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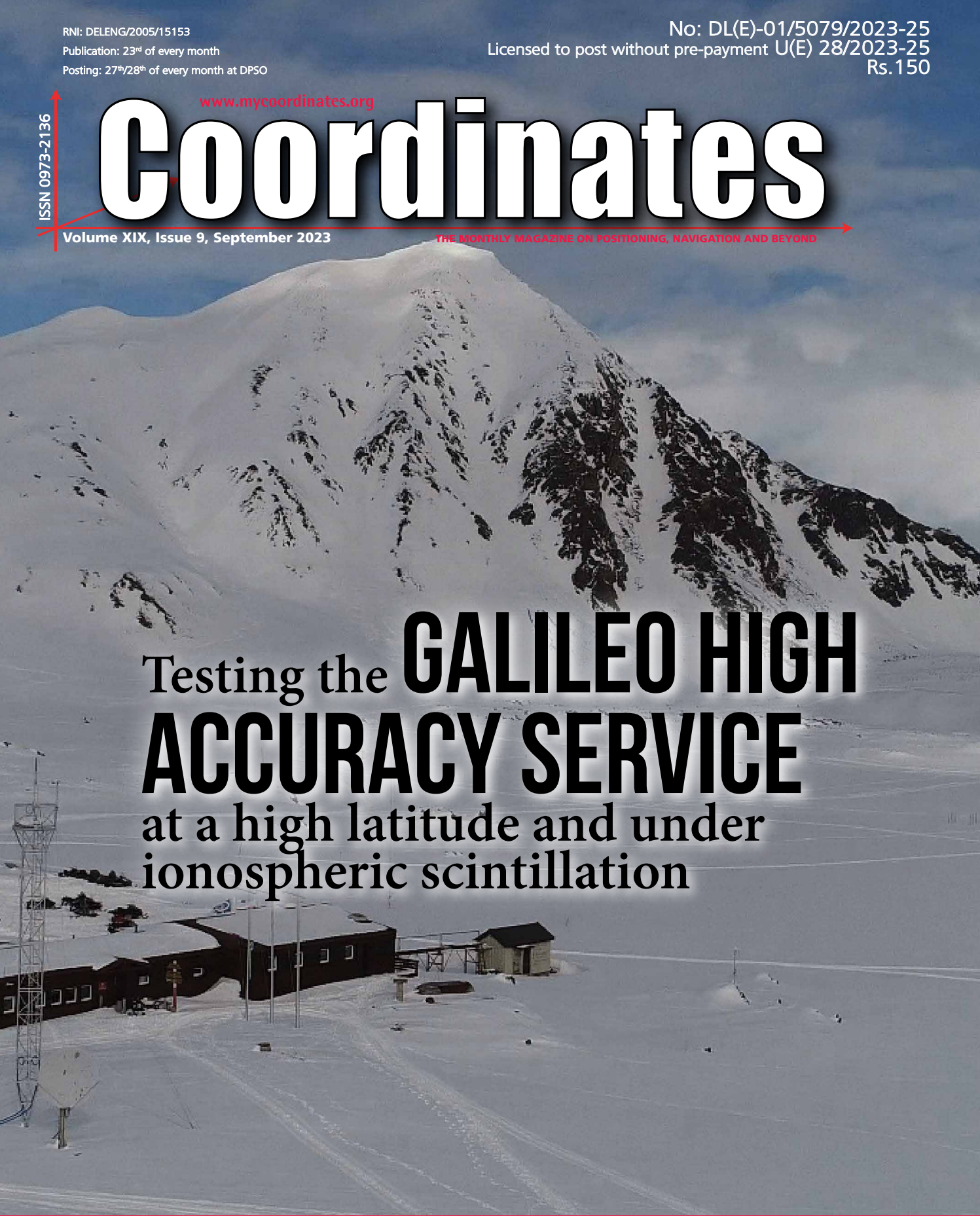
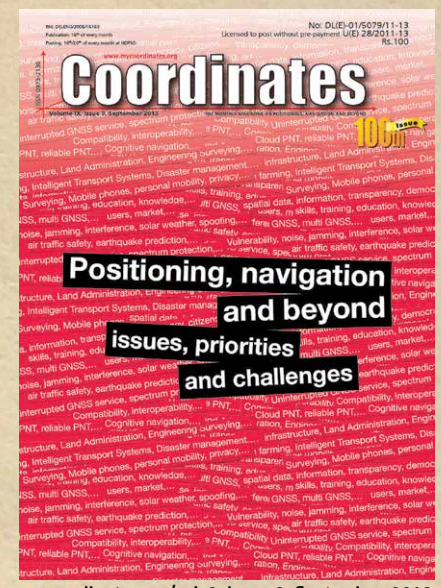
THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND



Testing the GALILEO HIGH ACCURACY SERVICE at a high latitude and under ionospheric scintillation

Land registration acceleration in Indonesia

In Coordinates



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10 years before...

Positioning, navigation and beyond

Experts share their views on issues, priorities and challenges on the occasion of 100th issue of Coordinates.

There is no doubt that the basic premise and philosophy behind Coordinates as a respected journal will endure into the future with its constant re-invention to adapt to the digital and natural environment. The challenges could be whether the digital environment has inadvertently determined that the paper copy is being transformed into the paperless copy and that such a business model will prove enduring. - **Professor George Cho AM,** University of Canberra, Australia

As Coordinates magazine enters its second hundred issues, these matters will be tested and some of them resolved. I will be paying particular attention to watching the developing use of spoofing: commandeering GNSS receivers by transmitting false signals. Once just a theoretical possibility, spoofing has now been demonstrated and effective equipment is becoming available. **- Professor David Last, Professor Emeritus** University of Bangor, Wales

The establishment of ICG recognizes that GNSS has become a truly international resource, and demonstrates the willingness of providers and users to ensure that GNSS services continue to be available in the future for the benefit of humankind. - **Sharafat Gadimova, Programme Officer, Office for Outer Space Affairs** United Nations Office at Vienna

The future of multi-GNSS is always but one satellite launch away.- **Chris Rizos, Professor** University of New South Wales, Australia

With GNSS-based equipment being such an important part of everyday life, it is astonishing that politicians and other decision makers have so little knowledge and take so little interest in this matter. **- Professor Börje Forssell Norwegian** University of Science and Technology, Norway

GNSS-related spectrum protection should become the international priority - **Dr Renato Filjar, FRIN** University of Rijeka, Croatia

Air traffic safety and earthquake prediction are key applications - **James L Farrell** VIGIL Inc., USA

Cloud PNT and the reliable PNT are the most important - **Sang Jeong Lee Professor** Head of National GNSS Research Center, Chungnam National University, South Korea

QZSS has a unique function called augmentation- **Akio Yasuda, Professor** Emeritus, Tokyo University of Marine Science and Technology, Japan

Role of the surveyor as a measurement specialist has now become blurred. - **Emeritus Professor John Hannah** School of Surveying University of Otago, New Zealand

LAS underpins efforts to realising Spatially Enabled Societies.- **Professor Abbas Rajabifard** University of Melbourne, Australia

Resilient PNT – Making way through rough waters

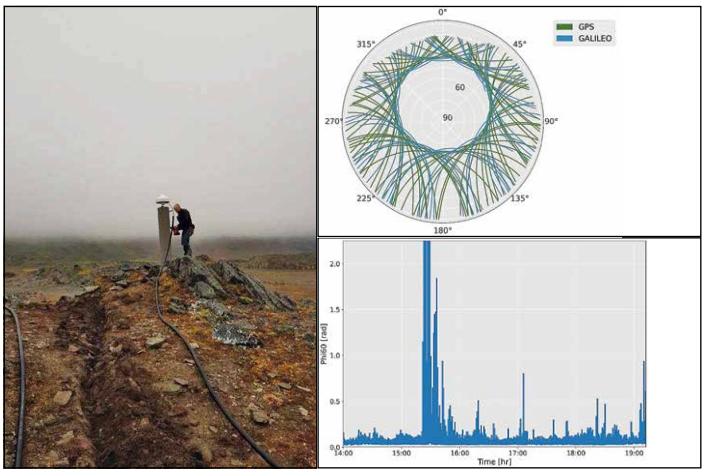
P Williams, A Grant and C Hargreaves Research and Radionavigation Directorate, General Lighthouse Authorities of the United Kingdom and Ireland

This work has shown that the Accessibility for Shipping, Efficiency Advantages and Sustainability (ACCSEAS) project has not only developed a prototype resilient PNT solution, but that it has been successfully tested and demonstrated under live conditions on a typical ship's bridge.

GALILEO-only Position Fix from India: First Experience

Anindya Bose, Saikat Das, Rakesh Malik and Debipriya Dutta Department of Physics, The University of Burdwan, Burdwan, India

Observations presented in the paper reports the rst successful Galileo-only position solution from India that indicate towards the much-awaited multi-GNSS signal availability for the Indian users increasing the possibility of redundancy and system independence. After successful GLONASS availability from India, Galileo availability would call for more detailed and long- term studies with fully operational Galileo along with GPS and GLONASS.



In this issue

Coordinates Volume 19, Issue 9, September 2023

Articles

Cover Image Credit: Hornsund – by Tomasz Wawrzyniak

About Polish Polar Station in Horsund: The Stanisław Siedlecki Polish Polar Station in Hornsund is located in the southern part of Spitsbergen island of the Svalbard archipelago in northern Norway. The station was founded in July 1957 by the Polish Academy of Sciences Expedition, and until today it is managed by the Institute of Geophysics of the Polish Academy of Sciences. The year-round Polish Polar Station carries out an extensive monitoring programme, including seismological, Earth magnetism, glaciological and oceanographic observations etc. Its location gives researchers a rare opportunity to study the arctic environment with respect to climate change. (webpage: hornsund.igf.edu.pl)

Columns

This issue has been made possible by the support and good wishes of the following individuals and companies
Althaf Azeez, Daniele Borio, Frank F K Byamugisha, Ignacio Fernandez-Hernandez, Jihye Park, Kinga Węzka, Mazliza Mohamad, Melania Susi, Nancy Dubosse, Ricco Survival Yubaidi, Saidatul Nadia Abd Aziz and Sherman Lo; SBG System, and many others.

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Editor Bal Krishna
Owner Coordinates Media Pvt Ltd (CMPL)

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

Moved on

The disasters that recently hit Morocco and Libya

Are different in nature,

But they remain same in terms of deaths and devastations.

The victims, as generally happens in such situations,

Were largely left to fend for themselves

The trauma of the affected,

Though, will take a long time to heal,

The world is quick to move on.

As the usual rituals of follow up discussions,

To make a difference continue …,

The all-pervasive indifference is perverse

And colossal too.

Bal Krishna, Editor
bal@mycoordinates.org

"A world of multi-GNSS brings faster and more innovations "

Says Sherman Lo, President of the Institute of Navigation (ION). He shares his views on a range of issues in an interview with Coordinates

Sherman Lo

Senior research engineer at the Stanford GPS Laboratory. He also is executive director of the Stanford Center for Position Navigation and Time (SCPNT) and a Stanford instructor. His research work focuses on navigation safety, security and robustness. At Stanford, he was Associate Investigator for the FAA evaluation of enhanced Loran and alternative position navigation and timing (APNT) systems for aviation. He currently leads work examining GNSS resiliency, interference and spoofing detection and mitigation. He has over 150 conference, 28 journal, 14 magazine publications and 9 issued US patents. He is the current president of the Institute of Navigation (ION)

Would you like to elaborate on some of the achievements of the ION and also the challenges before?

I feel that ION has done a lot to elevate and bring attention to navigation and its associated technologies and challenges. It has offered a great forum to communicate and publish consistent high quality work in our field.

One tremendous achievement that the ION has made is to bring together a diverse, worldwide group and form a community around that. I have made so many great colleagues and friends from around the US and the world through the ION.

The challenge facing ION is to be able to staying on top of and then fostering new important trends and developments in PNT. Another challenge is in attracting and connecting young people to the community.

Can you briefly touch upon your research priorities of Stanford Centre for Position, Navigation and Time (SCPNT)?

SCPNT is about bring together different groups from around campus and industry to work together on challenges that may cross several disciplines.

One example is to develop PNT for ocean science and protecting marine life. The challenges of operating in the ocean and on marine life is different than that encountered in other domains such as land or aviation.

In the oceans, we may not have the luxury of other communications channels, good satellite visibility or even much more than a few seconds to receive satellite signals. So we are working to develop fast offline positioning that can provide position in a few seconds without the need for external networks. In this effort, we work with the School of Humanities and Science (Department of Biology).

Another SCPNT research area examines concepts for the next generation of satellite PNT, whether that be augmented constellations, low earth orbiting satellites or secure navigation signals.

This is a world of multi-GNSS systems. What advantages do you see about this scenario?

The most evident benefit of multi-GNSS is that it bring more satellites, more availability and more choice leading to better performance. Another, less obvious benefit, is that a world of multi-GNSS brings faster and more innovations due to the competition between the different systems. So now there are systems offering high accuracy, navigation message authentication, improved signal design, and service improvements. Currently every system seeks to measure themselves against GPS which pushes them to improve performance and offer new features. In turn, this pushes GPS to incorporate new features and provide greater functionality.

Would you like to comment on GPS III and also on other existing and upcoming systems?

Not much to say except it is exciting to see these improvements to current systems as well as the upcoming systems come online. The GPS IIIA and IIIF bring new technologies and capabilities. Future satellites such as the next generation Galileo will have more flexible transmission capabilities. The Koreans are developing the Korean Positioning System (KPS) and Africa is working on their Satellite Based Augmentation System (SBAS) system. I am also excited to see the development of low earth orbiting (LEO) navigation constellations, both governmental or commercial. Not only does having LEOs bring geometry benefits, LEO satellites can be more quickly and cost effectively refreshed allowing new capabilities faster.

With increasing dependence on GNSS, how do you the perceive the threats like interference, jamming and spoofing?

Interference is an important problem. Even relative straight-forward jamming events (and even jamming exercises) has cause some disruptions to GNSS dependent operations. We've seen several interference events have some effect on air traffic - most prominent of which is in the eastern Mediterranean. The challenge is that the threat we have to deal with is evolving. There is greater ease of access to the means to implement those threats. Attacks that were hard or very expensive a decade ago are within the means of determined individuals today. The Ukraine war again showed the importance of GNSS and that denial and deception of GNSS will be used as tools. So we need to deal with this reality. On the technical side, Prof. Brad Parkinson talks about protecting, toughening and augmenting (PTA) GNSS. I agree with this concept. We need to have laws, policies, and infrastructure in place to protect GNSS. We need to develop AND implement technologies on GNSS to toughen its use, Finally we should have means of navigation that are independent of GNSS. I believe we have many of the ideas, methods and technologies (antenna technologies such as CRPA and polarization antenna, internal receiver metrics like AGC & C/No, or examining the complex ambiguity function, etc.) to really make GNSS robust against most interference threats. They may still need to mature more but they exist, are implementable and, I believe, can be cost effective. The challenge is getting all parties (decision makers, manufacturers and customers) to recognize the need to have these in place.

Given this, what's your opinion on GNSS back ups?

I worked on non-GNSS navigation systems for much of my career and it is near and dear to me. So naturally I think "back ups" are absolutely necessary - especially in critical applications. However, I don't like to think of them as back ups but rather a part of a navigation ecosystem or strategy. The community is working on hardening and improving GNSS to attacks as discussed earlier but it is may not be enough for the most determined adversaries. So I think GNSS "back ups" are absolutely vital - a prudent navigator should have multiple independent means. We should be thinking of navigation not as a single system but an ecosystem of systems which includes non GNSS means. There is a reason why we still keep traditional terrestrial navigation aids in aviation. I think the important aspect of the alternates is that we need to develop them so they provide capabilities similar to GNSS, and preferably, features that either compliment GNSS or that are not found in GNSS. This provides incentive for adoption as well as deterrence to people who want to harm GNSS and navigation.

What technology trends you envision in GNSS and what kind of innovative applications you anticipate in near future?

Application of artificial intelligence (AI) to different fields is the current hot topic and it certainly is the case with applications of it to GNSS. Related is autonomy (which has employed a lot of machine learning and AI) and navigation to support autonomy (see later answer). In the last year, we've seen a significant uptick in research and publications on lunar and cis-lunar navigation along with a further growing interest in LEO PNT. I suspect as access to space further improves and we think about landing more sophisticated or even human missions to Mars, we will need the precise navigation infrastructure there to support that.

Getting back down to earth, I see at least two trends. First, integration of even more navigation sensors (inertials, barometer, 5G, WiFi, GNSS, etc.) will improve performance and availability of accurate positioning. The trend towards greater connectivity between our vehicles may lead to more coordinated or distributed positioning where we integrate measurements from multiple distributed users (vehicles). Second, is improved processing. We have more satellites, more data,

and more user processing capabilities and so we can potentially squeeze more performance out of GNSS. Improved processing can come in many forms. In the past decade, PPP really came to the forefront in the last decade. More recently, we have seen things such as the use of factor graph optimization to improve position solutions and the development and incorporation of super correlation into consumer devices. These three are operate in different parts of the GNSS PNT processing chain - PPP is infrastructure, super correlation is receiver processing while factor graph is post receiver processing. It just goes to show that there is still innovation and possibilities in many aspects of GNSS.

How do you think the GNSS positioning technology can take the advantages of alternative positioning technologies cell phones, Bluetooth and WiFi, etc?

I am not saying any novel or new but 5G promises more dedicated positioning capabilities with better capabilities than prior generations. We can get potentially a lot more indoor navigation signal. That and more GPU power in consumer devices allow us to accurately model both direct and in direct signals to get accurate positioning. More specifically, this benefit to GNSS is in providing combined hybrid solutions which is particularly for needed urban and indoor navigation. With these data channels we can use them for improved performance (e.g, PPP corrections) or security (e.g. authentication capabilities).

How do you see the impact of Generative AI in positioning and navigation domain?

I don't have a lot of expertise in that but I'll comment on machine learning (ML). A lot of GNSS research at the university level has applied ML techniques. Through large amounts of GNSS data, it may be able to provide improvements in accuracy. That is where ML is powerful - it may be able to find relationships in the data that we may not readily identify, allowing to be leveraged for greater performance. However, working in the safety of life field also makes me cautious about its use in certain applications as sometimes it may find relationships that are not really there.

Would you like to comment on autonomous navigation?

That is a very broad question. Autonomy and autonomous navigation means different things in different eras. Today we imagine autonomous cars and how they will be able to negotiate typical human driving (A side note - they are not quite there yet - I just saw one make a stop in the middle of the street with no cars ahead of it). In past eras, it may have been a space probe or rover that has to operate without much intervention. The scope and domains of course is increasing as we get ubiquity and redundancy in navigation, it will filter into more and more categories. In the early days, it was very specialized tasks but now autonomy in more challenging or everyday tasks. But only because we have the navigation to support it. It is a feedback loop. What we provide in PNT helps drive what people think is possible with autonomy which then challenges us to create PNT systems that can achieve that dream. For example, in the original DARPA grand challenge participants relied a lot on GPS. Of course, it wasn't robust enough which drove innovations to supplement GPS with other sensors, AI, etc. to get a vehicle that could complete the challenge.

You have a long association with academia. Given the pace of technology evolution, what challenges you see before the academic community and GNSS education?

I group challenges in GNSS in three categories based on the audience.

I have many undergraduate students who are curious about navigation because of their phones and google maps. For them I think the challenge to get to generally understand which role navigation and timing technologies play in their lives and generally how these technologies work. For some it is a little like magic which is dangerous. I want them to gain basic understanding and limitations of these common navigation tools so they can use it safely. I don't want to still be reading about people blindly depending on their satnav devices leading them to danger.

For students in the field, I think the allure of the next shiny hot topic needs to be tempered with fundamental understanding. Of course ML and AI are the current hot things and they have great utility. But some things still require basic physics and math. AI while not magic is somewhat of a black box. And as we use our navigation system for critical applications, the safety of their results can't be a black box (or at least you have to have some well defined means of checking that box). So use ML but also learn, understand and use the fundamentals to complement those techniques.

For the academic community as a whole the challenge is getting people into the field. We recently had a meeting at ION GNSS 2023+ discussing this very issue. It is a complicated problem as it involves getting young people into STEM as well as letting them see that there is such a thing as a career in PNT. I certainly didn't know that this was a field when I was an undergraduate. I was fortunate to stumble into GPS while doing some flight test work in the early 90s. We can see from industry and government that there is a demand for people with PNT skills. The challenging task is attracting and training capable people into PNT. It is a great field to be in, with great people and I am certainly lucky to be working in it.

Testing the Galileo High Accuracy Service (HAS) at a high latitude and under ionospheric scintillation

In this article, the results obtained assessing the Galileo HAS performance at high latitudes in a period of intense ionospheric activity during the ongoing 25th solar cycle are presented

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Introduction

From the start of 2023, the Galileo High Accuracy Service (HAS) is officially transmitting free Galileo and GPS Precise Point Positioning (PPP) corrections worldwide through the Galileo E6B signal. In addition, HAS corrections are also disseminated via the internet for receivers which do not support E6B.

Already in 2022 valid corrections were transmitted through the Galileo E6B signal for testing purposes. Therefore, since last year an intense research activity has been conducted to assess HAS performance using the live signals/corrections showcasing the effectiveness of the service in terms of dissemination capabilities [1] quality of the corrections [2] and position performance [3-5]. The majority of the work focused on the assessment of the service under nominal conditions and at mid-latitudes. In this work, we analyse the HAS performance at high latitudes during a day characterised by intense ionospheric activity. The article is based on the results presented during the European Navigation Conference (ENC) 2023 [6].

High latitudes can represent a harsh environment for high-accuracy applications due to the reduced visibility of satellites at a high elevation and the occurrence of ionospheric scintillation that can affect the signal quality. Indeed,

when a radio wave travels through the ionosphere, the presence of irregularities can lead to signal refraction and/or diffraction. These effects can produce phase and amplitude scintillation, namely random fluctuations of the signal phase and/or amplitude. This phenomenon occurs mainly at high latitudes and in the equatorial regions. At high latitudes, the occurrence of scintillation is mainly driven by geomagnetic activity and generally amplitude scintillation is almost absent while phase scintillation can be significant. Phase scintillation can strongly degrade the quality of the signal carrier phase, leading to cycle slips, tracking loss of lock and deteriorating the carrier-based position solutions, such as the ones obtained through PPP [7].

We are currently in the 25th solar cycle, which started in 2019, and going forward the solar cycle maximum, foreseen for 2025/2026. We are also assisting to an enhancement of the ionospheric activity which is also above the forecasts [8]. Therefore, considering the solar activity increase, it is of particular interest to assess the HAS performance under scintillation.

For this purpose, data collected at the Polish Polar Station in Hornsund at the Svalbard are used. The station is equipped with an Ionospheric Scintillation Monitoring Receiver (ISMR) that allows monitoring the occurrence of scintillation events. Moreover, the receiver has been set to record the Galileo E6B navigation message in order to be able to retrieve HAS corrections from the same receiver providing the measurements for the positioning assessment. Therefore, data demodulation is performed in the same challenging conditions. While a first analysis of the HAS demodulation performance at high latitudes was performed in [9], only quiet ionospheric conditions were considered.

In this study, we present an assessment in terms of orbit/clock corrections quality and position performance.

For the analysis, the corrections were extracted using an in-house developed correction parser and then applied to the broadcast data, properly formatted and sent as input to a PPP algorithm to assess the positioning performance. The article is structured as follows. At first, we describe the methodology adopted to demodulate and apply HAS corrections to broadcast data in order to carry out an HAS-based PPP processing. Then the experimental setup is introduced. Experimental results of the PPP analysis are then described. Finally, the conclusions are presented.

Decoding and applying HAS corrections

The HAS corrections, which are transmitted through the live E6B signal, are encoded through a high parity vertical Reed Solomon (RS) code. The HAS message pages are vertically stacked and multiplied by the Reed-Solomon encoding matrix in order to generate a redundant set of pages. Then, each Galileo satellite broadcasts a subset of such pages, which are currently stored in binary format by receivers supporting E6B processing. In order to retrieve the HAS corrections

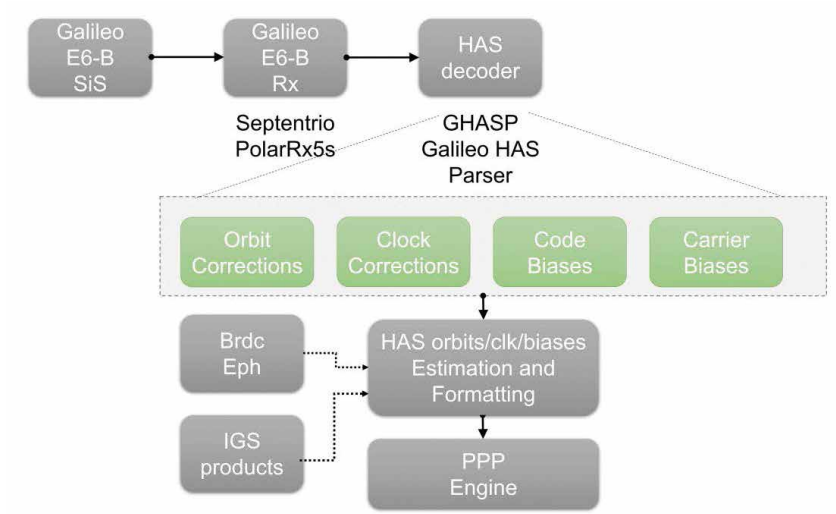

Figure 1: Schematic rrepresentation of the process adopted for decoding and applying HAS corrections (extracted from [6])

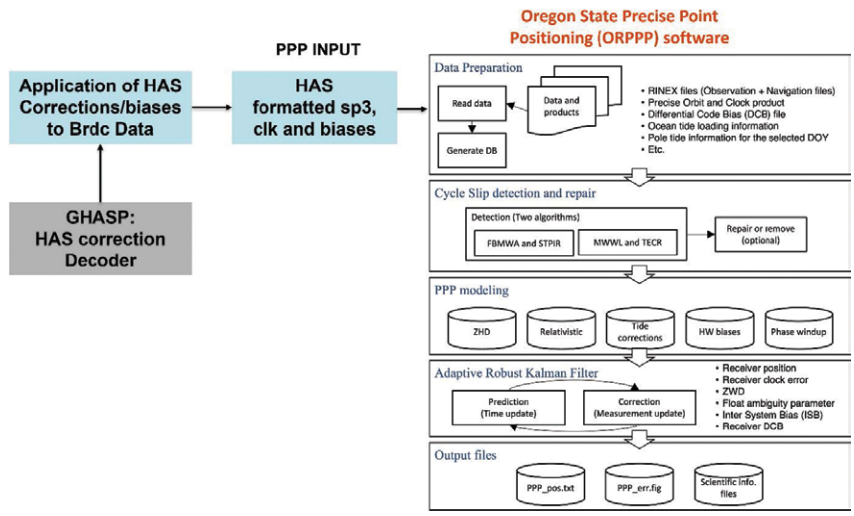

Figure 2: Scheme of the ORPPP software taking as input the HAS formatted sp3, clock and bias files

from the received binary pages, a decoder has been developed in Python [10]. The decoder is now provided as open-source tool and available on github (https://github.com/borioda/HAS-decoding). The decoder, denoted as Galileo HAS Parser (GHASP), is able to process binary files from different receiver manufacturers, such as Septentrio, Novatel and Javad. The output of GHASP is a set of Comma-Separated Values (CSV) files containing HAS orbit and clock corrections, code and phase biases. The tool can be used through a user-friendly Graphical User Interface (GUI), which offers plotting options as well. In Figure 1, the full processing chain adopted in this work is illustrated: from the reception of the Galileo E6B signal to the demodulation and application of HAS corrections.

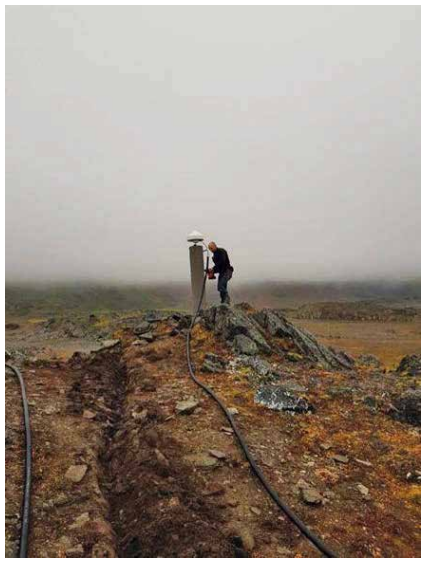

Figure 3: A researcher from the Warsaw University of Technology installing the antenna of the WUTH reference station

The corrections have been applied to the broadcast data as indicated in [11]. For this purpose, a dedicated script was developed to apply the HAS corrections to the broadcast data and generate Standard Product 3 (SP3) files that can be easily processed by any commercial and open-source PPP software. In this study, the Oregon State University PPP (ORPPP) engine, developed by the Oregon State University, was used.

The ORPPP software exploits ionosphere-free linear combinations of GNSS measurements and it estimates the unknown vector composed of the position, clock error, zenith wet delay, float ambiguity parameter, differential code biases, and intersystem bias. An adaptive robust Kalman Filter (KF) is used to estimate the unknown parameters [12]. Tidal corrections, phase wind-up, and relativistic corrections are applied as well.

A schematic representation of the processing adopted by ORPPP engine is provided in Figure 2, which also shows the retrieval and integration of the corrections extracted by the GHASP decoder.

Figure 4: The Polish Polar Station seen from a drone (picture by Wojciech Flak)

Figure 5: Map view of the WUTH location

Experimental set-up

The data were collected by the WUTH GNSS reference station located in the Polish Polar Station Hornsund (77.00°N, 15.54°E) on Spitsbergen in the Norwegian Svalbard archipelago. Figure 3 shows the the antenna location while an aerial view of the reference station location is provided in Figure 4. Figure 5 shows the map of the Svalbard archipelago indicating the location of the station with the related coordinates.

The WUTH GNSS station is operated by the Warsaw University of Technology and plays an important role in interdisciplinary research like analysis of GNSS signals at high latitudes, monitoring of geodynamic movements (isostatic movements of the Earth's crust), Earth atmosphere monitoring and indirect climate change monitoring (glacier movement, glacier mass balance). Furthermore, the WUTH station is included in international GNSS networks such as the International GNSS Service (IGS), the European Reference Frame (EUREF) Permanent GNSS Network (EPN) and European Plate Observing System (EUPOS).

The station is equipped with a high-precision reference Septentrio receiver, a PolaRx5S, connected to a SEPCHOKE_B3E6–SPKE choke-ring antenna. The receiver is set to track the full spectrum of current GNSS signals, and it is logging high-frequency (50 Hz) measurements for ionospheric analysis. Indeed, the receiver is an ISMR embedding an ultra-low phase noise Oven Controlled Crystal Oscillator (OCXO). The use of an OCXO ensures that the oscillator phase noise does not exceed the effects of low-level phase scintillation.

The high rate of data sampling and the low noise clock allows for monitoring of the amplitude and phase fluctuations due to ionospheric scintillation. Moreover, for this research, the receiver has been set to record the E6B Galileo navigation messages, in order to be able to demodulate the HAS corrections from the same receiver providing the observations and, consequently, under the same harsh conditions.

Data

The data analysed in this paper were collected from the WUTH station on the 4th of September 2022 (DOY 247). The day

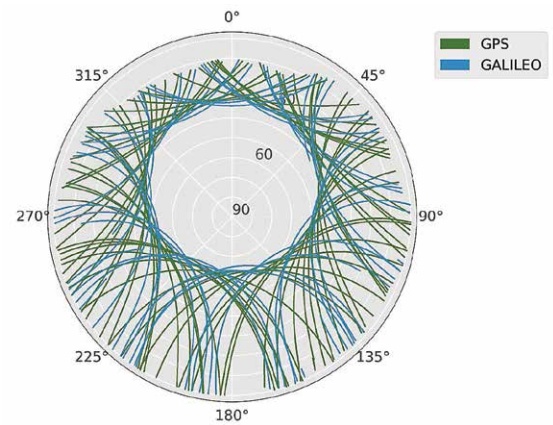

Figure 6: Skyplot seen from the WUTH reference station during the whole day of the 4th September 2022

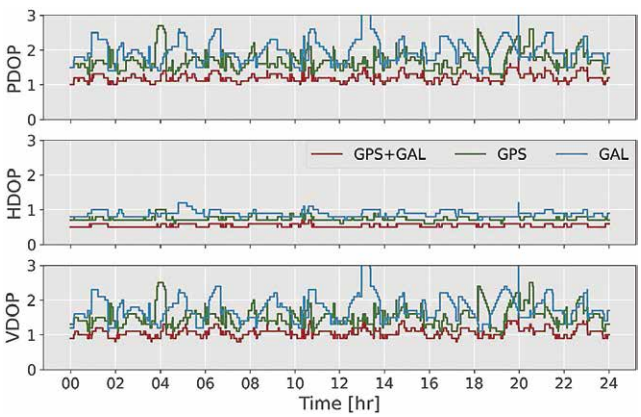

Figure 7: PDOP, HDOP and VDOP evaluated for the WUTH during the full day of the 4th September 2022

was selected for the occurrence of very strong ionospheric activity. In Figure 7 the sky plot observed from the WUTH station for the full selected day is reported. It can be observed that the maximum satellite elevation is around 60 degrees for the entire day. Despite the reduced maximum satellite elevation, good PDOP/HDOP and VDOP values are recorded for the combined GPS + Galileo case (i.e. below 1.5), as shown in Figure 7. In Figure 8 , the level of scintillation is shown through the Phi60 scintillation index reported by the ISMR during a period of the day with strong ionospheric event. As the name suggests, the Phi60 estimates the level scintillation by computing the standard deviation of the detrended carrier phase measurement, averaged over one minute of data [13].

For the analysis, we focused on the interval between 15:17 and 19:00 that was affected by very strong phase scintillation. More specifically, we can observe a very strong phase scintillation peak around 15:20. Moreover, scintillation of weak /moderate intensity is present until the end of the observation period. In the literature slightly different Phi60 thresholds are used to classify different levels of phase scintillation, for example considering different locations. Based on [14] and [15] the values of Phi60 corresponding to different levels of scintillation are reported in Table 1.

Results

The quality of the HAS orbits and clocks was assessed by comparing them with the final precise products downloaded from the Center for Orbit Determination in Europe (CODE). Summary statistics (95th percentile) of the residual errors observed are provided in Table 2 for Galileo and GPS.

The corrections, after proper formatting were then used as input for the PPP processing. PPP processing was set to start just before the very strong scintillation event discussed above. The GPS L1C/A-L2 P and Galileo E1-E5b configuration was selected for the processing. Moreover, the PPP has been configured in static mode. The horizontal and vertical position errors are shown in Figure 9. With respect to the results presented at ENC, in this

Table 1: Phase Scintillation levels adapted by [12] and [13]

Phase Scintillation Level	Phi60 range (radians)
Weak	0.25 <Phi60< 0.4
Moderate	0.4 <Phi60< 0.6
Strong	0.6 <Phi60< 0.8
Very Strong	Phi60> 0.8

Table 2: Orbital/Clock errors (95th percentile)

Constellation	Galileo	GPS
3D Orbital Error	10.5 cm	11 cm
Clock Error	15 cm	11 cm

article, we assess the PPP algorithm by starting the processing even closer to the maximum scintillation peak to further challenge the PPP engine. The processing started at 15:17 only almost 3 minutes before the maximum scintillation peak that occurred at about 15:20. This represents a very challenging and extreme scenario since the PPP convergence starts in the middle of the very strong scintillation period. As expected, this choice impacts the convergence time which is of about 20 minutes. Moreover, it should be underlined that no HAS phase biases have been used, since they were not available yet at the time of the data collection. The engine was set to provide a float PPP solution, so no ambiguity resolution was performed to speed up the convergence. After the convergence the positioning accuracy is well below the maximum target values of 20 and 40 centimetres for the horizontal and vertical cases, respectively.

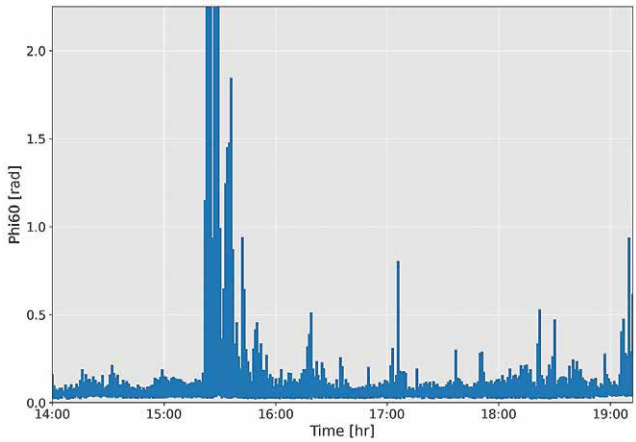

Figure 8: Phi60 recorded for all satellites in view on the L1 band (adapted from [6])

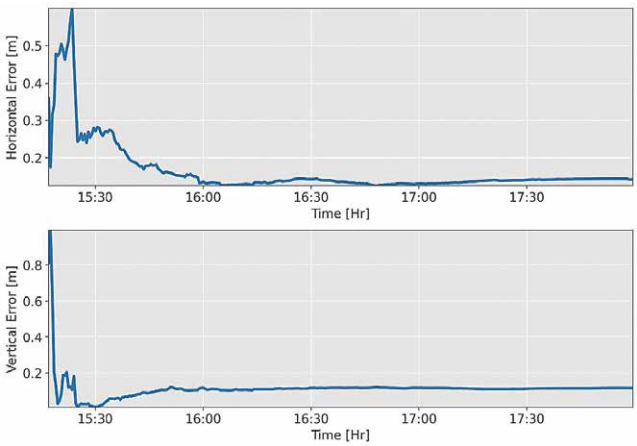

Figure 9: Horizontal and vertical errors under ionospheric scintillation

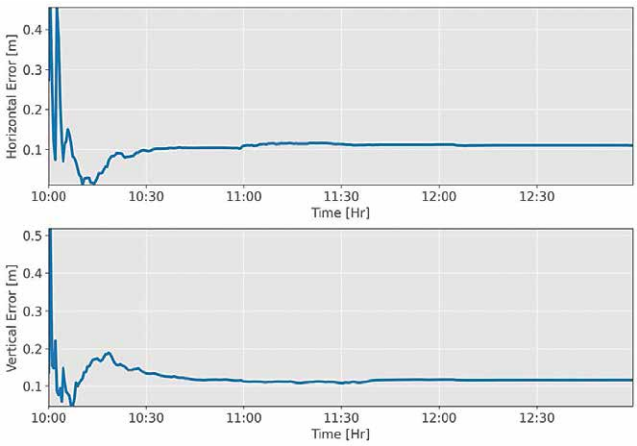

Figure 10: Horizontal and vertical errors under quiet ionospheric conditions

The error is stable below the target values even if moderate/strong scintillation is still present until the end of the observation period. For comparison, the horizontal and vertical errors are reported in Figure 10 for a period of quiet ionospheric conditions during the same testing day. In this case, the target accuracy is achieved after only 230 seconds (less than four minutes). After convergence, the positioning accuracy is also in this case well below the maximum target values.

Conclusions

Phase scintillation can strongly affect the quality of the signal carrier phase which is crucial for PPP positioning algorithms used by HAS users. In this article, we presented the results obtained assessing the Galileo HAS performance at high latitudes in a period of intense ionospheric activity during the ongoing 25th solar cycle. We analysed a particular day (4th September 2022) when very strong phase scintillation was recorded, and tested PPP convergence using Galileo HAS data applied to GPS and Galileo. The PPP processing was started in the middle of a very strong scintillation event, only few minutes before the maximum scintillation peak. This represents a very extreme event, that as expected, leaded to an increase of the convergence

High latitudes can represent a harsh environment for high-accuracy applications due to the reduced visibility of satellites at a high elevation and the occurrence of ionospheric scintillation that can affect the signal quality. Indeed, when a radio wave travels through the ionosphere, the presence of irregularities can lead to signal refraction and/or diffraction

time. Despite the very strong phase scintillation event, HAS achieved the target position performance after convergence in a stable way even if scintillation persisted until the end of the observation period. Further work may include a statistical characterization of the convergence time during scintillation (of which only one occurrence is presented here), and using more recent HAS data, particularly after service declaration in January 2023, from which a slightly higher performance is expected.

Acknowledgement

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Reference

[1] Susi M., Borio D., Gioia C. and Fernandez-Hernandez I. (2022) "Analysis of Different Galileo High Accuracy Service (HAS) Dissemination Options Using Live Signals and Real Corrections," Proceedings of the Navitec Conference, April ESA/ESTEC, Noordwijk, The Netherlands

[2] Martini I., Susi M., Paonni M., Sgammini M. and Fernandez-Hernandez I. (2022), "Satellite Anomaly Detection with PPP Corrections: A Case Study with Galileo's High Accuracy Service," Proceedings of the International Technical Meeting of The Institute of Navigation, Long Beach, California, January 2022, pp. 1246-1262.

[3] Naciri N., Yi D., Bisnath S., de Blas J. and Capua R. (2023) "Assessment of Galileo High Accuracy Service (HAS) test signals and preliminary positioning performance". GPS Solutions Vol. 27, No. 73. https://doi.org/10.1007/s10291-023-01410-y

[4] Pintor P., Gonzalez E., Senado A., Bohlig P., Sperl A., Henkel P., Simón J., Hernandez C., de Blas J. and Vazquez J., (2022) "Galileo High Accuracy Service (HAS) Algorithm and Receiver Development and Testing," in Proceedings of the 35th International Technical Meeting of the satellite division of the Institute of Navigation (ION GNSS+ 2022), Denver, Colorado, September 2022, pp. 836-851.

[5] Fernandez-Hernandez I., Chamorro-Moreno A., Cancela-Diaz S., Calle-Calle J. D., Zoccarato P., Blonski D., Senni T., de Blas J., Hernandez C., Simón J. and Mozo A. (2022) "Galileo High Accuracy Service: Initial Definition and Performance" GPS Solutions, 2022, Vol. 26, No. 65. https://doi.org/10.1007/s10291-022-01247-x

[6] Susi M., Borio D., Azeez A., Park J., Wezka K. and Fernandez-Hernandez I. (2023), "Assessing the High Accuracy Service at High Latitudes", Proc. of the European Navigation Conference (ENC), May-June, Noordwijk, The Netherlands, MDPI Engineering Proceedings

[7] Aquino M., Dodson, A. Souter, J. Moore, T. (2007) "Ionospheric Scintillation Effects on GPS Carrier Phase Positioning Accuracy at Auroral and Sub-auroral Latitudes". In: Tregoning, P., Rizos, C. (eds) Dynamic Planet. International Association of Geodesy Symposia, vol 130. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-49350-1_121

[8] https://www.swpc.noaa.gov/products/solar-cycle-progression

[9] Susi M., Borio, D., Gioia, C., Brunes M. T., Dahnn M., Grinde G., Rost C. (2021) "Assessment of Galileo E6-B Data Demodulation Performance at High Latitudes: A Norwegian Vessel Case Study," Remote Sensing 2021, Vol. 13, pp. 46-69, https://doi.org/10.3390/rs13224669

[10] Borio D., Susi M., Gioia C. (2023) "GHASP: A Galileo HAS Parser", GPS Solutions, GPS Toolbox, accepted for publications, July 2023

[11] European Union (2022) Galileo high accuracy service signal-in-space interface control document (HAS SIS ICD), Issue 1.0, May 2022. https://www.gsc-europa.eu/sites/default/files/sites/all/files/Galileo_HAS_SIS_ICD_v1.0.pdf

[12] Guo F. and Zhang X. "Adaptive robust Kalman filtering for precise point positioning", Measurement Science and Technol-ogy, 2014, Vol. 25, No. 10, pp. 1-8, https://doi.org/10.1088/0957-0233/25/10/105011

[13] Van Dierendonck A. J. "Eye on the Ionosphere: Measuring Ionospheric Scintillation Effects from GPS Signals". GPS Solutions 1999 Vol. 2, No. 4, pp. 60– 63. https://doi.org/10.1007/PL00012769

[14] European Union. Galileo High Accuracy Service Signal-in-Space Interface Control Document (HAS SIS ICD). May 2022. Available online: https://www.gsc-europa.eu/sites/default/files/sites/all/files/Galileo_HAS_SIS_ICD_v1.0.pdf

[15] Dubei S., Wahi R., Mingkhwan E. and Gwal, A.. (2005) "Study of amplitude and phase scintillation at GPS frequency." Indian Journal of Radio and Space Physics. 34.

[16] Tiwari R., Skone S., Tiwari S., and Strangeways, H.J. "WBMod assisted PLL GPS software receiver for mitigating scintillation effects in high latitude region," 2011 URSI General Assembly and Scientific Symposium, Istanbul, Turkey, 2011, pp. 1-4,

Land registration acceleration in Indonesia: Lessons learnt from land registration system in Malaysia

The results conclude that both Indonesia and Malaysia still face land registration issues

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Abstract

Every country has its land policy system. Indonesia employs deeds registration which refers to the Basic Agrarian Law (BAL) and Malaysia uses a title registration system called the National Land Code (NLC). Indonesia has yet to complete its land registration mandate throughout the country since the mandate was officially introduced in the BAL 1960. While Malaysia has adopted a Torrens system concerning land matters, recognising that land registration is everything. The first part of the paper focuses on beneficial ownership, confidential land ownership data, identifying land registration constraints and strengthening land administration abilities, while the second part focuses on land registration as a legal instrument and land rights ownership affirmation. The main question in this research is to analyse whether the quantity, quality and legal certainty guarantees of land registration are strongly influenced by a well-organised land registration system. Indonesia and Malaysia are still addressing weaknesses in their respective land registration systems based on issues. There is a need for improvement of roles from two main stakeholders, namely the government's role in streamlining administration and the role of community participation in supporting successful land registration. This paper will also provide recommendations for academicians, government/institutional leaders, and legislators to assess and continuously strengthen the BAL as the fundamental principle of land law in Indonesia, especially in its land registration system and legal certainty over land registration.

Introduction

Land is one of the basic human needs to live. Human activities in daily life, directly or indirectly cannot be separated from the need for land. According to 2021 statistics by Worldometer, the population of Indonesia and Malaysia is 275,986,047 and 32,720,404, respectively. In developing countries throughout the world, population growth and urbanization bring about an increasing demand for affordable and stable housing, especially in Indonesia and Malaysia. Land ownership is important, considering it is one of the primary human needs for shelter and livelihood. Land ownership will be complete with the process of recognition of ownership rights recognised by the state.

After Indonesia's independence in 1945, land registration was mandated after the enactment of Act No. 5 of 1960 concerning Basic Agrarian Law (BAL). The objective of the land registration system, as stipulated in the BAL is to provide legal certainty in the agrarian sector (Palilingan et al., 2019). Since

the mandate for land registration in the BAL 60 years ago until the enactment of the Government Regulation No. 24 of 1997 as the implementing regulation of BAL, if land registration has yet to use advanced technology to accelerate implementation, it will take at least 100 years to fulfil and complete the land registration mandate (Rahmi, 2019). To date, only 73 million land parcels in Indonesia have been registered and certified, out of an estimated total of 126 million plots. The Government targets that in 2025 all land parcels in Indonesia will have been registered and certified. Of course, land registration is not only aimed at accelerating the number of land registration parcels. but that the good quality land registration system will provide legal certainty for rights holders and third parties.

In order to ensure legal certainty, land registry operations are carried out in all regions of the Republic of Indonesia, according to the requirements set out in the Government Regulation No. 24 of 1997 namely: (1) collecting and processing physical data (including measuring and mapping, determining the boundaries of land parcels, making registration maps, making land registries and producing measuring letters), (2) proofing of rights and bookkeeping (including bookkeeping of rights and issuing certificates). It is also mentioned in Article 19 clause 1 of the BAL, which reads, "To ensure legal stability, the Government of the Republic of Indonesia hereby shall conduct land registry in the territories of the Republic of Indonesia." Land registration as referred to in this research includes (1) "First- time land registration", namely land registration for land parcels that have not been registered, and (2) land registration for land parcels for the purpose of transfer or any dealings.

Land registration is an official recording of legally recognized interest in land. There is no universal system of land registration but it is generally accepted that there are two different approaches, deeds registration or title registration (World Bank Group, 2017). While in Malaysia, since independence in 1957, all statutes concerning land have been replaced by the Torrens system. This conversion followed similar developments in Singapore in 1956, Penang in 1966, Melaka in 1966 and the enforcement of the 1965 National Land Code (Johari et al., 2014). In the Malay states, personal possession of land is only available through a grant from the government and this is achieved through registration. Therefore, Indonesia and Malaysia, through the BAL and NLC, respectively believe and recognise that land registration is quite important.

Indonesia and Malaysia are still facing issues especially concerning land registration. Based on World Bank data on land dispute resolution index measuring the accessibility of dispute, the scope of responsibility of individuals or agents that report land transactions is ranged between 0 and 8. Indonesia was ranged at 3 while Malaysia was ranged at 4.5 between 2019 and 2020. The determinants of the measurement entail the following eight elements: (1) whether it is mandatory for the law to ascertain that the registration of whole property sale transactions should be applied at the immovable property registry so that they are legally enforceable to third parties, (2) whether there is a guarantee to determine the formal system of registered immovable property,

(3) whether a particular compensation (finding a settlement to a legal argument without involving the court) is provided to replace the losses faced by parties putting their trust in property transactions grounded on misinformation asserted by the immovable property registry, (4) whether verifying the legality of documents (sales, transfer, including deeds) in a property transaction is required by the legal system, (5) whether verifying the identities of parties to a property transaction should be implemented by the legal system, (6) whether a national database is accessible for verifying the validity of identity documents, the length of time that should be taken to arrive at a decision made by the court hearing a case for the first time (an appeal is not required) in a land dispute involving two local businesses concerning tenure rights worth 50 times per capita income in which the location is in an enormous business city, and (8) whether statistics concerning land disputes in the first instance are provided openly (The World Bank, 2020).

This study uses a causal-comparative method. Causal-comparative research is a study in which the researcher tries to determine the causes or reasons for differences. The basic design for causal-comparative research involves the selection of two distinct groups (Sumanto, 2020). The long historical lines of Indonesia and Malaysia differ in terms of land registration and dispute resolution. Indonesia and Malaysia were selected as case studies of this research. This study is aimed at analysing and identifying the differences between Indonesia and Malaysia concerning land registration systems. Identifying the land registration system in Indonesia and Malaysia will provide an overview of what has been done and what is required to improve land registration systems; to serve as lessons learnt in accelerating land registration in Indonesia, and to furnish and support recommendations for the government to strengthen future legislation.

Identifying land registration constraints

Land registration at the land office serves to guarantee legal land possession, and to safeguard families and the welfare of future generations (Rahmi, 2019). It is expected that land registration may lead to a positive impact on the government, landowners, and third parties. Land registration procedures are important because it supports the management of sustainable development. This development has been conducted as an outcome of deliberate action by the community to achieve a better life (Ahyani, 2017). When the purpose of land registration is achieved, the country can enjoy fairness and prosperity. Rapid development and various requirements for securing proprietor interests have placed tremendous

demands on land administration. The lack of speed in services and the lengthy process in securing property due to bureaucracy have also triggered the loss of investment opportunities for the country (Zulkifli et al., 2015).

One of the selected sample cases in Indonesia by Mahuli (2017) found that the constraints faced in the implementation of land registration at the National Land Office / 'Badan Pertanahan Nasional' (BPN) of Medan city, Indonesia were as follows:

1. Limited equipment and human resources
   BPN of Medan city is short of human resources to handle the high number of land registration applicants. Besides, it also lacks land survey equipment.
2. Poor legal awareness by the community
   Due to poor awareness by the community, many lands remain unregistered. To date, most people assume that registered land is referred to as land obtained via any letter issued by any government institution.
3. Inability to present adjacent neighbours and land boundaries Applicants must be present at the land being surveyed. The majority of the applicants, however, could not take part in a series of survey activities. Based on Article 18 of Government Regulation No. 24 of 1997, applicants must be accompanied by their adjacent neighbours to convey or assert their agreement to land boundaries.
4. Use of illegal negotiators
   The illegal broker only files for the land registry process and will not engage in the necessary follow-up agreements. Through the report, it can be inferred that the unauthorized negotiator will not be liable for any problems or shortfall before issuance of the land certificate.
5. People's ignorance of PRONA
   PRONA (The National Agrarian Operation) is one of the Indonesian Government's attempts to boost the wealth of the people. PRONA is not meant to replace the process of land title registry governed by the Government Regulation No. 24 of 1997. PRONA is a form of legalizing asset activity and, it is essentially a land administrative process which includes: adjudication, land registration, and publishing land certificates which is held on a large scale. The PRONA project is temporary to begin with, however, many people are unaware of the project.
6. Remote location for land administration
   Medan is a large city with a land area of 265 km², and its neighbourhood areas are far removed from the Medan City National Land Office. This situation has contributed to a lack of commitment to register lands at the National Land Office/ BPN.

The definition of land registration according to Article 1 clause 1 of Government Regulation No. 24 of 1997 is a set of operations conducted by the government on a constant, continuous and routine basis, including bookkeeping, compilation, preservation, display and processing of juridical and physical records, in the form of lists and maps concerning parcels of land and units of flats, and the awarding of certificates of proof for plots of land rights on which there are rights and ownership rights over flats, and those rights that burden it. The land registration system in Indonesia seems to experience dualism in the recognition of land ownership rights. There is a recognition of the owner based on the recognition of the local community. However, there is also the recognition based on a certificate as proof of registration of land rights. The recognition of both has led to a dilemma, which has triggered debates on justice and legal certainty issues. The recognition of land rights based on certificates is less legitimate from the community's point of view. Debates on recognition (legitimacy) of land has affected justice and legal certainty over land rights (Sinaga et al., 2016).

Meanwhile in Malaysia, according to Salleh et al. (2017) the issues or weaknesses in law that arise are related to land administration, which include corruption in land administration, squatters, and the validity of temporary occupation licenses (TOLs) of land. Research by Samsudin (2011) in her article has revealed that all responsibilities concerning land is under the same administration especially in Sabah and Sarawak. Land possession, land use and land administration are all under the same administration. Each state's administrative duties are carried out by the same person, namely, the Director of Land and Survey. This framework offers greater accountability and helps speed up matters relating to property, as all operations take place under the same administrative responsibility. However, in Peninsular Malaysia, public survey, land use planning, and land registry are not combined. Land management is governed by the District Land Office and organized by the Office of Land and Mining. Land management is handled by the Department of Survey and Mapping Malaysia (DSMM). The valuation and property services department is under the Federal Ministry of Finance while the town and country planning (T&CP) department is under the Ministry of Housing and Local Government. There is a need for wise arrangements regarding the authority between each department in order to provide convenience and not unnecessary bureaucracy.

Land registration, if examined more closely, contains various aspects; among others, economic and social aspects. The slow and unresolved land registration process can also lead to new issues such as unlawful occupation/squatters. Under the National Land Code (NLC), occupying lands belonging to others including government land is an offence (Salleh et al., 2017). The law in Malaysia stipulates squatters as trespassers who occupy land unlawfully. They do not possess any legal rights. Although some squatters understand the laws concerning squatting, they do not take it seriously (Ibrahim et al., 2012).

Illegal occupation of land rights can be in various forms. It can even be followed by certificate duplication and/or certificate forgery, or other combinations of actions known as fraud. Fraud in the title register often creates concern for house owners as

it is a breach of property rights (Abdullah et al., 2017). Among the most common occurrences is the falsification of: original court order, identification card, issue document of title (IDT), power of attorney, signature, and transfer form (Form 14A), besides impersonating as an estate agent or as an occupant. Abdullah (2017) in her article has concluded that the number of cases concerning fraud involving title registration in Malaysia is not showing any decline. She surmises that it sufficiently proves that the title registration system in Malaysia is susceptible to fraud. Apart from the inherent weaknesses of land statutes, enhanced effort should be undertaken to ensure that the registration system is fraud-proof, reliable, safe, and secure. System security should be improved to diminish fraud. Audits should be conducted more frequently to detect any system abnormalities. Access control to the system should also be tightly regulated. Special officers should be allowed to conduct specific tasks in the system; involving several officers is a good way to prevent insider fraud.

Research conducted by Harun (2012) has also provided recommendations to minimize fraud, such as expanding the implementation of the biometric system in matters concerning transfer of land rights, improving security with electronic notifications/notices to land owners, and the need to clarify definitions and elements that fulfil fraud in the National Land Code (NLC). This is also confirmed by Harun and Hassim (2015) that the NLC as the highest law in Peninsular Malaysia regarding land registration matters need to ensure justice for concerned parties, especially in order to defend and maintain the trust of bona fide buyers or good faith in the purchase of land.

Beneficial owner vs confidential data of land ownership

Proof of ownership is the main thing in formal and material evidence. If a problem occurs, this evidence shall guarantee legal certainty in the future. Proof of formal and material ownership of land shall be accountable and in accordance with factual data. The Torrens system in Malaysia is a system of land ownership that ensures that the person recorded as the land owner is the true owner. The register is conclusive evidence that the person named therein, as the proprietor of an interest in the land, is the legal owner of that interest (Zulkifli et al., 2015). Thus, there is no evasion of law affecting third parties specifically or the country in general since such practice can cause losses due to invalid or non-transparent information of land rights.

Land registration requires caution to prevent such malpractices and to create systematic land data for the benefit of the country's future development. So far, two issues need to be more widely discussed in Indonesia and Malaysia, namely issues related to beneficial owners and land ownership data protection. These two issues are contradictory because the beneficial owner applies the principle of transparency while protecting data concerns privacy. According to Zulkifli et al. (2015), Malaysia has a different practice of using the cadastre, which records property boundaries under the authority of the Federal Ministry. The Federal Ministry also sets its own laws while the extent of the state's reliance upon the Federal Ministry is highly unpredictable. This has resulted in separate investigations being made about the right to possession and right to use, which has led to discrepancies and overlaps in policies. Thus, it is recommended that data sharing amongst the different agencies is crucial.

A typical use of the word beneficial ownership is in relation to property. These rules are imposed in Malaysia as a way to regulate land matters. In Malaysia, the definition of beneficial ownership in the Securities Industry Act of 1991 is perhaps the most useful guide. According to Nik Abdul Ghani (2018) it contains the following:

> Beneficial owner in relation to deposited securities who is the person who is entitled to all rights, benefits, powers and privileges and is subject to all liabilities, duties and obligations in respect of, or arising from, the deposited securities, and does not include a nominee of any description.

It is readily evident that the advantageous owner is the rightful owner and has both the title and other true owner rights. Furthermore, if a conflict between the legal and the beneficial owner arises, the courts' ruling in deciding the true owner will go to the beneficial owner, since the legal owner is simply considered a guardian, holding the land for the benefit of the beneficial owner (Nik Abdul Ghani, 2018).

There are many court decisions in Malaysia applying the principle of equity in recognising beneficial or equitable ownership. This can be seen in *Kersah La'usin v. Sikin Menan* [1966], 2 MLJ 22; *Munah v. Fatimah* [1972], 2 MLJ 158. In *Othman v. Mek* [1972], 2 MLJ 158, the Supreme Court ruled that upon payment of the price and delivery of ownership of the land, the owner had gained full title to the land. In relation to the vendor, who had the legitimate right to obtain full title to the property transferred to him, the donor's right to transfer title to the land was untouched by any restriction period or laches (Nik Abdul Ghani, 2018).

Beneficial ownership requires the willingness of the government to implement transparency which concerns the achievement of good governance. Beneficial ownership can detect land ownership that is unqualified and does not meet the necessary requirements. In observing the regulation of land ownership in Indonesia, the principle is still a matter of pros and cons, namely the interpretation of the State's Right to Control / '*Hak Menguasai Negara'*. The Constitutional Court in its several decisions, namely decision No. 36 / PUU-X / 2012, decision No. 058-059-060-063 / PUU-II / 2004, and decision No. 001-021-022 / PUU-1 / 2003 have granted the State's Right to Control / *'Hak Menguasai Negara'* towards the earth, water and

natural resources and requires the state to carry out limited to 5 (five) functions, namely, the policymaking function, management function, regulatory function, management function, and control function. The Constitution and the BAL mandate the state to control land, but not to own land. Article 2 clause (1) of the BAL mentions that all of the earth, space, water and natural resources managed by the state are protected at the highest level. Beneficial ownership reflects the peoples' power since it helps the public to know generally who owns each parcel of land in their country whether it is qualified, unqualified, unlawful, etc.

To date, Indonesia still needs to complete the registration documentation of all land rights, in order for it to be integrated into a land data bank as the country's vital archive and also for the implementation of beneficial ownership principles. According to Palilingan et al. (2019), in general, the vital archive has a number of roles: (1) as a data record of land registration connecting landowners with their lands; (2) as evidence of the correctness of the certificate issuance procedure; (3) as evidence of land ownership rights by the right holder; (4) vital archive is a reference document for future corrections; and (5) as a dispute resolution document.

Integration of land registration data as a vital archive connected with land ownership can pre-empt land smuggling, legal irregularities and money laundering practices. According to Palilingan et al. (2019) there are several things that can be proven through vital archive which are as follows:

1. Proof of fulfilling the '*Contradictory Delimitatie*' principle can be identified from measurement data (drawings) documents and the signatures of adjacent neighbours. *'Contradictory Delimitatie'* is the principle contained in Article 18 of Government Regulation No. 24 of 1997 which means that in order to prevent disputes over the determination of land parcels, it is necessary to establish land parcels by BPN that are witnessed and approved by land owners and parties directly adjacent to the land to be registered.
2. Proof of land site and size correctness can be identified from the map of the plot of land.
3. Proof of continuous control can be identified from the vital archive in the form of physical land ownership statement letter and that it is recognised by the local government.
4. Proof of good faith in land acquisition can be identified from transitional evidence used as vital archive such as a deed of grants, deed of sale and purchase, and others.
5. Proof of fulfilling the publication principle can be identified from documents in the form of an official report.
6. Proof of prudence application in land registration can be identified from the minutes of land inspection.

Strengthening land administration abilities

The Malaysian land law system adopts the Australian Torrens system, provided that the register is everything and conclusive evidence shall be obtained from the register. Land registration under the Torrens system provides a person with an indefeasible title to the property as provided in Section 340 (1) of the NLC. The ownership of a property is transferred through title registration instead of using deeds. The main purpose is to simplify land transactions and give ownership of an absolute title to the property of the registered proprietor (Mohammad et al., 2017).

Under Article 76 of the Federal Constitution of Malaysia, land is a state matter. This explains why land administration in Malaysia is carried out through the management of land issues by the federal authority. At present, states are responsible for land issues in the region. These states protect their capital by joint governmental roles such as the State District Land Office and State Land and Mining Office. On the other hand, official mapping surveys are supervised by the Federal Department of Survey and Mapping (DSMM). The DSMM is responsible for designing the survey method for Peninsular Malaysia. The surveys are undertaken by licensed land surveyors. Cadastral survey and land registry are administered by one government agency that offers similar services throughout the regions in Sabah and Sarawak (Zulkifli et al., 2015).

The Indonesian land administration is performed by the National Land Agency under the instructions from the Bureau of Public Works in Jakarta. At the provincial level (in Indonesia's 34 provinces), district departments of the government sector are responsible for approving or disapproving, directing and controlling land administration and cooperation while district offices or *'Kantor Pertanahan'* offers services to the population. Despite the centralization of policies across Indonesian cities, there is a difference in the time taken to register property (Monkkonen, 2013).

Land registration is not merely limited to the process of legalising land assets that have not yet provided justice for ownership of land rights. Other forms of affirmation in land registration activities can be conducted by the government so that the regulation and the use of land rights can benefit the community.

Land registration in Indonesia is divided into two types, namely sporadic and systematic. Sporadic is the activity of land registration for the first time regarding one or several objects of land registration in the territory or parts of a village, individually or in bulk. While systematic is the first land registration activity that is carried out simultaneously covering all objects of land registration that have not been registered in one area or part of the territory of a village The two types of land registration aim to accelerate the process of land registration, either the implementation of mass or the purpose of mass parcels of land. The mass land registration in a very short target duration without adequate facilities, human resources, and infrastructure have created significant obstacles to the project. The mass land registration project is not based on careful

planning taking into consideration the capabilities of the implementers. The National Land Office (BPN), as the implementing land registration agency in Indonesia, has very limited human resources to handle an extremely high volume of services. As a result, the issuance of proof of rights for mass land registration does not consider the formal and material correctness of title certificates since the program focuses on achieving the target duration and quantity (Setiabudhi et al., 2019).

Malaysia is well known for maintaining a distinct governing agency norm of land records under the Federal Ministry. The state government has authority over taxes and property rights for various schools. The Federal Ministry also sets its own laws while the extent of the state's reliance upon the Federal Ministry is highly unpredictable. Because of these contradictions and conflicting problems, two separate investigations were made regarding the right of possession and the right to use, resulting in misunderstanding and duplication. This has led to data inaccuracies that must be corrected. It is necessary for agencies to combine different types of data (Zulkifli et al., 2015).

The division of authority over land affairs between the central government and regions, such as in Indonesia and Malaysia, certainly needs to be clarified. The effectiveness and responsiveness of the government in resolving issues related to land affairs can have a positive impact in addressing issues concerning land registration. However, evidence has shown that miscommunication still occurs between the central and regional roles. Sometimes this is not only related to the legalisation process but also related to the land registration services budget. The distribution of authority is one of the principles that may be able to provide benefits in state administrative law, especially in terms of check and balance, in creating mutual oversight and balance between government institutions.

Indonesia's centralised land administration has exhibited ineffectiveness and inefficiency in responding to local diversities. Besides, the civil law system seems to be merely normative when it comes to the court, resulting in the court's decisions being made on a uniformity basis. As a result, discrepancies and multiple normative orders exist. It is anticipated that the deficiencies could be minimised through decentralisation and local autonomy programmes, providing local government with greater authority concerning land affairs. Besides, the state's right to agrarian resources should be reinterpreted. It is also expected that the decentralised land system could trigger more public awareness, consensus, and participation to encourage effective and sustainable land use and management (Daryono, 2010).

Affirming land rights ownership

Land registration is an affirmation of land rights. This provides a space for affirmation by the government to the community in protecting the right to life of their citizens, the right to land. Land policies which ensure the security of land rights, sustainable management of land resources, and well-functioning land market that contribute to economic development, efficient public service delivery, environmental conservation, and social stability and security (World Bank Group, 2017).

One of the affirmations carried out by the Indonesian government is the affirmation of the old rights that existed prior to Indonesia's independence, such as customary land or western land rights such as '*Eigendom', 'Erpacht*', and '*Opstal'*. Eigendom is known as ownership rights and is the highest individual rights in the Western Land Law. Eigendom's rights are regulated in Article 570 of the Civil Code. Erpacht is known as the right to use business or material rights to fully enjoy land owned by other parties in the Western Land Law. Eigendom's rights are regulated in Article 720 and Article 721 of the Civil Code. Opstal is known as a property right to own buildings or plants on someone else's land in the Western Land Law. The rights of opstal are regulated in Article 711 of the Civil Code.

This was mandated by the BAL, a law indicating the end of the Dutch legislation and the beginning of the BAL as the unification of land law. This law still needs to be strengthened as one of them relates to certainty over ownership. This is due to the fact that this law recognises that transactions related to land are legal even though land registration is not carried out because customary law only requires the existence of cash / '*tunai*' and clear / '*terang*' principles as a condition for the validity of land-related transactions. This potentially creates the inability of communities to register land or rights that they obtain from buying and selling of land as well as informal land occupation.

Another problem is that there is a typical occupation of land not following the classification of regulated land rights. As in the case of unclear communal land ownership status by indigenous peoples in Indonesia, the certification of communal land is a violation of existing regulations due to both, Government Regulation No. 24 of 1997 and the BAL.

In Malaysia, the Department of Survey and Mapping (JUPEM) is responsible for managing and maintaining the cadastral system. JUPEM deals with cadastral surveys to determine the dimension, size and location of properties. JUPEM is also responsible for preparing certified plans, producing and managing spatial components including surveying and mapping of cadastral parcels (Tan et al., 2015).

To defend against fraud, it is important to put in place strategic steps to minimise its potential. Besides the fundamental shortcomings of property laws concerning the issue of indefeasibility leaves original proprietors uncompensated when their land is transferred to innocent third parties, and the absence of State-guaranteed title insurance funds as a recourse to remedy for aggrieved parties, the land law scheme

cannot do anything to shield them. While the electronic and paper land registry schemes suffer from flaws, they are incapable of withstanding theft and new forms of cybercrime. While title insurance is a suitable mechanism to protect against defects occurring in real estate, it appears to be an unsuitable mechanism in Malaysia because of the low general knowledge, prevalence, and subscription rate of general insurance among Malaysians. This suggests that public opinion is unlikely to consider title insurance appropriate in Malaysia. On top of that, if title insurance is needed, it would demonstrate the complexity, lack of trust, and unreliability of the land management system. This would present a negative impression to investors and the public about the government's capacity to have a stable land management system. Therefore, additional care should be taken to ensure the application process is safe, secure, and accurate (Abdullah et al., 2017).

Land registration in perspective as legal instrument

The provisions of the law are indeed hard because they have been made by the makers (the law has been determined as such) as a principle that is quite popular among law activists in Indonesia, better known as the *'Lex Dura Secta Mente Scripta*' principle. Supreme Court Decision No. 1069 K/Pid.Sus/2014, p. 11 explained that the *Lex Dura Secta Mente Scripta* principle means that the law is rigid and has been written. Therefore, no one can change it. Thus, judges or other law enforcers as the executors of law must carry it out purely and consistently. While the decision of the Ciamis District Court No. 155/PID. SUS/2013/PN.CMS, p. 63 in explaining the *Lex Dura Secta Mente Scripta* principle stated that the law is indeed cruel. Therefore, the law as a legal instrument, which has been passed by the state must be adhered to by all citizens to achieve order and justice. To create a law-compliant community, the law itself must be complete and does not lead to discrepancies in interpretations, which may confuse the people. It is believed that many people still assume that land registration has not been a legal instrument promoted by the law. As evidenced from the land registration in Indonesia, the BAL mandate to register all land parcels has not been accomplished since 1960. It is according to the total area of Indonesia, which is 191.686.220 hectares (Badan Pusat Statistik, 2019), while the total area of certified land is only 39.829.560 hectares (Kementerian Agraria dan Tata Ruang Republik Indonesia, 2020).

The issuance of the BAL marks the end of Dutch colonial law in regulating land-related issues in Indonesia. The principle in Article 2 clause (1) of the BAL states that earth, space, and water, and all of its natural resources are governed by the state, as an authoritative organization of all citizens. The words "controlled" does not mean "owned" but gives authority to the state as an organisation of all people to manage land, space, water, and natural resources including granting land rights to the public (Woruntu et al., 2016). BAL as the main basis means the need to be the main reference related to other vertical/horizontal law concerning land and land tenure. BAL seeks to eliminate pluralist legal systems that have traditionally established land rights in Indonesia and to unify all land rights under one umbrella statute. Despite the fact that numerous legislation since 1960 have been adopted, some core aspects of the BAL's overall strategy have so far not been enforced (Daryono, 2010).

The urgency of the legal substance is first to systematically place the landowners and users in Indonesia. Second, to guarantee legal certainty and justice for landowners either as individuals or corporate entities; and third, to reduce land disputes in Indonesia (Sinaga et al., 2016). Research conducted by Nuragifah et al. (2018) has indicated that there are problems during the registration of property rights like the lack of knowledge of land registry. They argued that land office laws are too stringent. Another challenge is the time/opportunity, owing to the substantial distance which could be time-consuming, and expensive. The community's lack of information about the value of land registry is another challenge. Hence, they do not feel the need for their land ownership due to the amount of selling deals that are not in compliance with claims. Other issues include the presence of any land registered without the buyer's and seller's knowledge, and land registration that is not performed systematically.

Matters regarding title registration in Peninsular Malaysia are handled by the state and related departments at the district level. Land offices are mainly responsible for aggregating, partitioning, and subdividing land, executing land sales, raising revenue, handling land applications, registering land titles, and other related matters (Tan, 2013).

Land registration as a state legal instrument is also expected to be able to reduce price increment for residences in the property market. With systematic land data bank, area mapping can be used to identify affordable housing development. In a study by Bilal et al. (2019) they concluded that house prices in Malaysia are consistently above the affordability standard since 2004 which is three times of the gross household income. In the latest 2020 data, house prices are still above the gross household income as evidenced for example, in several areas such as Kuala Lumpur, Penang, and Selangor which show the following price-income ratio (PIR) of 11.05, 8.79, and 12.07, respectively (Numbeo, 2020).

Conclusion

Land registration is not a new issue. The authors found numerous writings concerning land registration issues either in Indonesia or Malaysia. The results concluded that both Indonesia and Malaysia are still facing land registration issues. The existing land registration system differences in Indonesia and Malaysia, where deed registration in Indonesia refers to the BAL and title registration (Torrens) in Malaysia refers to the NLC indicate that these differences do not significantly impact the reduction of cases and land

There is a strong need for improvement of roles from two main stakeholders, namely the government's role in streamlining land registration administration and the community's participatory role in supporting successful land registration.

ownership conflicts, especially with reference to the aforementioned data related to Land Dispute Resolution Index by the World Bank.

Despite this, the issue of land registration will remain in the society because land registration is closely related to cultural, economic, political, social, and other aspects. There is a strong need for improvement of roles from two main stakeholders, namely the government's role in streamlining land registration administration and the community's participatory role in supporting successful land registration. This research also provides important input in strengthening human resources, land administrators, digitizing services, reinforcing the principle of ownership of land rights and guaranteeing legal certainty for land registration rights holders.

Other than that, the BAL in Indonesia and the NLC in Malaysia serve as basic rules and main laws concerning land and land tenure, which play a critical role in building a just and prosperous society. This paper also provides recommendations for academicians, government/ institutional leaders, and legislators to assess and strengthen the BAL continuously as the fundamental principle of land law in Indonesia, especially in strengthening the land registration system and legal certainty concerning land registration. Therefore, formal and material content in the BAL must be clear and devoid of horizontal or vertical inconsistencies with other laws.

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References

Abdullah, N. C., Ramly, R., & Ikhsan, M. I. (2017). Land registration of titles at stake: West and East Malaysia compared. *Environment–Behaviour Proceedings Journal, 2*(6), 197–203, https://doi.org/10.21834/e-bpj.v2i6.988

Ahyani, S. (2017). Land registration as a legal construction of law in order to facing Asean economic communities. *International Journal of Nusantara Islam*, *6*(2), 201. https://doi.org/10.15575/ ijni.v6i2.6227

Badan Pusat Statistik. (2019). *Statistik Indonesia 2019.*

Bilal, M., Meera, A. K. M., & Razak, D. A. (2019). Issues and challenges in contemporary affordable public housing schemes in Malaysia: Developing an alternative model. *International Journal of Housing Markets and Analysis*, *12*(6), 1008. https:// doi.org/10.1108/ IJHMA-11-2018-0091

Tan, C. L. (2013). *Towards developing a three-dimensional cadastre for three-dimensional property rights in Malaysia* [PhD thesis, Universiti Teknologi Malaysia]. http://eprints.utm.my/id/ eprint/32647/

Tan, C. L., Zulkifli, N. A., Ujang, M. U., & Thoo, A. C. (2015). Malaysian land administration domain model country profile. *Asian Social Science*, 11(24), 305. https://doi.org/10.5539/ass. v11n24p301

Daryono. (2010). The transformation of land law in Indonesia: The persistence of pluralism. *Asian Journal of Comparative Law*, *5*, 1–32. https://doi.org/10.1017/S2194607800000259

Harun, N. (2012). Frod dalam urus niaga tanah: Satu kajian perbandingan dengan undang-undang tanah Australia. *UUM Journal of Legal Studies*, *3*, 133. http://e-journal.uum.edu.my/ index.php/ uumjls/article/view/4551

Harun, N., & Hassim, J. (2015). Pembeli bona fide dalam penipuan tanah: Isu dan cabaran. *UUM Journal of Legal Studies*, *6*, 115. https://doi.org/10.32890/uumjls.6.2015.4590

Ibrahim, I., Aziz, N. A., Hussain, F., Aminudin, N., & Yahya, M. A. (2012). Issues and policies on the aftermath of squatters resettlement: A case study on Kg. Desa Hormat Tambahan, Selangor. *Procedia-Social and Behavioral Sciences*, *36*, 698- 706. https://doi.org/10.1016/j.sbspro.2012.03.076

Johari, F., Ibrahim, P., Mohd Radzi, W., & Ibrahim, M. F. (2014). The Malaysian land taxation system: A chronological review of the Torrens system from the Islamic perspective. *Wulfenia Journal*, *21*(1), 118-133. https://umexpert.um.edu.my/public_view.php? type=publication&row=MzAwNTY%3D

Kementerian Agraria dan Tata Ruang Republik Indonesia. (2020, April 22). *Statistik sertipikat hak atas tanah*. https://www.atrbpn.

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The investment case for land tenure security in Sub-Saharan Africa: A cost-benefit analysis

Land tenure security is a critical government service that has repercussions on agricultural productivity, housing development, business investment, and the development of urban areas. The present study presents a cost-benefit analysis of tenure security in Sub-Saharan Africa. We present this study in two parts. The first part focusses on the cost factor and benefit analyis will be published in the next issue

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Government is the custodian of the most critical (and limited) factor of production, namely, land. Assuring security of tenure, arbitrating disputes, and facilitating the transfer or sales of titles renders the land market more efficient and less volatile, attracting investors and promoting sustainable urban development.

Land tenure security is also a critical government service that has repercussions on agricultural productivity, housing development, business investment, and the development of urban areas. However, land administration is mired in corruptive practices, elite capture and inefficient allocation. Globally, only 24% of rural areas are mapped (46 in urban areas), with approximately the same percentage registered, i.e., 22%. In Africa, only about 14% of rural land is formally recorded in a public register.

Land tenure security can take a variety of forms depending on national regulatory frameworks that allocate land and specify its use. Success stories include transferable user certificates in China and individual land titles in Rwanda.

Systematic evaluation of the evidence on tenure programs demonstrates that improved tenure security increases agricultural output (40% on average), increases urban land values (25% on average) and increases household welfare (15% on average). Other observed country-specific benefits include additional years of schooling, better academic performance, access to credit, reforestation and improved household nutrition.

The costs of establishing tenure security in Sub-Saharan Africa include the separate costs of rural (US$ 3 billion) and urban (US$ 2.2 billion) land registration; the cost of digitizing land registries and information to improve efficiency and transparency (US$ 880 million), the cost of strengthening institutions and systems to resolve land disputes and manage expropriations (US$ 960 million) over a ten-year implementation period, and land administration operations and land records maintenance over 30 years (US$ 64 billion). The net present value (8%) of costs is US$ 21.7 billion for rural land tenure and US$ 5.3 billion for urban areas.

The benefits of rural land registration were based on the observed 15% household wealth effect noted in the literature. The net present value (8%) of a 30-year benefits stream is US$ 396 billion. The benefit-cost ratio of completing and modernizing land registration and improving land administration coverage and effectiveness in rural Sub-Saharan Africa is 18.

The benefits of urban land registration were based on the average 25% increase in

property values observed in the literature. Using housing prices for the 20 largest, Sub-Saharan African countries, the net present value (8%) of the benefits over a 30-year period is US$ 237 billion, yielding a benefit-cost ratio of 45 when the average housing price is used. When the population-weighted housing price is used, benefits are valued at US$ 160 billion, yielding a benefit-cost ratio of 30.

The Importance of Land Tenure Security for Development

Government is the custodian of the most critical (and limited) factor of production, namely, land. Assuring security of tenure, arbitrating disputes, and facilitating the transfer or sales of titles renders the land market more efficient and less volatile, attracting investors and promoting sustainable urban development. Yet, one of the most underperforming parts of public administration in developing countries is land administration. This is borne out by the observed land conflicts, squatting in undesignated urban areas, non-compliance to land use planning and construction regulations and lack of investment in housing and farms across the world.

Private land in developing countries remains largely unmapped and unregistered. Generally, urban areas are better mapped and registered than rural areas. Globally, only 24% of rural areas are mapped (46% in urban areas), with approximately the same percentage registered, i.e., 22%. There is no region with universal mapping and registration; even the OECD region has 97% and 68% of urban plots mapped and registered, respectively, as compared to 71% and 68% for rural areas (Enemark et al. 2014). However, Sub-Saharan Africa has the lowest proportion of mapped land in the world, i.e., 14%.

A further complexity is the rate of migration from rural to urban areas: By 2050, 66% of the world's population is projected to be living in urban areas. The most urbanized regions include Northern America (82% of the population living in urban areas in 2014), Latin America and the Caribbean (80%) and Europe (73%). In contrast, Africa and Asia remain mostly rural, but are urbanizing faster than the other regions and are projected to become 56% and 64% urban, respectively, by 2050 (UN-HABITAT 2021).

Land tenure, as defined by the United Nations Food and Agriculture Organization, is the relationship, whether legally or customarily defined, among people, as individuals or groups, with respect to land. It involves rules to regulate behavior, as it defines how access is granted to rights to use, control and transfer land as well as associated responsibilities and restraints, hence determining market participation. Practically, land tenure security implies two main right dimensions: (a) the rights to use and the rights to transfer, and (b) the autonomy to enjoy these rights (Bambio and Bouayad Agha 2018).

Land can be private, communal, open access or public, and there are a variety of instruments that assign rights to the use of land, including use rights, control rights and transfer rights. There are various proven instruments, as listed below, to improve land tenure security, which range from issuing transferable user certificates and community mapping with customary leader adjudication under customary tenure regimes (e.g., China and Benin) to land titling under freehold regimes (e.g., Rwanda).

- certificates of customary ownership in areas where customary tenure dominates (e.g., Uganda)
- social land concessions (e.g., Cambodia)
- land use certificates in the case of informal settlements like in Senegal, community land trusts in Kenya, or certificates of comfort in Trinidad and Tobago; all have the objective of protecting squatters from eviction. Experience has shown repeatedly that such tenure security does not require the allocation of individual titles.
- user certificates and transferable user certificates (e.g., China)
- land titles under both freehold and leasehold regimes, known as emphyteutic lease (e.g., Rwanda)

Security of tenure refers to the recognition of these rights by others, the absence of which results in competing claims to the land and possibly conflict. In Niger, although an extreme case, only 4.5% of the adult population has land documents. Other countries, which report in their Voluntary National Reviews on the Sustainable Development Goal Indicators, reflect more moderate tenure security: Nepal 26%, Peru 34%, Uganda 36%, Benin 43% and Georgia 60%. The gender (female-male) gap in tenure security among rural farmers is also palpable: in Nigeria (30% vs 60%), Peru (8% vs 19%), Uganda (31% vs 49%) and Tanzania (49% vs 61%) (SDG Land Momentum Group 2020a).

Land administration is the way in which the rules of land tenure are applied and made operational. Land administration, whether formal or informal, comprises an extensive range of systems and processes to administer. These include but are not limited to the allocation of rights to use, lease or sell land; land use regulation as is the case for public works or better

Table 1: Land Registration Indicators, Doing Business Survey (World Bank 2019).

Region	Procedures (number)	Time (days)	Cost (% of property value)
East Asia + Pacific	5.5	71.9	4.5
East Asia + Pacific	5.5	71.9	4.5
Europe + Central Asia	5.5	20.8	2.7
Latin America + Caribbean	7.4	63.7	5.9
Middle East + North Africa	5.4	26.6	5.6
OECD	4.7	23.6	4.2
South Asia	6.9	107.8	7.0
Sub-Saharan Africa	6.1	51.6	7.3

Source: Doing Business Survey (World Bank 2019).

managed environmental impacts; and land valuation and taxation. Land is typically administered at the lowest levels of government where there are capacity constraints relating to human resources and technology. This is reflected in the performance indicators in the World Bank's Doing Business Survey that attempts to determine the efficiency of the land registration process. Table 1 lists the results of the land registration indicators by region. While it is not the most inefficient region where it relates to time, Sub-Saharan Africa has the highest compliance costs, measured as a percentage of the property value.

Under the Sustainable Development Goal 1 target to end poverty by 2030, all men and women, in particular the poor and the vulnerable, should have equal rights to economic resources as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, and appropriate new technology and financial services, including microfinance. Sustainable Development Goal 5 speaks to gender disparity in land ownership, in which, globally, of agricultural land holders. Despite the plethora of organizations working towards the realization of these targets, there has been limited uptake to the global monitoring mechanism. During the years 2016 and 2019, no countries reported in their Voluntary National Reviews on SDG 1.4.2, and only 10 countries submitted reports on SDG 5a. There has also been no country reporting on the perceptions of tenure security (SDG Land Momentum Group 2020x).

Low levels of land registration and ailing land administration coupled with urban migration pressure places the focus on Sub-Saharan Africa. Tenure insecurity is costly to society. Land transfers, where they are possible, consume time and resources on both sides of the transaction and for government. Land registration and other compliance costs as a percent of property value are higher. Another consequence of tenure insecurity is sub-optimal agricultural output: agricultural lands suffer under insecure tenure and are subject to conflicts, thus showing 20% lower yields than those without conflicts (Byamugisha 2016).

To unlock the vast agricultural potential of Sub-Saharan African countries as well as ensure that urban land is allocated to its highest yielding potential, the granting of tenure security (in its locally relevant form) is considered a best investment based on countries' experiences; the material outcome being a legal document ascertaining that the rights held on a plot of land are provided by the law against any third party.

Cost–benefit analysis of land tenure security in Sub–Saharan Africa

Establishing land tenure security goes beyond land parcel registration and involves policy, administrative and regulatory actions including sensitization, awareness and education campaigns; participation and the engagement of opinion leaders (including cultural and religious ones); mobilizing and training of field staff; adjudicating, surveying, mapping and demarcating boundaries; capturing and digitizing field data; publicly disclosing and confirming field adjudication results; and registering and distributing land rights documents.

The state of land tenure security in Sub–Saharan Africa

Customary tenure prevails on the continent, estimated to be over 78% of land holdings. Individual land holdings (or private property) dominate in only six of the 54 states and cover only 10% of the land in Africa.

Tenure security can and does exist under customary tenure. Among the Kikuyu in Kenya, wills are not recognized, and all sons inherit in equal parts. Linkow (2019) demonstrates that this is sufficient security to incentivize investment: both tree-planting and tree density (conditional on trees having been planted) are positively related to inheritance by sons. In cases where women find themselves in possession, there is insecurity of tenure and thus significantly less investment.

Thirty-one African states now formally recognize customary tenure as a viable system for regulating land rights. Socially based collective property is fast becoming an accepted part of property relations guided and protected by statutes, taking its place among more traditional and individual-centric norms (Alden Wily 2018). This recognition is characterized by (a) the formalization of tenure; (b) the incorporation of customary practices into statutory law, and (c) the professionalization and creation of institutional legibility in customary tenure and democratization of customary tenure practices. Land administration is adopting a hybrid approach, bringing together elements of traditional authority and fusing this with some of the values of the statutory institutions with which they interface. The result is the facilitation of land transactions because local authorities are becoming more professional in the way that they administer and manage land (Chimhowu 2019).

Baseline data

To estimate the shares of rural land that is registered or unregistered in Sub-Saharan Africa, we derive them from survey data analyzed by Deininger, Savastano and Xia (2017) using the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) implemented by the World Bank. An agricultural household owns 2.2 land plots (parcels), which is the weighted average (weighted by the country's population) of farm plots owned by a household in the surveyed six Sub-Saharan African countries (five surveyed in 2010/2011 and one in 2011/2012) whose total population makes up 41% of Sub-Saharan Africa's population[1]; a 14% weighted average of the area (weighted by the country's population) is covered by formal ownership documents.

Regarding the share of urban land that is registered in Sub-Saharan Africa, no data are available on this. In absence of such data, we make estimates based on registration information obtained for two Sub-Saharan African cities, namely, Nairobi in Kenya and Dar es Salaam in Tanzania, whose land registration experiences have been studied more closely and reported by Henderson and Liu (2020). Using their findings, we assume that half of the urban areas in Sub-Saharan Africa have as good a land registration record as Nairobi, with 90% of private land (outside slums) registered while the other half of Sub-Saharan African urban areas is assumed to have as poor a registration record as Dar es Salaam, with only about 20% of the urban land registered. It should be noted that the latter category of urban area cities, including Bamako, Kampala and Lagos, have a large proportion of their unregistered land covered by less formal documents, such as Residential Licenses in Dar es Salaam that cover about 50% of its unregistered land, have some legal backing and give a level of comfort to occupants but fall short of formal titles (Henderson and Liu 2020). To conclude, therefore, we assume that half of Sub-Saharan African private urban land parcels, excepting slums, are of the Nairobi type with a 90% registration rate while the other half are of the Dar es Salaam type with a 20% registration rate. We also assume that land in urban slums all over Sub-Saharan Africa are all unregistered and are treated separately in the costing.

To estimate the number of households and corresponding land parcels in both rural and urban areas, we begin with the latest estimate of the total population in Sub-Saharan Africa in 2020, which was 1.136 billion (World Bank Open Data), and approximately, 41.3% lived in urban areas (by deduction, 58.7% in rural areas). Thus, the total number of rural and urban land parcels in Sub-Saharan Africa is 212.6 million and 68 million, respectively.

Costs

The costs of establishing tenure security in Sub-Saharan Africa include the costs of rural and urban land registration; the cost of digitizing land registries and information to improve efficiency and transparency; the cost of strengthening institutions and systems to resolve land disputes and manage expropriations, and the annual operations costs of the new or expanded land administration and land records maintenance costs.

Rural registration costs

Of the 213 million total rural land parcels, an estimated 14% are registered, leaving 86% of the total or 183 million parcels, unregistered. The bulk of this unregistered rural land—estimated at 90% of the total and amounting to 164.5 million parcels—is of relatively low value and can be demarcated using aerial photos or high-resolution satellite imagery, as Rwanda and Ethiopia have done, and registered at an average cost of US$ 10 per parcel, for a total cost of US$ 1.65 billion (see Table 2).

The balance of the unregistered land, 18.3 million parcels, is estimated to be of higher value due to increasing demand either for production or conversion to urban or other high value uses. This land is vulnerable to contestation and hence requires more precise boundary measurement at a higher cost. Based on experience from Ethiopia, Uganda and Ghana, we estimate an average cost of surveying and registration of US$ 20 per parcel, for a total cost of US$ 366 million. Hence, the total cost of adjudicating, demarcating and registering the individually owned rural arable land (both relatively low value and high value) would amount to about US$ 2.0 billion (see Table 2).

Table 2: Baseline Data on Population, Household and Land Parcels

Region	Population (millions)	Households (millions)	Land parcels (millions)	Unregistered parcels (millions)
Rural	666.83	96.64	212.61	182.84
Urban	469.16	67.99	68	30.6

Communally owned land, excluding rangelands and forests

Until recently, registration of communal land was not urgent since the rights of community members in many countries were quite secure and demand for land from non-community members was minimal. However, increases in land values due to population growth and investor demand have raised demand and contestation over communal lands, hence raising the need for their registration. The urgency for communal land registration is in countries with large chunks of communal land, such as Mozambique, Zambia, Angola, Ghana, Sierra Leone, Liberia, Tanzania and the DRC and in parts of countries with large chunks of communal lands such as northern Uganda and the western and south-eastern areas of Ethiopia. Registration and securing tenure typically involve: (a) organizing and formalizing land-owning groups and strengthening local institutions of land governance, and (b) adjudicating and demarcating external boundaries and registering the rights of the formalized groups (Byamugisha 2013; Barnes, Digiano and Augustinus 2015). Cost estimates are based on experiences of Tanzania (about US$ 500–US$ 2,000 for survey and registration per village) where villages were already organized into administrative units and in Mozambique (US$ 2,000–US$ 10,000 per community) to formalize land-owning community groups, delineate external community boundaries and register communal rights. We estimate the total cost of registering communal land rights (about 15,000 community groups) in a country to be about US$ 30 million if communities are already organized and formalized as in Tanzania (about 15 countries), or about US$ 40 million if land owning community groups are not yet organized and formalized like in Mozambique and Kenya (also about 15 countries). The total budget for approximately 30 countries is US$ 1.05 billion (see Table 2)[5].

Exclusion of rangelands and forests from the quantification of costs (and benefits) of land tenure security does not mean they are not important. Indeed, they are important not only in generating national economic benefits and providing livelihoods to vulnerable people but also in providing climate change and environmental services. These benefits together with the associated land tenure intervention costs are difficult to quantify partly because there has not been much implementation experience on which to base the quantification. Moreover, since surveying of rangelands and forests is mostly based on community mapping, it would be considerably cheaper than the surveying and mapping commonly used in the registration of rural and urban lands. Since surveying and mapping is a big part of the costs of registration, the provision of land tenure security for rangelands and forests based on communal mapping is likely to be cost-effective. Hence, excluding rangelands and forests in the quantification of costs and benefits would not affect the conclusions of the overall cost-benefit analysis.

Altogether, the total cost of registering individually and communally owned rural land in Sub-Saharan Africa is approximately US$ 3.1 billion.

Urban registration costs

In terms of registration of urban land, no reliable information is available on the share of registered land in urban areas in Sub-Saharan Africa. In absence of data, we use the studies of two cities, Nairobi (Kenya) and Dar es Salaam (Tanzania), as representing two categories of urban entities in Sub-Saharan Africa. In Nairobi, 90% of private land is registered, while in Dar es Salaam, only up to 20% of land is registered, with about 50% of the unregistered land having documents that have a legal backing and give a level of comfort to occupants but fall short of formal titles (called Residential Licenses and renewable after every five years). Bamako (Mali), Kampala (Uganda), Lagos (Nigeria) and many more Sub-Saharan African cities are in a similar property rights situation as Dar Es Salaam (Henderson and Liu 2020).

We assume that half of Sub-Saharan Africa's private urban land parcels, with the exception of slums, are of Nairobi type with a 90% registration rate and the other half are of the Dar es Salaam type with a 20% registration rate. Given that Sub-Saharan Africa has an estimated 68 million urban land parcels in total, the unregistered parcels for the Nairobi-type amount to 3.4 million while the unregistered parcels for the Dar es Salaam type amount to 27.2 million, together generating a total of 30.6 million unregistered parcels. Assuming a planning, surveying and registration cost of US$ 25 per parcel (based on the Thailand, Ghana and Uganda experiences), the cost of registering 30.6 million urban land parcels, excluding land in slums, is estimated to be US$ 765 million (see Table 2).

Unregistered land in slums

We assume that land in urban slums is all unregistered. Informal settlements (slums) arise mostly on public land and did not originally form part of local land use plans. Preliminary results from donor-supported formalization programs in Kenya, Lesotho and Tanzania indicate that it can be done more cost-effectively if it is done through joint field activities of physical planning and surveying, area by area systematically and done in bulk. This bulk planning and surveying, when coupled with new participatory and cheaper approaches to capture land rights information using tablets and smartphones, can reduce costs in participatory processes involving representatives of slum dwellers in a six-step process: community education and participation on rights and responsibilities; adjudication and enumeration of rights of individuals and groups (including tenants and structure owners); agreement on and survey of land

Table 3: Costs of Securing Sub-Saharan Africa's Land

Activity	Description of units	Units	Unit price (USD)	Cost (USD mill.)
stsoc noitartsiger dnal laruR				
Individually owned average value land	No. of parcels in millions	164.6	10	1646
Individually owned high value land	No. of parcels in millions	18.3	20	366
Communally owned land of formalized groups	No. of countries (unit prices are in millions)	15	30	450
Communally owned land of unformalized groups	No. of countries (unit prices are in millions)	15	40	600
Total rural land registration costs				***3062***
smuls edistuo stsoc noitartsiger dnal nabrU				
In areas with high registration rate	No. of parcels in millions	3.4	25	85
In areas with low registration rate	No. of parcels in millions	27.2	25	680
Urban Land registration costs in slums	No. of countries (unit prices are in millions)	48	30	1440
Total urban land registration costs				***2205***
Costs of digitizing land registries and information	No. of countries (unit prices are in millions)	44	20	880
Costs to strengthen institutions to resolve disputes and manage expropriations	No. of countries (unit prices are in millions)	48	20	960
TOTAL COST OF SECURING TENURE IN Sub-Saharan Africa				***7107***

boundaries; physical planning with wide community participation; adjustment of boundaries, walls, fences, and buildings to meet the physical plan; and registration of rights in a local or central public land registry (Byamugisha 2013).

Experience from Kenya indicates that at least five types of titles can be issued from regularization of tenure in urban slums: individual titles; joint titles including for couples; block titles (with shares of each member indicated); community or communal titles (with members organized into legal entities); and sectional property titles similar to condominium titles, with individual ownership of structural units but common ownership of the land (personal communication with Kenyan Authorities, January 2022). Given that slums, although declining, have persisted with urbanization in developing countries (Cai, Selod and Steinbuks 2018) including those where registration of urban land is quite advanced such as Vietnam, China, South Africa, Ghana and Rwanda,[2] not all land in slums will be registered entirely or eliminated in Sub-Saharan Africa within 10 years even with increased funding and policy reforms. It will take a longer time of engagement to tackle not only the issues of planning, surveying and registration but also other issues that contribute to the proliferation of slums to eventually reduce slums closer to levels in developed countries. For this costing exercise, we provide cost estimates of a sizable program to enable Sub-Saharan African countries to learn and customize global and regional best practices and initiate or accelerate implementation of long-term programs to register about half of the land in slums and to prevent new slums from occurring. For such a program, we are estimating an average cost of US$ 30 million per country in all Sub-Saharan African countries (n = 48), totaling US$ 1.44 billion (see Table 2).

Altogether, the cost of registering urban land including slums is about US$ 2.2 billion.

Estimating the cost of digitizing land registries and information to improve efficiency and transparency

Improving efficiency and transparency in Sub-Saharan Africa involves streamlining and digitization of processes and data in public land registries and other land administration services. The digitization builds on the successes of Rwanda, Uganda, and Mauritius that have completed their digitization programs as well as on some progress made in this area by other Sub-Saharan African countries including Ethiopia, Benin, Côte D'Ivoire, Malawi, Mozambique and Zambia. The digitization program is budgeted to cover about 44 countries at an average cost of US$ 20 million per country, based on Uganda's experience with the development and implementation of its digitization program but excluding infrastructure such as buildings (personal communication with Ugandan Authorities, January 2022). The total cost of digitization of land registries and information services is US$ 880 million (see Table 2).

Estimating the cost of strengthening institutions and systems to resolve land disputes and manage expropriations

In almost all Sub-Saharan African countries, land disputes make up a high share of court cases, in the range of 50% in Ghana and Uganda, and one third to one half in Ethiopia. Weaknesses in resolving land disputes undermine land tenure security. Sub-Saharan African countries including Ghana and Tanzania, have implemented incremental measures to strengthen judicial systems including hiring retired judges and paying overtime for sitting judges to reduce the backlog of court cases, increasing capacity of the courts through training of judges and giving them more resources, establishing specialized courts, and deploying alternative dispute resolution (ADR) mechanisms and customary institutions. A review of experience with such incremental efforts to strengthen judicial systems and the rule of law in resolving land disputes indicates that while there was some progress, no single mechanism alone has been successful (Byamugisha 2013). Success requires a combination of approaches to ensure system-wide reforms.

A similar review of experience with implementation of interventions to tackle problems in compulsory land acquisition and compensation, which are common in Sub-Saharan Africa and undermine land tenure security, suggests that multiple actions as opposed to single solutions have a greater chance of success; such actions should include updating laws to keep pace with innovations in land policy and passing laws like a number of countries, including Tanzania, Ghana and Uganda, have done; avoiding the undervaluing of land rights and poorly tailored forms of compensation; avoiding the use of the "public interest" principle to acquire land for the production of private goods and services or to lease to investors; and fixing deficiencies in governance such as underpayment or delayed payment of compensation (Byamugisha 2013). Implementing system-wide reforms to resolve land disputes and multiple actions to tackle problems in land acquisition and compensation is estimated to cost an average of US$ 20 million per country and, for the 48 Sub-Saharan African countries, total US$ 960 million (see Table 2).

Annual operations and maintenance costs

A key benefit of registries is their ability to provide authoritative information on all parcels of interest, within a reasonable period for land transactions (transfers, sales, inheritances). Even in a low-income country, the size of the land market is non-negligible. For example, in Rwanda, 5.6% and 1.54% of Kigali's residential and agricultural land parcels, respectively, were transferred through a registered sale each year. For the other provinces, figures are 0.27% and 0.07% for residential and agricultural land, respectively

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(Ali, Deininger, and Duponchel 2016). They also estimated a total of USD 2.6 billion of mortgage lending annually.

The costs associated with land administration services include the following:

- Back-office costs, including personnel, hardware and software maintenance and upgrades and information technology upgrades, like integration of blockchain technology. As the technology is rapidly evolving, there is now emerging literature of migrating land registries from physical servers to blockchain, which would improve security and traceability, thereby increasing user confidence.
- Decentralization costs, while highly contextual, typically entail some combination of sub-national land service offices and agents who cover the last mile for remote and rural residents. In Rwanda, there are sector land managers (SLMs) to receive, validate and notarize transactions, disseminate information, and help implement land use plans at sector local level (Ali, Deininger, and Duponchel 2016).
- Networking costs that link the registry to other public agencies like the revenue authorities and credit agencies like the Land Administration Information Service of Rwanda, which is integrated with data on land use and agro-ecological suitability and is maintained by the Ministry of Agriculture and Animal Resources to monitor land use and its changes and in doing so, facilitate siting of investments higher up in the value chain, e.g., in agro-processing (Ali, Deininger, and Duponchel 2016).
- Document management system of cadastral surveys and certificates.
- Complaints management system to manage disputes and competing claims.
- Land use planning and development, which need to be revised as populations grow and migrate and economic activity evolves.
- Continued sensitization of land rights and responsibilities, as well as communication on how to access services, costing, etc., to encourage the continued registration of parcels and stem informal transactions of land. In Rwanda, it was discovered that some buyers believed taking possession of the seller's title without a name change would establish ownership. Thus, the government conducted two national campaigns, referred to as 'land weeks', during 2014–15, which involved extensive coverage on television and radio and some face-to face events (Ali, Deininger, and Duponchel 2016).

These operations and maintenance costs ensure the sustainability of the overall land tenure security intervention. When these functions are insufficiently budgeted for, beneficiaries, especially women and rural residents, are unable to access the potential wealth that exploitation of land can bring. One of the observed consequences is the increased informality of land transactions. Mozambique is a case in point. Despite the legal and institutional reform and the development of the Land Information Management System (SiGIT), challenges associated with land administration include institutional weaknesses. Municipalities, which remain responsible for establishing and maintaining the cadaster in urban areas are unable to perform basic land administration tasks, partly due to insufficient human and financial resources. They were also using outdated maps, which vary between 27 and 40 years (World Bank 2017). In Colombia, only 5.7% of the parcels are up to date, while 66% are outdated, showing an average last registration of 12 years prior, and with 28.3% of parcels unregistered. The main reasons were attributed to a shortage of human and technical capacity of the institutions responsible for the creation and maintenance of the cadastral records and the use of outdated procedures and regulations that are based on compliance with technical standards rather than on the purpose and use of the information collected (Morales et al. 2021).

The national agency tasked with administering lands and maintaining records has annual costs, assumed here to be proxied by the ratio of annual running costs per registered parcel. A survey undertaken by Burns et al. (2006) revealed that the average is between US$ 5 and US$ 10. Individual country costs are shown in Table 3.

The midpoint of the range (US$ 7.50) is used in the analysis and inflation-adjusted to US$ 10.16 in 2020. It is assumed that there is no significant difference in administration of rural and urban parcels. These costs increase with parcel registration uptake, which occurs in increments of 10% over ten years,

Table 4: Land Administration Costs by Country

Country	Annual running cost/ parcel (US$)	Country	Annual running cost/ parcel (US$)
Philippines	1.17	Latvia	7.0
Trinidad and Tobago	2.70	Kyrgyzstan	17.00
Thailand	2.10	Armenia	46.92
Moldova	2.46	South Africa	2.76
Indonesia	0.79	India (Karnataka)	0.16
El Salvador	27.47		

Table 5: Costs Summary in US$ Billions (Undiscounted)

Description of costs	Rural	Urban
Parcel mapping, registration	3.1	2.2
Digitization	0.509	0.371
Institution strengthening	0.555	0.405
Operations and maintenance	64.5	10.8
Total cost	68.6	13.8

followed by an annual markup of 2% for the remaining intervention period, an additional 20 years[2]. The undiscounted rural land administration costs over the 30-year period are estimated to be US$ 69 billion and US$ 14 billion for urban parcels (see Table 4).

The total cost of securing land tenure in Sub-Saharan Africa over 10 years, including registering the remaining unregistered rural and urban land (both individually and communally owned), initiating or accelerating implementation of long-term programs of participatory planning and regularization of tenure to steadily reduce urban slums to the levels in developed countries, digitizing public land registries and information, implementing system-wide reforms to resolve land disputes and multiple actions to tackle problems in land expropriation and compensation, extending land administration, and ensuring records maintenance for an exclusively rural tenure security intervention has a net present value of US$ 21.7 billion and US$ 5.3 billion when efforts are concentrated solely in urban areas.

Tirupati, India Smart City Project

NEC Corporation India has launched the latest Smart City project in Tirupati, India.

It is implementing ICT solutions throughout the city and setting up a City Operations Centre (COC) in Tirupati. The ICT solutions, including integrated services and a Unified Command and Control Centre, will facilitate real-time data collection & analysis and two-way communications, which will help to provide more efficient responses to issues related to safety, security, healthcare, the environment, and more. Furthermore, a City Network Infrastructure and On Premises Data Centre will help to implement a more data-backed decision-making mechanism for the operations of the city. *www.nec.com*

Flood Hazard Web GIS Application in Japan

Higashihiroshima City, in Hiroshima Prefecture, Japan, recently hosts a flood hazard and disaster prevention related web GIS application developed with the TatukGIS Developer Kernel (DK) for ASP.NET edition that focuses on flood risks posed by hundreds of agricultural irrigation reservoirs. The application enables anyone in the vicinity of a reservoir to understand in advance the flooding impact if the reservoir fails - such as due to an earthquake or heavy rainfall during a typhoon. Citizens can easily understand if their home or business is at risk, how much time following a reservoir collapse before flood water reaches their location (i.e., time available to evacuate), projected depth of the inundation (represented using color gradients), and optimal evacuation path to higher ground and emergency shelter.

The territory of Higashihiroshima City contains 1,821 priority-level agricultural reservoirs, more than any other city in the Hiroshima Prefecture, and approximately 2,200 smaller irrigation ponds. According to the Higashihiroshima Agriculture and Forestry Division, 48 agricultural reservoirs in Hiroshima Prefecture collapsed in 2018, sometimes resulting in deaths. It is hoped this application will help citizens become more aware in advance of the risk posed by nearby reservoirs and be better prepared. *www.tatukgis.com*

SAP and Google Cloud enhance open data cloud

SAP and Google Cloud announced an expanded partnership at Google Cloud Next, to help enterprises harness the power of data and generative AI. The companies will combine their integrated open data cloud using the SAP Datasphere solution with Vertex AI to launch new generative AI-powered industry solutions starting with automotive and introduce new capabilities to help customers improve sustainability performance. By integrating generative AI into SAP software and Google Cloud's open data cloud, customers can deploy powerful new solutions that use information from SAP Datasphere and from virtually any other data source to significantly improve business insights, analysis, and decision-making. *https://news.sap.com*

UNDP India partnership with NABARD

The United Nations Development Programme (UNDP) and the National Bank for Agriculture and Rural Development (NABARD) signed a Memorandum of Understanding (MoU) to co-create data-driven innovations in agriculture and food systems to support smallholder farmers. Both organizations will work to improve the lives and livelihoods of smallholder farmers by sharing open-source data for product development, transfer of technology and supporting the framing of agrarian policies.

Under the MoU, UNDP will leverage its expertise in open innovations, data collaboratives, data science approaches and global know-how for supporting NABARD's agenda of embedding data-driven decision-making in agriculture investments.

The partnership includes enhancing and disseminating collaborative digital public goods like DiCRA (Data in Climate Resilient Agriculture). DiCRA is a collaborative digital public good which provides open access to key geospatial datasets pertinent to climate resilient agriculture. DiCRA, which is curated by UNDP and partner organizations to inform public investments in agriculture, already provides intelligence on climate resilience for 50 million hectares of farmland across India. By partnering for enhancing and scaling its use, NABARD will host and maintain the DiCRA platform and use its key geospatial datasets for policy making, research and development activities, with UNDP's technical support. *www.undp.org*

OGC release the IGIF-(M) SDI maturity roadmap

The Open Geospatial Consortium (OGC) has released the first iteration of the IGIF-(M)SDI Maturity Roadmap and supporting materials for community consideration and engagement across not only the marine domain, but any geospatial domain connected to the oceans.

Developed as part of OGC's ongoing Federated Marine Spatial Data Infrastructure (FMSDI) Initiative, the Integrated Geospatial Information Framework – (Marine) Spatial Data Infrastructure (IGIF-(M)SDI) Maturity Roadmap is a quick-start guide for nations and marine organizations that seeks to advance and simplify efforts in Marine SDI and ensure their alignment with the UN-IGIF principles.

One of the key messages of the document is that an (M)SDI is a continual journey and not an "end state" of expensive technological solutions. The document asserts that nations are sovereign in what manner of (M)SDI they genuinely need for their national requirements, and not governed by an externally imposed or presumed level of technological sophistication. *www.ogc.org*

DOT releases Complementary PNT Action Plan

The U.S. Department of Transportation (DOT) has unveiled its Complementary Positioning Navigation and Timing (CPNT) Action Plan, which contains steps the department is taking to drive CPNT adoption across the United States transportation system and within other critical infrastructure areas.

In 2020, the U.S. DOT Volpe National Transportation Systems Center conducted field demonstrations of various PNT technologies that could offer complementary service if GPS is disrupted. The department was able to gather information on PNT technologies at a high technology readiness level that can work in the absence of GPS.

The U.S. DOT have selected 11 candidate technologies to demonstrate positioning or timing functions:

- Two vendors demonstrated low-Earth orbit satellite PNT technologies — one L-band and one S-band;
- two vendors demonstrated fiber-optic timing systems, both based on the White Rabbit Precision Time Protocol;
- one vendor demonstrated localized database map matching database, inertial measurement unit, and ultra-wideband technologies; and,
- six vendors demonstrated terrestrial radio frequency PNT technologies across low frequency, medium frequency, ultra-high frequency, and Wi-Fi/802.11 spectrum bands.

Five of the selected technologies were demonstrated at Joint Base Cape Cod in Massachusetts, and six were demonstrated at NASA Langley Research Center in Virginia. The demonstrations were scenario-based implementations modeled on critical infrastructure use cases under different operating conditions.

Two central recommendations from the demonstration were made: the U.S. DOT should develop system requirements for PNT functions that support safety-critical services; and the U.S. DOT should develop standards, test procedures, and monitoring capabilities to ensure that PNT services, and the equipage that utilize them, meet the necessary levels of safety and resilience identified in recommendation one. *www.transportation.gov*

Russia launches Glonass-K2

The Russian Federal Space Agency has launched one of its Glonass global positioning satellites, Glonass-K2 No. 13 (Kosmos 2569), into medium-Earth orbit (MEO) on August 7. It was launched to improve the accuracy of the Russian dual-use GNSS. The K2 satellites are the fourth iteration in satellite design for GLONASS.

The new generation of satellites provide navigation accuracy of less than 30 cm and feature an unpressurized satellite bus (Ekspress-1000) manufactured by ISS Reshetnev. The satellites also use a novel navigation signal, code-protected selection, to transmit three signal types, including two in the L1 and L2 ranges for military users, and one channel in the L1 range accessible to the civilian users.Each K2 satellite weighs 1,645 kg and has an operational lifetime of 10 years. *www.russianspaceweb.com*

I/NAV improvements are now available to all Galileo Open Service users

The Galileo OS has been upgraded with three new features added to its I/NAV message, one of the four message types broadcast by Galileo satellites. Collectively referred to simply as I/NAV improvements, these features are now available to all Galileo Open Service users.

Starting on 12 August 2023, the gradual process of upgrading the operational Galileo FOC constellation satellites has been finalized, and the I/NAV improvements are openly accessible through the I/NAV message carried by the E1-B signal.

In simple terms, in case you have experienced delays when turning on your GNSS device, the I/NAV

improvements can reduce them significantly. Let's have a look at the features more in detail.

The Reed Solomon Outer Forward Error Correction (RS FEC2) increases demodulation robustness at all times and therefore enhances the sensitivity. It also improves the overall time to retrieve Clock and Ephemeris Data (time to CED) thanks to the broadcast of additional, redundant CED information, while allowing for the device to restore potentially corrupted data bits autonomously.

The Reduced Clock and Ephemeris Data (RedCED) allows for a fast-initial positioning, albeit with lower than nominal accuracy, by decoding one single I/NAV word, while waiting to receive the four I/NAV words carrying the full-precision CED.

The combination of these two features allows not only to obtain a first coarse position solution much faster (RedCED), but also to reduce significantly the time required to obtain a first full accuracy solution (RS FEC2). This translates into a much-reduced Time to First Fix (TTFF) for the OS users, particularly when operating in harsh environments.

The improvements also benefit applications working in assisted GNSS (A-GNSS) mode, through the Secondary Synchronisation Pattern (SSP). In A-GNSS mode, when navigation data is received from non-GNSS channels and the receiver's knowledge of the Galileo System Time is affected by a relatively large error, typically in the order of a few seconds, the clock uncertainty must be resolved quickly and stably.

With the I/NAV improvements, receivers will be able to do this via the new SSP feature, thus reducing the TTFF also in A-GNSS mode. *www.euspa.europa.eu*

Globalstar contracts SpaceX

On August 28, 2023, Globalstar, Inc. entered into a Launch Services Agreement by and between the Company and Space Exploration Technologies Corp. and certain related ancillary agreements (the "Launch Services Agreements"), providing for the launch of the first set of the satellites the Company is acquiring pursuant to its previously disclosed Satellite Procurement Agreement. *www.sec.gov*

Getech heads into orbit as Planet partner

Getech has announced an agreement with Planet to join its "Orbit" partner programme.

It will enable Getech to access Planet's wealth of earth observation data for use in data-led geo energy exploration projects across sectors as diverse as mineral exploration, geothermal etc. *https://getech.com*

Umbra partners with EUSI to offer SAR imagery

Umbra has announced a strategic partnership with European Space Imaging (EUSI. This partnership will allow customers to purchase Umbra's industry-leading Synthetic Aperture Radar (SAR) data directly through EUSI. It will also gain the ability to oversee global tasking and delivery of SAR imagery for its customers using Umbra's advanced satellite constellation and tasking platform. *euspaceimaging.com*

Lumotive launches Optical Beam Steering Semiconductor

Lumotive has announced the launch of LM10 - Light Control Metasurface (LCM™) technology – the world's first digital beam steering solution.

Lumotive's digital beam steering overcomes the limitations of traditional lidar sensors with its superior cost, size and reliability compared to mechanical systems. As pure solid-state optical semiconductors which can be manufactured in high volume, Lumotive's LCMs are enabling the next generation of lidar to expand into new applications and become the pervasive standard for intelligent 3D sensing worldwide. *https://lumotive.com*

Hydrogen fuel storage solution for UAVs

The National Renewable Energy Laboratory (NREL) embarked on a year-long collaboration with Honeywell Aerospace in 2023 to prototype and support the commercialization of a novel cartridge-based hydrogen fuel storage solution for UAVs. The project, Fuel Additives for Solid Hydrogen (FLASH) Carriers in Electric Aviation, is a new hydrogen carrier technology developed at NREL within the HyMARC Energy Materials Network and is funded by the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy's Hydrogen and Fuel Cell Technologies Office through DOE's Technology Commercialization Fund.

FLASH seeks to deliver an alternative approach, in which efficient and long-lasting hydrogen storage is coupled to a fuel cell that continuously converts hydrogen to electricity to power electric UAV flight. That system would enable long-range flights, but without the carbon emissions of combustion engines. It would also enable sensitive drone applications like atmospheric monitoring, where exhaust gases and rumbling engines would reduce performance. *www.nrel.gov*

Sentient vidar sensors integrated on Edge Autonomy UAV

Sentient Vision Systems has successfully completed live demonstrations of its AI-enabled ViDAR (Visual Detection and Ranging) payload deployed on Edge Autonomy's VXE30 UAS. The VXE30 vertical take-off and landing (VTOL) solution is the latest and most advanced version of the "Stalker" series of small uncrewed aerial systems (sUAS) from Edge Autonomy. When coupled with Sentient's ViDAR, the VXE30 provides a passive, wide area search capability, enabling it to serve a myriad of maritime operations. *https://edgeautonomy.io*

Integration between RIEGL and StriekAir engineering

The renowned VUX-12023 laser scanner from RIEGL has been seamlessly integrated into the innovative VTOL CarryAir by StriekAir engineering GmbH from Germany. During its inaugural flight, this remarkable duo successfully captured accurate data of the ground structure.

The RIEGL VUX-12023 laser scanner is globally recognized for its exceptional precision and accuracy in aerial surveys. By integrating this cutting-edge technology into the VTOL CarryAir by StriekAir engineering GmbH, the advantages of both technologies are combined in the best manner. Its cruising speed of 85 km/h offers an optimal combination of point cloud density and efficient data acquisition.

With the VTOL CarryAir and the VUX-12023 laser scanner, customers can acquire data about eight times faster than with conventional multicopters. This significant time-saving feature enhances project efficiency, particularly for endeavors reliant on accurate measurements. *https://newsroom.riegl.international*

Scanning and mapping solution by Teledyne Optech

Inertial Labs has announced a new scanning and mapping solution for the RESEPI line. The RESEPI TELEDYNE OPTECH CL-360HD was strategically designed for projects requiring high performance.

RESEPI™ (Remote Sensing Payload Instrument) is a sensor-fusion platform for accuracy-focused remote sensing applications. It utilizes a high-performance Inertial Labs INS (GPS-Aided Inertial Navigation System) with a tactical-grade IMU and a high-accuracy dual antenna GNSS receiver, integrated with a Linux-based processing core and data-logging software. The platform also provides a WiFi interface, optional imaging module, and external cellular modem for RTCM corrections. https://inertiallabs.com

Syntony doubles the SDR L1C/A equivalent signals

Syntony GNSS has doubled the SDR L1C/A equivalent signals of its multi-GNSS simulation solution, Constellator.

With Constellator's computation power doubled from 660 L1C/A equivalent signals to 1200, users can simulate a complex RF environment for GNSS testing with a powerful and high-fidelity machine, the company said. Additionally, users can now test equipment with multiple traditional GNSS constellations and new ones to come, such as Xona's PULSAR.

As a result of doubled computation, massive new constellations can be simulated. When fully deployed, the Xona constellation will count hundreds of satellites on multiple bands, in complex RF environments including specific atmospheric parameters, jamming, spoofing and multipath. It also introduces the controlled reception pattern antenna (CRPA) testing capacities of the device, when the demand is increasing for resilient multi-GNSS and low-Earth orbit (LEO) position, navigation and timing (PNT) solutions. *https://syntony-gnss.com*

Hexagon equips the world's first fully autonomous road trains

Hexagon has announced a landmark agreement with leading diversified mining company Mineral Resources (MinRes) to provide an autonomous haulage solution for a fleet of 120 fully autonomous road trains in Australia, which will transform safety, productivity and sustainability in the region.

The world-first, fully autonomous road trains are a full-site, truck-agnostic solution. The addition of unmanned and autonomous systems will form an essential part of the supply chain for the MinRes Onslow Iron project in Western Australia's Pilbara region.

The centre of the autonomous platooning system is Hexagon's autonomous solutions stack integrating drive-by-wire technology with an autonomous management system to orchestrate vehicle movement in road train haulage. *hexagon.com*

Harxon introduces GNSS solution for precision agriculture

Harxon has launched its TS122 family of smart antennas for demanding precision agriculture applications. It is designed for high-performance semi-autonomous or autonomous applications that require centimeter-level accuracy – even in highly variable terrain and GNSS-obstructed environments. It can be used for agriculture OEMs, integrators that develop precision agriculture solutions, autonomous solution providers and more. There are two models for the new TS122 smart antenna: EUAA and EUUB. Each model has different performance options to fit users' individual needs. *https://en.harxon.com*

ANELLO Photonics releases new IMU

ANELLO Photonics has announced the availability of the ANELLO IMU+ for robust and reliable autonomous Navigation and Positioning in GNSS-denied or GNSS-compromised environments.

It delivers high precision and reliability in demanding conditions including shock, vibration, electromagnetic interference and temperature. The ANELLO IMU+ is intended for autonomous applications in the Construction, Robotics, Mining, Trucking and Defense space. Unlike other solutions in the market, it delivers superior long-term dead reckoning in high-temperature and high-vibration environments. *www.anellophotonics.com*

ComNav Technology launched Mars Pro Laser RTK

ComNav Technology Ltd. has introduced the Mars Pro Laser RTK, the latest addition to its Universe Series GNSS receiver lineup, which includes the Venus Laser RTK and Mars Laser RTK. It's laser mode helps in signal-blocked, hard-to-reach or hazardous areas,

where conventional GNSS receivers struggle. Users can effortlessly use the laser distance meter on the back of the Mars Pro to determine the distance between the receiver and the point. The effective distance of the laser is up to 10 m, ensuring signal-friendly accuracy even in GNSS-challenged places, such as in a garage, under a bridge, over the water, or in traffic.

Additionally, the integrated inertial measurement unit sensor provides up to 60°tilt compensation, ensuring efficiency and accuracy in conventional mode and laser mode. *www.comnavtech.com*

A Reconfigurable GNSS Payload in LEO Orbit

M3 Systems has launched a disruptive project, co-financed by the Occitanie Region, aiming to provide new GNSS services.

The IOD-full software-defined radio (SDR) GNSS project will enable new services through a reconfigurable SDR payload, enabling on-demand analysis of GNSS signals from space. Through space-based signal analysis, this project paves the way for reconfiguring GNSS signal processing and developing expertise in adaptable and scalable GNSS receivers to accommodate signals from future constellations.

M3 Systems, Loft Orbital, and Space Co-Design play a key role by providing rapid access to space for the facilitated and accelerated deployment of the receiver in orbit. Co-financed by the Occitanie Region, the IOD-full-SDR-GNSS project was selected as part of the "Nanosatellites Plan – Acceleration of In-Orbit Validations (IoD/IoV)" call for projects, co-developed with the French government based on the needs expressed by regional companies under the ADER 4 Recovery Plan. *https://m3systems.eu*

High-res aerial drone-based SAR System

GalaxEye, an Indian spacetech startup, has unveiled a cutting-edge high-resolution aerial drone-based Synthetic Aperture Radar (SAR) system. It allows for detailed and high-resolution imaging, even in adverse weather conditions like rain or clouds. The company's proprietary data fusion technology enables satellite constellations to overcome atmospheric obstacles and capture all-weather images.

The company aims to create a compact satellite constellation that can provide global coverage within a 12-hour timeframe. This continuous and high-quality imaging, combined with precise object geometry analysis, brings significant value to various industries such as insurance, precision agriculture etc.

Established in 2021 as a spin-off from IIT Madras, GalaxEye is focused on building India's first and the world's highest resolution multi-sensor imaging satellite. The company has forged strategic partnerships and commercial contracts with renowned organizations like Antaris Inc, XDLINX Labs, Ananth Technologies, and Dassault Systemes. *https://fagenwasanni.com*

GEODNET: Revolutionizing Access to Centimeter-Level GNSS Corrections

GEODNET, a decentralized blockchain-based network, is bringing a ground breaking solution to the problem of accessing low-cost GNSS corrections with centimeter-level accuracy. Unlike other providers that lack the necessary station density or have outdated stations, it offers an affordable approach that is accessible to everyone.

Since its launch in 2022, GEODNET has grown to encompass over 3,000 high-precision multi-band GNSS base stations worldwide. Individuals can set up Satellite Mining stations and receive the project's native Polygon token, GEOD, as a reward for contributing qualified CORS (Continuously Operating Reference Station) data.

One of the unique aspects of GEODNET is that anyone can be part of the network. Users can set up new stations, utilize existing stations, or build applications on top of the network. Transparency and community involvement are ensured through the network's implementation of a blockchain protocol.

The GEODNET Foundation, a non-profit organization, manages the open network protocol and promotes service use within the traditional GNSS and IoT industry. The foundation seeks to align the interests of miners and customers, ultimately enhancing the utility and value of the GEOD token.

To ensure the accuracy and reliability of data provided by GEODNET stations, there are two tiers of stations: backbone stations with over 99% reliability and more affordable stations with a target of 98% reliability. Stringent quality assurance measures are in place to monitor the signals for accuracy and spoofing. Each device has a unique ID, facilitating easy identification of valid stations and preventing the insertion of fake GPS data into the network. *https://fagenwasanni.com*

Reliance and NVIDIA Partner to Advance AI in India

NVIDIA and Reliance Industries have announced a collaboration to develop India's own foundation large language model trained on the nation's diverse languages and tailored for generative AI applications to serve the world's most populous nation.

The companies will work together to build AI infrastructure that is over an order of magnitude more powerful than the fastest supercomputer in India today. NVIDIA will provide access to the most advanced GH200 Grace Hopper Superchip and DGX™ Cloud, an AI supercomputing service in the cloud. GH200 marks a fundamental shift in computing architecture that provides exceptional performance and massive memory bandwidth.

The NVIDIA-powered AI infrastructure is the foundation of the new frontier

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October 2023

FIG COMMISSION 7 Annual Meeting 2023
2-4 October
The Netherlands
figcommission7@fig.net

Asian Conference on Remote Sensing (ACRS 2023)
30 October to 3 November
Taipei, Taiwan
https://acrs2023.tw

Intergeo 2023
10-12 October
Berlin, Germany
www.intergeo.de

United Nations/Finland Workshop on the Applications of GNSS
23 - 26 October 2023
Helsinki, Finland
https://www.unoosa.org

November 2023

GEOINT Innovation Summit
1-2 November 2023
National Harbor, Maryland, USA
https://geoint.dsigroup.org

43rd INCA International Congress
06-08 November 2023,
Jodhpur, Rajasthan.
https://43inca.org

Trimble Dimensions 2023
6-8 November
Las Vegas, USA
www.trimble.com

GoGeomatics Expo
6-8 November 2023
Calgary, Canada
https://gogeomaticsexpo.com

The Smart GEO Expo 2023
8-10 November
Gyeonggi Province
Republic of Korea.
www.smartgeoexpo.kr/fairDash.do

18th International Conference on Location Based Services (LBS 2023)
20-22 November
Ghent, Belgium
https://lbs2023.lbsconference.org

The Pacific GIS and Remote Sensing Conference
27 November - 1 December
Suva, Fiji
https://pgrsc.org

March 2024

Munich Satellite Navigation Summit 2024
20 - 22 March
Munich, Germany
www.munich-satellite-navigation-summit.org

April 2024

IGRSM Conference 2024
29 - 30 April
Kuala Lumpur, Malaysia
https://conference.igrsm.org

into AI for Reliance Jio Infocomm, Reliance Industries' telecom arm. *https://nvidianews.nvidia.com*

WiMi developed multi-objective 3D modeling

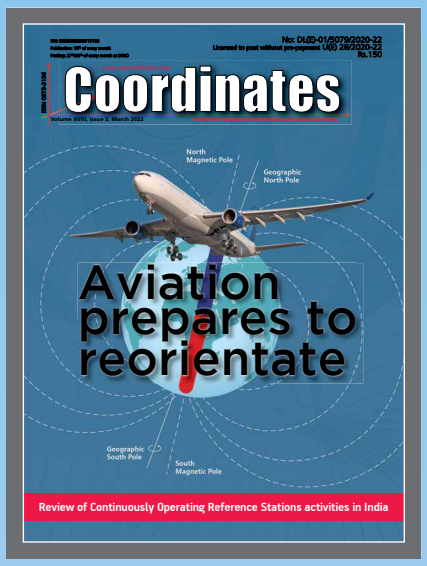
WiMi Hologram Cloud Inc. has announced that a multi-objective 3D modeling and reconstruction system has been developed based on artificial intelligence techniques. The system is able to be trained on large-scale datasets through deep learning algorithms and other advanced techniques, and optimization algorithms are used to improve the accuracy and generalization ability of the network. It also employs a variety of preprocessing and reconstruction algorithms to enable efficient and accurate 3D modeling and reconstruction. The core module of the system includes point cloud data acquisition, data preprocessing, feature point extraction, and mesh reconstruction. *http://ir.wimiar.com*

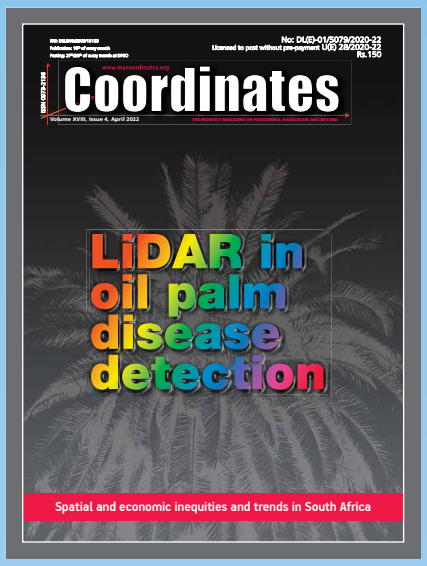
ICEYE for Near Real-Time Flood and Bushfire Data

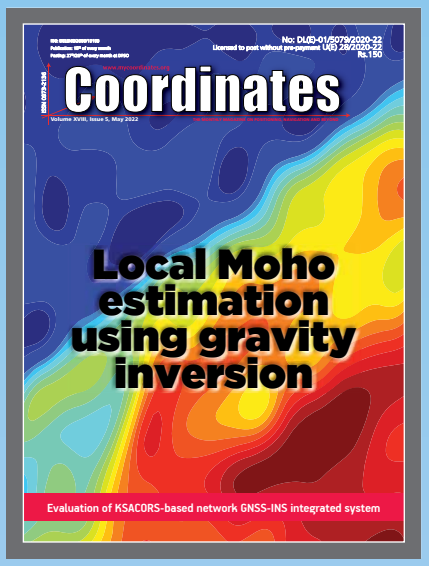
ICEYE has been selected by the Federal Government of Australia to supply flood and bushfire hazard data for all states and territories across the country. The announcement expands on the existing relationship between ICEYE and the Federal Government. *www.iceye.com*

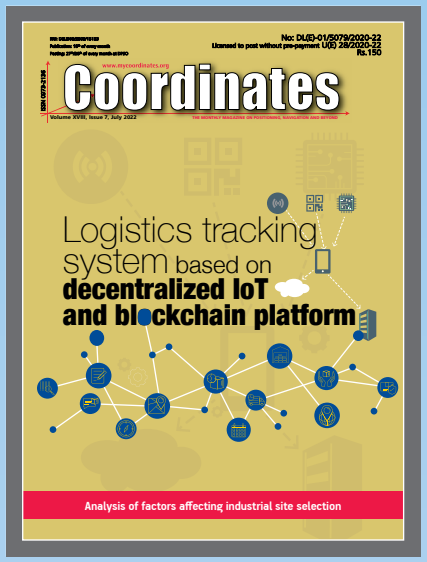
Qualcomm collaborates with Hyundai Motor Group

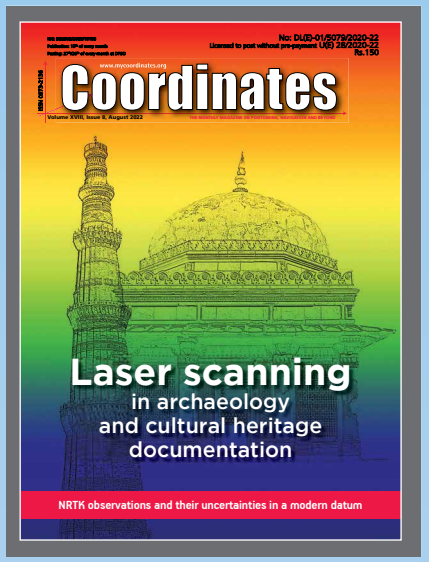
Qualcomm Technologies, Inc. has announced a technology collaboration with Hyundai Motor Group (HMG/the Group) in the area of purpose-built vehicles (PBVs). Designed to serve as a future mobility solution from the Group, the PBVs are engineered to provide transportation services, as well as additional services that cater to the diverse needs of individuals, such as comfort, logistics, commercial activities, and healthcare. As a part of the technology collaboration, the Group will incorporate the latest Snapdragon® Automotive Cockpit Platforms in its PBV infotainment system to provide a holistic, seamlessly connected and smart user experience. *www.qualcomm.com*

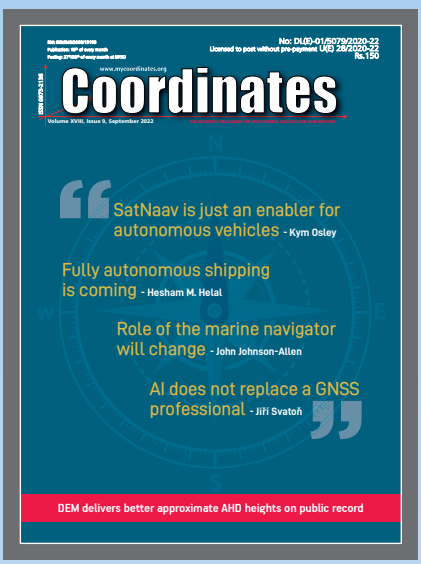


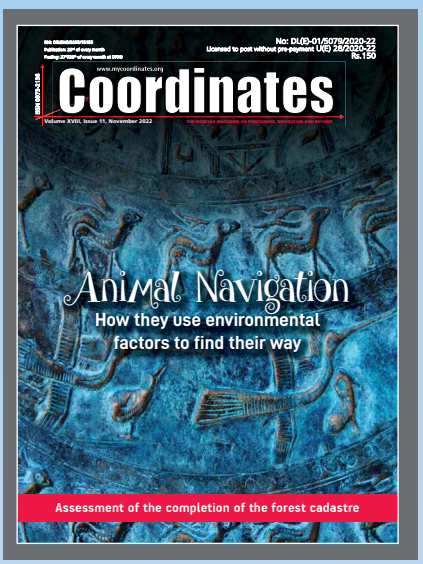












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