Technological Forecasting & Social Change 167 (2021) 120677

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

Multifaceted applicability of drones: A review

Matthew Ayamga [a,*], Selorm Akaba [b], Albert Apotele Nyaaba [c]

[a] Business Management and Organization Chair Group, and the Information Technology Chair Group, Wageningen University & Research, P.O. Box 8130, 6700 EW Wageningen, the Netherlands

[b] Department of Agricultural Economics and Extension, School of Agriculture, College of Agriculture and Natural Sciences, University of Cape Coast, Cape Coast, Ghana, West Africa

[c] Youth Harvest Foundation, Box 656 Yikene, Bolgatanga, Ghana

ARTICLE INFO

Keywords:
Digital economies
Drones for agriculture
Medical emergencies
Security and surveillance
SWOT analysis

ABSTRACT

Technology is playing its part in globalization and the drone technology is such a technology with a usage ever increasing in a vast range of disciplines such as agriculture, health and military. Drones can provide real-time data on farms that enable farmers to make informed decisions regarding farm inputs usage. Also, they can be used to aerially deliver medical supplies like blood, vaccines, drugs, and laboratory test samples during health emergencies to remote areas in developing countries. Military drones also help in security and surveillance on the enemies' movements which then helps select for target killings. Though beneficial, drones can cause injuries and damages to people and properties if the user is not trained and if there is a component failure during flight. Drones could also be hijacked by an extremist and divert the payload for their self-interest. In this paper, the Strength, Weaknesses, Opportunities, and Threats analysis of the current developments of agricultural, medical, and military drones are presented.

1. Introduction

Drone technology provides enormous benefits and opportunities in a vast range of disciplines. Drones support tasks such as surveying, humanitarian work, disaster risk management, research, and transportation (Ayamga et al., 2020). In agriculture, drones can provide real-time imagery and sensor data from farm fields which cannot be quickly accessed on foot or by a vehicle (Malveaux et al., 2014). Global Positioning System (GPS) and customizable apps for smartphones and tablets have provided improved flight durations, reliability, ease of use and the ability to better utilize cameras and other sensors needed for applying drones in agriculture and natural resources (Hogan et al., 2017). The use of drones is becoming so intimately interwoven within the fabrics of most sectors of developed and developing economies, losing control of it would have potentially far-reaching if not calamitous implications.

Common drone applications in medicine include but not limited to the provision of disaster assessments when other means of access are severely constrained; delivering aid packages, medicines, vaccines, blood and other medical supplies to remote areas; providing safe transport of disease test samples and test kits in areas with high contagion; and potential for providing rapid access to automated external defibrillators for patients in cardiac arrest to save lives (Balasingam, 2017) and during health emergencies. In the era of COVID-19 drones could deliver Personal Protective Equipment (PPEs), test kits, vaccines, medication, and laboratory samples. It can help in easy social distance inspection in public places in an automatic way (Ramadass et al., 2020). As a novel technology, drones provide tailor made solutions in a context of extreme emergencies, undulating topography, and transportation infrastructure. Adoption of drones for delivering crucial and lifesaving medicines to all citizens in an economy could help achieve the aim of universal health coverage (McCall, 2019). A potential benefit from drones in the transport sector is logistics and passenger transportation (Kellermann et al., 2020).

The extension of drones from the military perspective into the civilian context have also brought in regulatory hurdles that need to be overcome to utilise the full potential of the drone technology. Greenwood (2016) pointed out that, to realize drone's full potential, regulatory regimes are necessary, while keeping citizens' safety and privacy rights secure. Misuse (e.g., terrorism), privacy and military use are some of the public concerns from the study of Clothier et al. (2015).

Notwithstanding these issues, Sylvester (2018) indicates that the drone technology can give employment to the youth who could use drones to provide services to rural farmers. Against this background, this

* Corresponding author.
E-mail addresses: matthew.ayamga@wur.nl (M. Ayamga), sakaba@ucc.edu.gh (S. Akaba), albert.nyaaba@harvestmail.org (A.A. Nyaaba).

https://doi.org/10.1016/j.techfore.2021.120677
Received 7 February 2021; Accepted 14 February 2021
Available online 19 February 2021

review seeks to present the current developments of using drones in agriculture, medical field, and the military. To achieve this aim, we first presented a brief theoretical background on drones and in these sectors and then the review took a SWOT analysis approach.

2. Theoretical background

A drone or an unmanned aerial vehicle (UAV) according to the definition by International Civil Aviation Organization (ICAO, 2011) is an aircraft operated without a human pilot on-board. Another term, Unmanned Aircraft System (UAS) is defined as been made up of components such as a drone, the controller (ground-based), and the communication system between the two (the drone and the controller). ICAO (2015) defined the terms; *(i)* Remotely Piloted Aircraft System (RPAS) - which is a remotely piloted aircraft, its associated remote pilot station(s), the required command and control links, and any other components as specified in the type design and *(ii)* Remotely Piloted Aircraft (RPA) - an unmanned aircraft piloted from a remote pilot station.

All these terms are referring to a drone which is remotely controlled by an operator on the ground or pre-programmed to fly specific routes (Nelson and Gorichanaz, 2019). Hogan et al. (2017) and Wallace et al. (2018) define two types of drones: *(i)* a fixed-wing – which generates lifts as it moves enabling it to sustain velocity through the air and *(ii)* the rotor which is highly manoeuvrable and can hover and rotate with a flight controller. These two types of drones have their advantages and disadvantages when it comes to flight range (endurance), battery capacity and payload (Ayamga et al., 2021).

2.1. Agricultural drones

In recent years, the agricultural sector has seen some innovative technologies that support farm management strategies in enhancing efficiency through the precision application of farm inputs. One of such innovations is the drone technology which has gained popularity (Kim et al., 2018) and has been widely used in precision agriculture (Zhang and Kovacs, 2012).

According to Hedley (2015), several optical sensors are linked to a GPS so that the position of the readings is recorded and can be accurately mapped to inform variable rate fertiliser or growth regulation application; and are available to farmers to actively monitor the development of growing crops such as cereals, brassica, maize and ryegrass. Depending on the crop analysis to be made on a farm, cameras such as red, green, and blue (RGB), multispectral, hyperspectral, thermal cameras, and low-cost consumer-grade cameras are fitted on a drone to capture near-infrared (NIR) pictures (Haghighattalab et al., 2016). Drones use together with other Information Communication Technologies (ICTs) are opening a new phase in the agriculture domain where we have digital agriculture, smart agriculture, e-agriculture, and precision agriculture (El Bilali et al., 2019). From the Internet of Things (IoT) we now have Internet of Drones (IoD) which provides generic services for various drone applications, such as package delivery, traffic surveillance, search, and rescue, and more (Gharibi et al., 2016).

2.2. Medical drones

Aerial delivery of medical supplies by drones to health facilities in remote communities with bad road infrastructure and undulating topography has been successfully carried out in some African countries like Rwanda and Ghana. Ling and Draghic (2019) point out that, drones are providing faster response times, reduced transportation costs, and improved medical services to remote and or underserved environments. In the wake of Covid-19 pandemic, the United States (US) has approved Zipline and other companies to deliver medical and food suppliers in some states, through which the drone delivery market is expected to make substantial gains (NASDAQ OMX's News Release Distribution Channel, 2020). According to Laksham (2019), the success of drones in the fields of ecology and environment alludes the believe that they can also be used in the field of Public Health as medical couriers. The motivation for medical drones has to do with the fact that they can provide precision delivery with an efficient cost perspective than conventional delivery systems (Kitonsa and Kruglikov, 2018). In emergency medicine, evidence showed that the use of drones proves to be safe and feasible for delivering an automated external defibrillator (AED) for out-of-hospital cardiac arrests (OHCA) in areas identified using GIS (Geographic Information System) models (Claesson et al., 2016).

2.3. Military drones

The drone technology history is one that can be traced far back to World War I and II, and the development has changed over these periods to how modern Western War is wage (Kindervater, 2016). In the military, drones have the potential to reduce costs and risks to personnel as they are/or can be used in lethal surveillance and targeted killings compared to using manned aircraft (Bousquet, 2018; Hunt, 2017). Drones used in lethal surveillance are directly linked to targeted killings with merging mechanisms for making decisions on life and death (Kindervater, 2016).

Artificial intelligence (AI) plays a key role in military drones which has made such drones able to differentiate between civilians and the targets (De Swarte et al., 2019). The discourse is on the ability of the AI machines to be able to execute tasks with ethical considerations. Cummings (2017) states that "*The debate, which has many dimensions and stakeholders, concerns whether artificially intelligent machines should be allowed to execute such military missions, especially if there is a possibility that any human life could be at stake*" (p. 2). There is a growing interest in drone technology across critical scholarships and security studies that seeks to place the drone within a wider set of practices (Kindervater, 2016).

3. Methodology

Articles and related literature were searched through Scopus, PubMed, Web of Science, ScienceDirect and Google to carry out the SWOT analysis of drones in the specified domains. Also, we adopted the snowball technique (Jalali and Wohlin, 2012) in identifying other relevant literature, and cross references were done. For each aspect of the analysis (the strengths, weaknesses, opportunities, and threats), we defined appropriate keywords in our search and optimized the keywords iteratively depending on the database.

4. SWOT analysis

SWOT is an acronym for Strengths, Weaknesses, Opportunities, and Threats. This review from this section would analyse drones according to their SWOT in the agriculture, medical and military domains.

4.1. Strengths

4.1.1. Agricultural drones

Agricultural drones are providing real-time data that enables farmers to make informed decisions regarding the use of farm inputs. Micro-drones have the potential to further improve and enrich the data collected by operating close to the crops, enabling the collection of higher Spatio-temporal resolution data (Anthony et al., 2014). Drone imagery can be used to give an accurate estimate of loss. The study of Michez et al. (2016) describes a drone as a potential tool for estimating more accurately the wildlife damage to crops and subsequently, the compensation costs for that.

According to Stehr (2015), drones have better image resolution than aerial images of a field from satellite or manned aircraft, and they have the advantage of being able to monitor a field every week throughout the growing season than satellite which has a week or two delays before the images are available. The use of drone technology in agriculture is currently helping agricultural businesses meet the changing and growing demands of the future, whereby drones helps to increase efficiency in certain aspects of the farming process, from crop monitoring to planting, livestock management, crop spraying, irrigation mapping, and more (Africa Surveyors News, 2020). Drones have different features that make them unique to be applied in agriculture, specifically how they assist farmers in maximizing their harvest by detecting problems early and managing the crops by using specific cameras to detect pests and water shortages (Reinecke and Prinsloo, 2017).

4.1.2. Medical drones

The use of drones during Covid-19 pandemic helped to reduce the virus infections spread as they are used to deliver automated external defibrillators (AEDs) and personal protective equipment (gloves, facemasks, etc.) to emergency scenes and health facilities in some countries (van Veelen et al., 2020). At times, doctors require blood samples to complete medical diagnosis. Under such circumstances, the drone is the option as it can deliver faster than the usual transportation by road which could take longer time (Sachan, 2016). In Africa, drones have come to bridge the transportation gap during health in emergencies such as anaemia caused by malaria or pregnancy-related complications (Ling and Draghic, 2019). Example of drones helping saving lives in Africa is the used of Zipline's drone to deliver blood to health facilities in Rwanda (Ackerman and Strickland, 2018). In developing countries, drones along with mobile technology, are enabling these countries to leapfrog ahead with healthcare delivery to remote locations even with an unreliable road infrastructure (Scott and Scott, 2017).

4.1.3. Military drones

The move towards drones in the military is driven by cost, less risk of losing personnel and reduction of military budget (McLean, 2014). This makes sense in that, drone pilots cannot be shot down, captured, or tortured (Warrior, 2015). Security of every nation is at the heart of governments and could mean, spending millions of US dollars in securing a nation's security is paramount. Land-border security is currently an important aspect where drones are used to help check illegal activities and more (Shishkov et al., 2017; Yaacoub and Salman, 2020).

It is the military demand for drone use that has led to the spread of the drone technology into civilian context specially in the sectors of agriculture, medical, and transportation (Vacca and Onishi, 2017). The concept of delivering precision-guided weapons with drones in the military has also been adopted or extended to support humanitarian missions such as earthquakes and other natural disasters like flood (Mendoza et al., 2021; Yaacoub and Salman, 2020).

4.2. Weaknesses

4.2.1. Agricultural drones

Flying a drone is a skill and regulators requires trained and certified individuals to operate a drone. Using agricultural drones is not an exemption and would therefore mean loss of jobs for manual labourers for some farmers. However, this could also mean, employing new workers and training them to operate the drones (Laksham, 2019).

Another weakness of a drone is the payload and the range of flights. The payload of a drone varies between 2 and 4 kg, and a drone's components during flights can fail to result in a crash that may harm people or damage property (Clarke and Moses, 2014; Scott and Scott, 2017). Mitigating this weakness requires many improvements are made on drones to integrate improved battery technology, GPS and customizable apps for smartphones and tablets which in turns would improve flight durations, reliability, ease of use and the ability to better utilize cameras and other sensors needed for applications in agriculture and natural resources (Hogan et al., 2017).

4.2.2. Medical drones

Akin agricultural drones, medical drones are subject to loss of jobs for delivery personnel of medical supplies to health facilities and during health emergencies by road. However, this could also mean employing new workers and training them to operate the drones to handle the deliveries (Laksham, 2019).

In developing countries especially in Africa, medical drones have been successfully implemented and integrated into the medical delivery systems, but there are contentions about the initial cost involved in rolling out drones for delivery in the medical domain (Haidari et al., 2016; Pulver et al., 2016; Robakowska et al., 2019). The evolution of drones in recent years has become increasingly efficient for many fields especially in the medical field, yet drones are constraint by some technical characteristics. In terms of payload, current drones can carry packages of reduced weights and size (Euchi, 2020). There is a school of thought that though drones demonstrate effectiveness and reliability, it does not account for patient psychology. Hence exposing patients to an environment where drones are flying about can compromise their safety and security (Balasingam, 2017).

Again, regulation is a hurdle in acquiring legal permission to fly a medical or agricultural drone with the aviation authorities (Laksham, 2019; Sachan, 2016). Solving the regulatory challenge could be by developing enabling drone policy frameworks that can be adopted to expedite individual countries' developing drone regulations (Ayamga et al., 2020).

4.2.3. Military drones

In like manner, the military concept of weaponizing drones for lethal operations has been extended to civilian use by individuals with bad intentions to achieve their malicious objectives (Yaacoub and Salman, 2020). It has been reported that, some of the unacceptable uses of drones in flying drugs, mobile phones, blades, knives etc. into prisons has increase investments by the UK police and prison service (Johnson et al., 2017). Though drones have their technical shortcomings, the considerable use of drones in both civilian and military is mimicked and reversed for malicious use (terrorist and criminal) (Yaacoub and Salman, 2020).

4.3. Opportunities

4.3.1. Agricultural drones

Agriculture is the fastest-growing field where drones are employed (Watkins et al., 2020). By providing products and services (Beninger and Robson, 2020), drone technology promises to foster innovations that will disrupt existing industries (Giones and Brem, 2017). Engaging the youth in agriculture is one of the promising opportunities that drone technology has provided, where youth could engage in drone service provisions to farmers in rural areas (Sylvester, 2018). The adoption of drones (smart technologies) by farmers promises to bring about precision agriculture (PA) where resources are used efficiently to help improve productivity. This PA is a modern approach for agricultural management that exploits cutting-edge technologies to monitor and optimize agricultural production processes (Trivelli et al., 2019).

4.3.2. Medical drones

The healthcare sector is another promising opportunity for aerial delivery of medical supplies by drones during health emergencies by reducing response time and are cost-effective compared to conventional transport systems (Fakhrulddin et al., 2019; Ling and Draghic, 2019; Laksham, 2019; Scott and Scott, 2017). Recent studies (Boutilier et al., 2017; Poljak and Šterbenc, 2020; Sanfridsson et al., 2019) have shown how drones are used to deliver medical supplies like blood, vaccines, laboratory test samples, human kidney, AEDs, anti-venom against snake bites, etc., and food to medical facilities. Drones can offer many opportunities. Not only can they ensure minimized human interaction to reduce the spread of the virus, but they can also be used to reach otherwise inaccessible areas. China, been the first country to face the wrath of the COVID-19, has made great use of drone technology to counter the COVID-19 outbreak (Chamola et al., 2020). Again, in September 2019, researchers from the National University of Ireland (NUI) were able to use a drone to deliver diabetes medication from Galway to a remote location in the Aran Islands. This was the first ever successful Beyond Visual Line of Sight (BVLOS) diabetes drone mission, and it showed the world how drones have the capability to carry medical supplies reliably (NUI, 2019). The WHO and the Centers for Disease Control and prevention (CDC) could not have put in a better way when they said digital technologies can play an essential role in improving public health response to the COVID-19 pandemic (WHO, 2020).

4.3.3. Military drones

Technology has played an instrumental part of globalization and being at the forefront of this disruptive change (Fox, 2020), military drones have played a crucial role in paving the way for many sectors adopting the technology. Since the demand for drones is increasing in the military (Vacca and Onishi, 2017), more opportunities of usage could be explored in varying fields to derive the manifold benefits of the drone technology.

4.4. Threats

4.4.1. General threats

Whether agricultural, medical, or military drones, they can fall in case of component failure on to people and properties causing enormous injuries and damages (Chung et al., 2017; Chow et al., 2016). A drone's system not properly secured during a flight can be hacked into by individuals with disruptive mindsets and may then weaponized the drones for terror attacks (Laksham, 2019).

Irresponsible drone owners have been a nuisance in cases related to accidents that interferes with emergency responders and on the flip side, celebrities and others are concerned that drones can spy on them (Scott and Scott, 2017). Drones can also interfere in controlled airspace causing confusions for manned aircraft (Laksham, 2019).

5. Conclusion and policy implications

The SWOT analysis presented above affirms the great opportunities of agricultural, medical, and military drones in the respective domains. Drones can be typically used to obtain real-time imagery and sensor data from farm fields, giving farmers the ability to make informed decisions regarding farm inputs. They can also be used to transport medical supplies to remote areas and especially when the topography of the road infrastructure is not favouring conventional transportation by car. Aerial drones are technological tools that can enable medical personnel to perform their task more efficiently, effectively, and ultimately save more lives. The military can also use drones in their dealings while ethically mindful of civilians' lives. Research and development (R&D) are every crucial in advancing the drone technology which could help mitigate or minimize the weaknesses and threats of using drones in the specified fields. To utilise the full potential of the drone technology, enabling regulations are needed across the globe. Users and potential users could be made aware of existing regulations which can help curb unauthorized usage. Further studies are needed on integrating drones into existing transport systems and supply chains, including extending payload and flight durations, and considering cultural underpinnings into which drones can easily be accepted and adopted for use in developing countries.

Authors' Contributions

Conception and design of study: MA; literature review: MA, SA and AAN; Drafting the manuscript: MA, SA and AAN; revising the manuscript critically for important intellectual content; MA, SA and AAN. All authors have read and approved the final manuscript.

Funding

There is no funding to declare.

References

Ackerman, E., Strickland, E., 2018. Medical delivery drones take flight in east Africa. IEEE Spectr. 55 (1), 34–35.

Africa Surveyors News, (July 21, 2020). AGRICULTURAL DRONES: why a modern farmer needs a drone. [Internet] [cited on 15/01/2021] Available from https://www.africasurveyorsonline.com/2020/07/21/agricultural-drones-why-a-modern-farmer-needs-a-drone/.

Anthony, D., Elbaum, S., Lorenz, A., Detweiler, C., 2014. On crop height estimation with UAVs. In: Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2014). IEEE, pp. 4805–4812.

Ayamga, Matthew, Tekinerdogan, Bedir, Kassahun, Ayalew, 2021. Exploring the Challenges Posed by Regulations for the Use of Drones in Agriculture in the African Context. Land 10 (2), 164. https://doi.org/10.3390/land10020164.

Ayamga, M., Tekinerdogan, B., Kassahun, A., Rambaldi, G., 2020. Developing a policy framework for adoption and management of drones for agriculture in Africa. Technol. Anal. Strateg. Manag. 1–18. https://doi.org/10.1080/09537325.2020.1858047.

Balasingam, M., 2017. Drones in medicine—the rise of the machines. Int. J. Clin. Pract. 71 (9), e12989.

Beninger, S., Robson, K., 2020. The disruptive potential of drones. Mark. Lett. 31, 315–319. https://doi.org/10.1007/s11002-020-09542-8.

Bousquet, A., 2018. The Eye of War: Military Perception From the Telescope to the Drone. U of Minnesota Press.

... Boutilier, J.J., Brooks, S.C., Janmohamed, A., Byers, A., Buick, J.E., Zhan, C., Chan, T. C., 2017. Optimizing a drone network to deliver automated external defibrillators Circulation 135 (25), 2454–2465.

Chamola, V, Hassija, V, Gupta, V, Guizani, M, 2020. A comprehensive review of the COVID-19 pandemic and the role of IoT, drones, AI, blockchain, and 5G in managing its impact. Ieee access 8, 90225–90265.

Chow, E., Cuadra, A., Whitlock, C., 2016. Hazard Above: Drone Crash Database. Fallen From the Skies. Washington Post. Available from: https://www.washingtonpost.com/graphics/national/drone-crashes/database/.

Chung, L.K., Cheung, Y., Lagman, C., Yong, N.A., McBride, D.Q., Yang, I., 2017. Skull fracture with effacement of the superior sagittal sinus following drone impact: a case report. Child's Nerv. Syst. 33 (9), 1609–1611.

... Claesson, A., Fredman, D., Svensson, L., Ringh, M., Hollenberg, J., Nordberg, P., Ban, Y., 2016. Unmanned aerial vehicles (drones) in out-of-hospital-cardiac-arrest Scand. J. Trauma Resusc. Emerg. Med. 24 (1), 1–9.

Clarke, R., Moses, L.B., 2014. The regulation of civilian drones' impacts on public safety. Comput. Law Secur. Rev. 30 (3), 263–285. https://doi.org/10.1016/j.clsr.2014.03.007.

Clothier, R.A., Greer, D.A., Greer, D.G., Mehta, A.M., 2015. Risk perception and the public acceptance of drones. Risk Anal. 35 (6), 1167–1183.

Cummings, M., 2017. Artificial Intelligence and the Future of Warfare. Chatham House for the Royal Institute of International Affairs, London.

De Swarte, T., Boufous, O., Escalle, P., 2019. Artificial intelligence, ethics and human values: the cases of military drones and companion robots. Artif. Life Robot. 24 (3), 291–296.

El Bilali, H., Bottalico, F., Palmisano, G.O., Capone, R., 2019. Information and communication technologies for smart and sustainable agriculture. Scientific-Experts Conference of Agriculture and Food Industry. Springer, Cham, pp. 321–334.

Euchi, J., 2020. Do drones have a realistic place in a pandemic fight for delivering medical supplies in healthcare systems problems. Chin. J. Aeronaut.

Fakhrulddin, S.S., Gharghan, S.K., Al-Naji, A., Chahl, J., 2019. An advanced first aid system based on an unmanned aerial vehicles and a wireless body area sensor network for elderly persons in outdoor environments. Sensors 19 (13), 2955.

Fox, S.J., 2020. The 'risk'of disruptive technology today (a case study of aviation–enter the drone). Technol. Soc. 62, 101304.

Gharibi, M., Boutaba, R., Waslander, S.L., 2016. Internet of drones. IEEE Access 4, 1148–1162.

Giones, F., Brem, A., 2017. From toys to tools: the co-evolution of technological and entrepreneurial developments in the drone industry. Bus. Horiz. 60 (6), 875–884. https://doi.org/10.1016/j.bushor.2017.08.001.

Greenwood, F. (2016). Drones on the horizon: new frontier in agricultural innovation.

... Haghighattalab, A., Pérez, L.G., Mondal, S., Singh, D., Schinstock, D., Rutkoski, J., Poland, J., 2016. Application of unmanned aerial systems for high throughput phenotyping of large wheat breeding nurseries Plant Methods 12 (1), 35.

... Haidari, L.A., Brown, S.T., Ferguson, M., Bancroft, E., Spiker, M., Wilcox, A., Lee, B.Y., 2016. The economic and operational value of using drones to transport vaccines Vaccine 34 (34), 4062–4067.

Hedley, C., 2015. The role of precision agriculture for improved nutrient management on farms. J. Sci. Food Agric. 95 (1), 12–19.

Hogan, S., Kelly, M., Stark, B., Chen, Y., 2017. Unmanned aerial systems for agriculture and natural resources. Calif. Agric. Berkel. 71 (1), 5–14.

Hunt, K.B., 2017. Targeted Killings of 'Suspected' Terrorists Carried Out by US Drones–An Analysis of the Applicability of International Humanitarian Law (Master's Thesis).

ICAO, Doc. 2015. 10019, "Manual on Remotely Piloted Aircraft Systems (RPAS)" 2015. http://store.icao.int/products/manual-on-remotely-piloted-aircraft-systems-rpas-

doc-10019.ICAO. 2011. Cir '328 AN/190', Unmanned Aircraft Systems (UAS) Circular.
Jalali, S., Wohlin, C., 2012. Systematic literature studies: database searches vs. backward snowballing. In: Proceedings of the ACM-IEEE International Symposium on Empirical Software Engineering and Measurement. IEEE, pp. 29–38.
... Johnson, L.K., Dorn, A.W., Webb, S., Kreps, S., Krieger, W., Schwarz, E., Wirtz, J.J., 2017. An INS special forum: intelligence and drones/Eyes in the sky for peacekeeping: the emergence of UAVs in UN operations/the democratic deficit on drones/the German approach to drone warfare/pursuing peace: the strategic limits of drone warfare/seeing but unseen: intelligence drones in israel/drone paramilitary operations against suspected global terrorists: US and Australian perspectives/The 'Terminator Conundrum'and the future of drone warfare Intell. Natl. Secur. 32 (4), 411–440.
Kellermann, R., Biehle, T., Fischer, L., 2020. Drones for parcel and passenger transportation: a literature review. Transp. Res. Interdiscip. Perspect. 4, 100088.
Kim, H.G., Park, J.S., Lee, D.H., 2018. Potential of unmanned aerial sampling for monitoring insect populations in rice fields. Florida Entomol. 101 (2), 330–334.
Kindervater, K.H., 2016. The emergence of lethal surveillance: watching and killing in the history of drone technology. Secur. Dialog. 47 (3), 223–238.
Kitonsa, H., Kruglikov, S.V., 2018. Significance of drone technology for achievement of the United Nations sustainable development goals. R Econ. 4 (3), 115–120. Vol. 4. Iss. 3.
Laksham, K.B., 2019. Unmanned aerial vehicle (drones) in public health: a SWOT analysis. J. Fam. Med. Prim. Care 8 (2), 342.
Ling, G., Draghic, N., 2019. Aerial drones for blood delivery. Transfusion 59 (S2), 1608–1611.
Malveaux, C., Hall, S.G., Price, R., 2014. Using drones in agriculture: unmanned aerial systems for agricultural remote sensing applications. 2014 Montreal. American Society of Agricultural and Biological Engineers, Quebec Canada, p. 1. July 13–July 16, 2014.
McCall, B. (2019). Sub-Saharan Africa leads the way in medical drones.
McLean, W., 2014. Drones are Cheap, Soldiers are Not: A Cost-Benefit Analysis of War. The Conversation US, Inc, p. 25.
Mendoza, M.A., Rodriguez Alfonso, M., Lhuillery, S., 2021. A battle of drones: utilizing legitimacy strategies for the transfer and diffusion of dual-use technologies. Technol. Forecast. Soc. Change 166, 120539. https://doi.org/10.1016/j.techfore.2020.120539.
Michez, A., Morelle, K., Lehaire, F., Widar, J., Authelet, M., Vermeulen, C., Lejeune, P., 2016. Use of unmanned aerial system to assess wildlife (Sus scrofa) damage to crops (Zea mays). J. Unmann. Veh. Syst. 4 (4), 266–275.
NASDAQ OMX's News Release Distribution Channel (2020). 'Drone package delivery market to hit USD 7,388.2 million by 2027; diverse entities such as amazon and FedEx to explore wider delivery applications of drones, states fortune business insights™: top companies covered in the drone package delivery market are DroneScan (south africa), cheetah logistics technology (US), flytrex (israel), flirtey (US), matternet, inc. (US), boeing (US), amazon inc. (US), wing aviation LLC (US), workhorse group inc. (US), drone delivery canada corp. (canada), zipline (US), DHL international GmbH (germany), united parcel service of america, inc. (US), FedEx (US), and more players profiled'. Retrieved from https://search-proquest-com.ezproxy.library.wur.nl/wire-feeds/drone-package-delivery-market-hit-usd-7-388-2/docview/2465400967/se-2?accountid=27871.
Nelson, J., Gorichanaz, T., 2019. Trust as an ethical value in emerging technology governance: the case of drone regulation. Technol. Soc. 59, 101131 https://doi.org/10.1016/j.techsoc.2019.04.007.
Poljak, M., Šterbenc, A., 2020. Use of drones in clinical microbiology and infectious diseases: current status, challenges and barriers. Clin. Microbiol. Infect. 26 (4), 425–430.
Pulver, A., Wei, R., Mann, C., 2016. Locating AED enabled medical drones to enhance cardiac arrest response times. Prehosp. Emerg. Care 20 (3), 378–389.
Ramadass, L., Arunachalam, S., Sagayasree, Z., 2020. Applying deep learning algorithm to maintain social distance in public place through drone technology. Int. J. Perv. Comput. Commun.
Reinecke, M., Prinsloo, T., 2017. The influence of drone monitoring on crop health and harvest size. In: Proceedings of the 1st International Conference on Next Generation Computing Applications (NextComp). IEEE, pp. 5–10.
... Robakowska, M., Ślęzak, D., Tyrańska-Fobke, A., Nowak, J., Robakowski, P., Żuratyński, P., Nadolny, K., 2019. Operational and financial considerations of using drones for medical support of mass events in Poland Disaster Med. Public Health Prep. 13 (3), 527–532.
Sachan, D., 2016. The age of drones: what might it mean for health? Lancet 387 (10030), 1803–1804.
... Sanfridsson, J., Sparrevik, J., Hollenberg, J., Nordberg, P., Djärv, T., Ringh, M., Claesson, A., 2019. Drone delivery of an automated external defibrillator–a mixed method simulation study of bystander experience Scand. J. Trauma Resusc. Emerg. Med. 27 (1), 1–9.
Scott, J., Scott, C., 2017. Drone delivery models for healthcare. In: Proceedings of the 50th Hawaii International Conference on System Sciences.
Shishkov, B., Hristozov, S., Janssen, M., van den Hoven, J., 2017. Drones in land border missions: benefits and accountability concerns. In: Proceedings of the 6th International Conference on Telecommunications and Remote Sensing, pp. 77–86.
Stehr, N.J., 2015. Drones: the newest technology for precision agriculture. Nat. Sci. Educ. 44 (1), 89–91.
Sylvester, G., 2018. E-Agriculture in Action: Drones for Agriculture. Food and Agriculture Organization of the United Nations and International Telecommunication Union, Bangkok.
Trivelli, L., Apicella, A., Chiarello, F., Rana, R., Fantoni, G., Tarabella, A., 2019. From precision agriculture to Industry 4.0. Br. Food J.
Vacca, A., Onishi, H., 2017. Drones: military weapons, surveillance or mapping tools for environmental monitoring? The need for legal framework is required. Transp. Res. Procedia 25, 51–62.
van Veelen, M.J., Kaufmann, M., Brugger, H., Strapazzon, G., 2020. Drone delivery of AED's and personal protective equipment in the era of SARS-CoV-2. Resuscitation 152, 1–2.
Wallace, R.J., Loffi, J.M., Vance, S.M., Jacob, J., Dunlap, J.C., Mitchell, T.A., 2018. Pilot visual detection of small unmanned aircraft systems (sUAS) equipped with strobe lighting. J. Aviat. Technol. Eng. 7 (2), 5.
Warrior, L.C., 2015. Drones and targeted killing: costs, accountability, and US civil-military relations. Orbis 59 (1), 95–110.
... Watkins, S., Burry, J., Mohamed, A., Marino, M., Prudden, S., Fisher, A., Clothier, R., 2020. Ten questions concerning the use of drones in urban environments Build. Environ. 167, 106458 https://doi.org/10.1016/j.buildenv.2019.106458.
Yaacoub, J.P., Salman, O., 2020. Security analysis of drones systems: attacks, limitations, and recommendations. Internet Things, 100218.
Zhang, C., Kovacs, J.M., 2012. The application of small unmanned aerial systems for precision agriculture: a review. Precis. Agric. 13 (6), 693–712.
https://www.ehealthireland.ie/News-Media/News-Archive/2019/A-World-First-as-Drone-delivers-medication-to-the-Aran-Islands.html#:~:text=Monday%2C%2016%20September%2C%202019%3A,Connemara%20Airport%20and%20Inis%20M%C3%B3r%2C. (Accessed 29 January 2021).
https://www.who.int/news/item/03-04-2020-digital-technology-for-covid-19-response. (Accessed 29 January 2021).

Matthew Ayamga (MSc) is a PhD candidate at the Business Management and Organization (BMO) Chair Group and the Information Technology Chair Group of Wageningen University and Research in the Netherlands. He holds MSc degree in Management, Economics and Consumer studies from the Information Technology Group at Wageningen University and Research, The Netherlands. Matthew received his BSc degree in Actuarial Science from the University for Development Students in Ghana. From 2015 to 2017, he worked as a market and research officer for Dumong's System; a software development company in Ghana. He can be reached through E-mail: matthew.ayamga@wur.nl or ayamgmatthew@gmail.com, Phone: +31 622724914

Selorm Akaba (PhD) is a lecturer in Digital Agri-food Systems and Agricultural Economics at the University of Cape Coast in Ghana. He has his PhD and MPhil in Agricultural Economics, and BSc in Agriculture, all from the University of Cape Coast in Ghana. He holds an Advanced Certificate in Peace and Development Studies from Cuttington University, Liberia, and a Postgraduate Diploma in Project Management from Maastricht School of Management in The Netherlands. He is a trained drone pilot and coordinates Unmanned Aerial Systems for Sustainable Agriculture Projects. He was co-principal investigator for socio-economic and efficacy study on using drones for controlling fall armyworm. He is currently the lead consultant for capacity building project on Improving Productivity and Biosafety of Vegetable Farmer Associations at Baifikrom-Mankesim Irrigation Scheme, Central Region, Ghana. His current research focuses on Food and Nutrition Security, UAS and Digital Sensors for transforming Agri-Food Systems, Agriculture and Food Systems Sustainability, Adaptive Capacity and Climate Change, and Rural and Agricultural Development. He can be reached on Phone: +233 505 401 918 or +233 54 993 4948; Email: sakaba@ucc.edu.gh

Albert Apotele Nyaaba (M. Phil) is a public health and development practitioner. He is currently implementing child protection project funded by Global Affairs Canada through UNICEF with Youth Harvest Foundation Ghana, a Non-Governmental Organization, NGO as the project officer. He is largely engaged in intervention design, project implementation, proposal writing and research work. He holds M.Phil. in Population and Health from University of Cape Coast in Ghana, Dip in Education from University of Education Winneba and, Bsc. Community Nutrition from University for Development Studies in Ghana. He is also a certified Project management professional. He can be reached through albertnyaaba13@yahoo.com and +233245992602.