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Drones in Agriculture: Current and future legal status in Germany, the EU, the USA and Japan

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Agriculture promises diverse and attractive uses for drones. However, farmers and service providers are often unaware of the legal situation in their new traffic space - “air”. What restrictions arise from current law and thus possibly block usage scenarios? What developments are to be expected from a legal perspective and which opportunities/risks may emerge in the future? The legal regulations in Germany, the EU, the USA and Japan are considered. Starting from the status quo of agricultural drone use, international legislation will be compared and an outlook on the future role of drones in agriculture will be presented.

Key words
UAV, UAS, drone, Precision Farming, Smart Farming, law, legislation

For many, the term “drone” is associated with modern weaponry that is used worldwide in military conflicts (Ahmad 2018, Wirtschaftswoche 2018, Geo TV 2018, AP 2017, AFP 2014). Drones are mainly used not only for reconnaissance and observation, but also for targeted air strikes, and are remotely controlled from field quarters. This scenario of an increasing anonymisation of war by the videogame-like control of weapons of war stigmatises the term socially. For the past few years, however, drones seem to trigger increasingly positive associations. The reason for this is the rapid increase in civilian use of unmanned aerial technology and the positive reporting on it. Drones have long been used, for example, in civil defence and the film industry, and also in the private sector for leisure by hobbyists (Longwell 2017, Giardina 2016). Views of a future in which, for example, drones distribute parcels fascinate society and conveys a high benefit and added value of the technology (Desjardings 2018, Donath 2016).

There are already some commercial agricultural applications of drones in Germany. For example, they are used in advance of meadow mowing to protect young game (e.g., for fawn identification) (Bauerdick 2016), in the determination of yield losses (e.g., damage by wild boars) (Allbach und Leiner 2016) or in the distribution of beneficial insects among crops (FarmFacts GmbH n.d.). Drones are also often associated with smart or precision farming. The combination of ground- and satellite-based applications enables site-specific (possibly punctual) processing, mapping and documentation of agricultural land. A certain amount of autonomy and non-invasive aerial surveillance also expands the time slot for actions, because the soil does not have to be travelled.

The history of drone use in agriculture is different in each country. Japan, where commercial drone technology has been on the market since the late 1970s, can be described as the motherland of agricultural drone use, e.g., for the application of PPP (plant protection products, pesticides) (Scherer et al. 2017). Additionally, the small-scale land use in Japan has a positive effect. Due to poorly

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accessible terrain and the extensive use of manual labour, the potential for increasing output in agricultural production is high (Scherer et al. 2017), but the main current uses are still the application of PPP and sowing. For these reasons, the acceptance and use of drone technology in Japan is around 70% and thus far higher than in the USA, which is also very technology-friendly, at about 40% (Scherer et al. 2017). In the USA, agricultural land is large and structured and, due to the enormous land area, is usually located on easily accessible terrain. Drones have a cost advantage in imaging up to a field size of 20 hectares, but in larger fields it turns into the opposite (Figure 1).

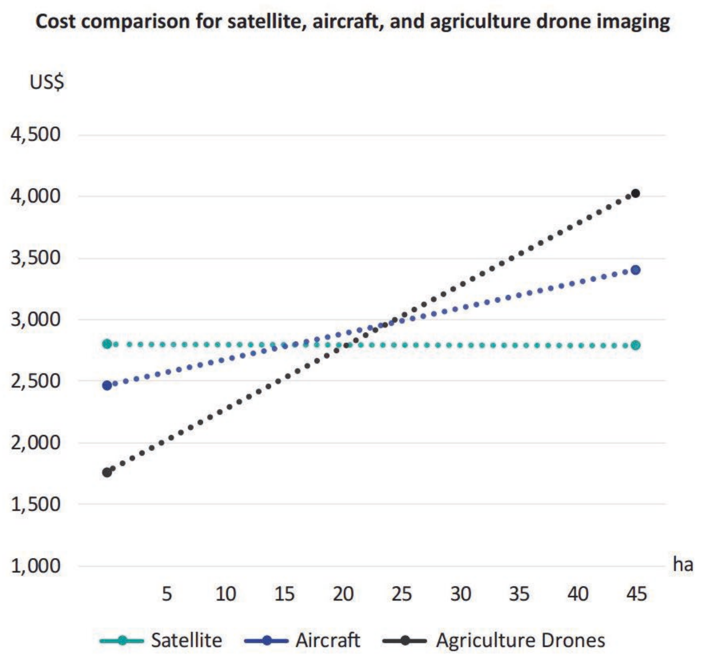

Figure 1: Cost comparison for satellite, aircraft and agriculture drone imaging (© Ipsos Business Consulting Analysis)

Consequently, predominantly “flying wing” drones, aircraft, or helicopters are used for the application of PPP in the USA. The output obtained from agriculture is already very high due to the use of machinery and drones are mainly used for mapping and obtaining information for precision farming applications. In other words, in the USA, drones are used in the context of precision agriculture farm management and to increase the quality of the harvest while maintaining or decreasing the input to production. In Japan, however, drone technology represents a solution to productivity challenges (Figure 2).

The EU is a conglomeration of small and large-scale land, plains and rough terrain. Viticulture, for example, comes close to Japanese rice cultivation in terms of drone requirements. In the large, parcelled countries of Eastern Europe, on the other hand, there is often large machine technology, like in the USA. Germany contains mainly small-scale, and few large-scale, cultivated areas, but it has an extensive high-tech agricultural economy that already produces very high yields. The focus here is more on resource-conservation and environmentally friendly land management. Drone use therefore promises all the above advantages for precision farming and environmental protection.

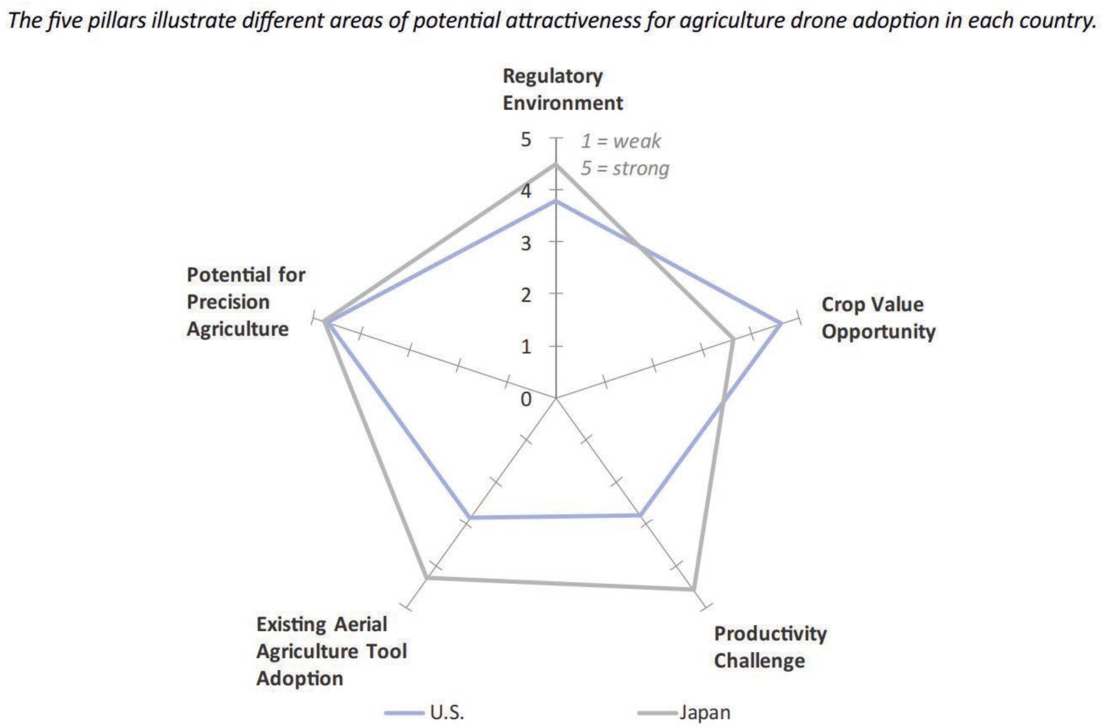

Figure 2: The network diagram illustrates five potential attractive uses for drones in agriculture and their manifestations in Japan and the USA. (© Ipsos Business Consulting Analysis)

Theoretical Background

Definitions

The term "drone" colloquially describes an unmanned aerial vehicle (Maekeler 2017). Additional internationally recognised designations are "unmanned aerial vehicle (UAV)," "Unmanned Aircraft System (UAS)," or "Unmanned Aircraft (UA)" (Bischof 2017).

Drones can reach the size of manned aircraft (Figure 3), such as the Boeing Condor (Yenne 2010). The Condor belongs to the group of "fixed-wing"-aircraft and exceeds the Boeing 747with its wingspan of 60.96 m. In most civilian applications, including agriculture, drones have the dimensions of standard model aircraft (Reinhard 2013) or are slightly larger, e.g., The Agronator® (Agronator AG, Fig. 3). The octocopter Agronator was specially designed for agricultural use and can already be equipped with a payload of 35 kg for the application of crop protection, seed and fertiliser (Koch 2017). The most common drones are called "rotorcraft" and are up to about 1 m in diameter and equipped with 4 to 8 propellers (also called multicopters). The term "multicopter" refers to the number of propellers and thus includes all types of rotorcraft with 2 or more propellers at the same level (Schröder 2017). The quadrocopter is the best-selling model for private use and is often used for video or photo shoots. Less common are "fixed-wing" aircraft, which generate lift by the air flow at the wings. Multicopters are usually slower than fixed-wing aircraft, due to the glide flight of fixed-wings, and have a shorter range for the same drive power (Tchouchenkov et al. 2012). However, the big advantage of multicopters is the VTOL principle (Vertical Take-Off and Landing). Unlike fixed-wing aircraft, no runways/ramps are necessary (Strickert 2016). Additionally, "floating" in the air can be a prerequisite for many applications, or may simplify them and, furthermore, multicopters can carry large payloads (Niemeyer 2014).

Figure 3: The "Condor" of Boeing (left, © Boeing); the Octocopter „Agronator"(centre, © RMB/Margielsky); the Quadrocopter (right, © M. Reger)

German Law

According to § 1 LuftVG (ger. "Luftverkehrsgesetz"; Air Traffic Act), drones are "Luftfahrzeuge" (ger.; aircraft), which entitles them to use airspace and places them on a legal level with larger aircraft (Maekeler 2017). Since the drone contributes to improving production, optimisation and yield in agricultural use, it is assigned to commercial use (BMVI 2016). Section 33 of the LuftVG provides for compulsory insurance requirement (liability insurance), but excludes drones of <0.25 kg (Maekeler 2017). Furthermore, in accordance with § 19 para. 3 LuftVZO (ger. "Luftverkehrs-Zulassungs-Ordnung"; Air Traffic Licensing Order) the owner of each UAV above 0.25 kg must label the aircraft with a permanent and fire-resistant inscription (name and address).

If the take-off mass of the UAV exceeds 2 kg, then the controller must provide proof of knowledge (colloquially also known as a "drone drivers's licence") according to § 21a para. 4 LuftVO, Luftverkehrs-Ordnung (ger. "Luftverkehrs-Ordnung"; Air Traffic Regulation). Acceptable proofs include a pilot's licence or a certificate demonstrating the passing an examination from a body recognised by the Luftfahrt-Bundesamt (ger.; Aviation Agency of Germany). An overview of facilities that have been licensed by the Luftfahrt-Bundesamt for the acquisition of proof of knowledge is given by Westphal (2017a). The certificate is valid for 5 years and requires that users have a minimum age of 16 years for commercial use.

If the UAV has a take-off mass of more than 5 kg and is operated at a distance of <1.5 km from the boundary of an airfield or at night, then ascent permission is required (§ 21a para. 1 no. 1, 2 and 3 LuftVO). The respective regional aeronautical authority ("Landesluftfahrtbehörde") issues the permit (§ 31 para. 2 no. 1 and 3 LuftVG). The UAV may only be launched and landed on a property with the landowner's consent (§ 25 para. 1 and 2 LuftVG). The form that this consent must take, whether oral or written, is not specified. Likewise, the transport of substances that are designated by law as dangerous goods (e.g., fertilisers and PPP) requires a licence from the regional aeronautical authority (§ 27 para. 1 LuftVG).

Basic operating prohibitions are (§ 21b LuftVO):

- Control out of the sight of the controller for UAVs under 5 kg
- Above or at a lateral distance of <100 m from sensitive areas
- Over nature reserves and national parks
- Over residential property for UAVs with a take-off mass of more than 0.25 kg or with video-enabled equipment and without permission from the landowner

- At altitudes above 100 m
- With video glasses (indirect view by the controller), except up to a maximum altitude of 30 m and a total mass of <0.25 kg or with another person who is constantly monitoring the device in sight
- With a take-off mass of more than 25 kg. For agricultural or forestry purposes, the competent authority may, upon application, allow exemptions from the prohibition
- Alcohol levels above 0.5 ‰ (Maekeler 2017)

The regional aeronautical authorities (federal states) can grant permits with the help of two types of procedures that allow exemptions from the basic operating prohibitions of § 21 LuftVO. In a "simplified procedure" permits may be granted on the basis of uniform provisions. The prerequisite is that the aircraft (< 25 kg) does not use combustion engines and is flown within the sight of the controller. Exceptions to the operating prohibitions are also possible, for example, regarding the distance to crowds of people (§ 21b para. 1 no. 2 option 1), trunk roads, federal waterways and railway facilities (§ 21b par. 1 no. 5), as well as residential land (§ 21b para. 1 no. 7) and for distances of <1.5 km from the boundary of airfields. Permits and approvals of exceptions are valid for a maximum of 2 years. The permission grants "in other cases" cover scenarios that do not occur in the "simplified procedure". They include operation out of sight with a take-off mass of greater than 5 kg, operation at night, take-off masses greater than 25 kg, or exceptions to the remaining operating prohibitions of § 21b para. 1 (e.g., altitude greater than 100 m). Following the European model, a risk-based approach is used to assess the safety of UAVs. The harmonised risk assessment specific operations risk assessment (SORA)-GER (National Operational Risk Assessment Germany) follows the SORA concept of JARUS (Joint Authorities for Rulemaking on Unmanned Systems; DFS 2017).

EU Law

Civil aviation in Europe is governed in the member states by a number of regulations and directives. As an EU member state, Germany is obliged to incorporate EU regulations and directives into national legislation. The underlying law for the establishment of common rules in civil aviation and the establishment of a European Aviation Safety Agency is set out by regulation (EC) No. 216/2008. "What is missing so far is a common European legal framework for the operation of unmanned aerial systems." (ADV 2016). Currently, the EASA (European Aviation Safety Agency) has the mandate for the regulation of drones, or so-called RPASs (Remotely Piloted Aircraft Systems), in civilian use (Juul 2015). To present, UAVs with a take-off mass of <150 kg have not been covered by the EU regulation and are therefore a matter for the member states (Europäisches Parlament 2016).

EASA developed initial proposals for a future European Drone Regulation in September 2015 (EASA 2015b) after being commissioned by the European Commission (EASA 2015a). In the next step towards a European Drone Regulation, EASA, the EU member states and industry partners have drafted EU-wide safety legislation (Schmidt 2017). On Nov. 28, 2017, negotiators from the EU Parliament, the Council of Ministers and the Commission reached an agreement on uniform requirements for civilian drones with the intent of further improving safe operation and data protection (Soone 2017). This negotiated regulation will not come to effect until it is formally endorsed by government representatives from the EU countries and Parliament's plenary (Krempl 2017). On 22 December 2017, Government members of the 28 EU Member States agreed with the European Parliament to revise the basic regulation (EC) No. 216/2008 and to extend the EU competences to the regulation of all UASs

(EASA 2018). The approval procedure is expected to be completed by spring 2018 (Europäischer Rat 2018).

EASA's concept intends to use the risk that people and assets are exposed to during a particular mission as a basis for categorising and approving drone missions (EASA 2015a). This takes into account the operation and the conditions under which a drone is used, and not just the characteristics of the drone. For example, in the A-NPA 2015-10 (Advance Notice of Proposed Amendment), EASA mentions the lesser risk of a large drone operating across the open sea compared to a small drone operating over spectators in a stadium. The categorization of drones takes place in three risk categories (EASA 2018; EASA 2015a):

- **"Open" Category (low risk)**
  A "minor" risk is represented by drone missions carried out under the pilot's direct vision, with a maximum take-off mass of <25 kg, at a maximum altitude of 120 m above ground or water and at a safe distance from uninvolved persons and objects on the ground. Competent authorities may issue flight bans of flight restrictions for certain areas. Compliance with these drone-free areas is to be achieved by automatic restriction of airspace (geofencing). If the altitude of the drone is more than 50 m, the pilot must demonstrate basic aeronautical awareness. (EASA 2018; EASA 2015b)
- **"Specific" Category (medium risk)**
  A classification into the "specific" category occurs when the UAV will fly over people or when it will share airspace with manned aircraft. The operator carries out the risk assessment and must obtain a permit from a national aviation authority.
- **"Certified" Category (high risk)**
  Drone missions of the "certified" category are at increased risk but have not been further specified. The requirements are comparable to those of manned aviation.

As the two main types of risk "air risks" and "ground risks" were highlighted. These two types of risk give rise to the main risk areas: air conflicts (collisions), aircraft disruptions and failures of other systems. The risk category again reflects these risk areas. For example, in the "open" category, air conflicts can be prevented by [1] flight altitude limitation, [2] control in the visual line-of-sight (VLOS), [3] the aviation skills of the controller, or [4] the establishment of no-fly zones. A risk assessment is required for drone missions of the "specific" category. This "SORA follows the methodology/concept of JARUS. Furthermore, damage-reducing security measures can be used that reduce the risk from the assessment. The competent authority (Landesluftfahrtbehörde) evaluates the risk assessment, including risk-mitigating measures, and issues the permit if merited. In order to minimise the administrative burden for both the competent authorities and the UAV operator, the use of standard scenarios or a light UAS operator certificate (LUC) has been proposed. A standard scenario already contains a risk assessment with associated risk-mitigating measures, which speeds up completion. The LUC grants the UAV operator certain privileges and allows him to independently grant permission for drone missions. (EASA 2018)

The application of pesticides with aircrafts (manned or unmanned) is generally prohibited in the European Union, since the drift of pesticides can have significant adverse effects on human health as well as the environment. Exemptions are possible if clear benefits for human health or the environment can be demonstrated or if there are no viable alternatives (2009/128/EC).

US American Law

The Federal Aviation Administration (FAA) is part of the U.S. Department of Transportation. It is responsible for both UAV regulation and its enforcement through warnings and civil penalties (Public Law 112-95).

Each aircraft must have an airworthiness certificate as well as a registration certificate (Title 14 § 91.203 CFR, Code of Federal Regulations). These are classified into three categories based on use:

- **"Public Entity"**
  Inclusion in the category "Public Entity" is delineated by the United States Code (USC) in Section 40102 of title 49. This category is reserved for UAVs used by or for public/government entities.
- **"Recreational/Hobbyist"**
  The FAA gives an example of the distinction between the "Recreational" category and the "Commercial" category with a direct agricultural reference:

Hobby or Recreation	***Not Hobby or Recreation***
Viewing a field to determine whether crops need water when they are grown for personal enjoyment.	*Determining whether crops need to be watered that are grown as part of commercial farming operation*

- **"Commercial/Business"**
  Drones that are used in agriculture are always assigned to the "Commercial/Business" category in the USA because of the above definitions. A drone in this category is also referred to as a "sUAS" (small UAS). The use and certification claims in this category are governed by Section 107 title 14 of the Code of Federal Regulations (CFR). For example, a sUAS must have a take-off mass of <25 kg and always be flown in the VLOS of the controller. In addition, only flights in daylight are allowed.

The operator of such a sUAS must be the owner of a "remote pilot certificate" or be supported by a person who has such a certificate and is ready to intervene. A person may acquire a "remote pilot certificate" if, among other things, he fulfils the following requirements (§ 107.65 title 14 CFR):

- Minimum age of 16 years
- English speaking (reading, writing, speaking and comprehension)
- Has passed an "aeronautical knowledge test" or has a pilot's licence

The "aeronautical knowledge test" must have been passed within the previous 24 calendar months. This results in the requirement for a periodical "refresher" of aviation knowledge every 2 years.
There are also operating bans for sUASs in the USA (107.51 title 14 CFR):

- Maximum airspeed of 100 mph (ca. 161 km/h)
- Maximum altitude of 400 ft (ca. 122 m)
- Maximum distance visibility of 3 miles (ca. 4,8 km)
- Minimum distance from clouds: vertical 500 ft (ca. 152 m) and horizontal 2,000 ft (ca. 610 m)

Japanese Law

The Civil Aviation Bureau (koukuu kyoku) is a division of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and is responsible for the regulation of civil aviation, which is governed by the Civil Aeronautics Act (koukuu hou) (Hayashi 2017). On December 12th of 2015 an adaptation of the Aviation Act that regulates UAVs came into force (MLIT 2017). On March 18th of 2016 no-fly zones have been added to the law, e.g., over state institutions and government buildings.

Japanese legislation does not distinguish between the recreational or commercial use of drones. The maximum altitude is 150 m and the maximum flight distance is limited only by the need for the VLOS; this means that flying is permissible as long as the drone is visible to the controller without the use of aids (except for glasses/contact lenses). Additionally, there are no restrictions with regard to take-off weight. A licence or proof of knowledge is unnecessary and drone labelling and compulsory insurance is only recommended but not required. Manned aircraft must be avoided. (Frey 2017)

The prefectures and local authorities in Japan may declare areas to be no-fly zones, such as city parks in the metropolitan area of Tokyo (Drone Law Japan o. J. a). For flights in the following airspaces (Prohibited Airspaces for Flight), drone pilots require a licence from the MLIT (MLIT 2017):

- At an altitude of over 150 m
- In the airspace of airports
- Over densely populated districts

A densely populated area is one whose population density exceeds 5,000 inhabitans per km^2 (Hayashi 2017). For comparison, the population density in Munich varies from 1.128 inhabitants per km^2 in the district of Aubing-Lochhausen to 15,270 inhabitants per km^2 in the district of Schwabing-West (Lenders 2013).

Similar to Germany and the USA, there are also operational limitations in Japan. Drone flights may only take place during the day and within the direct view of the pilot. It is forbidden to drop objects from the drone, to carry dangerous substances, or to fly over people or objects on the ground or on water surfaces (MLIT 2017).

The requirements for prohibited airspaces and the operational limitations do not apply for search and rescue operations by public organisations during accidents or disasters (MLIT 2017).

Drone pilots can also fly in prohibited airspaces or deviate from the requirements of operational limitations with the approval of the MLIT. The controller of the drone must apply for a permit from the MLIT 10 days in advance to a planned drone flight. (Hayashi 2017)

Results and Discussion – Consequences for Agriculture

Depending on the type of drone deployment, different hardware configurations are required. The weight and dimensions of a drone vary with design, attachments and payload. For example, if a drone is used for damage detection or the rescue of game, small dimensions and weights are possible. The sensors used (RGB and thermal imaging camera, infrared sensors, etc.) are light and compact. That means that the MTOW (Maximum Take-Off Weight) of the drone can also be <2 kg and therefore no ascent permission is required. In contrast, in order to carry out tasks with the drone, inputs (fertilisers, seeds, PPP) are usually loaded and distribution system is attached. To achieve a reasonable work rate, a certain input storage capacity of the drone is necessary. With its payload of 35 kg, the Agronator drone has a total weight of 110 kg, but in the USA and Germany a drone's MTOW is limited to 25 kg. In Germany, however, an exception is possible if the operation has agricultural or forestry purposes, according to § 21b para. 2 no. 2 LuftVO. Additionally, in the USA it can be assumed that an (individual) approval will be granted, while in Japan there is no legally prescribed MTOW.

Above the 5 kg limit in Germany, an ascent permission must be obtained from the regional aeronautical authorities of the federal states. This permission is issued by the respective federal state itself and is not, in principle, valid nationwide. The required documents, the responsibilities of authorities, the duration of validity and the approval processes may vary depending on the state. Further administrative structuring regarding responsibilities (e.g., regional councils), subdivision of weight classes and the costs of the approval procedure may vary. On October the 27th 2017 the Deutsche Flugsicherung (DFS, air traffic control) announced in the Nachricht für Luftfahrer 1-1163-17 (notice to airmen) common principles for the issuing of permits and the granting of exceptions to the operation of UAVs (DFS 2017). The establishment of a standard should facilitate the acceptance and recognition of granted permits between the regional aeronautical authorities of the federal states. Transnational activity for commercial drone users has so far meant a higher bureaucratic and financial burden (Westphal 2017b).

The European Union presents another legal "patchwork". Hitherto it has been up to the member states themselves to legislate drones with a MTOW of up to 150 kg. Legislation in member states with specific reference to the use of drones usually differs greatly in terms of the limits for certain thresholds or the classification of airspaces. Additionally, some member states do not yet have any specific regulations for drones or are currently revising them. In Hungary, specific legislation is still being worked on and current applications are granted individually (Markert 2018). In a first restrictive decree, Slovenia has banned the commercial and scientific use of drones until a revised regulation comes into force (Marolt 2016). In the United States, there is a legal framework from the FAA, but in the individual federal states additional regulations can be in effect. In Japan as well, prefectures and municipalities have the authority to identify airspaces. Table 1 gives a simplified overview of the most important national legislation. The data relate to commercial agriculture and are greatly simplified.

Table 1: The most important regulations for drone use in a comparison of countries

	Deutschland	USA	Japan
Distinction between commercial/ recreational	✓	✓	–
Maximum airspeed	–	✓ (100 mph ≙ 161 km/h**)	–
Maximum altitude	✓ (100 m)	✓ (400 feet ≙ 122 m**)	✓ (150 m)
Maximum take-off weight	✓ (25 kg/150 kg*)	✓ (25 kg)	–
Flight beyond VLOS (Visual Line of Sight)	– (✓*)	✓	✓
Liability insurance	✓	–	–
Labeling	✓ (ab 0.25 kg)	✓ (“commercial”)	–
knowledge proof („driver‘s license“)	✓ (ab 2 kg)	✓ (“commercial”)	–
Minimum age limit	✓ (16 years)	✓ (16 years)	–
Night flights	– (✓*)	–	–
Aerial plant protection	– (✓*)	✓	✓
Prohibited fly zones			
State institutions (government buildings, etc.)	✓	✓	✓
Public facilities (Hospitals, Schools, etc.)	✓	–	–
State buildings (traffic routes, etc.)	✓	–	✓
airports	✓ (1.5 km)	✓ (5 mi ≙ 8** km)	✓ (9 km)
Military facilities	✓	✓	✓
Events, gatherings	✓	✓	✓
Private buildings/property	✓/–	–/–	✓/–
Vehicles	–	–	✓
Nature reserve	✓	✓	–
Right-of-way provision	✓	✓	✓

*by permission | **rounded | ✓ = correct/allowed/existing | – = uncorrect/prohibited/not existing

Particularly in a densely populated country like Germany, roads, residential areas, environmental protection areas, etc., are directly adjacent to agricultural land. Here, no-fly zones according to § 21 LuftVO that go beyond restricted areas at and around airports have to be estimated in advance. To fly in these areas, the consent of the landowner (residential areas), the airspace-using facility (e.g., airports or industrial facilities), and the approval of the National Aviation Authority is needed. The airspace over private but unsettled land can be flown freely, but a horizontal distance of at least 100 m must be maintained from federal roads or railways. A general ruling from the regional aeronautical authorities can reduce this 100 m by following the 1:1 rule. This rule states that the aerial height of the UAV must be less than the lateral distance to the infrastructure and the lateral distance to the infrastructure must always be greater than 10 m. Furthermore, the infrastructure can be quickly flown over. The flyover must be carried out at a minimum height of 50 m and without any lingering over the traffic route (DFS 2017). Further exceptions to the flight in such prohibited zones or the abolition of operational limitations are possible through a general ruling of the respective regional aeronautical authority. This general ruling can be issued for a maximum of 2 years (DFS 2017, Luftamt Südbayern 2017).

Japan has a high population density, though the conditions are less concrete and more generous. Residential areas can be flown over up to a population certain density without permission. Explicit bans in public places exist in Japan only over gatherings, government buildings, city parks and state institutions. In addition, flying over power lines or trains is forbidden. However, no minimum horizontal distance to power lines or trains must be maintained. In contrast, at least a 30 m horizontal distance must be maintained from persons and objects (buildings or vehicles) on the ground.

The USA have a similar spongy, or rather no, definition regulating flying over private land. In its Advisory Circular No. 107-2 for sUASs, the FAA does not mention this topic. Since the USA airspace is legally assigned to the FAA, landowners can neither grant nor deny permission for it (Kipkemoi 2017). However, taking-off and landing on private property is the equivalent of unauthorised entry by a person and can therefore be reported.

Some companies already provide digital maps that indicate no-fly zones and restricted areas for private users. Often, this digital map information is already stored in automatic geofencing systems and warns or prevents the user from the unauthorised flying into restricted areas (z.B. flysafe, DJI). The company FlyNex offers a freely accessible map, “map2fly”, for the whole of Germany. After entering individual flight parameters, the required conditions or approvals are displayed (Jurran 2017). German Air Traffic Control (DFS) also offers a free drone app that contains its monitored airspaces and no-fly zones. The drone manufacturer DJI offers a so-called “Geo Zone Map”, wherein no-fly zones are designated for Japan, the USA or even Germany. At least for Germany, however, not all restrictions are considered. In Japan, there are official maps from the Geospatial Information Authority of Japan (GSI). A service provider or software could be conceived that identifies, in a similar manner, a farmer’s agricultural areas in terms of no-fly zones/restricted areas. Before starting a drone mission in a particular field the drone user could be updated about possible no-go areas and be advised to apply for permission to fly.

Chemically based plant protection in European agriculture is currently limited to application by tractors with the appropriate attached implement, or by specialised vehicles. The application of PPP has been used in the past, e.g., in the DDR (German Democratic Republic) using helicopters or aircraft. Adverse economic and ecological consequences of this type of application were always greater than with ground-based technologies due to drift in the atmosphere. This led to a ban on the aerial application of PPP in the European Union, and thus also in all EU member states. In contrast, in the United States aerial application is legally permitted (Title 7 US Code), and in Japan aircraft, helicopters, and drones are used for the application of PPP (Drone Law Japan 2015b). Only in exceptional cases (such as in viticulture) can permits be obtained in Germany or the EU. Exceptional cases are missions in which there are clear advantages in terms of reduced impacts on human health and the environment in comparison to other spraying methods (2009/128/EG). Drone technology should not pursue the goal of maximising work rates. On the contrary, it enables the next step of the the evolution from full-fledged farming (conventional farming), to site-specific farming (precision farming) of field areas and now to the farming of individual plants (spot farming). These small-scale treatments have great potential for resource savings and optimisation by moving from the principle “as little as possible, as much as necessary” to “as little as possible, only where necessary”. The positive effects for humans and the environment are self-explanatory.

The current control of UAVs requires that the pilot or a supportive person is in continuous eye contact with the drone. This applies to Japan and Germany, as well as to the USA. If a drone performs manoeuvres automatically after prior programming, the controller must always have the opportunity to take-over control. These rules are aimed at ensuring the safety of drone missions, although they also have a strong limiting effect on possible uses. In particular, the use of drones over large fields and meadows could invoke this operational limitation, since arable land may well have an extent of several hundred metres or even several kilometres. On vast agricultural land, an observer may reach the limit of his ability to see a drone, for example while measuring an area. Even in good visibility conditions, an average drone can no longer be seen at a distance of several hundred metres. A clearer definition of “out of sight of the controller” would, above all, be desirable for agricultural use. A daily autonomous flight of drones for continuous data collection is not possible yet. Reese Mozer, CEO of the agricultural drone manufacturer American Robotics, indicated in an interview that an modification of the VLOS-rule for UAVs is underway in the USA legislature, which will, in the future, also provide for full automation (planning, take-off, flight, image acquisition, landing, battery changes, data management and drone storage) of the in-house drone Scout (Cosgrove 2017). In Germany, a flight beyond the range of visibility can be requested from the responsible regional aeronautical authority. For this purpose, however, the drone must have a take-off mass of at least 5 kg (Markert 2017). Autonomous drone flights are allowed in the USA as well as in Japan, as long as they are in the VLOS and the controller can intervene at any time. In Japan, by the end of 2018, new regulations will come into force that permit the flying of drones beyond the VLOS of the controller (BLOS–Beyond Visual Line-of-Sight) and thus enable a complete autonomy (Margaritoff 2018).

In Germany and Japan, exceptions and permits issued by the regional aeronautical authorities are possible for all operating restrictions; thus, the night-time drone use can be permitted. In advance to the grass harvesting, which often starts early in the morning due to the weather and workload, the search for wild animals (e.g., game) could be conducted without interfering the farmer’s work time on the field. Moreover, a successful search for wild animals with a thermal camera is only possible at night or early in the morning, since the soil heats up over the day, making it difficult to clearly distinguish between the heat signature of a wild animal and the field’s surface.

Conclusions

An international comparison of the law and justice regarding UAVs reveals similarities but also clear differences. In the USA, the EU, Germany, or Japan, drone laws are either non-existent, currently in the making, or only recently in force. However, all countries are currently in the process of drafting or improving their laws. Parallels often show up in operation limitations or key figures of aviation/ airspaces, since civil aviation has long set certain standards, e.g., the 1944 Chicago Convention. Maximum legal altitudes range from 100 m (Germany), to 122 m or 400 ft (USA), to 150 m (Japan). Also identical is the right-of-way rule, i.e., the operation of drones in the VLOS and the prohibition of flights at night. Some of these operational limitations, such as maximum altitude, for example, can be removed by permission or certificate. However, Japan has less extensive legislation on drones and grants more leeway. The new regulation of drones in the EU is characterised by a risk-based approach. Besides technical specifications (e.g. MTOW), the mission's environment (e.g., open field) and the claimed airspace (uncontrolled airspace class G) are taken into account for the risk assessment, which may make it easier to approve and execute missions in the agricultural context. If all EU member states use a risk assessment based on the SORA methodology, cross-border missions would also be simplified. If the permission was granted by a legal authority of one member state, then this would also be recognised by other member states without the effort of obtaining additional documentation.

In both the USA and Germany, there is a legal distinction between the commercial and recreational use of drones, although this legally engages only for MTOWs over 5 kg. At this point, a proof of knowledge is required for commercial users, which can only be issued by accredited institutions. For model aircraft weighing more than 5 kg, a simplified version is sufficient, and this can also be issued by a model flight organisation. For commercial use, there are also requirements for the insurance of the drone and the maintenance of a flight book. The EU bill also distinguishes between commercial and non-commercial use. On the other hand, Japan does not distinguish between drones based on their use, and no additional categorization according to technical specifications or the mission's environment is conducted. This very modest regulation is consistent with the Japanese technology-friendly societal attitude. In Germany, in some cases, commercial use is difficult to separate from private use, since a the giving of a direct reward or a cash transaction does not always take place. For example, consider a person photographing a sports venue and providing these pictures to the sports club free of charge, and the sports club then publishing these pictures on its homepage. Such a case can be seen as both commercial (due to the intention to photograph) and as private (due to the personal pleasure of the drone pilot). Such conflicts arise from the new drone regulation of 2017 and this question of private or commercial is of great importance as it affects the type of insurance needed.

In the USA and Japan, the privacy of individuals is not automatically placed above the freedom of the use of drones. This is why flying over private land is not generally prohibited and, thus, drone traffic faces fewer infrastructural barriers and can also move in direct routes to, for example, crop fields. In Germany, more extensive limitations (e.g. flying over residential areas) are in effect that limit the airspace of drones. The simplicity of the reduced legislation as in Japan and the USA can be advantageous, but can also be seen as a negative, because this "soft" regulation results in many conflicts, such as neighbourhood disputes or a negative social response to drone missions in general, especially in agriculture.

Overall, a heavier drone weight (MTOW) currently leads to higher bureaucratic hurdles because the categorization and assessment of potential dangers often depends on it. The risk posed by a UAV is only partially accounted for by the sole consideration of the MTOW. Other factors, such as the location, contribute significantly to the potential risk and currently limit activity with flight restrictions in no-fly zones. The use of large drones on crop fields and meadows could justify a lower risk classification compared to a small drone over built-up areas since considerations of data protection or damage due to falling machines are far less critical, as they are over a lake or at sea. Granting of permission under such circumstances is seen as less critical and is likely to be possible with existing documents. Further legal developments, especially in the EU, are of great interest, and the directive for civilian drone use, whose first draft contains a flexible, risk-based system approach, will affect legislation in all EU member states.

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