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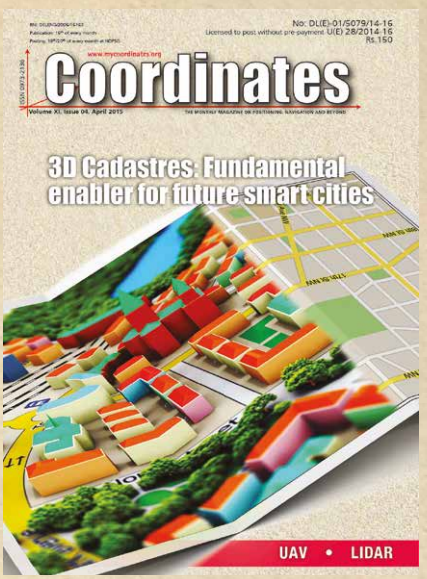
THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

Impact of climate and land use/cover changes on the sustainability of irrigation water

The growing importance of geospatial technology and challenges

In Coordinates

10 years before...



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Towards smart future cities: 3D cadastres as a fundamental enabler

Professor Abbas Rajabifard and Serene Ho, Department of Infrastructure Engineering
Director, Centre for SDIs and Land Administration, The University of Melbourne, Australia

While there is no doubt as to the increasing technological orientation of cadastres, it should not detract from the fundamental role that cadastres have in society, which continues to be central to facilitating the delivery of other national visions, digital economies, fundamental datasets and realising sustainable, resilient and smart cities of the future.

Applicability of rotary UAV for vegetable crop investigation

Insu LEE , Jihun Kang, Kil Jae LEE and Myong Kun LEE
Spatial Information Research Institute, Korean Cadastral Survey Corp., Seoul, Republic of Korea

Small UAV images are taken in order to survey the farm products at the local province in South Korea as a pilot project. The results show that UAV digital images are enough to be reasonable for analyzing the parcel area, cabbage density, and crop. In high altitude ight (about 100m), it is possible to identify the crop approximately; in low altitude, it shows a good resolution image enough to distinguish leaf status and crop growth status

Developing land registry and cadastre base data model to support Turkey national GIS initiative

Arif Cagdas AYDINOGLU Associate Professor, Gebze Technical University, Department of Geomatics Engineering, Istanbul, Turkey

Halil Ibrahim INAN Assistant Professor, Erciyes University, Department of Geomatics Engineering, Kayseri, Turkey

This study reects contribution to LADM only in terms of the needs of TRGIS stakeholders. For full contribution, all land registry and cadastre process should be considered and presented as the Turkish country prole.

Automated digital workflows and transactions using machine readable language to represent 2D & 3D cadastral surveys

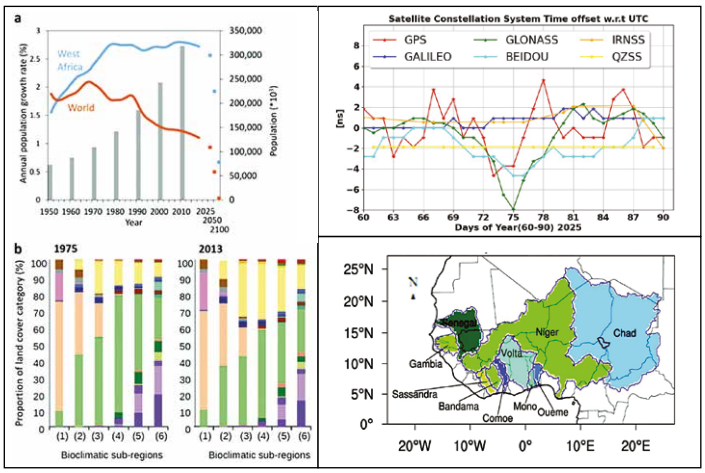
Ian HARPER, Director, Geodata Australia, Australia

We can move forward with complex modern technologies guiding our processes but integrating the manual outcomes that dene our past and current lands must also be addressed in a pragmatic way.

Modern acquisition technology of spatial data

Toša Ninkov, Zoran Sušl, Dejan Vasi and Marko Markovi
Faculty of Technical Sciences, Trg Dositeja Obradovi a, Novi Sad, Serbia

Practically all most-recent geo-information systems have an integrated module for 3D visualization that enables a 3D positioning of the buildings in relative and absolute model, i.e., coordinate system. Engineers of different professions connected with spatial planning shall consider this 3D analysis as extremely useful for regional and urban planning, designing of transport and telecommunications, environment protection, etc.



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Coordinates Volume 21, Issue 4, April 2025

Articles

Columns

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Mailing Address
A 002, Mansara Apartments
C 9, Vasundhara Enclave
Delhi 110 096, India.
Phones +91 11 42153861, 98102 33422, 98107 24567

Email
[information] talktous@mycoordinates.org
[editorial] bal@mycoordinates.org
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Editor Bal Krishna
Owner Coordinates Media Pvt Ltd (CMPL)

This issue of Coordinates is of 36 pages, including cover.

De-globalisation

Until a few years ago,

Trade flowed freely,

Technology partnerships spanned continents,

And the movement of people faced relatively few restrictions.

Today, however, globalisation is in retreat.

This shift has been further accelerated

By the rise of economic nationalism,

Along with export controls,

Disrupted supply chains,

And growing trust deficits.

It will be interesting to observe,

The potential consequences of these trends

In the PNT domain.

Bal Krishna, Editor
bal@mycoordinates.org

ADVISORS Naser El-Sheimy PEng, CRC Professor, Department of Geomatics Engineering, The University of Calgary Canada, George Cho Professor in GIS and the Law, University of Canberra, Australia, Professor Abbas Rajabifard Director, Centre for SDI and Land Administration, University of Melbourne, Australia, Luiz Paulo Souto Fortes PhD Associate Professor, University of State of Rio Janeiro (UERJ), Brazil, John Hannah Professor, School of Surveying, University of Otago, New Zealand

The growing importance of Geospatial technology and challenges

Geospatial education is often incorporated into engineering, geography, or environmental science programs, leading to inconsistencies in knowledge and skills

Dr. T. Vijayalakshmi
Associate Professor,
Centre for Environment,
UCEST Coordinator,
DST SPR in GST4ESD*
(*DST -Satellite Centre for Policy Research in Geospatial Science and Technology for Environment and Sustainable Development, JNTUH).

Geospatial technology has become an indispensable tool across various sectors, including transportation, urban planning, sustainable development, environmental monitoring, resource management, surveillance, security, and legal frameworks. Its ability to provide accurate positioning, precision analytics, and spatial intelligence enhances governance, decision-making, and resource optimization.

Following the success of India's **Chandrayaan mission**, there has been a notable surge in student interest in geospatial technology. Many students now recognize its role in space exploration and India's scientific advancements. However, despite this enthusiasm, geospatial programs at both undergraduate and postgraduate levels continue to face challenges in attracting students, as they often prioritize other branches of engineering and science over geospatial studies.

Recognizing its significance, the **Centre for Environment at Jawaharlal Nehru Technological University Hyderabad (JNTUH), Hyderabad, Telangana** has been at the forefront of geospatial education. Since 2004, Centre is offering a Master's program (M.Tech) in Environmental Geomatics, and in 2023, it expanded its academic offerings by introducing an undergraduate program (B.Tech) in Geomatics, reinforcing its commitment to advancing geospatial education and research.

Geospatial Technology as a Multidisciplinary Science

Geospatial Technology and Science (**GI Tech/GI Science**) is inherently multidisciplinary, integrating fields such as Computer Science, Engineering, Information Technology, Geography, and Geodesy. However, rather than being recognized as a distinct scientific and technological domain, it is often treated as a tool applied selectively in various disciplines. This limited perspective has hindered its recognition as an independent academic field, affecting its growth, research funding, and institutional support.

Acknowledging this gap, regulatory bodies like **AICTE and DST** have taken significant steps to establish geospatial technology as a distinct discipline. The inclusion of **Geomatics Engineering under the Graduate Aptitude Test in Engineering (GATE)** is a milestone in formalizing geospatial education and enhancing career prospects for students in this domain.

India's Growing Demand for Geospatial Professionals

The **National Geospatial Policy 2022 (NGP 2022)** aims to harness geospatial technology for governance, economic growth, and sustainable development. To achieve this vision, India needs a **skilled workforce** with technically

proficient graduates and industry-ready professionals in geospatial technology.

The sector is experiencing unprecedented growth, driven by technological advancements and increased adoption across industries. Government initiatives and collaborations with academia and industry further underscore the growing demand for geospatial professionals.

However, despite this rising need, the sector faces several challenges, including skill gaps, outdated curricula, limited industry collaboration, and a shortage of research opportunities.

Challenges in Geospatial Education Faced by Universities and Higher Educational Institutions (HEIs)

1. Lack of a Standardized Curriculum

Geospatial education is often incorporated into engineering, geography, or environmental science programs, leading to inconsistencies in knowledge and skills. The absence of a universally accepted framework for undergraduate and postgraduate programs results in varying levels of proficiency. Furthermore, **rapid technological advancements in AI, Machine Learning (ML), the Internet of Things (IoT), cloud computing, advanced visualization techniques, and GeoAI** necessitate frequent curriculum updates. Without structured curriculum reforms, graduates risk being underprepared for industry demands.

> To improve placements for our Master's students in Geomatics, it's essential to highlight their specialized expertise and the growing industry demand for geospatial professionals.

2. Incomplete Integration in Academic Curricula

The **National Education Policy (NEP) 2020** emphasizes interdisciplinary education, yet geospatial technology remains inadequately integrated into engineering and science curricula. While it intersects with various fields, its fragmented inclusion prevents students from gaining a holistic understanding. A more structured and **cross-disciplinary approach** is required to ensure that students acquire relevant skills for emerging industry needs.

3. Shortage of Skilled Faculty

There is a **significant faculty shortage** at both the undergraduate and postgraduate levels. As an interdisciplinary domain, geospatial education requires expertise in emerging fields such as **Spatial AI, Digital Twins, and cloud-based geospatial analytics**. The **rapid evolution of technology** makes it challenging for faculty to stay updated, further compounded by **limited professional development programs and industry-academia collaborations**. Addressing this issue requires structured faculty training, industry partnerships, and enhanced support for research and curriculum development.

4. Limited Infrastructure and High Cost of Software

Many institutions, particularly state universities, **lack access to high-performance computing, cloud-based GIS, and advanced geospatial software** due to resource constraints. Proprietary GIS software and high-end computing resources are expensive, forcing institutions to rely on **outdated tools and older software versions**. This restricts students' exposure to modern technologies, impacting their practical skills and industry readiness. **Investment in modern infrastructure, adoption of open-source alternatives, and industry partnerships** are crucial to bridging this gap.

5. Limited Practical Training and Field Exposure

Geospatial education in many institutions is heavily **theory-focused**, with **insufficient hands-on training** in advanced technologies such as **drones, LiDAR, and satellite data analysis**. A lack of real-world applications and field-based learning limits students' ability to tackle practical challenges. Enhancing field training, industry-led workshops, and access to cutting-edge tools is essential for improving employability and preparing students for industry demands. However, universities are failing to meet these requirements.

6. Low student enrolment and lack of awareness of career opportunities

Despite its growing significance, geospatial technology is **not widely promoted** as a viable career path, leading to **low student enrolment** in GIS and remote sensing courses. Many students remain unaware of the **vast opportunities** in the geospatial industry, and universities lack strong outreach programs to attract talent.

7. Limited Internship and Placement Opportunities

Most geospatial companies **prefer experienced candidates**, making it difficult for fresh graduates to secure employment. Additionally, the lack of structured **internship and apprenticeship programs** further hinders their transition into the workforce. Strengthening **industry-academia collaborations, creating structured internship opportunities, and promoting mentorship programs** can help bridge this employment gap.

To improve placements for our Master's students in Geomatics, it's essential to highlight their specialized expertise and the growing industry demand for geospatial professionals. Many companies train candidates from other fields for these roles, but hiring domain experts directly adds greater value. Strengthening industry connections and showcasing these skills can create more opportunities in this evolving field.

GNSS Constellation Specific Monthly Analysis Summary: March 2025

The analysis performed in this report is solely his work and own opinion. State Program: U.S.A (G); EU (E); China (C) "Only MEO- SECM satellites"; Russia (R); Japan (J); India (I)

Narayan Dhital
Actively involved to support international collaboration in GNSS-related activities. He has regularly supported and contributed to different workshops of the International Committee on GNSS (ICG), and the United Nations Office for Outer Space Affairs (UNOOSA). As a professional employee, the author is working as GNSS expert at the Galileo Control Center, DLR GfR mbH, Germany.

Introduction

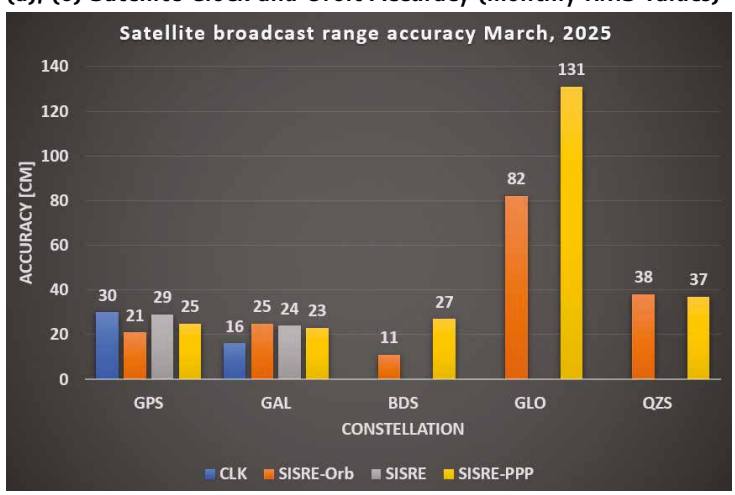
The article is a continuation of monthly performance analysis of the GNSS constellation. Please refer to previous issues for past analysis. As an addition, there is a section that explores the modernization and evolution of the satellites in the past one year.

Analyzed Parameters for March 2025

(**Dhital et. al, 2024**) provides a brief overview of the necessity and applicability of monitoring the satellite clock and orbit parameters.

a. Satellite Broadcast Accuracy, measured in terms of **Signal-In-Space Range Error (SISRE)** (**Montenbruck et. al, 2010**).
b. **SISRE-Orbit** (only orbit impact on the range error), SISRE (both orbit and clock impact), and **SISRE-PPP** (as seen by the users of carrier phase signals, where the ambiguities absorb the unmodelled biases related to satellite clock and orbit estimations. Satellite specific clock bias is removed) (**Hauschlid et.al, 2020**)
c. **Clock Discontinuity**: The jump in the satellite clock offset between two consecutive batches of data uploads from the ground mission segment. It is indicative of the quality of the satellite atomic clock and associated clock model.
d. **URA**: User Range Accuracy as an indicator of the confidence on the accuracy of satellite ephemeris. It is mostly used in the integrity computation of RAIM.
e. **GNSS-UTC offset**: It shows stability of the timekeeping of each constellation w.r.t the UTC
f. **Evolution of GPS and Galileo Satellites**: The GNSS system is consistently modernizing and evolving. The last 1 year represents a couple of key milestones in the modernization of the satellite systems and their performances.

(a), (b) Satellite Clock and Orbit Accuracy (monthly RMS values)



Note:- for India's IRNSS there are no precise satellite clocks and orbits as they broadcast only 1 frequency which does not allow the dual frequency combination required in precise clock and orbit estimation; as such, only URA and Clock Discontinuity is analyzed.

Important notes: the author sincerely apologies for an error in the statistics represented for Galileo constellation SISRE for the month of January and February 2025. The SISRE and SISRE-PPP are: 25 cm and 24 cm, instead of 15 cm and 14 cm for both months.

(c) Satellite Clock Jump per Mission Segment Upload

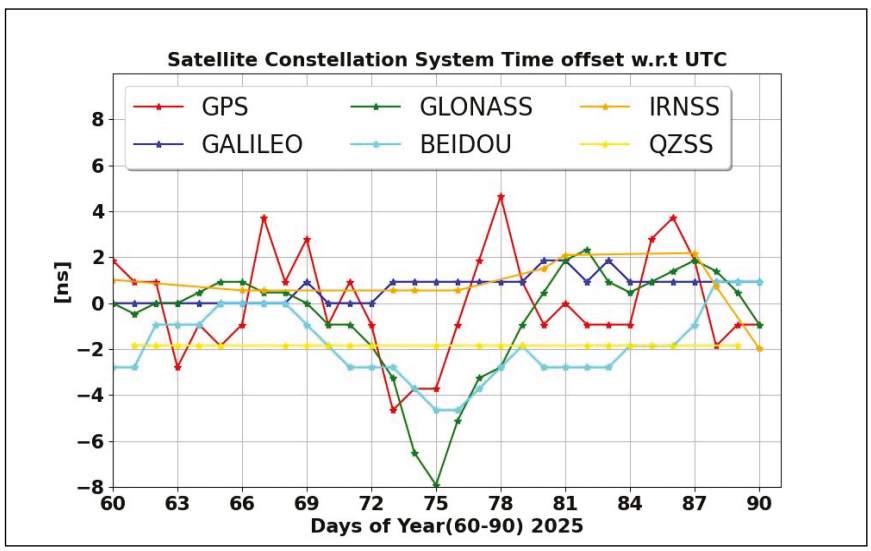
Const	Mean [ns]	Max [ns]	95_Percentile [ns]	99_Percentile [ns]	Remark (Best and Worst 95 %)
IRNSS	2.69	1026.51	4.06	12.05	Best I06 (3.31 ns) Worst I10 (22.53 ns) Big jumps for each satellite in multiple days; I10 had, unusually, large jumps; I06 performed better than before
GPS	0.46	95.01	0.87	2.25	Best G23 (0.47 ns) Worst G03 (2.26 ns) Various jumps detected: G21 (DOY 060); G08 (between DOY 061-067)
GAL	0.09	4.22	0.20	0.47	Best E03 (0.16 ns) Worst E19 (0.36 ns). E12 had a large jump on DOY 090

Due to data glitches, the satellite clock jump statistics for February 2025 was not provided. However, it was resolved, and the statistics represent the similar characteristics as shown for March 2025 in the table.

(d) User Range Accuracy (Number of Occurrences in Broadcast Data 01-31 March)

IRNSS-SAT	2 [m]	2.8 [m]	4.0 [m]	5.7 [m]	8 [m]	8192 [m]	9999.9	Remark Other URA values (frequency)
I02	2903	33	12	9	2	17	22	11.3 (3)
I03	-	-	-	-	-	-	-	-
I06	2993	7	1	-	2	-	-	16 (1), 11.3 (1), 32 (1)
I09	555	16	1	-	1	-	-	-
I10	1115	2	1	-	2	1	-	-

(e) GNSS-UTC Offset



(f) Evolution of GPS and Galileo Satellites: Looking Back to Last 1 Year

It has been more than 1 year since the monthly GNSS performance analysis reporting started. In this time, a couple of interesting evolutions in the satellite systems and their obtained performances are detected. As a legacy system, GPS has consistently modernized its satellite infrastructure including the signals and broadcast messages. Through the monthly monitoring it was observed that there was a significant improvement in the SISRE (upto 30 cm performance enhancement with LNAV dual frequency) from March 2024 onwards. This is mostly attributed to the switch in the atomic clock from Cs standard to Rb standards for satellite G08 and G10. In addition, it has been mentioned **(Montenbruck et. al, 2024)** that upload rate from the mission control segment has been improved that rendered the better performances. The relatively weak stability of some of the GPS satellites (the performance of the Rb clocks varied among satellites) constrained the achievable SISRE to around 45 cm prior to this evolution. To overcome this issue, the additional mission control segment supported the generation of navigation message upload twice a day rather than once a day. The combined impact is clearly visible in the clock and SISRE performance.

In the following Allan deviation plots (Figure Fa and Fb), the comparison between the atomic clock stability for a single representative day in January 2024 and March 2025 is shown. The performance after the switch to the Rb standard is improved significantly for the integration time. It is observed that the stochastic clock variation over the fitting interval of 10,000 seconds is improved by 10 folds. modified Allan deviation is improved by 10 folds for integration time of 10,000 seconds. This corresponds to, using $c.dt(\tau)=c.ADEV(\tau).\tau$, around 25 cm of uncertainty between the actual clock and the prediction through the polynomial model.

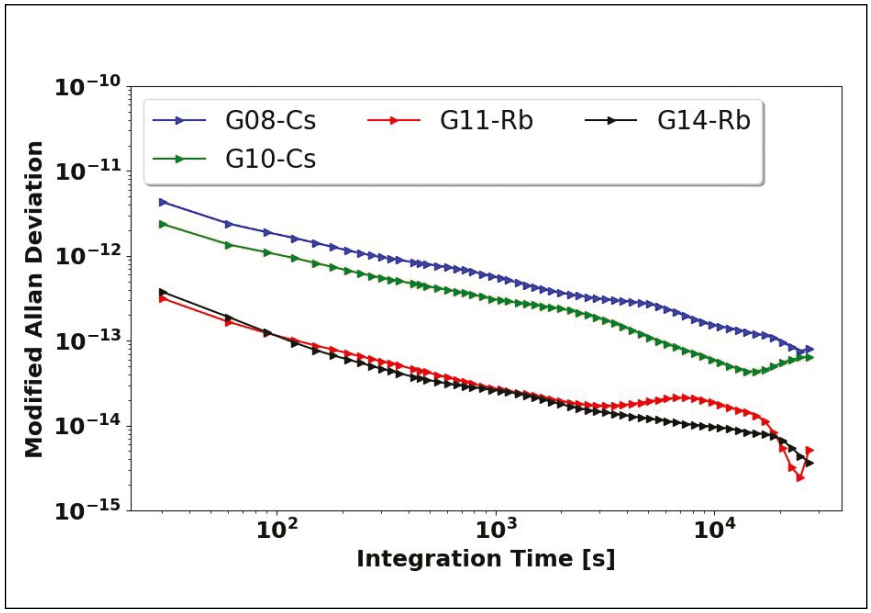


Figure Fa: The stability of the satellite clocks representing a 24-hour period in January 2024 shows distinct quality between Cs and Rb atomic standards used in different GPS satellites. The Rb standards performs better for all integration time.

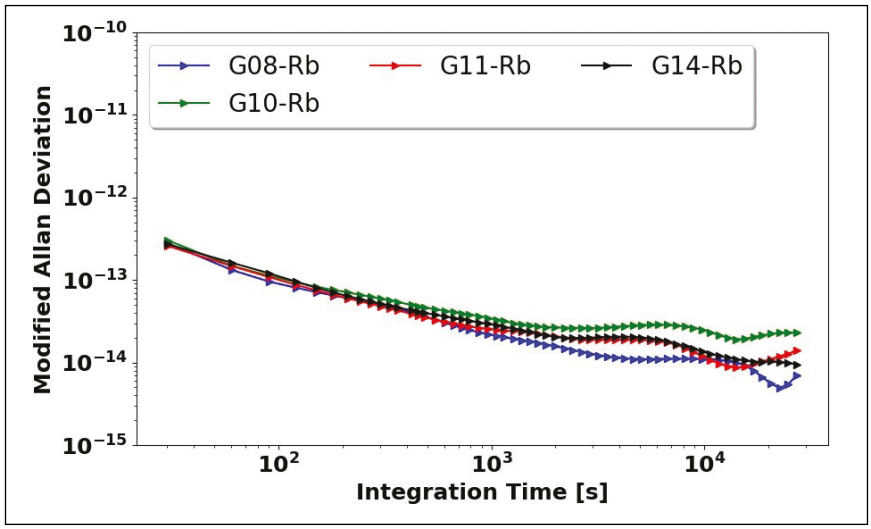


Figure Fb: The stability of the satellite clocks after the switch in March 2024 represents better performance for G08 and G10 satellites. The plot is created for a representative 24-hour period in March 2025.

For Galileo systems, there was a massive upgrade in the ground segment to the Ground Segment System Build 2.0 (SB 2.0). It includes a modernized Ground Mission Segment (GMS) with improved resilience, enhanced Public Regulated Service (PRS), and robust security monitoring through the Security Operations Centre at Galileo Security Monitoring Centers. Additionally, cybersecurity protections have been upgraded, laying the groundwork for future developments like the transition to Galileo Second Generation.

From 11th March at 13:39 UTC, Galileo satellites started transmitting the first navigation message from this new system. The Galileo is a system relied upon by four billion users every day and hence, cannot afford any significant downtime. The strategic upgrade phases of the system were finely executed without any noticeable changes in the service performances (**InsideGNSS et.al, 2024**). The mycoordinates monthly reporting summary (please refer to each issue of mycoordinates in 2024) did not detect any changes in March. In fact, the Galileo performance has remained consistent and solid throughout the last 12 months supporting the facts claimed in the article.

The evolution of the Beidou and QZSS systems will be provided in the next month's issue. Both systems consist of different satellite orbits and their associated atomic clock characteristics. Due to highly varying satellite orbits for inclined and geosynchronous satellites, the impact of force models including gravitational and solar radiation forces are more pronounced.

Monthly Performance Remarks:

1. Satellite Clock and Orbit Accuracy:
   - The performance of all constellations is relatively stable and unchanged from previous month.
   - The satellite clock jumps identified a couple of issues in GPS satellites and one issue in Galileo E12 satellite.
   - The improvement in the GPS satellite broadcast ephemeris from the switch in the atomic clock standards and the increased upload rate from the mission control center is verified.
   - The URA for I02 showed a little more scatter in comparison to previous months. It suggests a degraded confidence in its satellite orbit.
2. UTC Prediction (GNSS-UTC):
   - GPS and Beidou showed some variations in comparison to previous months.

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(The monitoring is based on following signals- GPS: LNAV, GAL: FNAV, BDS: CNAV-1, QZSS:LNAV IRNSS:LNAV GLO:LNAV (FDMA))

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FCC launches proceeding on GPS alternatives

The Federal Communications Commission (FCC) recently launched an inquiry to explore commercial technologies that would complement the Global Positioning System (GPS). Although GPS is indispensable to America's economic and national security, it represents a single point of failure that can be vulnerable to disruption or manipulation by US adversaries. That is why leaders from President Trump to Chairman Cruz and Senator Markey have called to develop alternative systems that provide "position, navigation, and timing" (PNT) data.

PNT data is integral to countless military, public safety, agricultural, and commercial activities. Because the American economy and national security depend on GPS as the sole source of PNT data, the U.S. government has shown great interest in developing resilient backups that would protect critical operations from any disruption in GPS signals.

The Notice of Inquiry examines how the Commission might foster GPS complements and alternatives. The Notice asks about a wide array of PNT technologies under development by broadcasters, wireless operators, satellite constellations, and startups that use FCC-licensed spectrum. It also seeks comment on the tradeoffs among these emerging PNT offerings based on factors like performance, adoption, scale, geographic coverage, durability, cost, and commercialization.

The Commission intends to build a comprehensive record on what actions it can take to strengthen GPS and promote other PNT technologies. These actions could include FCC rule changes, public-private partnerships, testbeds, Innovation Zones, and more. *fcc.gov*

Thales Alenia Space secures contract to extend EGNOS service life

Thales Alenia Space — a joint venture between Thales and Leonardo — has secured a €51 million ($56 million) contract from the European Union Agency for the Space Programme (EUSPA) to extend the operational life of the European Satellite-Based Augmentation System (EGNOS).

Named Life Extension Phase 1 (LIFEX), this contract will ensure that EGNOS V2 continues to provide reliable, secure and high-performance navigation services for Europe's aviation, maritime, land transport, mapping and agricultural sectors beyond 2028.

EGNOS system is designed to enhance the accuracy, reliability and integrity of positioning signals by improving the performance of GNSS, such as GPS and, in the future, Galileo. As part of this contract, Thales Alenia Space will address EGNOS V2 critical system upgrades and infrastructure improvements, reinforcing the system's resilience and operational durability. These updates will focus on enhancing security measures, modernizing components, and ensuring the ongoing reliability of EGNOS's Safety of Life Service, which plays a key role in aviation, enabling accurate approaches at European airports without requiring ground guidance systems. *www.thalesgroup.com*

Impacts of climate and land use/cover changes on the sustainability of irrigation water in West Africa: A systematic review

This study aims to review the existing literature on the impacts of climate, and LULC changes on the sustainability of irrigation water in West Africa.

Gemechu Fufa Arfasa
Department of Natural Resource Management, Wolaita Sodo University, Sodo, Ethiopia

Ebenezer Owusu-Sekyere
Faculty of Natural Resources and Environment, Department of Environment and Sustainability Sciences, University for Development Studies, Tamale, Ghana

Dzigbodi Adzo Doke
Faculty of Natural Resources and Environment, Department of Environment and Sustainability Sciences, University for Development Studies, Tamale, Ghana

Justice Aygei Ampofo
Faculty of Natural Resources and Environment, Department of Environment and Sustainability Sciences, University for Development Studies, Tamale, Ghana

Abstract

Climate and LULC changes have a great influence on the hydrological processes which include evapotranspiration, infiltration, surface runoff, groundwater flow, and stream discharge regime. This study aims to review the existing literature on the impacts of climate, and LULC changes on the sustainability of irrigation water in West Africa. The future of irrigation in West Africa will be driven by strong external factors, such as rapid population growth, climate change, and LULC change. The annual average temperature is between 25.9 and 34°C. Rising temperatures have affected all sectors, including water resources, increased irrigation demand, and the sustainability of agricultural production. Reduction in precipitation will reduce river flows and increase evaporation due to a drier atmosphere, thereby reducing the amount of water available in reservoirs for irrigation. The current demand for freshwater in West Africa for irrigation purposes is expected to triple by 2050. From 1997 to 2018, forest area decreased by 24.6%, while residential and agricultural land areas increased by 140% and 11.7%, respectively, in West Africa. Effective mitigation and adaptation measures are the policy issue for the observed adverse impacts of future climate and LULC changes on the sustainability of irrigation water availability in West Africa

1. Introduction

The global hydrological cycle is being hastened by climate change (Bulkeley & Newell, 2023). The effects of climate change are anticipated to be more profound than they are now (Tilahun et al., 2023). Since water is considered the lifeblood of the biosphere, water stress problems directly hinder food, as they are inputs for the process (Anna et al., 2023). Climate change and land use/cover are key factors affecting water yield and availability (Zhu et al., 2023). Climate change can affect water productivity by changing precipitation and evaporation in river basins (Boonwichai et al., 2018). Changes in LULC can alter the water cycle, affecting evaporation, infiltration, and water retention patterns, which in turn can affect water availability (Che et al., 2022). Competition between the irrigation agriculture, hydropower generation, and water supply sectors can increase vulnerability to water scarcity, as can management practices in these sectors (Flörke et al., 2018). Changes in climate and land cover are expected to exacerbate the complex interactions between water security and social development (van der Esch, 2017). Since the 1970s, there has been rapid progress in the development of remote sensing technology and hydrological models (Dong, 2018). To achieve a more rational distribution of water resources, an increasing number of

scholars are making efforts to quantify, visualise, and improve the assessment and analysis of regional water supply through model-based simulations (Li et al., 2022).

Changes in climate and land cover have influenced the hydrological cycle in West African countries (Flörke et al., 2018). Land use and climate are two major factors that directly influence irrigation water availability, and understanding their respective impacts is of great importance for land use planning and land management (Neupane & Kumar, 2015). It has been shown that climate change and land use planning have a greater impact on the regulation of seasonal streamflow distribution than the regulation of mean annual streamflow (Liu et al., 2020). Climate change is expected to produce highly variable rainfall and increased temperatures, making water availability uncertain (Kotlarski et al., 2023). In all West African basins, the relationship between rainfall, runoff and streamflow is complex due to land use/land cover change (LULCC) (Obahoundje & Diedhiou, 2022). The Senegal, Niger and Volta basins, where the main irrigation dams are located, are expected to be severely affected by climate change (Shamseddin & Chaibi, 2020). The Niger River basin is likely to experience the largest decrease in river flows in all of Africa due to climate change and the Senegal River basin at a higher risk of LULCC (Zhu et al., 2023). In west Africa and in Ghana, agriculture has been experiencing decline through the decades; whereas the sector once contributed more than 60 percent to GDP in the 1970s, in 2020 agriculture accounted for just 19 percent of GDP (Mensah et al., 2022). Due to the high risks associated with water availability, future irrigation projects may be significantly affected by changes in climatic conditions (Shamseddin & Chaibi, 2020).

In West Africa, rain-fed agriculture is most important for ensuring income and overcoming poverty (Akudugu et al., 2021). Crop production in West Africa is mostly dependent upon rainfed agriculture. Irrigation is a vital need due to uneven distribution of rainfall and seasonality of water resources (Tiamgne et al., 2022). Irrigation is a fundamental strategy for ensuring agricultural production and food security in the developing countries. Irrigated agriculture accounts for about 4% of arable land in sub-Saharan Africa and remains largely underdeveloped due to a lack of sufficient economic resources and political will (Djoumessi, 2021). Irrigation development is high on the agenda of several regional initiatives in West Africa. Over the past decades, drought, population growth, and water shortages have increased water stress in major river basins in West Africa (Dibi-Anoh et al., 2023). According to official statistics, about 1Mha in West Africa are equipped with irrigation, with over 60% equipped for full-control irrigation and 40% in lowlands (inland valleys or bas-fonds). Further, over 1 Mha are reported to be under recession irrigation, primarily in Nigeria, bringing the total area under agricultural water management (AWM) to over 2 Mha (Amali et al., 2021). Irrigation potential is estimated at 9.1 Mha with 55% in just three countries: Nigeria, Ghana and Sierra Leone (de Fraiture, 2014). Most countries in West Africa hardly developed their irrigation potential, with the exception of Mali and Senegal who developed 41% and 29% of their irrigation potential, respectively (Faye, 2023). Irrigation is of importance for local food security, with sustainable irrigation practices having the potential to boost West African agricultural productivity in many areas without adverse environmental impacts on freshwater resources. Previous studies on the impact of climate change on crops in the region have often predicted that yields will even decline by 2050 due to rising temperatures during the growing season and changes in crop variability monsoon rainfall, thereby adding to food insecurity in an already vulnerable region. In West Africa, the sustainability of irrigation water resources has not been thoroughly researched and planned by policymakers and water resources managers. To ensure timely irrigation water sustainability and accessibility in the context of climate and land use change, appropriate planning, optimisation of appropriate investments, and realistic forecasting are required about input and output is a very important task. The main objective of this review is to collect and organise the current scientific literature and research results on the sustainability of irrigation water resources in the context of climate change and land cover in West Africa.

2. Method

2.1. Principles and procedures

In this paper, a systematic review was used to determine how climate and land use/land cover influence the sustainability of irrigation water resources in West Africa. Systematic review steps were used. A systematic review may be used to explore the academic impact of a particular author, groups of authors, or publications on a particular topic (Table 1). The aim is to describe research impacts, knowledge flows, and knowledge networks within a specified body of literature. As emphasised by (Tawfik et al., 2019), the questions that are asked in the systematic review are relevant. The analysis involved an initial reading of each article, which was guided by the desk review of existing literature to respond by answering these particular questions:

1. What are the impact of climate and LULC change on water resource?
2. How are the Climate and LULC change affect the sustainability of irrigation water?
3. Which thematic areas of the publications are included?

To the best of our knowledge, the application of systematic review to examine the contribution of academia to the discourse on Climate change and LULUC change impacts on Water resources, and current available water assessment and future prediction is the first of its kind in the literature. As such, this article makes a significant empirical contribution to the research on Climate and LULC change impact and to the advancement of new methods for development and policy research in general. To

ensure there is transparency, structure, and accuracy in the systematic review process, we adopted the general approach to systematic review by (Tawfik et al., 2019) to facilitate the implementation and translation of findings. The general framework adopted in the study is illustrated below (Figure 1):

Identification – The number of published articles on Climate and LULC within the Elsevier database was done using different search terms as described in the search strategy.

Screening – After the identification of relevant published articles within the database, screened was done to remove duplicates and avoid double counting. Then the number of publications screened and selected was documented and included for further analyses.

Table 1. Results of keyword search terms.

S/N	Keywords- Query	Number of articles
1	Impact of climate on water resource in West Africa	207
2	Impact of LULC on water resource in West Africa	102
3	Coupled Impacts of climate and LULC change on water resource	115
4	Sustainability of irrigation water in West Africa	65
5	Irrigation potential of West Africa	85
Initially screened titles		235
Initially screened abstracts		145
Post-deduplication total		92

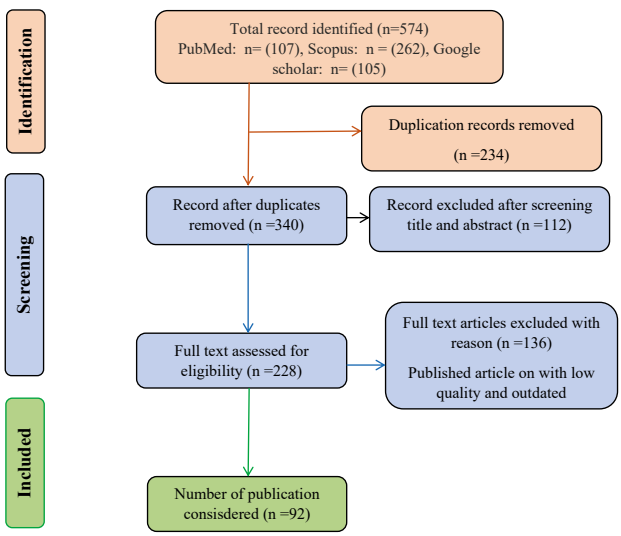

Figure 1. Inclusion and exclusion criteria.

Eligibility – After the screening, articles were assessed for relevance, and full-text articles that appeared irrelevant were excluded.

Included – An examination of full-text articles was conducted to include those considered to be relevant for qualitative and quantitative synthesis while the irrelevant ones were excluded.

The selected keywords for database are illustrated as shown in Table 1.

2.2. Analysis method

Visualising similarities (VOS) viewer software has become increasingly popular in systematic review of literature. This software was developed by (van Eck & Waltman, 2010) to present bibliometric maps visually appealingly. As a result, literature may be efficiently collated, similarities between selected publications identified within the parameters, and significant themes identified among publications (Nobanee et al., 2021). Data obtained from Scopus were used for a performance analysis that included the number of publications, citations, and impact factor, derived using the following equations, respectively:

$$\text{Impact factor}_{Y} = \frac{\text{citations}_{Y}}{\text{publications}_{Y-1} + \text{publications}_{Y-2}} \quad (1)$$

where: *citationsy* = the whole number of citations that journal received in the year 'y', publications−1 = the sum of articles that were published in the year (y − 1), *publicationsy* −2 = the sum of articles that were published in the year (y − 2).

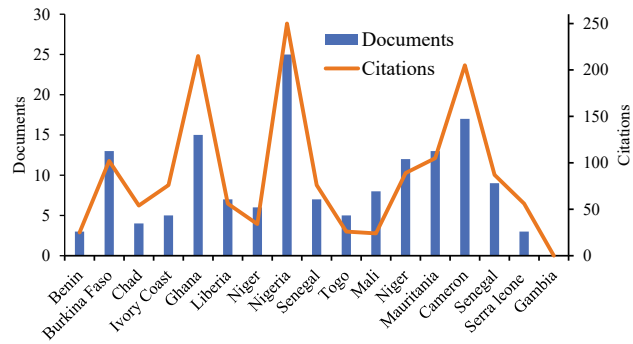

Figure 2. The number of publications and citations from countries from 2011 to 2023.

Table 2. Search result in the databases Scopus, web of science, SpringerLink journal, and Google scholar.

Database					
Scopus	Web of Science	Springer	Google Scholar	Area of Research	Analysis Software
✓	5	3	6	Climate and land cover change challenge in West Africa	VOS viewer software
✓	5	6	10	Impact of climate on water resource in West Africa	VOS viewer software
✓	7	6	9	Impact of LULC on water resource	VOS viewer software
✓	5	4	8	Sustainability of irrigation water management	VOS viewer software
✓	2	4	11	Irrigation potential of West Africa	VOS viewer software
✓	2	3	6	Climate smart irrigation in West Africa	VOS viewer software

A total of Nin tee two (92) articles were discovered in the Scopus database, three articles in the Springer database, eight articles in the Web of Science database, and six articles in Google Scholar. After excluding duplicate articles and non-English publications, 32 articles ready to review. Table 2 shows the research area and software used in these articles.

3. Results and discussion

3.1. Climate and land cover change challenge in West Africa

Climate change exposes millions of people to risks from climate extremes, desertification, land degradation, and the loss of food and livelihood security (Smith et al., 2020). West Africa is experiencing climate change at a faster rate than the global average (Omotoso et al., 2023). The 11 countries that make up West Africa are Benin, Burkina Faso, Ivory Coast, Ghana, Guinea, Liberia, Niger, Nigeria, Senegal, Sierra Leone, Mauritania, Mali and Togo. West Africa is currently facing rising temperatures, changing rainfall patterns, and increased extreme events (Fouque & Reeder, 2019). Climate change will undoubtedly pose one of the most significant risks to Africa's Sustainable Development Goals over the next decade (Ladan, 2018). In West Africa, the monsoon season accounts for most of the total annual rainfall for several months (Lélé et al., 2015). Agricultural output, water resources and livestock in sub-Saharan Africa are therefore highly dependent on rainfall, which can be strongly influenced by the timing and intensity of irregular monsoons (Turyasingura et al., 2023). Changes in climate and land cover have influenced the hydrological cycle in West African countries (Tiamgne et al., 2022). Climate change and land use planning have been shown to have a greater impact on changing seasonal streamflow distribution as well as water availability and sustainability. Analysis of spatio-temporal changes in land cover in West Africa shows changes from the Guinea-Congolia region to the Sahara region (Palumbo et al., 2011). Figure 2 shows the number of publications and citations from countries from 2011 to 2023. This data could reveal which countries actively Involved in Climate and LULC change and it challenge.

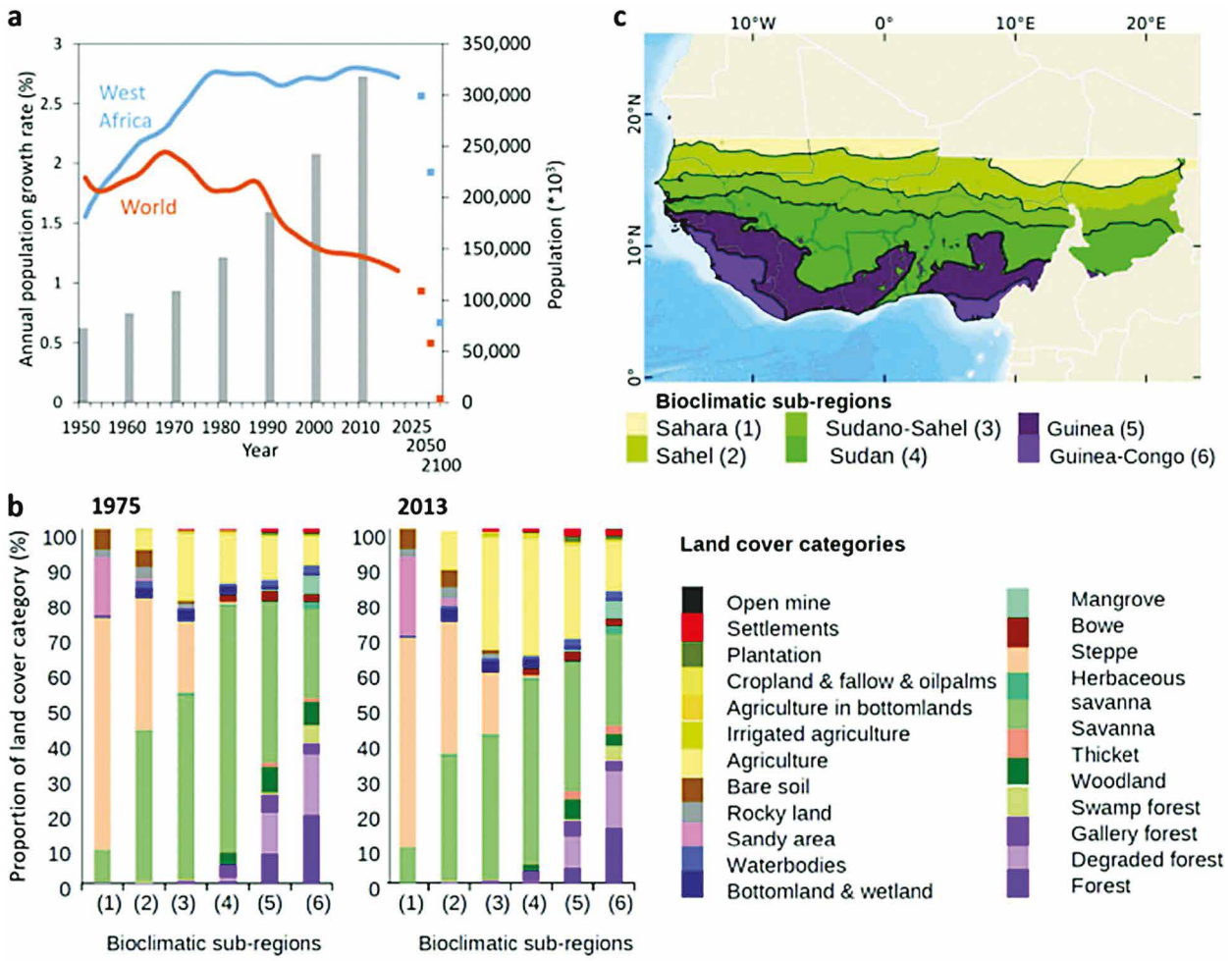

Figure 3. Land cover and population trends in the study region. (a) annual population growth rates in the study region (blue line) and globally (orange line) from 1950 to 2018 with projections for 2025, 2050 and 2100, as well as total population of the study region per decade (gray bars). (b) land cover compositions of the six sub-regions in 1975 and 2013. (c) map of the study region is divided into six bioclimatic sub-regions defined by their mean annual rainfall (Herrmann et al., Citation2020).

The growing population has exerted considerable pressure on the land resources, leading to subtle modification (e.g. reduction of woody vegetation in savannas and increase of field trees) as well as more radical conversion (e.g. transition from savanna or forest to agriculture) of land cover. Local-scale studies from the region hint to rural population growth as an important driver for cropland expansion in semiarid southern Burkina Faso and northern Ghana (Figure 3).

3.2. Water resource and irrigation potential of West African countries

Irrigation development is critical to ensuring food security and reducing climate vulnerability in Sahelian countries (Ibrahim et al., 2021). However, 'irrigation' encompasses many different systems and activities, some of which are little known to policymakers and scientists (Higginbottom et al., 2021). About 1 million hectares in West Africa are equipped with irrigation systems, of which more than 60% are equipped with fully controlled irrigation systems and 40% are in the lowlands (de Fraiture, 2014). In addition, more than 1 million hectares will be subject to flood irrigation, mainly in Nigeria, bringing the total area under agricultural water management (AWM) to more than 2 million hectares (Wendimu et al., 2023). The estimated irrigation potential is 9.1 Mha, of which 55% is located in just three countries: Nigeria, Ghana, and Sierra Leone. Most West African countries have marginally developed their irrigation potential, with the exception of Mali and Senegal, which have developed 41% and 29% of their irrigation potential, respectively (Richards, 2023). Overall, less than 12% of West Africa's irrigation potential is available (Table 3).

In Burkina Faso conflicts over water resources due to overdrawing by pump owners were observed (Hutton & Chase, 2017). African countries spend 10% of their national budgets on agriculture to create an annual agricultural growth rate of 6% (Varela et al., 2020). In West Africa, very few countries have a strong strategic, legal and regulatory policy framework that provides the basis for economically efficient distribution of water among different users, making it possible to access the potential of water (Grönwall & Danert, 2020; van Koppen & Schreiner, 2014). The country's productivity becomes more equitable and sustainable. West Africa has 10 major river basins (Figure 4). In Senegal, Gambia, central Niger, northern Volta, and northern and southern Chad, rainfall decreased. In the Sahelian basins, such as Senegal, Gambia, Niger, Chad and to some extent in the Volta, reductions are limited to about 10 to 30% (Sylla, Pal, et al., 2018). However, in smaller basins located in the Gulf of Guinea (such as Sassandra, Bandama, Comoé, Mono and Ouémé), the reductions were significantly larger, ranging from 35% to 65%, with the largest and highest reductions recorded in Bandama and Ouémé (Imorou et al., 2019). West Africa's 10 major river basins are likely to face significant challenges in meeting future water demands under global warming, with the Gulf of Guinea basin experiencing major water shortages (Sylla, Pal, et al., 2018). While irrigation demand is likely to require increased water consumption and will strongly affect the sustainability of irrigation water sources in the region (Table 4).

West Africa is enriched with numerous surface water resources (rivers, estuaries, lakes, reservoirs), including major rivers such as the Niger, Senegal, Gambia, and Lake Chad. These rivers take their sources in tropically wet major groundwater basins and regions with considerable amount of annual rainfall. But with climate change disrupting the frequency, timing, and intensity of the rainfall patterns across the continent, extended droughts and intensified flooding have become the new normal (Ndehedehe, 2019).

Table 3. Water resources by country.

Country	Average rainfall in depth (mm/yr)	Average rainfall inVolume (10^9 m^3/yr)	Ground water(10^9m^3/yr)	Surface water (10^9 m^3/yr)	Total water resource (10^9 m^3/yr)	Water resources per capita (m^3/inhabitant/yr)	Reference
Benin	1,039	117	2	26	26	3,144	(Odeloui et al., 2022)
Burkina Faso	748	205	10	8	13	849	(Idrissou et al., 2022)
Cote d'Ivoire	1,348	435	38	78	81	4,032	(Soro et al., 2017)
Gambia	836	9	1	8	8	4,950	(Séne et al., 2023)
Ghana	1,187	283	26	52	53	2,326	(Agodzo et al., 2023)
Guinea	1,651	406	38	226	226	23,505	(Mohamed et al., 2023)
Guinea-Bissau	1,577	57	14	27	31	20,117	(Marcolla et al., 2019)
Liberia	2,391	266	45	232	232	63,965	(Koon et al., 2023)
Mali	282	350	20	90	100	8,059	(Diancoumba et al., 2023)
Mauritania	92	95	0	11	11	3,632	(Faye, 2023)
Niger	151	191	3	31	34	2,380	(Abdou Mahaman et al., 2023)
Nigeria	1,150	1,062	87	279	286	1,937	(Ozegin et al., 2023)
Senegal	686	135	4	37	39	3,262	(Sambou et al., 2023)
Sierra Leone	2,526	181	25	150	160	29,520	(Kamara & Kamara, 2014)
Togo	1,168	66	6	14	15	2,333	(Yomo et al., 2019)
Tota1		3,859	317	1,270	1,315	4,638	

According to official statistics, about 1 Mha in West Africa are equipped with irrigation, with over 60% equipped for full-control irrigation and 40% in lowlands (inland valleys or bas-fonds). Further, over 1 Mha are reported to be under recession irrigation, primarily in Nigeria, bringing the total area under agricultural water management (AWM) to over 2 Mha. Irrigation potential is estimated at 9.1 Mha with 55% in just three countries: Nigeria, Ghana and Sierra Leone. Most countries in West Africa hardly developed their irrigation potential, with the exception of Mali and Senegal who developed 41% and 29% of their irrigation potential, respectively. Overall, less than 12% of the irrigation potential is developed (Richards, 2023).

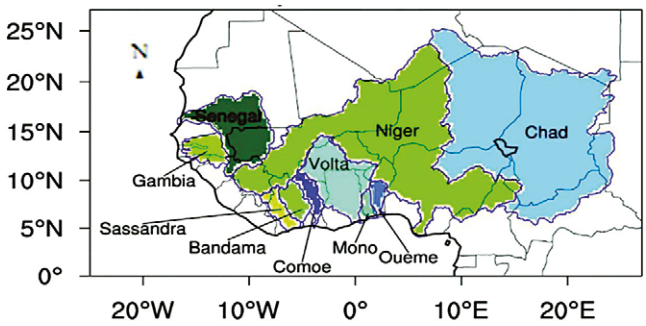

Figure 4. West African major river basin.

3.3. Impact of climate change on sustainability of irrigation water availability in West Africa

Irrigation plays a crucial role in promoting sustainable growth, ensuring economic stability, and providing employment stability (Mondejar et al., 2021). It has helped certain areas recover from droughts and acted as a protective measure during their occurrence. Irrigation plays a role in boosting agricultural production and ensuring consistent yields and productivity, despite its indirect benefits. Supplying water to meet the plant's requirements enhances the production of food, reduces hunger, and fosters the development of high-quality plants. The future of irrigation and agriculture is unpredictable due to the limited, inconsistent, and unexpected rainfall caused by climate change. It serves as a foundation that helps farmers and reduces their dependence on weather conditions, enabling them to enhance their overall agricultural output. This is determined by the presence of water, which greatly affects irrigation, agricultural output, and manufacturing. Furthermore, it plays a vital role in promoting higher agricultural productivity per unit of land area and in expanding agricultural reach. According to the (Malek & Verburg, 2018) Over 70% of the world's irrigation water is abstracted and used annually for irrigation purposes.

Table 4. Irrigation statistics for West Africa.

Country	Irrigation Potential (Ha) '000 ha	Area Equipped for full-control irrigation '000 ha	Equipped Low land areas '000 ha	Total area equipped for irrigation '000ha	Percentage of Irrigation Potential equipped %	Total AWM (including recession irrigation) '000 ha	Percentage of irrigated by ground water %	Reference
Benin	322	11	1	12	3.8	19	20	(Snezhko et al., 2023)
Burkina Faso	165	19	6	25	15.2	46	3	(Yabre et al., 2023)
Cote d'Ivoire	475	48	25	73	15.3	89	18	(Dossou-Yovo & Saito, 2021)
Gambia	80	2	0	2	2.7	15	23	(Boussouga et al., 2023)
Ghana	1,900	31	0	31	1.6	31	11	(Tuffour et al., 2023)
Guinea	520	20	75	95	18.3	95	2	(Terán-Chaves et al., 2023)
Guinea-Bissau	281	9	14	23	8.0	52	6	(You et al., 2011)
Liberia	600	11	2	13	6	57	4	(Nkiaka et al., 2023)
Mali	566	98	138	236	41.7	296	1	(Birhanu et al., 2023)
Mauritania	250	45		45	18.0	109	10	(Higginbottom et al., 2023)
Niger	270	14	60	74	27.3	85	6	(Odofin et al., 2023)
Nigeria	2,331	238	55	293	12.6	972	9	(Ugalahi et al., 2016)
Senegal	409	102	18	120	29.3	150	10	(Higginbottom et al., 2023)
Sierra Leone	807	1	28	29	3.6	155	8	(Moinina et al., 2021)
Togo	180	2	5	7	4.1	7	2	(Gadédjisso-Tossou et al., 2018)
Total	9,156	640	425	1,065	11.6	2,122		

Climate change has a notable impact on the availability of water for agricultural purposes and irrigation, which poses potential risks to food security at both domestic and global levels (Kumar & Sharma, 2022). The changes in time and space of the main elements of the water cycle greatly affect hydrological processes. The area most affected by climate change is irrigation, as it utilises a larger amount of water compared to any other industry. On the other hand, climate change has an opposite effect as it leads to an increase in evaporation, which in turn boosts the need for water in irrigation. This demand is particularly high as irrigation already consumes the majority of the available water in the present surroundings (Egbueri et al., 2023; Hamududu & Ngoma, 2019).

West Africa's climate depends on the variability of the West African monsoon, the southward movement of the Intertropical Convergence Zone (ITCZ), and the location and intensity of the East African jet and thermal jet eastern zone (Biasutti, 2019). The ITCZ is the region where the Sahara's warm, dry harmattan air mass to the north (northeast trade winds) meets cool, moist monsoon air (southwest winds) from the South Atlantic (Augustin et al., 2023). From December to February, the ITCZ moves towards the Gulf of Guinea, and from March to November it moves from the Gulf to higher latitudes, even passing through some areas twice (Bahrami et al., 2017). Therefore, in southern West Africa (i.e. the Guinea coast) there are two rainy seasons (March-June and August-November) and two dry seasons (December-February). The northern part of West Africa (i.e. the Sahel) experiences a rainy season from July to September and a long dry season starting in October (Orimoloye et al., 2021).

Surface temperatures in West Africa have increased over the past 50 years, between 0.5 ◦C and 0.8 ◦C between 1970 and 2010 (Riede et al., 2016), with higher over the past 50 years in the past 20 years compared to previous decades. Temperature increases in the West African region are expected to be larger than average global temperature increases, and heat waves are expected to occur more frequently and last longer (Sylla, Faye, et al., 2018). Rising temperatures have affected all sectors, including water resources, increased irrigation demand and the sustainability of agricultural production (Cai et al., 2015). River flows are expected to decrease by 20 to 40% by 2050 (Obahoundje & Diedhiou, 2022). In transboundary basins such as the Niger, Senegal, and Volta, river flows are expected to decline between 5% and 34%, depending on time period and location (Aziz et al., 2019). At Lake Guiers in Senegal, it was found that climate change and population growth will put pressure on available water resources, leading to greater competition between irrigation and municipal demand (Aina et al., 2023).

In the Volta basin, not all water needs (urban and irrigation) can be met simultaneously with current and future needs. In Ghana, agricultural production frequently fails during periods of rainfall deficit due to low water levels of the Tono irrigation dam (Agodzo et al., 2023). Reduced rainfall will reduce river flows and increase evaporation due to a drier atmosphere, thereby reducing the amount of water available in reservoirs for irrigation. Rising temperatures will increase evaporation, which can contribute to reduced water levels in reservoirs and negatively affect irrigation sustainability (Figure 5). Current demand for freshwater in West Africa for agricultural, industrial, and domestic irrigation purposes is expected to triple by 2050 (USAID 2013). Therefore, it is important to carefully consider the impact of upstream socioeconomic development on reservoirs while also assessing the impact of climate change on the sustainability of irrigation water resources in West Africa (Baratto et al., 2022).

3.4. Impact of land use/land cover change on sustainability of irrigation water availability in West Africa

The impacts of land use change and climate change on water resources pose a major threat in semi-arid environments, especially in sub-Saharan Africa. West African basins are facing rapid changes in land use and land cover and have lost or are losing large areas of natural landscape, which are being replaced by large tracts of land largely influenced by humans due to agriculture, forest fires, and logging (Obahoundje & Diedhiou, 2022). From 1975 to 2013, forest area decreased by 24.6%, while residential and agricultural land areas increased by 140% and 11.7%, respectively, in West Africa (Obahoundje et al., 2021). The size

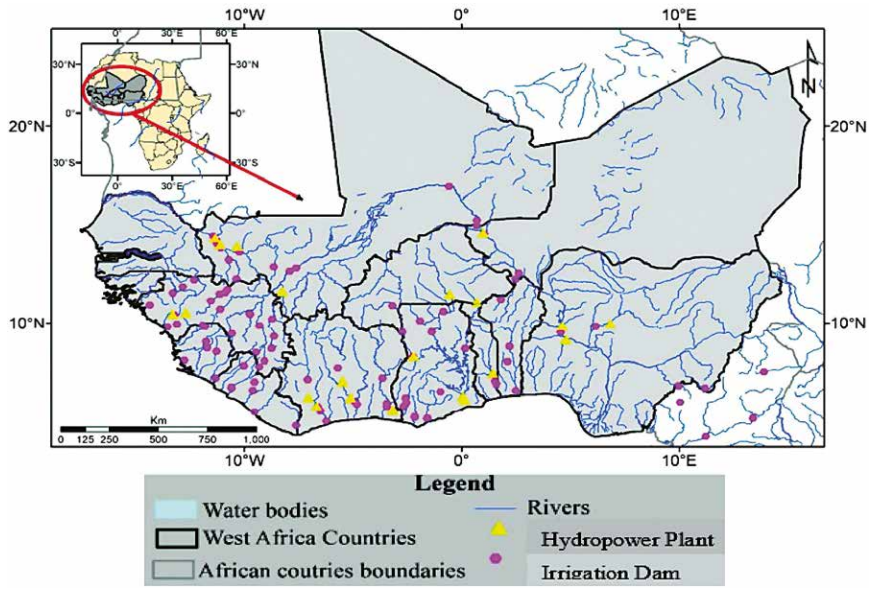

Figure 5. West African Irrigation Dam.

of vegetated areas continues to decrease as rainfall decreases and temperatures increase, especially in arid regions. The hydrological response to changes in LULC varies by region (Koffi et al., 2023). In the Black Volta sub-basin, LULC development between 2000 and 2013 contributed to increases in surface runoff and lateral flow by 27% and 19%, respectively, while the groundwater contribution to runoff River flow decreased by 6% due to land use climate change, as well as 4.6% increase in evapotranspiration due to rising temperatures (Kayitesi et al., 2022). At all scales in the Sahelian region, runoff coefficients generally increase with river flow, driven by reduced vegetation cover (Descroix et al., 2018).

Runoff has increased in the Sahelian basins despite a 20–25% increase in rainfall recorded between 1997 and 2017 (Descroix et al., 2018) and an increased number of dams built in the basins (Efon et al., 2023). This increase in runoff and runoff despite decreased precipitation is known as the 'Sahelian paradox' and was first observed in small catchments in Burkina Faso by (Yonaba et al., 2021). In contrast, a 15% decrease in rainfall in Sudan resulted in a more intuitive reduction in annual runoff and streamflow (Hector et al., 2018). In the latter region, the decrease in flow rate is two to three times greater than that of precipitation (Massazza et al., 2021). In the southern region of West Africa, reduced vegetation cover may also contribute to reduced soil water holding capacity and infiltration rates, leading to reduced water tables and sustainability (Obahoundje & Diedhiou, 2022). Reduced groundwater recharge capacity or water table levels can drastically reduce dry season flows, which, in addition to increasing evaporation due to rising temperatures, can also seriously affect reservoir water availability for irrigation (Mendoza-Grimón et al., 2021).

The potential impact of changing land use and land cover on the Bui Hydropower Project in the Black Volta Basin under climate change was studied using the WEAP model from 2000 to 2040 (Obahoundje & Diedhiou, 2022). Evaluation using the WEAP model in wet and dry climates shows that the combined impact of changing land cover/land use and climate will reduce water availability for all sectors in need water demand (Mensah et al., 2022). Wet conditions are seen as a 14% increase in precipitation and dry conditions as a 15% increase in precipitation between 2012 and 2040 (Obahoundje et al., 2017). Consequences of human-induced land-use change on irrigation water has received little attention from political decision makers and dam managers in the West Africa, while integrating this information about changes on earth, is important for strategic planning, for effective national and regional adaptation policies and for sustainable development (Asenso Barnieh et al., 2020).

3.5. Best irrigation system for agriculture under water stress dry land of Africa

Irrigation agriculture is an essential sector in West Africa, providing food, employment, and income for millions of people. However, the sector is facing numerous challenges, including limited access to water, unreliable rainfall patterns, and climate change, among others. Irrigation systems play a critical role in addressing these challenges and improving agricultural productivity and food security (Baratto et al., 2022). The effects of irrigation on livelihoods are particularly high in areas where agriculture is the main source of livelihood (Akudugu et al., 2021). Sprinkler irrigation: Sprinkler irrigation is the most common type of irrigation system used in West Africa, especially for large-scale cultivation. It uses a system of sprinklers to distribute water over crops. It plays a vital role in the Maximizing water use efficiency and minimising evapotranspiration Büyükcangaz et al. (2017).

4. Conclusion

The future of irrigation water resources and sustainability in West Africa remains uncertain. Large areas are experiencing new dynamics, especially in Senegal and Mali, through private agricultural sectors and small private and individual systems, either spontaneously or with the support of government. The future of irrigation in West Africa will be driven by strong external factors, such as rapid urban growth, climate change and land acquisition. Achieving food security, reducing poverty and adapting to climate change are among the major challenges facing irrigated agriculture in West Africa. Farmers' ability to adapt to this landscape will depend on the agricultural, energy and land policies their governments implement. Land use/cover changes interact with the warmer temperatures affect water availability for irrigation by increasing evapotranspiration and surface runoff and decrease in water yield. As population and urbanisation intensify and economies grow, increasing municipal and industrial water demands are likely to amplify the overall water demands in West Africa. Land and water management practices have great potential to mitigate the impacts of future climate and land use/cover changes on water resource, thus increasing its availability. In addition, these management practices will potentially reduce the stress caused by the decline in available water resource due to climate change. Land and water management practices namely filter strips, terracing and contouring and grassed waterways have to be effective mitigation and adaptation measures for the observed adverse impacts of future climate and land use/cover changes on sustainability of irrigation water availability. Adoption of climate-smart irrigation for climate change adaptation, improved food security, and environmental sustainability in the West Africa.

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AIBOT achieves eVTOL milestone at Norton

AIBOT has successfully conducted a flight test at the Unmanned Aircraft Systems (UAS) Center at San Bernardino International Airport (SBD) under the newly established Norton Test Range. The flight was conducted through a partnership with the FAA's UAS Test Range: Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) for operations on the Norton Test Range. This marks a significant advancement in the regulatory and technical progress needed to bring autonomous aviation closer to commercial deployment. The successful test validated the performance, safety, and operational feasibility of its aiEVTOL technology within an airport environment. *aibot.ai*

Epirus introduces Leonidas H2O

Epirus has announced the introduction of Leonidas H2O, a, high-energy, high-power microwave (HPM) system developed to counter boat motors, unmanned surface vessels (USV) and unmanned aerial vehicles (UAV). The system is built using the scalable Leonidas energy-based, high-power microwave technology platform. It demonstrated effectivity against vessel motors at record ranges during the U.S. Navy's Advanced Naval Technology Exercise Coastal Trident (ANTX-CT) program, during which the system was tested against four commercially available vessel motors ranging from 40 to 90 horsepower at a multitude of ranges. *www.epirusinc.com*

Spoof-proof drone delivery

Japan's CORE Corporation, together with ACSL Ltd. and Rakuten Group, recently conducted a demonstration of anti-spoofing capabilities using Japan's Quasi-Zenith Satellite System (QZSS) Navigation Message Authentication (QZNMA) service.

At the center of the project was the newly developed ChronoSky PF2-AE. The platform brought together CORE's new QZNMA-enabled Cohac∞ Ten++ GNSS receiver and ACSL's PF2-AE delivery drone. Project partners simulated disaster-relief supply missions in Chichibu City, Saitama Prefecture, demonstrating real-world resilience against spoofing attacks.

During the demonstration, two distinct operational scenarios under controlled spoofing conditions were evaluated. In the first scenario, where only a subset of satellite signals was spoofed, the drone quickly detected the anomaly, alerted its ground control station (GCS), and safely continued its autonomous flight. In the second, where all satellite signals were compromised, the drone again detected the spoofing, alerted the GCS, and transitioned to manual flight, allowing the operator to complete the delivery mission.

EagleView enhances Its Drone Solution

EagleView is now expanding its drone offering to provide insurance carriers with more complete options for obtaining property inspections, property analysis reports, and repair estimates.

The company's current offering, EagleView AssessTM, uses American-made drones to capture imagery and then harnesses machine learning and artificial intelligence to detect roof abnormalities. This helps validate and resolve claims, while also helping reduce human errors and subjectivity. *eagleview.com*

SPH Engineering launches UgCS Open

SPH Engineering has launched UgCS Open, a free version of its industry-leading software. It provides the same 3D flight planning, terrain-aware automation, and mission control capabilities as the paid version, with just a few limitations. The new product is making advanced drone flight planning more accessible. *www.sphengineering.com*

AirWarden drone detection system

AeroDefense has introduced AirWarden Essentials, a drone detection system designed to provide cost-effective airspace monitoring through networked Remote ID broadcasts. It aims to enhance situational awareness for organizations concerned about unauthorized drone activity.

It operates using a small receiver, which can be installed on a building or pole within ten minutes. The device connects to a cloud-based command console via LTE or ethernet, offering users real-time drone and pilot location alerts through text, email and on-screen notifications. The technology is based on AeroDefense's Collaborative Drone Detection Network, developed under a Department of Defense contract. It allows multiple agencies to share a common operational picture, improving coordination in responding to potential drone threats. *aerodefense.tech*

Saildrone deploys tech for GPS-denied environments

Saildrone has successfully demonstrated operations in the Middle East with new hardware and software capabilities that allow it to operate in a GPS-denied environment.

The US Navy established Task Force 59 in 2021 as part of the US Naval Forces Central Command (NAVCENT) and US Fifth Fleet to advance the operational employment of unmanned systems and artificial intelligence in fleet operations. Due to recent regional events, GPS jamming and spoofing have hindered unmanned operating systems in the area.

Saildrone now has the ability to autonomously operate in GPS-denied or spoofed maritime environments. Its innovative solution leverages multiple forms of localization, ensuring seamless operation without relying exclusively on satellite systems, and allowing operations to continue in contested environments. *www.saildrone.com*

UK Positioning, Navigation and Timing: Overview

As of March 2025, the UK's Framework for Greater PNT Resilience, introduced in October 2023, continues to drive efforts to enhance Positioning, Navigation, and Timing (PNT) services. A significant milestone was achieved on 20 November 2024, when the National PNT Office, established within the Department for Science, Innovation and Technology (DSIT), collaborated with the Royal Institute of Navigation (RIN) to launch the world's first best practice principles and checklist for resilient PNT. This initiative provides businesses with actionable guidance to mitigate risks and invest in robust PNT technologies, marking a global lead in standardizing resilience measures. Additionally, the 2025 National Risk Register, part of the National Security Risk Assessment (NSRA), reaffirmed the critical risk of PNT disruptions due to potential catastrophic Global Navigation Satellite System (GNSS) failures, underscoring the urgency of ongoing resilience efforts.

Introduction

PNT services are vital to the UK's economy, security, and daily operations, supporting sectors such as finance, defence, transportation, telecommunications, and emergency services. PNT encompasses **Positioning** (determining location and orientation), **Navigation** (guiding movement between positions), and **Timing** (maintaining precise time from a global standard). Primarily delivered through GNSS, such as the US Global Positioning System (GPS), PNT is an "invisible utility" enabling communications, global supply chains, and activities like banking and broadcasting. The UK's reliance on GNSS, however, exposes it to disruptions, prompting the government to prioritize enhanced PNT resilience.

Why PNT Matters

PNT underpins all 13 sectors of the UK's Critical National Infrastructure (CNI), including energy, transport, and emergency services. It enables secure financial transactions, media broadcasts, and emerging technologies like autonomous vehicles and smart cities. The 2018 Blackett Review, *Satellite-derived Time and Position: A Study of Critical Dependencies*, highlighted the risks of GNSS dependency, noting that disruptions from technical failures, space weather, or intentional interference could severely impact the economy and national security. The 2025 National Risk Register further emphasizes the need for robust contingency measures to address these vulnerabilities.

Government Framework for Greater PNT Resilience

The *Framework for Greater PNT Resilience*, a 10-point policy plan launched in October 2023, aims to reduce dependency on vulnerable GNSS signals, enhance resilience, and foster innovation. Building on the 2018 Blackett Review, the 2021 Integrated Review, and the UK Space Agency's Space Based PNT Programme (SBPP), the framework remains a cornerstone of UK PNT policy. Its key components include:

1. National PNT Office

The National PNT Office, housed in DSIT, coordinates PNT policy and delivery across government. Launched post-2023 framework, it drives resilience by collaborating with stakeholders to address vulnerabilities and promote innovative solutions, as evidenced by the 2024 RIN collaboration.

2. PNT Crisis Plan

A cross-government PNT Crisis Plan is maintained to mitigate GNSS disruptions, identifying short-term solutions to ensure continuity of critical services, as informed by the 2023 RIN White Paper and 2025 National Risk Register.

3. National Timing Centre (NTC)

A proposed National Timing Centre, based on the National Physical Laboratory's UTC(NPL) time scale, would provide resilient, terrestrial, and sovereign timing using advanced optical clocks. Supported by £14 million, this builds on the NTC R&D programme since 2020.

4. Ministry of Defence (MOD) Time

A proposed "MOD Time" system would ensure resilient timing for defence applications, leveraging NTC capabilities to enhance national security in contested environments.

5. Enhanced Long-Range Navigation (eLORAN)

A terrestrial, sovereign eLORAN system is proposed to provide backup positioning and navigation. In May 2023, Ofcom sought industry interest in eLORAN broadcast licenses, advancing implementation.

6. UK Satellite-Based Augmentation System (SBAS)

A UK Precise Point Positioning SBAS is under exploration to replace reliance on the European Geostationary Navigation Overlay Service (EGNOS), supporting high-accuracy positioning and GNSS integrity monitoring.

7. Next-Generation PNT Technologies

Investments in quantum navigators and potential UK sovereign regional satellite systems aim to diversify PNT sources and bolster resilience against emerging threats.

8. Infrastructure Resilience

The framework promotes resilient GNSS receiver chips, holdover clocks, and potential legislation to mandate minimum PNT resilience standards for CNI sectors.

Economic and Strategic Impact

The framework addresses vulnerabilities while positioning the UK as a PNT innovation leader. By fostering skills, industry collaboration, and R&D, it supports economic growth and aligns with the 2023 UK Science and Technology Framework's vision of a science and technology superpower by 2030. Resilient PNT systems are critical for autonomous vehicles, digital twins, and 5G networks, ensuring global competitiveness.

Conclusion

The UK's *Framework for Greater PNT Resilience* strengthens critical infrastructure and drives economic opportunities. Recent advancements, including the National PNT Office's 2024 best practice principles and ongoing NTC and eLORAN proposals, demonstrate progress toward a secure PNT ecosystem. For further details, visit www.GOV.UK.

Tracking the world's forests: how the ESA's Biomass mission will work

The European Space Agency (ESA) is set to launch its ambitious Biomass mission later this month. The mission will map the world's forests to provide the very first comprehensive measurements of forest biomass at a global scale. It will find out how forests are changing, and further our understanding about their role in the carbon cycle.

The satellite is scheduled to lift off on April 29 aboard a Vega C rocket from the ESA's Korou spaceport in French Guiana.

What will the Biomass mission do?

All life on Earth, from smallest microbes to gigantic California Redwoods, is carbon-based. As such, carbon is the element that makes life as we know it possible. But Earth does not gain or lose carbon. The element only moves between the atmosphere, living organisms, Earth's crust and soil, and the oceans.

This process is known as the carbon cycle, of which forests are an essential part. This is because forests store massive amounts of carbon — scientists estimate that they absorb around 16 billion metric tonnes of carbon dioxide (CO2) per year, and currently hold 861 gigatonnes of carbon in their soils and vegetation.

Unfortunately, data on forest biomass — the mass of organic matter in forests — are severely lacking on a global scale. This fundamentally limits our understanding of the state of the forests, and their impact on the carbon cycle (and climate). The Biomass mission aims to bridge this knowledge gap. The mission will allow scientists to more accurately measure how the distribution of carbon in the planet is changing, as humans continue to cut down trees, and increase CO2 levels in the atmosphere.

In 2023, Earth lost 3.7 million hectares of tropical forests, equivalent to losing around ten football fields worth of forest land every minute, according to a report by the World Resources Institute. "This forest loss produced roughly 6% of estimated global CO2 emissions in 2023," the report said.

Simonetta Cheli, director of Earth Observation Programmes for the ESA, told The Observer, "We need to know the health of our tropical forests… We need to know the quality and diversity of its vegetation and the amount of carbon stored there. To get that information we are going to create 3D images of them — from the top of the forest canopy to the roots of its trees." Beyond forest monitoring, the Biomass mission will also observe the movement of ice sheets in Antarctica, and generate digital models of terrains covered by dense vegetation.

How will the Biomass mission monitor forests?

To fulfil its objectives, the mission will use a synthetic aperture radar (SAR) to map the Earth's surface. Notably, the satellite, which is fitted with a massive 12-m antenna, will be the first in space to use a long-wave P-band SAR.

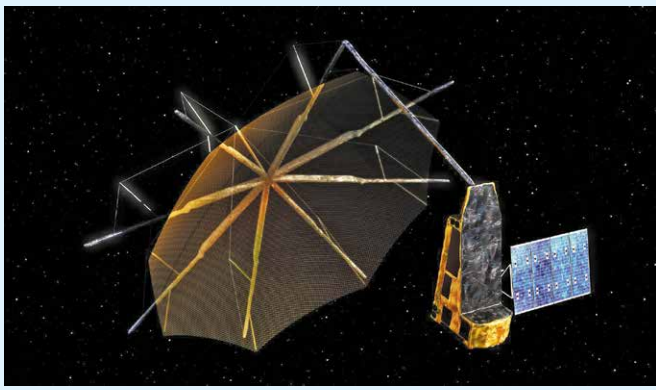

Image CREDIT: Airbus Defence and Space | Copyright: ©ESA

It will thus be able to penetrate dense forest canopies to assess how much carbon is stored on the floor and in the branches of the trees, and to assess how these levels are changing over time. Note that as a general rule, shorter wavelengths of electromagnetic radiation penetrate matter less than longer wavelengths.

Shaun Quegan, a researcher at Sheffield University (England) and head of the Biomass science team, told The Guardian: "What the mission will do, effectively, is weigh the forests it studies… We know half that weight must be made up of carbon. So we are going to be able to weigh the carbon content of the world's… forests from space and, crucially, work out how much these are changing over time. We will then know the balance of carbon that is flowing to and from the atmosphere. That is enormously important."

NASA science continues after Firefly's first moon mission concludes

After landing on the Moon with NASA science and technology demonstrations March 2, Firefly Aerospace's Blue Ghost Mission 1 concluded its mission March 16. Analysis of data returned to Earth from the NASA instruments continues, benefitting future lunar missions.

As part of NASA's CLPS (Commercial Lunar Payload Services) initiative and Artemis campaign, Firefly's Blue Ghost lunar lander delivered 10 NASA science and technology instruments to the Mare Crisium basin on the near side of the Moon. During the mission, Blue Ghost captured several images and videos, including imaging a total solar eclipse and a sunset from the surface of the Moon. The mission lasted for about 14 days, or the equivalent of one lunar day, and multiple hours into the lunar night before coming to an end.

All 10 NASA payloads successfully activated, collected data, and performed operations on the Moon. Throughout the mission, Blue Ghost transmitted 119 gigabytes of data back to Earth, including 51 gigabytes of science and technology data. In addition, all payloads were afforded additional opportunities to conduct science and gather more data for analysis, including during the eclipse and lunar sunset.

Among other achievements, many of the NASA instruments performed first-of-their-kind science and technology demonstrations, including:

- The Lunar Instrumentation for Subsurface Thermal Exploration with Rapidity is now the deepest robotic planetary subsurface thermal probe, drilling up to 3 feet and providing a first-of-its kind demonstration of robotic thermal measurements at varying depths.

- The Lunar GNSS Receiver Experiment acquired and tracked Global Navigation Satellite Systems (GNSS) signals, from satellite networks such as GPS and Galileo, for the first time enroute to and on the Moon's surface. The LuGRE payload's record-breaking success indicates that GNSS signals could complement other navigation methods and be used to support future Artemis missions. It also acts as a stepping stone to future navigation systems on Mars.

- The Radiation Tolerant Computer successfully operated in transit through Earth's Van Allen belts, as well as on the lunar surface into the lunar night, verifying solutions to mitigate radiation effects on computers that could make future missions safer for equipment and more cost effective.

- The Electrodynamic Dust Shield successfully lifted and removed lunar soil, or regolith, from surfaces using electrodynamic forces, demonstrating a promising solution for dust mitigation on future lunar and interplanetary surface operations.

- The Lunar Magnetotelluric Sounder successfully deployed five sensors to study the Moon's interior by measuring electric and magnetic fields. The instrument allows scientists to characterize the interior of the Moon to depths up to 700 miles, or more than half the distance to the Moon's center.

- The Lunar Environment heliospheric X-ray Imager captured a series of X-ray images to study the interaction of the solar wind and Earth's magnetic

After delivering ten NASA science and technology payloads to the near side of the Moon through NASA's CLPS (Commercial Lunar Payload Services) initiative and Artemis campaign, Firefly Aerospace's Blue Ghost Mission 1 lander captured this image of a sunset from the lunar surface. Credit: Firefly Aerospace

field, providing insights into how space weather and other cosmic forces surrounding Earth affect the planet.

- The Next Generation Lunar Retroreflector successfully reflected and returned laser light from two Lunar Laser Ranging Observatories, returning measurements allowing scientists to precisely measure the Moon's shape and distance from Earth, expanding our understanding of the Moon's inner structure.

- The Stereo Cameras for Lunar Plume-Surface Studies instrument captured about 9,000 images during the spacecraft's lunar descent and touchdown on the Moon, providing insights into the effects engine plumes have on the surface. The payload also operated during the lunar sunset and into the lunar night.

- The Lunar PlanetVac was deployed on the lander's surface access arm and successfully collected, transferred, and sorted lunar soil using pressurized nitrogen gas, demonstrating a low-cost, low-mass solution for future robotic sample collection.

- The Regolith Adherence Characterization instrument examined how lunar regolith sticks to a range of materials exposed to the Moon's environment, which can help test, improve, and protect spacecraft, spacesuits, and habitats from abrasive lunar dust or regolith.

The data captured will benefit humanity in many ways, providing insights into how space weather and other cosmic forces may impact Earth. Establishing an improved awareness of the lunar environment ahead of future crewed missions will help plan for long-duration surface operations under Artemis.

To date, five vendors have been awarded 11 lunar deliveries under CLPS and are sending more than 50 instruments to various locations on the Moon, including the lunar South Pole and far side. *www.nasa.gov*

Vexcel Imaging announces the newest UltraCam Osprey 4.2

Vexcel Imaging introduces the UltraCam Osprey 4.2, the latest evolution in large-format nadir and oblique aerial imaging technology. The new 4.2 model offers 27% greater flight line efficiency with a swath width of over 25,000 pixels in nadir, along with enhanced operational flexibility - reducing costs and improving coverage. It delivers the highest-detail photogrammetric image quality, ensuring maximum productivity for 3D city modeling, infrastructure monitoring, and high-precision urban mapping applications.

The UltraCam Osprey 4.2 is the first Vexcel system to feature the cutting-edge 247 MP Sony IMX811 CMOS sensor in combination with custom Vexcel lenses, fully resolving the new CMOS sensor. Built with an advanced panchromatic nadir channel, the system delivers precise measurements for superior feature extraction, providing the best foundation for creating demanding derivative data products like 3D city models. The UltraCam Osprey 4.2 is available in two lens configurations for enhanced operational flexibility and minimized dependence on airspace restrictions.

NSTC names Pingtung as Taiwan's space launch site

Taiwan's National Science and Technology Council (NSTC) recently announced that it has selected Jiupeng Village in Pingtung County's Manjhou Township as the location for the country's national space mission launch site. The decision was the result of a comprehensive review conducted by an inter-agency panel, which evaluated environmental conditions, launch conditions, development execution, and potential for further development, according to a news release from the Cabinet-level NSTC. *focustaiwan.tw*

Bellatrix, Astroscale Japan partner for space debris removal

Bengaluru-headquartered Bellatrix Aerospace and Astroscale Japan have signed an MoU for propulsion solutions. The collaboration will address opportunities within India's growing space market and expand to developing international markets. The partnership aims to drive active debris removal, satellite servicing, and in-orbit mobility, contributing to a cleaner and safer space environment. *timesofindia.indiatimes.com*

China, Pakistan to send first foreign astronaut to Chinese space station

For the first time, the Chinese space program will train a Pakistani astronaut, who will also be the first foreign astronaut to visit China's space station.

The agreement, called the "Cooperation Agreement on the Selection, Training of Pakistani Astronauts and Participation in China's Space Station Flight Mission," was signed by officials from the China Manned Space Engineering Office (CMSE) and the Pakistan Space and Upper Atmosphere Research Commission (SUPARCO) on Feb. 28. *www.space.com*

Chandrayaan-5 approved

India's ambitious Chandrayaan-5 mission has been officially approved by the Government of India. The mission will carry a significantly larger rover—250 kg compared to the 25-kg rover 'Pragyan' used in Chandrayaan-3.

The Chandrayaan series has been crucial to India's lunar exploration efforts. The first mission, Chandrayaan-1 (2008), conducted chemical, mineralogical, and photo-geologic mapping of the Moon.

The Chandrayaan-2 mission (2019) achieved a 98% success rate, though the lander failed in its final stage. However, the onboard high-resolution camera continues to send hundreds of images, Narayanan, also the Secretary of Department of Space.

The Chandrayaan-3 mission successfully landed the Vikram lander on the Moon's south pole on August 23, 2023, demonstrating India's end-to-end lunar landing capabilities.

Following Chandrayaan-5, ISRO is gearing up for Chandrayaan-4, expected to launch in 2027, with the goal of collecting and bringing back lunar samples to Earth. *www.businesstoday.in*

South Korea turning abandoned coal mine into moon mission test site

South Korea plans to transform the former mining city of Taebaek into a national testing ground for lunar resource exploration, leveraging the city's abandoned coal mines as proving grounds for space mining technologies that could one day help extract helium-3 and rare metals from the moon's surface.

This initiative was highlighted recently when the Korea Institute of Geoscience and Mineral Resources (KIGAM) conducted a demonstration inside a defunct tunnel of the former Hamtae mine in Taebaek, Gangwon Province. The event showcased rover prototypes equipped with autonomous navigation, soil analysis, and excavation technologies - tools that could eventually be deployed on the moon to collect valuable resources.

Taebaek, situated at an average elevation of 900 meters, is Korea's highest city and symbolically its closest point to outer space. The environmental conditions inside its abandoned mines - complete darkness, low temperatures, rugged terrain, and limited visibility due to fine dust - closely resemble those of the lunar south pole, making the area ideal as a pre-deployment test site of lunar exploration equipment. *pulse.mk.co.kr*

Planet, ESA sign deal

Planet Labs has signed a new contract with the European Space Agency on behalf of the Hellenic Ministry of Digital Governance to support the Greek National SmallSat Programme, funded by the Recovery and Resilience Fund (RRF) Greece 2.0. Using Planet's commercial satellite data, Greece aims to inform and complement the development of their national satellite technology. *www.planet.com*

Disaster response with satellite technology

Juvare and ICEYE have announced a strategic partnership designed to deliver unprecedented situational awareness and actionable insights to emergency management agencies, insurers, and government organizations worldwide. Through this collaboration, ICEYE's high-resolution, all-weather satellite solutions will be integrated into Juvare's industry-leading WebEOC® platform, strengthening Juvare's position as the System of Record for emergency management. *Juvare.com*

Pix4D, ProStar partnership

Pix4D and ProStar Holdings have announced a strategic partnership. It combines Pix4D's advanced 3D modeling capabilities with ProStar's PointMan® platform to support the next evolution in augmented reality for critical underground infrastructure. This combination will enable users to view a representation of what lies beneath the Earth's surface in 3D from a smartphone. PointMan's mobile and cloud-based architecture is designed to precisely capture and map subsurface assets, while Pix4D's software transforms this data into real-time 3D mapping. *prostarcorp.com*

GEOSA and SLA launch achievements of Joint Geospatial System Project in Singapore

The General Authority for Survey and Geospatial Information (GEOSA) and the Singapore Land Authority (SLA) officially launched the outcomes of their cooperation project to develop and manage the geospatial system. The partnership is part of GEOSA's broader effort to establish a robust national geospatial infrastructure, aligning with global best practices to enhance the positive and sustainable impact of geospatial data across multiple sectors.

The cooperation serves as a model for effective international collaboration, supporting the integration of geospatial information into public, private, academic, and non-profit sectors, and advancing national development priorities.
As part of the project, both parties worked to strengthen ties between the Arab Committee of Experts, chaired by Saudi Arabia, and the UN Asian Committee of Experts on Geospatial Information Management, represented by Singapore. The Arab Committee shared insights on developing geospatial governance and infrastructure, while the Asian Committee contributed its expertise in disaster management and land administration. *www.spa.gov.sa*

GomSpace adds Neuraspace traffic management to HOOP platform

Denmark's GomSpace has partnered with Portugal's Neuraspace to add their space traffic management to its hands-off operations platform (HOOP) for satellite operators. The combination of both will provide improved safety and further cost reduction to GomSpace's customers.

The partnership also showcases that Neuraspace's AI-based space traffic management, in addition to enabling operators to directly monitor their assets in orbit and pre-launch screening for rocket starts is ideally suited to be integrated into other service platforms.

HOOP is an advanced satellite operations platform built for automation, scalability and flexibility. Through it, customers can grow their business from the first satellite to a global constellation without having to invest in the operational infrastructure or needing to know how to operate them or care for the day-to-day operations. *neuraspace.com*

Atlas GIS platform receives significant upgrades

Atlas has introduced several new features aimed at simplifying geospatial workflows for teams without requiring coding expertise. The centerpiece of this launch is the Workflows engine, which allows users to visually design

and automate spatial analysis processes — such as filtering data, performing calculations and updating layers — without writing code. By streamlining these tasks into automated chains, the feature seeks to reduce the time and effort traditionally spent on repetitive scripting. The Atlas platform offers real-time collaboration and no-code solutions for spatial analysis, automation, and app building. *atlas.co*

EUSI, Albedo to bring 10cm satellite imagery to Europe

European Space Imaging (EUSI) has joined forces with Albedo, the company behind the first commercial satellite designed for Very Low Earth Orbit (VLEO). Together, they aim to deliver the world's highest-resolution satellite imagery to the European and North African markets, setting a new standard in Earth observation. This announcement follows the successful launch and initial commissioning of Albedo's Clarity-1 satellite, marking a significant milestone in Earth observation capabilities. *albedo.com*

Ahmedabad civic body employs GPR tech to map underground utilities ahead of infra projects

With all of the city's utilities, including power supply lines, going underground, the Ahmedabad Municipal Corporation (AMC) in Gujarat, India has begun using Ground Penetration Radar (GPR) technology to map underground distribution networks to avoid damage and prevent delays in the ongoing work for upcoming projects.

The technology, which is a non-destructive geophysical method that uses radio waves to image the subsurface, allowing for the detection and mapping of underground utilities without excavation, is currently being tried at the Panjrapole crossroads for a flyover project by the civic body.

The non-destructive method that can detect objects up to 10 metres below ground was first put to trial on the Ashram Road around two years ago for the purpose of microtunneling for a storm water pipeline between Vadaj and Mahalaxmi Society.

In one past instance where the AMC employed its trial pit method for a bridge project, it realised there was a drainage pipeline underneath the chosen location just as digging began. What followed was communication to concerned agencies, approvals, and re-alignments that led to avoidable delays.

Similarly, in another microtunneling project, the gas of one of the pipelines and electricity cables got damaged, while in other cases, digging led to cave-ins — all leading to delays, inconvenience to residents and additional costs.

A site where the GPR survey was recently used, though not by AMC, was at the proposed location of the bullet train project area at Sabarmati. Sources revealed that it was used to map the underground findings in order to prevent damage during construction to depth of up to 10 metres.

Segway expands Navimow lineup with X3 Series launch

Segway Navimow has launched the X3 Series, the latest addition to its portfolio of boundary-cord-free robotic lawnmowers. The range consists of four new models – the X315, X330, X350 and X390 – and is designed to handle unprecedented lawn sizes with precision, mowing areas of up to 10,000m² (the equivalent of one and a half football pitches). It has upgraded its Exact Fusion Location System (EFLS) for the X3 Series, introducing EFLS version 3.0. This features major upgrades in Real-Time Kinematic (RTK) coverage, Visual Simultaneous Localisation and Mapping (VSLAM), and Visual Inertial Odometry (VIO) technology. *navimow.segway.com*

Q-CTRL overcomes GPS-denial with quantum sensing, achieves quantum advantage

Q-CTRL announced successful field trials of a new generation of quantum-assured navigation solutions validated to outperform comparable conventional alternatives in challenging real-world settings. This marks the first achievement of commercial quantum advantage for any of the recently posed applications of quantum technology.

Q-CTRL has produced a new generation of quantum-assured navigation systems, Ironstone Opal, that delivers GPS-like positioning, is completely passive and undetectable, and cannot be jammed or spoofed. It solves the most pressing navigation challenges in the defense and civilian domains, enabling new missions, streamlining transport operations, and powering autonomous systems. *https://q-ctrl.com*

Inertial Labs unveils anti-jamming CRPA system

Inertial Labs has introduced the M-AJ-QUATRO anti-jamming antenna system, designed to ensure assured positioning, navigation and timing (A-PNT) in GNSS-challenged environments. The system incorporates advanced Controlled Reception Pattern Antenna (CRPA) technology and digital processing capabilities, making it suitable for applications ranging from military operations to commercial aviation. *www.viavisolutions.com*

ComNav unveils new USV for hydrographic surveying

ComNav Technology has released the SV600 unmanned surface vessel (USV) for hydrographic surveying. It incorporates adaptive water-flow straight-line and hovering technology, enhancing efficiency and ease of operation. A key feature of the SV600 is its dual-moon pool design, which allows for simultaneous deployment of various surveying equipment. This includes Acoustic Doppler current profilers, single-beam echo sounders, side-scan sonar, pipeline detectors and miniaturized multi-beam echo sounders. *comnavtech.com*

Rx Networks launches cm-level GNSS correction service

Rx Networks has introduced TruePoint | FOCUS, a high-precision, cloud-based GNSS correction service that offers instantaneous cm-level accuracy for a variety of applications. This service is designed to address the needs of industries requiring real-time precision, such as micro-mobility, smart agriculture, robotics, UAVs, IoT and machine control. It supports both Real-Time Kinematic (RTK) and PPP-RTK modes to offer flexibility and high performance. The RTK mode is hardware-agnostic, ensuring compatibility with any RTK-enabled GNSS receiver. The PPP-RTK mode leverages State Space Representation (SSR) to deliver high-accuracy positioning with optimized bandwidth usage. This mode combines the benefits of global coverage from PPP with the fast convergence times of RTK. *rxnetworks.com*

OxTS launches WayFinder

OxTS has released WayFinder, a new localization solution designed for use in GNSS-denied environments. The system combines a GNSS/INS system, onboard processor, lidar scanner and two cameras to enable accurate positioning in areas with limited satellite coverage, such as urban canyons and underground tunnels. *www.oxts.com*

High-precision positioning modules by Unicore

Unicore has introduced the UM981 series, a high-precision positioning module that integrates RTK and inertial navigation system (INS) technologies. The solution leverages GNSS and INS navigation to cater to applications in precision agriculture, surveying and mapping. The module is compatible with all major navigation systems and frequencies. Additionally, the UM981 series supports open Precise Point Positioning (PPP) services such as BDS-3 PPP-B2b, Galileo E6 HAS and QZSS L6 MADOCA-PPP, achieving 10 cm positioning accuracy with a convergence time of under 10 minutes, according to Unicore. *en.unicore.com*

SBG Systems unveils MEMS gyrocompass IMU

SBG Systems has unveiled its MEMS-based North-seeking inertial measurement unit (IMU) that operates independently of GNSS. According to the company, this launch lays the foundation for future products, such as attitude and heading reference systems (AHRS) and inertial navigation systems (INS), broadening the scope of MEMS-based navigation solutions.

The MEMS-based IMU can achieve a heading accuracy greater than 1° secant latitude without GNSS assistance. When integrated with GNSS and SBG Systems' navigation algorithms, it can achieve INS heading accuracy greater than 0.01°.

The device features a true MEMS-based design with no moving parts, eliminating the need for carouseling mechanisms. This ensures enhanced durability and reliability across a wide range of operating environments. *www.sbg-systems.com*

SBG Systems improves GNSS and INS post-processing capabilities

SBG Systems has released Qinertia 4.2, an updated version of its post-processing software for GNSS and inertial navigation system (INS) data. This release introduces several new features and improvements aimed at refining processing accuracy and usability, according to SBG Systems.

One of the notable additions is the beta version of Precise Point Positioning Fixed Ambiguity, which allows centimeter-level accuracy processing without the need for a base station. The update also includes a new RTS smoothing option, known as the Trajectory Smoother, which enhances INS processing by removing artifacts while maintaining precision. Another feature is the standalone Lever Arm Estimation Tool, now available as a separate application with a simplified interface. The Advanced Virtual Base Station Network Creation has been enhanced with improved base station quality indicators to increase reliability. *www.sbg-systems.com*

Septentrio unveils AsteRx RB3 and RBi3 ultra-rugged receivers

Septentrio announces the launch of two new products: AsteRx RB3 GNSS receiver and AsteRx RBi3 GNSS/INS (Inertial Navigation System). These IP69K-rated receivers push the limits of durability even further with the most rugged housing and components yet. Under the hood is state-of-the-art multi-frequency GNSS technology, delivering robust centimetre-level positions even during heavy shocks and vibrations and in environments which are challenging for GNSS. *www.septentrio.com*

Syntony GNSS introduces the Echo™ 4RP

Syntony GNSS has introduced the Echo 4RP, the latest addition to its Echo series of GNSS record and playback systems. This new model builds on the capabilities of the Echo R&P, offering advanced features designed to address the evolving needs of GNSS testing and development. The Echo 4RP expands its frequency range to include L, S, and C bands, surpassing the previous model's coverage of 1100 MHz to 2550 MHz. This broader spectrum supports both current and emerging GNSS and non-GNSS signals, making it adaptable for diverse testing scenarios. *syntony-gnss.com*

U.S. Space Force field commands announce accelerated GPS III mission

U.S. Space Force's Space Systems Command and Space Operations Command announce the expected launch of the National Security Space Launch GPS III-7 mission, Space Vehicle 08, with SpaceX's Falcon 9 rocket from Space Launch Complex 40 at Cape Canaveral Space Force Station, Florida., no earlier than the end of May 2025.

Following the successful Rapid Response Trailblazer launch in December 2024, the two field commands are executing another accelerated mission. It involves a complex integration of effort across multiple Space Force organizations to retrieve a Global Positioning System III satellite from storage, expedite integration with a launch vehicle and prepare it for launch on an accelerated timeline.

The GPS III satellite, equipped with M-Code technology, provides the warfighter with a capability that is three-times more accurate and eight-times more resistant to jamming. This effort ensures rapid delivery of modernized Precision, Navigation and Timing capabilities to the Joint Force. *www.spaceforce.mil*

Sierra Space demonstrates resilient GPS Satellite technology

Sierra Space has successfully demonstrated its Resilient GPS (R-GPS) technology for the U.S. Space Force (USSF). This milestone, achieved in collaboration with General Dynamics Mission Systems, involved generating all GPS navigation signals required for the R-GPS mission. The technology seeks to address the growing need for resilient GPS systems capable of countering threats such as jamming and spoofing, which pose risks to the current GPS infrastructure.

Sierra Space was awarded an R-GPS contract by the USSF Space Systems Command in September 2024 to develop design concepts for smaller and more affordable satellites. *www.sierraspace.com*

Bentley Systems partners with Google

Bentley Systems has announced new asset analytics capabilities that leverage Imagery Insights from Google Maps Platform to rapidly detect and analyze roadway conditions. Unveiled at Google Cloud Next 2025, the new capabilities in Bentley's Blyncsy product offering, which applies AI to crowdsourced imagery for automated roadway asset detection and inspection, will help infrastructure professionals. Both announced a strategic partnership in October 2024 to integrate Google's high-quality geospatial content with Bentley's infrastructure engineering software to improve the way infrastructure is designed, built, and operated. *bentley.com*

Axelspace to launch seven GRUS-3 Earth observation satellites

Axelspace Corporation announced plans to launch seven next-generation Earth observation microsatellites, "GRUS-3," in 2026. This will expand the company's microsatellite constellation to include more than ten satellites, enabling observation of broader areas with increased frequency. GRUS-3 will build upon Axelspace's existing constellation

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11-15 May 2025
Baška, Croatia
https://rin.org.uk

GeoIgnite
12-14 May2025
Ottawa, Canada
https://geoignite.ca

European Navigation Conference
21-23, May 2025
Wrocław, Poland
https://enc-series.org/2025/

June 2025

GEO Business 2025
04-05 June
London, UK
www.geobusinessshow.com

July 2025

Esri User Conference
14-18 July 2025
San Diego, USA
www.esri.com

September 2025

IAG Scientific Assembly 2025
1-5 September
Rimini, Italy
https://eventi.unibo.it/iag2025

Commercial UAV Expo 2025
2-4, September
Las Vegas
www.expouav.com

Esri India User Conference 2025
September - Delhi 3rd & 4th, Kolkata 9th, Hyderabad 10th, Mumbai 12th
www.esri.in

ION GNSS+
08-12 September 2025
Baltimore, USA
www.ion.org

October 2025

Intergeo 2025
7-9 October
Frankfurt, Germany
https://dvw.de/intergeo/en

The Arab Conference on Astronomy and Geophysics
13 - 16 October 2025
Cairo, Egypt
https://acag-conf.org

November 2025

Canada's National Geomatics Expo 2025
3 - 5 November
Calgary, Canda
https://gogeomaticsexpo.com

of five microsatellites, "GRUS-1," which provides services to government agencies and private companies in more than 30 countries worldwide. *axelspace.com*

World's smallest, lightest precision LiDAR sensor

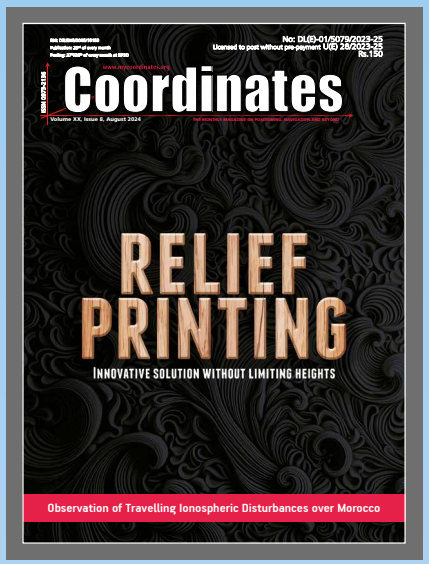
Sony Electronics Inc. has announced commercialization of the AS-DT1 LiDAR Depth Sensor. It is the world's smallest and lightest LiDAR Depth Sensor structure measuring just 29mm x 29mm x 31mm (approximately 1.14 inch width x 1.14 inch height x 1.22 inch depth), excluding protrusions, and weighing only 50g (approximately 1.76 ounces). It leverages miniaturization and optical lens technologies from Sony's machine vision industrial cameras making it ideal for applications where space and weight constraints are paramount, including drones, robotics, and more. *sony.com*

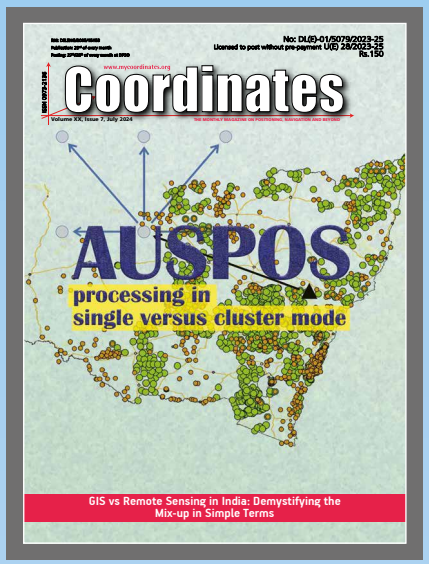
Topcon expands road tech with new scanning, paving

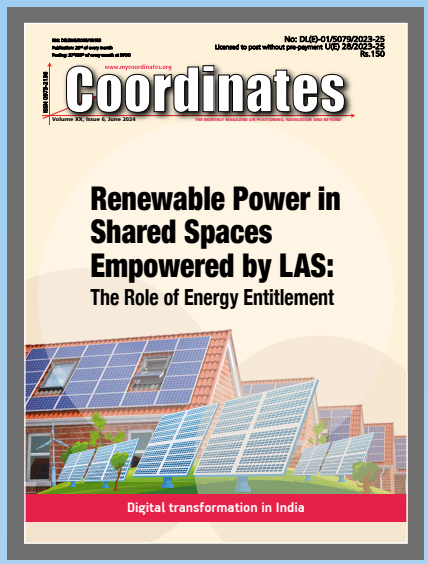
A new version of the mobile LiDAR scanner — the RD-M2 — is introduced by Topcon Positioning Systems . The scanner is part of the longstanding SmoothRide solution, which is designed to minimize road closures, shorten planning times and optimize processes when evaluating road surfaces while keeping crews safe. The scanner utilizes an integrated GNSS receiver, and the new version includes the ability to track more satellite constellations for added accuracy and options on the job site. It has also introduced the new MC-Max Paving aftermarket solution to control screed height, width and steering for integrated pavers. *topconpositioning.com*

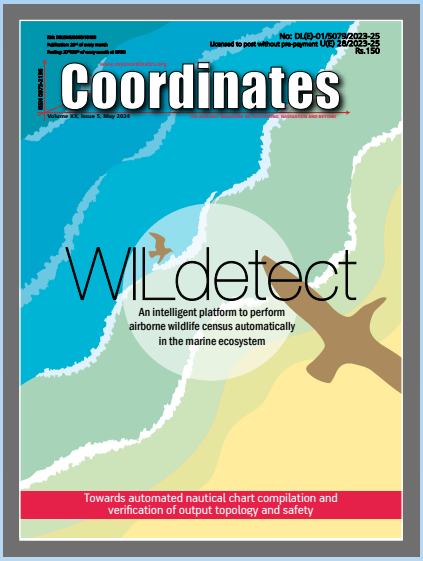
Eos Tools Pro for Android™ Now Supports Skadi Series™ GNSS Receivers

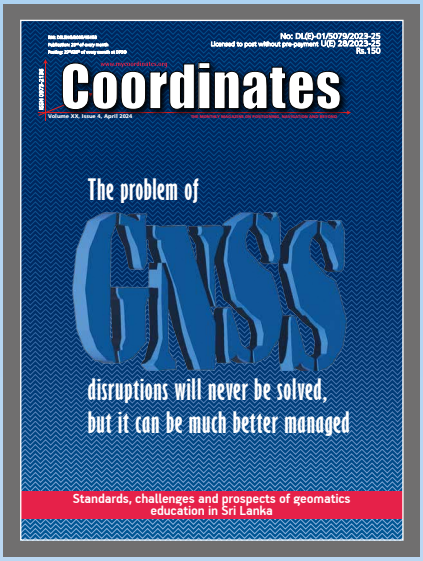
Eos Positioning Systems has announced that the Android™ version of the Eos Tools Pro™ app now fully supports the new Skadi Series™ GNSS receivers. This exciting update brings all advanced capabilities of the Skadi Series — including Skadi Tilt Compensation™ and the Skadi Smart Handle™ — to Android users. *https://eos-gnss.com*

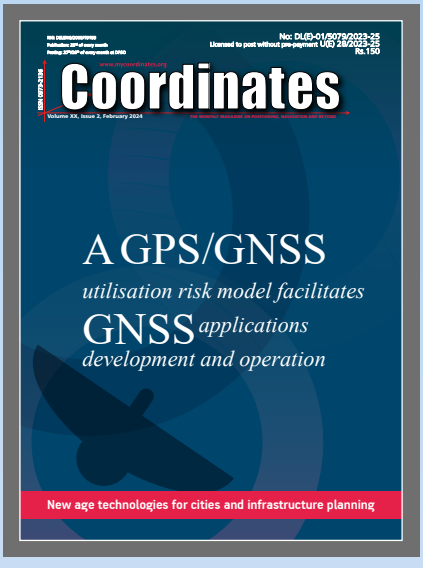


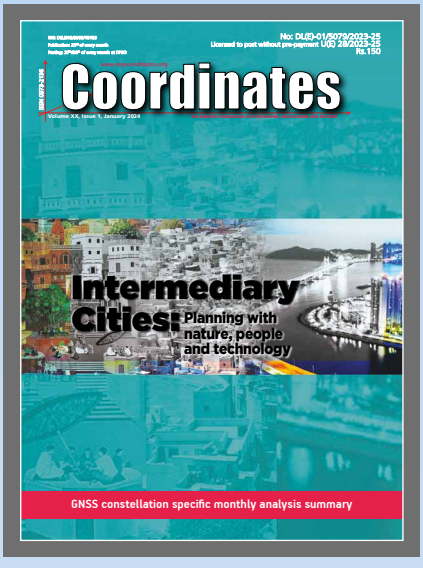


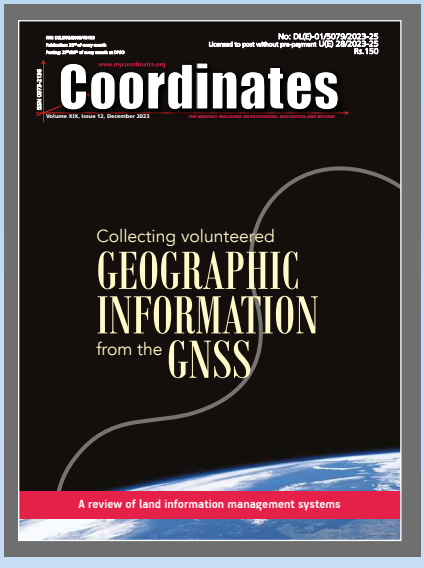












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