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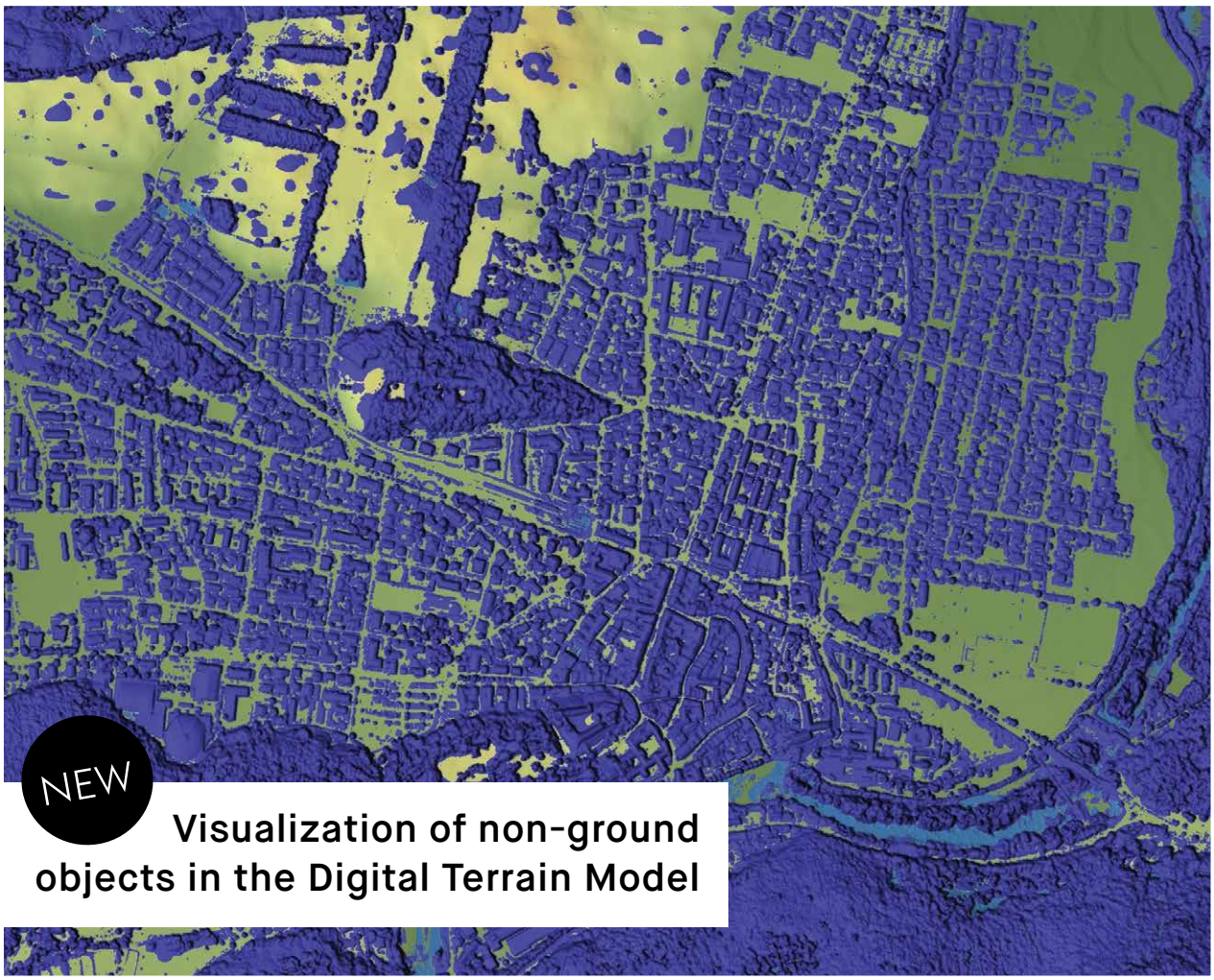

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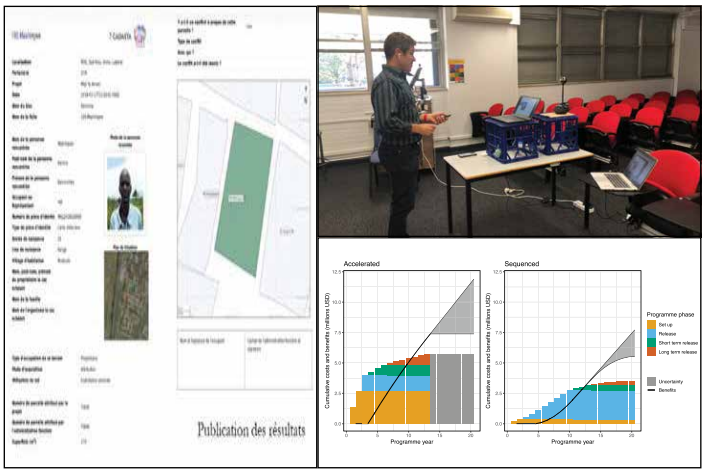

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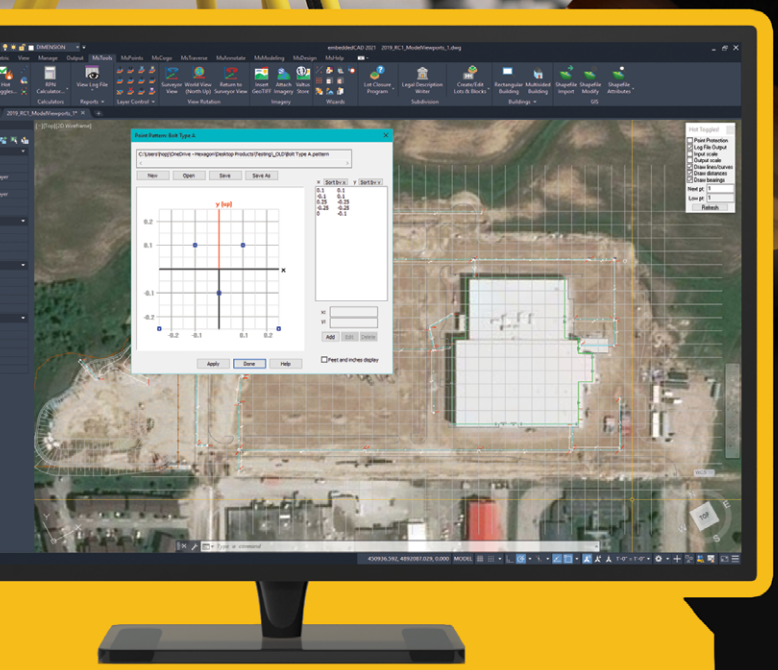

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Blind men and an elephant

It has been months …

But only time has passed

Not the chaos and nor the calamity

And worse, it remains as confusing as it was.

Even basic questions still struggle for answers…

First wave, second wave or the third one?

Whether to lock, and if yes then what and how?

As we unlock, the question then arises why was it even locked?

Wear facemask or not.

Physical distancing then where and among whom?

Vaccine – will come soon or may take years.

Many in Asian continent may be aware of a parable.

How blind men grapple to figure out what an elephant is?

Here, it is a case of virus.

Which is invisible and worse probably, intelligent too!

Bal Krishna, Editor
bal@mycoordinates.org

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Surveying education in the time of Covid

Teaching in the time of COVID has been challenging for all of us. We have adopted an honest, hard working approach

Dr Craig Roberts
Senior Lecturer
Surveying and Geospatial Engineering
School of Civil and Environmental Engineering
UNSW, Sydney, Australia

On 16 March 2020, all teaching staff in the School of Civil and Environmental Engineering (CVEN) at the University of New South Wales (UNSW) received a decisive email from our acting Head of School Professor Nasser Khalili entitled "Remote Delivery of Courses and Shutdown." The threat of COVID-19 had forced university administrators to shut down the entire institution in the coming days. But the message from Prof Khalili was clear, no one would be recycling old lecture recordings. Every teacher in the school would be delivering lectures live on-line, starting in 7 days, and Dr Steve Davis (Chair of our Teaching and Learning committee) would be teaching us all how to do it the very next day in an extraordinary, "all teaching staff" meeting.

Everyone came with laptops and determination. Our IT support wizards were there. There was no complaining, no excuses, no blame, just a desire to roll up our sleeves and make this work. UNSW supports Microsoft Teams and Blackboard Collaborate (BBCU) which was embedded in our university -wide education platform called Moodle. Everyone used Moodle but none of us had tried BBCU and few had used MS Teams.

The school purchased external video/ microphone devices for lecturers and updated laptops and tablets where necessary. We learnt how to set up and enter online classes, share screens/ videos, make students presenters, use whiteboards, create polls, record lectures, invite guests, ask chat questions and create breakout rooms. In the coming days, different lecturers practiced together in preparation for their first ever live lecture with students. It was challenging, but somehow refreshing and exciting to have to use your educative talents in a new constrained environment.

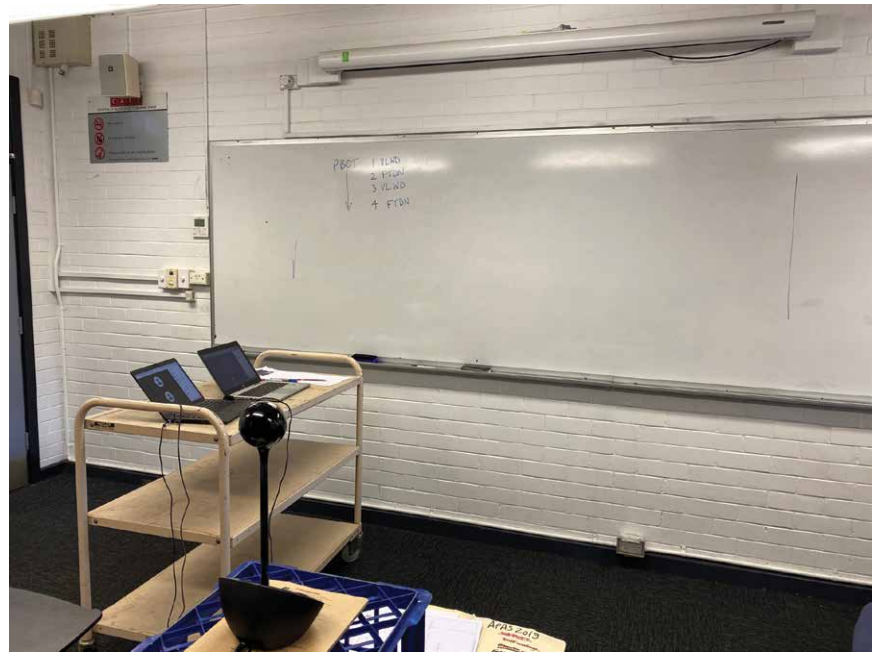
Across the school, some classes are very large (over 500 in a class) and some are much more manageable (15 – 20). MS Teams was more suited to large classes, whereas BBCU was restricted to a maximum of 250 participants.

On Monday March 23, teaching recommenced in earnest, except this time live online and remote from the familiarity of face-to-face classes. We were quick to point out to students that this was new to us. We asked students to help teachers if we forgot to unmute our mic or hit the record button. The students realised that their feedback could help improve their online experience and started to engage differently. In a face-to-face class they might never ask a question but typing a chat message seemed less intimidating.

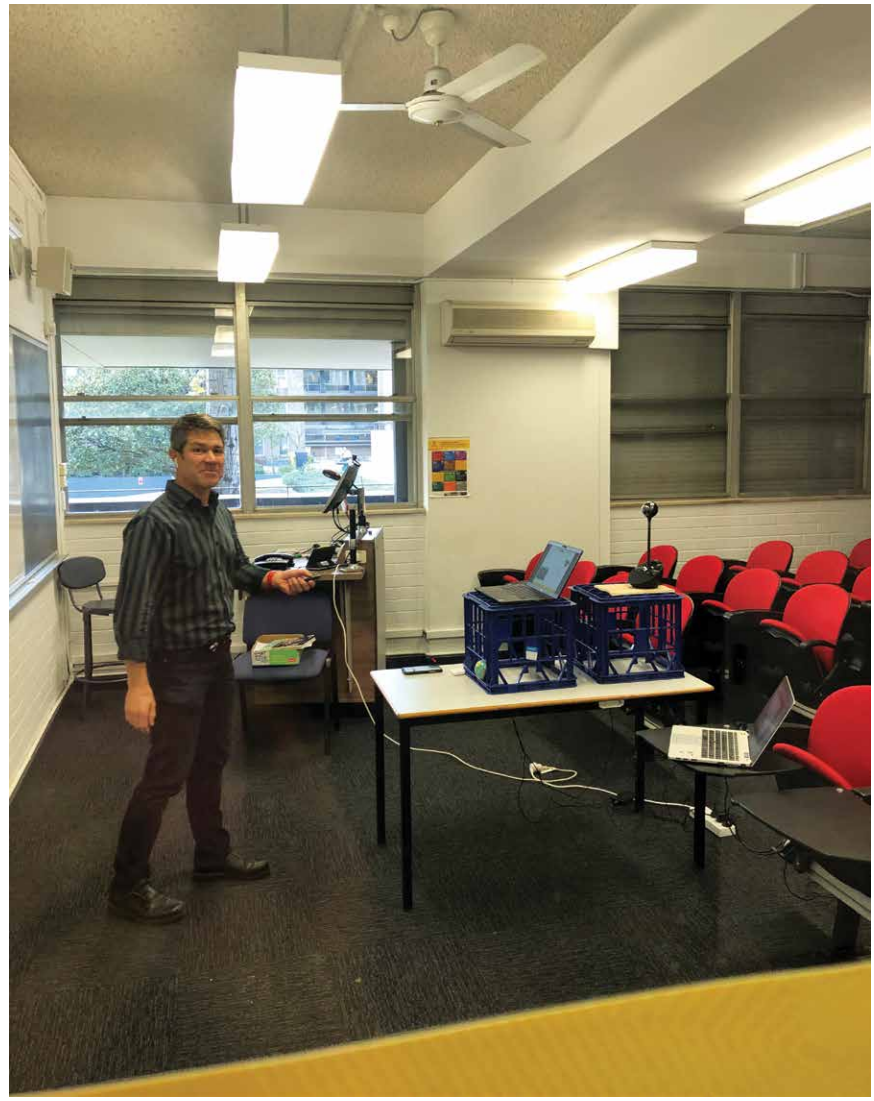
Almost 4 years prior I had given one of the first live webinars nationally in Australia with the support of the Surveying and Spatial Sciences Institute (SSSI). It was my first experience with the feeling of sitting alone in a room, talking to a screen and knowing that many are tuned in listening – not unlike my high school days working at a community radio station. But my big lesson from this first experience was that the natural position for lecturing is standing up. I feel I can present with more energy and passion.

I had also learnt that the whiteboard function restricted me to the clunky use of a mouse, unless I had a tablet – and

I did not. For these reasons, I booked a lecture room with a real whiteboard and set myself up for each lecture in a room, by myself and conveniently located next to my survey store. I could switch between sharing my screen and sharing my video to show a real whiteboard and/or demonstrate surveying equipment or simply describe things with my hands as I would do in a face-to-face lecture. I found being in a room liberating – and strangely comfortable considering that, to an outside observer, I was apparently gesticulating and talking to myself.



As lecturers we soon learnt that if we shared our screen then we could not see the chat messages from students. Our solution was to join the lecture as a guest with a second screen (laptop, iPad, tablet) and monitor the chat messages. It enabled students to ask questions and the lecturer to respond immediately – but as teachers we were kept busy. I advanced from external microphone, to USB headset with 2m cord to the freedom of Airpods. We learnt by experimenting and sharing our new experiences.



In surveying, the class sizes were thankfully smaller (never more than 40 – 50), however even though the more senior students knew each other well, few were prepared to show their face. Whilst some would unmute their microphone to ask a question, most preferred to use the chat. It is unclear if this is out of politeness or shyness, but it did take away that instant facial feedback of the student not understanding a point or falling asleep in class. For tutorial or workshop type sessions, I tried a different strategy. I emailed students to advise that I would not be recording the session beforehand, partly to ensure attendance but mostly to observe behaviour. Students who attended seemed to be more willing to unmute, speak freely and engage more.

Some workshops were designed to go through assignments or projects that had been set and required processing with CAD or GPS Baseline processing software. Licensing arrangements had been previously made (before COVID)

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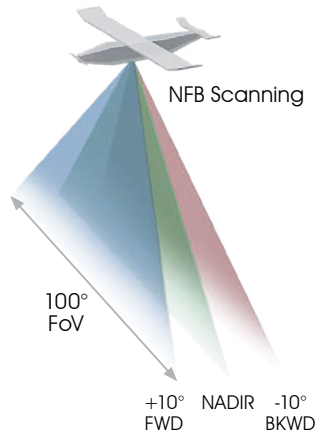

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to enable students to remotely access these softwares from home using a virtual private network (VPN) connection. The sudden influx of new users was initially a challenge to our IT staff but teething problems were overcome. Sometimes it was useful to record small sessions using the software live – very much like the many tutorials on YouTube, except these could be tailored to student assignments. With our new knowledge of online teaching, this became a simple exercise and a valuable resource to assist student learning.

Young students are sometimes classified as "digital natives" which assumes that they can simply learn any new software or delivery platform and it does not bother them. This was not my experience. We tried hard to stick to just a few delivery platforms so students could focus on the discipline specific learning and not "which button to press to share a screen". Students certainly appreciated this as evidenced in feedback surveys at the end of term.

Given that the shutdown was imposed on all staff and students in week 5 of a 10-week term, the university recommended that all courses would simply be pass/fail. This was to accommodate those students whose personnel IT circumstances were poor, also those international students who could not return to Australia at the start of the year due to travel restrictions in their own home countries, but mostly to provide equity in assessment for all students.

Some academics tried to create online quiz style exams, but this was restrictive. Others tried to re-design their assessment toward assignments only. Some wrote exams as normal and sent them via email to students at a set date and time and asked that the students return the completed papers within 2 hrs, 6hrs or even 24 hrs (to accommodate students enrolled across all longitudes). Given the short time-frame to re-design such assessment, pass/fail was considered the most equitable solution in the short-term.

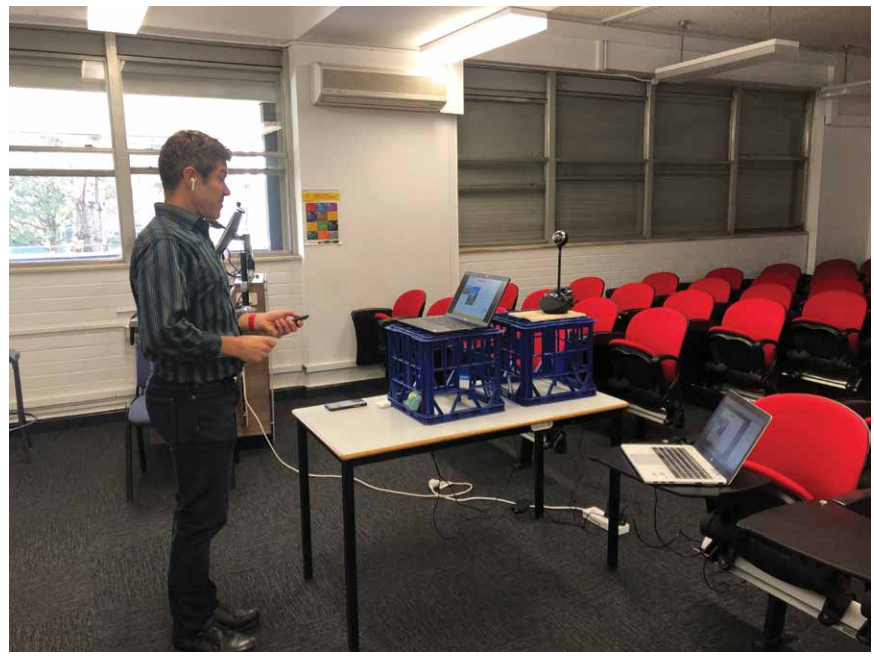
Luckily, our 3rd year surveying students had completed their intensive, one-week field camp exercises prior to the shutdown and now only needed to complete their assignments. In this case, we were able to preserve our usual assessment, but in term 1 we were the exception not the rule. It seemed that half of the students liked the pass/fail rule and almost identical numbers wanted assessment.

In term 2, commencing June 1, assessment was restored. All classes remained online. Very few students or academics attended the UNSW campus and for surveying, all field practical classes were cancelled. This presented a difficult problem as we place a large emphasis on practical teaching (Roberts & Harvey, 2019). I teach a first-year surveying course. I rely on field practicals to help explain new concepts to students. I provide three practical exercises namely levelling, GPS and a building setout. I was required to provide alternative exercises for students to replace hands on field exercises.

Anticipating the shutdown, I brought some surveying gear from our survey store to my home to aid in development of new teaching resources. Using my teenage sons as assistants, I directed a very amateur film in short segments of how to perform a levelling run in my local park. I learnt how to edit these into short clips which I embedded into a Moodle quiz for students. My colleague Dr Bruce Harvey suggested it was good to show the mistakes students make as beginners. The quiz gave students the opportunity to critique my deliberate mistakes, which I corrected in the next short film clip.

But simply watching a quiz and answering some leading questions was an unsatisfactory replacement to performing a hands-on task. The students had seen the process, so part 2 of the exercise asked students to go to their local park and design their own level run. Unfortunately, they would not be able to take the measurements, but in my experience, it is the reconnaissance and design of the survey that beginner surveyors find most challenging. They were then required to draft a fully annotated locality sketch and short report describing their level run design.

Further to this, due the Open Data policy across NSW state government (NSW Govt 2020), NSW Spatial Services had recently produced a new app (NSW Spatial Services 2020) that could be used to search for any of the 220,000+ survey marks across NSW. This was the first time 1st yr students had actually searched for survey marks by themselves in their own locality. Their survey needed to commence at an established mark and be shown on their locality sketch. Students



learnt that finding suitable marks was more challenging than they had first anticipated.

The GPS prac utilised this survey mark app as well as some suggested GPS measurement and GNSS constellation apps. Students were required to measure survey marks and suitable photocontrol marks in their local suburb with their phone apps, assess the quality of the positioning versus given coordinates and/or georeferenced imagery and report on difficulties. This exercise was scheduled after the GPS lecture and took some explaining in unrecorded practical briefing type "rooms" before students understood what was required.

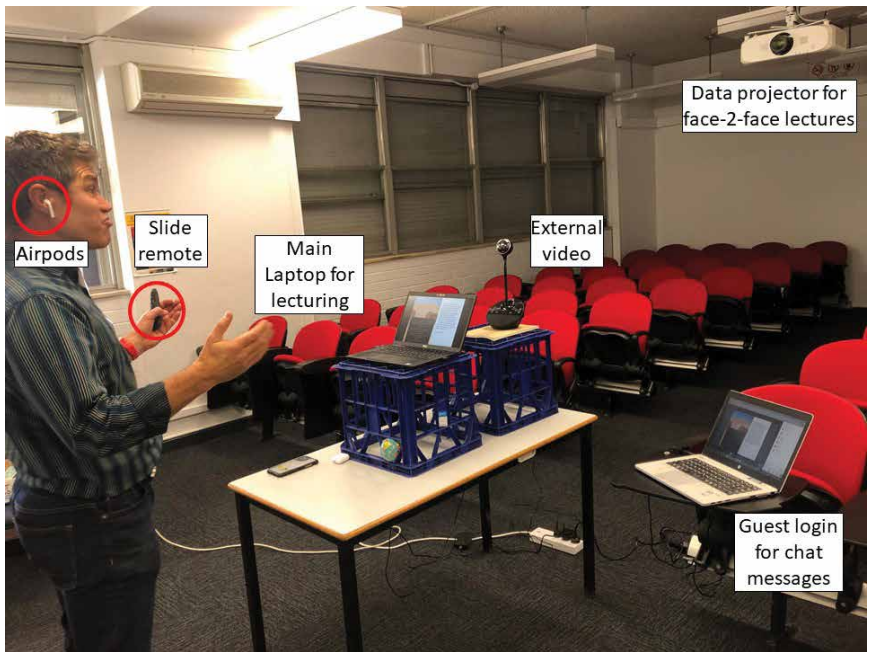
The final exercise was a typical building set-out where students were required to compute radiations from a known point and set-out a 6-pointed building to ±5mm accuracy. Normally this would be the first introduction to the use of total stations, but instead students were asked to find a partner (family or friend) and set out using just distances (using a 30m tape or similar), showing all checks to confirm squareness and accuracy. Evidence with photographs was required.

These three practical exercises received good feedback from students, given the circumstances, but all craved real, hands-on activities. As a teacher I also missed the opportunity to be in the field and offer guidance, suggestions, tips and tricks to the students.

My 3rd yr Geodesy course includes a large rapid static GNSS practical exercise where all students combine to run a 4-session survey with 8 GNSS receivers on 12 new marks and combine all observations with surrounding CORS data to perform a fully constrained network adjustment. In 2020, we simply processed the data from the 2019 students, but not before first designing our own logistics and survey planning on how to run the sessions and optimally combine the data. 2020 students were asked to compare their plan with that of the 2019 cohort and critically assess pros and cons.

These geodesy students are also asked to research a selected topic and prepare a presentation and reference list. Usually I schedule a time for live, conference style presentations and require all students to attend. The emphasis of the presentation is on sharing new found knowledge with the class, not only directed at the lecturer to garner marks.

Under COVID conditions, all students pre-recorded their presentations. As a lecturer I gave some suggestions on the best way to record, including tips on clear use of microphones. Video files were uploaded to an online repository for all types of video files which seamlessly linked to Moodle. All students were required to attend the session which was split into 4 x 50-minute sessions which were moderated and introduced by the lecturer. An additional MS Form was developed so that all students could provide assessment on their colleague's presentations. I could then download these comments as an excel spreadsheet. Feedback for this session was very positive. I will continue to use these MS forms post-COVID.



Term 3 has commenced, and thanks to some good discipline from our government and citizens, COVID-19 restrictions are easing and the university now permits outdoor field practical exercises. This is a huge relief as I teach 2nd yr and 4th yr classes which both include large components of field work. The sense of relief, excitement and gratitude was palpable during the first prac exercise when the students returned to campus, following strict COVID protocols. Students were instructed to maintain social distancing when gathering in groups, collecting gear or performing measurements. We check temperature of students prior to collecting gear. When in close contact, masks are always worn. Hand sanitiser is provided and instruments are wiped down after use.

All lectures are still presented online, but for some smaller classes where the 4 m^2 rule can be maintained, students are permitted to attend face-to-face lectures if they so desire. This presents an additional challenge to teachers who must now present to an online class, but also to students in the room. I now juggle three computers as I must project my lectures on the big screen in the room as well as online and have an additional screen to monitor chat messages. It is workable but sometimes a bit frantic.

Assessment remains a challenge and especially for final exams. For larger classes, cheating is a huge problem. There is no current software that can effectively

COVID-19 has forced teachers to adapt quickly. Some good things have been learnt and will continue to be used to enhance student learning, but given the practical nature of surveying, some face-to-face will always be required for a rich and worthwhile university education

stop students who want to cheat from doing so. We have tried to re-design questions that minimise cheating. Making exams open book, putting time limits on the exam or just including a lot of work to not give students the time to consult their colleagues. Online quiz style questions are restricted by the functionality of the software. Computational style questions can be written such that different values for different students can be programmed into the question, but this requires some specialist skill and time for preparation. We developed some questions using numbers from an individual student's university ID number – (eg. "Using the last 4 digits of your ID number what is the …").

For smaller surveying classes, my colleagues and I found almost no evidence of cheating. We spoke to our students about the purpose of exams, their required adherence to a code of ethics later in their professional careers and basically appealed to their honesty. It seemed to work.

Teaching in the time of COVID has been challenging for all of us. We have adopted an honest, hard working approach. We have tried to provide the best education possible given the changing restrictions and adapt accordingly. The online lectures have provided certain advantages. Many of our students must travel up to 2 hrs one way to attend campus. We have provided recorded lectures for a few years now, but the added advantage of live interaction during lectures certainly enhances the experience for students. Attendance online is indeed higher than previously when face-to-face. I imagine we will continue to lecture this way into the future, and I am happy to do so. Similarly, online workshops with software and pre-recorded presentations offer a certain educational advantage in some circumstances but should not be overused. We found that students have been very forgiving of lecturers when it was clear that they are trying hard to offer the best educational experience. Sometimes amateurish mistakes were met with sympathy and an offer to assist. This has been a nice outcome of this situation.

But for surveying there is no substitute for hands-on field practical exercises. We are fortunate in Australia that the restrictions are now easing. This has exposed the contrast between the online practical exercises which we had to develop in term 2 versus the usual hands-on exercises that we are now permitted to undertake in term 3. For larger, more complex field tasks such as those in yr 2, 3 and 4 of the program, there is simply no alternative.

COVID-19 has forced teachers to adapt quickly. Some good things have been learnt and will continue to be used to enhance student learning, but given the practical nature of surveying, some face-to-face will always be required for a rich and worthwhile university education.

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Dr Y Jade Morton receives Kepler award

The Institute of Navigation's (ION) Satellite Division presented Dr. Y. Jade Morton with its Johannes Kepler Award September 25, 2020 during the ION GNSS+ VIRTUAL Conference.

Dr. Morton was recognized for advances in scientific and navigation receiver technology, automated data collection, robust carrier phase tracking, remote sensing, and profound impact as an educator and author.

Dr. Y. Jade Morton has made pioneering contributions to the advancement of GNSS receiver technology and utilization of these enhanced capabilities for scientific discovery. Her work brings together scientific rigor with state-of-the-art engineering innovations to simultaneously improve PNT, while revealing remarkable new applications for GNSS.

Dr. Morton's lab developed event-driven GNSS data acquisition systems (EDAS), designed to capture severe space weather and ionosphere disturbances of GNSS signals, which could not be handled by existing GNSS monitoring receivers. Her lab designed and built remotely-configurable, multi-GNSS, multi-band, SDR hardware using off-the-shelf components; and developed software including machine-learning algorithms for automatic event detection to trigger raw data recording during these events. Her lab deployed these receivers worldwide.

Dr. Morton's group has made groundbreaking advances in GNSS carrier phase processing and established theoretical performance bounds. Her group developed optimal carrier tracking loop architectures and implementations, and successfully applied the techniques to processing signals experiencing strong ionospheric scintillation for ionosphere and space weather research; radio-occultation signals traversing moist lower troposphere for weather and climate modeling; weak coherent reflected signals from ocean, land, and sea ice for precision altimetry applications; and navigation in urban canyons and on high dynamic platforms. *ion.org*

Embrace the current scenario as a motivator, rather as a temporary nuisance

Our goal this year is not to do the "best we can do" despite COVID-19, but to make a first attempt at what will become a permanent blended offering of our program

Robert William Kingdon
Department of Geodesy and Geomatics Engineering University of New Brunswick, Canada

At University of New Brunswick Geodesy and Geomatics Engineering, we have perhaps an uncommon view on COVID-19, because we see it as an opportunity. Possibilities in remote geomatics education has been on our mind of a few years, and on those of others within Canada, as we have a significant capacity gap in surveying and many technicians or foreign professionals who could help to fill this gap if educational opportunities were available that could be pursued flexibility in their life situations. Thus, these are not new discussions for us, but COVID-19 has given a much needed push (and some resourcing) to evolve in this direction.

Our goal this year is consequently not to do the "best we can do" despite COVID-19, but to make a first attempt at what will become a permanent blended offering of our program. As you also mention, we are not the first to talk about remote geomatics education, and it has even been implemented at University of Maine in the US, and University of South Queensland in Australia. We do not see remote education as a detriment. Rather, we believe that an eventual blended program can ultimately deliver educational objectives more effectively than a traditional, in-person only program.

Despite most of our courses being technology mediated to start with, and most instructors already having some of the required technical skills and being familiar with video conferencing, we have all devoted significant time toward the conversion to remote teaching at the expense of other work

Our major resourcing needs have only been partly technological. For example, we all now have decent webcam, microphone, and production setups at home. For our first year course, that focuses on introducing the concepts of surveying instruments, we have also rented a Leica MS60 total station (and cellular data plan) that can be remotely controlled by students while an external camera shows them its movements and a telescope camera shows them a user's viewpoint. However, the greater resourcing requirement is in personnel. Despite most of our courses being technology mediated to start with, and most instructors already having some of the required technical skills and being familiar with video conferencing, we have all devoted significant time toward the conversion to remote teaching at the expense of other work. We have devoted even more time to this because we seek a permanent solution for remote delivery. We have also allocated the time of staff members to help with the transition, for example coordinating industry partnerships or facilitating online student community. This all happens at the expense of other activities, and we hope in the long term that these needs will be supported to allow a sustainable transition.

Partnerships to enhance education in a remote context are essential to any effective solution. In our winter term surveying courses, for example, we are arranging for students to work with industry partners—some of the largest surveying companies in Canada have signed up to help—to complete field exercises

What could be the best strategies, and I will list three below. I am not going to include some things that seem more obvious to me like: ensuring faculty are trained in online education; providing sufficient resourcing; and making online education accessible with respect to things like time zones, students in different living arrangements with different levels of connectivity, and needs for academic accommodations. The following are some of the things beyond those fundamentals that I consider important.

1. Most important is to embrace the current scenario as a motivator for sustainable change, rather than treating it as a temporary nuisance to be overcome. In the long view, this opportunity can produce a stronger Geomatics industry in Canada. Integrity, creativity, and cooperation will be essential in realizing this transformation.
2. I believe that partnerships to enhance education in a remote context are essential to any effective solution. In our winter term surveying courses, for example, we are arranging for students to work with industry partners—some of the largest surveying companies in Canada have signed up to help—to complete field exercises. This is a model that has been working for a few years at University of Maine, and in our case has been met with enthusiasm by both students and the surveying community. Well-implemented, it may provide a more relevant experience for students and be superior to the traditional teaching assistant supervised laboratories, simultaneously freeing up teaching assistants to assist with other aspects of the educations experience. Looking beyond our plans for this year, partnerships with colleagues from academia, industry, or government across Canada to share in virtual teaching would also be fruitful. In the long term, these could help to bring expertise and experience from across Canada to students in all of the programs and to share workload among institutions. All of these things must be carefully organized, but the potential benefit is immense.
3. I beleive, this year and going forward, the importance of student community should not be lost. Students serve as a support system for one another academically, personally, and professionally. This value could be lost in remote learning without daily in-person interaction unless it is intentionally maintained. Our students regularly interact over facebook in any academic year, but for this year we have involved the student leadership in facilitating online community and they are doing a tremendous job. This should be student led, and it will be important in our long term transition to ensure that remote students participate in student community as actively as those participating in-person.

IRDAI committee recommends insurance for drones

Insurance Regulatory and Development Authority of India (IRDAI) constituted a Working Group in June 2020 to study and understand the insurance needs of RPAS owners and operators and make recommendations relating to design and development of products meeting the needs of RPAS owners and operators, including Third Party Liability.

The Working Group has now submitted the report. The committee notes that the Draft UAS 2020 has suggested compensation in respect of Third-Party Liability to be on the lines of Motor Vehicles Amendment Act 2019, which in the group's opinion is partially acceptable in situations like Section 164 of Amendment Act of 2019 (Payment of compensation in case of death or grievous hurt).

However, as per the committee the unlimited liability (Section 166) and Solatium Fund appearing under MV act is a cause of concern to develop a feasible drone insurance ecosystem in view of non-availability of claim data for drone losses and lack of re-insurance support for unlimited liability.

The report has looked into the insurance requirements of the RPA owners and operators, suggested coverage's along with draft / specimen wording, factors which affects the pricing (premium) and finally the underwriting considerations which may be followed.

Few suggestions / recommendations have been made on the governance /privacy issues, and if adopted will provide a robust environment in the country for the drone operations. *www.irdai.gov.in*

Emerging GIS trends and forecasting

With trends such as data analytics, IoT, AI, VR etc. gaining popularity across the globe, we can expect GIS to also see the transformation and also aid in how organisations around the globe utilise these technologies in the future

Ashwani Rawat
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In the past decade, there has been an increased adoption of GIS technologies for various facets of facilities management, business intelligence, smart cities development, urban planning, etc. that has fuelled its growth. The adoption and amalgamation of various advanced technologies such as IoT, VR, AR, with GIS as well as the evolution of technologies such as geospatial AI, 4D GIS software etc. have only led to the creation of numerous opportunities in the field.

Today's digital age is witnessing complex technology transformation at a rapid rate with data proliferation opening up newer revenue streams. According to reports, the global GIS software market was valued at $3.24 billion in the year 2017, and is expected to double its market share and become almost $7.86 billion by the year 2025 and is expected to register a CAGR of 11.8% between the years 2018 - 2025.

Taking a look at emerging technology trends that will shape the future of GIS, the following observations have been made:

- **Real-Time Factor:** The generation of real-time spatiotemporal data is almost ubiquitous right now, and its application in areas pertaining to research in commerce is rapidly expanding. This, in turn, has accelerated our capability of creating and interacting in real-time with the data generated, and is in fact, acting as the core catalyst in GIScience and other relevant geospatial fields.

- There has been a profound realignment of traditional structures, relationships, an expansion in research horizons and of course of a transformation in the way geospatial data is now collected, mapped and modelled. Real-time interaction has to lead to the creation of new geographic research initiatives, fused spatiotemporal data and various applications for governments, businesses, etc.

- **Mobile Geospatial Sensor Platforms:** We have witnessed the miniaturization of technologies that has enabled the exploration of new modalities for sensor distribution. With the advent of mobile geospatial sensor platforms, the abilities of businesses, governments as well as individuals to be able to garner vast volumes of data that has been remotely sensed has exponentially expanded. Owing to this, utilisation of data for critical purposes such as public safety, disaster response, etc. has been enhanced and continues to be finessed.

- **The AR Opportunity:** Augmented Reality and Virtual Reality continue to grow and carve out a niche for themselves by integrating with GIS technologies. With GIS-enabled AR apps becoming more and more common, their varied field usage by service providers ranging from architects to municipal corporations etc, have demonstrated the direction in which the future is heading. When powered by 3-D spatial information, GIS applications can create immersive experiences for users across fields.

- **Moving Inwards:** Similar to the manner in which GIS maps citizen roadways, it is now being used for developing indoor maps. Though it is in the early stages of development and adoption, the popularity of in the future is likely to skyrocket as it can be used for various functions such as improved safety for emergency responders, gauging critical points of entry and other such information. Another really big opportunity that is going to arise for GIS in the future is on the UI level. Introducing UI will come as a major breakthrough for the technology because it will end up making maps much friendlier for developers as well as the users.

Maps being the visual language for understanding the context of the data, taking into consideration all the new exciting developments that we are looking forward to in GIS – the future looks really optimistic. Geared for a wider scale adoption, more and more organisations are now realising the sheer volume of business value that can be derived out of geospatial data. With trends such as data analytics, IoT, AI, VR etc. gaining popularity across the globe, we can expect GIS to also see the transformation and also aid in how organisations around the globe utilise these technologies in the future.

The land reforms in the Democratic Republic of Congo

Practical solutions for the protection of smallholder land rights

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Abstract

In the East of the Democratic Republic of Congo (DRC), insecurity of tenure rights, displacement, poverty and general security issues are major obstacles to economic and social development and a transition to a more peaceful and prosperous society. Congolese land reforms are part of a process to promote the country to the status of emerging economy by 2030 and industrialized country by 2050. Reforms that promote and protect the rights of vulnerable farmers and contribute to these objectives require pragmatic and effective solutions. This paper presents such a practical solution to the insecurity of occupation and land use in the east of the Democratic Republic of Congo, where people in most cases access and govern land via customary systems. The presented case describes the efforts around improving tenure security of a consortium that is working to contribute to peace building through a large-scale irrigation project called Maji Ya Amani - Water for peace.

Introduction

In the East of the Democratic Republic of Congo (DRC), insecurity of tenure rights, displacement, poverty and general security issues are major obstacles to economic and social development and a transition to a more peaceful and prosperous society (see: Betge 2019). Persisting tensions between legal and customary land governance systems, which also occur in many other countries in sub-Saharan Africa, are increasing the complexity of the situation and in particular the challenges facing smallholder farmers (see also: Knight 2010).

In much of sub-Saharan Africa, the colonial land policies used customary law and land tenure as instruments, inviting colonial governments to justify the dispossession of the local population while serving local communities as an (apparent) tool to protect themselves against new land losses (Peters 2013). Since the colonial times, African governments have repeatedly tried to reorganize their land tenure systems. Extensive land titling programs were initiated in the 1960s and 1970s by the newly independent countries (ibid.). These aimed at transforming customary forms of land ownership to create a modern land market and strengthen the security of land rights. Most of these programs did not lead to increased investment and productivity, but have strengthened the patterns of unequal access to land and increased conflicts around land (ibid.). However, it is clear that customary tenure systems can similarly create high inequalities, highly exclusive property systems and, in many cases, have not been able to prevent the alienation of land through large-scale external investment with very negative effects for the poor.

In recent years, land tenure reforms have generated renewed interest and various African governments have developed new land policies (Cotula et al 2004). Land policies and reforms are meant to be used as pro-poor land tools for more transparent and accountable land administration (Peters 2013).

At the same time, they are supposed to respond to economic growth and development. The DRC government has engaged in a broad process of land reform in the current decade, with different phases of progress and stagnation

(Koné et al 2016). Congolese land reforms are part of a process to promote the country to the status of emerging economy by 2030 and industrialized country by 2050 (CONAREF 2018).

In November 2018, an interprovincial workshop was held in Bukavu to draft a national land policy for the Democratic Republic of Congo where basic aspects were agreed upon, among which:

- The need to revise the land law of 1973;
- Securing and registering user rights and use of technological innovations;
- Greater mobilization of land for economic growth and poverty reduction;
- Development of more effective and efficient land administration systems;
- Guarantee of access to land in line with the interests of the majority of the population.

Recently, a consultation process was launched in different provinces of the DRC to gather feedback on the first draft of the national land policy document (see: conaref-rdc.org). At a Conference on Lands and Conflict in Eastern DRC, held in Bukavu in June 2019, various practical options for improving the land rights situation in the Democratic Republic of Congo were discussed by a broad range of stakeholders including local governments, customary chiefs, national government, NGOs and international partners. A central point of discussion was the fragility of informal and customary land ownership, particularly in conflict-affected areas.

The formalization (titling) of customarily owned land poses its own problems and may even exacerbate conflicts. However, the previous significant acquisitions of customary land (see for example Peters 2013) and ongoing violent conflicts around land in areas where land governance is mainly customary, as well as frequent dispossessions of customary landowners in the DRC (see for example Vlassenroth nd) clearly require practical and effective solutions to the prevailing insecurity of land tenure.

This paper presents such a practical solution to the insecurity of tenure in the east of the Democratic Republic of Congo, where people mainly access and govern land via customary systems. The context, process, prospects and potential traps of the solution are discussed in detail, based on the experience of a consortium-led integrated water resources management project. As part of this project, a system for the allocation of grouped titles was tested as the most practical way to protect existing land rights in an environment highly affected by the conflict.

Case context

The presented case describes the efforts of the Dutch International NGO ZOA in a consortium that is trying to contribute to peacebuilding through a large-scale irrigation project called Maji Ya Amani - Water for peace. The project is set in the border region of the DRC with Burundi and Rwanda in the Ruzizi plain. In this context, land rights are a particular concern because in the area, different communities have a history of conflict over land issues, notably due to repeated clashes between pastoralists and farmers, as well as broader issues of political and economic power. In addition, the sharp increase in land value that will be achieved through irrigation of about 1035 hectares of land in the plain will be a potential source of conflict, especially if outside actors are interested in taking advantage of it. From the beginning, it was understood that improving the land through irrigation would result in an increase in land value and potential speculation, jeopardizing those who currently occupy and use the land (see Betge et al 2019. In the project area, most of the land rights are rooted in customary systems that are strained due to ethnic tensions, migratory pressure, and violent conflict. The land related problems in the area are exacerbated by the influx of new residents, the shrinking of available fertile land (due to demographic and climatic reasons), land sales organized by chiefs without the knowledge of the smallholders, and co-operatives that are well organized but whose boundaries are not always clear (ibid.). Routes to cattle watering holes have been altered as water becomes more scarce, while other routes have been appropriated by small farmers in need of land (ibid.).

In order to prevent the local population from losing access and ownership of land, an overview of current patterns of land use and ownership was needed, on the basis of which existing rights could be guaranteed.

ZOA facilitated an extensive participatory mapping exercise supported by the Cadasta Foundation and using the Cadasta platform for data storage. This demarcation, based on the principles of the Social Tenure Domain Model (STDM), has provided a platform for reaching consensus among the different actors involved at all levels and including traditional authorities, different organizations and civil society, local and provincial authorities, land administration (cadastre & CTI), technical services (agriculture and rural development) and each affected landowner.

The fundamental legislation regulating land rights in RDC includes law no. 73-021 of 20th July 1973 on the general property, land, and real estate and the regime of security interests (so- called Bakajika Law). This text and its decrees of application function as the Land Tenure Code (Betge et al 2019).

Process

To mitigate the risk of conflict, ZOA and Cadasta Foundation facilitated a broad participatory mapping exercise together with the government, the customary authorities, and local communities to map and document land rights and the irrigation infrastructure across an initially estimated 5,000 parcels (Betge et al 2019). Including the land administration authorities in this process was key to enable the preparation for recognition of land rights and to ensure process ownership by the state.

Despite the long-standing rivalries and history of violence in the area, key

traditional leaders agreed to support the project following their involvement in the participatory mapping exercise (Betge et al 2019). Provincial authorities have also given guarantees that the current access and land use arrangements will be protected and the participatory demarcation was conducted with the active involvement of the communities, local land bureaus, and technical experts trained by Cadasta. ZOA's partners are simultaneously working on the establishment of land management councils and other supportive measures. They actively engage the broader community in awareness raising campaigns and the drawing up of by-laws for land management to prepare for the re-established irrigation infrastructure.

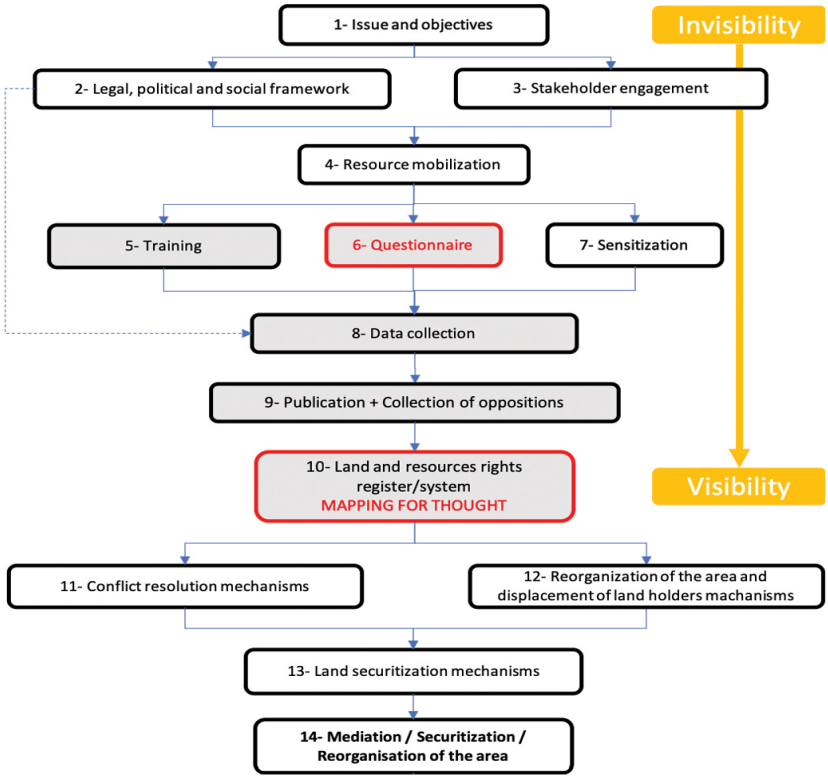

Figure 1: The graph gives an overview of the participatory mapping process

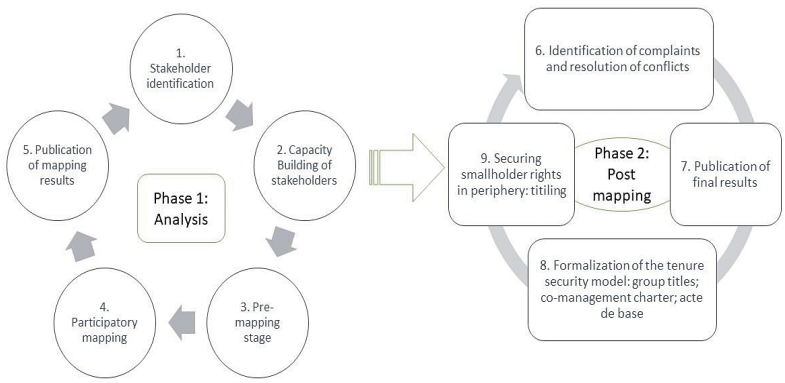

Figure 2: An overview of the different steps followed until the issuing of the group titles

The graph (figure 1) gives an overview of the participatory mapping process that eventually led to the legal solution for securing tenure described below.

The "Consolidated Title" as a method of land tenure security adopted by the stakeholders, notes the co-ownership between the occupants in the irrigated area of Luberizi to protect the land rights of family farmers. For any co-owner of a land title in the irrigated area of Luberizi, the individual land right is recorded in an individual file issued from the participatory mapping. This individual file shows the picture of the owner, his/her family and relatives who can inherit the land in case the owner passes away and is attached to each group title to establish the extent of the rights of the members of the co-ownership. The plots are grouped according to legal standards in the DRC to be the object of the grouped securitization in order to secure the irrigated area of Luberizi, and improve the land security and access to land of the population.

The group titling of land is a special regime to protect the collective interest of the farmers and ensure the sustainability of the family farm, in accordance with Congolese Law. Given the initial situation of the occupants, including the challenges related to the exorbitant cost per individual title and contextual factors (impossibility to facilitate the creation of a special zone in Luberizi to protect specific local rights), it was agreed, with all the operators to secure their lands in the area through the grouped titles.

The graph (figure 2) provides an overview of the different steps followed until the issuing of the group titles.

In the graph (figure 2), it can be seen that the whole process took place in nine steps divided into two phases (analysis of the existing plots through participatory mapping and post mapping operations). During these stages, there was a direct

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and active implication of the members of the community, local, territorial, provincial and national authorities, it is important to highlight that the technical part of the work was done by specialized technicians from both the government technical services and project technicians in collaboration with Cadasta (https://cadasta.org/). At the beginning of this process, it was a question of obtaining the commitment of the different stakeholders through identification and mobilization and memorandum of understanding to support the process was signed.

Subsequently, six teams, each made up of four people (a representative of the local land administration, a representative of the community, a social facilitator and a cartographer) were trained on the "CADASTA" technology. CADASTA technology was created in 2015 to allow individuals, organizations, communities and governments to collect precise information related to land tenure and natural resource management. It makes it possible to analyze, save and share real data on any given land with a precision of approximately 30 cm.They were also trained on how to use electronic equipment (developing an ODK Collect form, using smartphones and Trimble catalyst antennas) and participatory mapping techniques.

Before the participatory mapping, thanks to the support of community leaders, the owners of the plots in the perimeter were identified, sensitized, mobilized and made aware of the importance of this approach to securing land using "CADASTA". During this stage, the roles and responsibilities of each member of the team and the planning of activities for the participatory mapping were defined. The participatory mapping activities took place in two stages. (i) Field work in which information such as the dimensions of the plots/boundaries, identities and relatives of the owner of each plot were collected electronically and manually. (ii) The second step was to download the information from the smartphones to the server (Cadasta platform) and thus recover them via QGIS in order to develop the sketches (croquis) of the plots.

The publication of the results consisted of printing out all the information and were made public in each village to make sure that any complaints, disputes, possible errors and conflicts have been identified and referred to specialized structures for mediation and conflict resolution. This is a crucial stage as in this model no group title can be delivered if not all the conflicts have been resolved.

The process proved highly complex as different stakeholders needed to be involved in all the steps: government authorities, local authorities, land administration officers, famers and civil society organisations; to resolve the conflicts before issuing the group titles.

The group titling model was assumed to be the best available option for the following reasons:

- It reconciles legality and the legitimacy, through the participatory process;
- It increased the social cohesion among the population of this area;
- The group titles allowes poor farmers to have access to credit and to be able to invest in agricultural activities;
- Moreover it prevents potential land grabbers to easily acquire land from the poor famers.

Securing rural land in a conflict-affected area is an important and delicate issue that requires special attention from interveners and broad stakeholder participation

Securing rural land in a conflict-affected area is an important and delicate issue that requires special attention from interveners and broad stakeholder participation

Figure 3: Publication of the result

The land governance system in the DR Congo is changing in response to urgent challenges related to land tenure security and conflicts that are exacerbated by or even rooted in land questions. At the same time, the authorities in DRC are struggling to provide good governance and administrative services on all levels and the ongoing conflicts in the eastern part of the country frequently disrupt attempts to improve service delivery and governance

requires special attention from interveners and broad stakeholder participation. In addition, with regard to the land of local communities and indigenous (specifically Pygmy/Batwa) peoples, the 1973 Act created uncertainty about their exact status and insecurity with regard to the rights of users by providing that usufruct rights acquired according to custom, would be settled by an order of the President of the Republic. This order has never been signed to date.

Given the extent of land conflicts in all territorial entities of the South Kivu Province, resulting among others from the multiplicity of practices that are considered outside the law, and taking into account the process of land reform launched by the Government of the Democratic Republic since July 2012, a custom-based decentralized land management system in South Kivu Province is needed to secure the rights of customary land users while protecting them from arbitrariness.

Risks and risk mitigation

There are certain risks to the chosen approach relating to four broader categories: social, political, power-related, and economic. Social risks mainly relate to the peaceful cohabitation among the people sharing the same group title as they are from different ethnic backgrounds and communities in the area. Political risks relate to the lack of *good governance* in DRC and the potential that in due time a different (land) governance regime may come up with new laws altering and potentially complicating access to land. Economic risks are also related to the relations among people sharing the same title. For example, in case they agree to apply for credit as a group and some of the group members do not adhere to the credit rules, banks and other finance institutions might have to stop providing credit service to the group as a whole. Abuse of power by power holders remains the most incalculable and most difficult to mitigate risk. Generally, in order to mitigate the identified risks, the occupants need to remain social coherence and continue to cooperate to safeguard the acquired social peace and to boost the local development. The external interveners need to do their utmost to support this process, fulfilling the different and complementary roles established by the consortium. This requires e.g. the setting up and accompaniment of land management committees, structures for increased community cohesion, continuous monitoring of social developments by the consortium partners and flexibility in programming based on feedback from the communities.

Arguably, in order to mitigate the risks in a sustainable way, it is believed that the *basic act* (acte de base) as a supporting document of each grouped title is a key element. This basic act is a legal-administrative document governing all rights and duties between persons grouped in a title. This allows the co-owners to determine who will keep the common title, the person who will represent the others at financial institutions, in case they request a credit "input", etc. In addition to this basic act, the co-owners define how the succession will be made in case of sale of part or all of the individual plot of a co-owner, but also who bears the costs related to the transfer of rights. Likewise, the procedure on how conflicts arising in the group will be managed internally and their possible referencing to higher levels for dispute resolution will be detailed in this document to prevent and manage any disputes.

Discussion

As described above, the land governance system in the DR Congo is changing in response to urgent challenges related to land tenure security and conflicts that are exacerbated by or even rooted in land questions. At the same time, the authorities in DRC are struggling to provide good governance and administrative services on all levels and the ongoing conflicts in the eastern part of the country frequently disrupt attempts to improve service delivery and governance.

In this context and without a clear indication when new land laws will be adopted and implemented, different types of interveners who aim to contribute to conflict reduction and social and economic development in the country need to find practical solutions to land related challenges that hinder progress in other domains.

Both customary and state systems are challenged either by lacking legitimacy or lacking legality, in some cases both. This requires finding solutions that can address these challenges as well as possible. In the context of ongoing reform processes and violent conflicts, such solutions will always be imperfect and

Group titling presents a challenging but highly interesting option in the context of the Congolese land reform process. The model can provide a solution when it comes to securing the land of poor rural famers who cannot pay for an individual title due to its immense costs but whose tenure security is permanently threatened because of a lack of formal recognition and social and political stability.

likely require trade-offs. However, the approach described in this paper has to date proven to enable a cooperative mode of progressing with a programme that has the potential to significantly improve the economic opportunities and the social cohesion and stability of one highly fragile area. The development of this approach required adaptive programming, time and resources committed by the different stakeholders, including the donor, and a healthy dose of pragmatism. Despite these requirements, the approach appears a promising option for other areas of the DRC that experience similar challenges.

Conclusion

Group titling presents a challenging but highly interesting option in the context of the Congolese land reform process. The model can provide a solution when it comes to securing the land of poor rural famers who cannot pay for an individual title due to its immense costs but whose tenure security is permanently threatened because of a lack of formal recognition and social and political stability.

The group title can contribute to economic development is serves as a guarantee to financial institutions while tenure security allows for land investments.

Furthermore, the group title supports processes to increase social cohesion among the co-owners as they set rules on how and where to keep their common titles and collaboration. Positive impact has been observed in Luberirzi, where different community members who could not even talk to each other in the past are now collaborating and plan common development activities together.

Last but not least, the group titling model proves an opportunity in the context of the DRC with parallel systems of customary and statutory land tenure. The legality and relative legitimacy of the group title approach serve to reconcile the statutory and customary system as the traditional authorities and formal authorities are among the key stakeholders within this model and are brought together in a pragmatic and cooperative way. While this model might not be the best solution imaginable, for contexts like the Ruzizi plain it seems to be the best one available.

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The cost-effectiveness of controlling dengue in Indonesia

Wolbachia releases in high-density urban areas are expected to be highly cost-effective and could potentially be the first cost-saving intervention for dengue. Sites with strong public health infrastructure, fiscal capacity, and community support should be prioritised

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Background

The mosquito species *Aedes aegypti* and *Ae. albopictus* are responsible for transmitting a range of growing global arboviral infections. Existing vector control tools alone have been unable to sustainably control these mosquito species or the diseases they transmit [1], and a range of novel technologies are under development [2].

One such novel intervention is the release of mosquitoes infected with the intracellular bacterium *Wolbachia* [3]. Mosquitoes infected with *Wolbachia* (i) are less likely to disseminate dengue, chikungunya, Zika, and yellow fever viruses and thus are less likely to become infectious [3–5] and (ii) can suppress or replace the natural mosquito population due to fatal cytoplasmic incompatibility among *Wolbachia* wild-type mating pairs [3]. *Wolbachia* can, therefore, be used to either replace the existing mosquito population with a lower competence phenotype by releasing females or suppress existing population by releasing males. To date, 13 countries have ongoing replacement programmes at various stages of development, with 12 through the World Mosquito Programme (WMP [6]) and an independent programme in Malaysia [7]. Meanwhile, China (with *Ae. albopictus*) [8], Singapore [9], and the USA [10] have chosen to use suppression-based programmes due to perceived greater compatibility with their existing intensive and long-term efforts to suppress mosquito populations.

Replacement programmes with *Wolbachia* entail substantial initial investments to establish *Wolbachia* in the mosquito population through intensive releases at the beginning of the programme but potentially offer considerable long-term benefits. The replacement approach contrasts with suppression strategies with *Wolbachia*, sterile insect techniques, or conventional vector control tools, which likely need ongoing application. Both approaches are in the early stages of gathering entomological and epidemiological evidence of effectiveness [2]. Among these novel methods, replacement with *wMel Wolbachia* has, arguably, the most developed evidence base so far [11] because it has demonstrated replacement in multiple sites [12, 13], durability of unaltered replacement since 2011 and cessation of autochtonous transmission in northern Australia [14, 15], reductions in reported dengue cases in observational study designs in five countries[16], and a cluster randomised trialis currently underway in Yogyakarta, Indonesia[17, 18], with epidemiological outcome results expected in late 2020.

Recent events including the 2015–2017 Latin American Zika outbreak and the record-breaking 2019 global dengue outbreak have hastened the adoption of novel *Aedes* control tools. Given the acute need to make decisions on adoption, mathematical models can be used to predict impact in different areas long before field data become available [19, 20]. Pairing these epidemiological predictions with intervention cost and cost-of-illness data enables cost-effectiveness calculations that can inform decisions on *Wolbachia* scale-up.

One such priority setting is Indonesia, where city-wide *Wolbachia* releases are already planned in Yogyakarta City after the randomised trial [17]. In 2016, Indonesia launched its "Healthy Indonesia Program with Family Approach", which includes cleaning the environment and addressing communicable diseases, including malaria and dengue [21]. This programme provides encouragement and some national funding. In addition, in the Yogyakarta Special Autonomous Region (SAR), the governor has confirmed his support for novel technologies, including *Wolbachia* [22], suggesting support for expansion beyond Yogyakarta City.

Cost-effectiveness analyses (CEAs) have proved instrumental for the early adoption of a number of interventions, including for *Aedes*-borne pathogens. Fitzpatrick et al. estimated that, assuming they were 70–90% effective, conventional *Aedes* suppression tools would achieve cost-effectiveness between $679 and $1331 per disability-adjusted life year (DALY) averted (2013 USD) [23]. The recently developed dengue vaccine, Dengvaxia®, also included model-predicted CEA as part of its feasibility assessment, with predictions without serotesting of $11–44 per DALY averted (2014 USD) [24]. Dengvaxia® has also been estimated to be highly cost-effective ($1800 per DALY, health systems perspective) or cost saving ($-1800 per DALY, societal perspective) under the WHO's modified individual test-and-vaccinate recommendation, however with more limited overall impact (14.3% reduction in hospitalisation) [25].

Here we use the existing *Wolbachia* release cost and programme data to build a model that predicts the cost of release in different environments. Using a dynamic simulation model, we synthesise cost predictions with previously published estimates of *Wolbachia* effectiveness[19] to assess cost-effectiveness. We then assess the sensitivity of predicted cost-effectiveness to alternative programmatic options for government or private funders to consider the next stage of scale-up of this technology.

Methods

Phases of the programme

In this analysis, we conceptually divide a potential *Wolbachia* replacement programme in a given city into four phases based on previous WMP operations. We do not consider the additional costs of obtaining regulatory approval in Indonesia as *Wolbachia* release has already been approved by the local Yogyakarta SAR government and the national government already has an active involvement in the project as part of the independent data monitoring committee. Phase 1 ("setup", 2-year duration) includes establishing insectaries and a mosquito colony, laboratories, site offices, local regulatory approval, hiring staff, baseline entomological surveys (including insecticide resistance monitoring), and planning and administering the programme and pre-release community engagement. Phase 2 ("release", 1-year duration) involves the release of *Wolbachia* mosquitoes over target areas applying the resources established during phase 1. In phase 3 ("short-term monitoring", 3-year duration), ongoing surveillance of the mosquito and human population is conducted in the release area. Phase 4 ("longterm monitoring", 7-year duration) entails reduced entomologic monitoring as the intervention proves its reliability.

In the existing programme in Yogyakarta City, programme setup took 4 years [18]; however, this included gaining national approval, design of the cluster randomised trial, all phase1 activities, and release in half the city. We anticipate faster setup times of subsequent programmes elsewhere in Indonesia due to the experiences and approvals gained in Yogyakarta City.

For the main analysis, we consider two speed scenarios: (i) an "accelerated" scenario, with every area conducting phases 1–4 simultaneously and independently (total programme length 13 years), and (ii) a "sequenced" scenario, in which phase 2 releases are spread over 10 years with certain centralised resources moved or reutilised across different locations (total programme length 20 years, Additional file 1, S1.1)[13, 19, 26–31].

Costing *Wolbachia* releases (phases 1 and 2)

We hypothesised that the main determinants of the cost of releasing *Wolbachia* per square kilometre (km) were directly or indirectly related to (i) the human population density in the release area, (ii) release material (adult or egg mosquitoes), (iii) local cost of labour (as measured by country Gross Domestic Product adjusted for Purchasing Power Parity (GDP PPP)[32]), and (iv) phase of the programme. Previous *Wolbachia* releases have shown that higher human density areas require higher mosquito release numbers per unit area because they typically have higher natural mosquito population sizes, hence raising costs [33]. Transportation costs of *Wolbachia*-infected mosquito eggs are lower than for adult releases because they can be distributed in smaller containers and because the community can undertake releases; however, this can also increase community engagement costs. Adult releases require specific equipment and personnel to drive around the target area and conduct releases at pre-specified sites, but can potentially be achieved more quickly.

Data were extracted from WMP budgets for releases in Indonesia, Colombia, Sri Lanka, Australia, and Vanuatu (Additional file 1, S1.2). These data

were used to fit a generalised linear regression model between cost per km^2 of release area and the above covariates (Additional file 1, S1.3).

Costing long-term surveillance (phases 3 and 4)

Our estimates of the long-term monitoring costs of a *Wolbachia* programme (phases 3 and 4) build on a detailed budget analysis developed by the WMP for phase 2 of the programme in Yogyakarta City (Additional file 1, S1.2). This includes a gradual reduction in monitoring intensity with corresponding budget reductions (Additional file 1, S1.1).

Modelling effectiveness and cost of dengue illness averted

Spatially explicit estimates of baseline and averted dengue cases were obtained from a recent related study [19]. In this study, spatially varying estimates of the current case burden across Indonesia were first estimated using a geospatial model that accounts for the effects of climate and socioeconomic factors in the spatial distribution of dengue burden. Within each 5 km×5km pixel, a dynamic simulation model then estimated the long-term average force of infection required to generate the number of estimated cases. Data from laboratory vector competence experiments [29] were then used to estimate the reduction in force of infection likely to occur if *Wolbachia* were present in 100% (or 50% for the sensitivity analysis) of the natural mosquito population from the beginning of phase 3 of the programme (i.e. once all releases have been completed). The dynamic simulation model was then used to translate this force of infection reduction into the number of cases averted per year once a new steady endemic state has been reached which also includes indirect or spillover effects if *Wolbachia* coverage were less than 100%. DALYs were calculated based on the average age of dengue cases and life expectancy at a national level in Indonesia. We assume that neither the age distribution of cases nor the costs associated changes as a result of the *Wolbachia* programme. Disease severity-specific (but not geographically varying) cost per case data [34] was then applied to case totals to estimate the economic costs of dengue cases and the economic benefits of averting *Wolbachia* relative to a baseline scenario of no action. All case counts and costs were then downscaled to 100 m×100 m spatial resolution to match the resolution of population datasets using bilinear interpolation.

Candidate release sites

In this analysis, we produce estimates for four candidate sites: (1) Yogyakarta City, (2) remaining areas in Yogyakarta SAR, (3) most of the special capital region of Jakarta (excluding Kepulauan Seribu [Thousand Islands] Regency), and (4) the island of Bali.

We chose this focus based on a combination of political, economic, and epidemiologic considerations. The Yogyakarta City trial carried an ethical and political expectation to assess expanding releases across the rest of Yogyakarta City and the remainder of the SAR. The other two candidate sites, Jakarta and Bali, are two of the country's most important economic regions as commercial and tourism hubs. In epidemiologic terms, high-density cities, such as Jakarta and Denpasar, Bali, have a disproportionately high concentration of national dengue burden [19] and island-wide releases are likely to minimise the risk of re-introduction of native *Ae. aegypti* populations.

Within each of these sites, not every area is expected to be covered by *Wolbachia*. We consider only areas with a human population density of at least 1000 people per km^2 as eligible for *Wolbachia* releases. Previous WMP releases in Townsville and Cairns, Australia, have proven the ability to establish *Wolbachia* in areas approaching 1000 people per km^2 (Fig. 1), but based on existing programme experience, lower population densities are likely to prove prohibitive to natural mosquito dispersal and may significantly increase the cost or lower persistence of *Wolbachia* mosquitoes.

Time horizon, acquisition of benefits and discounting

As *Wolbachia* is an early-stage technology, we take a conservative approach to our calculation of cost-effectiveness. We only assume benefits of *Wolbachia* persist for 10 years post completion of releases in the target area (i.e. benefits only accumulated in phases3–4, Additional file 1, S1.1) based on the duration of continued persistence of *Wolbachia* releases in northern Queensland since 2011[35].

We assumed that the number of cases averted would be the same each year. All costs and benefits are given in present value 2018 USD and were discounted at 3% per annum [36], calculated at the end of each year. The cost of the programme was predicted using population data at 100m×100m resolution fromWorld pop [37] assuming a programme using egg releases with Indonesia's national 2018 per capita GDP(PPP, $12, 378).

Two measures of cost-effectiveness are shown: first, from a health systems perspective (gross cost-effectiveness), where the investment cost of the programme is divided by the number of DALYs averted over the 10 years post deployment (discounted at 3% per year); second, from a societal perspective (net cost-effectiveness), where offsets to direct medical treatment costs are first deducted from the programme investment costs. Benefit-cost ratios are also calculated from health systems and societal perspectives separately. We compared all scenarios against the alternative option of continuing existing dengue control measures, which primarily consist of insecticide-based vector control. We did not cost such interventions and assume that they will continue in parallel to and independently of the *Wolbachia* programme due to their purpose spanning vector control for a variety ofdifferent vector species.

Sensitivity analyses

To assess the sensitivity of our predictions to uncertainties in various inputs to our model, we performed a univariate

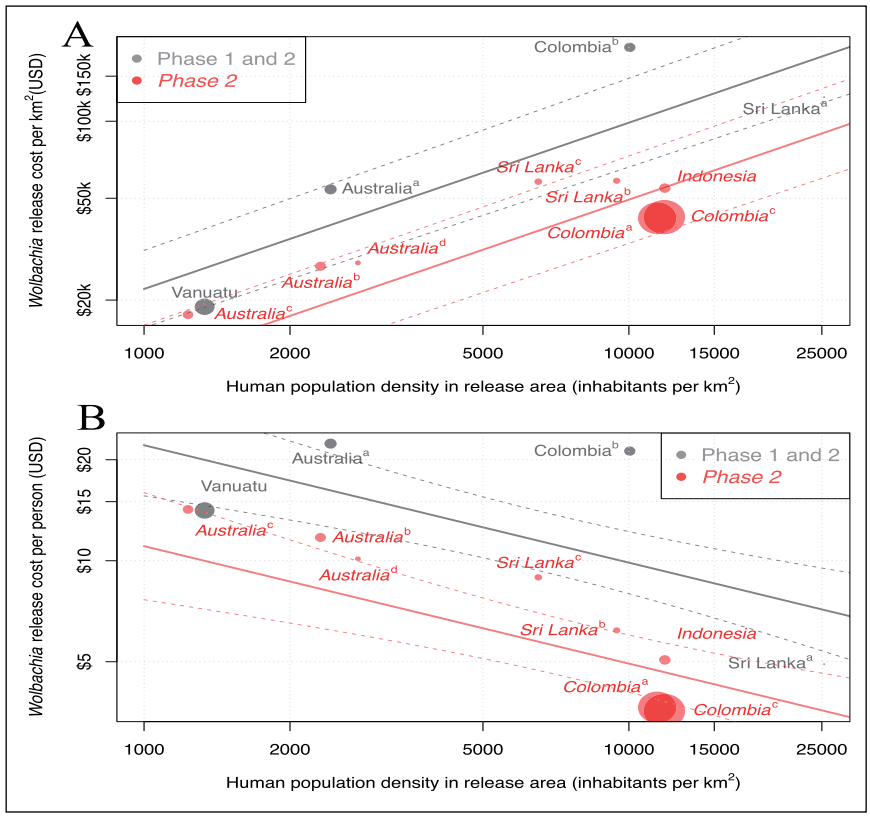

Figure 1 The fitted relationship between human population density and projected cost of deployment of *Wolbachia* per km² (a) and cost per person (b). All axes are on log10 scales. The cost per km² model fit mean (solid lines) and standard error (dashed lines) for each programme phase are shown. Circle area is proportional to the size of the release area in each site

sensitivity analysis based on the 2.5% and 97.5% estimates for each of the following parameters: (i) case burden, (ii) *Wolbachia* effectiveness, (iii) cost of *Wolbachia* releases, and (iv) cost per episode of dengue illness. In addition, we also examined the sensitivity of cost-effectiveness to several hypothesised environmental and genetic challenges and changes that may occur as a consequence of *Wolbachia* introduction [38]. These include (i) low coverage (50% vs baseline 100% coverage), (ii) releases that are initially uncompetitive with wild-type mosquito populations, and (iii) emergence of resistance (after 5years). The cost-effectiveness of programme modifications to address these challenges is also assessed. Furthermore, we predict the cost-effectiveness of future cost-saving adaptations of the programme including (iv) reliance on passive disease surveillance (as opposed to continued entomological surveillance in phase 4 of the programme) and (v) generic innovations, efficiencies, and economies of scale that reduce the cost base of the programme by 50%. Further details on the rationale for these scenarios and their parameterisation are available in Additional file 1, S1.4. All analyses were performed in Rversion 3.6.1. with all code publicly available in the following GitHub repository (https://github.com/obrady/Wolbachia_CE/tree/V1). This manuscript conforms to the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist which can be found in Additional file 2.

Results

Wolbachia programme costs

The results of our model to predict the cost of releasing *Wolbachia* mosquitoes in new areas using existing programme budgets are shown in Figure 1. This model identified human population density and programme phase as significant covariates of programme cost per km² of release area ($p = 0.003$ and $p = 0.026$ respectively, two-sided t test, Additional file 1, S1.3). Release material (eggs or adult mosquitoes) or national GDP per capita (as a proxy for local labour costs) were not found to be significant ($p = 0.98$ and 0.31 respectively) but were retained in the final model due to limited between site variance. Models with the response variable of cost per km² gave superior cost data fit to models with a response variable of cost per person, so were used throughout (Additional file 1, S1.3).

Each of the four candidate sites differs in size and human population density, comprising a small city (Yogyakarta City), a large city (Jakarta), and two moderate-size urban-rural mixes (Yogyakarta SAR and Bali, Table 1). Because we assume *Wolbachia* to be suitable only in areas with density greater than 1000 people per km², only 24.8% and 14.9% of the land area in Yogyakarta SAR and Bali are eligible for *Wolbachia* release, compared to 100% in urban areas, although these areas do still contain the majority of people (Table 1).

The estimated cost of an accelerated (10-year) *Wolbachia* programme ranges from $5.8 million in Yogyakarta City to $133.3 million in Jakarta (present value 2018 USD, Table 1). While the urban sites have a smaller release area than their urban-rural mix counterparts, the cost per km² of releasing in high-density areas is much higher (Figure 1); however, because more people are covered, urban areas lead to more favourable cost per person covered (~$12 vs $14–21, Table 1).

Conducting releases over a longer sequenced programme (total programme length 20 years vs 13 years) can reduce overall costs by 11–38% (Table 1), but also delay benefits (Figure 2). In this analysis, we assume10 years of benefits for each area in which *Wolbachia* mosquitoes are released because there is currently substantial uncertainty over costs and effectiveness beyond 10 years (Figure 2).

Should *Wolbachia* prove more durable than this, accelerated programmes and their quick eracquisition of benefits would become more preferable relative to sequenced pro-grammes; however, the challenges of their greater upfront costs would remain.

Benefits

Combining health systems costs and societal costs (lost wages due to work absences attributable to sickness and the value of life lost due to premature death), Indonesia's national economic burden of dengue in 2017 has been estimated at $681.26 million [34], with costs due to hospitalised non-fatal cases (44.7%), fatal cases (44.3%), ambulatory non-fatal cases (5.7%), and non-medical cases (5.3%)[34]. We predict substantial reductions in dengue case and economic burden in all sites. As estimated in previous work [19], long-term average percentage reductions are likely to be highest in low transmission intensity environments (87.2% reduction in Yogyakarta SAR vs 65.7% reduction in Jakarta, Table 2). However, because *Wolbachia* programmes can achieve higher coverage in dense high transmission intensity cities, the percentage reduction across the whole site area becomes more favourable (65.7% in Jakarta vs 59.1% in Yogyakarta SAR and 52.4% in Bali). Medium transmission intensity high-density cities, such as Yogyakarta City, are likely to see the highest percentage reduction and may even see elimination (94.4%, 95% uncertainty interval [95UI] 36.5–100%).

The annual cost savings of averting these cases are substantial, ranging from $980, 000 (95UI $350, 000–$2, 170, 000) in Yogyakarta City to $27.1 million (95UI $10.58–$49.35 million) in Jakarta. As estimated in previous work [34], these cost savings are divided approximately equally between medical costs and societal costs.

Cost-effectiveness

Due to the heterogeneous nature of risk and cost, estimated cost-effectiveness values are spatially variable (Table 3, Figure 3). Generally, cost-effectiveness is most favourable in high-density urban environments with gross cost-effectiveness (cost of averted disease cases not included) reaching as favourable as $1100 per DALY averted in specific places (Fig. 3c), especially in a sequenced programme (Table 3). Although the overall gross cost-effectiveness of the projected programmes in Yogyakarta SAR and Bali are less favourable than their urban counterparts (Table 3), there are many sub-areas within these sites where *Wolbachia* programmes could have equally as favourable cost-effectiveness (Figure 3b, d). This is most pronounced for the Yogyakarta SAR scenario where the surrounding urban areas of Sleman, Bantul, and the isolated towns of Sentol and Wonosari are predicted to be highly cost-effective (< $1700/DALY) while many rural areas are less favourable. We even predict some of these towns in Yogyakarta SAR to be more cost-effective than Yogyakarta City; however, this result occurs only because we assume that the core resources (e.g. laboratory and rearing facilities) that have already been paid for and developed for the existing *Wolbachia* programme in Yogyakarta City can be reused for the surrounding areas in Yogyakarta SAR.

When the health sector and societal costs of averted cases are deducted from the original programme investment, *Wolbachia* becomes a cost-saving intervention in cities and a highly cost-effective intervention elsewhere (Table 3 and Figure 4a). One dollar invested in *Wolbachia* can return between $1.35 and $3.40 (95UI $0.17–$9.67) in medical

Table 1 Baseline characteristics and model-predicted release costs for current and future release areas. Prices are in present value 2018 USD. Figures in brackets represent 95% uncertainty intervals. All costs are discounted at 3% per annum. Accel. denotes accelerated; Seq. denotes sequenced

	Existing area	Candidate sites					
	Yogyakarta City	Yogyakarta SAR		Jakarta		Bali	
Residents (millions)	0.46	3.24		11.19		4.08	
Percentage of peopl covered by *Wolbachia*	100	65.9		100		59.7	
Area (km^2)	37.24	3666.21		764.48		6476.03	
Percentage of area eligible for *Wolbachia*	100	24.8		99.9		14.9	
Density in covered area (persons/km^2)	12,351	2352		14.647		2532	
Total cost (US$ millions)	Accel. 5.84 (5.81–5.87)	Seq. 27.41 (27.37–27.45)	Accel. 30.68 (30.65–30.73)	Seq. 83.33 (83.22–83.49)	Accel. 133.30 (133.14–133.49)	Seq. 34.88 (34.81–34.93)	Accel. 51.66 (51.57–51.72)
Cost per person covered	12.70 (12.63–12.77)	12.83 (12.81–12.85)	14.36 (14.35–14.38)	7.45 (7.44–7.46)	11.92 (11.90–11.93)	14.32 (14.29–14.34)	21.21 (21.17–21.23)

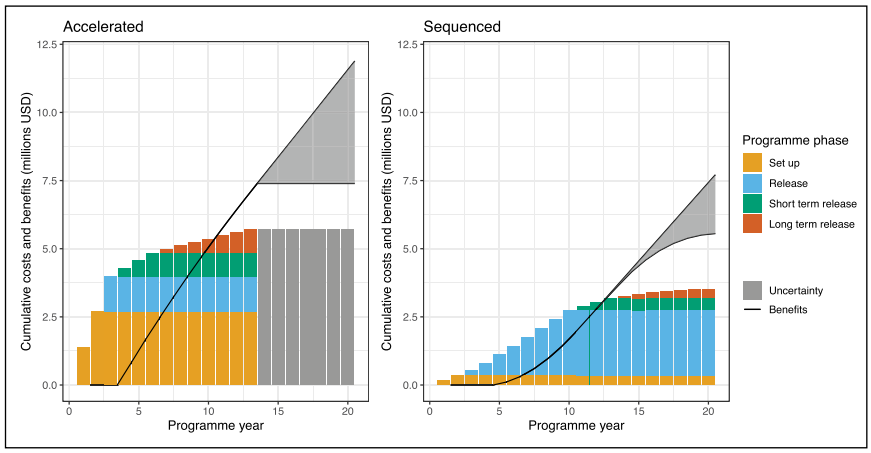

Figure 2 Distribution of cumulative costs and savings over time in an accelerated (3 years, left panel) and sequenced (10 years, right panel) roll out in Yogyakarta City in 2018 USD. Uncertainty represents uncertainty in programme cost and intervention effectiveness beyond the 10-year postrelease time horizon used in this analysis. All costs and benefits are in present-day value 2018 USD discounted at 3% per annum

Table 2 Predicted per year benefits of *Wolbachia* programmes in four sites. Only eligible areas (at least 1000 people per km²) receive treatment. All costs are in 2018 US dollars and are not discounted. Figures in brackets represent 95% uncertainty intervals

	Committed area	Scale-up scenario		
	Yogyakarta City	Remaining Yogyakarta SAR	Jakarta	Bali
Baseline cases per year (area wide)	14,488 (2955–47,858)	93,604 (21,527–249,843)	444,528 (97,542–1,189, 217)	117,840 (27,862–324,114)
Post Wolbachia cases per year (area wide)	722 (0–30,140)	36,674 (6805–180,567)	127,712 (0–749,850)	62,033 (9810–237,984)
Area-wide percent reduction (%)	94.4 (36.5–100)	59.1 (25.6–69.6)	65.7 (36.7–100)	52.4 (24.2–66.9)
Percent reduction within treated areas	94.4 (36.5–100)	87.2 (37.2–100)	65.7 (36.7–100)	82.8 (37.3–100)
Averted medical costs per year (millions USD)	0.46 (0.14–1.19)	2.16 (0.67–4.70)	12.91 (4.49–25.08)	2.58 (0.82–5.11)
Averted societal costs per year (millions USD)	0.52 (0.21–0.98)	2.36 (1.05–4.28)	14.17 (6.09–24.27)	2.77 (1.23–4.74)

and societal benefits depending on where the programme takes place (Figure 4a). In Jakarta, the medical benefits alone are predicted to outweigh the cost of investment in *Wolbachia* (Figure 4a).

Sensitivity and uncertainty

Ourprediction that *Wolbachia* is cost savingis robust to a reasonable range of parameter values(Figure 4b).In a univariate sensitivity analysis of the 2.5 and 97.5 percentiles of the true parameter value, only a low value of the baseline burden of dengue is sufficient to prevent *Wolbachia* from becoming cost saving, and even then, the programme is still highly cost-effective ($1652/DALY, sequenced programme inYogyakarta City, societal perspective). Parameters for the cost of the programme, cost per case, and efficacy of the intervention were less critical for overall cost-effectiveness than baseline burden due to the higher uncertainty in the true burden of dengue.

Programmes are even predicted to be cost saving if substantial challenges occur during deployment. If only 50% coverage were reached in the target area, resistance emerges after5 years or released mosquitoes are initially uncompetitive with wild-type mosquitoes, benefit-cost ratios remain above1 (Figure 4c, societal perspective). Further more, if these events do occur, cost-effectiveness of the programme can

Table 3 Predicted cost-effectiveness of *Wolbachia* at the end of the programme. Accelerated and sequenced programmes correspond to completing roll out in 3 and 10 years, respectively. Only eligible areas (at least 1000 people per km²) receive treatment. All costs are in present value 2018 US dollars. All costs and benefits are discounted at a rate of 3% per annum. Net costs include cost offsets for medical and societal benefits from averted cases. Figures in brackets represent 95% uncertainty intervals

	Committed area	Scale-up scenario		
	Yogyakarta City	Remaining Yogyakarta SAR	Jakarta	Bali
		Accelerated introduction		
Gross $/DALY averted	$ 1831 (892–4522)	$ 2133 (1048–4953)	$ 1566 (857–3244)	$ 2996 (1599–6778)
Net $/DALY averted (including averted medical and societal costs)	$ – 543 (– 1419–1976)	$ - 242 (– 1275–2438)	$ – 839 (– 1500–731)	$ 671 (– 719–4219)
		Sequenced introduction		
Gross $/DALY averted	$ 1519 (737–3732)	$ 2168 (1064–5042)	$ 1111 (611–2307)	$ 2366 (1264–5379)
Net $/DALY averted (including health sector and societal costs)	$ – 862 (– 1572–1185)	$ – 210 (– 1258–2528)	$ – 1280 (– 1772–– 207)	$ 64 (– 1050–2834)

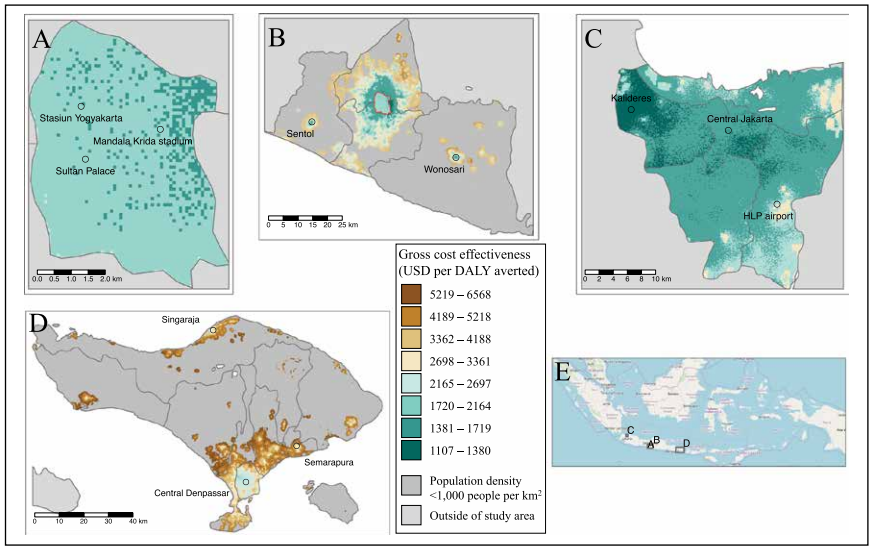

Figure 3 Maps of the gross cost-effectiveness of accelerated *Wolbachia* releases in Yogyakarta City (a), Yogyakarta SAR (b), Jakarta (c), and Bali (d). Cost-effectiveness is measured in present value 2018 USD per disability-adjusted life year (DALY) averted with green areas being most favourable. Select areas of interest and the national orientation of these sites (e) are shown for reference; more detailed background maps are available in Additional file 1, S1.6. Site A falls within site B and is marked in a red outline

still be recovered by addressing these threats (Figure 4c and Additional file 1, S1.5). As *Wolbachia* programmes become more proven over time, it is expected that relaxed surveillance (relying on passive disease monitoring), innovations, and economies of scale will reduce the cost of deployment. These have the potential to increase the benefit-cost ratio by as much as 47%, as long as they do not come at the expense of avoiding to detect more damaging failures of the programme (Figure 4c).

Discussion

Here we use existing cost data to build a programmatic model for *wMel Wolbachia*. By applying this model in Indonesia, we show that this novel technology can be an economically advantageous intervention for dengue control and predict under what circumstances it might be most cost-effective. Cost-effectiveness of *Wolbachia* is predicted to be most favourable in dense cities where a high concentration of people and dengue incidence allow the high investment costs of *Wolbachia* to be quickly offset. In such areas, programmes can become cost saving, or dominant over existing practices, with each $1 invested in a *Wolbachia* programme repaying $1.35–$3.40 in averted medical and society costs of illness. Finally, we show that *Wolbachia* can also be cost-effective in suburban and rural areas, particularly if they can utilise programme infrastructure from nearby urban areas. This is particularly relevant for the existing *Wolbachia* programme in Yogyakarta City and suggests that expansion to nearby areas in Sleman and Bantul in Yogyakarta SAR should be considered.

Assessing the cost-effectiveness of novel rear and release vector control strategies is important because of their high upfront costs but potentially long-term benefits. This makes the cost-effectiveness dynamics of *wMel Wolbachia* more similar to mass vaccination than conventional vector control. Like vaccination, this makes cost-effectiveness of *Wolbachia* sensitive to the time horizon of the evaluation. *wMel Wolbachia* has been robustly established in Cairns, Australia, since early 2011 [35], hence our assumed 10-year benefit time horizon.

More research is required to understand the sustainability of *Wolbachia*

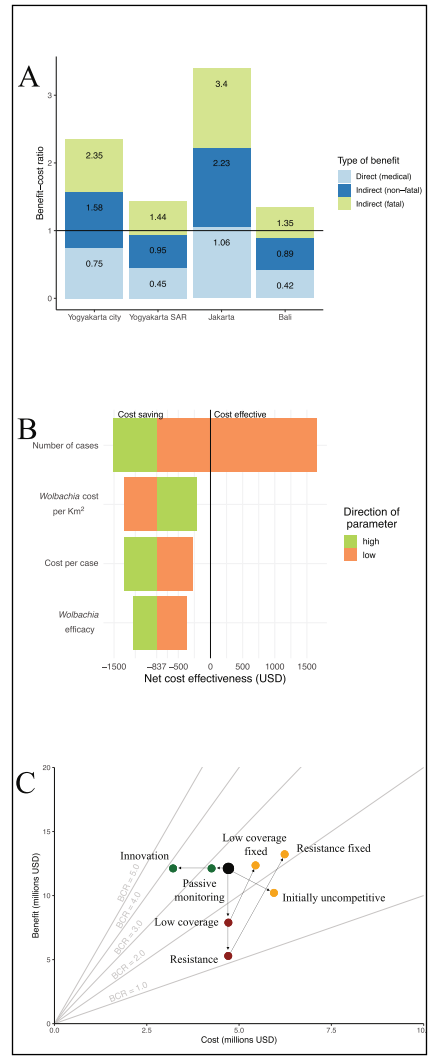

Figure 4 Benefit-cost ratios and their sensitivity. a The predicted benefitcost ratios of a sequenced release programme in each site disaggregated by the type of benefit. A benefit-cost ratio of 1.0 or higher indicates cost saving. b Sensitivity of cost-effectiveness of a sequenced release in Yogyakarta City if the 2.5% value (orange) or 97.5% value (green) were used as opposed to the median value for selected parameters. Net cost-effectiveness is in 2018 present-day value USD per disability-adjusted life year averted and includes offsets from health sector and societal perspectives. c Sensitivity of benefitcost ratios (BCRs) to future challenges or changes to a sequenced release in Yogyakarta City. Green dots show potential cost-saving measures, red dots unaddressed challenges to the programme, and yellow dots addressed challenges to the programme. Dots above the BCR = 1.0 line are cost saving from the societal perspective

replacement in dengue-endemic countries with more complex *Aedes* population genetics and higher virus and mosquito importation rates from outside areas [39].

A number of previous studies have attempted to estimate the cost-effectiveness of vector control interventions for dengue[23, 40–43]. The methods used tend to fall into one of two approaches: field trials or model-based assessments. Experimental and observational control trials have been used to estimate cost-effectiveness (per DALY averted) for larvicides in Cambodia ($313) [40], community clear up campaigns ($3953) and ultra-low volume spraying ($4472) in Mexico[42], and an integrated package of vector control interventions in Sri Lanka ($98)[43]. Short-term control trials with disease endpoints are likely to overestimate effectiveness due to the effects of heard immunity and may mean interventions delayrather than avert disease.

In response to this, model-based cost-effectiveness evaluations can be used to give a more accurate estimate of long-term effectiveness of a particular intervention. However, because long-term effectiveness is not easily measurable, such modelling studies often have to assume a range of plausible efficacies with variable theoretical support. Modelling studies have suggested larval control ($615–1267/DALY) [41], and more generic packages of vector control ($679–1907/DALY) [23] can also be cost-effective depending on true effectiveness. Finally, several models have predicted the cost-effectiveness of dengue vaccines [25, 44]. The cost-effectiveness of WHO's recommended test-and-vaccinate strategy in Indonesia in 2015 was 0.8 to 0.6 times the per capita GDP (i.e. $2700 and $2000) if dengue seroprevalence rates at age 9 were 50% and 70%, respectively [25]. Despite vaccination having a less favourable predicted cost-effectiveness than *Wolbachia*, it is likely both vaccine and vector control will be necessary to achieve control in the highest transmission areas. Further work is needed to understand how the economics of combinations of interventions vary across transmission strata.

Given that *Wolbachia* is also not predicted to fully eliminate dengue virus transmission in highly endemic settings [19, 20] and given that many countries already have established dengue control programmes, there is a pressing need to understand how *Wolbachia* interacts with other types of vector control and how the optimal package of interventions may change in different environments. Modelling and mapping techniques are critical for such investigations due to the impracticality of conducting field trials among the many combinations of different interventions[45, 46].

Our approach to assessing the cost-effectiveness of *Wolbachia* combines the best currently available evidence for the effect of *Wolbachia* on transmission [29] with a long-term mathematical model [19] to overcome limitations of both of these approaches. This work aims to provide an evidence-based first estimate that gives quantitative support behind the decision to invest large sums of money in an intervention that is likely to have deferred but substantial benefits. Using model-based estimates of the true case and economic burden of dengue [19, 34] in Indonesia was a critical step in our approach. Using reported case data would have significantly underestimated the cost-effectiveness of *Wolbachia*, and more research is needed to understand, adjust for, and ultimately fill gaps in disease surveillance [47].

This analysis was subject to a number of limitations. First, our model did not consider logistical constraints that may exist in releasing *Wolbachia*-infected mosquitoes at this scale. The largest current planned releases of *Wolbachia* mosquitoes are in Medellin Colombia where a sequenced programme will cover a combined 1.7 million people over 151 km^2. Reaching high coverage of *Wolbachia* for Jakarta's 11 million residents and 764km^2 land area, particularly over a 3-year accelerated campaign, may not be logistically feasible. New approaches to large-scale community engagement and recruitment of release teams need to be developed. There may also be constraints on the portability of assets, such as centralised distribution of mosquitoes or laboratory testing, across areas as wide as Bali that we did not consider. Second, cost data for existing *Wolbachia* releases were based on budgeted costs; actual costs may differ by the end of the programme. Third, our analysis only included the effects of *Wolbachia* on dengue, despite showing strong protective effects against a range of other arboviral diseases [3–5]. Given chikungunya is also ubiquitous in Indonesia [48], our predictions may underestimate the cost-effectiveness of *Wolbachia*. Fourth, we may underrepresent sub-national heterogeneity in the costs of dengue cases and in the cost of a *Wolbachia* programme. While both of these variables were informed by other data from different countries and were reasonably extrapolated across Indonesia using geospatial mapping approaches, our Indonesian data from both parameters came only from Yogyakarta city, the capital of a region with a per capita GDP 39% below the Indonesian average. More data on cost of illness and cost of the intervention in other parts of Indonesia would strengthen the case for national decision-making [49]. Finally, it should be mentioned that the cost-effectiveness analysis presented here is intended to form one part of the wider evidence base on whether or where *Wolbachia* should be scaled up. To date, successful *Wolbachia* programmes have been underpinned by sustained and robust engagement with both the community and local stakeholders [14, 50]. In this analysis, we make clear assumptions about the success of establishing *Wolbachia* in a target area, but clearly an assessment of feasibility of this aim is a necessary precursor to assessments of cost-effectiveness.

The biggest strength of our analysis is the use of comprehensive, detailed spatiotemporal models that incorporate the latest projections of dengue case and economic burden, and the likely impact *Wolbachia* could have when deployed at scale. Given *Wolbachia* is an early-stage novel intervention, we have also endeavoured to include the broad range of uncertainty that exists in each of these

inputs and assess their impact overall cost-effectiveness. Such comparisons are important if the high upfront investment costs of *Wolbachia* are to be justified, and these results can be used as part of the evidence base in the decision to accelerate scale-up of *Wolbachia* to address the growing needs of arboviral control.

Conclusions

In conclusion, in this study, we show that *Wolbachia* has the potential to be a highly cost-effective and even cost-saving intervention, especially if targeted to high-density cities where the burden of dengue is concentrated. These findings are largely robust to uncertainties in the long-term performance of *Wolbachia*, but further longitudinal field data with epidemiological outcome measures are required to validate these predictions and assess how cost-effectiveness changes when combined with other vector controlinterventions and vaccines. Supplementary information accompanies this paper at https://doi.org/10.1186/s12916-020-01638-2.

Abbreviations

CEA: Cost-effectiveness analysis; DALY: Disability-adjusted life year; GDP: Gross Domestic Product; PPP: Purchasing Power Parity; SAR: Special Autonomous Region; USD: United States Dollar; WHO: World Health Organization; WMP: World Mosquito Programme

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The design of the study was developed independently, but benefitted from a series of in-depth discussions with representatives from WMP global headquarters in Melbourne, Australia (including Cameron Simmons, ScottO'Neil and Reynold Dias), and field site coordinators from UGM, Yogyakarta City, Indonesia (including Adi Uterini). The investigators had access to all the data and had final responsibility for the decision to submit for publication.

Authors' contributions

OJB and DSS conceived and designed the study. KMO, OJB, EH, DDK, NNW, and LSB analysed the data. OJB, DDK, NNW, KMO, EH, LSB, LY, and DSS drafted and revised the manuscript. The authors read and approved the final manuscript.

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Availability of data and materials

All data used in this analysis is publicly available and can be accessed in the related paper O'Reilly et al. [19] or in Additional file 1 of this paper. All code to reproduce our analysis is publicly available in the following GitHub repository: https://github.com/obrady/Wolbachia_CE/tree/V1.

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Dual payload satellite architecture by BlackSky

BlackSky, a leading provider of global monitoring services, geospatial intelligence and satellite imagery, has announced the next phase of expansion of its high-revisit commercial satellite constellation with the unveiling of its next generation, Gen-3, satellite architecture. The commercial constellation expansion features Gen-3 satellites capable of producing images with 50-centimeter resolution and of hosting multiple sensors including short-wave infrared (SWIR).

In addition, the company also announced it has conducted the preliminary design review of its Gen-3 satellite design for the U.S. Army Tactical GEOINT prototype program as part of a multi-year contract with the Defense Innovation Unit. *www.blacksky.com*

Global contract for combating deforestation

Norway's Ministry of Climate and Environment recently awarded an international contract to Kongsberg Satellite Services (KSAT), who, together with Planet and Airbus, will provide universal access to high-resolution satellite monitoring of the tropics in order to support efforts to stop deforestation and save the world's tropical forests. Through this program, the coalition of three geospatial organizations will bring new technologies and transparency to advance the mission of Norway's International Climate and Forests Initiative (NICFI).

Planet will provide high-resolution (sub-5m per pixel) Basemaps of the full tropics, covering over 64 developing countries, updated every month. These will be freely available for anyone to view and use through Norway's technology partners like Global Forest Watch. *www.planet.com/*

Maxar to deliver portable satellite imagery ground systems

Maxar Technologies has announced that it has been selected by the U.S. Army Geospatial Center to deliver multiple highly portable, direct-downlink tactical ground systems that provide critical geospatial intelligence to users in remote locations.

The system, called the U.S. Army Remote Ground Terminal (RGT), is easily transported by two people and can be set-up in about an hour. The RGT enables troops in remote locations to rapidly downlink, analyze and disseminate data from commercial Earth observation satellites to support military, humanitarian and disaster relief missions. The RGT system is based on Maxar's Tactical Architecture for Near-real-time Global Operations (TANGOTM) platform, the most portable ground system of its kind. *www.maxar.com*

MOSAiC Arctic expedition reaches North Pole

On 19 August 2020, the world's largest and longest polar research expedition – known as MOSAiC – reached the North Pole after making an unplanned detour owing to lighter-than-usual sea ice conditions. The expedition is now entering its final stage, during which researchers will study the last piece of the Arctic puzzle: the growth of new sea ice marking the end of the summer season.

In September 2019, the German research icebreaker Polarstern set sail from Tromsø, Norway, to spend a year drifting through the Arctic Ocean – trapped in ice. After leaving the ice floe it had been sitting in for the previous ten months, the icebreaker travelled through the Fram Strait and along the northeast coast of Greenland – a region that is usually home to thick, multi-year ice.

Using radar satellite imagery and sea-ice data, researchers onboard the vessel determined that the ice conditions this year were 'lighter than usual' and were able to complete their journey to the North Pole in just six days. Onboard, during the year-long experiment, around 600 researchers from 20 countries have been carrying out various experiments on the sea ice surrounding the ship in order to gain fundamental insights that are key to better understand global climate change. *www.esa.int*

Aatmanirbhar Bharat ARISE–ANIC Initiative

Atal Innovation Mission (AIM), NITI Aayog, has launched the Aatmanirbhar Bharat ARISE-Atal New India Challenges, to spur applied research and innovation in Indian MSMEs and startups. The programme will be driven by Indian Space Research Organization (ISRO), four ministries—Ministry of Defence; Ministry of Food Processing Industries; Ministry of Health and Family Welfare; and Ministry of Housing and Urban Affairs—and associated industriesto facilitate innovative solutions to sectoral problems. *https://pib.gov.in*

Atmospheric monitoring and earth observation microsatellites

Space Flight Laboratory (SFL), a developer of 52 distinct microspace missions, has successfully launched and deployed the GHGSat-C1 greenhouse gas monitoring microsatellite and the Slovenian NEMO-HD Earth observation microsatellite. SFL developed the small satellites at its facility in Toronto.

Both satellites were in contact with ground control within hours of their launch on September 2, 2020, aboard an Arianespace Vega rocket from the Guiana Space Center in French Guiana, South America. The satellites are healthy and operating as planned.

Established at the University of Toronto Institute for Aerospace Studies (UTIAS) in 1998, SFL has developed CubeSats, nanosatellites, and microsatellites that have achieved more than 126 cumulative years of operation in orbit. These microspace missions have included SFL's trusted attitude control and, in some cases, formation-flying capabilities. Other core SFL-developed components include modular (scalable) power systems, onboard radios, flight computers, and control software. *www.utias-sfl.net*

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Promoting GIS in Africa

Esri has announced a joint initiative with AfroChampions, a Pan-African nonprofit that aims to promote policies that foster private-public collaboration for Africa's economic transformation. The goal of the initiative is to engage leaders in business, governments, the African Union, and other regional economic communities through dialogue and potential partnership building in applying geospatial technology and solutions. *www.esri.com*

UK Government publishes new data strategy

Digital Secretary, UK, Oliver Dowden has launched a National Data Strategy and set out the action the government will take to support the use of data in the UK. It will put data at the heart of the country's recovery from the pandemic so companies and organisations can use it to drive digital transformation, innovate and boost growth across the economy.

The strategy, which lays out five priority 'missions' the government must take to capitalise on the opportunities data offers, is a central part of the government's wider ambition for a thriving, fast-growing digital sector in the UK. *www.gov.uk*

IHO releases new standards for hydrographic surveys

International Hydrographic Organization (IHO) has released a new edition of the Standards for Hydrographic surveys (S-44). In addition to surveys to support the safety of navigation, these standards can be adapted for oil and gas, renewable energies, dredging, geophysics, and geotechnics.

One of the notable changes in this latest version is the introduction of a new more stringent classification for surveys called "Exclusive Order" which expands the standards' applicability. This is designed for specific critical areas such as harbours and channels with minimum underkeel clearance and bottom characteristics which could be hazardous to vessels. In these specific areas, an increased accuracy of +/- 10 cm on a map can help precisely determine requirements for dredging and avoid unnecessary costs.

Another key feature of this edition is a new "Specification Matrix", a matrix of parameters and data types, which defines the required accuracy depending on the hydrographic needs. The aim is to allow flexibility in the survey definition and to accommodate these various needs as well as emerging technologies such as satellite derived bathymetry. *https://iho.int*

Bentley Systems announces availability of OpenGround Cloud

Bentley Systems, Incorporated has announced the availability of OpenGround Cloud, a new cloud service that enables geotechnical professionals to access reliable geotechnical data for better engineering decision support and to improve collaboration across the entire supply chain. It offers a complete solution for planning, data entry, borehole log production, lab data management, reporting, visualization, and more. The cloud service improves collaboration across multidisciplinary project teams and significantly increases the value of geotechnical data by making it easily accessible to key project stakeholders. *www.bentley.com*

Teledyne CARIS AI software onboard successful UTAS USV mission

Teledyne CARIS was an integral part of the illustrious team involved in the ground-breaking uncrewed offshore survey mission in the Atlantic Ocean. Teledyne CARIS' Mira AI and CARIS Onboard software were present on the vessel to enable autonomous survey and real-time processing operations. The mission's Uncrewed Surface Vehicle (USV) built by SEA-KIT mapped over 1000 sq kms of the ocean floor in 22 days, while being continuously monitored via satellite communications at its Remote Operations Center in Essex, United Kingdom. A specialized team comprised of the GEBCO-Nippon Foundation Alumni Team operated the survey equipment and provided quality control of the data from various 'work-from-home locations' around the world. *teledyne.com*

S$40M product development centre in Singapore by Lendlease

International property group Lendlease has announced that it will set up a S$40 million product development centre in Singapore, with the support of the Singapore Economic Development Board to accelerate the digital transformation of the property and construction sector.

The Singapore product development centre is part of the wider Lendlease Digital ecosystem, which includes product development centres in Silicon Valley and Sydney. Using an Agile working methodology – a project management framework for teams to iteratively and incrementally complete tasks and projects, Lendlease is creating a scalable supply chain and integrated logistics software platform for property development and construction projects in Singapore and globally. www.*lendlease.com*

Online 'Map Search' feature by UA

United has announced that it is the first U.S. airline to introduce an interactive map feature powered by Google Flight Search Enterprise Technology. Customers can access Map Search on United.com to easily compare and shop for flights, based on departure city, budget and location type, including popular national park, skiing and cultural destinations. This new digital tool displays fares in a map view, allowing customers to simultaneously compare travel to a variety of destinations in a single search. *https://hub.united.com*

£2 million transport location data competition

The Geospatial Commission has partnered with Innovate UK to create a new £2 million competition which will look at how location data can spark innovation and support the future of mobility for the United Kingdom.

This competition aims to stimulate commercial innovation to help create geospatial solutions to our transport challenges and support the future of mobility. The competition has four themes:

- Mobility as a service - to help better integration of transport modes
- Active travel - creating safer ways to enable active travel
- Supply chains - helping better distribution, storage and delivery
- Boosting capacity - increasing efficiency of transport networks.

www.gov.uk

Mitigating COVID-19 in Nigeria

To help mitigate the spread of the COVID-19 pandemic in Nigeria, Unacast, a location platform and analytics firm, and MTN Nigeria, the leading mobile telecommunications provider, recently announced a partnership in which the two will use privacy-friendly, aggregated and anonymized, human mobility insights derived from MTN's network data, to make available a version of Unacast's COVID-19 Social Distancing Scoreboard for Nigerian citizens and officials. Together, the companies will provide this easy-to-use dataset on a pro-bono basis to enable public officials, public health leaders and other organizations, and the public itself to understand and convey the importance of social distancing in fighting the spread of COVID-19.

The partnership between MTN and Unacast will make the Social Distancing Scoreboard available for Nigeria to help public & private enterprise, public health, NGOs, and governments make data driven decisions during the pandemic. It will leverage Unacast's Turbine platform for aggregated and anonymized telecommunication data via MTN. Turbine turns raw location data from mobile networks to privacy-safe, anonymized, and aggregated human mobility insights. The technology allows end users to distill vast datasets that accurately understand human mobility across a large area like Nigeria. *www.mtnonline.com*

Winvic secure Innovate UK Funding for Computer-Vision-SMART

Winvic is working on a second Innovate UK funded project, which aims to keep site staff even safer; the three organisations involved will together leverage the latest real-time image and machine learning technologies to detect, recognise and track hazards on a construction site, which will then alert nearby operatives via IoT enabled, GPS devices.

The Big Data Enterprise and Artificial Intelligence Lab (Big-DEAL) at UWE Bristol, and Bristol industrial intelligent video specialists One Big Circle are the two other organisations in the consortium that were successful in their application for an Innovate UK – the UK's innovation agency – Smart Grant. *www.winvic.co.uk*

HERE offers rich geospatial data

HERE Technologies has released HERE Data Layers to improve software developer and data scientists' access to the rich cartographic features and attributes captured within an enterprise-grade mapping platform. They are standalone geospatial representations of the world's road networks, pathways, buildings, structures, places, land use and land cover. They serve as a menu for developers and data scientists to select the datasets needed to power today's location-based functions, applications and customer experiences.

LEO Satellite Communication for Global Maritime Connectivity

Saab will, together with the companies ORBCOMM and AAC Clyde Space, lead a groundbreaking Swedish space project; to develop space based communication for the maritime sector via the new automatic tracking standard, VDES. The new VDES package does not only enable safer, more sustainable and greener shipping but the technology also has spin-off potential for other industries.

The company is now taking a next step and investing in a satellite project that will expand global data communication opportunities for the maritime industry but also potentially for other industrial Internet of Things (IoT) applications. The first demonstration satellite is intended to be followed by a larger constellation of satellites that will form the new part of the maritime communication infrastructure. *https://saabgroup.com*

Developing Geolocation IP solution for IoT modems

Synopsys, Inc. and Nestwave have announced a collaboration to combine Nestwave›s soft core GPS navigation IP with the Synopsys DesignWare® ARC® IoT Communications IP Subsystem for a complete low-power GNSS solution for integration into IoT modems. The collaboration will provide designers with a power-efficient, high-accuracy GPS solution for battery-operated devices without the additional cost of a dedicated GNSS chip. *www.nestwave.com*

Antenova adds high performer to its 5G antennas

Antenova Ltd, UK manufacturer of antennas and RF antenna modules for the Internet of Things and M2M applications has added a high performing 5G SMD design to its array of 5G antennas. This brand-new antenna, Lepida SR4L054, is a wideband antenna in SMD form, designed to achieve high efficiency and performance right across the spectrum from 600MHz to 3800MHz.

Lepida operates right across the cellular bands B71 (617-698 MHz), LTE 700, GSM850, GSM900, DCS1800, PCS1900, WCDMA2100, B40 (2300 – 2400 MHz), B7 (2500-2690MHz), and B78 (3300-3800MHz). *www.antenova.com*

Marlyn update by Atmos UAV

Atmos UAV has introduced a series of upgrades in Marlyn's flight planning and control software, MarLynk. The two features which according to the team will have the biggest impact on user experience with Marlyn, are (1) the enhanced corridor mapping to plan more easily and maximize the coverage of long-assets mapping and (2) the new intelligent checklist which is focused on the man-machine interface (MMI) by integrating automated system checks that result in completing the pre-flight procedure faster without compromising on safety. *atmosuav.com*

AUVSI XCELLENCE humanitarian award

WildTrack, a non-profit organization dedicated to non-invasive wildlife monitoring and conservation, has been awarded a prestigious AUVSI XCELLENCE Humanitarian Award. The organization won for pairing its Footprint Identification Technique (FIT) in JMP software with high-resolution drone imagery captured using senseFly eBee X fixed-wing mapping drones.

The ground-breaking project was recognized by the Association for Unmanned Vehicle Systems International (AUVSI) in the Awards' Humanitarian and Public Safety category for its innovative use of unmanned aerial vehicles (UAVS) in monitoring and protecting endangered species, such as black rhino in Namibia. *www.sensefly.com*

EGNSS at the core of the drone revolution

The European GNSS (EGNSS) is at the core of the drone revolution and future U-space services. EGNOS and Galileo provide significant added value to drone navigation, positioning, and related applications, and the use of their differentiators will be instrumental in developing new business opportunities. Receiver manufacturers, well aware of the benefits that GNSS can bring to the users, are eager to adopt Galileo and EGNOS and pass on these advantages to their users.

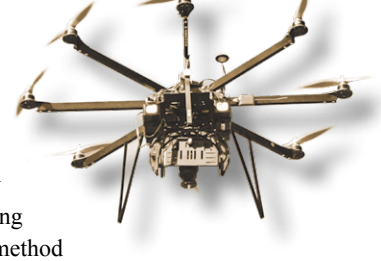
A growing number of drone applications require accurate positioning information. According to the 2019 GSA's GNSS Market Report survey, almost 50% of drone users expect a horizontal accuracy of below 10 cm and 38% a vertical accuracy of below 10cm. This increased performance is critical for multiple drone applications and is not achievable without any GNSS signal augmentation. The EGNOS Open Service can augment GPS signal to a minimum accuracy of 3 metres in the horizontal and 4 metres in the vertical planes compared to 17 and 37 metres for non-augmented GPS.

EGNSS receivers for drones are already populating the market, with Europe supplying around 12% drone receivers worldwide. Companies like u-Blox, Septentrio, Novatel, and Javad have been the early adopters of Galileo and EGNOS and invested in the technology now revolutionising the drone industry. Thanks to this forward thinking companies, EGNSS is now a standard feature for the drones and to date, there are 190 EGNOS-capable or Galileo-ready chipsets and modules available in the market. *www.gsa.europa.eu*

Drone that can fly in areas with no GPS reception

Earth Analyzer, a startup based in the city of Ayabe, Kyoto Prefecture has developed a drone that can be operated on autopilot in places with no GPS reception, such as below girder bridges or in tunnels. The drone receives location information from sensors set up around places with no GPS signals, which is converted into the same kind of signals used in GPS. This enables the drone to automatically identify its location.

There had previously been no other option but for people to operate drones manually inside buildings and other places where GPS signals could not reach. Although there is also a method to operate drones by equipping them with cameras and lasers and have them fly while analyzing images, this method apparently requires slowing down their speed and there are also limitations on the locations they can be flown.



The new drone system was developed in a joint effort by Earth Analyzer, Tokushima University, and i System Research Corp., a tech firm based in Kyoto's Nakagyo Ward. *https://mainichi.jp*

Enhanced functionality in drone surveying software

In release 7.4, Virtual Surveyor has added new functionality to the free pricing level of its popular drone surveying software. The "Valley" plan of Virtual Surveyor now allows users to create engineering CAD models from drone orthophotos and/or LiDAR data sets. It enables surveyors to derive topographic information from drone data that engineers need for construction, mining, and other excavation projects. The software has become popular among surveyors and engineers because its tools allow them to work effectively with drone data. *www.virtual-surveyor.com*

Freefly and Auterion announce the release of Astro

Freefly Systems, leading drone manufacturers and Auterion, the \open source drone software platform announced the releases of the Astro Enterprise Drone Solution. In partnering, the two companies have combined their respective expertise in hardware and software to build and release the Astro – the best multi use enterprise drone for utility, telco, and infrastructure companies, as well as drone service providers and first responders. *www.auterion.com*

3D mast inspection by Pix4D and SAP

Pix4D has announced that it is starting a joint innovation project with SAP® to open up the market for drone-based, digital 3D inspections for telecommunications companies. *www.pix4d.com*

UK Government to explore new ways of delivering 'Sat Nav'

New options for a UK satellite navigation and timing capability programme to support the nation's critical infrastructure will be explored by the government.

The Space-Based Positioning Navigation and Timing Programme (SBPP) will explore new and alternative ways that could be used to deliver vital satellite navigation services to the United Kingdom which are critical for the functioning of transport systems, energy networks, mobile communications and national security and defence, whilst boosting the British space industry and developing the UK's own capabilities in these services.

UK GNSS is an exploration programme which has developed outline plans for a conventional satellite system as an alternative to American GPS or the EU's Galileo. The programme will now be reset as the SBPP to build on this work to consider newer, more innovative ideas of delivering global 'sat nav' and secure satellite services to meet public, government and industry needs.

Capitalising on the ingenuity of British businesses and academics, the programme will explore the use of different kinds of satellites at various levels of orbit by exploiting technologies offered by companies at the cutting-edge of innovation such as OneWeb, Inmarsat and Airbus. *www.gov.uk*

Rehabilitation of Mara ecosystem using GNSS technology

The Mau Forest Complex in the Rift Valley in Kenya is the largest indigenous montane forest in East Africa. A hunter-gatherer community lives sustainably in the forest. However, encroachment and illegal allocation of the forest has left large parts cleared for settlement, agricultural use and logging.

To assist in efforts to remove illegal settlers and settlements and to rehabilitate the forest complex, Survey of Kenya (SOK) demarcated the Mau Forest boundaries to precisely delineate forest cut lines and solve the problem of fuzzy boundaries that have contributed to human encroachment.

To more safely perform the survey in disputed lands and difficult hostile terrain, SOK relied on the Spectra Geospatial SP80 GNSS receiver. The multi-constellation SP80 has the speed, accuracy, low-weight and ease-of-operation that enabled the SOK survey team to work quickly and reduce survey time in disputed areas. *www.trimble.com*

Development phase of the GNC system by GMV

On 15 September, the European Space Agency (ESA) signed with the German company OHB the €129.4-million contract covering the detailed design, manufacturing, and testing of the HERA mission. This mission, ESA's first ever planetary defense mission, will be Europe's contribution to an international asteroid deflection effort carried out jointly with NASA and due for lift-off in October 2024. The contract takes in the complete design of the interplanetary probe, integration and tests, including an advanced Guidance, Navigation and Control (GNC) system that has been awarded to the technology multinational GMV as subcontractor of OHB. *www.gmv.com*

GRIFFIN - GPS J&S Rapid Threat Geo-Location

Under a recent Australian Government production demonstration contract, GPSat Systems has continued with both capability expansion and commercialization of it's GRIFFIN precision Jamming & Spoofing (J&S) geolocation technology. It is uniquely optimised for working with extremely weak GPS RF satellite signals, well below the ambient RF noise floor. By employing phased array signal amplification processes, coupled with advanced spectrum cleansing/whitening techniques to remove "known RF sources", the GRIFFIN network of synchronised Sensor Nodes very accurately characterises and geolocates multiple RFI sources instantly.

Under this contract, the technology has now passed TRL7 milestone by successfully completing formal project stakeholder field demonstrations. With the effects of Covid19 manifesting towards project end, limiting the final production, fine tuning and the field demonstrations new work-arounds need to be implemented quickly.

Dr Kimia Shamaei receives Parkinson award

The Institute of Navigation's (ION) Satellite Division presented Dr. Kimia Shamaei with its Bradford W. Parkinson Award September 25, 2020 during the ION GNSS+ 2020 VIRTUAL Conference.

Dr. Shamaei was recognized for her thesis,

"Exploiting Cellular Signals for Navigation: 4G to 5G." The Bradford W. Parkinson Award is awarded annually to an outstanding graduate student in the field of Global Navigation Satellite Systems (GNSS). This award, which honors Dr. Parkinson for his leadership in establishing both the U.S. Global Positioning System and the Satellite Division of the ION, includes a personalized plaque and a $2,500 honorarium. *ion.org*

GNSS+INS technology for hydrographic survey applications

VERIPOS have introduced SPAN GNSS+INS technology from NovAtel, also part of Hexagon, into the offshore oil and gas marine market. NovAtel and its SPAN technology accelerated development in GNSS positioning, sensor fusion and inertial navigation systems for

over 15 years. Now, VERIPOS brings this proven technology to the marine market to optimize positioning solution with GNSS and inertial measurement units (IMUs) to provide heading, attitude and heave measurements on the open water.

Through deep coupling, SPAN technology fuses measurements from the GNSS receiver and the IMU together to calculate robust and reliable position, heading, velocity attitude and heave. This process delivers a holistic and precise 3D solution, powering hydrographic survey applications through extended GNSS outages. *veripos.com*

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Space-dedicated Gyro and IMU modules by Sensonor

The high-accuracy tactical-grade STIM277H Gyro module and STIM377H Inertial Measurement Unit are based on experiences and requirements from serving customers in the space segment during the last decade.

The modules have a hermetic aluminum enclosure with a glass-to-metal sealed electrical micro-d connector and a laser-welded lid to secure long-term hermetic operation. All parts are tested for fine and gross leak to conform to MIL-STD-883J, Class H.

The hermetic enclosure protects the system from the external environment and ensures long-term reliability to meet requirements within the space segment and other applications needing exceptional long-term reliability. The design is tested for a 20+ years' operating life through high-temperature operating life (HTOL) testing.

The parts are a good fit for satellite attitude & orbit control systems (AOCS), launchers, portable target acquisition systems, UAV payloads, land navigation systems, turret stabilization, missile stability and GNSS- supported navigation systems. *sensonor.com*

Russia to place 7th ground station of Glonass in Brazil

According to the report in TASS, the Precision Instrument-Making Systems research and production corporation (part of the State Space Corporation Roscosmos) has signed a contract to place a non-request measuring station of the SM-Glonass satellite navigation system in the municipality of Colorado do Oeste (the state of Rondonia in Brazil.

The Russian company signed the corresponding contract with the Federal Institute of Education, Science and Technology of Rondonia and the Research Support and Development Fund.

The measuring station of the SM-Glonass system is designed to continuously monitor the signals of the Glonass, GPS, Galileo, Compass and QZSS navigation systems. The station is also required for controlling the reliability parameters of navigation signals of global navigation satellite systems. *https://tass.com*

Trimble Connect integrates with Microsoft 365 and BIMcollab

Trimble has announced new integrations for Microsoft 365 and BIMcollab with its Trimble® Connect™ cloud-based collaboration platform. It provides users of both platforms with a common data environment for connecting project stakeholders with the data they need to inform decisions and improve team efficiency. In real-time, project stakeholders can share, review, coordinate, and comment on data-rich constructible models, schedules, and critical project information. *www.trimble.com*

C1 GNSS receiver by Bynav

Bynav released the C1 GNSS RTK OEM receiver and the A1 industrial-grade IMU-enhanced GNSS OEM receiver based on Bynav GNSS baseband ASIC Alita and RFIC Ripley. The receiver board measures 46×71mm and supports dual-antenna heading and full-constellation, including GPS, BDS, Galileo, GLONASS, QZSS, NavIC and SBAS, as well as providing enhanced interfaces like UART serial port, Ethernet, 3 EVENT_IN, 3 EVENT_OUT, 1PPS, CAN bus etc. for easy integration with external IMU, odometry, LiDAR or visual SLAM. *bynav.com*

SSTL demonstrates new GNSS-R capabilities

Surrey Satellite Technology Ltd (SSTL) has successfully demonstrated GNSS-Reflectometry (GNSS-R) from its 18kg DoT-1 satellite. It has pioneered the new field of GNSS-R with successful payloads on board TechDemoSat-1 and the CYGNSS constellation, and is continuing to develop the technology and data analysis in pursuit of this new science. The latest GNSS-R payload on-board the DoT-1 satellite is incorporated within the new small form factor Core Avionics module integral to all SSTL's future satellite platforms.

GNSS Reflectometry is an Earth observation technique that uses GNSS signals as L-Band radar sources, allowing

the satellite to take measurements of ocean wind speeds, polar ice and hydrological land parameters, at a higher spatial resolution and an order of magnitude lower cost than other methods. *www.sstl.co.uk*

Hexagon unveils HxGN Smart Census 2020

Hexagon's Geospatial division has launched HxGN Smart Census 2020, a significant update to its end-to-end population and housing census management solution. The latest release improves digital enumeration by allowing households to complete census questionnaires online or over the telephone, significantly reducing the need for in-person interviews and field-based data collection. It combines traditional GIS functionality with a powerful workflow and workforce management tool. It provides a complete solution for each stage of the census cycle: pre-enumeration mapping, digital enumeration, and post-enumeration dynamic mapping. *www.hexagongeospatial.com*

Carlson Civil and Hydrology 2021

Carlson's latest releases of Civil and Hydrology include time-saving innovations and automated new features, as well as improvements to many existing commands. There are several, new, time-saving parking layout tools including ParkingNet which works from multiple alignments like Road Network. There's also a 'Parking Inside Perimeter' which creates a parking layout within a closed polyline, then dynamically updates as you edit the perimeter. 'Parking along alignment' creates a series of parking stalls, islands, and zones along a centerline and allows elevation for quick site modeling. There's also a new 'parking island' command for the quick creation of these features. *carlsonsw.com*

NextNav vertical positioning service

NextNav has announced the availability of its vertical positioning service in sixteen major metropolitan areas in the US. The vertical positioning service helps first responders save lives by finding people faster in multi-story buildings, opens up new urban markets for location-based applications, and unlocks an entire new ecosystem of 3D geolocation products. The technology exceeds the FCC requirements for wireless E911 location accuracy, offering z-axis data within three meters, 94% of the time. *www.nextnav.com*

Spectra SP90m selected by racing Yacht

The Spectra Geospatial SP90m GNSS receiver has been selected by the racing yacht Maître CoQ for the 2020 Vendée Globe, single-handed, non- stop around-the-world yacht race. The Vendée Globe is an extreme endurance test for both sailor and boat and widely considered the ultimate challenge in ocean racing. The Maître CoQ is an advanced design mono-hull foiling sailing yacht in the category of IMOCA (International Monohull Offshore Class Association) which have a fixed length of 18.28 m (60 feet), Antoine Connan, head of engineering for the Maître Coq racing team, selected the SP90m. The hostile environment and requirements for precise position information at sea far from land made the selection of the SP90m an important technical choice. It always delivers an accurate position and precise heading with no GNSS corrections. *trimble.com*

i73 GNSS and iBase GNSS receivers by CHC

CHC Navigation has announced the immediate availability of the i73 GNSS, a versatile pocket-sized IMU-RTK GNSS rover with an integrated inertial module and the iBase GNSS, a rugged base GNSS receiver. The combination of the i73 GNSS and the iBase GNSS offers the most productive and affordable solution for measuring and staking out points in any surveying, mapping, or construction application.

The i73 GNSS offers superior GNSS signal tracking enabling surveys beyond the usual constraints. It features full 624-channel GNSS technology and connects seamlessly to RTK GNSS networks as well as to UHF GNSS station over its embedded UHF modem. The GNSS internal interference-free inertial module (IMU) allows automatic pole tilt compensation of up to 45 degrees. Projects are completed 30% faster and with increased efficiency and safety when measuring hard-to-reach points. The GNSS iBase is a fully integrated GNSS base station, specifically designed to meet 95% of surveyors' needs when working in UHF GNSS base and rover mode. The performance of the iBase UHF base station compared to a conventional external UHF radio modem is virtually identical. But its unique design eliminates the need for a heavy external battery, bulky cables, an external radio, and a radio antenna. Its 5-watt radio module provides operational GNSS RTK coverage up to 8 km. *www.chcnav.com*

Applanix introduces next generation OEM solution

Applanix has introduced the Trimble® AP+ Air OEM solution for Direct Georeferencing of airborne sensor data. The solution enables users to accurately and efficiently produce maps and 3D models without the use of ground control points. It is a powerful solution for manned platforms yet small enough for use on UAVs. It is also compatible with virtually any type of airborne remote sensor, including photogrammetric cameras, LiDAR, hyper and multi-spectral cameras, and synthetic aperture radar. *www.applanix.com*

Hexagon selected for Innovate UK rail infrastructure AI project

Innovate UK, the country's innovation agency, has selected Hexagon's Geospatial division to conduct a research project that will result in faster and higher-precision mapping of railway infrastructure through the use of artificial intelligence. The project is funded by Network Rail, the owner and operator of Great Britain's railway infrastructure, under its R&D portfolio

and delivered by Innovate UK through the SBRI competition, Innovation in Automated Survey Processing for Railway Structure Gauging, Phase One. A small group of teams was selected for this effort. *www.hexagongeospatial.com*

Collins Aerospace adds navigation receivers

Collins Aerospace Systems has been selected by Boeing to provide its proven NAV-4500 navigation receivers for the T-7A Red Hawk, the U.S. Air Force's (USAF) new advanced pilot training system in development by both Boeing and Saab.

This award builds on previously announced Collins Aerospace positions on the T-7A, including its ACES 5® ejection seat; the platform's fully integrated landing gear system; various Power & Controls components, including the aircraft's Power Take Off (PTO) shaft, Auxiliary Power Engine Control Unit (APECU), engine start system and Main Electric Power Generation System (MEPGS); as well as air data, ice detection and total air temperature sensors. *CollinsAerospace.com*

First software-defined GNSS simulator with MNSA

Orolia Defense & Security has been granted security approval by SMC Production Corps. for BroadSim MNSA (Modernized Navstar Security Algorithm). BroadSim is the only software-defined GNSS simulator on the market to receive such approval, marking an industry first. *www.Orolia.com*

SBG Systems supports education

SBG Systems is highly involved in supporting future engineers in their challenges and skill learning. The company has built a specific program to sponsor student teams participating in competitions as well as specific discount to Universities and Research Centers on inertial sensors and post-processing software.

Supporting teams competitions with inertial navigation systems

The company offers sponsorship to students participating in competitions in various fields, such as robotics, autonomous vehicles, UAV, rockets, unmanned and solar boats, and many more.

Get your school the latest miniature AHRS, and RTK GNSS/INS Sensors

The Ellipse Series, eligible to the Education Program, is composed of the most advanced and miniature Inertial Measurement Unit, Attitude and Heading Refence Systems and Inertial Navigation Systems. The whole product line has recently been renewed to deliver unmatched accuracy even in harsh environments.

Go further in your training and research with post-processing

In just a few clicks, Qinertia Post-Processing Software allows to replay, analyze, improve their trajectories, and access RTK corrections worldwide to bring your project to the centimetric accuracy. *www.sbg-systems.com/education*

SBG Promotional Offer: Free Qinertia PPK software for 6 months

SBG Systems to announce a promotional offer consisting in a free 6-month post-processing license of SBG Systems' Qinertia PPK software for the purchase of a High Performance SBG inertial navigation system. The offer applies from October 1st to November 13th, 2020.

The promotion applies to the Ekinox-D and Apogee-D, both fully integrated dual antenna inertial navigation systems with RTK capabilities, and to the Navsight Marine and Land/Air motion and navigation solutions designed for hydrographers and surveyors. *www.sbg-systems.com*

Smart city solutions research in Singapore

NUS and ST Engineering are collaborating on a S$9 million, multi-year advanced digital technologies research programme to further their common goals of building a people-centric, smart future for Singapore and beyond.

Research efforts of this new programme will focus on technologies related to Smart City as well as Smart Maintenance, Repairs and Overhaul (MRO), covering five areas: resource optimisation and scheduling; prescriptive analytics; decision and sense-making; reasoning engine and machine learning; as well as digital twin. These research areas support ST Engineering's focus on developing differentiated and people-centric, smart city solutions that meet the present and future needs of cities around the world. The interdisciplinary research areas are also aligned with NUS' endeavours as a driving force behind smart city innovations, leveraging its deep expertise that spans multiple domains and faculties. *https://news.nus.edu*

Cybersecure navigation system by iXblue

iXblue has delivered to Naval Group, the cybersecure navigation system for the first Defense and Intervention Frigate (FDI) for the French Navy under the project management of the French General Directorate of Armament (DGA).

Based on the iXblue Fiber-Optic Gyroscope technology, the Marins units are very high performance inertial navigation systems, meeting the military requirements of the most modern combat ships. They provide highly accurate position, heading, roll, pitch and speed information regardless of the environment and even when GNSS signals are inaccessible. *www.ixblue.com*

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