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# Coordinates

Volume XVIII, Issue 11, November 2022

THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

## Animal Navigation

How they use environmental factors to find their way

Assessment of the completion of the forest cadastre



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# In Coordinates



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10 years before...

## UN-GGIM: Global vision and perspectives

**Joobin Im**

Director General National Geographic Information Institute Republic of Korea

UN-GGIM and its activities are based on national and regional activities structured with involvement of related organizations of its field for an in-depth discussion as well as activities from a profession. UN-GGIM is a representative and effective consultation mechanism striving to resolve globally challenging issues through utilization of the geospatial information and has a system that can implement directly to policies, factors relating to the global geospatial information with a professional knowledge basis. UN-GGIM pursuing factors are something that cannot be resolved in a short timeframe but through continuing efforts carried out on an extended term.

## Measuring effects of mining on surface structure

**Eray Can, Senol Kusçu, Hakan Akçin and Çetin Mekik**

Geomatics Engineering Dept. Bulent Ecevit University Zonguldak, Turkey

Kozlu mining production region with extensive mining activities houses many crucial engineering structures, such as Kozlu Seaport, which are the core of this study and there are plans for new constructions on a daily basis in the region. In order to maintain the mining operations along with urban developments in a healthy way, the subsidence monitoring measurements and observations play an important role in mitigating or even preventing the damages that possibly will occur in the future and in giving way to desired urban development in the region.

## Leveraging national laws to protect community land rights

**Rachael Knight**

Director, Community Land Protection Program Namati

Once a community has successfully documented its land claims, the hope is that it may then work hand-in-hand with government agencies and civil society organizations to leverage its lands for locally-driven development, prosperity and human flourishing.

## Recognising indigenous community rights

**Tarun Ghawana**

Integrated Spatial Analytics Consultants, India

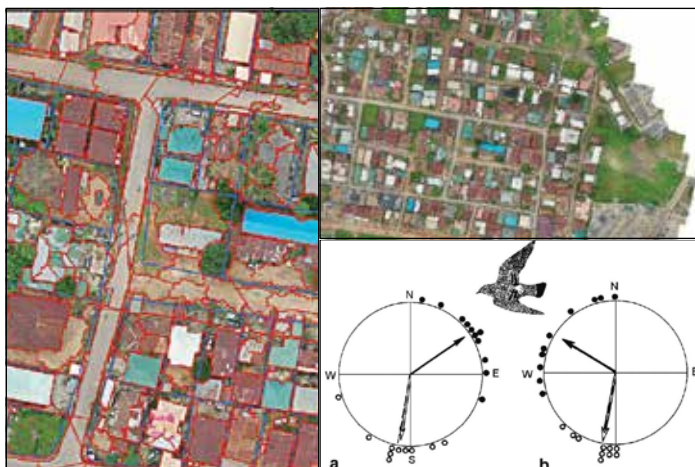
**João Paulo Hespanha**

University of Aveiro, Portugal

**Jaap Zevenbergen**

University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), The Netherlands

The study of the Act concerning the identification of the participating Actors and their roles in the administration of Indian Forest Land, led to the creation of two specialized classes, one for Group Parties, and other for individual Party elements, having each a dedicated enumeration type, respectively 'typeIFR' and 'roleIFR'.



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The euphoria around the creation of the Loss and Damage Fund

At the 27th Conference of the Parties to the United Nations

Framework Convention on Climate Change (COP27)

Has limited justifiability.

Though even to achieve this has been a herculean task, it is still not sufficient.

The objective of such negotiations should be simple.

To fix accountability of those, whose actions have endangered the entire planet

All of us are suffering because of them,

Not only the human kind but also all the living beings, for none of their faults.

Paying for the destruction against the nature is not enough.

It is less about the price.

It is more about the justice.

**Bal Krishna, Editor**  
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# Assessment of the completion of the forest cadastre considering the legal grounds, collaboration, and the use of technology

The General Directorate of Land Registry and Cadastre and The General Directorate of Forestry together with the participation of the private sector completed the forest cadastre of 6,246,845 hectares in eight years between 2010 and 2017



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## Abstract

The forests are among the natural resources that have important economic, environmental, and cultural functions. However, global problems, which have been increasing each passing day, such as industrialization, increasing urban population, global climate change, and destruction of biodiversity also threaten forests. The first condition for the protection of forests and carrying out forestry activities is the demarcation of forest boundaries and the registration of the forests. The forest cadastre has remained a major issue on Turkey's agenda for years. In this article, the process beginning with the demarcation of the forest boundaries until their registration in the land registry system was reviewed and assessed considering the institutional and legal frameworks and amendments, technology use, the collaboration between institutions, and the participation of the private sector. As a result of this collaboration, the General Directorate of Land Registry and Cadastre and the General Directorate of Forestry together with the participation of the private sector completed the forest cadastre of 6,246,845 hectares in eight years between 2010 and 2017. Moreover, the registration of 82.52% of these lands

was completed. Besides, solutions were proposed for other countries experiencing the same problem within the framework of the United Nations Sustainable Development Goals.

## Introduction

The latest data covering the forest assets in Turkey was published in 2015. The area of the forest lands was stated to be 21,537,091 hectares in 2010. This figure was stated as 22,342,935 hectares in 2015 (TFA 2019). According to the forest cadastre works completed in 2017, the area of the forest lands was found to be about 24,000,000 hectares.

According to the General Directorate of Forestry (GDF) Strategic Plan 2010-2014, the ownership of 99% of the forests in Turkey belongs to the state. The forest lands, which cover 27.6% of the area of Turkey, have important economic, environmental, and cultural functions. About 10% of the population of Turkey lives in forest villages or the villages in the vicinity of the forests, where forest resources provide a vital contribution to the livelihood of the villagers. Urban dwellers have a growing interest in forests, particularly due to their biodiversity and environmental and social functions. (FAO 2015).

Within the framework of Goal 15 of the United Nations' 2030 Agenda for Sustainable Development Goals, several studies have been carried out to provide sufficient incentives for the protection, restoration, and promoting sustainable use of forests, sustainable management of all forest types, stopping deforestation, restoring degraded forests by rehabilitation by 2030. Moreover, the proposed solutions for the forest-related issues were brought to the agenda of the international community.

The primary condition for the proper execution of the forest regime in line with modern forestry principles is the demarcation of the boundaries of the lands considered forests and their cadastre (Çağlar 2004). Forests are subject to registration in accordance with Article 11 of Forest Law No. 6831. The land is registered with the attribute of "forest" in the name of the Treasury. The registration can only be made after the completion of the forest cadastre. Forest cadastre covers the demarcation of the boundaries of the forests, the application works for the previous forest demarcation or cadastral operations following the new legislation, and registration of the lands whose boundaries are determined by the implementation of Article 2 of the Forest Law to the land registry system. The lands where the forest cadastre works and the application works were recently completed should be registered to the land registry system after solving the problems arising from the registration legislation of the General Directorate of Land Registry and Cadastre (GDLRC) and those arising from the private registered properties within the forest boundaries (GDF Strategic Plan 2013-2017).

In Turkey, the modern forest cadastre works started in 1937, when Forest Law No. 3116 entered into force. It was observed that forest demarcation and forest cadastre works were addressed in separate articles in the relevant Law. Article 10 of the Law stipulated that the forest demarcation works should be completed within five years. while Article 21 of the same Law stipulated that the

cadastral works should be completed within 10 years. However, the forest cadastre works could not be completed until today due to various problems encountered in the implementation of this Law and its related regulations (Gençay 2012; GDF Strategic Plan 2010-2014).

The fact that the forest cadastre and ownership problems have not been resolved yet were based on the following reasons: property cadastre and forest cadastre works being carried out by different authorities (Ayanoğlu 1992; Anbar 2004; Gençay 2012); rural cadastre works being carried out faster than forest cadastre works due to these difficulties in forest demarcation (Ayanoğlu 1992); the relations between the administration and the local people negatively affected due to ownership disputes in many places; carrying out forestry activities in areas whose boundaries have not yet been demarcated; intensive political and social pressures; frequent amendments in legislation; insufficient number of staff; lack of expert staff; deficiencies in technology transfer and applications; that the economic, social, and educational status of the forest villagers are lower; that the forestry activities are open to nature; that the administration traditionally has centralized and instruction-oriented approaches; that the forest villagers constitute the economically poorest part of Turkey and they are generally forest-dependent for their livelihoods, etc. (GDF 2006).

On the other hand, the following solutions were proposed to ensure the protection and the safety of the forest assets: demarcation

of the forests and registering them to the land registry system as soon as possible; facilitating the registration of the previous forest cadastre, which could not be registered to the land registry system, by cadastral renewal and update works (Köktürk 2004; Anbar 2004) carrying out property cadastre and forest cadastre works by a single administration (Anbar 2004); establishment of Forest Cadastre Information System (Köktürk 2004), and using modern technologies (Yalçın 2012; Livia et al. 2012).

The completion of the forest cadastre has become a corporate policy of the GDF. Also, this policy was included as a strategic goal in the annual reports and strategic plans of the institution. Annual Report 2011 states that it was aimed to complete the demarcation and cadastral procedures of all forest lands by the end of 2014, as well as, to complete the land registry procedures of the forest lands whose cadastre was completed and finalized. Moreover, it was stated that completing the forest cadastre procedures and registration of these lands to the land registry system was set as the ultimate goal in the Annual Report 2015 and Annual Report 2017 of the institution. On the other hand, in the GDF Strategic Plan 2010-2014, the goal was stated as completing the forest cadastre by the end of 2014. The issue was addressed in the GDF Strategic Plan 2010-2014 as the completion of the demarcation and cadastral procedures of the forest lands, as well as, the completion of the land registration procedures of the forest lands whose cadastre was completed and finalized. It was also

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In Turkey, the modern forest cadastre works started in 1937, when Forest Law No. 3116 entered into force. It was observed that forest demarcation and forest cadastre works were addressed in separate articles in the relevant Law. Article 10 of the Law stipulated that the forest demarcation works should be completed within five years.

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stated that significant legal and technical infrastructure works had been completed. The GDF Strategic Plan 2010-2014 stated the strategic goal as the complete elimination of the forest cadastre issue together with GDLRC by using state-of-the-art technologies at the end of the plan period. Moreover, the establishment of a “Forest Cadastre Information System”, where all digital and textual data about the permits granted for the lands considered forest and not forest were kept together, was also included in the goals of the GDF.

In a study on the factors that delayed the forest cadastre works and the solution of forest cadastre issue, Gençay (2012) stated that lack of coordination between institutions, insufficient attention paid by the administration, shortage of trained personnel and equipment were the most significant factors among others. However, the most significant conclusion of this study was that the problem could be solved by facilitating the collaboration of the institutions.

The present study evaluates the organizational structures, legal infrastructures, the uses of technology of GDLRC and GDF in terms of collaboration within the scope of the solution of the forest cadastre issue, examines the solution methodology, reveals the results of the implementation of the method, offers suggestions for the joint projects between institutions.

## Institutions and their duties

### The General Directorate of Forestry

The first initiatives in the forestry sector in Turkey started in 1839. In 1924, the Ministry of Agriculture was established and the GDF was affiliated. Forestry activities were carried out by GDF, which was affiliated with various ministries until today. GDF was affiliated with the Ministry of Agriculture and Forestry as per the Presidential Decree No. 4 dated 2018.

GDF carries out the forest cadastre activities through the Department of

Forest Cadastre and Ownership. The major duties of the Department of Forest Cadastre and Ownership can be listed as follows: performing forest cadastre procedures; carrying out works and procedures regarding the determination and evaluation of the areas taken out of forest boundaries; settlement of various disputes regarding state forests; carrying out works and procedures regarding the inspection and control of forests belonging to parties other than the state; carrying out works for granting permission, usufruct, and easement for forest areas; following up and finalizing the land registry procedures of the lands for which the forest cadastre works are completed, etc.

### General Directorate of Land Registry and Cadastre

The First Land Registry Organization was established in 1847, and it served under various names until 1923 when the Turkish Republic was declared. In 1924, the “General Directorate of Land Registry” was established, and the cadastre branch was added in 1925. GDLRC, which attained its current organizational structure in 1936, was affiliated with the Ministry of Finance, then it was affiliated with the Ministry of Justice in 1939. GDLRC had been affiliated with the Prime Ministry in 1951 and served 51 years in this organization until it was affiliated with the Ministry of Public Works and Settlement in 2002. Finally, it was affiliated with the Ministry of Environment and Urbanization in 2011 and has been providing service under this Ministry.

The Presidential Decree No. 4 dated 2018, defined the following tasks for GDLRC:

- i. Carrying out cadastre procedures in Turkey and to follow up the changes,
- ii. Ensuring renewal and updating of the cadastre plans and performing the related control and auditing services;
- iii. Ensuring the reliability of land registries, which is under the responsibility of the state, regularly,
- iv. Performing all kinds of contractual and non-contractual registration

- v. Following up and controlling the changes on the registers,
- vi. Ensuring the protection of records and documents by archiving,
- vii. Establishing a geodetic network, spatial information system infrastructure, and map production monitoring centre for the production of large-scale cadastral and topographic maps.

## Laws and regulations on forestry

### Laws and regulations on the Forestry Procedures

Land Law dated 1858, which was the first regulation on forests, stated that forests were public property and could not be subject to private property. On the other hand, Article 24 of the Forest Regulations dated 1870 prohibited the acquisition of the state-owned forests and forests specific to villages and towns through prescription.

The regulations on the forests are inspired by the principles of protection of forests and ensuring their sustainability, governance, and execution of the forest regime by the State, and demarcation of the forest boundaries within this framework. During the Republic period, forestry regulations were made after the Civil Code, which entered into force in 1926. The first comprehensive regulation on forestry was Forest Law No. 3116 dated 1937. This Law aimed to demarcate the boundaries of the State forests, to survey the forest lands and register them to the land registry system, and to complete these procedures within 5 years. The task of demarcation and mapping of the forests was assigned to the Forest Cadastre Commissions affiliated with the GDF. The “Regulation on the Demarcation and Registration of Forests” entered into force as the technical principles for the demarcation of the forests. The demarcation of the state-owned forests could not be completed in 5 years due to several challenges in terms of surveying, etc. According to the provisions of Law



No. 4785, which entered into force in 1945, all forests belonging to real or legal persons were expropriated.

Law No.5653 and Law No. 5658, which were entered into force in 1950, amended the regulations. According to these laws, the forest lands that were subjected to private ownership in the forest demarcation/cadastral works carried out until 1945, were taken out of forest boundaries. With Law No. 6831 dated 1956, the term “forest” was defined, the lands that could not be considered forest were determined, and forests were classified in terms of their ownership and management.

The prerequisite for the sustainability of the forest regime is the demarcation of the forest boundaries, performing the cadastral works, and securing it by registering it to the land registry system. With the Constitution of 1961, the principle that the ownership and management/operation of the forests would be carried out by the Government has become the basic principles of the Forest Law for the protection and sustainability of the forests. Article 131 of the Turkish Constitution of 1961 ruled that the areas that scientifically and technically lost their forest character before 15 October 1961 should be taken out of forest boundaries.

Turkish Constitution of 1982 assigned the duty of protecting forests and expanding forest lands to public institutions. The Constitution ensured that the ownership of forests belonging to the state could not be transferred. However, the following areas were allowed to be taken out of forest boundaries:

- i. The lands on which preservation of forest would be of no scientific and technical benefit, even converting them into agricultural lands would provide certain benefits,
- ii. The lands that scientifically and technically lost their forest character before 31 December 1981, and determined to be suitable for various agricultural purposes such as farmland, vineyard, garden, orchard, olive

- grove, or livestock purposes,
- iii. The residential areas where city, town, or village buildings exist together.

As can be understood from Article 169 and Articles 170 of the Turkish Constitution of 1982, the forests that are guaranteed by the Constitution and the shrinkage of which are prohibited are subject to registration.

Forest demarcation is the delimitation works carried out within the scope of Forest Law No. 3116 dated 08.02.1937.

The Forest Cadastre means the determination of all real estates in the forests and adjacent to forests, and the common boundaries of the forests, as well as, the registration of these forest lands with the ownership of the Treasury (the works carried out within the scope of Forest Law No. 3116, Forest Law No. 6831, and Article 4 and Additional Article 5 of the Cadastre Law No. 3402). Taking out the areas that scientifically and technically lost their forest character in the name of Treasury (i.e. execution of Article 2/B) is also a part of forest cadastre.

With Forest Law No. 3116 dated 01.07.937, the works for demarcation (delimitation) and mapping of the forest lands were started by GDF (via the Forest Cadastre Commissions). Forest Law No. 3116 was repealed, and Forest Law No. 6831 dated 08.09.1956. With the new law, Forest Cadastre Commissions continued to the forest cadastre works for the forest lands belonging to the state, the forests that had been previously demarcated as forest but taken out of forest boundaries during the last demarcation even though it was forest land, the forests belonging to the public institutions with a legal personality, the private forests, as well as, determination

of the common boundaries of all real estates in the forests and adjacent to forests.

On the other hand, with the “Law No. 1744 on the Amendment of Some Articles of the Forest Law No. 6831 and Adding a Provisional Article to this Law”, which entered into force on 04.07.1973, the lands that scientifically and technically lost their forest character before 15 October 1961 began to be taken out of forest boundaries as stipulated by Article 131 of the Turkish Constitution of 1961.

With Law No. 2896 dated 23.09.1983 which amended Forest Law No. 6831, the lands that scientifically and technically lost their forest character before 31 December 1981 were continued to be taken out of forest boundaries for the settlement of all or part of the inhabitants of the villages located in the forest lands or allocation for these purposes after reclamation works carried out by the Government as stipulated by Article 169 and Article 170 of the Turkish Constitution of 1982.

With Law No. 3302 dated 05.06.1986, which also amended Forest Law No. 6831, the procedures of taking an area out of forest boundaries were carried out together with the demarcation works for the first time in forest cadastre.

The Forest Laws stipulated that technical works such as surveying and mapping during forest demarcation/cadastral works would be carried out by the Forest Cadastre Commissions. However, there was no “survey engineer” in these commissions. Therefore, the forest maps prepared during the demarcation/cadastral works following Forest Laws were not produced under the responsibility of a survey engineer until 2003. Most of the forest maps produced until this year could not

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be registered to the land registry system due to the lack of technical quality. The forest maps that were registered directly to the land book without undergoing technical control by the cadastre directorates, also posed problems as they contained technical deficiencies.

Due to the need for legal regulations in this context, the following provisions have been introduced with the “Law on Amending the Forest Law” No. 4999 dated 18.11.2003:

- i. Technical errors detected in the lands whose cadastre procedure has been finalized shall be corrected by the Forest Cadastre Commissions,
- ii. Taking aerial imagery and map production works required for cadastre and other forestry services shall be carried out by GDF,
- iii. For the lands where forest demarcation or cadastre works are completed and finalized by the announcement, in case of an issue detected in terms of the acreage and technical errors arising from surveying, drawings, and calculations, except for the change of classification and ownership, these errors shall be corrected by Forest Cadastre Commissions under the notice and supervision of GDF,
- iv. The correction shall be announced following Article 10 of the Law, in case of no lawsuit is filed with the civil court of peace within thirty days from the date of the announcement, the correction shall be finalized.
- v. The lapse of time stipulated in Article 11 shall not be applied to the corrections,
- vi. Survey and cadastre engineers shall be responsible for surveying, calculating, drawing, and application work in the preparation of the maps of forests whose cadastre is completed, and these maps, which are produced following the cadastral technical standards, shall be approved by the head of the commission after the control by the survey and cadastre engineers.

With Law No. 6292 dated 19.04.2012, an additional paragraph was added to Article 10 of Law No. 6831. This paragraph states that “Surveying, calculation, drawing, and application works for the preparation of maps of forests whose cadastre works are completed or ongoing shall be carried out by survey and cadastre engineers or technicians; the responsibility shall belong to the survey and cadastre engineers; a control engineer shall be assigned by the local directorate of GDLRC to ensure that the surveying and mapping procedures conducted in the field are carried out duly and to control and approve these works; the maps, which are produced following the cadastral technical standards, shall be approved by the head of the commission after the control approval of the survey and cadastre engineers”.

Law No. 7139 dated 19.04.2018 also amended the Forest Law No. 6831. This amendment states that the Forest Cadastre Commissions shall be organized with a head of a forest engineer appointed by GDF and three members including a forest engineer, or a forest technician in case of their absence, an agricultural engineer, or an agricultural technician in case of their absence, and a representative to be notified by the municipal committee in the towns and by the village head (mukhtar) in the neighbourhoods and villages. Also, Article 10 of Law No. 7139 amended the seventh clause of Paragraph 7 of Article 9 of the Forest Law No. 6831. This amendment stipulates that the correction shall be finalized in case of no lawsuit is filed to the cadastral courts or courts responsible for the cadastral cases where there are no cadastral courts for the cancellation of the correction within thirty days from the date of the announcement.

### **Laws and regulations on land registry and cadastre procedures**

GDLRC, which is affiliated with the Ministry of Environment and Urbanization, has been carrying property cadastre procedures since 1925 until today as per the following laws: Cadastre Law No. 658 dated 1925, Cadastre and Land Registration Law No. 2613 dated

1937, Land Registration Law No. 5602 dated 1950, Land Registration Law No. 509 dated 1964, Law No. 766 dated 1966, and Cadastre Law No. 3402 dated 21.07.1987; however, Law No. 2613 and Law No. 766 were repealed upon need.

As per Law No. 2613 dated 1934, demarcation of the forest lands and their cadastre were excluded from the scope of the cadastral procedure of the real estates located in the central municipalities of the provinces and districts.

The Land Registration Law No. 5602 dated 1950, and the Land Registration Law No. 766, which entered into force in 1966 and was in force until 10 October 1987, were introduced to establish the land registration stipulated in the Civil Code. These laws stated that they could not be applied in forest lands. Article 2 of the Land Registry Law No. 766 stipulates that “Unclaimed lands that are not suitable for agriculture and unclaimed rocks, hills, mountains with the same character, and the lands deemed forests under the Forest Law shall not be subject to registration”. Therefore, the forests that have not yet been subjected to forest cadastre by GDF were excluded from the scope of the cadastral finalization works carried out by GDLRC until Law No. 3402 dated 1987.

However, because the boundaries of the forest lands were not certain, several objections were made about the finalization of those lands, the works dragged on; as a result, the required efficiency could not be achieved. Therefore, a meeting was held with the participation of the representatives of the State Planning Organization (SPO), GDF, and GDLRC to overcome the problems in the demarcation of the forest boundary and ownership of real estates in these lands, to accelerate the work by taking joint administrative and technical measures, and to improve the work efficiency. As a result of this meeting, a protocol was signed between GDLRC and GDF on 18.03.1965. Then, GDLRC published the circular numbered 4-1-1-7.1391 and dated 09.07.1965. In this circular, the works to be carried out and the measures to be

taken by both institutions regarding the forest lands in the villages to be subjected to the rural cadastre were explained.

The Cadastre Law No. 3402 was introduced in 1987 to complete cadastral works quickly and without interruption and to prevent unnecessary financial losses and waste of labour by causing duplicate works with different practices carried out by various institutions. Article 4 of Law No. 3402 stipulated the following provisions:

- i. In case of forest land that is not demarcated or subjected to forest cadastre in the cadastral area, the situation shall be reported to GDF two months before starting the cadastral work,
- ii. The procedures of forest demarcation and taking areas out of forest boundaries shall be carried out by forest cadastre commissions as per Forest Law No. 6831. Forest cadastre commissions shall finalize the procedures and mark them on the map and deliver them together with their records to the cadastral teams.
- iii. Cadastre teams shall complete surveying and mapping works of these lands based on the above-mentioned boundaries,
- iv. In case the forest boundaries cannot be demarcated by the forest cadastre commissions within two months, the boundaries of the cadastral area shall be determined by the cadastral teams,
- v. In the places finalized and announced by the cadastral teams in this way, the forest cadastre procedures shall be deemed to have been completed, these boundaries shall be strictly observed in places where the forest cadastre is finalized.

This practice continued until 2005 when a new regulation was introduced on this issue. In 2005, with the amendment made in Article 4 of the Cadastre Law No. 3402, the following provisions were stipulated:

- i. In case there is forest land in the cadastre project area and the forest

cadastre per Forest Law No. 6831 has not been started, the cadastral team shall carry out the forest cadastre and determine the common boundaries of all kinds of real estates in these forests and adjacent to these forests and finalize them.

- ii. In these works, at least one forest engineer to be assigned by the provincial organization of the GDF and an agricultural engineer to be assigned by the Agricultural Directorates shall participate in the cadastral team within seven days from the notification.
- iii. In case the village head (mukhtar) and expert witness do not participate in these works, the works shall be continued ex officio,
- iv. In the examination of the objections made about the forest, a forest engineer to be assigned by the provincial organization of the GDF and an agricultural engineer to be assigned by the Agricultural Directorate, who have not taken part in the finalization work subject to objection, shall participate in the cadastral commission,
- v. The demarcation of the forests in the cadastre project area and their finalization shall be made by this team, and it shall be partly announced for thirty days.
- vi. The forest cadastre in these places shall be deemed to have been made, and these boundaries shall be followed exactly where the forest cadastre is finalized.

The additional Article 5 added to the Cadastre Law No. 3402 in 2013 stipulated that the forests that were not demarcated or did not undergo forest cadastre within the project areas where cadastre or rural cadastre works were completed should be subject to cadastre within the framework of the principles stated in Articles 4 and 39.

The following provisions were introduced with the paragraphs added to Article 4 of the Cadastral Law No. 3402 in 2018:

- i. In case of detection of incompatibility between records,

sheet, and ground requiring correction in forest maps that are finalized after forest demarcation or cadastre, regardless of whether it is registered to the land registry system or not, the cadastre team to be formed with the participation of at least one forest engineer to be assigned by the related forestry directorate and a control engineer or engineer to be assigned by the cadastre directorate as per Article 3 of this Law shall apply the boundary points and lines of the forest to the ground based on the forest cadastre records,

- ii. The detected incompatibility shall be corrected following the technical regulations by the abovementioned cadastral team organized; at the end of the work, a report shall be prepared, and this report shall be signed together by the team members and the forest and cadastre engineers.
- iii. The correction procedure shall be finalized following the announcement to be made as per Article 11 of this Law,
- iv. Provided that GDLRC obtain the approval of the Ministry with which it is affiliated and the costs of such works are paid by GDF to the account of GDLRC Revolving Fund, GDLRC may also have some or all of the technical parts of such works done by natural or legal persons by way of tenders, and these tenders shall allow making commitments for the next years.

## Use of technology

In the forest cadastre works, compass tacheometry method (1937-1964), photogrammetric method (1965-1982), terrestrial surveying methods (1982), and GPS method (1998) were used from past to present (Döner et al. 2016).

As per Law No. 6831, theodolites were started to be used in the forest cadastre works after 1960 (Tüdeş T & Bıyık C 1997). In the survey method, the starting

point was selected from certain points; however, the sequential boundaries of the forests, instead of the district boundaries, were taken this time. To complete the surveying of the boundaries of the forest more quickly, the angles were measured using a theodolite in grades, and distances were measured using a levelling rod in the traverse surveying according to those days' technology. The polygonal chains obtained were not connected to the national triangulation network. A specific point of the village or town, such as a mosque or a school, was taken as a reference, and the boundaries were ditched in the field; however, they disappeared over time. The collapse or displacement of buildings, which were deemed fixed and stationary points, did not often allow the demarcation map correctly to the ground (Ayanaoğlu 1992). This method was abandoned after using aerial photographs in mapping.

Then, the Photogrammetry Method, which is defined as "Photo interpretation and manual marking of forest lands into aerial photographs with 60% overlapping under stereoscopic view", was used. The aerial photographs marked in this way were evaluated using photogrammetry devices and transferred to 10K-scale maps obtained from 25K-scale standard topographic maps by using photomechanical methods. Later, this method, which aimed to demarcate the boundaries of forests quickly, brought about the issue of producing maps without technical quality.

The above-mentioned method was also used in the "Forest Cadastre" works within the scope of Law No. 1744. In addition to this method, the forest cadastre works were carried out using the images of 5K-scale Standard Topographic Maps and Standard Topographic Cadastral Maps showing integrity with the land in places where these maps were already produced. Also, the forest cadastre works were carried out by marking the parcels surveyed using the terrestrial surveying method on 10K- and 5K-scale maps.

All of the above-mentioned methods were abandoned as of 1983. Moreover, the principle of performing forest cadastre

works using the terrestrial surveying method has been adopted since then. In case the forest cadastre or forest demarcation was to be re-marked (application) on the ground, it was suggested as the main principle that the work would be renewed by using the same technique and tools that had been used in the previous work.

The Technical Circular on the Forest Cadastre, which entered into force in 1997, aimed to ensure unity and solidarity in the forest cadastre works and procedure, implementation of Article 2/B of the Forest Law No. 6831, and implementation of Article 4 of the Cadastral Law No. 3402. In this framework, the terrestrial surveying method was used as the main surveying method to demarcate the borders of the forests. However, the use of aerial photographs was permitted if they complied with the principles specified in the Regulation on the Production of Large-Scale Maps. Moreover, the Circular dated 2014 allowed the use of the GPS method in surveys. Now, the Regulation on the Production of Large-Scale Maps and Map Information and the current "Technical Circular on the Forest Cadastre" are followed in the forest cadastre works.

## Solution methodology

### Collaboration

GDLRC has started the initial cadastre works in 1925, and GDF has started the forest cadastre works in 1934. However, the performance of the cadastre works by two institutions has brought about several problems since then.

Several problems were faced in the registration of the forest maps produced by the Forest Cadastre Commissions since they did not employ a survey engineer and these maps did not comply with the technical standards. Therefore, some of the forest cadastre works could not be registered by GDLRC. Another problem was that the technical errors could not be corrected by GDF without a judicial decision (as well as the lack of a legal regulation on this issue).

Another issue was that the number and the organization of the teams and the cadastral activities (initial cadastre and forest cadastre activities) of both institutions were different. Therefore, the works could not be carried out synchronously, which caused duplications.

Two actions were taken to eliminate these problems. Firstly, employing a survey engineer to the forest cadastre commissions was decided to eliminate the technical errors in the forest maps under the responsibility of the survey engineer. However, the number of forest cadastre commissions was another issue even they were supported by employing a survey engineer. Therefore, the second effective formula was decided to increase the number of forest cadastre commissions to facilitate completing the forest cadastre works throughout the country. The best formula to solve this problem was the combination of the resources of GDF, as an expert institution in forestry, and GDLRC, as an expert institution in mapping. It was concluded that the collaboration environment should be provided for both institutions to carry out this work together.

Thus, carrying out the works with an understanding of 'collaboration' by mutual transfer of resources and staff (assignment) was decided to be an effective solution. Therefore, several fundamental and radical amendments were made in both Forest Law No. 6831 and the Cadastre Law No. 3402 in 2003, 2005, 2013, and 2018. These amendments could be considered reforms required for the needs of the time.

### Establishment of the legal infrastructure

Until 2003, the Forest Laws stipulated that technical works such as surveying and mapping in the forest demarcation/cadastre should be carried out by the Forest Cadastre Commissions. Since these commissions had no "survey engineer" within their organizations, the forest maps were prepared according to forest demarcation/cadastre, which was not carried out under the responsibility

of a survey engineer. Moreover, since most of these maps lacked technical accuracy, several challenges were faced in the registration. Law No. 4999 on the Amendment of the Forest Law dated 18.11.2003, stipulated that the correction of the technical errors detected in the finalized cadastre should be carried out by the Forest Cadastre Commissions for the solution of this problematic issue (for the lands where forest demarcation or cadastre works are completed and finalized by the announcement, in case of an issue detected in terms of the acreage and technical errors arising from surveying, drawings, and calculations, except for the change of classification and ownership).

After the first step was taken for correcting the technical mistakes in forest maps, a further step was taken in 'collaboration'. This time, Article 3 of Law No. 5831 dated 15.01.2009 stipulated the following provisions: "In the places where cadastre works started as per Cadastre Law No. 3402, in case of acreage errors arising from the calculations is detected during the control of the previously finalized forest maps, these errors shall be corrected by the cadastral team formed as per Article 4 of the Law No. 3402. In case of other issues in terms of the acreage and technical errors arising from surveying, drawings, and calculations, except for the change of classification and ownership, the Cadastral Directorate shall report the issue to the local forest directorate. A forest cadastre commission shall be assigned within 15 days from the date of notification and the correction shall be announced".

Then, Paragraph 10 of Article 11 of Law No. 6292 dated 19.04.2012 was repealed by Article 54 of Law No. 7139 dated 19.04.2018. Also, as per Article 35 of this Law, Paragraph 13 and Paragraph 14 were added to Article 4 of Law No. 3402. These paragraphs stipulated the following provisions:

- i. "In case of detection of incompatibility between records, sheet, and ground requiring correction in forest maps that are finalized after forest demarcation or cadastre, regardless of whether

it is registered to the land registry system or not, the cadastre team to be formed with the participation of at least one forest engineer to be assigned by the related forestry directorate and a control engineer or engineer to be assigned by the cadastre directorate following Article 3 of this Law shall apply the boundary points and lines of the forest to the ground based on forest cadastre records,

- ii. The detected incompatibility shall be corrected following the technical regulations by the above-mentioned cadastre team to be organized; at the end of the work, a report shall be prepared, and this report shall be signed together by the team members and the forest and cadastre engineers. The correction procedure shall be finalized following the announcement to be made as per Article 11 of this Law,
- iii. Provided that GDLRC obtain the approval of the Ministry with which it is affiliated and the costs of such works are paid by GDF to the account of GDLRC Revolving Fund, GDLRC may also have some or all of the technical parts of such works done by natural or legal persons by way of tenders, and these tenders shall allow making commitments for the next years.

Thus, the technical errors in forest maps could be corrected by the forest cadastre commissions, as well as, by the cadastre team to be formed by GDLRC with the participation of a forest engineer from the GDF and a control engineer from the cadastre directorate.

An additional paragraph was added to Article 10 of Law No. 6831 as per Article 13 of Law No. 6292 dated 19.04.2012. This additional paragraph states that "Surveying, calculation, drawing, and survey applications for the preparation of maps of forests whose cadastre works are completed or ongoing shall be carried out by survey and cadastre engineers or technicians; the responsibility shall belong to the survey and cadastral

engineers; a control engineer shall be assigned by the provincial directorate of GDLRC to ensure that the surveying and mapping procedures conducted in the field are carried out duly and to control and approve these works; the maps, which are produced following the cadastral technical standards, shall be approved by the head of the commission after the control approval of the survey and cadastre engineers".

Moreover, an additional paragraph was added to Article 10 of Law No. 6831 as per Article 13 of Law No. 6292. This additional paragraph stipulated that "Surveying, calculation, drawing, and application works for the preparation of maps of forests whose cadastre works are completed or ongoing shall be carried out by survey and cadastre engineers or technicians; the responsibility shall belong to the survey and cadastre engineers; a control engineer shall be assigned by the local directorate of GDLRC to ensure that the surveying and mapping procedures conducted in the field are carried out duly and to control and approve these works; the maps, which are produced following the cadastral technical standards, shall be approved by the head of the commission after the control approval of the survey and cadastre engineers".

Collaboration between the two institutions can be achieved in two ways. In the first option, in case the technical errors in forest maps are corrected by forest cadastre commissions, a control engineer from GDLRC may involve in the correction procedure. In the second option, in the forest cadastre works to be carried out by forest cadastre commissions, the surveying, calculation, drawing, and application work for the preparation of forest maps are carried out by the survey engineers or technicians to be assigned by the related cadastre directorate.

GDLRC has been carrying out forest cadastre during the initial cadastre works since 2005 (Article 4 of Law No. 3402). Moreover, GDLRC has been carrying out forest cadastre for the forest lands that were not finalized during the initial cadastre works completed in the villages or

The amendments made to the laws in 2004 and 2005 introduced radical changes in both forest cadastre and general cadastral activities carried out by GDLRC. With these changes, the task of demarcating the forest boundaries in places that did not undergo cadastre was assigned to the GDLRC cadastre teams. It was stipulated that at least one forest engineer from the GDF and an agricultural engineer from the agricultural directorate should be assigned to these teams.

quarters since 2013 (Additional Article 5 of Law No. 3402). In these works, a forest engineer from GDF and an agricultural engineer from the agricultural directorate participated in the cadastre team.

### Use of technology

The amendments made to the laws in 2004 and 2005 introduced radical changes in both forest cadastre and general cadastral activities carried out by GDLRC. With these changes, the task of demarcating the forest boundaries in places that did not undergo cadastre was assigned to the GDLRC cadastre teams. It was stipulated that at least one forest engineer from the GDF and an agricultural engineer from the agricultural directorate should be assigned to these teams. Thus, GDF personnel participated in the cadastral works carried out by GDLRC in 3,000 villages since 2006 as per Law No. 3402.

GDF established GPS Teams in 8 Regional Directorates of Forestry for supporting all Forest Cadastre Commissions, densification of the triangulation network, and digitization of forest cadastral maps. Also, a control system based on a database was developed and put into practice. Moreover, a geographic information system-based map server was also put into service for the first time on a portal on the official website of GDF. Technical Circular on Forest Cadastre was prepared again to harmonize sub-regulations in line with the amendments in the laws considering the current techniques and technologies specified in the amended Regulation on the Production of Large-Scale Maps and Map Information in 2005.

As of 2014, great progress has been achieved by adopting the following approach in the Technical Specification for the Production of Forest Maps: “All kinds of coordinates shall be produced based on the latest version of Turkish National Fundamental GNSS Network (TUTGA), and 1/5000 scale digital photogrammetric vector maps and orthophotos shall be georeferenced with the Universal Transverse Mercator (UTM) projection with 3-degree zones using GRS80 ellipsoid and ITRF96 Datum. The digital data to be produced shall meet the standards specified in the relevant articles of the Regulation on the Production of Large-Scale Maps and the draft Regulation on the Production of Large-Scale Maps and Map Information.

On the other hand, GDLRC used the Regulation on the Production of Large-Scale Maps and the circulars published by the institution on the GNSS (Global Navigation Satellite System) surveying, calculation, and control, which are not addressed in the regulation.

With the widespread use of the CORS-TR (Continuously Operating Reference

Stations) project, both institutions began to use it in 2009. Since CORS-TR has become the national fundamental infrastructure in geospatial projects, it has been widely used by all institutions and organizations. Also, geographical information systems applications have been widely used for creating the spatial data infrastructure in both institutions. With these technological developments, both GDLRC and GDF began to produce and share digital geospatial data.

### Results

Several significant factors caused the problems experienced for years in forest cadastre. The first factor was that the cadastre was classified as forest cadastre

**Table 1. Forest lands that underwent forest cadastre and were registered**

Year	Acreage of the forest lands that underwent forest cadastre		Acreage of the Forest lands that were registered	
	Cumulative acreage (ha)	Increase (ha)	Cumulative acreage (ha)	Increase (ha)
1973	4,558,000	-	3,055,079	-
2004	12,446,407	7,888,407	4,653,000	1,597,921
2010	17,573,155	5,126,748	11,824,130	7,171,130
2011	17,746,416	173,261	12,188,834	364,704
2012	19,073,052	1,326,636	16,230,739	4,041,905
2013	19,175,273	102,221	16,749,736	518,997
2014	20,774,691	1,599,418	16,950,000	200,264
2015	21,240,530	465,839	17,799,940	849,940
2016	23,450,000	2,209,470	18,860,000	1,060,060
2017	24,000,000	550,000	19,500,000	640,000
2018	-	-	19,806,000	3,506*

\*The data for 2018 are taken from the GDF official website.

**Table 2. Forest lands that the areas taken out of forest boundaries**

YEAR	Acreage of the areas taken out of forest boundaries	
	Cumulative acreage (ha)	Increase (ha)
1973	-	-
2004	341.521	341.521
2010	411.843	70.322
2011	432.397	20.554
2012	439.473	7.076
2013	450.461	10.988
2014	473.081	22.620
2015	483.155	10.074
2016	502.000	18.845
2017	535.598	33.598
2018	538.005	2.407

and property cadastre, and they were carried out by different institutions. The second factor was the technologies used in the cadastre works; although they were widely used in those days, they were obsolete today. Another factor was the complex structure of regulations due to frequent amendments due to needs.

The solution to the problem was achieved by giving priority to the completion of the property cadastre for meeting the investment priorities for the development of the country and the evolving needs with the conditions of the day, as well as, to solve the ongoing problems about forest lands and other property problems that arose in the following years due to these problems (such as ownership, acquisition, possession/occupation, real estate boundaries belonging to real persons, as well as, disputes about the property boundaries, zoning, settlement, land consolidation, energy projects, dam construction, infrastructure, agriculture, pasture, Article 2/B applications, renewal, technical error correction, etc.).

Forest cadastre was carried out by cadastre teams following Article 4 of the Cadastre Law No. 3402 during the initial cadastre, which was carried out following this Law. Then, it was carried out by forest cadastre commissions following Forest Law No. 6831.

As per Law No. 6495, Additional Article 5 was added to Law No. 3402. With this amendment, cadastre teams (with the participation of a forest engineer and an agricultural engineer as stipulated by Article 4 of Law No. 3402) have begun to carry out all forest cadastre works.

The collaboration between institutions was achieved based on the idea to eventually register the forest cadastre, and the required regulation amendments were made. Within the scope of the solution methodology,

the approach of the participation of the private sector in forest cadastre works was adopted for digital and quick cadastre.

Therefore, the technical parts of the cadastre works were given out by contracts to the private sector by GDLRC under the coordination of both institutions. This outsourcing approach accelerated the projects through the use of modern technology.

Table 1 shows the distribution of forest cadastre and registration completed in recent years (TFA 2019). The history of the forest cadastre in Turkey started with Law No. 3116 in 1937. By 1973, only 4,558,000 hectares of the forests could undergo cadastre procedure. Between 1937 and 2004, only 51.8% of the forests could undergo cadastre procedure, and only 19.38% of the forests could be registered. However, thanks to the collaboration between the institutions and the use of the private sector, the forest cadastre of the remaining 48.2% and the registration of 60.2% were completed between 2010 and 2017. As of 2018, the forest cadastre of 24,000,000 hectares of forest has been completed, and 19,806,000 hectares of forest were registered. Registration works continue for forests that have not been registered yet.

As can be seen from Table 2, within the scope of forest cadastre studies, 538.005 hectares of land were removed from the

forest and registered in the land registry according to the article 2-B of the Forest Law Number 6831 as of the end of 2018 (TFA 2019). According to the 2020 report of the National Property General Directorate, 581,000 of the registered parcels were taken out of the forest and sold to their users (NREB'20).

## Conclusion

Cadastre Law No. 3402 aims to determine the legal status of real estates by marking their boundaries on the ground and map according to the national coordinate system and based on the cadastral maps or topographic cadastral maps. Thus, the land registry shall be established as stipulated by the Turkish Civil Code No. 4721, and the spatial information system infrastructure shall be established. Cadastre Law No. 3402 does not classify the cadastre of the real estates as property cadastre, forest cadastre, pasture cadastre, agricultural cadastre, etc. In other words, this law aims to determine the technical and legal status of real estates through cadastre and to establish their land registry accordingly.

Collaboration was achieved between the two institutions engaged in property cadastre and forest cadastre by establishing legal and technical infrastructures within the framework of the definition of Cadastre.

Thanks to the participation of the private sector, the forest cadastre was completed in digital format and in a very short time between 2010 and 2017 at the end of the project. Moreover, the registration of 82.52% of these lands was completed. Effective and efficient use of public resources has been through collaboration. However, a major social problem was solved by making cadastre of the areas taken out from the forest and these parcels were sold to the users.

In addition to these achievements, a model compatible with the UN Agenda 2030, Digital Transformation, Sustainable

Development Goals has been created. This model sets an example for other countries experiencing similar problems within the framework of Goal 15.

## Conflicts of interest

The authors declare no conflicts of interest.

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# Integrated UAV photogrammetry and automatic feature extraction for cadastral mapping

The principal objective of this research is to investigate the applicability of UAV photogrammetry integrated with automatic feature extraction for cadastral mapping. We present here the concluding part of the paper. The first part was published in the October 22 issue



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## Results and discussion

Figure 2a presents the orthomosaic generated from the acquired images which serves as the base map for the extraction of land boundaries, building footprints and other features while Figure 2b is a screenshot of a zoomed portion of the image showing a sample of the markers used for the GCPs. The land plots and building lines from the orthomosaic were obtained by two different techniques; which are manual digitization and automated feature extraction technique using MRS, while the ground survey parcel data was used as reference. Also, the manually digitized property boundary features were used as reference information for the automatically extracted features. Figure 3 depicts the AutoCAD drawing obtained from ground survey approach which was used as reference data for the UAV survey data.

Other results obtained are the result of the accuracy evaluation of the automatically extracted visible boundaries using the MRS algorithm at different SPs (see Tab. 4 and Tab. 5), and the result of the cost and time comparison of the UAV and GNSS survey (see Tab. 6 and Tab. 7).

### Scale Parameters of MRS

The results obtained when the SP of the MRS was set at 150, 400 and 500 are shown in Figure 4a - Figure 4c with the blue line depicting the boundary lines of

every segment. It was observed that the output polygon continues to decrease with an increase in the value of the SP. Also, the visual clarity of the output polygon improves with increase in the value of the SP. When compared to the output of the automatically extracted visible boundaries using MRS with SP values 150 and 400 (Fig. 4a and Fig. 4b), the pixel level in the output map was observed to be decreasing continuously with increase in SPs as observed in the result obtained when the SP value was set at 500 (Fig. 4c).

Figure 5 presents the automatically extracted visible boundaries when the SP value of the MRS was set at 700, while Figure 6 presents the segmentation result obtained when the SP was fixed at 1000. Analysis of these two results showed that the pixel level decreased with increased value of SP. The output map of SP = 1000 gives a more cartographically appealing result based on its stronger pixel level. The yellow line in Figure 5 shows the boundary lines of every segment when SP = 700 was used while the red line in Figure 6 shows the boundary lines of every segment when SP = 1000 was used.

### Accuracy assessment for the generated orthomosaic and automatic feature extraction

Table 2 presents the planimetric coordinates and discrepancy between the GNSS acquired coordinates and the extracted coordinates of the CPs

from the UAV generated orthomosaic. From Table 2,  $\Delta N$  (m) and  $\Delta E$  (m) represents the difference in planimetric (northing and easting) coordinates as obtained from GNSS acquired data and UAV generated orthomosaic.

The obtained horizontal RMSE (RMSE<sub>x, y</sub>) as computed using equation (7) is 0.3575. This is consistent with the result obtained by Karabin et al. (2021) and it affirms the applicability of UAV in cadastral or property mapping.

The result of the estimated completeness, correctness and overall accuracy of the automatically extracted building footprints at different SPs is presented in Table 3, while the results obtained from the estimated completeness, correctness and overall accuracy of the automatically extracted land parcels at different SPs is presented in Table 4.

The result (see Tab. 3) shows that a completeness, correctness and overall accuracy of 16%, 12% and 14%, respectively, was obtained when the MRS algorithm was deployed for the automatic extraction of the building lines or footprints at a SP = 150. When the SP was set at 700, 89% and 91% completeness and correctness, respectively were obtained with overall accuracy of 86% while an overall accuracy of 88% was obtained when the SP was set at 1000 with 92% and 95% completeness and correctness, respectively. Meanwhile, a completeness, correctness and overall accuracy of 25%, 18% and 19% was obtained when the SP was prefixed at 150 for the automatic extraction of land parcels (see Tab. 4), while 65%, 59% and 54% were obtained for the completeness, correctness and overall accuracy, respectively, when the SP was set at 1000 for the automatic extraction of the land parcels using the MRS algorithm. The poor completeness, correctness and overall accuracy obtained from the automatically extracted land parcels when compared to the result of the building footprints can be attributed to the presence of shadows, unclear delineation of the boundary lines of the land parcels in vegetated areas, and the presence of mixed pixels in the automatic extraction (Horkaew et al., 2015; Wassie, 2016). The findings show that increase in the SP of the MRS algorithm also leads to increase in the obtained completeness, correctness and overall accuracy for the extraction of the building footprints and the land parcels. Also, it was observed that optimal completeness, correctness and overall accuracy of the automatic feature extraction was obtained when the SP is set at 1000, while setting the SP at 150 will not yield a reliable result. The result of the accuracy assessment is consistent with the findings of Luo et al. (2017), Munyati (2018) and Chen et al. (2019).

### Cost and time comparison

The results obtained from the time and cost analysis of the integrated UAV-photogrammetry approach and the GNSS survey methods used for the survey of 248 land parcels are presented in Table 5 and Table 6, respectively.

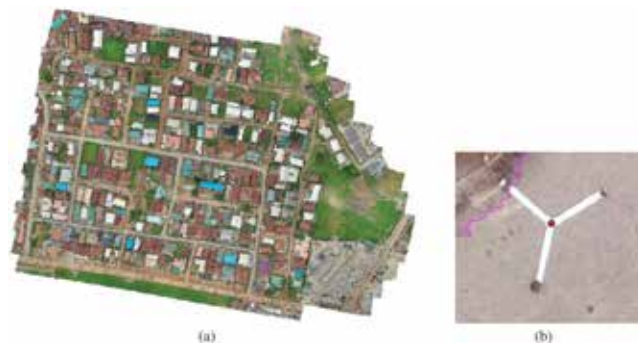


Fig. 2. (a) UAV orthomosaic of the study area, Fig. 2. (b) photo of the marker used for the GCP

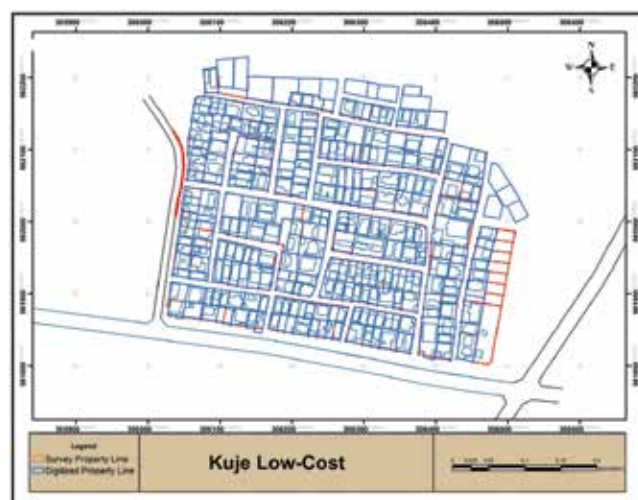


Fig. 3. Manually delineated visible cadastral boundaries surveyed with GNSS receiver, used as reference data

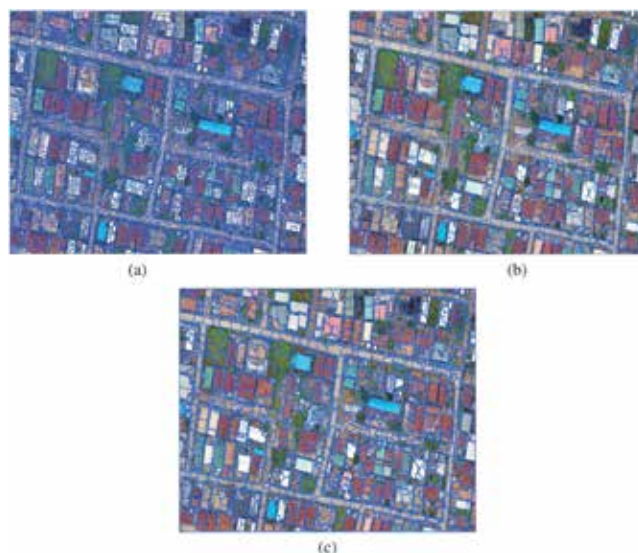


Fig. 4. Automatically extracted visible boundary lines overlaid on the ground truth data. (a) at SP = 150, (b) at SP = 400 (c) at SP = 500

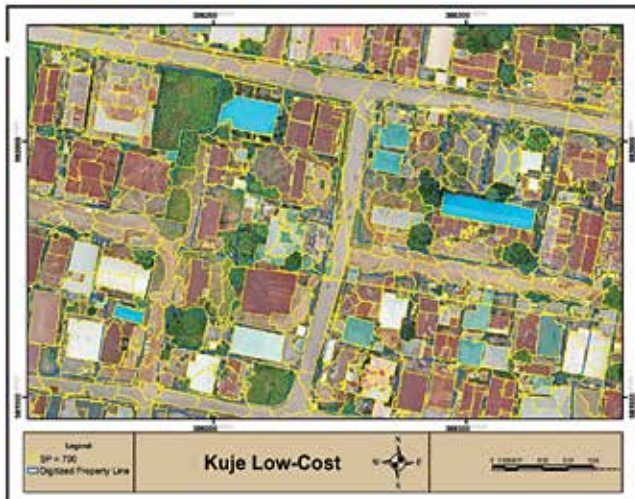


Fig. 5. Automatically extracted visible boundary lines overlaid on the ground truth data with SP = 700



Fig. 6. Automatically extracted visible boundary lines overlaid on the ground truth data with SP = 1000

From the results presented in Table 5 and Table 6, it can be observed that the parcel boundary extracted using GNSS method requires more intense field observation, thus, it consumes more time and cost. However, cadastral boundary extractions from UAV generated orthomosaic involves less field work and more off-field processing, and it is also more economical when compared to the GNSS method. Based on the time analysis, it was observed that the total time taken to map the 248 properties using the UAV photogrammetry approach was just about one-third (1/3) of the total time expended when GNSS method was adopted. While the project was executed within just 12 days using the UAV approach, it took a total of 30 days for the project to be completed using the conventional GNSS approach which shows that the integrated UAV approach is 2.5 times faster than the conventional GNSS approach, even when the same manpower was deployed for the project.

It was also observed that the cadastral boundary obtained using GNSS method requires more personnel, equipment and resources for detail field observation and data processing. However, less human effort with very few equipment is required for UAV data capturing and image processing, and also in vectorizing the UAV generated orthomosaic, which is also consistent with the findings of Karabin et al. (2021). The results obtained from the cost comparison of these two approaches as presented in Table 6 shows that a total amount of ₱1 190 000.00 was expended for the mapping of 248 land parcels at the cost of less than ₱5 000.00 per parcel when the UAV approach integrated with the automatic feature extraction was used, while an approximate cost of ₱11 160 000.00 was expended when GNSS approach was used to survey the same 248 land parcels at an average cost of ₱45 000.00 per parcel. This implies that for large scale property mapping, the presented UAV approach integrated with automatic feature extraction is approximately nine (9) times cheaper or less expensive than the classical GNSS surveying approach without compromising the obtainable accuracy.

Table 2. Discrepancy between GNSS acquired coordinates and extracted coordinates

Control ID	Ground Survey		UAV Survey		Deviations		
	N (m)	E (m)	N (m)	E (m)	$\Delta N$ (m)	$\Delta E$ (m)	$\sqrt{(x-x_1)^2+(y-y_1)^2}$
CP001	981911.086	306084.448	981911.102	306084.420	-0.012	0.030	0.258
CP002	981896.422	306229.281	981896.467	306229.295	-0.047	-0.015	0.132
CP003	981871.979	306374.395	981872.011	306374.408	-0.031	-0.008	0.207
CP004	982002.171	306389.874	982002.185	306389.891	-0.015	-0.021	0.791
CP005	982116.230	306422.570	982116.216	306422.581	0.014	-0.011	0.329
CP006	982022.596	306260.252	982022.547	306260.251	0.053	-0.001	0.092
CP007	982150.160	306264.810	982150.129	306264.796	0.031	0.014	0.085
CP008	982041.911	306106.608	982041.943	306106.589	-0.033	0.021	0.379
RMSE <sub>x, y</sub> =							0.3575

## Conclusions

The principal objective of this research is to investigate the applicability of UAV photogrammetry integrated with automatic feature extraction for cadastral mapping. MRS algorithm with different SP was implemented for the automatic extraction of visible cadastral boundaries defined by linear features such as defined nodes and building footprints. The result obtained from the automatic feature extraction shows that the accuracy of the cadastral boundary line extraction depends majorly on the SP which is the key control of the MRS algorithm. For the experiments conducted using varying SPs and constant shape and compactness value, the result obtained shows that the pixel level in the output map decreases continuously with increase in SPs while the optimal result of the conducted experiment was obtained when the SP was set at 1000, while the shape and compactness values were set at 1.5 m and 0.8 m, respectively. The result of the evaluation of the reliability of the automatic extraction also shows that the completeness, correctness and overall accuracy or quality increases with increase in the value of the SPs. Also, the MRS algorithms proved to be more efficient in automatically extracting building footprints when compared to its performance in the extraction of land parcels.

Furthermore, the results of the accuracy assessment obtained from the integrated UAV approach when compared with conventional survey approach shows that 99% of automatically extracted property boundaries from the UAV survey falls within the minimum acceptable horizontal accuracy for cadastral and property mapping of third order (1: 5,000). Further analysis on the cost and time expended for the property mapping using the integrated approach shows that the approach is approximately 2.5 times faster and 9 times cheaper than the conventional ground surveying approach, especially when GNSS receivers are used for the spatial data acquisition. While

**Table 3. Result of the MRS accuracy assessment of extracted building footprints**

S/N	SP	Completeness (%)	Correctness (%)	Overall accuracy (%)
1	150	16	12	14
2	400	45	43	37
3	500	76	72	62
4	700	89	91	86
5	1000	92	95	88

**Table 4. Result of the MRS accuracy assessment of extracted land parcels**

S/N	SP	Completeness (%)	Correctness (%)	Overall accuracy (%)
1	150	25	19	18
2	400	38	32	22
3	500	43	37	25
4	700	52	48	32
5	1000	65	59	54

**Table 5. Summary of the project components and the execution timeframe (number of days)**

UAV Photogrammetry method						
Activities	Reconnaissance	GCPs and CPs	UAV flight mission	Image Processing	Digitizing	Other duties
No of Days	2	1	1	2	3	3
No of Persons	3	2	3	2	1	2
Total No of Days = 12						
Total No of Persons = 13						
Classical (GNSS) method						
Activities	Reconnaissance	Data Acquisition	Data filtering, processing and plotting			Others
No of Days	2	18	7			3
No of Persons	3	6	4			3
Total No of Days = 30						
Total No of Persons = 16						

**Table 6. Cost comparison between UAV mapping and classical GNSS survey approach**

Activity	Number of days	Cost (N)
UAV survey		
Reconnaissance	2	80 000
GCP	1	70 000
UAV Flight mission	1	200 000
Image Processing	2	500 000
Digitizing	3	150 000
Other	3	190 000
Total	12	1 190 000
Number of land parcels surveyed		248
Estimated cost of survey per land parcel (N)		4 798
Ground survey		
Reconnaissance	2	140 000
Data Collection	18	10 620 000
Data filtering, processing and plotting	7	250 000
Others	3	150 000
Total	30	11 160 000
Number of land parcels surveyed		248
Estimated cost of survey per land parcel (N)		45 000

MRS algorithm has proved to be a veritable model for automatic extraction of building footprints in cadastral mapping in this study, further research efforts shall seek to investigate the applicability of other segmentation algorithms in the automatic extraction of parcel boundaries for cadastral applications. Meanwhile, it should be noted that the automatic extraction of boundaries is only a step to the facilitation cadastral mapping, as mere detecting and extracting the boundaries alone is not sufficient for complete and correct cadastral mapping.

### Author contributions

**O.G.A:** Conceptualization, research concept and design, article writing, critical revision of the article and final approval of the article. **O. E:** Collection and assembly of data, data analysis and interpretation, and writing of the article draft.

### Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Further analysis on the cost and time expended for the property mapping using the integrated approach shows that the approach is approximately 2.5 times faster and 9 times cheaper than the conventional ground surveying approach, especially when GNSS receivers are used for the spatial data acquisition.

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The result obtained from the automatic feature extraction shows that the accuracy of the cadastral boundary line extraction depends majorly on the SP which is the key control of the MRS algorithm.

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# Animal navigation: How animals use environmental factors to find their way

Migratory animals have innate programs to guide them to their still unknown goal. Highly mobile animals with large ranges develop a so-called navigational 'map', a mental representation of the spatial distribution of navigational factors within their home region and their migration route. We present here the first part of the paper. The concluding part will be published in December issue



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## Abstract

Animals use the geomagnetic field and astronomical cues to obtain compass information. The magnetic compass is not a uniform mechanism, as several functional modes have been described in different animal groups. The Sun compass requires the internal clock to interpret the position of the Sun. For star compass orientation, night migrating birds seem to use the star pattern as a whole, without involving the internal clock. Both the astronomical compass mechanisms are based on learning processes to adapt them to the geographic latitude where the animals live and, in long living animals, to compensate for the seasonal changes. Several mechanisms are used to determine the compass course to a goal. Using information collected during the outward journey is mostly done by path integration: recording the direction with a compass and integrating its twists and turns. Migratory animals have innate programs to guide them to their still unknown goal. Highly mobile animals with large ranges develop a so-called navigational 'map', a mental representation of the spatial distribution of navigational factors within their home region and their migration route. The nature of the factors involved is not yet entirely clear; magnetic intensity and inclination are the ones best supported so far.

## 1 Introduction

Many animals perform extended migrations. Most famous are the annual migrations of millions of birds that, in autumn, leave regions with adverse winter conditions to overwinter in more favorable parts of the Earth. The record holder in distance is the Arctic tern, *Sterna paradisaea*, a sea bird breeding in the Arctic regions that spends the winters at the edge of the Antarctic Continent, thus staying in eternal summer, avoiding coldness and darkness. But many other birds migrate as well, covering several thousand kilometers every year; among them are, e.g., water birds, raptors, swifts and small songbirds such as swallows, warbler and others. They spend the summer in the northern temperate zones and move to lower latitudes, some of them crossing the equator for wintering. Whales cover long distances between their Arctic or Antarctic feeding grounds and areas with warmer water where they give birth to their calves. But also terrestrial mammals, like many hoofed animals, perform long distance migrations to follow the annual change in vegetation, e.g., the caribous in northern Canada or zebras, gnus and antelopes in eastern Africa. Some animals migrate between nesting and feeding grounds, e.g., marine turtles. Many fishes migrate; some of them, like eels and salmon, only at the beginning and end of their life. Even some insects migrate: the monarch butterfly, *Danaus plexipus*, is a prominent example.



Most of these migrations involve specific routes and defined end points. Eels and salmon, as well as marine turtles are known to leave their feeding sites after years to return to the places where they were born to lay their eggs. Banded birds were found to return to the same breeding site year after year, and many of them seem to spend the non-breeding season in the same wintering grounds every year.

Birds are also known to return after passive displacement from unfamiliar sites. Homing pigeons, *Columba livia domestica*, bred from the Mediterranean rock dove, were domesticated and used to transport messages already since antiquity. But other bird species, too, were found to be able to compensate for displacements; that is, they can directly head toward a specific goal. The same appears to be true for numerous other animals, with the distances involved correlated with the size of their home range.

Yet, the ability to navigate is not only required for extended migrations and displacements like those mentioned above, but also during their everyday movements within their home range animals profit greatly from good orientation, because it is advantageous to optimize routes—this saves energy and helps to avoid predation.

To answer the question what factors animals use to navigate, it is important to understand how they proceed when they want to reach a specific goal. Birds

are by far the best studied group— homing pigeons are available *ad libitum* and can be easily used for orientation experiments. When they are released at a distant site, they leave this site heading in directions close to the home direction. With migratory birds, their innate tendency to seasonally move in their migratory directions provides a reliable, solid baseline for cage experiments. Hence much of our present knowledge on animal navigation comes from studies with birds, but many of the processes and procedures identified in birds seem to have parallels in other animals.

## 2 The "Map-and-Compass" model

Systematic research on animal navigation began in the second half of the twentieth century, when Gustav Kramer [1] and Karl von Frisch [2] in 1950 reported that birds and bees can use the Sun for orientation. The *Sun compass*, thus, was the first orientation mechanism described (see below). In the course of his experiments with homing pigeons, Kramer recognized that avian navigation is a two step process and proposed his *Map-and-Compass model* (e.g., [3]): When birds intend to return home from a distant site, they first determine the compass course leading to the goal and then use a compass to look up this direction and follow it home. Thus the first step of navigation, the *Map step* means applying mechanisms for determining the present position and

put it in directional relation to the goal, and the second step, the *Compass step*, means applying mechanisms which allow to locate specific directions.

The Map-and-Compass model was first developed to describe the homing process of pigeons after displacement, with the Sun compass for the compass step, while the mechanisms by which the pigeons determine their home course could not yet be identified. This model, however, can be expanded to characterize avian navigation in general. In the beginning, young birds use information obtained during the outward journey, and for the first migration to the still unknown wintering area, the map step is replaced by a genetic program that makes birds move into an innate direction for a certain time. Experienced birds, however, are then able to truly navigate, using local site specific information, within and beyond their home region as well as during migration (for review, see, e.g., [4]). Little is known about the navigation procedures of other animals, but we tend to assume that in many cases they might proceed in a similar way when they have to reach a specific goal. However, in some cases under certain conditions, they might use more direct mechanisms.

When Kramer [3] proclaimed the Map-and-Compass model, the Sun compass was the only navigational mechanism yet known. Research during the last decades increased our knowledge on the factors and mechanisms of animal navigation considerably, even if many questions are still open. In particular, the compass mechanisms have fairly well been analyzed in many animals.

## 3 Compass mechanisms

How do animals proceed when they have to locate directions? In principle, they use the same factors that we humans, too, use, namely the geomagnetic field and astronomical cues. Three compass mechanisms have been identified in animals, namely a

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### 3.1 The magnetic compass

We humans need a technical device—a compass where a magnetic needle aligns itself with the course of the field lines—to locate the direction of the geomagnetic field. Many animals, in contrast, can sense the direction of the magnetic field directly.

#### 3.1.1 The distribution of a magnetic compass among animals

A sense for magnetic directions was first discovered in migratory birds: During the migratory season, these birds show a spontaneous tendency to prefer their migratory direction also in suitable cages, and when the north of the ambient magnetic field was shifted by a coil system, European robins (*Erithacus rubecula*, Turdidae) changed their preferred direction accordingly (Fig. 1a, b) [5]. These findings initially met with considerable skepticism because it was a novel, unexpected sensory ability alien to man. Meanwhile, however, a magnetic compass has been demonstrated in more than 20 bird species, including other migrants and also in non-migrants, e.g., homing pigeons [6] and even domestic chicken (*Gallus gallus domesticus*) [7]. It was also found in animals of other groups, first in cave salamanders [8], but soon also in all groups of vertebrates—in fish such as stingrays [9], salmon [10,11], eels [12,13] and others, in frogs (e.g., [14]), alligators [15], marine turtles [16] and mammals like rodents [17] and bats [18]. Findings in humans have been controversially discussed (see [19]).

A magnetic compass was also demonstrated in sea slugs (Nudibranchia) [20], in crustaceans like spiny lobsters [21], sandhoppers (Amphipoda) (e.g., [22]) and others, and also in insects such as termites [23], beetles [24], moths [25] and butterflies (e.g., [26]), honeybees [27] and ants [28,29]. A magnetic compass thus appears to be widespread and may even be a general characteristic of mobile animals.

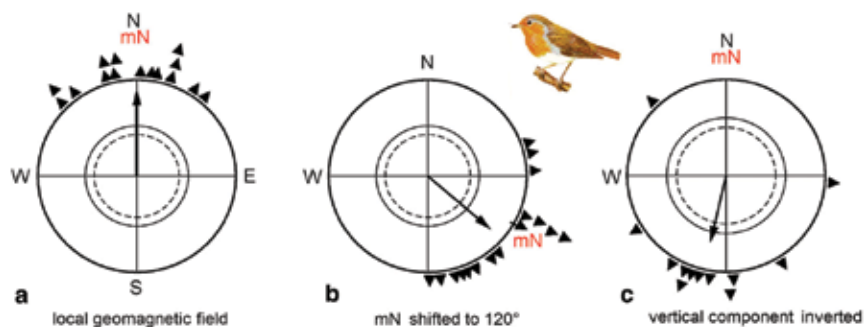
#### 3.1.2 Different functional modes

The magnetic compass in animals is not a uniform mechanism, however. It has been analyzed in detail only in very few species so far, but there are at least two fundamentally different functional modes and some modifications. The mechanisms in birds are the ones best known so far and, here, the magnetic compass functions very differently from our technical compass.

Birds are not sensitive to the polarity of the magnetic field (see Fig. 1a, c); instead, they sense the axial course of the field lines and distinguish between their two ends by the inclination [30]. This means that for birds, the magnetic compass does not indicate *magnetic north* and *south*, as our technical compass does, but *poleward*, where the field lines point downward and *equatorward*, where they point upward. This type of compass, an *inclination compass*, becomes ambiguous at the magnetic equator and requires long distance migrants to ‘reverse’ their heading from *equatorward* to *poleward* when they cross the equator to continue heading southward. The inclination compass was first analyzed in European robins, but was also found in all other bird species tested for it so far. It is remarkably accurate; it was shown to still work at an inclination of 87°, i.e., only 3° from the vertical [31,32] and at 5°, close to the horizontal [33].

The avian magnetic compass proved to be light dependent, requiring short wavelength light from UV to about 565 nm green (see Fig. 1); under red light, birds are disoriented [34–36]. It spontaneously functions only in magnetic intensities with which the birds are familiar; decreasing or increasing the ambient intensity about 25% leads to disorientation [37,38]. However, birds can adjust to intensities outside this functional window when they are exposed to other intensities for a while: Robins caught and kept in a field of 46 μT thus became able to orient at intensities as low as 5 nT [39] and as high as 150 nT, but could not orient at the intermediate intensity of 81 nT [37]. This ability allows migrating birds to cope with the decreasing intensities that they encounter when reaching lower latitudes.

These characteristics of their magnetic compass indicate that birds have a specific way to perceive magnetic directions. In the 1980s, Schulzen and Windemuth [40] suggested the *radical pair model*, which was later detailed by Ritz and colleagues. It assumes the avian magnetic compass to be based on radical pair processes, with the direction of the ambient magnetic field changing the ratio singlet/triplet of the radical pair (for details, see [41]). This effect does not depend on the polarity of the magnetic field and thus results in an *inclination compass* as found in birds.



**Fig. 1** Orientation behavior of European robins during spring migration in round cages under dim narrow-band 565 nm green light, demonstrating compass orientation by the geomagnetic field. Headings a in the local geomagnetic field (46 nT, mN = 360°, 66° inclination); b with the horizontal component (magnetic north) shifted to 120° ESE; c with the vertical component inverted.—mN, magnetic north. The triangles at the periphery of the circles indicate the mean headings of individual birds, the arrows represent the grand mean vector in the respective test condition in relation to the radius of the circle = 1. The two inner circles mark the 5% (dotted) and the 1% significance border of the Rayleigh test (see [213] for details) (data from [214])

As site of magnetoreception, the authors suggested the eyes, because of their spherical shape, and there are receptor cells aligned in all spatial directions. Hence the different ratio of singlet/triplet would result in an activation pattern on the retina that is centrally symmetric to the course of the field lines (see [41] for details). Changes in intensity would modify the activation pattern, which appears to confuse the birds at first, but since the pattern retains its central symmetry to the field lines, birds can learn to interpret the altered pattern.

As receptor molecule providing the radical pairs, Ritz and colleagues suggested cryptochrome, a protein with FAD (flavin adenine dinucleotide) as chromophore [41], because it is the only known photo pigment in animals that forms radical pairs. Several types of cryptochromes were indeed found in the retina of birds (see, e.g., [42]). In particular Cry1a, located in the outer segment of the V/UV receptor cells of robins, chickens and zebra finches (*Taeniopygia guttata*, Estrlidae) seems highly suitable for magnetoreception. These cells are distributed all across the retina [43,44] and thus could produce the assumed activation pattern. Cry1a is activated at all wavelengths where birds were found to be oriented [45]. Later studies indicate that the crucial radical pair is formed during reoxidation ([46]; for review, see [42]).

Amphibians and marine turtles were also shown to have an *inclination compass*, i.e., a compass that is not sensitive to the polarity of the magnetic field. Their compass mechanisms, however, were found to differ from that of birds in their light dependency. While birds are still oriented under 565 nm green light, the wave length range of normal orientation in the newt *Nothophthalmus* (Salamandridae) appears to end at about 450 nm blue [47]. Marine turtles, in contrast, could use their inclination compass also in total darkness [48]. Only little is known about the magnetic compass of other vertebrates. A few fishes and mammals have been studied:

salmons [49], subterranean rodents [50], and bats [51] were found to respond to the polarity of the magnetic field—they have a *polarity compass*. Details of their reception mechanisms have not yet been analyzed; permanent magnetic material like *magnetite* (a specific form of iron oxide, Fe(II)Fe(III)2O4) has been discussed.

Even less is known about the functional mode of the magnetic compass of arthropods. Among crustaceans, only the compass mechanism of spiny lobsters has been analyzed; they were found to have a *polarity compass* [52]. The two species of insects tested so far, the flour beetle *Tenebrio* [53] and the monarch butterfly [54], in contrast, have an *inclination compass*.

The different functional modes of the magnetic compass suggest independent evolutionary developments. The magnetic compass is an important orientation mechanism with the great advantage of being always available, independent of the time of the day and the weather conditions. Magnetic disturbances, such as magnetic storms and local anomalies, are rarely strong enough to interfere with it.

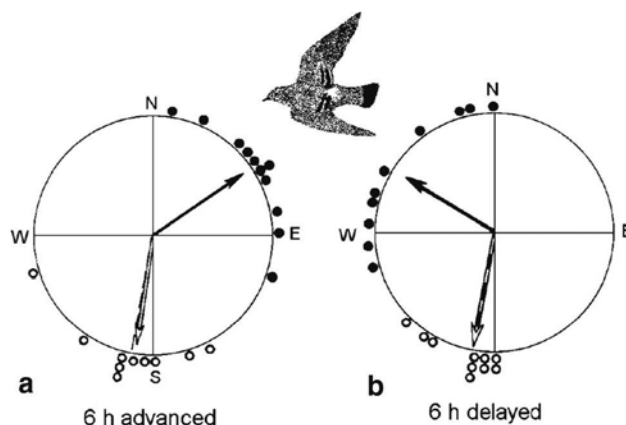
### 3.2 The Sun compass

The Sun is widely used for direction finding during the day. The first indications of the Sun as an orienting cue were already reported in the beginning of the twentieth century, when Santschi [55] could redirect ants by reflecting the Sun with a mirror. In 1950, the Sun compass was discovered independently in animals as different as birds [1], and in honeybees [2]. This initiated a systematic

search for Sun compass orientation in the animal kingdom. Soon a Sun compass was found in various crustaceans (summarized by [56]), various insect groups like ants and bees, beetles and others, spiders (summarized by [57,58]), butterflies like the Monarch [59], and marine snails [60]. Among vertebrates, it was found in several species of fishes (e.g., [61]; for review see [62]), in reptilian species such as lizards [63], snakes [64,65], turtles [66,67] and alligators [68]). Yet in amphibians (e.g., [69]) and mammals, where rodent species were tested (e.g., [70]), the data were less clear. It has to be considered, however, that amphibians mostly avoid being exposed to clear sunlight, and rodents are mostly nocturnally active.

#### 3.2.1 Functional mode and ontogeny of Sun compass orientation

To derive directional information from the Sun, the animals must know the Sun's arc and consider the time of the day. This does not pose a problem, because animals are endowed with an internal clock. Their endogenous circadian rhythm is synchronized with the natural day by sunrise and sunset, (see, e.g., [71]). With this sense for the time of the day, they interpret the Sun's position. The customary demonstration of Sun compass use is



**Fig. 2** Clock-shift experiments with displaced homing pigeons, demonstrating the use of the Sun compass. **a** Fast shift: internal clock is 6 h advanced; **b** slow shift: internal clock is 6h delayed. The dashed line marks the home direction 192°, the symbols at the periphery of the circle give the vanishing bearings of individual birds: open, controls living in the natural day, solid: experimental birds with their internal clock shifted. The arrows indicate the mean vectors (see [213])

based on this phenomenon. In the so-called *clock-shift* experiments, the internal clock of the test animals is shifted, mostly for 6 h, by subjecting them to an artificial photoperiod that, e.g., starts 6 h before sun-rise and ends 6 h before sunset. After about 5 days, the internal clock is adjusted to the new, artificial photoperiod. When the animals are then exposed to the Sun, they misjudge its position and orient in a direction that deviates markedly from that of untreated controls—in the Northern Hemisphere, a forward shift results in a counterclockwise, and a backward shift in a clockwise deviation (Fig. 2). Such *clock-shift* experiments were first conducted by Schmidt Koenig [71] with homing pigeons, but soon this method has been widely applied, e.g., also in connection with directional training (see e.g., [72])

When animals are tested in a *clock-shift* experiment, the altitude of the Sun is markedly different from what they should expect according to their subjective time, e.g., 6 h forward shifted pigeons tested at 6:00 in the morning should expect the Sun high up in the sky because this is their subjective noon; instead it is low above the horizon. They seem to ignore this discrepancy, however, which indicates that for the Sun compass of birds, only the Sun's azimuth is important, whereas its altitude is ignored. Schmidt-Koenig therefore describe the Sun compass of pigeons as a *Sunazimuth compass* ([72]; see also, e.g., [73] for ants). The same seems to apply to many other animals; for fishes, however, the Sun's altitude seemed to be also involved in the orientation process (see e.g., [74]).

Yet the Sun's azimuth does not change uniformly in the course of the day; just after sunrise and just before sunset, when the Sun rapidly gains or loses altitude, its increase is rather slow, below the average of 15° per hour, whereas around noon, when the Sun is high up in the sky, it moves much faster. This raised the question whether the animals are aware of this and compensate for the changes in azimuth correctly. This was first demonstrated in the desert ant *Cataglyphis* (Formicidae): These ants are aware of the

different rates of change in the course of the day [73] and interpret the Sun's azimuth accordingly. The same appears to apply to honeybees [75,76]. Fishes, too, consider the different rates of change in Sun's azimuth largely correctly [77], and this is also true for birds [78].

The Sun's arc, however, and with it the rate of changes in azimuth, depends on the geographic latitude and season. This means that for precise Sun compass orientation, the animals' compensation mechanisms must be based on the true Sun's arc of their home region and the correct time of the year. This is accomplished by learning processes: ants and bees observe the sky before they begin the foraging phase of their life. These learning processes are rather fast, taking only a few days, and seem to be supported by innate components (see e.g., [79] for details)—ants that had experienced the Sun only early in the morning could interpret its position in the afternoon correctly [80]. This is probably required because of the rather short life span of these social insects, which also makes an adaptation to the seasonal changes largely unnecessary. Ants that have overwintered, however, must learn the Sun compass in spring anew [81], which may also apply to overwintering bees.

In birds, the ontogeny of the Sun compass has been studied only in homing pigeons. Here, it is likewise learned [82], with the learning processes taking considerably longer and requiring observation of the Sun's arc during large portions of the day. Birds that had experienced the Sun only in the afternoon could not use their Sun compass in the morning [83]. Learning the Sun compass normally begins when the pigeons are about 12 weeks old, but it can be advanced by early flying experience [84]. The magnetic compass serves as reference against which the movement of the Sun is observed [85]. We tend to assume that the respective processes are similar in all bird species. How the avian Sun compass is adjusted to the seasonal changes has not yet been

analyzed; it is to be expected, however, that the processes are similar to those of its first establishment. Little is known about the establishment of the Sun compass in other animals. Experiments with fishes that never saw the natural Sun suggested that their Sun compass may be in large parts innate (see [85]).

The Sun compass is the most important orientation mechanism within the animals' home range and over shorter distances, where animals follow their Sun compass in spite of contradicting information from their magnetic compass. During long range migrations, however, animals would have to additionally cope with the changes of the Sun's arc with geographic latitude or, when they migrate east/west, with the resulting shift in local time. Interestingly, while a Sun compass was demonstrated in numerous fish species (see e.g., [60,61]), experiments involving migration with species like salmon and eels failed to produce unequivocal evidence for Sun compass orientation [87,88]. With birds, the Sun compass is likewise demonstrated in displacements and conditioning (see e.g., [89] for summary), but day migrating birds during migration did not respond to clock shifting as expected (e.g., [90]). The findings suggested that they paid attention to the Sun, but that the Sun compass does not serve as major compass system for orienting the migration flight.

### 3.2.2 The role of polarized light

The Sun is accompanied by a particular pattern of polarization in the sky light, with the polarization reaching a maximum 90° from the Sun. It gradually changes as the Sun moves. In contrast to us, many animals can see this polarization pattern in the sky and use it for orientation, so that for them, the Sun compass is actually a 'skylight' compass (see e.g., [91]). The pattern of polarization is also visible below the water surface (see e.g., [92]) so that polarized light is also a potential orientation cue for aquatic animals living near the surface. Responses to polarized light have indeed been observed in crustaceans such as *Daphnia* (e.g., [93]) and decapods [94].

The use of polarized light for orientation was first discovered in honeybees and ants [95,96] and in the following years was also found in many other insect species. In insects, where the upper parts of the eyes are specialized to detect the polarization of light (for reviews, see e.g., [57,97]; for details about the insects' polarization vision, see e.g., [98]). Experiments with desert ants of the genus *Cataglyphis* showed that these ants are familiar with the polarization pattern and its changes in the course of the day; they use it for compass orientation [80]. They need not see the entire sky, but a small portion is sufficient. Dung beetles have even been reported to be able to use the polarized moonlight for nocturnal orientation [99].

Many vertebrates, too, are sensitive to polarized light. This is indicated in fishes (e.g., [100]), amphibians [101], reptiles (e.g., [102,103]) and, among mammals, bats [104]. Birds are also able to perceive polarized light [105] and with them the effect of polarized light on orientation behavior has been studied in some detail. The pattern of polarized light at sunset was shown to play some role in the orientation of a night migrating American songbird [106] that starts migration flight at about that time. Several authors began to test the relative importance of polarized light compared to other cues, with some studies appearing to indicate a dominance of polarized light [107–109]. Several of these studies are not unproblematic, however, because they involved polarizers, which polarize the entire skylight almost 100%, and this unnatural pattern appears to alter the normal behavior. Birds were observed to orient roughly parallel to the axis of polarization, which was significantly different from their response to the natural polarization pattern [110]. A dominant role of polarization could not be generally confirmed (e.g., [111,112] a.o.).

Yet migratory birds can use the natural polarization pattern for orientation. A twilight migrant stayed oriented when other orienting cues like the geomagnetic field had been removed (e.g., [113]), and

this is also applicable for a day migrant. In a compensated magnetic field, the birds were still oriented as long as the natural skylight was visible, even when the Sun itself was obscured [114].

A crucial role of polarized light is also that it can mediate celestial rotation to migratory birds, which is an important factor for transforming the genetically coded information on the migratory direction into an actual direction (see below). This effect was only observed in birds that had full view of the natural sky, whereas birds that had observed the sky through depolarizers could not do so, even if they had been able to see the Sun and its movement [115].

The Sun compass, i.e., the skylight compass, is the dominant mechanism in the compass orientation of many animals: They prefer to use it when it is available.

### 3.3 The star compass

Using the stars for orientation has been described so far only for nocturnally migrating birds; they can use the stars as a compass. This was first demonstrated in planetarium experiments. Reversing the planetarium sky caused birds to reverse their headings (Fig. 3) [116,117].

A star compass is also indicated by outdoor experiments, where birds at night headed in their migratory direction with the stars as only available cue (e.g., [118–120]).

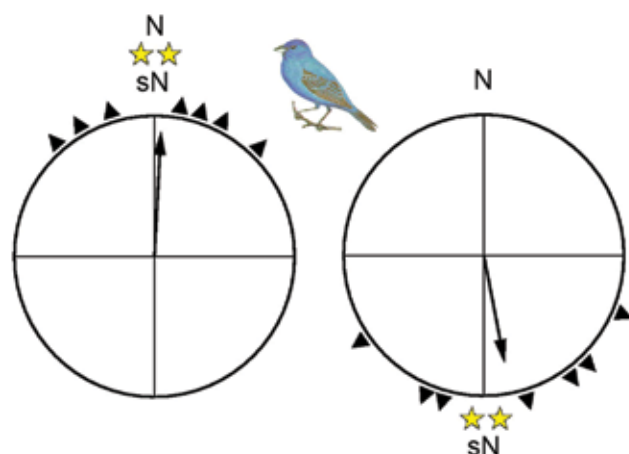
The stars move in the course of the night, but an analysis of the star compass showed that the internal clock was not involved [121]. This excluded mechanisms similar to that of the Sun compass (see above) and spoke against the use of individual stars, suggesting that birds might derive directions from the pattern as a whole or parts of the pattern. Experiments blocking certain constellations revealed a considerable individual variance. In general, the circumpolar stars within 35° of the center of rotation center seemed to be important, yet the results did not allow a final conclusion [121].

The star compass is also a learned mechanism. Young migrants could use the stars as a compass only if they had observed the sky rotating before they start autumn migration. In an experiment, two groups of hand raised birds were exposed

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The Sun compass, i.e., the skylight compass, is the dominant mechanism in the compass orientation of many animals: They prefer to use it when it is available.

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**Fig. 3** Planetarium experiments with indigo buntings, *Passerina cyanea*, demonstrating the star compass. The orientation of the same birds a under the normal planetarium sky with the northern stars projected toward north, b under a reversed planetarium sky with the northern stars projected toward south. (data from [11], Appendix 8). The triangles at the periphery of the circles mark the mean headings of the individual birds: the arrows represent the mean vectors (see [213])

to a rotating planetarium sky, with the control group under the normal sky, rotating around the polar star *Polaris*, while the test group was exposed under a sky rotating around *Betelgeuze* in Orion. Later, during autumn migration, both groups were tested under the now stationary planetarium. The control group preferred the normal southerly migratory direction, heading away from *Polaris*, whereas the test group headed away from *Betelgeuze* [122]. Birds do not seem to have an innate concept about what the sky looks like. The complex natural sky could be replaced by a simple pattern of only 16 light dots—as long as the birds had observed this pattern rotating with 1 rotation per day, they later could use it to orient in their migratory direction relative to the center of rotation [123,124]. *Celestial rotation* was thus identified as the crucial factor for establishing the migratory direction with respect to the stars.

The view of the sky changes gradually. The stars rise 4 min earlier each day, so that the sky in autumn looks different from that in spring. At the same time, the sky changes its appearance with geographic latitude. During autumn migration, as the bird moves south, the northern stars slowly lose altitude and approach the horizon, while new stars appear at the southern horizon. Birds have to integrate these new stars into their star compass. Experiments under the natural sky with altered magnetic fields indicate that the magnetic compass provides the reference system which gives directional meaning to the new stars during migration (e.g., [118,119], a.o.).

So far, a star compass has been demonstrated only in a few species of songbirds that migrate at night. Since the majority of birds are primarily day active, the star compass could be a special mechanism developed by the nocturnal migrants to orient their extended flights. It is unknown whether generally night active birds, like, e.g., nightjars or owls, also use the stars as a compass as such birds have not yet been studied.

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*To be concluded in December issue. ▴*



## FUKUI COMPUTER partners with Bentley Systems

FUKUI COMPUTER, Inc has entered into a strategic partnership with Bentley Systems to accelerate the adoption of digital workflows in the Japanese construction industry and support the promotion of digital transformation (DX) in the infrastructure field. It will leverage the Bentley iTwin platform to augment its cloud-based data sharing service CIMPHONY Plus with 3D/4D visualization, simulation, and digital twin capabilities. The company will launch a digital solution that supports the entire infrastructure lifecycle, spanning project management, design, construction, and maintenance. [www.bentley.com](http://www.bentley.com)

## CDG Introduces 3-GIS Integration for MBS

Communications Data Group (CDG) is pleased to announce the recent integration between CDG's MBS consumer and enterprise billing and OSS solution and 3-GIS's fiber network management software. The initial phase of the integration allows MBS clients utilizing 3-GIS software solutions to manage the address structure creation and ONT equipment creation and removal in 3-GIS through MBS, while the 3-GIS Patch Panel assignment to the address is managed in 3-GIS and then automatically generated in MBS. [www.cdg.ws](http://www.cdg.ws)

## UKHO provides bathymetric surveys for the Seabed 2030 project

The UK Hydrographic Office (UKHO) has started supplying bathymetric survey data for non-UK waters to the General Bathymetric Chart of the Oceans (GEBCO), after signing the MOU with The Nippon Foundation-GEBCO Seabed 2030 Project (Seabed 2030) earlier this year.

The UKHO has started supplying data that covers the South Atlantic and the waters around Antarctica to GEBCO via the Seabed 2030 Southern Ocean Regional Centre, located at the Alfred Wegener Institute. This data is an important contribution to the

International Bathymetric Chart of the Southern Ocean (IBCSO), GEBCO and Seabed 2030. The supplied data has contributed 3,753,614 new data points to IBCSO and GEBCO, covering a combined 13,500 nm<sup>2</sup>. [www.gov.uk](http://www.gov.uk)

## Intermap announces new contract powering urban air mobility

Intermap Technologies announced a new contract with Skyroads AG and cloudeo AG to power an Automated Airspace Management and Vehicle Guidance System. Its NEXTView will be integrated into Skyroads' system to ensure safety, efficiency and obstacle avoidance as vehicles travel above urban environments. [www.intermap.com](http://www.intermap.com)


## NGS releases NGS map to production

The NGS map provides the ability to view multiple datasets provided by the National Geodetic Survey. These datasets are:

- NGS Datasheets
- OPUS Shared Solutions
- NOAA CORS Network

This application not only allows users to plot these datasets but there is a measuring tool available, multiple basemaps, a select tool to select and export data as well as an attribute table to view all the attributes and filter the datasets by their attributes. [noaa.gov](http://noaa.gov)

## Eos Positioning Systems Receives Customer Success and Collaboration Award

Eos Positioning Systems, Inc. received the Customer Success and Collaboration Award at the 2022 Esri Infrastructure Management and GIS (IMGIS) Conference held in Palm Springs, California from October 31-November 2, 2022. This award was presented to Eos for fostering customer success across infrastructure sectors through its partnership with Esri. Eos provides utilities, local governments, AEC firms, and transportation organizations with GNSS receivers and solutions that pair seamlessly with Esri mobile apps. 

## ESA plans for low-orbiting navigation satellites

ESA's Navigation Directorate is planning an in-orbit demonstration with new navigation satellites that will orbit just a few hundred kilometres up in space, supplementing Europe's 23 222-km-distant Galileo satellites. Operating added-value signals, these novel so-called 'LEO-PNT' satellites will investigate a new multi-layer satnav system-of-systems approach to deliver seamless Positioning, Navigation and Timing services that are much more accurate, robust and available everywhere.

Simply by virtue of physics, with less of a distance to cover down to Earth, the signals from these LEO-PNT satellites can be more powerful, able to overcome interference and reach places where today's satnav signals cannot reach.

And by adopting novel navigation techniques and a wider range of signal bands the satellites can address particular user needs: for instance at lower orbits the satellites themselves move more rapidly relative to Earth's surface – think of the International Space Station at 400 km that orbits the Earth every 90 minutes – which offers possible advantage in the time needed to reach very accurate positions. Also some bands could offer greater penetration in difficult environments while other bands could offer higher robustness and precision.

The purpose of ESA's plan to perform an in-orbit demonstration of low Earth orbiting satnav satellites is precisely to consolidate the types of signals, enabling technologies and their potential for future services.

The plan is to build and fly an initial mini-constellation of at least half a dozen satellites to test capabilities and key technologies, as well as demonstrating signals and frequency bands for use by a follow-on operational constellation, in the same way that Europe's GIOVE test satellites paved the way for Galileo. [www.esa.int](http://www.esa.int)

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## Russia, China sign contracts on mutual deployment of navigation stations

Russia and China have signed contracts for the deployment of Russia's GLONASS stations in China and China's Beidou system stations in Russia, the state corporation Roscosmos said in a news release.

Roscosmos CEO Yuri Borisov and the chairman of the China Satellite Navigation System Committee, He Yubin saw contracts signed for the deployment of Russian GLONASS stations in China and Chinese stations of the Beidou system in Russia, the news release says.

At the meeting, a statement was also signed by the Information and Analytical Center for Coordinate, Time and Navigation Support of the Central Research Institute for Machine Building (TsNIIMash, an affiliate of Roscosmos) and the Test and Assessment Research Center at the China Satellite Navigation Office on jointly providing information support services to GLONASS and Beidou customers. <https://english.almanar.com>

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## GPS interference caused the FAA to reroute Texas air traffic

The Federal Aviation Administration is investigating the cause of mysterious GPS interference that prompted the closure of one runway at the Dallas-Fort Worth International Airport and some aircraft in the region had to be rerouted to areas where signals were working properly.

The interference first came to light in the early October this year, when the FAA issued an advisory over ATIS (Automatic Terminal Information Service). It warned flight personnel and air traffic controllers of GPS interference over a 40-mile swath of airspace near the Dallas-Fort Worth airport. The advisory read in part: "ATTN ALL AIRCRAFT. GPS REPORTED UNRELIABLE WITHIN 40 NM OF DFW."

An advisory issued around the same time by the Air Traffic Control System Command Center, meanwhile, reported the region was "experiencing GPS anomalies that are dramatically impacting" flights in and out of Dallas-Fort Worth and neighboring airports. It went on to say that some of the airports were relying on the use of navigation systems that predated GPS. Then, around 11 pm Dallas time, the interference ended. As mysteriously as the interference began, it had stopped.

Civilian GPS relies on low-power satellite signals broadcast in the L band, a radio frequency range that's also used by civilian terrestrial radio sources, including 5G mobile devices. That makes GPS susceptible to unintentional interference from the rollout of this next-generation technology. Equipment used on military bases is also a frequent cause.

Typically, however, when unintentional interference occurs, authorities can pinpoint the cause within a few hours. With no known cause, experts can only speculate.

"We don't know if there are malicious actors behind this incident, or if it's a result of interference," Josh Lospinosa, co-founder and CEO of aircraft and transportation security company Shift5 and a former US Cyber Command official said. "Interference is a timely issue for airports and airlines right now. There was a big push by wireless carriers to roll out 5G in airports a few months ago that was a terrible idea from the perspective of how many legacy devices in aircraft rely on the wireless bands that are impeded by 5G."

Lospinosa also noted the susceptibility of civilian GPS to intentional spoofing and jamming. North Korea used GPS jamming in 2012. Three years ago, the Center for Advanced Defense Studies reported that Russia had performed extensive spoofing of signals used by GPS and other GNSS in Syria and other combat zones.

In 2012, for instance, researcher Brad Haines reported that he was able to

spoof the ADS-B signals surveillance technology aircraft rely on to determine their position via satellite navigation. The researcher demonstrated how attackers could use these spoofed signals to create "ghost planes" that would appear on air traffic controllers' screens. Researchers have also devised a low-cost hack that spoofs the instrument landing systems that planes rely on to safely land.

GPS interference isn't life threatening. But as noted, episodes like these do cause cancellations, delays, and other inconveniences. <https://arstechnica.com>


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## Australia's SouthPAN early Open Services now live

Early Open Services delivered by the Southern Positioning Augmentation Network (SouthPAN) are now live in Australia and New Zealand, improving location-based capabilities for the Australasia region.

SouthPAN provides accurate, reliable and instant positioning services across all of Australia and New Zealand's land and maritime zones without the need for mobile phone or internet coverage. It will improve positioning from 5-10 meters, to as little as 10 centimeters — a 50-fold increase in accuracy.

This satellite-based augmentation system (SBAS) test-bed project took place between 2017 and 2019, demonstrating the value of SouthPAN to Australian and New Zealand economies and communities. Economic analysis indicates that it is more than \$6.2 billion for Australia alone.

In February 2020, Geoscience Australia and Toitū Te Whenua Land Information New Zealand (LINZ) began a joint collaboration on SouthPAN under the Australia New Zealand Science, Research and Innovation Cooperation Agreement (ANZSRICA). A comprehensive procurement process followed, awarding an AUD\$1.18 billion, 19-year contract on Sept. 16 to Lockheed Martin Australia. [www.ga.gov](http://www.ga.gov) 

## NASA extends contract with Planet

Planet Labs PBC has announced NASA has exercised an option to extend its contract with Planet under the Commercial SmallSat Data Acquisition (CSDA) Program through September 2023. Planet has been providing data to NASA scientists and federally funded researchers under this program since 2018. [www.planet.com](http://www.planet.com)

## Innovative method of generating topographic surfaces

Virtual Surveyor has unveiled newly developed Auto-Flip Edges functionality that generates more accurate terrain surfaces from drone survey data. This innovative triangulation process is included in Version 8.7 of the popular Virtual Surveyor software package. [www.virtual-surveyor.com](http://www.virtual-surveyor.com)

## NASA Laser project benefits animal researchers

In a new scholarly paper that details research in northwest Wyoming, University of Wyoming researchers explain how NASA's Global Ecosystem Dynamics Investigation (GEDI) mission can provide valuable information about the world's forests for wildlife scientists. The article appears in the journal *Forest Ecology and Management*.

Using a light detection and ranging (LiDAR) laser instrument installed on the International Space Station, GEDI collects high-resolution observations of the three-dimensional structure of Earth's forest -- including precise measurements of forest canopy height, canopy cover and vertical structure. GEDI was attached to the International Space Station in 2018 for a two-year mission that has been extended until January 2023; it is expected to collect over 10 billion samples of Earth's tropical and temperate forests.

Working in the greater Yellowstone ecosystem -- including two national parks, parts of three national forests, one national wildlife refuge and Bureau of Land Management land -- the researchers deployed 107 camera traps for three

consecutive winters. Based on photographs of target species, they calculated habitat use for Pacific martens, Rocky Mountain red foxes and coyotes, along with prey species red squirrels and snowshoe hares.

The scientists then paired data from GEDI with other remote-sensing platforms to create forest height and structure maps,

which they used to run computer models to evaluate animal-environment relationships. They found that the pairing of GEDI data with other sensors resulted in a substantial improvement in characterizing vertical and horizontal forest structure, which aided efforts to understand important habitat features for the animals studied. <https://gedi.umd.edu>

## Vexcel UltraNav version 7 and a new partnership with TopoFlight

Vexcel Imaging introduced the next version of UltraNav, its all-in-one Flight Management and direct georeferencing solution. UltraNav version 7 guides customers every step of the way from 3D Flight Planning to real-time navigation and quality control during flight to post-processing GNSS/INS data. To offer this integrated solution, Vexcel Imaging entered into a new partnership with TopoFlight for flight planning/management and continues its longstanding partnership with Applanix for the GNSS/INS modules & post-processing.

## New UltraCam Eagle 4.1 photogrammetric aerial camera system by Vexcel Imaging

Vexcel Imaging recently released the new UltraCam Eagle 4.1, the pinnacle of nadir photogrammetric aerial camera systems increasing flight efficiency at truly mapping-grade image quality for precise analysis and interpretation.

Based on Vexcel's ground-breaking 4th generation camera technology, the UltraCam Eagle 4.1 collects high-resolution panchromatic, R, G, B and NIR information at over 500 Megapixels—an impressive footprint that can be exploited at different altitudes, thanks to three field-exchangeable lens kits at focal lengths of 90 mm, 120 mm and 150 mm. The Eagle 4.1 is further enhanced by the proprietary Adaptive Motion Compensation (AMC) software approach that addresses image blur caused by

multi-directional camera movement during the flight. Featuring new sensors, coupled with new electronics and new lenses, the Eagle 4.1 delivers visually stunning, photogrammetric-grade quality imagery. The Eagle 4.1 is in a class of its own. The difference is found in the camera's panchromatic "backbone." High-resolution PAN sensors collect and resolve object details more faithfully and with higher geometric accuracy. Consequently, UltraCam panchromatic and full-resolution color data (produced through pansharpening) feature a higher image-resolving power. Imagery is more detailed, more accurate and more actionable.

## Vexcel releases property damage insights for Hurricane Ian

Vexcel Data Program has collected high-resolution aerial imagery of buildings and properties impacted by Hurricane Ian. The unprecedented level of destruction and scope of this event means thousands of homes, buildings, and other structures were destroyed or sustained heavy damage.

Vexcel, on the behalf of its partner the Geospatial Insurance Consortium (GIC), activated a full response to Hurricane Ian by deploying multiple fixed-wing aircraft to collect super-detailed imagery at a 7.5-10cm resolution. This imagery was captured with Vexcel's UltraCam sensors then put through its world-class processing pipeline and delivered within 24 hours post-collection. Both orthomosaic and oblique aerial imagery are published, providing multiple views of the damaged areas in Florida. [vexceldata.com](http://vexceldata.com)

**UAV Navigation defines operational envelope for VECTOR-600 autopilot**

An independent study conducted by UAV Navigation has defined the operational envelope of the VECTOR-600 autopilot based on the Specific Operations Risk Assessment (SORA) methodology. The operational envelope defines the operational risk profile within which an aircraft can operate safely, taking into consideration all risk mitigations included within the system.

The SORA methodology evaluates the safety risks involved with the operation of an unmanned aerial system (UAS) of any class, size or type of operation. The concept of operation (ConOps) is normally used as the input for this analysis; the output takes the form of the Specific Assurance and Integrity Level (SAIL) for a particular operation, which indicates the level of robustness that must be demonstrated for the operational safety objectives.

In this case, instead of performing a conventional SORA analysis from the ConOps to the SAIL output, this study was performed the other way around because the objective of the study was to identify the operational envelope of the system. [www.uavnavigation.com](http://www.uavnavigation.com)

**LidarSwiss deploys Cepton lidar for high-fidelity mapping**

Cepton announced that it is working with LidarSwiss Solutions GmbH to deploy its lidar technology in a drone-based mapping and analytics solution for infrastructure management and engineering design applications.

Nano P60 integrates Cepton's Sora sensor with a high-precision IMU/GNSS unit and a high-resolution camera system. Its intelligent controller with LidarSwiss proprietary software automatically combines all raw data to generate high-density, high-precision RGB-attributed 3D laser point clouds during flight. [www.lidarswiss.com](http://www.lidarswiss.com)

**JAVAD GNSS Announces New Products**

JAVAD GNSS launched new GNSS products for geospatial applications.

The TRIUMPH-1M Plus and T3-NR smart antennas bring the latest satellite tracking technology into the Geospatial portfolio using GNSS and inertial sensor fusion augmented by updated modules for UHF, Bluetooth, Wi-Fi, and power management.

The RS-3S is a rugged, mountable GNSS enclosure equipped with the latest tracking technology designed for outdoor use. The new Victor-2 and Victor-4 rugged field computers for data collection has also been introduced. The Victor-2 features an inbuilt keyboard with a classical data collector look and feel, while the Victor-4 is an 8-inch tablet optimized for field use. Both solutions will run the new J-Mobile for Android™ data collection software. J-Mobile is optimized with user-friendly workflows and industry-standard menu structures for immediate use with minimal training. [www.javadgnss.com](http://www.javadgnss.com)

**Rx Networks collaborates with Qualcomm**

Rx Networks, Inc. announced the availability of TruePoint.io precise location services on Snapdragon 8 Gen 1 and Snapdragon 888 5G Mobile Platforms. TruePoint.io integration empowers Android smartphones to achieve enhanced location accuracy down to a meter or less – something only previously seen with high-grade receivers. <https://rxnetworks.com>

**Hexagon & LocLab partnership**

Hexagon's Geosystems division and LocLab announced a strategic partnership to jointly empower industries with Smart Digital Realities in their design, construction and operations processes. The strategic partnership is focused on increasing the automation of 3D digital twin creation by leveraging reality capture solutions and making digital twins seamlessly accessible to customers by connecting them with HxDR, Hexagon's

cloud-based storage, visualisation, and collaboration platform for reality capture and geospatial data. [www.hexagon.com](http://www.hexagon.com)

**Trimble & General Motors marks milestone in semi-autonomous driving**

General Motors and Trimble recently reached a milestone in the hands-free driving world—more than 34 million miles driven with Super Cruise engaged on General Motors vehicles.

The partnership aims to develop a reliable way to maintain in-lane positioning for hands-free driving, putting safety top-of-mind. [www.trimble.com](http://www.trimble.com)

**Hemisphere GNSS Introduces GradeMetrix® Scraper**

Hemisphere GNSS, Inc. has announced the release of the GradeMetrix® Scraper Solution for pull pan and belly pan scrapers.

The kits will be available for purchase for new customers. Existing customers will have the option to add scraper support to their current GradeMetrix® system via a software upgrade and machine activation. [www.HGNSS.com](http://www.HGNSS.com)

**Lantronix launches new GNSS receiver modules**

Lantronix Inc. has launched its new PNT Series GNSS Receiver Modules. It provides an easy-to-use, cost-effective solution to enable the addition of GNSS functionality to products. The receiver modules are appropriate for use in consumer solutions, including people/pet and asset tracking devices etc. [lantronix.com](http://lantronix.com)

**Spirent GNSS simulator integrated with MVG over-the-air test systems**

Spirent GSS7000 GNSS simulator has been integrated into Microwave Vision Group (MVG) over-the-air (OTA) and passive antenna test systems. MVG enables the characterization and evaluation of antennas for testing

wireless connectivity, reliability, and standards compliance. MVG near-field test systems perform fast and accurate measurements for OTA tests of antennas designed for satellite communications and other GNSS-enabled products, systems, and networks. [www.spirent.com](http://www.spirent.com)

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## Mosaic integrates RIEGL Mobile Mapping Systems

Mosaic has announced its product portfolio would integrate RIEGL's mobile mapping systems to gather more advanced 3D data. The technology alliance also allows Mosaic end-users to record and analyse 3D object surfaces and environments to assist with city planning, construction, and maintenance.

The Mosaic X and Mosaic 51 photogrammetry cameras now leverage RIEGL V-Line Scanning technology to produce high-precision LiDAR-based point clouds that accurately digitise environmental textures, which use RIEGL VMY-1, VMY-2, VMQ-1HA, and VMX-2HA Mobile Mapping Systems. [www.mosaic51.com](http://www.mosaic51.com)

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## RFoF equipment achieves a trifecta in space

(RFoF) systems' latest deployment have supported a customer's crewed mission into space! Throughout the successful flight operation into space, the equipment worked perfect as designed and was used to cover three different technology verticals simultaneously. - GPS for timing and synchronization, UHF/VHF for telemetry, tracking and control, and L-band for satellite communications. ViaLite has been supporting the privately funded aerospace manufacturer for a number of years in each of these categories.

The use of ViaLite's unique Hyperwide Dynamic Range RF over fiber links in these type of Space and Mil-Aero applications offers the competitive advantage of very low signal power losses across long distances. [www.vialite.com](http://www.vialite.com)

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## Quectel launches LC29H

Quectel Wireless Solutions has launched LC29H. It is a dual-band multi-constellation GNSS module built using the Airoha AG3335 platform. It is available in multiple variants and optionally integrates real-time kinematic (RTK) and dead reckoning. [quectel.com](http://quectel.com)

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## Qualcomm releases Snapdragon W5 Gen 1 and W5+ Gen 1 platforms

Qualcomm Technologies releases Snapdragon W5 Gen 1 and W5+ Gen 1 platforms. Both the platforms are designed to advance ultra-low power and breakthrough performance for next-generation connected wearables with a focus on extended battery life and premium user experiences. They incorporate innovations including low power islands for GNSS, Wi-Fi and audio; ultra-low power Bluetooth 5.3 architecture; and low power states such as Deep Sleep and Hibernate. [qualcomm.com](http://qualcomm.com)

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## Hi-Target GNSS receiver

The pocket-sized vRTK GNSS real-time-kinematic (RTK) receiver is equipped with dual cameras to enable non-contact image surveying. It also has a nine-axis IMU module with auto installation for tilt surveying. Visual positioning technology combines imagery with high-precision positioning equipment, allowing users to obtain the location of the target from a distance. The Live View Stakeout function improves stakeout speed, while non-contact measurement greatly improves the usable range of GNSS. The vRTK receives 1,408 channels (GPS, GLONASS, BeiDou, Galileo, QZSS, IRNSS and SBAS). A new generation of GNSS engine supports the new frequency points B1C, B2a and B2b RTK decoding of BeiDou-3 satellites. [en.hi-target.com.cn](http://en.hi-target.com.cn)

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## Teledyne announces new Ladybug6 cameras

Teledyne FLIR Integrated Imaging Solutions has announced the all new Ladybug6—the latest addition to its field

proven Ladybug series. Ladybug6 is the leading high-resolution camera designed to capture 360-degree spherical images from moving platforms in all-weather conditions. Its industrial grade design and out-of-the-box factory calibration produces 72 Megapixel (MP) images with pixel values that are spatially accurate within +/- 2 mm at 10-meter distance. [www.teledynelifir.com](http://www.teledynelifir.com)

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## SBG Systems introduces Quanta Micro INS for UAS surveying

SBG Systems recently released the Quanta Micro, an inertial navigation system (INS) for UAS surveying.

The miniature inertial sensor embeds a dual frequency/quad constellations GNSS receiver for centimetric position with a high performance IMU into a compact form factor, according to a news release. The RTK capable sensor is 50 x 37 x 23 mm and weighs 38g. It offers roll/pitch with less than 0.02° error and heading with less than 0.06° error.

Even though it comes in a small form factor, the sensor embeds all the features found in other SBG inertial sensors, including a built-in datalogger, Ethernet connectivity, a PTP server, multiple serial ports, and a CAN port. A built-in, user friendly web configuration interface makes it easy to configure. The sensor also be configured using SBG API or ROS drivers. The Quanta Micro supports dual GNSS Antenna mode to improve heading accuracy in low dynamic applications, but also can maintain optimal heading performance in a single antenna.

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## Topaxyz, the high-performance navigation solution

Thales offers the TopAxyz solution, a control unit that provides navigation, orientation, position and velocity data based on measurements of the vessel's angular velocity using its inertial core.

This is one of the key assets of the RLG (Ring Laser Gyroscope) technology

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## MARK YOUR CALENDAR

### February 2023

GeoWeek 2023

13-15, February  
Denver, CO, USA  
[www.geo-week.com](http://www.geo-week.com)

### March 2023

Munich Satellite Navigation Summit 2023

13-15 March  
Munich, Germany  
[www.munich-satellite-navigation-summit.org](http://www.munich-satellite-navigation-summit.org)

DGI 2023

27 Feb-01 March  
London, UK  
<https://dgi.wbresearch.com>

### April 2023

GISTAM 2023

25-27 April  
Prague, Czech Republic  
<https://gistam.scitevents.org/Home.aspx>

### May 2023

International Conference on

Geomatics Education

10-12 May 2023  
Hong Kong  
[www.polyu.edu.hk/lsgi/icge22/en](http://www.polyu.edu.hk/lsgi/icge22/en)

Geo Business 2023

17-18 May  
London, UK  
[www.geobusinessshow.com](http://www.geobusinessshow.com)

FIG Working Week 2023

28 May – 01 June  
Orlando, Florida, USA  
[www.fig.net/fig2023](http://www.fig.net/fig2023)

### June 2023

TransNav 2023

21-23 June  
Gdynia, Poland  
<https://transnav2023.umg.edu.pl>

### July 2023

IGARSS 2023

16 – 21 July  
Pasadena, CA, USA  
<https://2023.ieeeigarss.org/index.php>

### September 2023

Commercial UAV Expo

5-7, September 2023  
Las Vegas, USA  
<https://www.expouav.com>

ION GNSS+ 2023

11-15 September  
Denver, Colorado, USA  
[www.ion.org/gnss/index.cfm](http://www.ion.org/gnss/index.cfm)

developed by Thales and composed of a single-piece gyrometer that operates in all three dimensions of space (the X, Y and Z axes referred to in the name TopAxyz), with total immunity to the external environment and extreme performance stability. [www.thalesgroup.com](http://www.thalesgroup.com)

## New indoor mapping product by DATAMARK

DATAMARK, the public safety GIS team of Michael Baker International, has released 'Inside', a new cloud-native Software-as-a-Service (SaaS) solution designed to enhance indoor location intelligence and enable mission-critical decision making in real-time during public safety incident response. Inside software is powered by Esri and allows users to create, interact with and manage valuable indoor data for emergency dispatchers, first responders and school safety personnel. [www.datamarkgis.com](http://www.datamarkgis.com)

## Geometer International launches mobile RTK receiver

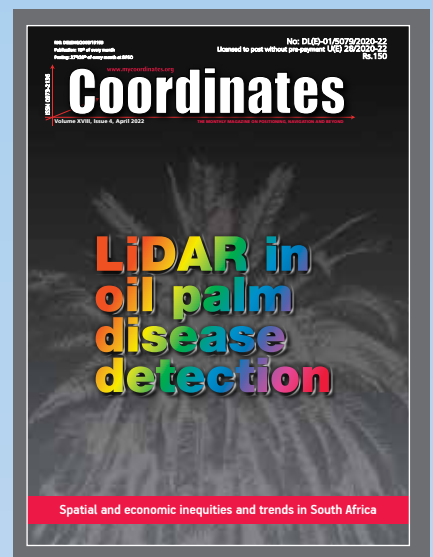
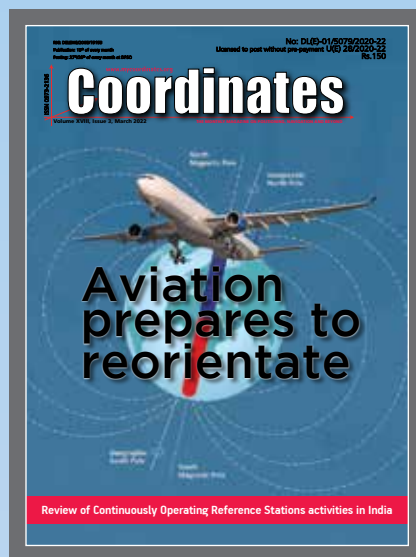
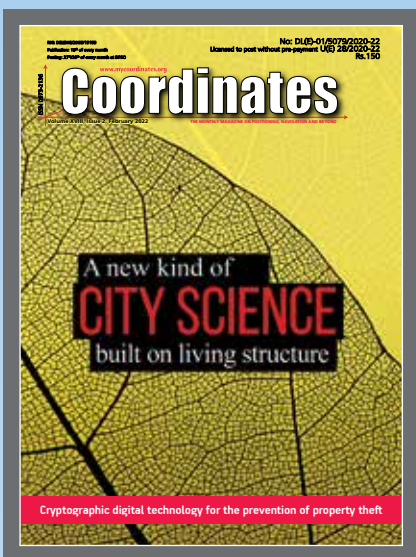
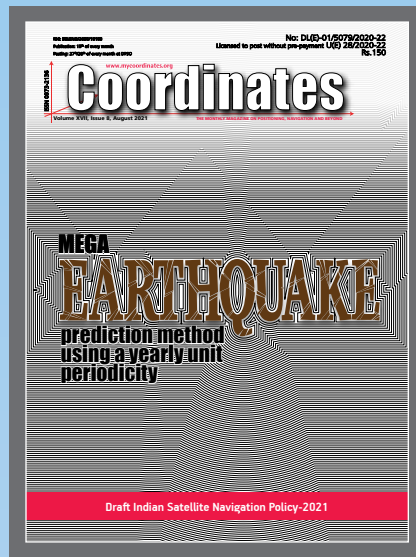
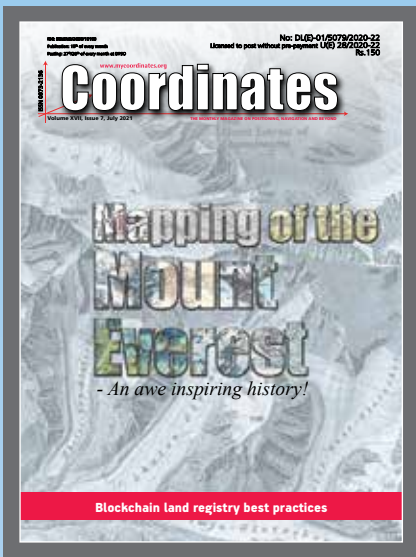
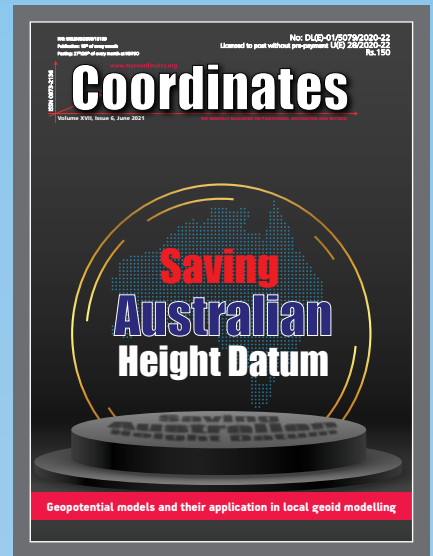
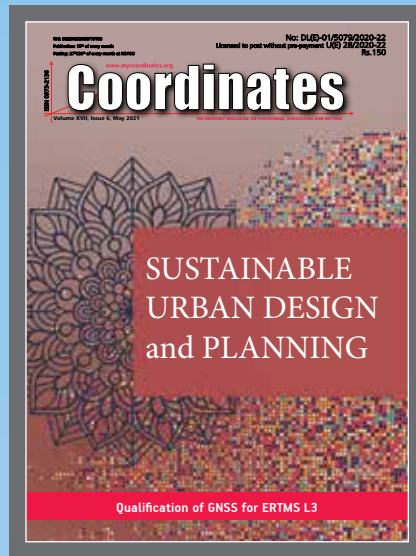
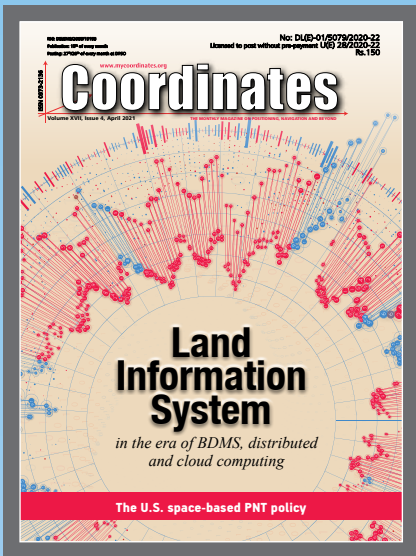
Ukrainian firm Geometer International has launched a product, which can be used on-farm for surveying, landscaping, and mapping trenches and fields.

Designed as a mobile, handheld and real-time kinematic positioning (RTK) receiver, the Walker allows users to determine their location within centimetre accuracy. <https://walkerstk.com>

## Northrop Grumman's new navigation capability for fleet deployment

The U.S. Navy has approved Northrop Grumman Corporation's new Electronic Chart Display and Information System (Navy ECDIS) for deployment to its fleet.

The Navy's Operational Test and Evaluation Force (OPTEVFOR) issued a formal determination that Navy ECDIS is "operationally suitable, operationally effective and cyber survivable." This new capability will be a core element to all U.S. Navy bridge and navigation systems. ▽



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## GNSS Testing with Direct Flights Departing from Your Desk

LabSat GNSS simulators offer multi-constellation and multi-frequency capabilities for **reliable, repeatable and consistent testing.**



### Dynamic Scenarios

Create custom trajectories for take-off, flight path and landing



### Developer API

Automate tests with **centralised control available** via ethernet connection



### Real-Time Option

Generate **real-time GNSS RF signals** with a current time stamp



### Autonomous Dev

**Repeatable and consistent testing** for development of drones and UAVs

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