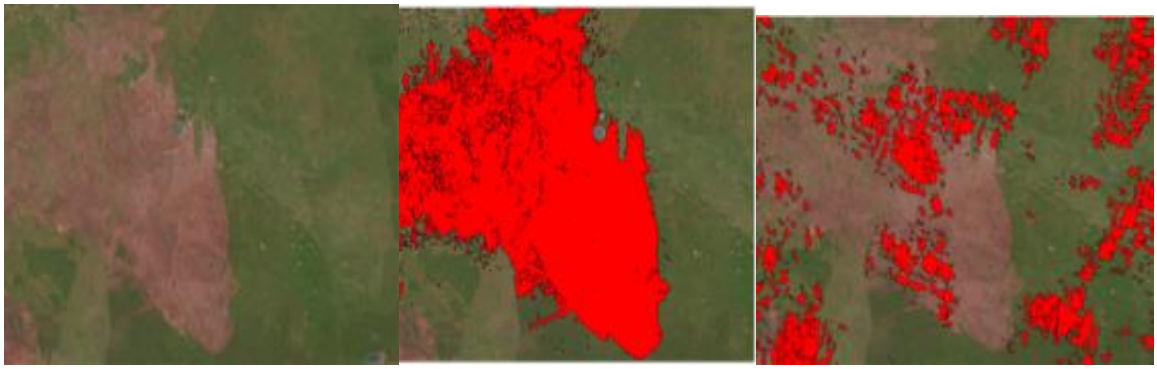


Fig 7. **a)** First image shows an original natural hue composite based on the sample region area, **b)** Middle image shows the detected a complete burned area by Sentinel-2 imagery **c)** Last image shows the detected burned area by Landsat-8 burned areas product.

Table 6. Summary of Sentinel-2 Imagery for Forest Applications.

Sr. No.	Specific Forest Application	Country	Technique	Accuracy
1	Forest tree species mapping	Europe	Sentinel-2 imagery 1) Mean Decrease based Accuracy (MDA) and 2) Mean Decrease Gini (MDG) based Measures,	90%
2	Forest fire burn area mapping	Uttarakhand, Western Himalaya	Sentinel-2 Machine learning algorithms on GEE cloud platform	95-97 %.
3	Wildfire detection	Turkey	Deep learning (DL) semantic segmentation models	F1-score of 98.78%
4	Tree Logging Observations	Poland and Belarus	Sentinel Application Platform (SNAP)	69–80%
5	Overall Assessment of Wildfire Area Damage	Australia	Remote sensing Sentinel-2 Satellite Imagery and advanced land cover product of MODIS	1)kNN-algorithm was improved from 59.13% to 87.34% 2)SVM classification algorithm increased from 72.67% to 78.87%

3.2 Agricultural Monitoring by using Sentinel-2:

The ESA-Sentinel-2 satellite has become a very powerful tool for monitoring / mapping agricultural activities. The application of Sentinel-2 in agriculture can help the agricultural monitoring and face different types of challenges by providing information related Mapping Crops, Crop Production Forecasting methods, Assessment of overall Crop Damage and Crop Progress, observing different soil

conditions, Soil Observation, Monitoring of Droughts, Water Resources Mapping techniques [41], and [42]. The satellite of "Sentinel-2" collected images / information has mostly used for real time application such as activity of agricultural mapping by using a cloud based advanced computing platform (Google Earth Search Engine).The new Sentinel type-2 satellite is based on Normalized Difference Vegetation category Index (NDVI) Maps Application (Sentinel App) is available to provide the current NDVI category of map mainly based on Sentinel-2 data / Information, provided by Copernicus research program. The Sentinel-2 (NDVI) Maps based Mobile App is providing following imagery layers are available: 1) Normalized level of Difference Vegetation category Index-NDVI Imagery 2) Enhanced advanced Vegetation category Index-EVI Imagery 3) True color imagery 4) False colour imagery [27].

Fig 8. Crop Irrigations Sentinel -2 Images a) Boise city, Oklahoma b) Centre pivot irrigation, USA c) Crop irrigation, USA.

Table 7. Summary of Sentinel-2 Imagery for Agricultural Monitoring.

Sr. No.	Specific Agricultural Monitoring	Country	Technique	Accuracy
1	Crop production Statistics	Burkina Faso	Linear Regression Models	41 and 80 %
2	Crop irrigation	Southern Tuscany (Italy	Sentinel-2 MultiSpectral based Instrument (MSI) for NDVI images	50-70 %
3	Monitoring of Agricultural Areas	Northern part of Austria.	Time Series (TSs) & Deep Learning Techniques	F-score (F1%) of 78.32% and an Overall Accuracy (OA %) of 85.86.
4	Agricultural Croplands	South Africa	Convolution Neural Network (CNN)	F1, Precision, and Recall all at ~0.86.
5	Overall Estimation of canopy level of nitrogen present in winter session wheat	France and Belgium	1) Technique of Look-up-table based (LU-Table) advanced inversion of the canopy reflectance model based on "PROSAIL" (2) Technique of Partial Least Square based Regression (PLSR) and (3) Calculated Nitrogen category of -sensitive vegetation indices.	R2 = 0.49

3.3 Urban Area Monitoring by using Sentinel type-2:

The Importance of Satellite Sentinel type-2 is that the global earth land cover is rapidly changing in developing countries, often uncontrolled urban development, expansion of agricultural land, natural processes including fire forest, flooding. These global land changes impact human and animal survival, and hence, very effective urban area monitoring levels of mechanisms are important for the ecological system control, planning and deployment of original natural earth resources (e.g., forest areas, water sources). The characteristics of Sentinel-2 support maintainable urban growth, are reliable and provide all advanced information on urban land usage and land cover (LULC) changes [43]. These ESA-Sentinel-2 provides different remote sensed satellite data for multiple applications of remote sensing mainly as wild forest, green forest, natural wildfire hazard, water and agricultural remote sensing monitoring and these remotely sensed satellite data are freely available access (e.g LANDSAT) in mainly developing all countries where economic incomes for purchase of advanced remotely based sensed satellite data / information are very short limited. The various application of Sentinel type-2 Multispectral based Instrument (MSI) data mainly for urban area monitoring include urban planning, negative serious effects of rapid climate change in urban category of areas, flood protection at local scale, urban forest and green area monitoring, disaster monitoring and for evaluating resultant impacts on ecosystem services (ES) [28], and [44].

Fig 9. Urban Area Monitoring a) PANTEX criterion computed on Sentinel-2 original image b) Urban Planning -European Space Imaging c) Urban water quality using Sentinel type- 2 advanced satellite imagery.

Table 8. Summary of Sentinel type-2 advanced Imagery for Urban Area Monitoring.

Sr. No.	Specific Urban Area Monitoring	Country	Technique	Accuracy
1	Urban Classification	Hanoi city	Coherence characteristics of pairs of SAR images	89% and 93%.
2	Effective a complete Monitoring of Impervious Surface based Area (ISA) Dynamics mainly in Urban Areas	Jinan City, China	CBAM Module	Precision, Recall, IoU and F1-Score values reached 83.24%, 93.38%, 78.01% and 0.87, respectively.
3	Fragile Ecosystems	Shahdagh National Park	Sentinel-2A MSI Data	85 to 90 %
4	Extraction of Urban Areas	Three Cities Djelfa,	Combination of Spectral Indices and	92.6%

		Messaad & Ain Oussera	Google Earth Engine (GEE)	
5	Urban Sprawl Monitoring	Rome	ALOS AVNIR-2 and SENTINEL-2A Data	90 -95 %

3.4 Natural Hazards monitoring using Sentinel-2:

There are different global natural hazards that have negative impacts on infrastructure, environment, climate, human and wildlife as well as on economics. These natural hazards include forest fires, earthquakes, volcanic eruptions, tsunamis, water logging, flood, landslides, it is very difficult and expensive to analyse and monitor from the ground [45], and [46]. The Sentinel-2 data are very helpful in mapping and observing large scale areas to easily assess their extent and volume estimation of a disaster, damages, helping us to estimate their behaviour and makes it possible for future developments and planning. These Sentinel-2 imagery can simply assist earth monitoring by detecting changes in the earth's surface vegetation, ocean colour changes, sea boundaries and agricultural droughts. In the last couple of years, we have seen a record of flooding occurring in terms of human mostly lives lost, infrastructure damaged, impacts of the economy, floods are among a very dangerous category of natural earth disasters. To assess the natural disasters damages, Copernicus sentinel-2 data are providing real time remote sensed based satellite images, and are a very useful source of valid information for authorities handling the disaster during and after floods. These sentinel-2 imagery showing a very clear image of the overall waterlogged areas and extent of the flood areas. Sentinel-2 satellite imagery can be used to determine hurricanes wind (storm) speed, view the hurricanes and map their size, and interpolate hurricanes path. Nowadays Earthquakes, cyclones and tsunamis are mapped using Sentinel-2 satellite imagery information. These Large scale high resolution satellite imagery makes it possible to accurately determine the overall extent and volume estimation of the destruction between before and after the natural disaster is looked at and the resulting several changes in the maps, corresponding to destruction [29].

Fig 10. Landslide detection by the tropical storm "ETA hurricane" in early November 2020.

Sr. No.	Specific Natural Hazards Monitoring	Country	Technique	Accuracy
1	Flood detection assessment	Europe	Sentinel 1 and Sentinel 2 Optical Imagery	Average 58 %
2	Earthquake, Building Damage Assessment	Indonesia July 29, 2018	Random Forest Classifier	Overall accuracy value (62.4%)

3	Forest Fire Analysis	Mati vicinity on 23 July 2018	Relative Burn Ratio (RBR)	91.5 to 92.9 %
4	Landslide Detection	India, China, and Taiwan 14 September 2018, 15 May 2018, and 30 June 2019,	Unsupervised Deep Learning	Precision 76%, Recall 91%, F1-score 83%, and mIOU 70% respectively.
5	Wind throws Monitoring and Delimiting	North-Eastern Italy, 29th of October 2018	NDWI8A and NDWI	70 to 85 %

Table 9. Summary of Sentinel-2 Imagery for Natural Hazards Monitoring.

4. Conclusion:

This research primarily focused on the importance of the research contribution of European Research Space Agency-ESA remote sensing Sentinel type-2 collected data / imagery for Land surface usage and Land surface coverage (LULC) monitoring. The researchers have shown that Sentinel-2 data / imagery is more probable for (LULC) land monitoring in the whole world. The Sentinel-2 is a very powerful multispectral based imaging mission, high (pixel) resolution, wide swath, and high level of temporal (pixel) resolution with a 5 days revisit frequency. The Sentinel-2 has various 13 spectral categories of bands, red color of edge and Short level of Wave Infrared RGB Composite SWIR at 20 meters. It provides sentinel type-2 data suitable for soil monitoring, water cover, extent and volume estimation of flooding, natural hazards and disasters, forest monitoring. In many fast developing worldwide countries, sentinel-2 is combined with LiDAR and UAV data which are freely accessed and data is simply integrated with Sentinel type-2 in most of all developing countries such as (such as Germany and Finland) and Sentinel-2 remote sensed data / information are freely accessible on "ESA-Copernicus Open Access Hub". Many machine learning algorithms have been applied with sentinel type-2 satellite data in the remote sensing community (Decision- based Tree (DT), Random standard-Forest (RF) method, New Support-Vector Machine (S-VectorMachine), Artificial-Neural based Network (A-NN) have proved that highly improving Land surface use / Land surface Cover (LULC) classification. The Sentinel type-2 data has a high level of spatial pixel resolution and it can accurately achieve a very high accuracy compared to medium level resolution 5-30 m/pixel such as U.S. based Geological based Survey Information (USGS) / NASA remote sensing Landsat 8 Satellite. The Sentinel-2 presents some challenges and limitations such as Data harmonization is one of the major issues, data may not be collected at critical times, additionally, the sentinel type-2 is generating large data volume and it requires more efficient storage, processing techniques and analysis. The ESA-remote sensing Sentinel-2 offers various new opportunities for researchers, government and private research sectors, the research oriented scientific field of organizations to mainly research on the Land surface usage / Land surface coverage (LULC) monitoring primarily based on the sentinel-2 high (pixel) spatial resolution data. In the future, the remote sensing advanced sentinel-2 a complete review studies can discover the further various remote sensing applications of remote sensing sentinel-2 data for most particular in the overall earth area. (E.g. African Countries, South-East Asia and South Pacific region).

References:

[1] Hansen, M.C.; DeFries, R.; Townshend, J.R.; Sohlberg, R. Global land cover classification at 1 km spatial resolution using a classification tree approach. Int. J. Remote Sens. 2000, 21, 1331–1364.

[2] Hosonuma, N.; Herold, M.; De Sy, V.; De Fries, R.S.; Brockhaus, M.; Verchot, L.; Angelsen, A.; Romijn, E. An assessment of deforestation and forest degradation drivers in developing countries. Environ. Res. Lett. 2012, 7, 044009.

[3] Phiri, D.; Morgenroth, J.; Xu, C. Long-term land cover change in Zambia: An assessment of driving factors. Sci. Total Environ. 2019, 697, 134206.
[4] Jucker, T.; Caspersen, J.; Chave, J.; Antin, C.; Barbier, N.; Bongers, F.; Dalponte, M.; van Ewijk, K.Y.; Forrester, D.I.; Haeni, M.J.G.C.B. Allometric equations for integrating remote sensing imagery into forest monitoring programmes. Glob. Chang. Biol. 2017, 23, 177–190.
[5] Haack, B.N. Landsat: A tool for development. World Dev. 1982, 10, 899–909.
[6] Turner, W.; Rondinini, C.; Pettorelli, N.; Mora, B.; Leidner, A.K.; Szantoi, Z.; Buchanan, G.; Dech, S.; Dwyer, J.; Herold, M. Free and open-access satellite data are key to biodiversity conservation. Biol. Conserv. 2015, 182, 173–176.
[7] Denize, J.; Hubert-Moy, L.; Corgne, S.; Betbeder, J.; Pottier, E. Identification of winter land use in temperate agricultural landscapes based on Sentinel-1 and 2 Times-Series. In Proceedings of the IGARSS 2018-2018 IEEE International Geoscience and Remote Sensing Symposium, Valencia, Spain, 22–27 July 2018; pp. 8271–8274.
[8] Immitzer, M.; Vuolo, F.; Atzberger, C. First Experience with Sentinel-2 data for crop and tree species classifications in Central Europe. Remote Sens. 2016, 8, 166.
[9] ESA. Sentinel-2 Missions-Sentinel Online; ESA: Paris, France, 2014. 10.
[10] Malenovský, Z.; Rott, H.; Cihlar, J.; Schaepman, M.E.; García-Santos, G.; Fernandes, R.; Berger, M. Sentinels for science: Potential of Sentinel-1,-2, and-3 missions for scientific observations of ocean, cryosphere, and land. Remote Sens. Environ. 2012, 120, 91–101.
[11] Korhonen, L.; Packalen, P.; Rautiainen, M. Comparison of Sentinel-2 and Landsat 8 in the estimation of boreal forest canopy cover and leaf area index. Remote Sens. Environ. 2017, 195, 259–274.
[12] Pesaresi, M.; Corbane, C.; Julea, A.; Florczyk, A.J.; Syrris, V.; Soille, P. Assessment of the added-value of Sentinel-2 for detecting built-up areas. Remote Sens. 2016, 8, 299.
[13] Drusch, M.; Del Bello, U.; Carlier, S.; Colin, O.; Fernandez, V.; Gascon, F.; Hoersch, B.; Isola, C.; Laberinti, P.; Martimort, P.; et al. Sentinel-2: ESA's Optical High-Resolution Mission for GMES Operational Services. Remote Sens. Environ. 2012, 120, 25–36.
[14] Sibanda, M.; Mutanga, O.; Rouget, M. Examining the potential of Sentinel-2 MSI spectral resolution in quantifying above ground biomass across di erent fertilizer treatments. ISPRS J. Photogramm. Remote Sens. 2015, 110, 55–65.
[15] Otunga, C.; Odindi, J.; Mutanga, O.; Adjorlolo, C. Evaluating the potential of the Red Edge channel for C3 (Festuca spp.) grass discrimination using Sentinel-2 and Rapid Eye satellite image data. Geocarto Int. 2018, 1–21.
[16] Bruzzone, L.; Bovolo, F.; Paris, C.; Solano-Correa, Y.T.; Zanetti, M.; Fernández-Prieto, D. Analysis of multitemporal Sentinel-2 images in the framework of the ESA Scientific Exploitation of Operational Missions. In Proceedings of the 2017 9th International Workshop on the Analysis of Multitemporal Remote Sensing Images (MultiTemp), Brugge, Belgium, 27–29 June 2017; pp. 1–4.
[17] 17. Xu,Y.; Yu, L.; Feng, D.; Peng, D.; Li, C.; Huang, X.; Lu, H.; Gong, P. Comparisons of three recent moderate resolution African land cover datasets: CGLS-LC100, ESA-S2-LC20, and FROM-GLC-Africa30. Int. J. Remote Sens. 2019, 40, 6185–6202.
[18] Gromny, E.; Lewi´nski, S.; Rybicki, M.; Malinowski, R.; Krupi´nski, M.; Nowakowski, A.; Jenerowicz, M. Creation of training dataset for Sentinel-2 land cover classification. In Proceedings of the Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments 2019, Wilga, Poland, 6 November 2019; p. 111763D.
[19] ESA.Mapping Germany's Agricultural Landscape. ESA, Ed.; 2017. Available online: https://www.esa.int/ESA_ Multimedia/Images/2017/2008/Mapping_Germany_s_agricultural_landscape (accessed on 28 April 2020).
[20] Sitokonstantinou,V.; Papoutsis,I.; Kontoes,C.; LafargaArnal,A.; ArmestoAndrés,A.P.; GarrazaZurbano,J.A. Scalable Parcel-Based Crop Identification Scheme Using Sentinel-2 Data Time-Series for the Monitoring of the CommonAgricultural Policy. Remote Sens. 2018, 10, 911.
[21] Goldewijk, K.K.; Ramankutty, N.J.L.U. Land use changes during the past 300 years. In Land-Use, Land Cover and Soil Sciences-Volume I: Land Cover, Land-Use and the Global Change; EOLSS: Paris, France, 2009; pp. 147–168.
[22] DeFries, R.S.; Rudel, T.; Uriarte, M.; Hansen, M. Deforestation driven by urban population growth and agricultural trade in the twenty-first century. Nat. Geosci. 2010, 3, 178–181.
[23] Hansen, M.C.; Potapov, P.V.; Moore, R.; Hancher, M.; Turubanova, S.A.; Tyukavina, A.; Thau, D.; Stehman, S.V.; Goetz, S.J.; Loveland, T.R.; et al. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 2013, 342, 850–853.
[24] Sloan, S.; Sayer, J.A. Forest Resources Assessment of 2015 shows positive global trends, but forest loss and degradation persist in poor tropical countries. For. Ecol. Manag. 2015, 352, 134–145.

[25] Chen,J.; Chen, J.; Liao, A.; Cao, X.; Chen, L.; Chen, X.; He, C.; Han, G.; Peng, S.; Lu, M. Global land cover mapping at 30 mresolution: A POK-based operational approach. ISPRS J. Photogramm. Remote Sens. 2015, 103, 7–27.
[26] Vuolo, F.; Neuwirth, M.; Immitzer, M.; Atzberger, C.; Ng, W.-T. How much does multi-temporal Sentinel-2 data improve crop type classification, Int. J. Appl. Earth Obs. Geoinf. 2018, 72, 122–130.
[27] Hansen, M.C.; Loveland, T.R. A review of large area monitoring of land cover change using Landsat data. Remote Sens. Environ. 2012, 122, 66–74.
[28] Spoto, F.; Martimort, P.; Drusch, M.J.E. Sentinel-2: ESA's Optical High-Resolution Mission for GMES Operational Services. In Proceedings of the First Sentinel-2 Preparatory Symposium, Frascati, Italy, 23–27 April 2012.
[29] Yan,L.; Roy, D.; Zhang, H.; Li, J.; Huang, H. An Automated Approachfor Sub-Pixel Registration of Landsat-8 Operational Land Imager (OLI) and Sentinel-2 Multi Spectral Instrument (MSI) Imagery. Remote Sens. 2016, 8, 520.
[30] Segal-Rozenhaimer, M.; Li, A.; Das, K.; Chirayath, V. Cloud detection algorithm for multi-modal satellite imagery using convolutional neural-networks (CNN). Remote Sens. Environ. 2020, 237, 111446.
[31] Chastain, R.; Housman, I.; Goldstein, J.; Finco, M. Empirical cross sensor comparison of Sentinel-2A and 2B MSI, Landsat-8 OLI, and Landsat-7 ETM+ top of atmosphere spectral characteristics over the conterminous United States. Remote Sens. Environ. 2019, 221, 274–285.
[32] Lu, D.; Weng, Q. A survey of image classification methods and techniques for improving classification performance. Int. J. Remote Sens. 2007, 28, 823–870.
[33] Olaode, A.; Naghdy, G.; Todd, C.J.I.J.O.I.P. unsupervised classification of images: A review. Int. J. Image Process. 2014, 8, 325–342.
[34] Miranda, E.; Mutiara, A.B.; Wibowo, W.C. Classification of land cover from Sentinel-2 imagery using supervised classification technique (preliminary study). In Proceedings of the 2018 International Conference on Information Management and Technology (ICIMTech), Jakarta, Indonesia, 3–5 September 2018; pp. 69–74.
[35] Nomura,K.; Mitchard, E. More than meets the eye: Using Sentinel-2 to map small plantations in complex forest landscapes. Remote Sens. 2018, 10, 1693.
[36] Li, C.; Wang, J.; Wang, L.; Hu, L.; Gong, P. Comparison of classification algorithms and training sample sizes in urban land classification with Landsat thematic mapper imagery. Remote Sens. 2014, 6, 964–983.
[37] Blesius, L.; Weirich, F. The use of the Minnaert correction for land-cover classification in mountainous terrain. Int. J. Remote Sens. 2005, 26, 3831–3851.
[38] Zhu, Z.; Wang, S.; Woodcock, C.E. Improvement and expansion of the Fmask algorithm: Cloud, cloud shadow, and snow detection for Landsats 4–7, 8, and Sentinel 2 images. Remote Sens. Environ. 2015, 159, 269–277.
[39] Verrelst, J.; Muñoz, J.; Alonso, L.; Delegido, J.; Rivera, J.P.; Camps-Valls, G.; Moreno, J. Machine-learning regression algorithms for biophysical parameter retrieval: Opportunities for Sentinel-2 and-3. Remote Sens. Environ. 2012, 118, 127–139.
[40] Nzimande, N.; Mutanga, O.; Kiala, Z.; Sibanda, M.J.S.A.G.J. Mapping the spatial distribution of the yellowwood tree (Podocarpus henkelii) in the Weza-Ngele forest using the newly launched Sentinel-2 multispectral imager data. S. Afr. Geogr. J. 2020, 1–19.
[41] Bontemps, S.; Arias, M.; Cara, C.; Dedieu, G.; Guzzonato, E.; Hagolle, O.; Inglada, J.; Matton, N.; Morin, D.; Popescu, R.J.R.S. Building a data set over 12 globally distributed sites to support the development of agriculture monitoring applications with Sentinel-2. Remote Sens. 2015, 7, 16062–16090.
[42] Bontemps, S.; Arias, M.; Cara, C.; Dedieu, G.; Guzzonato, E.; Hagolle, O.; Inglada, J.; Morin, D.; Rabaute, T.; Savinaud, M. "Sentinel-2 for agriculture": Supporting global agriculture monitoring. In Proceedings of the 2015 IEEE International Geoscience and Remote Sensing Symposium (IGARSS), Milan, Italy, 26–31 July 2015; pp. 4185–4188.
[43] Tavares, P.A.; Beltrão, N.E.S.; Guimarães, U.S.; Teodoro, A.C.J.S. Integration of sentinel-1 and sentinel-2 for classification and LULC mapping in the urban area of Belém, eastern Brazilian Amazon. Sensors 2019, 19, 1140.
[44] Møller-Jensen, L. mapping the rural-urban transition zone: Peri-urban development in Accra, Ghana. In Proceedings of the EARSEL-SIG 5th Joint Workshop, "Urban Remote Sensing–Challenges & Solutions", Bochum, Germany, 4–26 September 2018.
[45] Kääb, A.; Altena, B.; Mascaro, J. Coseismic displacements of the 14 November 2016 Mw 7.8 Kaikoura, New Zealand, earthquake using the Planet optical cubesat constellation. Nat. Hazards Earth Syst. Sci. 2017, 17, 627–639.
[46] Caballero, I.; Ruiz, J.; Navarro, G.J.W. Sentinel-2 satellites provide Near-Real time evaluation of catastrophic floods in the West Mediterranean. Wate 2019, 11, 2499.