FINAL REPORT

Potential gains from relaxing regulation of drones in the agricultural sector

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NSW Productivity Commission

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CANBERRA

Centre for International Economics
Ground Floor, 11 Lancaster Place
Canberra Airport ACT 2609

Telephone +61 2 6245 7800
Facsimile +61 2 6245 7888
Email cie@TheCIE.com.au

Website www.TheCIE.com.au

SYDNEY

Centre for International Economics
Level 7, 8 Spring Street
Sydney NSW 2000

Telephone +61 2 9250 0800
Email ciesyd@TheCIE.com.au

Website www.TheCIE.com.au

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Executive summary

The agricultural sector in Australia continues to innovate in the search for productivity[1], and this paper highlights some of the impacts of using new technologies to improve farm productivity, with a focus on drones. A broad spectrum of technologies are expected to continue to drive improvements in agricultural productivity in the future.

Drones have the potential to complement and augment a wide range of agricultural practices as part of the broader shift toward 'precision agriculture'. Certain use cases have been successfully implemented in overseas jurisdictions, such as spraying in Japanese rice fields and Californian vineyards.

The spectrum of innovative applications is expanding as users experiment with the functionalities and capabilities of drone technology. For example in Australia, Airseed Technologies are using drone technology for works to restore land after the Australian bushfires of 2020. They are using a drone fitted with a customised spreading system that disperses a seed encapsulated in a nutrient rich pod. Another example is drone company Commander Australia, a Queensland operator providing drone services to the agricultural sector that has recently been given approval by the NSW EPA to fly drones which drop poison bait to slow the NSW mouse plague.

Anecdotal evidence suggests that currently the most common and easiest adopted activities for using drones on a farm are for inspections of livestock and farm infrastructure. For this application drones present a substitute for using a quad bike or ute to conduct these activities. This translates into benefits such as:

- increased efficiency of inspections translating to time and fuel savings
- reduced quad bike related fatalities
- reduced injuries as a result of falling from vehicles, horses and ladders.

For cropping, drones appear to be most competitive on smaller landholdings, particularly where high resolution imagery is required. For livestock management, drones have a competitive advantage in situations where land is on highly inaccessible/steep terrain. Australian farms are typically comparatively large by global standards and the terrain is relatively flat. This has resulted in complementary technologies such as precision tractors and satellite imagery being more cost effective. Novel drone applications such as spot thermal imaging for water leaks or pests are also part of the emerging technologies to support agricultural practices.

1 Heath R. (2018), An analysis of the potential of digital agriculture for the Australian Economy, Australian Farm Institute, https://www.farminstitute.org.au/wp-content/uploads/woocommerce_uploads/2020/08/FPJ-Autumn-2018-yublix.pdf

While drone use and increased uptake of drones into the future will support improvements in agricultural productivity, there are also risks that need to be managed. The risks include, for example, collision with aircraft when operating above 400ft above ground level, which could cause catastrophic damage in the case of windscreen or engine strike. Drones also present a risk to humans and property if they collide in a ground strike incident. Consequently, the risk profile of operating a drone significantly decreases the further distance from people, property and restricted airspace such as in agricultural/rural locations.

CASA (Civil Aviation Safety Authority) regulates the use of drones in order to manage the risks. These regulations can impose significant costs (and require additional skills) to operate a drone outside the standard operating conditions, irrespective of the location of operation.

The available literature and interviews conducted for this project suggest that some aspects of the current framework for regulating drones may act as a barrier for existing drone use, as well as, the future uptake of drones, and could be relaxed when the risk is minimised. In particular, the current restrictions of flying beyond line of sight would prevent some farmers from, say, adopting small scale spraying drones (sub 25kgs). Restrictions on 'flying at night' could also limit the use/uptake of drones in certain circumstances.

Relaxing aspects of CASA's regulatory framework is expected to deliver potentially large benefits for the agricultural sector. Based on research and consultation undertaken as part of this project, the key benefits are likely to arise from relaxing the requirements to fly 'beyond visual line of sight' and at night if the drone is operated solely within the bounds of rural private property. A training program similar to the remote pilot licence would be necessary. However, there is an opportunity to redesign this training with content and practice more suited to agricultural operations. In addition, a risk assessment of the property, checking for proximity to roads and restricted airspace would be required to satisfy a minimal risk outcome.

For farmers operating drones on their own land, these changes are not expected to increase the risks associated with drone use:

- There is limited evidence of any risks currently being imposed by drone use on farms. The fact that there have been no recorded collisions or near collisions with other aircraft from drone use in the agricultural sector would suggest that the current risks are very low.
- Any increase in drone use on farms would occur in very sparsely populated areas and away from airports.
- For agricultural use, drones are typically flown at altitudes below operating height of aircrafts.

Given the low risks associated with increased drone use on farms, there are expected to be net benefits (i.e. benefits minus costs) from relaxing some regulatory requirements in the agricultural sector.

Utilising a range of assumptions based on the best available information and based on average farm sizes, table 1 provides an indication of the quantum of benefits that could be expected from relaxing drone regulation. Based on these assumptions, relaxing these aspects of CASA's regulations for drones is expected to deliver between $239m to $500m (in present value terms) over the next 20 years.

1 Benefit cost summary of relaxing drone regulations

Category	Low scenario	High Scenario
	$m	$m
Benefits (present value of 20 years)		
Quad fatalities	49	74
Injuries	66	199
Routine farm work	94	157
Yield increase	37	79
Total benefits	245	508
Costs (present value of 20 years)		
Routine farm work uptake	4	4
Spraying drones uptake	2	4
Total costs	6	8
Net benefit		
Net benefit	239	500
Benefit cost ratio	41.86	64.44

Source: The CIE.

There are challenges in precisely quantifying the potential benefits from relaxing these aspects of the current regulatory framework. This, in part, reflects the uncertainty regarding the number of drones currently in use in the agricultural sector. Further, there is also currently some level of usage that is outside the 'standard operating conditions' imposed under the existing regulatory framework, reflecting the low probability of detecting 'illegal' activities in remote regional areas. If some existing drone users are already operating outside of the existing regulatory framework, this would reduce the potential gains from relaxing the regulations. There is also some uncertainty regarding the future drone adoption given the competing technologies available. The future uptake would depend on the type of use, size of farm and accessibility of the terrain.

While it is difficult to estimate the quantum of benefit from relaxing some of the operational requirements, providing farmers with greater flexibility to adopt favourable technologies would provide a positive societal benefit while only minimally increasing risk for aircraft, people and property.

1 Drone regulation in the agricultural sector

A new policy and legislative framework is being developed by the Commonwealth to regulate the emerging drone industry. While regulatory responsibility for drones sits with the Commonwealth Civil Aviation Safety Authority (CASA), there is some overlap with NSW regulatory responsibility (particularly enforcement).

There is scope for NSW to provide evidence on the potential benefits (and costs) of refinements to the existing regulatory arrangements and to create smarter, more flexible regulation to support emerging technologies. The agricultural sector has been identified for these reforms, as the sector is diverse in its sizes of enterprise, farming practices, technological adoption and willingness to support reform. Stakeholders such as the National Farmers' Federation (NFF) support the relaxation of regulations. In its submission to the Productivity Commission review, the NFF noted that

> These sophisticated tools will enable farmers to manage ever larger areas of land and assist them with decision-making … In turn, farmers will spend less time driving through paddocks as they will be able to manage larger areas of land by analysing data.

While there is general support for removing 'unnecessary' regulation, there has been limited quantification of the potential gains from relaxing the regulation and the potential costs (in terms of increased safety risks) of increased drone use. This report discusses the potential regulatory scenarios that would lead to net benefits (i.e. where the benefits outweigh the costs). It also seeks to quantify the net benefits from the options.

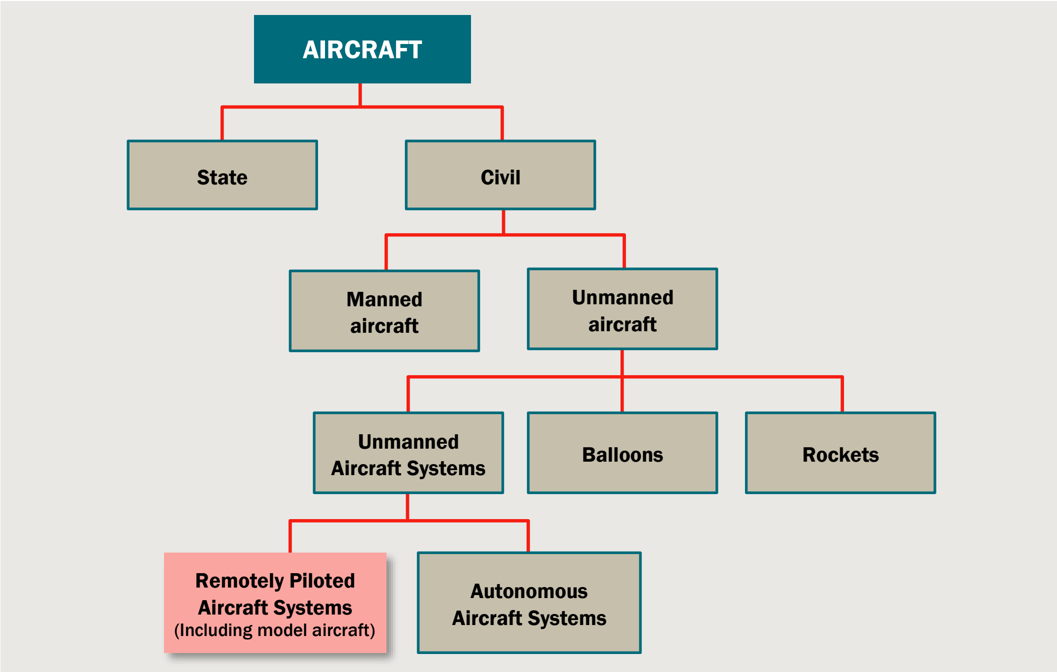
Existing drone regulation

CASA Regulation

Currently the use of drones is regulated by CASA which applies the same level of safety, noise and privacy standards to the use of drones in both the metropolitan and rural areas. Chart 1.1 provides CASA's classification hierarchy of unmanned aircraft. The primary concern of CASA regulation is airspace threat mitigation.

Drones are currently distinguished by Remotely Operated and Autonomous Aircraft Systems, the latter relating to aircraft where there is no pilot control of the aircraft during the flight. Autonomous operations will need to be approved by CASA on a case-by-case basis. CASA also distinguishes between "State aircraft and Australian Defence Force drones", the latter being subject of separate regulation. The focus of this paper is on the regulation of civilian aircraft, in particular, the unmanned aircraft systems, Remote Piloted Aircraft Systems (RPAS) and Autonomous Aircraft Systems.

1.1 CASA's classification hierarchy for unmanned aircraft



Data source: CASA.

The philosophy behind CASA's approach to regulation is captured in the following statement from its 2019 Advisory Circular.

> A suitable baseline level of aviation risk is that demonstrated by the conventionally piloted/manned aircraft industry. It is CASA policy that the drones sector demonstrate a level of safety that is similar to that currently achieved in the conventionally piloted/manned aircraft sector.[2]

That is, CASA adopts the existing framework for regulating other aircraft as the basis for regulating drones. In regard to the risk tolerance, CASA appears to adopt the precautionary principle whereby a higher level of regulation is adopted unless otherwise proven.

> Every government and every aviation safety regulatory authority in the developed world today is challenged by the growing number of still largely unanswered questions about the nature and magnitude of the risks associated with growing numbers of increasingly sophisticated RPAS technologies, coupled with effectively unfettered access to those technologies and devices, and the ease with which these can be used – responsibly and otherwise – in a variety of ways by virtually anyone.[3]

The appropriateness of applying the strict aviation level regulation to drones should be considered with respect to the NSW Government better regulation principles, see box 1.2. The risks of drone operation are significantly lower than regular aviation and,

2 CASA (2019), Remotely piloted aircraft systems - licensing and operations, Advisory Circular AC 101-01v3.0, December, p.15.

3 CASA (2018), Review of aviation safety regulation of remotely piloted aircraft systems, https://consultation.casa.gov.au/regulatory-program/dp1708os/results/reviewofaviationsafetyregulationofremotelypilotedaircraftsystems-may2018.pdf, p.6.

therefore, proportionality should be considered when creating regulation. Furthermore, the composition of stakeholders for drones is broader, as lower barriers to uptake mean a wider cross section of the public use drones, as compared with aviation where operations are contained within a specific sector. Finally, as drones are an emerging technology, regulation should be more frequently reviewed to ensure efficiency and effectiveness and that barriers to uptake are not restricting potential benefits.

1.2 Better Regulation Principles

Principle 1: The need for government action should be established. Government action should only occur where it is in the public interest, that is, where the benefits outweigh the costs.

Principle 2: The objective of government action should be clear.

Principle 3: The impact of government action should be properly understood by considering the costs and benefits (using all available data) of a range of options, including non-regulatory options.

Principle 4: Government action should be effective and proportional.

Principle 5: Consultation with business and the community should inform regulatory development.

Principle 6: The simplification, repeal, reform or consolidation of existing regulation should be considered.

Principle 7: Regulation should be periodically reviewed, and if necessary reformed to ensure its continued efficiency and effectiveness.

Sport and Recreational use[4]

For persons using drones for recreational purposes, the use is limited by the standard operating conditions which seek to "ensure that a person may not operate a drone in such a way as to create a hazard to another person, another aircraft or property" (see Box 1.5). Currently there are no requirements regarding the registration or other administrative requirements. However, from 30 May 2022 drones more than 250g and used for "sport and recreation" will need to be registered.[5] Annual registration fees are expected to be in the order of $20 per drone.[6]

4 'Sport or recreational purposes' means operating an drone as a hobby or for pleasure and where the operation does not generate a direct commercial outcome of any sort (for the pilot or any third party).

5 CASA, Registration and Accreditation https://www.casa.gov.au/knowyourdrone/registration-and-accreditation

6 CASA (2019), RPA registration & accreditation – summary of consultation, https://consultation.casa.gov.au/regulatory-program/pp1816us/results/d19294554summaryofconsultationonpp1816us.pdf, p.3

Commercial use

Drone use for 'commercial' purposes (including on-farm use) is subject to a set of specific requirements (table 1.3). Depending on which category the pilot operates, there are differing requirements, as outlined in Chart 1.4:[7]

1.3 Overview of drone pilot accreditations/certifications

Item	Description
Drone registration	All drones used for commercial purposes are to be registered with CASA
Aviation reference number	An aviation reference number is similar to an account/customer number which is required if you intend to hold any licence, permission or authorisation with CASA
Operator accreditation	A process for all users intending to use a drone for commercial purposes which includes completing a short quiz covering the standard operating conditions and rules
Remote pilot licence	A remote pilot licence allows you to fly remotely piloted aircraft (drone) for business or as part of your job in circumstances that need specialist training
Operator's certificate	A remotely piloted aircraft operator's certificate allows your business to operate as a drone service provider, earning money for hire or reward, employ remote pilots (remote pilot licence holders) and fly outside the drone safety rules - also known as the standard operating conditions
Aeronautical radio operator certificate	This is the certification that a person will need in order to transmit on an air band radio in Australia

Source: CASA.

- As of 28 January 2021, drones are required to be registered (regardless of weight) with CASA and renewed annually.
  - Drone registration is currently free, valid for 12 months and can be undertaken online. In the future an annual registration fee may be applied depending on the intended use of the drone – it is expected to be between $100-$160 per drone.[8]
  - A fine of up to $11 100 can be applied for flying an unregistered drone for 'business or as part of your job'.[9]
- An aviation reference number and operator accreditation are required:
  - An aviation reference number is a unique identifier, similar to an account number or customer number. A completed form, including identification (e.g. passport) is required
  - Operator accreditation is free and drone users will be required to undertake an online course on the rules that apply to them. An operator accreditation is not required if you hold a remote pilot licence or are flying the drone for sport or recreation.
- Consistent with the requirements for recreational users, a range of standard operating conditions apply. These requirements are intended to safeguard the community and other aircraft in the unlikely case of a drone accident.

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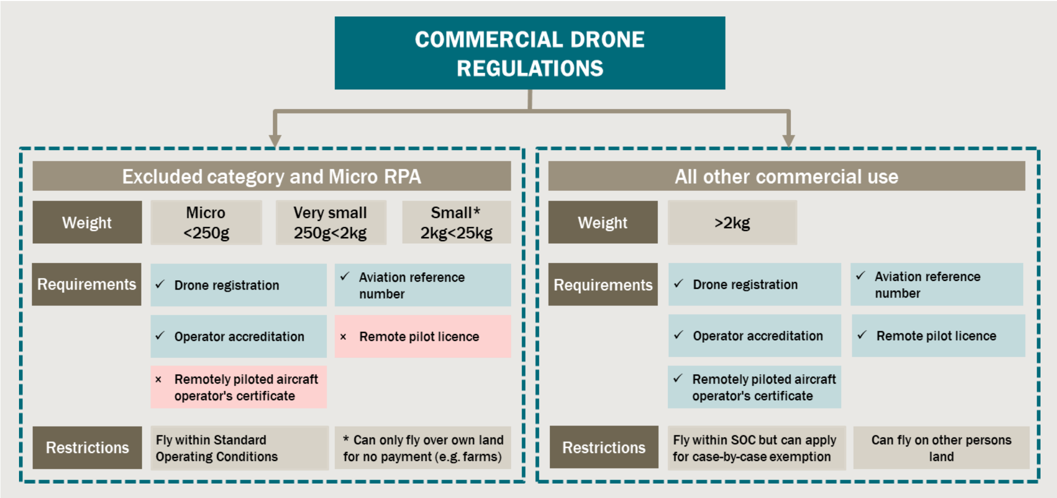
7 The rules are detailed in the *Civil Aviation Safety Regulations Part 101.*

8 CASA (2019), RPA registration & accreditation – summary of consultation, https://consultation.casa.gov.au/regulatory-program/pp1816us/results/d19294554summaryofconsultationonpp1816us.pdf, p.3.

9 https://www.casa.gov.au/drones/register

1.4 Existing regulation of drones



Data source: CIE, based on CASA regulations.

There are slightly different degrees of regulation depending on the weight and intended use of the drones:

- For farmers who choose to operate a drone on their own land and the drone is less than 25kg, a Remote Pilot Licence and drone operator's certificate are *not* required. If a drone is greater than 25kg a remote pilot licence and remote operator certificate are required, even when used only on a farmer's own land.
- For drone operators that fly over another person's land (e.g. a contractor undertaking chemical spraying on a farmer's land), then a remote pilot licence and remote operator certificate is required.

However, the most important difference between the two categories for commercial use relate to the standard operating condition requirements, described in Box 1.5. A drone operator that holds a remote pilot licence and remote operator certificate can apply for an exemption from the standard operating conditions. The exemption is applied on a case-by-case basis and a separate application needs to be submitted each time an operator seeks to fly a drone outside the standard operating conditions.[10]

1.5 Standard Operating Condition requirements

- The drone is operated:
  - by visual line of sight only - close enough to see, maintain orientation and achieve accurate flight and tracking
  - no higher than 400 ft (120 m) above ground level
  - during daytime only – effectively, not before sunrise or after sunset
- The drone is *not* operated
  - any closer than 30 m from people not associated with the flight

10 https://www.casa.gov.au/drones/reoc/additional-approvals

  - any closer than 15 m from people who have consented to the drone operating close to them
  - autonomously
  - within 3 Nm/5.5 km of a controlled aerodrome
  - in a prohibited area or 'restricted area' where civil aviation is not permitted
  - at night, unless in accordance with CASA 01/17
  - in or out of cloud
  - over populous areas
  - over the movement area or within the approach and departure paths of an aerodrome without approval from CASA.
- Only 1 drone flown per pilot at any one time.

NSW Regulation

There are additional approvals required for flying drones in a national park in NSW. This is unlikely to be a major impost for the agricultural sector, unless there are cases of farmers needing to find livestock that have inadvertently strayed within a national park.

However, in relation to chemical spraying from drones, the NSW EPA specifies that

> Pilots and remote pilots applying pesticides from a plane, helicopter or remotely piloted aircraft onto any land in NSW, and people or companies employing such pilots, must have specific qualifications, hold EPA licences and meet certain legislative requirements under the Pesticides Act 1999 and Pesticides Regulation 2017.[11]

The EPA requires the operator to:

- obtain the appropriate certification from CASA
- qualify for a drone applicator pilot licence, undertake the training
  - unit code AHCCHM303 Prepare and apply chemicals or
  - unit code AHCCHM307 prepare and apply chemicals to control pest, weeds and diseases, and
  - unit code AHCCHM304 Transport and store chemicals and
- on obtaining the appropriate CASA certification, apply to the EPA for a drone applicator pilot licence and a drone applicator business licence, or be employed by a person holding a drone applicator business licence.

11 https://www.epa.nsw.gov.au/your-environment/pesticides/licences-and-advice-for-occupational-pesticide-users/aerially-applying-pesticides

2 Potential gains from increased drone use

There are a range of potential gains of increasing drone use in the agricultural sector. These are discussed further below.

On farm safety benefits

There are a wide range of on-farm activities where there is a greater chance of injuries or fatalities. The Australian Institute of Health and Welfare (AIHW) has collated data on the different types of farm injuries (e.g. injuries involving horses, motorbikes, snake bites). In 2018, AIHW produced a report on the hospitalised farm injuries based on data from 2010/11 to 2014/15. Some of the injuries could be reduced by increasing the uptake of drones.

Table 2.1 presents data on the number of injuries associated with quad bikes, motorcycles and horses where the activities were work related.[12] In total, across Australia, there were 1,408 hospitalised incidents – 803 incidents on motorcycles, 389 on quad bikes and 216 on horses.

2.1 Hospitalised motorcycle, quad bikes and horse injuries on farm, Australia, 2010/11 to 2014/15

Mechanism of fall	Number of injuries
	No.
Motorcycle	**803**
Working for income – agricultural/forestry/fishing	756
Working for income – other industry	47
Quad bikes	**389**
Working for income – agricultural/forestry/fishing	365
Working for income – other industry	24
Horse	**216**
Working for income – agricultural/forestry/fishing	153
Working for income – other industry	63
Total	**1 408**

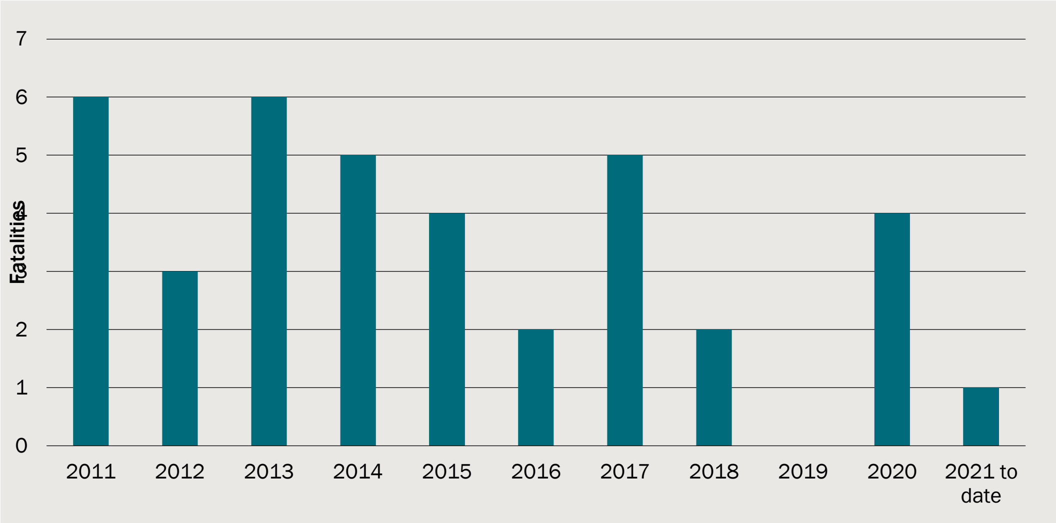
Note: For persons aged 15 and over

Source: https://www.aihw.gov.au/getmedia/279bb48f-d2fe-47b9-823c-63cdb2a1a3cf/aihw-injcat-189.pdf.aspx?inline=true

12 Accidents also occur in leisure activities.

Quad bikes are also a major contributor to on-farm deaths. Table 2.2 reports the number of fatalities (both work and non-work) reported by SafeWork NSW.

2.2 NSW quad bike fatality data from 2011 to date - both work and non-work related fatalities.



Note: Data was not available to separate work and non-work deaths.

Data source: Safework NSW.

There are other aspects of farming where there are also risks of injuries/fatalities. AIHW also reported hospitalised farm injuries related to 'falls'. Many of these injuries relate to activities conducted at height which could partially be undertaken by drones (e.g. inspecting silos).

Table 2.3 presents the data on the different types of injuries associated with falls. Slipping, tripping or stumbling on the same level accounted for over 33 per cent of hospitalisations who sustained a fall-related injury in a farm setting. Falls from height, such as, 'from tree', 'from cliff' and 'on or from ladder' accounted for around 41 per cent of fall-related injuries.

2.3 Hospitalised fall-related farm injuries, Australia, 2010/11 to 2014/15

Mechanism of fall	Number of injuries	Proportion of injuries
	No.	%
Same level from slipping, tripping, stumbling	683	33.0
On and from stairs/steps	29	1.4
On or from ladder	155	7.5
From, out of building/structure	156	7.5
From tree	26	1.3
From cliff	44	2.1
Other fall from another level	434	21.0
Other fall on same level	302	14.6
Unspecified fall	239	11.6
Total	**2 068**	**100**

Note: For persons aged 15 and over

Source: https://www.aihw.gov.au/getmedia/279bb48f-d2fe-47b9-823c-63cdb2a1a3cf/aihw-injcat-189.pdf.aspx?inline=true

The extent to which increasing drone use will reduce the risky activities is uncertain. The NSW Government's Quad Bike Safety Program includes a rebate for farmers purchasing a drone, suggesting that drones make a positive contribution to reducing risk of on-farm accidents.[13] From 27 February 2019, the quad bike safety rebate included one drone rebate per eligible business. Table 2.4 summarises the drone uptake under the Program since February 2019. Under the Program there were 71 drones purchased by farmers over this 2-year period.

2.4 Number of drones subsidised under Quad Bike Safety Program, since February 2019

SA4 Region	Number of drones
	no.
New England and North West	18
Far West and Orana	10
Capital Region [a]	9
Central West	9
Riverina	7
Mid North Coast	5
Richmond – Tweed	4
Coffs Harbour – Grafton	3
Hunter Valley exc Newcastle	2
Illawarra	1
Murray	1
Newcastle and Lake Macquarie	1
Sydney - Outer West and Blue Mountains	1
Total	**71**

[a] Includes the following LGAs - Goulburn Mulwaree, Upper Lachlan Shire, Queanbeyan-Palerang Regional, Snowy Monaro Regional, Yass Valley, Hilltops

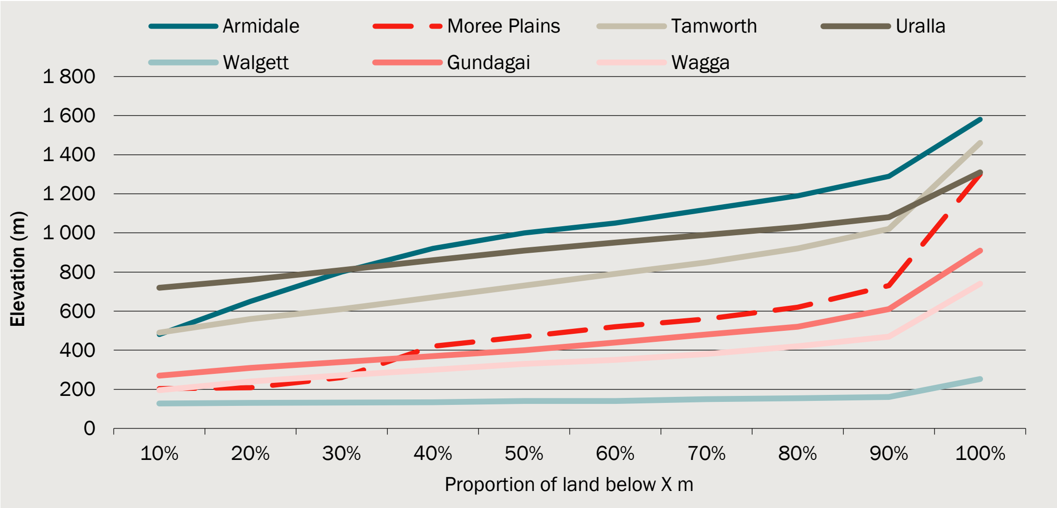
Source: SafeWork NSW

The potential for injuries from quadbikes, motorcycles and horses is likely to be higher in more steep/rugged terrain. Chart 2.5 provides data on the proportion of land above different elevations in a selection of LGAs. The Armidale LGA is the steepest[14], with the Walgett Shire being relatively flat. The relatively high drone uptake in the "New England and North West" region as part of the Program supports the view that drones offer greater safety benefits in the steeper terrain.

13 Appendix B provides further information about the Quad Bike Safety Program.

14 This could explain the relatively large number of drone purchases through the Quad Bike Safety Program.

2.5 Steepness of terrain in select LGAs



Data source: CIE calculations based on topographical data https://maps.six.nsw.gov.au/

Drones complementing routine farm work

Drones can be used to support day-to-day farm activities such as checking water troughs, fencing and silos. In the livestock industry, drones are used to support mustering of cattle. For example, drones are more efficient at identifying the location of livestock in a field to enable more 'targeted' mustering. Some drones also include speakers which can be used to command dogs used for mustering. Drones are particularly efficient in finding livestock in rugged/elevated terrain compared to vehicles and horses.

Australian cost estimates

As the uptake of drones is still in its infancy, it is difficult to attain detailed data around drone usage and cost savings. However, some Australian farmers have provided rough estimates on how much drones reduce their costs.

Will Wilson at Calliope Station in central Queensland, indicated that it cost $1 per kilometre to fly a drone, factoring in battery life and the replacement of broken drones, with the cost of drone mustering in a 600-hectare paddock around $20.[15]

Brightlands, a 30 000-hectare station on the Malbon River indicated that in place of fixed wing aircraft and helicopters they could use drones for water management, stock movement, and pest control: "Just in our operation, if we were to cut out six hours flying a week, you can equate that pretty conservatively to $1 000 a week just in flying".[16]

15 ABC (2020), Drones for mustering improves safety and efficiency on rural properties, https://www.abc.net.au/news/rural/2020-07-21/drone-musters-cattle-safely-at-calliope-station/12468058

16 ABC (2019), Graziers urge drone law changes to ease the cost of drought, https://www.abc.net.au/news/2019-12-19/graziers-urge-drone-law-change-to-ease-the-cost-of-drought/11811156

Scotland farm case study

Highland Drones Ltd performed a drone use case study using a DJI Mavic Pro Platinum in Clynelish, a 300-acre livestock farm in the north of Scotland. The case study was to measure the benefits for an average farmer performing routine farm jobs such as checking livestock on grassy and hilly terrain.[17]

The cost savings were determined by measuring the human element of the amount of time spent checking stock compared with using the drone twice a week. The drone was not used daily as human intervention would still be required

- Grassland checks on foot take 1.5 hours. This was reduced to 30 mins with a drone, resulting in a saving of 104 man hours per year.
- Hill checks take 40 minutes on quad/truck. This was reduced to 10 minutes with a drone, resulting in a saving of 26 man hours per year.
- Leads to a total saving of 130 hours per annum.

Considering the average Scottish skilled farm labour of £12.80, this equates to a saving of £1 664 per annum for checking the stock as per indicated. At a price of £1 169 the drone would recoup itself within the first year.

Using the drone instead of the quad or farm truck would see a reduction in fuel usage. The quad would achieve on average 3.3 miles per litre and the truck 5.5 miles per litre to check the stock, which equates to a reduction of 104 litres per year saved in fuel. This would provide a positive environmental benefit as it would enable approximately 281kg[18] of carbon dioxide from being emitted per year per farm.

In the NSW context the Scottish case study provides an indication of the potential savings for farmers. We have projected 2 scenarios for time savings and savings in fuel costs (tables 2.6 and 2.7). The scenarios show the projected savings of substituting a drone for activities normally performed by a quad bike or truck. We have modelled two scenarios which assume a larger utilisation of the drone than the Scotland case study. In addition, we have increased the distance travelled for each trip to reflect the greater sizes of Australian properties:

- In scenario 1 we project that drones could save a farm $5 866 in labour costs and $91 in fuel costs per year.
- In scenario 2 we project that drones could save a farm $9 777 in labour costs and $182 in fuel costs per year.

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17 Farm Advisory Service, Case Study: Cost Savings of using a Drone, https://www.fas.scot/downloads/cost-savings-of-using-a-drone/

18 1 litre of diesel will produce about 2.7kg of carbon dioxide

2.6 Potential time savings (per farm)

Type of check	Time saving	Trips per week	Hours per year saved	Labour cost	Cost saving per year
	Hours/trip	#	Hours/year	$	$
Scenario 1					
Grassland	1	3	156	25	3 911
Hill	0.5	3	78	25	1 955
Total			**235**		**5 866**
Scenario 2					
Grassland	1.5	3	235	25	5 866
Hill	1	3	156	25	3 911
Total			**391**		**9 777**

Source: The CIE

2.7 Potential fuel savings (per farm)

Vehicle	Vehicle fuel efficiency	Trip distance	Trips saved per week	Fuel saved	Cost saving per year
	Litres/km	km/trip	#	litres/year	$
Scenario 1					
Quad bike	5.28	1	3	22	29
Truck	8.8	3	3	47	62
Total				**69**	**91**
Scenario 2					
Quad bike	5.28	2	3	45	59
Truck	8.8	6	3	94	123
Total				**139**	**182**

Note: An average diesel price of $1.31 was derived from the NSW Government Fuelcheck website for 17 Feb 2021 to 16 Mar 2021
Source: The CIE, Fuelcheck.

High value applications

Benefits of drones for spraying and mapping

Predominately existing farm management equipment is limited to aerial-only or ground-only applications. Agricultural drones, however, can bridge this gap to deliver both aerial and ground farm management functions, simultaneously integrating both crop monitoring and crop protection applications with higher precision at lower cost.

Current agriculture drones have multi-application capabilities, extending from basic flight control and photographic imaging to hyperspectral data analytics, GPS guided automated flight, and payload delivery of variable rate spraying of seeding, fertilisers, and pesticides.

Despite their effectiveness and usefulness, a drawback of these systems is that they are calibrated only for specific tasks, such as classifying different kinds of vegetation, water bodies, bare soil etc, without being easily integrated into an agricultural management system/platform[19]. This lack of interoperability can result in additional work for the human operators, as there can be significantly large amounts of digital data[20] that needs to be interpreted and sometimes manually fed across systems.[21] To alleviate these issues, software modules and other equipment are being developed to create common information middleware and application interfaces.

Spray drones can be used to apply product at variable rates across a field or paddock, having created a zone map pulled from data out of a multispectral camera mounted on a drone (or other means). They can also be used to 'fill in' areas where a manned aircraft cannot access due to power lines or other infrastructure.

Australian adoption

Drones used for spraying are more costly to purchase than recreational drones, from upwards of $21 000 compared with $2 500, and are often much larger in size as they must carry a larger payload. In addition, spraying drones need to be integrated into the farm's pest and invasive species control systems. This solution requires significantly more planning with some professional expertise, compared with the 'out-of-the-box' solutions for recreational drones.

Nonetheless, the use of drones in agriculture is starting to gain traction in Australia. Data from Victoria, for example, indicates an increased interest in spray drones, particularly with Agriculture Victoria now allowing drone spraying to occur with a wider range of unmanned aircraft from the middle of December 2020.[22]

Skytech Solutions[23] (based in Northern NSW) are using spraying drones to apply product to tree crops. Spraying drones allow the farmer to access the tree canopy, which is traditionally difficult to reach via a ground-based system.

The Queensland Department of Agriculture and Fisheries' (DAF) Coastal Farming Systems team worked with Tully sugarcane farmer Dick Camilleri for several years

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19 Pasquale Daponte et al (2019), A review on the use of drones for precision agriculture, IOP Conference Series: Earth and Environmental Science, https://iopscience.iop.org/article/10.1088/1755-1315/275/1/012022/pdf, p.2

20 For example, the eBee drone can capture rates of up to 600ha a day at 3.6cm/pixel resolution, however processing 600ha will take in the order of three days on a 64gb RAM computer

21 Pasquale Daponte et al (2019), A review on the use of drones for precision agriculture, IOP Conference Series: Earth and Environmental Science, https://iopscience.iop.org/article/10.1088/1755-1315/275/1/012022/pdf, p.2

22 https://agriculture.vic.gov.au/farm-management/chemicals/spraying-agricultural-chemicals/aerial-spraying

23 skytechsolutions.com.au/about/

looking at the potential of drones to assist sugarcane growers both with mapping variability in the paddock and then later as a precision agriculture tool.[24] After three years, the trial proved successful and DAF has purchased two new drones to advance this field of research.

Business impact

According to a market analysis on applications within the Asian and South-East Asian regions conducted by IPSOS in 2017, spraying by agriculture drones is estimated to save up to 90 per cent of water usage for irrigation, and could save between 30 per cent to 50 per cent of chemicals in crop spraying[25].

The ideal farming conditions for agricultural drone adoption were identified as:

- Smaller, scattered, irregular plots of land
- Some machinery usage, more manual
- Plot accessibility challenges

For these types of land, an uptake in agricultural drones was estimated to improve efficiency by between 40x to 60x compared to manual labour, and up to 5x faster than tractor application of pesticide.[26] Due to the high level of manual labour, a health benefit for workers is present as agricultural drones would expose operators to fewer chemicals.

These gains would be unlikely to translate to the Australian region in the same magnitude as estimated above. Australian broadacre farms are significantly larger in size, and as a result rival precision agriculture technologies are far more competitive, such as tractor spraying and aerial and satellite mapping. For example, satellite mapping suitable for most Australian agricultural applications ranges from free to $5.50 per hectare[27]. Furthermore, there is significantly less manual labour on Australian broadacre farms as they embrace new technologies which are often developed specifically for larger farms.[28]

24 https://www.daf.qld.gov.au/agtech/be-inspired/discover-r-and-d/drone-and-mapping-tech

25 IPSOS Business Consulting (2017), Commercial Drone Adoption in Agribusiness: Disruption and Opportunity, https://www.ipsos.com/sites/default/files/ct/publication/documents/2017-09/Commercial-Drone-Adoption-in-Asia-Pacific-Agribusiness.pdf, p.8-9

26 ibid

27 University of New England Applied Agricultural Remote Sensing Centre

28 https://www.agriculture.gov.au/abares/research-topics/productivity/productivity-drivers#farm-size

Case study Australia

2.8 Using drone-acquired imagery to manage a high biomass crop[29]

In 2016, a paddock of Commander barley near Moree, NSW was assessed as having high yield potential. Nevertheless, at growth stage 30, areas of crop within the paddock were seen starting to lodge[30]. Applying a growth regulator to the crop was a good option to reduce the lodging but applying the full rate to the entire crop was considered unwarranted and expensive at $30/ha.

Agronomist Brad Donald estimated that applying a growth regulant to prevent lodging in the high crop biomass areas could potentially increase yields by 0.5 t/ha and, with barley worth $200/t, this would generate an additional $100/ha.

Persistent cloud cover at the time prevented the use of satellite NDVI imagery. Instead, Brad generated an approximation NDVI map of the paddock using 700 images collected using a modified Canon S100 camera with a near Infrared (NIR)/blue/green lens that filters out the NIR wavelengths, mounted on an AgEagle fixed wing drone.

From the drone image, Brad produced the variable rate (VR) prescription spray map, which was loaded into the spray unit controller and used to apply the growth regulant. By varying the water rate of the spray unit, the high biomass zones were sprayed at the full rate of regulant and the remainder of the paddock received half the rate by lowering the water volume to 40 L/ha.

The result was a reduction in cost of the product and increased yield due to a reduction of lodging. Additional un-costed, but significant, benefits in this case from the application of growth included ease of harvest and improved stubble management for the next season.

The advantages of using a drone in this instance were:

- Rapid capture of images, which were unavailable from other sources due to cloud cover.
- Timely processing of images and critical decision-making.
- Making observations at a time when the paddock was untrafficable due to wet conditions.

29 Beefcentral (2020), Drone find rising role in agriculture, https://www.beefcentral.com/ag-tech/drones-and-automated-vehicles/drones-find-rising-role-in-precision-agriculture/

30 Lodging is the bending over of the stems near ground level of grain crops, which makes them very difficult to harvest, and can dramatically reduce yield.

Targeted applications

Consultations conducted for this project indicate that other ad-hoc uses of drones could be feasible, such as thermal imaging of irrigated crops to detect water leaks, which could be undertaken every few hours on a small area or identifying feral pests such as wild dogs or mice at night using thermal imaging.

For example, Airseed Technologies[31] is using a drone for works to restore land after the Australian bushfires of 2020. They are using a drone fitted with a customised spreading system that disperses seed encapsulated in a nutrient rich pod. Another example is drone Commander Australia, a Queensland operator providing drones to the agricultural sector has recently been given approval by the NSW EPA to fly drones which drop poison bait to slow the NSW mouse plague.[32]

We can expect to see an increase in innovative solutions driven by drones, as entrepreneurs respond to a wide range of problems in agriculture. However, at this stage it is not possible to estimate the full impact of these solutions, as the cost-effectiveness, scalability and market fit of the solutions is still uncertain. The bulk of drone applications will continue to remain in this ad-hoc category until there are improvements in drone technology, such as battery life and data management, that would result in unit costs low enough to enable scalability and wide-spread adoption.

31 https://airseedtech.com/about/

32 The Guardian (2021), Are poison-packed drones the answer to eastern Australia's mouse plague?, https://www.theguardian.com/australia-news/2021/mar/03/are-poison-packed-drones-the-answer-to-eastern-australias-mouse-plague

3 Risks of increased drone use in agricultural sector

CASA has maintained strict regulation of drone use to protect other aircraft and the community from inadvertent drone strikes. The regulations associated with the standard operating conditions are likely to be a major contributor to this in the context of the agricultural sector. This chapter considers the potential risks associated with increased drone use in the agricultural sector.

Types of risks for drones operating in agriculture

When assessing drone risk, the main considerations are operator qualifications, weight class, altitude, range, intended use and technical features. Potential damage on the ground depends on the kinetic energy resulting from the weight (including payload), altitude and speed.[33] The level of risk is also highly dependent on the location of drone operation, as more populated areas or areas closer to restricted airspace have significantly more obstacles, thus increasing the likelihood of a collision. The key risks for increased drone usage are through collisions and breaching privacy. Aircraft collisions and ground strike accidents are the two scenarios where drones could most likely cause a potential loss of life or injury. Drones can also enable illegal surveillance activities and breach privacy laws for filming and monitoring.

Aircraft collisions

The Australian Transport Safety Bureau prepared a report analysing the safety of drones in 2017. The ATSB report concluded that a number of observations could be made, including that drone collisions with manned aircraft are likely to:

- penetrate the wing or fuselage of an air transport aircraft;
- cause engine damage and engine shutdown resulting from ingestion in high capacity air transport aircraft;
- pose a high risk of penetration to a general aviation aircraft's windscreen;
- damage a general aviation aircraft's flight surfaces, including wings and tail, potentially resulting in a loss of control; and/or
- cause a degree of propeller damage resulting in a precautionary or forced landing, if contacted.[34]

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33 Munich RE (2015), Unmanned aircraft are taking off, https://www.munichre.com/topics-online/en/mobility-and-transport/usage-risks-civilian-drones-increasing.html

34 Australian Transport Safety Bureau (2017), A safety analysis of remotely piloted aircraft systems 2012 to 2016, p.2–3.

The risk of aircraft collision is mitigated through regulations not permitting flying in proximity to restricted airspace where planes are landing and taking off, as well as not permitting drones to fly above 400 ft.

Ground strike collisions

Drones pose a potential threat to humans and property through ground strike collisions. This could be the consequence of losing control of the drone or the drones systems failing, causing it to collide with the ground at speed. The ASSURE[35] group has modelled the impact of ground strike collisions[36], noting that a person could be harmed as follows from a drone; collision with person causing blunt force trauma or laceration, payload collision with person and, chemical spill as a result of collision.

The report notes that

> … uses like agriculture inspection, wildlife observation, and flood relief/planning would occur in very sparsely populated areas. In jobs like these, a drone operator would fly over large plots of land with very few bystanders and inspect and report on different factors of the land, wildlife, or crops. It is unlikely that contact with any non-UAS (drone) personnel will occur during these jobs.[37]

Consideration does need to be taken for personnel working on the farm during drone operation. Incorporating drone use procedures into farm practices for employees and visitors will minimise this threat.

Privacy

Regulations focusing on privacy and drone use are relatively opaque in Australia. CASA as an aviation safety regulatory agency does not deal with privacy regulations. The Office of the Australian Information Commissioner, the main privacy regulatory body of Australia, has not yet adapted to address the increasing challenge of everyday drone users infringing on the privacy rights of other individuals. The Privacy Act 1988 was drafted to target businesses with an annual turnover of more than $3 million, which excludes most everyday drone operators. We expect there will be reform regarding privacy for this domain, however it will be beyond the scope of agricultural drone use reforms.

Other

According to Australian UAV who operate drones throughout Australia, they face at least once per day an attack by a wedge-tailed eagle on a drone. Whether the eagles

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35 The Alliance for System Safety of UAS through Research Excellence (ASSURE) is comprised of twenty-four of the world's leading research institutions and more than a hundred leading industry and government partners.

36 FAA UAS Center of Excellence Task A4 (2017), Final Report for the FAA UAS Center of Excellence Task A4: UAS Ground Collision Severity Evaluation, https://www.assureuas.org/projects/completed/a4/ASSURE_A4_Final_Report_UAS_Ground_Collision_Severity_Evaluation.pdf

37 Ibid

believe the drone to be prey or a threat is not known, however, the attacks are persistent and damaging.[38]

When a drone is operating, it produces noise that could disturb anyone in proximity. There are currently no internationally mandated noise aviation standards for drones. However in 2018, Infrastructure Australia conducted a review into noise regulations for drones.[39] The Review found there was limited support for management of drone noise under local environment regulations. Considering the population densities of rural areas, the noise pollution from drones would be minor.

Recent incidents

Data on drone incidents is currently collected by the Australian Transport and Safety Bureau. In the 4-year period between March 2017 to March 2021 there were 78 separate incidents (table 3.1)

3.1 Recorded drone incidents NSW, March 2017 – March 2021

Operation sub-type	Number of incidents
	No.
Aerial agriculture	3
Check and training	2
Pleasure & Travel	1
Search & Rescue	1
Survey & Photographic	34
Test & Ferry	6
Training dual	1
Training solo	3
Other	9
Unknown	9

Source: Australian Transport and Safety Bureau.

The majority of incidents involved technical failures to the drones (e.g. the drone was no longer responsive to controls) which led to the drone colliding into terrain or water. There was one incident of a drone colliding into a nearby crane. In the agricultural sector the 3 incidents were described as follows,

> During aerial operations, the remotely piloted aircraft (drone) became unresponsive to control inputs. The drone continued its flight path and subsequently collided with terrain resulting in substantial damage.

38 Grains Research & Development Corporation (2015), The use of unmanned aerial vehicles (UAVs) in agriculture - regulations, challenges and opportunities, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/the-use-of-unmanned-aerial-vehicles

39 https://www.infrastructure.gov.au/aviation/environmental/aircraft-noise/noise_regulation_for_rpa_drones.aspx

> During aerial spraying, the remotely piloted aircraft collided with a tree and sustained minor damage.
>
> During the flight, the remotely piloted aircraft became unresponsive to control inputs and collided with terrain resulting in substantial damage.

Given the possible number of flights being undertaken in NSW over the past 5 years, the number of recorded incidents would appear to be very small even accounting for the fact that drone incidents in the agricultural sector may not be recorded.

Proximity to airports

Increasing drone use in the agricultural sector also imposes risks to air traffic around airports. Tables 3.2 provides an estimate of the area of agricultural land around the airports in NSW for the different SA4 regions in NSW. The land area is a small proportion of productive agricultural land in NSW. For example, around 2.4 percent of agricultural land is located within 10km of an airport.

3.2 Proximity of agricultural land to airports, by region

Region	Number airports	Within 2km of airport	Within 5km of airport	Within 10km of airport	Total Ag Land in SA4
	no.	sqkm	sqkm	sqkm	sqkm
Capital Region	7	52.8	340.2	1 344.4	28 993
Central Coast	2	5.1	30.1	65.9	114
Central West	9	59.6	442.3	1 997.8	54 968
Coffs Harbour - Grafton	2	12.4	63.1	191.6	3 640
Far West and Orana	16	125.9	940.2	4 084.8	315 900
Hunter Valley exc Newcastle	7	21.2	223.7	971.2	10 922
Illawarra	1	-	-	11.1	57
Mid North Coast	5	-	29.8	212.1	4 816
Murray	8	54.3	403.9	1 697.3	89 752
New England and North West	10	68.4	481.4	2 257.5	72 553
Newcastle and Lake Macquarie	1	-	-	-	-
Richmond - Tweed	3	1.8	40.2	312.6	4 954
Riverina	7	77.1	502.7	1 948.7	46 104
Southern Highlands and Shoalhaven	1	3.2	18.7	23.2	1 248
Sydney - City and Inner South	1	-	-	-	-
Sydney - Inner South West	1	-	-	-	-
Sydney - Northern Beaches	1	-	-	-	-
Sydney - Outer South West	2	7.0	60.3	184.4	305
Sydney - Outer West and Blue Mountains	2	-	-	-	-
Sydney - South West	3	-	5.5	71.0	-
Total	**89**	**488.6**	**3 582.1**	**15 373.5**	**634 327**

Note: Airports include public, private, military and 'airschools'. The latitude/longitude of each airport was used and concentric circles (e.g. 2km, 5km, 10km radius) was established around the point.

Source: CIE calculations based on NSW Landuse 2013 and ABS Meshblock 2016 "Primary Production" category.

Table 3.3 presents data on the proximity of different types of agricultural land to airports. Around 0.4 percent of grazing activities are within 5kms of an airport and 1.9 percent within 10kms. Horticultural activities comprise around 0.2 percent of agricultural lands, but are commonly located closer to townships. Around 30 percent of horticultural activities are located within 10km of airports in NSW.

3.3 Proximity of agricultural land to airports, by agricultural activity

Agricultural activity	Within 2km of airport	Within 5km of airport	Within 10km of airport	Total Ag Land in SA4
	sqkm	sqkm	sqkm	sqkm
Grazing native vegetation	184.5	1 365.0	6 190.8	420 087
Grazing modified pastures	97.0	779.6	2 942.7	65 429
Grazing irrigated modified pastures	0.2	6.3	26.6	1 919
Intensive animal husbandry	-	2.8	28.4	79
Cropping	153.8	1 041.1	4 443.9	114 488
Irrigated cropping	18.0	173.6	883.8	19 372
Irrigated perennial horticulture	3.2	34.2	150.6	488
Perennial horticulture	12.0	53.4	191.3	633
Intensive horticulture	-	0.6	6.3	49
Seasonal horticulture	-	-	3.0	49
Production forestry	-	-	0.4	7 575
Plantation forestry	-	0.3	10.2	1 284
Residential and farm infrastructure	12.5	106.6	476.7	2 832
Land in transition	7.4	18.7	18.7	51
Total	**488.6**	**3 582.1**	**15 373.5**	**634 334**

Note: Airports include public, private, military and 'airschools'. The latitude/longitude of each airport was used and concentric circles (e.g. 2km, 5km, 10km radius) was established around the point.

Source: CIE calculations based on NSW Landuse 2013 and ABS Meshblock 2016 "Primary Production" category.

Proximity to densely populated areas

The agricultural land is typically undertaken away from densely populated areas. Table 3.4 estimates the number of persons located within agricultural land in NSW. Again, the risks of injury to a person of increasing drone use is unlikely to be material.

3.4 Population density within Agricultural land

Agricultural land	Population	Area	Persons
	No	Sq km	P/sqm
Grazing native vegetation	89 427	419 752	0.000000
Grazing modified pastures	84 870	65 393	0.000001
Grazing irrigated modified pastures	1 623	1 918	0.000001
Intensive animal husbandry	986	79	0.000012

Agricultural land	Population	Area	Persons
Cropping	46 133	114 425	0.000000
Irrigated cropping	8 041	19 364	0.000000
Irrigated perennial horticulture	3 018	488	0.000006
Perennial horticulture	5 610	633	0.000009
Intensive horticulture	416	49	0.000009
Irrigated seasonal horticulture	-	-	-
Seasonal horticulture	478	49	0.000010
Production forestry	796	7 570	0.000000
Plantation forestry	1 091	1 283	0.000001
Residential and farm infrastructure	13 859	2 831	0.000005
Land in transition	447	51	0.000009
Total	**256 795**	**633 884**	**0.000000**

Source: CIE calculations based on NSW Landuse 2013 and ABS Meshblock 2016 “Primary Production” category.

Managing the risks

As discussed further in chapter 5, CASA has prepared Guidance Material *AU-STS 6: Applicant Response beyond visual line of sight Operations in Remote Australian Airspace (below 400 ft).*[40] For this use-case the risks are deemed to be low in ‘sparsely populated areas’ defined as:

- average population density of < 10 persons/km2, and
- no towns or settlements of > 100 dwellings.

Tables F.1 and F.2 provide further information on the population and area located in different parts of NSW, across the different types of agricultural lands. Based on this, there are only limited cases where agricultural land ‘breaches’ the average population density above definition. In total only 0.7 percent of land where the ABS Meshblock is defined for Primary Production, has population density of greater than 10/sqkm. Table 3.5 presents the amount of land designated for Primary Production where the number of dwellings is greater than 100. If CASA was still concerned about the risks of increasing use of drones it could choose to provide more flexibility for different types of agricultural activities or different regions in NSW (recognising the differences in population density).

40 CASA (2019), AU-STS 6: Applicant Response BVLOS Operations in Remote Australian Airspace (below 400 ft), https://consultation.casa.gov.au/regulatory-program/bvlos-app/supporting_documents/AUSTS%206%20Applicant%20Response%20%20v0.2%20For%20Consultation.pdf

3.5 Population density on Primary Production land

Persons in Meshblock	Area of Ag land	Proportion of land
.	sq km	%
150 and above	15 670	2
100-150	46 301	7
50-100	151 103	23
20-50	247 253	37
10-20	116 876	17
1-10	71 648	11
0	20 495	3
Total	**669 345**	**100**

Source: CIE calculations based on NSW Landuse 2013 and ABS Meshblock 2016 “Primary Production” category.

4 Barriers to uptake and use of drones

While drone use has a range of benefits for the agricultural sector, there are a range of factors that limit the uptake of drones.

Upfront and ongoing costs

Drone purchase

One aspect is the upfront cost of drones. The consumer grade drones are in the order of \$2 000 - \$5 000 per drone, although there are drones that are cheaper but may not have all the required functionality. Drones over 2kg could be around \$10 000. Table B.1 provides an overview of the types of drones available under the NSW Quad Bike Safety Program.

Based on consultation we understand that more sophisticated drones such as larger 'sprayer drones' (a 40-50kg drone) are more in the order of \$40 000.[41] In addition to this there are the costs associated with drone uptake.

Costs compared to other competing technologies

Drones are just one of a range of technologies that could be adopted to reduce farm costs or improve productivity. The adoption of the alternative technology depends on a range of factors including the type and size of farms, crop type, terrain landscape, and crop protection challenges.

In Australia agricultural land is large and structured, and due to the enormous land area, is usually located on easily accessible terrain. In addition, there are multiple satellites that provide data for free or at minimal cost, which can be incorporated into agricultural information systems, see table 4.1 for a comparison. Satellite data is highly reliable as the imagery is consistent and frequent, which allows time series data analysis and applying machine learning algorithms to automate and understand crop trends and predict yields.

Previous reports have indicated that drones are more cost competitive compared to other technologies for farms smaller than 20 hectares[42], however, current estimates show satellites to be significantly cheaper.

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41 Farmers could currently undertake these activities with a ute and spray tank.

42 IPSOS consulting (2017), Commercial drone adoption in agribusiness https://www.ipsos.com/sites/default/files/ct/publication/documents/2017-09/Commercial-Drone-Adoption-in-Asia-Pacific-Agribusiness.pdf, p.7

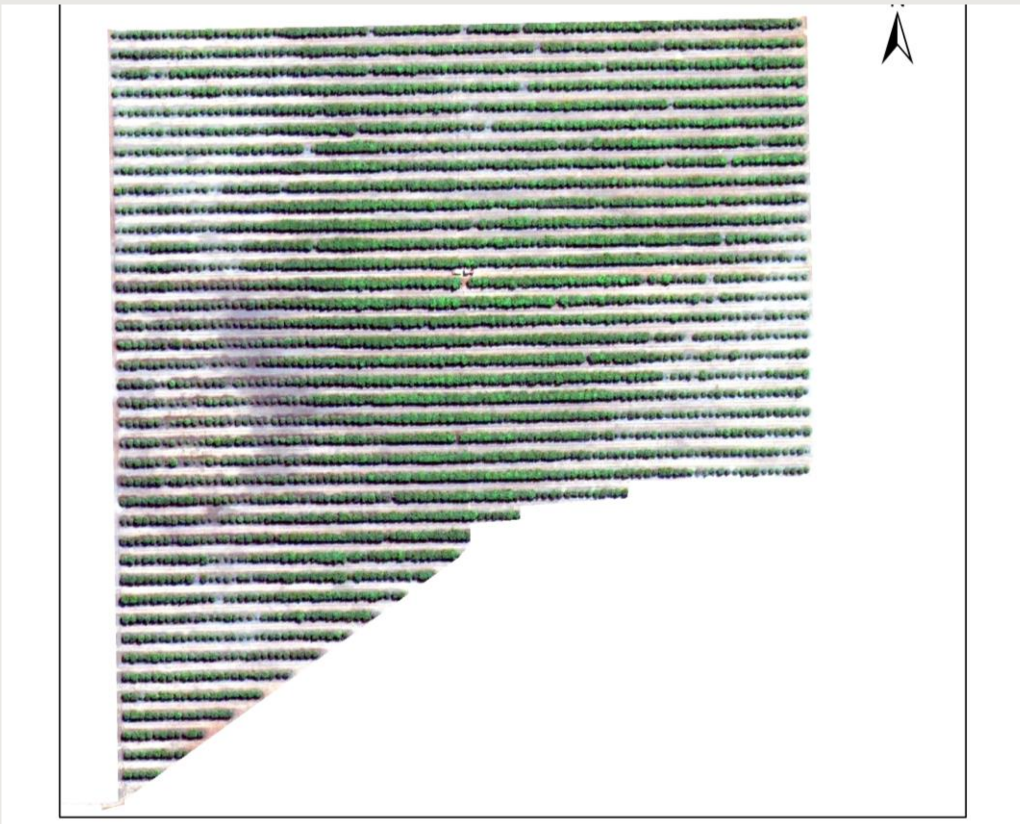
4.1 Comparison of relevant satellite platforms for agriculture

	WV-3	Sentinel-2	Geo-Eye	RapidEye	Spot 6-7	Landsat 8
Revisit time	>5 days	5 days	>3 days	1-6 days	As required	16 days
Pancromatic resolution	0.31m	n.a.	0.46m	n.a.	1.5m	15m
Multispectral resolution	1.24m	10m, 20m and 60m	1.84m	5m	6m	30m
Number of spectral bands	8 (16 with SWIR)	13	4	5	4	10
Cost	~$5.50/ha	Free	~$3.00/ha	~$0.16/ha	~$0.18/ha	Free

Source: University of New England Applied Agricultural Remote Sensing Centre

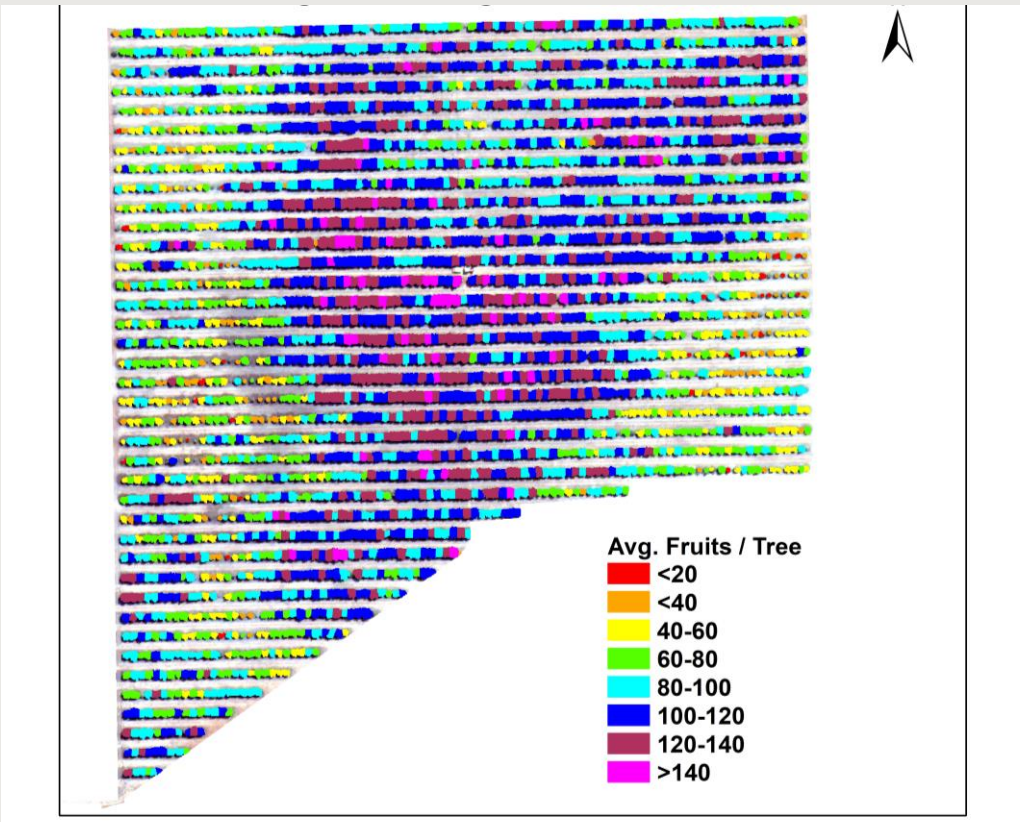
One of the key benefits of satellite is that it can be converted into yield (or other economic parameters) as the imagery is reliable, constant and can be corrected for atmospheric variation. Chart 4.2 and 4.3 show the quality of satellite imagery from the World View 3 satellite, in raw and normalized difference vegetation index (NDVI) format, which can be analysed to show the variable performance of the crop. Chart 4.4 and 4.5 show the image quality for broadacre applications.

4.2 Fruit crop raw World View 3 satellite imagery



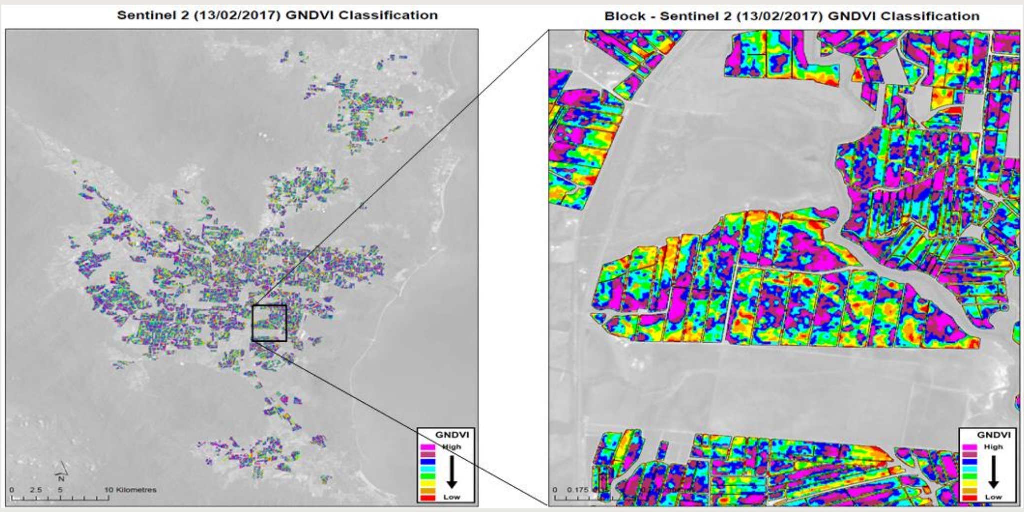
Data source: University of New England Applied Agricultural Remote Sensing Centre.

4.3 Fruit crop NDVI World View 3 satellite imagery



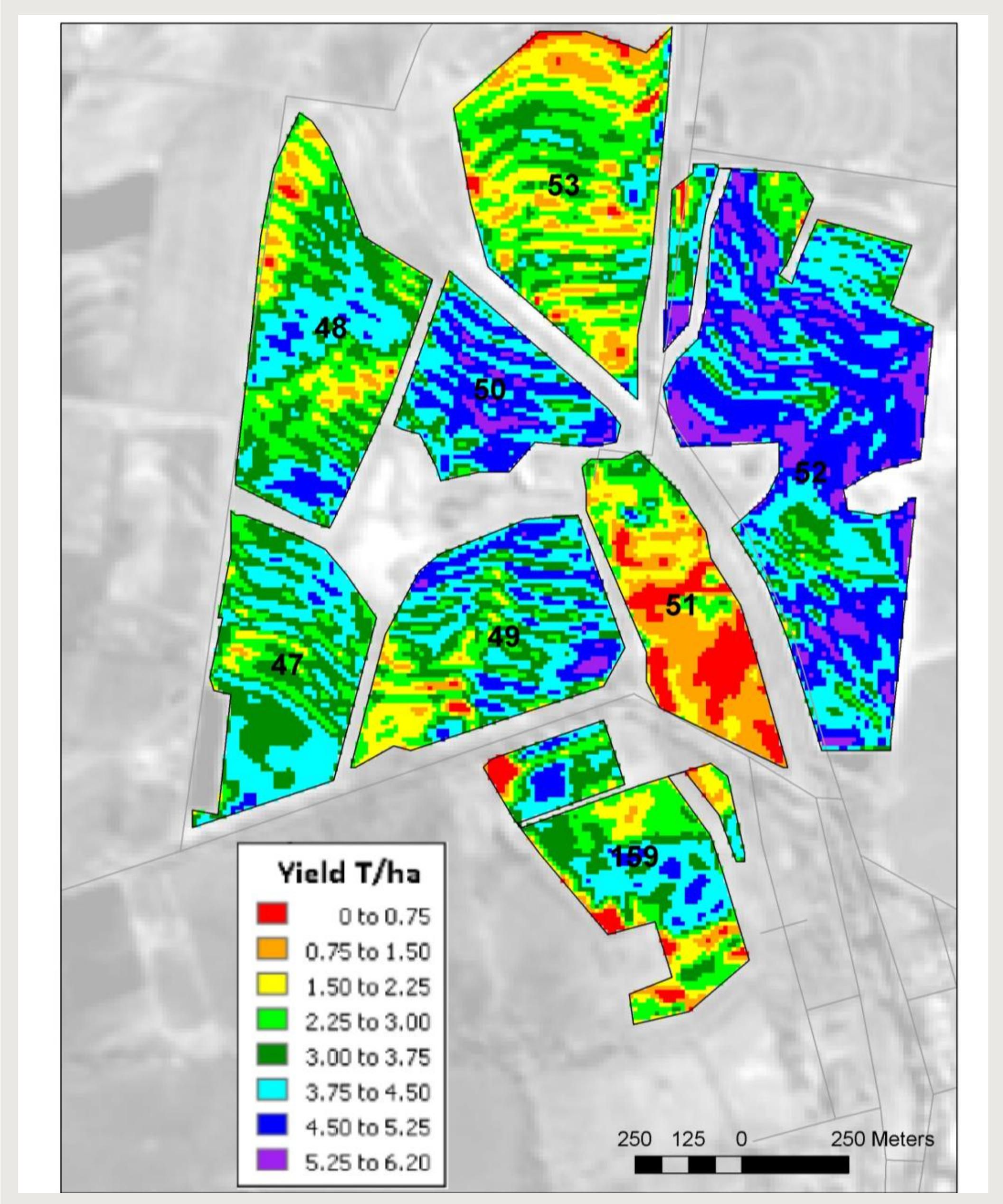
Data source: University of New England Applied Agricultural Remote Sensing Centre.

4.4 Broadacre crop GNDVI Sentinel 2 satellite imagery



Data source: University of New England Applied Agricultural Remote Sensing Centre.

4.5 Broadacre crop NDVI SPOT 5 satellite imagery



Data source: University of New England Applied Agricultural Remote Sensing Centre.

Technical/educational barriers

While the drone technology has improved and will continue to improve over time, uptake may be limited by the technical skills and time required to learn how to fly drones. However, over time we would expect that there will be a continual uptake of technologies as younger generations who have grown-up with the new technologies take on a lead role in the farms.

A similar case is likely to have occurred with the uptake of computers on farms. A 2016/17 farm survey reported that

> ….obstacles to adoption of ICT included skills, internet access, cost and availability of useful new technologies. The relative importance of these constraints varied with industry and farm size. For example, a lack of skills was most commonly reported as an impediment by the owners of small farms, particularly those in the livestock industry.[43]

Despite this the survey found that 96 per cent of Australian farmers owned/used ICT assets, and 95 per cent were connected to the internet. In comparison, the ABS reported that in November 2000 52 per cent of Australian households in country areas had a home computer.[44]

Regulatory barriers

Regulatory barriers and the cost of complying with the regulations is also likely to be a barrier to uptake.

Costs of complying with CASA requirements

As noted earlier the cost of drone registration is expected to be around $100-$160 per annum for each drone. For operators choosing to operate outside their own land or outside the Standard Operating Conditions then costs are substantial. Table 4.6 provides an indicative summary of the costs.

4.6 Direct costs of complying with CASA regulations

Item	Private Training/Support	CASA Fees
	$	$
Remote pilot licence	1 000 – 3 000 [a]	
Remote operator certificate & Setup	1 000	1 200
Extended visual line of sight	2 590	1 400
Beyond visual line of sight	10 360	2 880
Certificate renewals (every 3 years) for remote operator certificate, beyond visual line of sight & Other	0	1 200
Total	**14 950 – 16 950**	**6 680**

[a] Includes CASA fees

Source: CASA, HoverUAV

43 A 2016/17 ABARES survey indicated that 96 per cent of Australian farmers owned/used ICT assets, and 95 per cent were connected to the internet. https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/abares/ict-use-australian-agriculture.pdf

44 Australian Bureau of Statistics (2000), 8147.0 - Use of the Internet by Householders, Australia, May 2000, https://www.abs.gov.au/ausstats/abs%40.nsf/5e3ac7411e37881aca2568b0007afd16/8a1031cef42cb4e6ca25694500804435!OpenDocument

In addition to this, there is also the time required to undertake the activities. In order to obtain a remote pilot licence, the costs also relate to the time required to undertake the training. It needs to be undertaken in a specific location over a 5-day period. Apart from having to leave farms, there is also the cost of driving and accommodation for a 5-day period, see table 4.7.

4.7 Estimated extra costs of obtaining a remote pilot licence

Activity	Cost
	$
Driving to training	50-150
Time cost of 5 day training [a]	2 000
Accommodation	750
Total	**2 800 – 2 900**

[a] $50 per hour for 8 hours a day

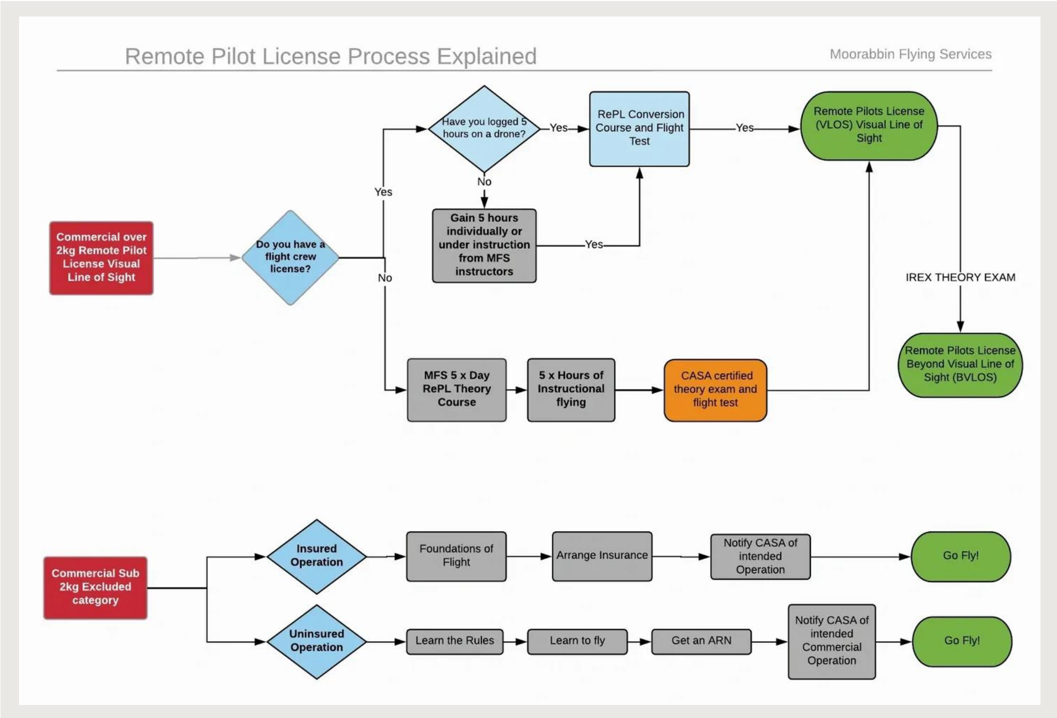
Source: The CIE.

Chart 4.8 provides an overview of the steps required to obtain a remote pilot licence.

In regards to the NSW EPA, there are requirements for training and licensing for spraying of chemicals, irrespective for any form of aerial chemical application.

Based on our interpretation of the regulatory requirements, an operator seeking to use a drone for aerial spraying would require a remote pilot licence. However, this does not appear to be a constraint given that the drones typically used for aerial spraying are over 25kg weight (closer to 40-50kg). Under CASA regulations, these drones would require a remote pilot licence.

4.8 Requirements for a remote pilot licence



Data source: Moorabbin Flying Service, https://mfs.com.au/remote-pilot-licence.

5 Options to refine regulations

Relaxation in the regulations will have the potential to allow more flexible use of existing drones or increase the uptake of new drones. Anecdotal evidence suggests that a significant amount of current drone use on farms is likely to be non-compliant (e.g. operating beyond the visual line of sight), reflecting the challenges of enforcing the regulations on farms. This is likely to reflect the smaller consumer grade drones which can be used to support day-to-day farming activities. Nevertheless, even if the regulations are restricting a smaller portion of drone use on farms, there are likely to be benefits to farmers of relaxing the regulations. Furthermore, a more permissive regulatory environment would encourage innovation in the capabilities of drones as supply increases and the market grows.

To date, CASA has assessed beyond visual line of sight applications on a case-by-case basis according to the specific operations risk assessment process, with the process individually repeated for each new application.[45]

CASA is currently developing guidance to help remotely piloted aircraft operator's certificate holders.[46] CASA has developed several draft standard scenarios to provide clarity about the minimum evidence and information requirements.

One relevant scenario for the agricultural sector includes drones operations in remote Australian airspace, defined by CASA as areas with a very low population density and negligible air activity (AU-STS 6[47] and AU-STS 7[48]*)*. The use-cases that fall within this scenario might include large scale rural surveys, agriculture and environmental monitoring in remote Australian airspace. For this standard scenario, sparsely populated areas are defined as:

- average population density of < 10 persons/km2, and
- no towns or settlements of > 100 dwellings.

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45 The specific operations risk assessment provides the minimum technical, operational and organisational requirements an operator must provide for an acceptable safety case.

46 https://consultation.casa.gov.au/regulatory-program/bvlos-app/consult_view/

47 CASA (2019), AU-STS 6: Applicant Response BVLOS Operations in Remote Australian Airspace (below 400 ft), https://consultation.casa.gov.au/regulatory-program/bvlos-app/supporting_documents/AUSTS%206%20Applicant%20Response%20%20v0.2%20For%20Consultation.pdf

48 CASA (2019), AU-STS 7: BVLOS Operations in Remote Australian Airspace (400 ft to below 5000 ft), https://consultation.casa.gov.au/regulatory-program/bvlos-app/supporting_documents/AUSTS%207%20Applicant%20Response%20%20v0.2%20For%20Consultation.pdf

There are also specific weather requirements for operating drones - 5 km visibility (forecast), 1000 ft vertically clear of actual cloud base, not operated within 5 km of thunderstorms or showers. If the weather deteriorates to these limits, the drone operations are not to be planned or, if in progress, the remote pilot in command is instructed to land the drone as soon as safely practicable (irrespective of whether a beyond visual line of sight application has been approved).

The visual 'line of sight' rules are likely to be the greatest constraint (for the Excluded Category and micro-drone). This would limit, for example, farmers from utilising drones to undertake some day-to-day activities, such as checking on stock conditions or whether there is water in troughs. Changing 'line of sight' rules would, therefore, more likely to be applicable to farmers that use and self-operate smaller drones. Some other potential relaxations of administrative aspects of the regulation include:

- Relaxing the standard operating condition requirements for drone for 2-25kg.
- Changes to licensing requirements so they become more tailored for the expected usage. Currently, applying for an exemption requires you to do the full training (even if you just want an exemption for one aspect, such as flying at night).

Regulatory options

Relaxing standard operating condition requirements

Based on discussions, a key barrier for adoption is likely to be the requirements to operate outside the standard operating conditions while under the 'excluded category'. The standard operating conditions related to flying above 400 feet, flying in poor weather or flying over populous areas are not likely to have an impact on drone use in the agricultural sector.

Operating outside the visual line of sight and at night are potential barriers for agricultural adoption of drones. There are no avenues for assessments or exemptions for a farmer to operate a drone outside of the standard operating conditions except after completing a remote pilot licence and subsequent remote operator certificate. Once a remote operator certificate is obtained, generally they will be able to fly at night but will require an additional assessment for flying beyond visual line of sight. This process can cost upwards of $13 000 and take over 2 months to be approved.

Flying a drone at night would prove beneficial to a farmer as they could use the drone to locate and check on livestock. Driving at night carries more inherent risks, especially when driving off-road on unpredictable terrain. In addition, it can allow farmers to spray at night, which is shown to be more effective than dawn.[49] Further, there is a lower risk of colliding with aircraft as they generally fly at higher altitudes at night (aircraft generally fly above 1,200 feet at night, unless landing).

49 Farming Smarter Association (2015), Project 2012F083R: Night Spraying - Pesticide Efficacy with Night Time Application (2012 – 2014), https://www.farmingsmarter.com/wp-content/files/2012/11/Night-Spraying-Herbicide-Report.pdf

The ability to fly beyond visual line of sight would significantly increase the efficiency by which farmers undertake both routine farm work and spraying. drones are particularly advantageous in hilly terrain that is not easily accessible with a vehicle. However, this means that the line of visual sight is significantly restricted due to the hilly terrain. The line of sight can be also obstructed when working with trees, such as at an orchard or plantation. Allowing flying beyond visual line of sight would not necessarily mean farmers are flying the drone large distances away from themselves, but rather flying it over surrounding hilly terrain to locate stock or spraying near trees.

It is important to note that currently there is no distinction when getting approvals for a remote operator certificate regarding whether you intend to fly on your own land or not. Therefore, a farmer will be subject to the same level of assessments and processes to fly solely on their own property as someone who intends to fly a drone close to people or over inhabited areas.

Landowners operating certificate

There is an opportunity to create an operator's certificate that is specific to the needs of farmers, who intend to only use the drone within the boundaries of their private property and below 400ft above ground level. Within this category, the regulations could be refined to include:

- Allowing operation beyond visual line of site without the need for CASA approval for smaller drones (less than 25kg).
- Reducing the timeframes for beyond visual line of sight applications to provide flexibility to farmers (given changing climatic conditions) by performing one risk assessment of the whole property and allowing unlimited use going forward
- Allowing operation at night.

The certificate would need to be structured to accommodate the primary concern of CASA regulation, being airspace threat mitigation. As part of the application process, CASA could undertake a risk assessment for the boundaries of the property to determine any potential threats. The outcome of this assessment can be incorporated into the procedures and manuals for the property.

The pilot should still receive an adequate minimum level of training and technical guidance, as currently administered by the remote pilot licence training. Discussions with stakeholders indicated that the remote pilot licence training is skewed towards theoretical activities with limited practical flying experience. In addition, some training programs do not teach the use of the screen connected to the controller, which is typically how pilots would operate the drone. Therefore, it would be appropriate to tailor the remote pilot licence training to a more farm use specific curriculum and training exercise.

Upon completion of the remote pilot licence training and risk assessment by CASA, the landowner should be free to use drones within their property while adhering to the set regulations and procedure.

In table 5.1 we assume that the remote pilot licence training could be condensed from 5 days to 2 days, with a portion completed online. In addition, the remote operator certificate training would be shortened to and tailored specifically to agricultural use, resulting in a cost reduction. This could lead to potential savings of $2 280 for certification to fly at night.

The beyond visual line of sight costs could be reduced if permission to operate the drone is within the bounds of the property with consideration for nearby airfields and restricted airspace. This could result in savings of up to $9 240 per beyond visual line of sight assessment. Significantly reducing the costs for attaining a certificate would encourage the uptake of drones in agriculture. Furthermore, it would encourage illegal drone usage to operate within the regulations set by CASA.

5.1 Application costs for Current vs Agricultural certificates

Activity	Current	Agricultural
	$	$
remote pilot licence	3 300	2 300
remote operator certificate	2 280	1 000
Total to fly at night	**5 580**	**3 300**
beyond visual line of sight	13 240	4 000
Total to fly beyond visual line of sight	**18 820**	**7 300**

Source: CASA.

The regulations for flying at night and beyond visual line of sight could be relaxed based on meeting certain criteria that would classify the farm as low risk. A determination for such farms could be based on:

- Population density of the surrounding area (such as the scenario envisaged in Guidance Material *AU-STS 6).*
- Proximity to restricted airspace or within certain flight paths
- Type of primary agricultural activities undertaken, e.g., livestock vs. broadacre
- Locations within the property, e.g., not within 100m of the nearest neighbouring property or public roads
- A restriction on the size of drone could be determined based on the risk classification of the farm.

In the following section we quantify the potential benefits and costs of increased drone uptake. We characterise a low and high scenario, which imply a partial implementation of the landowner's certificate and a full implementation of the landowner's certificate respectively.

A partial implementation could entail simplifying the remote operator certificate application process, resulting in lower costs to fly at night and a subsequent increase in drones used on farms

A full implementation would involve a significant reduction in the processes and costs for a beyond visual line of sight application, which would increase the use of drones in agriculture.

Quantifying the potential benefits and costs

Baseline drone use

The number of drones in Australia is not known with accuracy. Estimates of the number of drones used for recreational purposes range from 50 000 to hundreds of thousands. Some of these drones may also be used for 'commercial' use, such as on farms, where enforcement of the regulations is more challenging. Drone registration requirements are changing, and, in the future, there will be more robust information about the number of drones operating in the country.

While the extent of drone use is not known with certainty, the evaluation of regulatory reforms considered in this chapter provides some guidance on the potential gains versus the costs of relaxing some of the regulatory requirements. This chapter considers the merits of alternative regulatory reforms.

An indication of the number of commercial drones can be estimated based on the number of people who have either a remote pilot licence or a remote operator certificate. As of October 2020, there were over 2 100 remote operator certificate holders in Australia (of which 30 per cent are located in NSW) and close to 17 000 remote pilot licences in Australia, see table 5.2. The remote operator certificates have grown by around 25 per cent per annum since 2015-26, with the growth rates in remote pilot licences around 50 per cent per annum.[50]

5.2 Remote Operator Certificates

Number of	2015-16	2016-17	2017-18	2018-19	2019-20	Current
.	no.	no.	no.	no.	no.	no.
Remote Operator Certificates						
Initial issue RAP operator certificates	419	474	332	380	448	
Subsequent issue	136	392	444	381	400	
Variation	62	74	62	66	69	
Total	617	940	838	827	917	
Current RAP operator certificates (Australia)	688	1 070	1 357	1 628	1 952	2 108
RAP operator certificates (NSW)						644
Remote Pilot Licences						
Initial issue remote pilot licences	1 996	2 381	3 034	4 149	3 369	Not available
Current remote pilot licence holders (Australia)	3 282	5 664	8 698	12, 845	16 842	Not available

Source: CASA

50 Aviation Occurrence Statistics – Australian Transport and Safety Bureau (Transport Safety Report), 4 Nov 2020

The figures in the table above are likely to significantly underestimate the number of drones being used by the farming sector in NSW. Further, anecdotal evidence suggests that currently around 80 per cent of drone use in the farming sector does not comply with the regulations. Due to this uncertainty around drone usage, our baseline estimates will use the total number of farms which could accommodate drones, reduced by an estimated uptake percentage. See the following section on expected benefits for more details.

Drone usage on farms not complying with regulations is likely to relate to the visual line of sight requirements, rather than other standard operating condition requirements such as the flying above 400 feet where there are limited gains to the farmer from undertaking this activity. The technical 'breaches' of the regulations is likely to reflect the challenges in enforcing the regulations in remote areas where landholders are only operating drones within their farm boundaries.

Expected Benefits

The key benefits associated with these changes are discussed below.

Reduction in on-farm deaths/injuries

As reported in table 2.2, there were 39 quad bike fatalities since 2011, resulting in an average of 3.54 fatalities per year. For the low scenario we assume that the uptake of drones will decrease fatalities by 1 per year and for the high scenario we assume fatalities will decrease by 2 per year. We assume the growth rate of drone uptake is 5 per cent per year. We estimate the cost savings using the value of life figures from the Commonwealth Office of Best Practice Regulation, that reports the value of a statistical life as $4.9m[51].

This results in a potential benefit of $5m to $9m in year 1, with a total benefit of $52m to $104m over 20 years.

5.3 Cost savings of reducing quad bike fatalities

Scenario	Year 1	Year 2	Year 3	Year 4	...	Year 20
	$m	$m	$m	$m		$m
Low	5	5	6	7	...	12
PV						**49**
High	10	10	11	11	...	15
PV						**74**

Note: $2021, discount rate of 7 per cent

Source: The CIE

51 Department of the Prime Minister and Cabinet (2019). Best Practice Regulation Guidance Note Value of Statistical Life, https://www.pmc.gov.au/sites/default/files/publications/value-of-statistical-life-guidance-note_0_0.pdf

The use of drones would also contribute to a reduction in injuries suffered from using motorcycles, quad bikes, horses as well as falling from ladders and other buildings. The number of riding injuries and falling incidents are shown in table 2.1 and 2.3. This results in an average amount of injuries per year as a result of riding or falling of 522.

- We assume that of the 522 injuries per year, 30 per cent are minor injuries which will lead to short-term disability and 5 per cent are severe injuries which will lead to long-term disability.
- We have assigned a disability weighting of 0.13 for short-term injuries, based on the World Health Organisation disability weights.[52] For reference, a short-term ankle fracture scores 0.196, an open wound scores 0.108 and a sprain scores 0.064. The disability weighting is then applied the value of a statistical life to estimate the cost of a long-term injury.
- We have assigned a disability weighting of 0.2 for long-term injuries. For reference, a long-term femur injury scores 0.272, a fractured skull scores 0.350 and an amputated arm and leg are 0.257 and 0.300 respectively.
- We assume that drones could prevent 5 per cent of injuries in the low scenario and 15 per cent of injuries in the high scenario.

We estimate that drones could reduce short-term and long-term injuries in the range of $6m to $18m in year 1, with a 20 year total benefit of $66m to $199m, see table 5.4.

5.4 Cost savings of reducing short-term and long-term injuries across Australia

Scenario	Year 1	Year 2	Year 3	Year 4	...	Year 20
	$m	$m	$m	$m		$m
Low	6	6	6	6	...	6
PV						**66**
High	19	19	19	19	...	19
PV						**199**

Note: $2021, discount rate of 7 per cent

Source: The CIE

Reductions in operating costs and improved yield

We can estimate the potential benefits of using drones for routine farm work, such as checking livestock, by extrapolating the farm cost savings detailed in table 2.6 and 2.7 and by assessing the potential savings from a reduction in farm injuries. Table 5.5 shows the number and types of farms in NSW where drone usage could apply. For routine farm work, we assume this would be most beneficial for farms with livestock.

52 World Health Organisation (2004), Global burden of disease 2004 update: Disability weights for diseases and conditions, https://www.who.int/healthinfo/global_burden_disease/GBD2004_DisabilityWeights.pdf?ua=1

5.5 Number and type of farms in NSW

Industry classification	Number of farms	per cent of Region
.	no.	%
Beef Cattle Farming (Specialised) [a]	7 009	28.6
Sheep Farming (Specialised) [a]	3 786	15.4
Grain-Sheep or Grain-Beef Cattle Farming [a]	3 037	12.4
Sheep-Beef Cattle Farming [a]	2 593	10.6
Other Grain Growing	1 904	7.8
Horse Farming [a]	716	2.9
Dairy Cattle Farming [a]	709	2.9
Other Fruit and Tree Nut Growing	635	2.6
Vegetable Growing (Outdoors)	631	2.6
Grape Growing	524	2.1
Other	2 966	12.1
Total livestock farms	**17 850**	**73**
Total agriculture	**24 509**	**100**

[a] denotes farms that could use drones for routine farm work such as mustering and livestock management

Source: https://www.agriculture.gov.au/abares/research-topics/aboutmyregion/nsw#agricultural-sector

As discussed in section 3, a farm that adopts drone usage for routine farm work could save approximately $5 866 and $9 777 in time costs and $91 and $182 in fuel costs. We have applied this saving to the low and high scenarios to the total livestock farms (beef, sheep, horse, dairy) in NSW, totalling 17 850 farms. We assume a 50 per cent uptake of total benefit in year 1, with a 'year on year' growth rate of 5 per cent. This results in cost savings across Australia of $6m to $9m in year 1, with a 20 year total benefit of $94m to $157m, see table 5.6.

5.6 Routine work cost saving per year across NSW

Scenario	Year 1	Year 2	Year 3	Year 4	...	Year 20
	$m	$m	$m	$m		$m
Low	6	6	7	7	...	15
PV						**94**
High	10	10	11	11	...	25
PV						**157**

Note: Year 1 uptake is 50 per cent of max uptake, $2021, discount rate of 7 per cent

Source: The CIE, Fuelcheck.

There is a wide range of farms where drones used for mapping and spraying could be utilised, see table 5.7. Reports have shown that broadacre farmers are expecting yields to increase by up to 5 per cent from the use of drones. In addition, yield increases of up to

10 per cent are being reported by green vegetable, orchards, banana plantations and olive groves[53].

5.7 Different farm activities where mapping and spraying drones could apply

Farm types/activities	Number farms	Area (sq km)
	no.	sq km
2.1.0 Grazing native vegetation	386 224	429 920
3.2.0 Grazing modified pastures	138 105	65 633
3.3.0 Cropping	84 498	111 881
3.4.0 Perennial horticulture	11 468	615
3.5.0 Seasonal horticulture	990	43
4.1.0 Irrigated plantation forestry	93	21
4.2.0 Grazing irrigated modified pastures	3 278	1 176
4.3.0 Irrigated cropping	8 244	17 721
4.4.0 Irrigated perennial horticulture	2 644	654
4.5.0 Irrigated seasonal horticulture	1 536	84
4.6.0 Irrigated land in transition	1	0
5.1.0 Intensive horticulture	1 456	46
5.2.0 Intensive animal husbandry	3 471	323
5.4.0 Residential and farm infrastructure	116 856	7 648

Source: https://datasets.seed.nsw.gov.au/dataset/nsw-landuse-2013

The impacts of increasing yields from drone usage would be significant in NSW due to the high gross value of agricultural production, see table 5.8.

5.8 Value of agricultural production in NSW for the year 2018-2019

Industry	Gross value agricultural production
	$m
Broadacre crops – Total	2 514
Hay – Total	329
Nurseries, cut flowers or cultivated turf – Total	523
Fruit and nuts (excluding grapes) – Total	856
Fruit and nuts - Grapes – Total	315
Vegetables for human consumption – Total	495
Vegetables for human consumption - Lettuces - Total	17
Livestock products – Total	1 999
Livestock slaughtered and other disposals – Total	4 648
Total	**11 695**

Source: https://www.abs.gov.au/statistics/industry/agriculture/value-agricultural-commodities-produced-australia/latest-release.

53 Trowbridge G (2017), The drone Revolution and Australian Agriculture – Part Two: Case Studies and Practical benefits, https://www.futuredirections.org.au/publication/drone-revolution-australian-agriculture-part-two-case-studies-practical-benefits/

For our analysis we categorised farmland into vegetable, fruit and nut farms.

- For our low scenario, we assume that yields would increase by 5 per cent and the expected application rate of 3 per cent
- In our high scenario, we assume that yields would also increase by 5 per cent and the expected application rate would increase to 6 per cent

This results in potential savings in NSW of between $2m to $5m in year 1 up to $37m to $79m in year 20.

5.9 Yield increase per year in NSW

Scenario	Year 1	Year 2	Year 3	Year 4	...	Year 20
	$m	$m $	$m	$m		$m
Low	2	2	3	3	...	6
PV						**37**
High	5	5	6	6	...	13
PV						**79**

Note: $2021, discount rate of 7 per cent

Source: The CIE.

Potential costs of increased drone uptake

Cost of purchasing drones

There would be a cost to farmers from the increase in the number of drones purchased. We anticipate that the induced demand is more likely to relate to farmers seeking to pilot the drones for their farm use. This is likely to be smaller drones such as those provided by the NSW Quad Bike Safety Program. The price of each of these drones is provided in table B.1.

The overall cost would depend on the extent of uptake of new drones. At this stage there is limited information to understand the potential uptake (e.g. trends in uptake in other jurisdictions). Table 5.10 shows the costs for the uptake of drones for routine farm work. We assume a cost of $2 500 per drone, an initial uptake of 6 per cent of farms which corresponds to 1 000 drones and a 5 per cent growth in uptake thereafter. The low and high scenarios do not affect the costs as they estimate variable usage for the same number of drones.

5.10 Cost of drones used for routine farm work

Scenario	Year 1	Year 2	Year 3	Year 4	...	Year 20
	$'000	$'000	$'000	$'000		$'000
Cost per year	2 500	125	131	138	...	301
PV						**4 096**

Note: $2021, discount rate of 7 per cent applied

Source: The CIE.

Table 5.11 shows the costs for the uptake of drones used for spraying. We assume a cost of $21 500 per drone, an initial uptake of 3 per cent for the low scenario which corresponds to 50 drones and 6 per cent which corresponds to 107 drones for the high scenario. The uptake has a 5 per cent growth rate thereafter.

5.11 Cost of drones for used for spraying

Scenario	Year 1	Year 2	Year 3	Year 4	...	Year 20
	$'000	$'000	$'000	$'000		$'000
Low	1 078	54	57	59	...	130
PV						**1 766**
High	2 309	115	121	127	...	278
PV						**3 783**

Note: $2021, discount rate of 7 per cent.
Source: The CIE.

Increased risk of injuries

The anecdotal evidence regarding the widespread use of drones shows limited evidence that these activities have substantially increased the risks to other aircraft or the wider community. As previously presented in table 3.1, the current number of 'incidents' related to drones is small. Most of these incidents are likely to be associated with operations in more densely populated areas. As indicated in chapter 4 the vast majority of agricultural land is located outside of density populated areas or close to airports. Therefore, if there was an uptake in drone usage outside the standard operating condition requirements within a landowner's property, the level of additional risk would be very small.

A Existing drone regulation in Australia

Commercial drone operator requirements

Drone registration

As of 28 January 2021, registration for drones, or remotely piloted aircraft, flown for business or as part of your job is required. drones are exempt from registration if they are not intended to be flown or are only being flown for sport and recreation. At this stage drone registration is free and valid for 12 months.

Drone accreditation

As of 28 January 2021, drone operator accreditation is required for anyone who intends to fly a drone or drone for business or as part of your job. Operator accreditation is free, can be completed online and is valid for 3 years.

This only applies to operators that fly an excluded category or micro-drone for business or as part of your job and it weighs:

- 250 g or less (micro-drone)
- more than 250 g but no more than 2 kg (very small drone)
- more than 2kg but no more than 25 kg and you only fly it over your own land (small drone).

To get an operator accreditation, you need:

- to be 16 or older
- a myCASA account
- proof of identity, such as an Australian passport, Australian birth or citizenship certificate, or ImmiCard
- an individual aviation reference number
- an understanding of the standard operating conditions and the rules that apply to excluded category and micro-drone
- to pass an online quiz
- download and/or print your accreditation certificate from myCASA after you pass the quiz.

You do not need a drone operator accreditation if you hold a remote pilot licence or if you only fly you drone for sport or recreation.

You can be fined if you fly a drone for business or as part of your job without a valid drone operator accreditation or remote pilot licence. The fine is up to $11 100.

Excluded category and Micro drone

Some drone operators are excluded from needing a remote pilot licence or remotely piloted aircraft operator's certificate to fly a drone for business or as part of your job. This might include activities such as:

- selling photos or videos taken from a drone
- inspecting industrial equipment, construction sites or infrastructure
- monitoring, surveillance or security services
- any drone activities on behalf of your employer.

There are two types of excluded category drone:

- very small (more than 250 g but no more than 2 kg)
- small (more than 2 kg, but no more than 25 kg), where you only fly it over your own land.

A micro-drone is a drone that weighs 250 g or less that is flown for business or as part of your job.

If you fly an excluded category drone, you must follow the excluded drone safety rules, known as the 'standard operating conditions' on top of the drone safety rules that apply to all drones.

Landowner or private landholder excluded category

You can fly a small drone or drone that weighs more than 2 kg but not more than 25 kg over your own land for business or as part of your job provided you do not accept any type of payment or reward for the services. Examples of the types of operations that may be conducted under this excluded category include:

- aerial spotting
- crop, livestock or equipment inspections
- land surveying
- agricultural operations
- carrying cargo.

Remote Pilot Licence

A remote pilot licence allows you to fly remotely piloted aircraft for business or as part of your job in circumstances that need specialist training. You must apply for a remote pilot licence if you want to fly: a drone larger than 2 kg for commercial operations or outside the drone safety rules. You must also apply for a remote operator certificate or be employed by an existing remote operator certificate holder as a remote pilot. remote pilot licences do not expire. To receive a remote pilot licence you need to complete the required training, which is based on your aviation experience. Experienced applicants can forgo the theoretical element of the process.

Remotely piloted aircraft operator's certificate

A remotely piloted aircraft operator's certificate allows your business to operate as a drone service provider, earning money for hire or reward, employ remote pilots and fly outside the drone safety rules – i.e. the standard operating conditions.

Remote operator certificate holders can seek approval from CASA to fly:

- Using extended line of sight or beyond line of sight
- Closer than 30m to people
- In restricted airspace
- At night

The first remote operator certificate is valid for 12 months with subsequent renewals valid for up to three years. Applications can take up to 70 business days to process. This will vary based on the complexity of the application and proposed operation.

B Quad Bike Safety Improvement Program

The NSW Quad Bike Safety Improvement program was launched in June 2016 and includes a small business safety rebate and training package. The Program provides farmers and their workers with rebates to implement harm prevention measures in the workplace.

Eligible farm businesses can access two rebates worth up to $1 000 each for any combination of the following safety solutions:

- up to $1 000 for each agricultural side-by-side vehicle (SSV)
- up to $500 for each Quadbar TM or ATV Lifeguard Operator Protective Device (OPD)
- up to $90 for each helmet compliant to AS/NZS1698:2006, NZS8600:2002, UNECE22.05
- maximum of $500 for one new drone from a list of eligible models

Workers employed by an eligible farm business can access a rebate for a maximum of one helmet per worker. Applicants must attend an eligible educative interaction with SafeWork NSW on quad bike safety in rural workplaces prior to the purchase of eligible safety solutions.[54]

From 27 February 2019, the quad bike safety rebate included one drone rebate per eligible business.[55] Table B.1 lists the different types of drones available under the program.

B.1 Drones available under NSW Quad Bike Safety Program

Drone type	Retail price	Max Transmission Distance	Flight time	Source
Sub 2kg eligible drones				
DJI Phantom 4 Pro V2.0	2 399	5 000 (CE)	30	https://www.digidirect.com.au/dji-phantom-4-pro-v2-0?utm_source=RQmedia&utm_medium=google-free-shopping-listings
DJI Mavic 2 Pro	2 499	5 000 (CE)	31	https://www.digidirect.com.au/dji-mavic-2-pro
DJI Mavic Mini	599	4 000	30	https://www.digidirect.com.au/dji-mavic-mini

54 https://www.business.gov.au/grants-and-programs/quad-bike-safety-improvement-program-nsw

55 https://www.safework.nsw.gov.au/resource-library/agriculture,-forestry-and-fishing-publications/quad-bike-pubs/quad-bike-safety-improvement-program-FAQs

Drone type	Retail price	Max Transmission Distance	Flight time	Source
Parrot Anafi Work	1 487	4 000	25	https://dronesforhire.com.au/shop/drone/Parrot-Anafi-Work
Parrot Bebop [discontinued?]				
Parrot Disco FPV [discontinued?]	1 299	2 000	45	https://shop.spheredrones.com.au/products/parrot-disco-fpv-includes-disco-skycontroller-2-cockpit-glasses?variant=28028411216
Parrot Disco Pro [discontinued?]	6 875	2 000	30	https://shop.spheredrones.com.au/products/parrot-disco-pro-ag?variant=39409032656
Yuneec Typhoon H3	2 549 (USD)	2 000	25	https://us.yuneec.com/typhoon-h3.html
FIMI X8 SE	749	5 000	33	https://www.getdget.com.au/xiaomi-fimi-x8-se-4k-5km-gps-wifi-fpv-foldable-rc-drone-with-3-axis-gimbal-33mins-flight-time-rtf-white.html
Over 2kg eligible drones				
DJI Inspire	4 699	7 000	27	https://www.auselectronicsdirect.com.au/dji-inspire-2.0-quadcopter-drone-with-remote-contr?gclid=CjwKCAiAm-2BBhANEiwAe7eyFMmC7aBt_vA2u8QGhU2k80s57MZljbmQx29s3yvDToKGLR79Vwe-KhoCEnoQAvD_BwE
DJI Matrice (200, 210)	11 340	5 000 (CE)	34	https://www.auselectronicsdirect.com.au/dji-matrice-210-v2-drone
XAG (P10, P20, P30)	21 500	not disclosed	20	https://www.xagaustralia.com.au/product-page/p20-rtk-plant-protection-uas

Note: CE is the power level of transmission allowed in Australia. In the USA they can be more powerful which extends the range (FCC classification)

Source: Various.

B.2 Quad Bike Safety Rebate Applications 2016 - Jan 2021

Rebate item	Paid rebate applications
	n
Side-by-side vehicles	2 808
Operator Protective Devices	995
Helmets	753
drones	92

Note: drones were added to the rebate program on 27 Feb 2019, so drone figures are Feb 2019 – Jan 2021 inclusive.

Source: SafeWorkNSW.

Other data from Safework SA on quad bike injuries indicates that:

- on average, 15 per year die in Australia from accidents and a further 1,400 serious injuries associated with quad bikes.
- 46 per cent of the fatalities happen at work, 50 per cent recreational and 4 per cent unknown

- around 75 per cent occur on farms.
- young people aged between 10 and 24 years have a much higher risk of injury and adults aged 60 years and over have a much higher risk of being fatally injured.[56]

In addition, six people present to hospital each day as a result of quad bike related injuries.[57]

56 https://www.safework.sa.gov.au/industry/agriculture/quad-bikes#:~:text=There%20is%20an%20average%20of%2015%20fatalities%20every,a%20much%20higher%20risk%20of%20being%20fatally%20injured.

57 https://www.productsafety.gov.au/news/quad-bike-fatalities-have-almost-doubled-in-2020-compared-to-last-year

C Valuing loss of life and injury

To be fully incorporated into the cost-benefit analysis, the health impacts of increased drone use on farms need to be valued. This will be associated with both improvements in health outcomes by using drones for currently higher risk activities, as well as, a potential reduction in health outcomes associated with drone accidents.

While approaches used to estimate the value of lives may be inaccurate, inclusion of some cost to society associated with the loss of life is an improvement over complete exclusion.

There are recognised approaches to estimating the value of a statistical life (discussed below) which can be used in conjunction with the number of lives estimated to be lost in an incident.

Value of a statistical life

The two major approaches to calculate the value of a statistical life are the human capital approach and the willingness to pay approach. A comparison of the two approaches is provided in table C.1.

TfNSW (2013) recommends use of the willingness to pay approach because of challenges in using the human capital approach:

- Public policy is concerned with measuring what individuals are willing to pay to reduce the possibility of accidents rather than the value of what is lost
- The human capital approach, because it is based on future income and productivity, cannot be used for non-working individuals
- It does not allow for pain and suffering[58]

C.1 Comparison of approaches to valuing human life

Advantages	Disadvantages
Human Capital	
Data reliable and readily available.	Values some lives higher than others due to labour market imperfections, such as wage discrimination. If simplistically applied, the very young and old are undervalued.
Consistent and transparent results.	Overestimates costs in an economy with less than full employment.

58 TfNSW 2013, *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*, NSW Government, March.

Advantages	Disadvantages
Simple to use.	Does not reflect a key reason for investment in safety: aversion to death/injury rather than income protection.
	Ignores the loss of 'joy of life', while values for pain, suffering and grief are often arbitrary.
	Actuarial uncertainties regarding life expectancy and earnings.
	Selection of the appropriate discount rate is controversial.
Willingness to Pay	
Comprehensive.	People have difficulty understanding and valuing small risks (generally less than 1 in 10 000).
Incorporates subjective welfare costs.	Individual perceptions of risk may differ.
Reflects individual preferences.	Willingness to pay does not necessarily imply ability to pay.
	Differences exist between people's expenditure patterns/actions and their real preferences.
	Aggregating individuals' willingness to pay may not produce the social willingness to pay, as individuals may ignore external social costs.
	Difficulty in applying concept of a statistical life rather than a particular life.
	Methodological difficulties (eg. inaccurate responses) and strategic behaviour in surveys.
	Equity is not taken into account, as results are income-related.
	Discrepancy in results using willingness to pay and willingness to accept approaches.
	Value will change with incomes and variations in safety..

Source: BTE 2011.

The Commonwealth Office of Best Practice Regulation (OBPR 2008) also recommends using willingness to pay. For our analysis we use the statistical value of life from the Commonwealth Office of Best Practice Regulation of $4.9m[59]

General literature estimates the value of a statistical life at between $1.9m and $9.8m.[60]

59 Department of the Prime Minister and Cabinet (2019). Best Practice Regulation Guidance Note Value of Statistical Life, https://www.pmc.gov.au/sites/default/files/publications/value-of-statistical-life-guidance-note_0_0.pdf

60 TfNSW 2013, *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*, NSW Government, March.

Human capital approach

The human capital approach tends to measure the direct and indirect losses realised when a life is lost.[61] The value of labour includes:

- formal workplace productivity lost to premature death, temporary injury and permanent disability; and
- losses in household production due to premature death, temporary injury and permanent disability.

Estimates of labour lost in BTE (2001) are based on ABS age-and gender-specific life expectancy tables, employment rate data, average wage and salary data, gross wages and salaries data and time use survey data.[62]

Most applications of the human capital approach do not incorporate non-economic values. However, suffering and loss of quality of life are real costs and should be incorporated where possible. BTE (2001) used compensation data from the Victorian Transport Accident Commission as a proxy for estimating loss of quality of life.[63] Quality of life measures may include:

- pain and suffering of the injured
- inability to return to their way of life before the injury
- permanent disability
- uncertainty about recovery
- loss of ability to play sport, drive a car or perform everyday tasks
- future quality of life, such as having to abandon career or family plans.

Other costs that may be included in the human capital approach include medical expenses, long term care, coronial expenses and premature funeral costs. Table C.2 sets out estimated costs using the human capital approach.

C.2 Accident cost per person: Human Capital Approach

Cost components	Fatality	Serious injury	Other injuries
	$	$	$
Ambulance	452	452	245
Hospital in-patient	2 442	9 769	50
Other medical	1 811	14 665	71
Long-term care		110 964	
Labour in the workplace	626 786	29 636	0
Labour in the household	521 405	24 712	0
Quality of life	575 919	61 789	3 284
Insurance claims	18 005	31 728	1 897
Criminal prosecution	2 323	673	83

61 BTE 2001, *Economic Costs of Natural Disasters in Australia*, Report 103, Canberra.

62 BTE 2001, *Economic Costs of Natural Disasters in Australia*, Report 103, Canberra.

63 Ibid.

Cost components	Fatality	Serious injury	Other injuries
Correctional services	12 770	0	0
Workplace disruptions	12 118	12 455	807
Funeral	2 550	0	0
Coroner	838	0	0
Vehicle costs			
Repairs	12 354	10 323	10 187
Unavailability of vehicles	1 567	1 391	734
Towing	368	327	172
General costs			
Travel delays	71 534	86 577	113
Insurance administration	45 841	55 483	72
Police	9 223	3 169	48
Property	1 485	1 797	3
Fire	485	587	1
Total costs	**1 920 276**	**456 496**	**17 768**

Source: TfNSW 2013, *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*, NSW Government, March.

Willingness to pay approach

The willingness to pay approach measures the total intangible losses associated with a death or injury. The values are estimated using stated preference surveys and reflects what individuals are willing to pay rather than the value of what is lost.

TfNSW (2013) recommends the following values for fatality and injury costs in transport projects and policies, based on a willingness to pay approach (table C.3).

C.3 Fatality and injury costs, Willingness to Pay Approach, 2011-12 $

Risk categories	Urban	Rural	Weighted Average
	$	$	$
Value of fatality risk reduction	5 998 216	6 579 556	6 303 354
Value of serious injury risk reduction	440 571	613 576	466 614
Value of other injury risk reduction	73 070	104 233	77 761
Property damage only	8 102	8 102	8 102
Where a breakdown of different types of crashes is not available for a project, injury risk reduction	105 307	150 439	112 101
Average cost of crash – Rural (used in REVS model)		355 859	
Average cost of crash - Urban	92 670		

Source: TfNSW 2013, *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*, NSW Government, March.

D Airports in NSW

D.1 Airports in NSW

SA4	Number airports	SA4 Area
	no.	Sqkim
Central Coast	2	1 681
Sydney - City and Inner South	1	66
Sydney - Inner South West	1	164
Sydney - Northern Beaches	1	254
Sydney - Outer South West	2	1 278
Sydney - Outer West and Blue Mountains	2	3 968
Sydney - South West	3	539
Capital Region	7	51 896
Central West	9	70 297
Coffs Harbour - Grafton	2	13 230
Far West and Orana	16	339 364
Hunter Valley exc Newcastle	7	21 491
Illawarra	1	1 539
Mid North Coast	5	18 852
Murray	8	97 798
New England and North West	10	99 146
Newcastle and Lake Macquarie	1	871
Richmond - Tweed	3	10 271
Riverina	7	56 985
Southern Highlands and Shoalhaven	1	6 704
Total	**89**	**796 393**

Source: Wikipedia, List of airports in New South Wales, https://en.wikipedia.org/wiki/List_of_airports_in_New_South_Wales accessed 20 May 2021.

D.2 Airports in NSW

Region	Airport name	Type	SA4
Somersby	Gosford Airport	Public	Central Coast
Warnervale	Warnervale Airport	Public	Central Coast
Mascot, Sydney	Sydney Airport	Public	Sydney - City and Inner South
Bankstown, Sydney	Bankstown Airport	Airschool	Sydney - Inner South West
Palm Beach, Sydney	Palm Beach Water Airport	Public	Sydney - Northern Beaches
The Oaks	The Oaks Airfield	Private	Sydney - Outer South West

Region	Airport name	Type	SA4
Wedderburn, Sydney	Wedderburn Airport	Private	Sydney - Outer South West
Glenbrook	RAAF Base Glenbrook	Military	Sydney - Outer West and Blue Mountains
Richmond,	RAAF Base Richmond	Military	Sydney - Outer West and Blue Mountains
Camden	Camden Airport	Public	Sydney - South West
Holsworthy, Sydney	Holsworthy Barracks	Military	Sydney - South West
Sydney	Western Sydney Airport		Sydney - South West
Cooma	Cooma - Polo Flat Airport	Public	Capital Region
Cooma	Cooma – Snowy Mountains Airport	Public	Capital Region
Goulburn	Goulburn Airport	Public	Capital Region
Gundaroo	Gundaroo Airport	Private	Capital Region
Merimbula	Merimbula Airport	Public	Capital Region
Moruya	Moruya Airport	Public	Capital Region
Young	Young Airport	Public	Capital Region
Bathurst	Bathurst Airport	Public	Central West
Condobolin	Condobolin Airport	Public	Central West
Cowra	Cowra Airport	Public	Central West
Forbes	Forbes Airport	Public	Central West
Lake Cargelligo	Lake Cargelligo Airport	Private	Central West
Mudgee	Mudgee Airport	Public	Central West
Parkes	Parkes Airport	Public	Central West
Spring Hill	Orange Airport	Public	Central West
West Wyalong	West Wyalong Airport	Public	Central West
Coffs Harbour	Coffs Harbour Airport	Public	Coffs Harbour - Grafton
Grafton	Clarence Valley Regional Airport	Public	Coffs Harbour - Grafton
Bourke	Bourke Airport	Public	Far West and Orana
Brewarrina	Brewarrina Airport	Public	Far West and Orana
Broken Hill	Broken Hill Airport	Public	Far West and Orana
Cobar	Cobar Airport	Public	Far West and Orana
Collarenebri	Collarenebri Airport	Public	Far West and Orana
Coolah	Coolah Airport	Public	Far West and Orana
Coonabarabran	Coonabarabran Airport	Public	Far West and Orana
Coonamble	Coonamble Airport	Public	Far West and Orana
Dubbo	Dubbo City Airport	Public	Far West and Orana

Region	Airport name	Type	SA4
Goodooga	Goodooga Airport	Public	Far West and Orana
Lightning Ridge	Lightning Ridge Airport	Public	Far West and Orana
Narromine	Narromine Airport	Public	Far West and Orana
Nyngan	Nyngan Airport	Public	Far West and Orana
Red Hill	Warren Airport	Public	Far West and Orana
Tibooburra	Tibooburra Airport	Public	Far West and Orana
Walgett	Walgett Airport	Public	Far West and Orana
Cessnock	Cessnock Airport	Public	Hunter Valley exc Newcastle
Luskintyre	Luskintyre Airfield	Private	Hunter Valley exc Newcastle
Maitland	Maitland Airport	Public	Hunter Valley exc Newcastle
Scone	Scone Airport	Private	Hunter Valley exc Newcastle
Singleton	Dochra Airfield	Military	Hunter Valley exc Newcastle
Williamtown	Newcastle Airport	Public	Hunter Valley exc Newcastle
Williamtown, Newcastle	RAAF Base Williamtown	Military	Hunter Valley exc Newcastle
Wollongong	Illawarra Regional Airport	Public	Illawarra
Kempsey	Kempsey Airport	Private	Mid North Coast
Lord Howe Island	Lord Howe Island Airport	Public	Mid North Coast
Port Macquarie	Port Macquarie Airport	Public	Mid North Coast
Taree	Taree Airport	Private	Mid North Coast
Wallis Island	Forster (Wallis Island) Airport	Public	Mid North Coast
Albury	Albury Airport	Public	Murray
Balranald	Balranald Airport	Public	Murray
Corowa	Corowa Airport	Public	Murray
Deniliquin	Deniliquin Airport	Public	Murray
Hay	Hay Airport	Public	Murray
Pooncarie	Pooncarie Airport	Public	Murray
Tocumwal	Tocumwal Airport	Public	Murray
Wentworth	Wentworth Airport	Private	Murray
Armidale	Armidale Airport	Public	New England and North West
Glen Innes	Glen Innes Airport	Public	New England and North West
Gunnedah	Gunnedah Airport	Public	New England and North West
Inverell	Inverell Airport	Public	New England and North West
Kiama	Kiama Airport	Public	New England and North West

Region	Airport name	Type	SA4
Moree	Moree Airport	Public	New England and North West
Mungindi	Mungindi Airport	Public	New England and North West
Narrabri	Narrabri Airport	Private	New England and North West
Quirindi	Quirindi Airport	Public	New England and North West
Tamworth	Tamworth Airport	Public	New England and North West
Pelican	Belmont Airport	Private	Newcastle and Lake Macquarie
Ballina	Ballina Byron Gateway Airport	Public	Richmond - Tweed
Evans Head	Evans Head Memorial Aerodrome	Public	Richmond - Tweed
Lismore	Lismore Airport	Public	Richmond - Tweed
Cootamundra	Cootamundra Airport	Public	Riverina
Griffith	Griffith Airport	Public	Riverina
Narrandera	Narrandera Airport	Public	Riverina
Temora	Temora Airport	Public	Riverina
Tumut	Tumut Airport	Public	Riverina
Wagga Wagga	Wagga Wagga Airport	Public	Riverina
Wagga Wagga	RAAF Base Wagga	Military	Riverina
Nowra	HMAS Albatross	Military	Southern Highlands and Shoalhaven

Source: Wikipedia, List of airports in New South Wales, https://en.wikipedia.org/wiki/List_of_airports_in_New_South_Wales accessed 20 May 2021.

E Location of Remote Operator's Certificate holders

E.1 Remote operator's certificate holders

SA4 Region	Number of certificate holders
	no.
Capital Region	25
Central Coast	24
Central West	14
Coffs Harbour – Grafton	22
Far West and Orana	7
Hunter Valley exc Newcastle	24
Illawarra	24
Mid North Coast	21
Murray	8
New England and North West	28
Newcastle and Lake Macquarie	41
Richmond – Tweed	32
Riverina	11
Southern Highlands and Shoalhaven	9
Sydney - Baulkham Hills and Hawkesbury	20
Sydney – Blacktown	9
Sydney - City and Inner South	52
Sydney - Eastern Suburbs	27
Sydney - Inner South West	19
Sydney - Inner West	13
Sydney - North Sydney and Hornsby	56
Sydney - Northern Beaches	55
Sydney - Outer South West	11
Sydney - Outer West and Blue Mountains	14
Sydney – Parramatta	17
Sydney – Ryde	7
Sydney - South West	15
Sydney – Sutherland	23
Not defined	17
Total	**645**

Note: the 'operations' for all the certificate holders are described as 'Aerial work'.

Source: https://www.casa.gov.au/drones/reoc/certificate-directory

F Population density on agricultural lands

F.1 Number of persons ('000)

Activity	Far West and Orana	Murray	New England and NW	Riverina	Central West	Capital Region	Coffs Harbour - Grafton	Mid North Coast	Hunter Valley exc Newcastle	Southern Highlands Shoalhaven	Richmond - Tweed	Illawarra	Central Coast
.	no.	no.	no.	no.	no.	no.	no.	no.	no.	no.	no.	no.	no.
Production forestry	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.1	-	0.1	0.2	-	-
Grazing native vegetation	7.4	4.4	15.3	3.6	10.2	12.1	4.6	8.6	8.0	2.1	10.6	0.1	0.7
Cropping	6.7	4.8	8.2	9.4	10.0	2.7	1.1	-	0.5	0.2	2.6	-	-
Irrigated cropping	0.4	3.1	1.5	2.5	0.4	-	-	-	-	-	0.1	-	-
Grazing irrigated modified pastures	0.0	0.4	0.0	0.1	-	0.2	-	0.0	0.5	0.2	0.2	0.0	-
Plantation forestry	-	0.0	0.0	0.1	0.2	0.1	0.1	0.1	-	-	0.3	-	-
Grazing modified pastures	3.5	1.3	9.7	4.7	14.0	15.2	3.3	7.6	6.4	2.9	12.4	0.5	0.8
Residential and farm infrastructure	0.4	0.5	1.1	1.0	1.2	2.2	0.4	0.8	1.0	0.7	3.0	-	0.1
Irrigated perennial horticulture	-	0.1	-	2.8	0.1	-	-	-	0.1	-	-	-	-
Intensive horticulture	-	0.1	-	-	-	-	-	-	-	-	0.1	-	-
Land in transition	-	-	-	0.2	-	-	-	-	-	-	0.3	-	-
Perennial horticulture	-	0.3	-	-	0.4	0.2	-	0.5	0.2	0.1	3.4	-	0.5
Seasonal horticulture	-	-	-	0.0	-	-	-	-	-	0.1	0.1	-	0.2
Intensive animal husbandry	-	-	0.1	-	-	-	-	0.0	0.2	0.1	0.2	-	0.1
Irrigated seasonal horticulture	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**18.6**	**14.9**	**36.2**	**24.5**	**36.5**	**32.8**	**9.6**	**17.7**	**17.0**	**6.2**	**33.5**	**0.7**	**2.4**

Note: Based on population in Primary Production Meshblocks

Source: CIE calculations based on ABS 2016 Census Meshblock data and NSW 2013 Landuse maps

F.2 Area of land, by agricultural activity

Activity	Far West and Orana	Murray	New England and NW	Riverina	Central West	Capital Region	Coffs Harbour - Grafton	Mid North Coast	Hunter Valley exc Newcastle	Southern Highlands-Shoalhaven	Richmond - Tweed	Illawarra	Central Coast
.	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm	sqkm
Production forestry	3 859	1 819	257	386	237	122	416	10	-	283	182	-	-
Grazing native vegetation	277 317	61 547	30 816	14 586	11 577	11 346	1 618	2 279	6 116	436	1 984	11	26
Cropping	25 448	14 603	20 677	19 857	29 444	2 628	177	-	1 161	72	355	-	-
Irrigated cropping	1 524	7 971	4 656	3 740	1 458	-	-	-	-	-	13	-	-
Grazing irrigated modified pastures	6	830	0	918	-	21	-	23	69	28	19	4	-
Plantation forestry	-	61	175	111	214	223	126	116	-	-	256	-	-
Grazing modified pastures	7 408	2 233	15 721	5 516	11 525	13 846	1 243	2 304	3 365	352	1 672	43	42
Residential and farm infrastructure	44	357	157	522	400	790	57	49	104	57	223	-	1
Irrigated perennial horticulture	-	1	-	425	50	-	-	-	11	-	-	-	-
Intensive horticulture	-	34	-	-	-	-	-	-	-	-	9	-	-
Land in transition	-	-	-	19	-	-	-	-	-	-	32	-	-
Perennial horticulture	-	276	-	-	38	17	-	32	51	6	182	-	31
Seasonal horticulture	-	-	-	16	-	-	-	-	-	9	11	-	9

Activity	Far West and Orana	Murray	New England and NW	Riverina	Central West	Capital Region	Coffs Harbour - Grafton	Mid North Coast	Hunter Valley exc Newcastle	Southern Highlands-Shoalhaven	Richmond - Tweed	Illawarra	Central Coast
Intensive animal husbandry	-	-	11	-	-	-	-	0	37	6	8	-	5
Irrigated seasonal horticulture	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**315 605**	**89 734**	**72 472**	**46 096**	**54 943**	**28 992**	**3 636**	**4 812**	**10 915**	**1 248**	**4 947**	**57**	**114**

Note: Based on population in Primary Production Meshblocks

Source: CIE calculations based on ABS 2016 Census Meshblock data and NSW 2013 Landuse maps

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