Centre for WHS

# *Emerging work health and safety impacts on farmers*

**Horizon Scan**

March 2020

NSW GOVERNMENT

## Introduction

Australian farmers face a complex and diverse set of challenges associated with climate change. These challenges can be reduced into two distinct but related factors: the need to reduce greenhouse gas (GHG) emissions, and the need to adapt to the impacts of climate change. This report focuses on the latter of those factors, but it is important to note that some interventions and innovations to farming practices may simultaneously achieve both objectives – reduced emissions and increased agricultural resilience. Indeed, the Intergovernmental Panel on Climate Change (IPCC) report that:

> *"Sustainable land management, including sustainable forest management, can prevent and reduce land degradation, maintain land productivity, and sometimes reverse the adverse impacts of climate change on land degradation (very high confidence). It can also contribute to mitigation and adaptation (high confidence). Reducing and reversing land degradation, at scales from individual farms to entire watersheds, can provide cost effective, immediate, and long-term benefits to communities and support several Sustainable Development Goals (SDGs) with co-benefits for adaptation (very high confidence) and mitigation (high confidence). Even with implementation of sustainable land management, limits to adaptation can be exceeded in some situations (medium confidence)." (IPCC 2019)*

It is therefore argued that for economic, social and environmental sustainability, changes to agricultural practices are inevitable in a world affected by climate change. While undertaking this change, the agricultural sector may play an important role in offsetting the effects of GHG emissions through carbon sequestration and other initiatives that are mutually beneficial to the farm environment through top soil carbon enrichment (leading to more productive cultivation), and to climate mitigation efforts more broadly through reduced atmospheric $CO_2$.

Figure 1 presents an infographic from the IPCC report (IPCC 2019), which shows the expected impact of various land management options (left column) on climate change mitigation and adaptation, desertification (i.e., the degradation of vegetation into desert), land security and food security (right). Actions that offer the greatest impact are those that increase food productivity, agroforestry initiatives, and soil organic carbon content.

The Centre for Work Health and Safety seeks to improve the health and safety of workers through interdisciplinary, collaborative research that enables new, evidence-based approaches to harm prevention. Mental ill-health is an important work health and safety risk for male-dominated industries in Australia and abroad (Milner, Spittal, Pirkis, & LaMontagne, 2013). In NSW over the period 2000-2009, the suicide rate amongst farmers was 13.51 per 100000 with increasing suicide rates observed amongst older farmers (Arnautovska et al. 2016). By comparison, there were an average 10 suicides per 100000 people each year in the same period amongst the NSW population (Healthstats NSW, 2019). Paradoxically, workers compensation claims for mental injury amongst agricultural workers are proportionately lower than other industries. In FY18-19, 6.8% of all claims amongst NSW workers were for mental illness, whereas amongst farmers, the proportion of mental illness claims was less than 1.5% (State Insurance Regulation Authority (SIRA), 2019). The NSW Agriculture Work Health & Safety Sector Plan (Safework NSW, 2017) identifies mental health as one of 12 priority areas for the sector, based on stakeholder consultation. The Plan commits SafeWork NSW to collaborating with other agencies and rural mental health networks, noting that "living and working in isolation, challenging financial and environmental factors and poor access to support services contribute to poor mental health" (Safework NSW, 2017).

The aim of this horizon scan is to identify and discuss some emergent changes and disruptions to the agricultural sector in the context of climate change, and the associated adaptation and mitigation initiatives. Due to the magnitude and multifaceted nature of the issue at hand, we limit our focus to four key themes:

1. farming diversification
2. farm ownership and management models
3. technological advancements in farming
4. regenerative farming

We arrived at these themes through preliminary roundtable discussions amongst the Centre's project team, and we anticipate that further refinement to the potential research direction will be achieved through broader consultation with our research and industry stakeholder network. This horizon scan seeks to supplement and enable the process of consultation, but not replace it. We emphasise that this horizon scan is exploratory and broad-scope by design, and is therefore no substitute for a systematic literature review. The latter, by contrast, is characterised by a well-defined and relatively narrow scope, and one or more specific research questions.

This document is organised as follows. First, we introduce the topic of farming in Australia, and summarise relevant economic and social indicators in order to provide adequate context. Second, we discuss the current situation in NSW, and consider the social and structural institutions in place to manage climate change impacts, specifically focusing on drought due to the currency of this issue and the expectation that drought conditions will increase in frequency and intensity as the climate changes. We then provide a qualitative synthesis of academic and grey literature that we reviewed when exploring the topics of farming diversification, farm management models, and technological advancements in farming. Finally, we provide a bibliography with relevant abstracts in order to aid the reader to analyse any matters of interest in further detail.

## Potential global contribution of response options to mitigation, adaptation, combating desertification and land degradation, and enhancing food security

**Panel A** shows response options that can be implemented without or with limited competition for land, including some that have the potential to reduce the demand for land. Co-benefits and adverse side effects are shown quantitatively based on the high end of the range of potentials assessed. Magnitudes of contributions are categorised using thresholds for positive or negative impacts. Letters within the cells indicate confidence in the magnitude of the impact relative to the thresholds used (see legend). Confidence in the direction of change is generally higher.

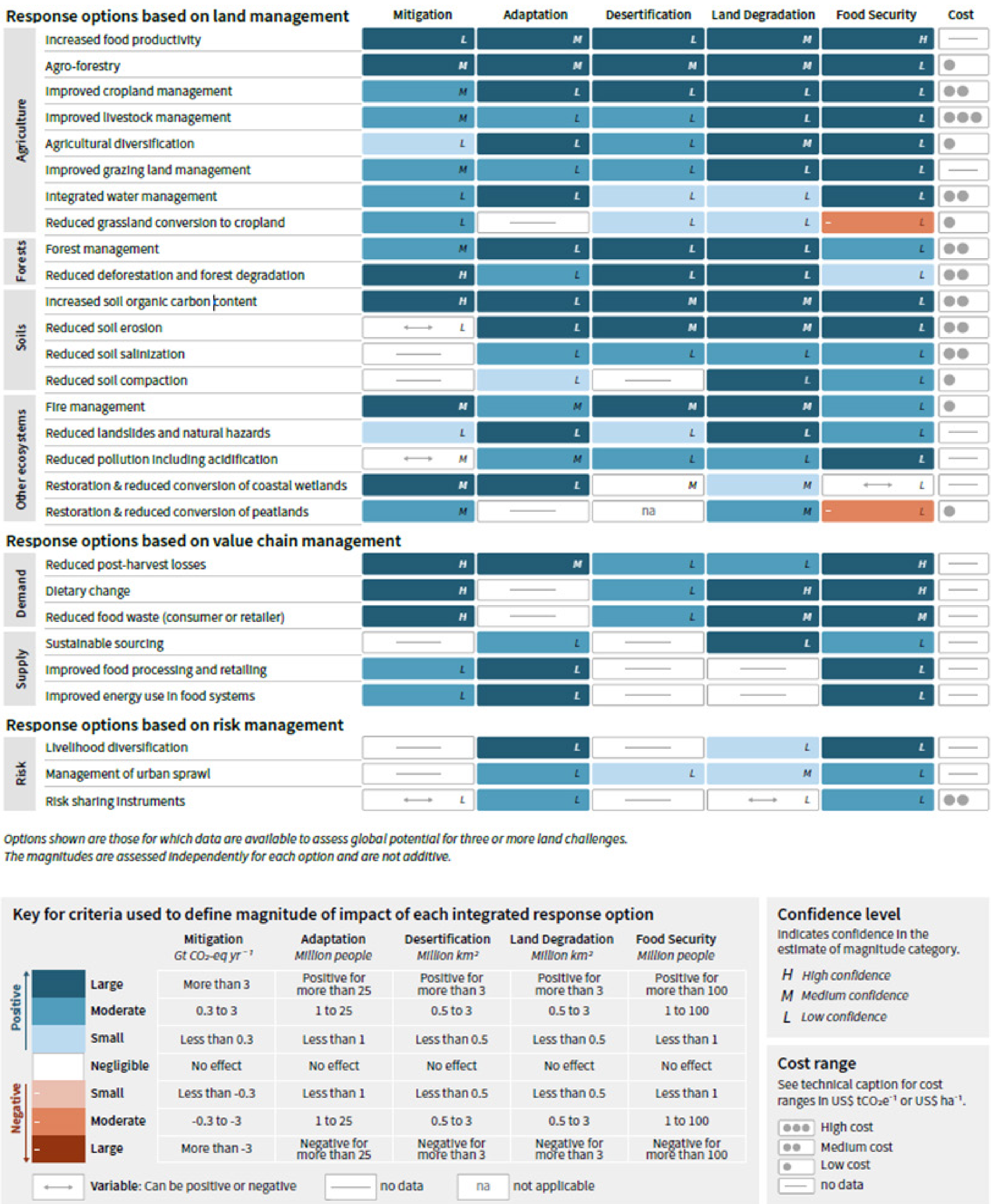



Figure 1. Source: (Intergovernmental Panel on Climate Change [IPCC], 2019)

## FARMING IN AUSTRALIA

Australian agricultural businesses contribute significantly to global food security, producing enough food to feed more than 80 million people each year (Bolan & Crawford, 2018). There are approximately 85,500 agricultural businesses in Australia, operating over about 378 million hectares, or about half of Australia's total land area (Australian Bureau of Statistics [ABS], 2019). Most of this agricultural land is used for stock grazing (87%); with a much smaller proportion of the land area used for crops (8%), forestry (<1%) and other agricultural purposes (<1%). In 2019, NSW had more livestock than any other Australian jurisdiction (>30 million, predominantly consisting of sheep). Farmers had, on average, 37 years' experience farming, were male (77%), and the average age was 57 years.

In terms of the functional classification of farming activities, the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 provides nine groups and 34 classes of distinct business activities under the agriculture subdivision (see Table 1). These different business activities each have a unique supply chain, and as such may have different productivity experiences. This is because the different activities can be sensitive to different factors such as economic drivers (e.g. commodity prices), supply industry factors (e.g. machinery, fertiliser), demand industry factors (e.g. meat processing, textile manufacturing), and global competition (Australian Bureau of Statistics [ABS], 2019).

Because of this variance in sensitivity, it is therefore argued that climate change will cause different effects on the production of different commodities. This is due not only to the changing physical environment (such as desertification, increased heat spells and increased frequency of extreme weather events), but also due to changes to economic and social factors that may directly influence the supply or demand of output commodities or indirectly affect the industry activities required for the production cycle of the commodity. For example, climate change might influence beef production by causing decreased grazing land (due to desertification), decreased consumer demand for beef due to environmental concerns, or increased production costs due to government policies to disincentivise greenhouse gas emissions (GHG).

Focusing on Southern Australia, Moore and Ghahramani (2013) modelled the impact of climate change on the output and profitability of livestock production up to 2070. Different scenarios were considered in order to account for climate projection uncertainty, natural resource constraints and differentiated temporal and special effects. The authors argue that this differentiation is important to consider, because increased atmospheric temperature is likely to increase pasture growth in wet areas but decrease growth in dry areas. The study concluded that the profitability and sustainability of livestock farming is highly sensitive to changes in rainfall and pasture that are likely to be brought about by climate change. The mean reduction in profitability by 2070 across four different climate scenarios was 48%, although the model showed substantial variability across stock different types of stock and in different locations.

Table 1. Business activities within the Agriculture sector, according to the Australian and New Zealand Standard Industrial Classification (ANZSIC). Source: Australian Bureau of Statistics (2006)

- A Agriculture, Forestry and Fishing
  - 01 Agriculture
    - 011 Nursery and Floriculture Production
      - 0111 Nursery Production (Under Cover)
      - 0112 Nursery Production (Outdoors)
      - 0113 Turf Growing
      - 0114 Floriculture Production (Under Cover)
      - 0115 Floriculture Production (Outdoors)
    - 012 Mushroom and Vegetable Growing
      - 0121 Mushroom Growing
      - 0122 Vegetable Growing (Under Cover)
      - 0123 Vegetable Growing (Outdoors)
    - 013 Fruit and Tree Nut Growing
      - 0131 Grape Growing
      - 0132 Kiwifruit Growing
      - 0133 Berry Fruit Growing
      - 0134 Apple and Pear Growing
      - 0135 Stone Fruit Growing
      - 0136 Citrus Fruit Growing
      - 0137 Olive Growing
      - 0139 Other Fruit and Tree Nut Growing
    - 014 Sheep, Beef Cattle and Grain Farming
      - 0141 Sheep Farming (Specialised)
      - 0142 Beef Cattle Farming (Specialised)
      - 0143 Beef Cattle Feedlots (Specialised)
      - 0144 Sheep-Beef Cattle Farming
      - 0145 Grain-Sheep or Grain-Beef Cattle Farming
      - 0146 Rice Growing
      - 0149 Other Grain Growing
    - 015 Other Crop Growing
      - 0151 Sugar Cane Growing
      - 0152 Cotton Growing
      - 0159 Other Crop Growing n.e.c.
    - 016 Dairy Cattle Farming
      - 0160 Dairy Cattle Farming
    - 017 Poultry Farming
      - 0171 Poultry Farming (Meat)
      - 0172 Poultry Farming (Eggs)
    - 018 Deer Farming
      - 0180 Deer Farming
    - 019 Other Livestock Farming
      - 0191 Horse Farming
      - 0192 Pig Farming
      - 0193 Beekeeping
      - 0199 Other Livestock Farming n.e.c.

## Current situation

Bushfires are an inevitable occurrence in Australia, due to a combination of weather-related, vegetation-related and terrain-related factors. However, since the 1950s climate change has been causing an increase in the occurrence of extreme fire, as well as longer duration of fire seasons. (Commonwealth Scientific and Insustrial Research Organisation [CSIRO], 2020).

The majority of New South Wales has been in drought[1] since 2017, with 27.4% experiencing 'intense drought' at the time of this report (NSW Department of Primary Industries [DPI], 2019). The NSW DPI is responsible for providing advice to the NSW Government in relation to drought policy and strategy. Other agencies and governments provide support functions, for example local governments that are empowered to impose water use by-laws in accordance with the Water Management Act 2000 (NSW). The NSW DPI have also established an interagency working group to monitor and respond to drought in a coordinated manner. This working group comprised of representatives from ten different government departments including Treasury, NSW Health, and Family and Community Services. However, at the time of writing this report, the NSW Department of Customer Service (or its predecessor cluster) was not represented on this working group (NSW DPI, 2019).

Climate change models predict that temperatures will increase by up to 2.8 - 5.0°C[2] in the Eastern part of Australia by the end of the 21st century, with a higher frequency of hot days and longer duration of warm spells expected. The frequency of extreme rainfall and, conversely, time spent in drought is also expected to increase (CSIRO, 2019). These meteorological conditions, when coupled with deforestation, can contribute to ecological desertification; that is, when formerly productive land becomes desert.

The impacts and adaptability of climate change are best considered not in isolation, but within the social, environmental and economic context. For example, it is well documented that agricultural communities in the Murray Darling Basin (MDB) have been exposed to demographic shifts away from rural areas, infrastructure loss/ decay (roads, rail, etc), input shortages, deregulation of trade barriers, changed demand patterns and commodity price variation (Dinh, Daly, & Freyens, 2017).

In addition, farmers in the MDB have been required to adapt to government policies that have redirected water resources from irrigation to environmental purposes (Dinh et al., 2017). Not surprisingly, a 2017 survey showed that irrigating farmers in the MDB reported a much higher frequency of water-related challenges than dryland farmers. Whether a farmer was able to adapt depended on farm characteristics. Farms were more likely to adapt to water related challenges if they were farm-income dependent, had large intensive-farming units, or undertook annual cropping.

[1] Drought is defined as 'a prolonged, abnormally dry period when the amount of available water is insufficient to meet normal use' and is an inherent feature of the Australian landscape (NSW DPI, 2019).
[2] By 2090, in a high emission scenario, average temperature is expected to increase from between 2.8 to 5.0 degrees, compared to 1986-2005. In an intermediate emissions scenario, average temperature is expected to increase by 1.3 to 2.6 degrees. (IPCC 2019)

### Farming diversification (pluriactivity)

We defined farming diversification as exploiting land to produce more than one commodity and the release of agricultural land to other forms of land stewardship.

In reviewing the literature relating to agricultural land use in Australia, Bell and Moore suggest that diversified production is not a new concept for Australian broadacre farming enterprises but has in fact the dominant practice (Bell & Moore, 2012). Environmental and economic drivers may influence farmers' decisions to use agricultural land assets for cropping or livestock, and emerging pressures such as climate variability, increased energy and fertiliser costs, and GHG emissions efforts are likely improve the economic prospects of legume-based crop rotations (Bell & Moore, 2012).

Some scholars argue that there is no such thing as a barrier to change, only legitimate reasons not to change (Vanclay 1992, cited in Fleming & Vanclay, 2010), and, therefore, 'a social focus on behaviour change is more useful in relation to facilitating action for climate change than a focus on the specific barriers to change' (ibid 2010). In a qualitative study of Tasmanian farmers (22 apple farmers, 29 dairy farmers, 12 agricultural consultants), Fleming and Vanclay (2010) examined the perspectives on climate change and sustainability within and between groups, and the nexus to behaviours. Major discourses included Money, Earth, Human Responsibility, and Questioning. The authors conclude that understanding the way that climate change is perceived and contextualised to farmers' beliefs and values may help in identifying the most amenable opportunities to change behaviour in order to mitigate and adapt to climate change.

In an editorial published in Food & Energy Security, Pollock advocates for greater innovation and resilience in agricultural business models, and suggests that strategies to achieve this end may include processing commodities on or near the farm, developing marketing cooperatives, exploitation of new products and markets and pluriactivity: 'A farm that generates income from sheep, beef, caravans, charcoal, and fishing rights is likely to be more resilient than its neighbours as well as more diverse'. On the other hand, Pollock (2016) argues that 'blanket' government subsidisation is likely to deter innovation and resilience and put downward pressure on commodity prices.

## Farm ownership and management

We defined farm ownership and management models as the systems for managing and differentiating capital and operational interests.

### Servitisation

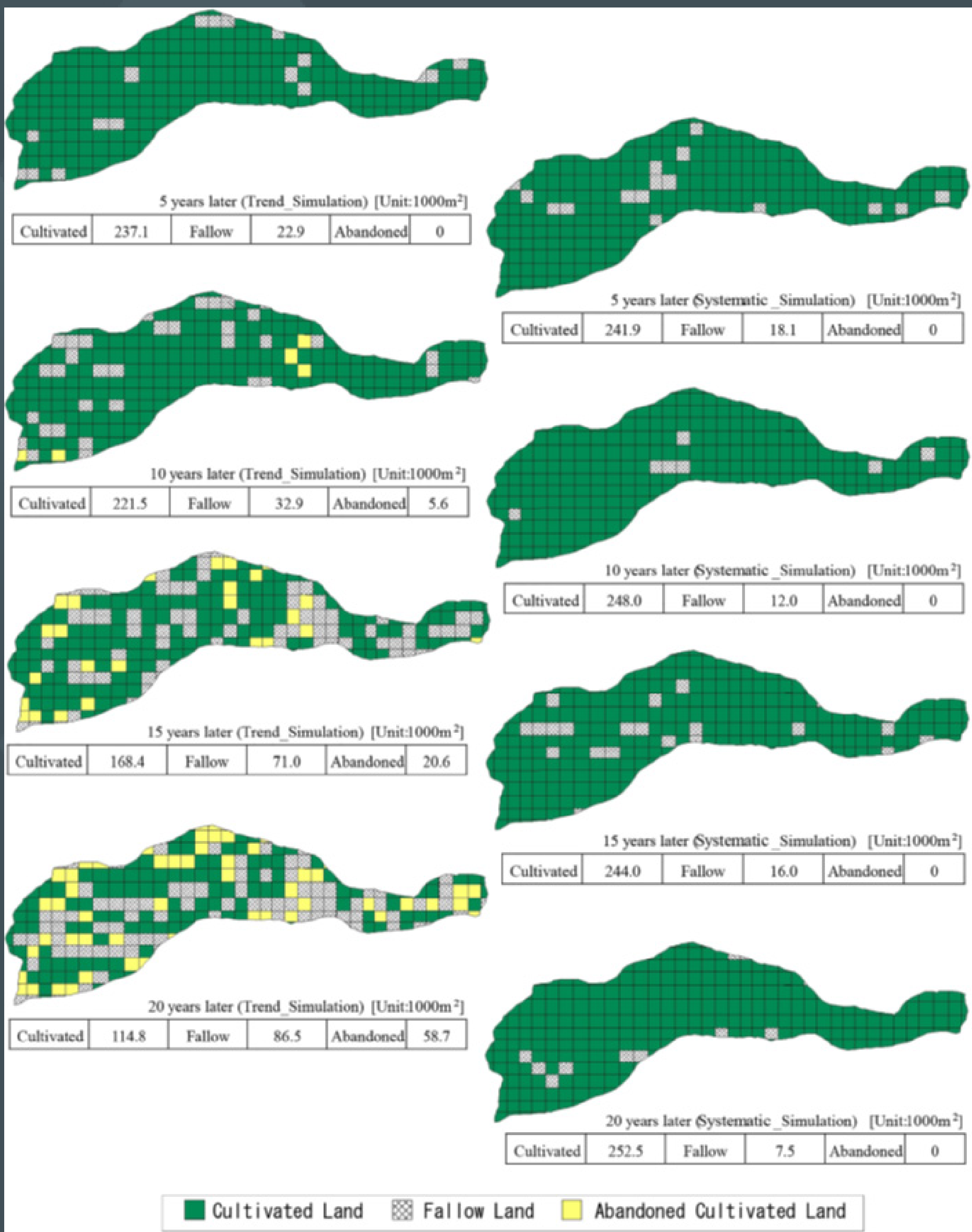
A concept related to both farm management and diversification is 'servitisation'. While diversification means producing agricultural products, servitisation means adding value to products by adding services, therefore shifting from exclusively product-driven to a product and service-driven business value proposition (Vidickiene & Gedminaite-Raudone, 2019). A classic example is the Xerox company, which was established as a producer of photocopy machines, but has since added services such as document management and business processing to their business model, and these services now account for more than half of Xerox's business (ibid., 2019).

Vidickiene and Gedminaite-Raudone (2019) argue that creating a networking-based servitised economy within the agricultural sector may unlock intellectual capital and form part of the solution to keeping ageing farmers within the workforce.

## Farming cooperative groups

Multi-agent system theory can be used in the field of economics to analyse and predict social phenomena and macro-level effects based on the actions of individual entities. This method was applied to the agricultural setting by Yamashita and Hoshino (2018), in a study that modelled the effect of farming cooperative groups (FCGs) and labour force participation on land utility. FCGs were defined as 'an agricultural group formed by the arbitrary participation of individual farmers and is an organisation where various cooperation and contracts concerning production and distribution are made'. A simulation model found that in a scenario where farmers participated in FCGs, abandonment of cultivated land could be prevented or delayed, compared to substantial land degradation expected over a 20 year period if the status quo was maintained (Figure 2). The authors suggest that FCGs could increase farm management efficiency by sharing labour and equipment resources within local community groups (ibid., 2018).

Figure 2. Simulation results of farmland use in Hyogo Prefecture, Japan Source: Yamashita and Hoshino (2018)



## Green lean

'Lean' is a flexible business management model that sets out to add value and reduce costs of production through continuous improvement. The key features of the Lean model are quality control, quality measurement and improvements in the work environment. The model is based on the Toyota Production System, but has been translated from manufacturing to large businesses in other settings (Barth & Melin, 2018). Recently, the principle of environmental sustainability has been incorporated into the Lean model, giving rise to the term 'Green Lean' (ibid). Green Lean, according to Barth and Melin (2018) sets out to 'improve operational efficiency and environmental sustainability and to deliver economic and social value to customers and society'.

A Green Lean implementation framework was recently developed and applied to the agricultural setting by Barth and Melin (2018) in a project called Lean Lantbruk (translation: Lean Agriculture). The aim of this project was to build capacity amongst farmers to implement Lean to improve business profitability, resource efficiency, competitiveness and business growth. Components of Lean Lantbruk included:

- motivational meetings (seminars and lectures)
- collection of baseline data through farm visits, and a questionnaire
- a two-day management training course on Lean
- engagement of a 'lean coach', who undertook on-farm visits
- group workshops
- one-on-one coaching
- network meetings

A parallel research project sought to employ action and interactive research methods to document a case study of 34 farms using the Lean Lantbruk project, 16 of which were followed through to 18 months. The investigators found that participants frequently used components of Lean after training, including 4S, standard operating procedures and visualisation boards. Farmers reported positive business benefits attributable to Lean, including reduced time searching for tools and materials, better routines for managing waste and recycling, and improved workplace safety. Farmers also reported more environmental benefits of practices attributable to Lean, including reduced GHG emissions from utility vehicles due to better spatial planning (e.g placement of feed silos), and reduced GHG emissions due to modification to calf rearing[3] and feeding efficiency. Barth and Melin (2018) note that farmers paid more attention to safety issues in the work environment, for example through opportunistic identification of hazards during 'waste walks'. Aggregate results of the Lean Lantbruk project are shown in Table 2.

## Leasing and succession: comparison between Australia and other countries

In 2013, Mr Duncan Ashby was awarded a Churchill Scholarship to travel overseas and explore how farms in Australia might benefit from 'improved leasing practices'. Mr Ashby travelled to the UK, USA and Canada and compared the farm ownership models of these countries, as well as the policy and social drivers for these models, drawing comparison to the farming practices usually carried out in Australia (Ashby, 2014).

[3]Greppa Näringen, 2013 (cited in Barth and Melin 2018) found that if cows have their first calf at 2 years of age, a farm of 80 cows may reduce its GHG emissions by 15 tons per year.

Table 2. Lean Audit Results of 16 farmers participating in Lean Lantbruk. Source: Barth and Melin (2018)

| Areas that have improved | Examples of improvements | Positive effect | No/negative effect |
|---|---|---|---|
| Resource efficiency | o Improved udder health of cow<br>o Better precision in feeding of animals<br>o Improved calf health<br>o Improved growth of animals<br>o Better fertility rates<br>o Reduced age at first calving<br>o Increased milk yield | 14 | 2 |
| A more structured workplace | o Less time spent on searching for tools<br>o Better planning of daily work due to the use of whiteboards<br>o A more proactive workforce | 15 | 1 |
| Teamwork | o Improved communication in the group<br>o A shared vision and common goals | 11 | 5 |
| Leadership | o More feedback to employees<br>o Employees self-directed to a greater degree<br>o Daily management is easier | 11 | 5 |
| Employee engagement | o Employees see the whole picture<br>o Easier to recruit new employees | 12 | 4 |
| Change and innovation | o More focus on problem solving<br>o Good ideas are documented<br>o A different way of thinking<br>o Easier to implement changes | 13 | 3 |
| Productivity (working hours/product) | o More time to do maintenance work<br>o Fewer hours, increased volume, and maintained product quality | 13 | 3 |
| Product quality | o Better and a more even product quality | 15 | 1 |
| Workplace environment | o Work is less stressful<br>o Improved safety at work<br>o A more even work load, with some individuals noticeably less exhausted | 14 | 2 |
| Customer focus | o Better customer offers in the farm store<br>o Deliver to customer demands<br>o Organization of open farm days | 5 | 11 |
| Other | o The bank positive to the Lean program<br>o Increased gender equality on the farm | 3 | 13 |

Mr Ashby argues that a number of country-specific policy drivers have probably shaped the farming practice models in each of the three countries – notably the policies relating to land value, land use and workforce transition (incentives into and out of the agricultural industry).

**Leasing**

Mr Ashby notes that leasing is common and has a long history in the UK, and the Tenant Farmers Association exists to represent tenant farmers and provide advice and support. Tenant protections afforded by the Agricultural Holdings Act (AHA) may incentivise long-term leasing arrangements and encourage young (or entry-level) farmers to enter the industry. On the other hand, an inheritance tax with 100% exemption for 'agricultural relief' purposes, may be a disincentive for land owners to lease agricultural land, and cause them to retain farm management within the family.

In Canada, Mr Ashby notes that approximately 40% of agricultural land is rented. However, compared to the UK where families often retain ownership, large capital investment funds have acquired substantial portions of Canadian land in the Saskatchewan province, and then leased this land back to farmers. Mr Ashby suggests that Australian superannuation funds could replicate this model locally, but then concludes that investor behaviour, market conditions and the absence of government ownership restrictions make this unlikely in the short-term.

**Share farming**

While share farming varies across North American and European systems, Mr Ashby notes that it is fundamentally a system whereby both a landowner and a farmer occupy an area of farmland, thereby sharing the natural resources.

This may also involve the sharing of machinery and equipment. While the specific nature of share farming agreements differ, Mr Ashby notes that the usual practice is for each farmer (owner and co-occupier) to receive an agreed share of the agricultural output.

### Contract farming

Contract farming involves an agreement between two parties – the farmer (landowner or tenant) and the contractor. Each party runs their own separate business and manages finances independently. The contract farming agreements are often for cropping but can include livestock.

## Technological advancements in farming

We defined technological advances in farming as the tools and technological innovations available now or in the foreseeable future that might aid farmers to increase or overcome threats to productivity.

### Precision agriculture

Precision agriculture is one form of technological advancement, and is defined by the National Research Council as: “the application of modern information technologies to provide, process and analyse multisource data of high spatial and temporal resolution for decision making and operations in the management of crop production” (Lyle, Bryan, & Ostendorf, 2015). A recent study investigated whether the use of precision agriculture could help grain farmers identify optimal positions for crops to be sown, and where land might be best repurposed due to low yields. The authors found that ‘the adoption of these strategies can help growers meet the demand for agricultural output and offer income diversity and adaptive capacity to deal with the future challenges to agricultural production’ (Fleming & Vanclay, 2010).

The recent emergence of the internet of things  and other cloud computing technologies has allowed precision agriculture to evolve into systems of ‘smart farming’. While both smart farming and precision agriculture involve technology-assisted measurement of field variables, smart farming employs artificial intelligence in farm management and decision making. In other words, smart farming systems are ‘context aware’, and capable of executing farm management processes to react to environmental changes (Wolfert, Ge, Verdouw, & Bogaardt, 2017). Proponents of smart farming systems argue that this technology will promote agricultural sustainability, food security and safety, while increasing output and efficiency and decreasing food waste (Marvin, 2019).

Wolfert et al. (2017) describe the cyber-physical management cycle of smart farming, comprised of smart sensing and monitoring, smart analysis and planning, and smart control, underpinned by cloud-based data and event management. Examples of smart farming applications are given in Table 3.

Table 3. Smart Farming Applications. Source: Wolfert et al. (2017)

| Cycle of Smart Farming | Arable | Livestock | Horticulture | Fishery |
|---|---|---|---|---|
| Smart sensing and monitoring | Robotics and sensors (Faulkner and Cebul, 2014) | Biometric sensing, GPS tracking (Sonka, 2014) | Robotics and sensors (temperature, humidity, $CO_2$, etc.), greenhouse computers (Sun et al., 2013a) | Automated Identification Systems (AIS) (Natale et al., 2015) |
| Smart analysis and planning | Seeding, Planting, Soil typing, Crop health, yield modelling (Noyes, 2014) | Breeding, monitoring (Cole et al., 2012) | Lighting, energy management (Li and Wang, 2014) | Surveillance, monitoring (Yan et al., 2013) |
| Smart control | Precision farming (Sun et al., 2013b) | Milk robots (Grobart, 2012) | Climate control, Precision control (Luo et al., 2012) | Surveillance, monitoring (Yan et al., 2013) |
| Big Data in the cloud | Weather/climate data, Yield data, Soil types, Market information, agricultural census data (Chen et al., 2014) | Livestock movements (Faulkner and Cebul, 2014; Wamba and Wicks, 2010) | Weather/climate, market information, social media (Verdouw et al., 2013) | Market data (Yan et al., 2013) Satellite data, (European Space Agency, 2016) |

## Bioenergy

In industrialised countries, energy production has started to shift from GHG-producing fossil-fuels to renewable sources, and the agricultural sector may play an important role in advancing this shift. Renouf and colleagues (2013) used a system based, consequential approach to assess the environmental impacts of using Australian sugarcane to produce bioenergy, biofuels and biomaterials. In a 'diversified' scenario, where by-products from existing yields are used, the study found that a modest reduction in non-renewable energy and global-warming potential could be achieved, and these benefits could be realised without trade-off. Production of ethanol and polylactide (PLA) plastics from cane juice also showed substantial benefit (reduction in non-renewable energy and global warming potential), but required trade-offs such as extra land and water use (Renouf et al., 2013). A recent report commissioned by the Clean Energy Finance Corporation and the National Farmers Federation provides a number of options for farmers seeking to capture, store and in some instances trade renewable energy on agricultural land. These include photovoltaic solar, microgrids, biodiesel, wind and small scale hydroelectric technology (Baillie, McCabe, Hill, & Skowronski, 2019).

## Soil technology

Soil technology is the focus of research conducted at the University of Newcastle's recently established Cooperative Research Centre for High Performance Soils (Soil CRC, www.soilcrc.com.au). Michael Crawford is the CEO of the Soil CRC, and he recently collaborated with Professor Nanthi Bolan on an article that discusses the areas of research for the Soil CRC, which include soil science and soil chemistry. The Soil CRC has a particular focus on nutrient recovery and development of new fertiliser products. Other foci include big data, sensor technology, nanotechnology, environmental science, social sciences and agricultural and farm management (Bolan & Crawford, 2018).

## Participatory technology assessment

In a pluralist society such as Australia, stakeholders may hold different views on the types of technological changes that ought (or ought not) to be adopted by the agricultural sector. Using the example of 'green gene' technology (a type of genetic modification of crops), a qualitative study by Schneider and Gill highlighted the utility of participatory technology assessment methods in aiding diverse stakeholders to consider new perspectives and options for development without necessarily reaching consensus. The authors found that small but purposively heterogeneous groups promoted divergent thinking and helped to break down entrenched beliefs (Schneider & Gill, 2015).

## Regenerative farming & agroecology

The recent IPCC report (introduced in the Introduction section of this paper), notes that regenerative farming methods such as agroforestry, perennial pasture phases and use of perennial grains can reduce soil erosion and nutrient leaching. These methods therefore have the dual benefit of improving soil quality while sequestering carbon from the atmosphere and improving the environment. The IPCC noted the following practices to have co-benefits for agricultural businesses and climate change reduction efforts: growing green manure crops and cover crops, crop residue retention, reduced/zero tillage, and maintenance of ground cover through improved grazing management (IPCC 2019).

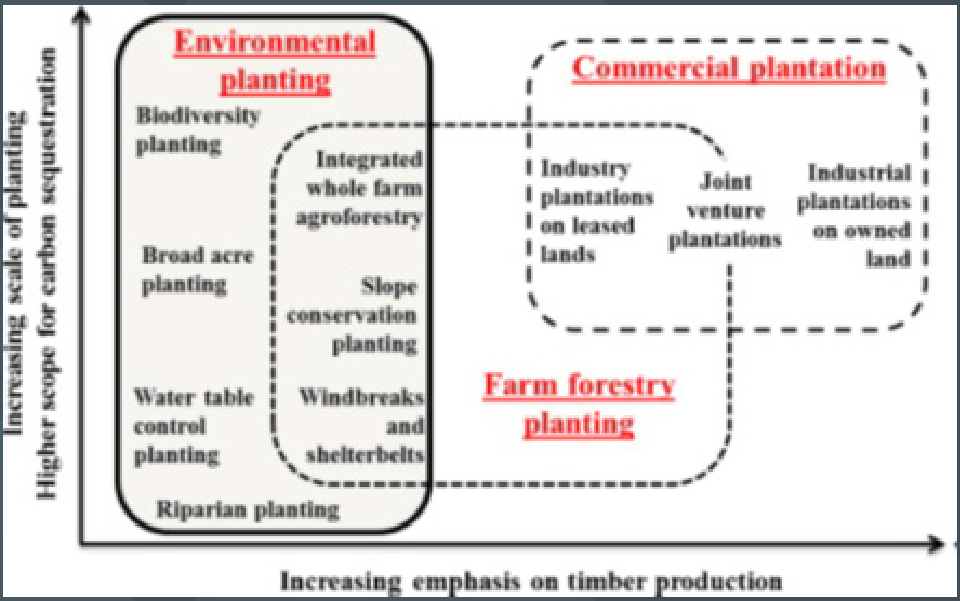
Some scholars emphasise that farmers need to understand the ecosystem they operate in so as to avoid deleterious environmental effects and to promote environmental sustainability. This view is consistent, in principle, with the notion of agroecology, which may be defined as:

> *'applying environmental concepts and principles with a view to the design and management of sustainable agroecosystems. [agroecology] involves mobilizing practitioners and academics to find innovative ways to increase productivity and sustainability in agriculture, while maintaining an environment that ensures quality of life'* (Delian, Chira, Badea, & Chira, 2019)

### Agroforestry

Agroforestry (or farm forestry) sits in the middle of the plantation continuum (George, Harper, Hobbs, & Tibbett, 2012, see Fig 6.), and can be defined as "... the commitment of resources by farmers, alone or in partnerships, towards the establishment or management of forests on their land." (Reid & Stephen, 2001). Agroforestry can take different forms and can be used to achieve a range of different outcomes including commercial timber production, biodiversity, land degradation control and reducing water treatment. Farmers may also derive benefit for agroforestry initiatives under the Carbon Credits (Carbon Farming Initiative) Act 2011 (Cth), which provides a monetary incentive for certain environmental planting and reforestation. George et al. (2012) suggest that agroforestry could be more effectively incentivised if payments were offered for other biodiversity enhancement projects because 'currently the economic rationale for biodiverse reforestation or maintaining remnant forest patches is not strong'. They argue that the societal benefits that may be derived from agroforestry - which include carbon sequestration, biodiversity conservation, and secondary salinisation abatement - justify expansion and better integration of the carbon credit scheme with other environmental initiatives (George et al., 2012).

Figure 3. Agroforestry/farm forestry, land protection planting, and industrial forestry based on the emphasis on timber production. Shaded portion encompasses agroforestry practices with potential for conjoint carbon sequestration and biodiversity benefits and salinity amelioration outcomes. Source: George et al. (2012)




## Land restoration and management

Smith & Watson (2018) document the example of a mixed cropping (irrigated cotton) and cattle grazing operation 'Kilmarnock', on the Namoi River near Boggabri, New South Wales. When the owners purchased the farm about 50 years ago, the land was overgrazed and suffering soil and river bank erosion and at risk of further degradation. However, they were able to restore the land by reinforcing farm boundaries to control livestock movement, revegetating and removing invasive willow trees. They also planted vegetation corridors that reduced spray drift from neighbouring properties, connected riparian vegetation with remnant floodplain vegetation and provided a movement corridor for fauna (Smith & Watson, 2018). Other agroecological strategies employed at Kilmarnock include:

- Using genetically modified cotton plants and frequently measuring invertebrate populations using the 'beat - sheet method' method to help minimise the need for pesticide application, which in-turn enhances biodiversity.
- Using overhead irrigation systems and capacitance probes to allocate water to crops efficiently, and also considering soil type, organic matter content and seasonal weather conditions and plant physiology.
- Reducing nitrogen fertilisers and replacing with manures, particularly chicken manure, which Watson & Smith found was economically advantageous to nitrogen-based fertilisers (although there is an initial lag between initial application and yield return).

Kilmarnock was the NSW State winner of the Landcare Sustainable Farming Award, and a national finalist. By adopting these and other strategies, the Watsons have been able to minimise their environmental footprint and the economic costs associated with cotton production, or colloquially, 'grow more crop for every drop' (Smith & Watson, 2018). Agricultural practices can also be sustainable and environmentally friendly by design, particularly if farmers 'understand the ecosystem they operate in, minimise off-target impacts of their management and restore habitat to improve their farm's environmental service provision' (Smith & Watson, 2018).

In a recent literature review and qualitative study focusing on farming practices in semiarid and subhumid African areas, Debray et al. (2019). found that some practices being implemented by farmers may aid in mitigating or adapting to climate change even when this was not necessarily the primary objective of the farmer.

### Climate smart agriculture

Delian et al. (2019) describe climate smart agriculture as the need for climate adaptation and mitigation potential into the planning and implementation of agricultural policies, practices and investments. A 2010 'Food and Climate Change Conference' was convened by major food and agriculture businesses in Europe, and three priorities were identified: (1) sustainable growth of agricultural productivity and income; (2) adapting and building resistance to climate change; (3) reducing and / or eliminating greenhouse gas emissions, wherever possible. These changes were deemed mandatory for both climate and food security reasons, given the global population projection is expected to exceed 9 billion by 2050 (Delian et al., 2019).

## Conclusion

If unmitigated, climate change is likely to have a deleterious effect on some farms and agricultural communities due to a broad range of factors including the variability in crop yield, increased risk of crop failure, and increased drought and bushfire conditions. These effects are likely to have a negative impact on mental health and other WHS factors within the farming sector.

This horizon scan has highlighted a number of new and emerging approaches, technologies and practices that may help Australian farmers to adapt to climate change, and achieve efficiency and environmental sustainability. While not exhaustive or systematic, this report may be useful for researchers wishing to source further material, and develop or refine research questions relating to the impact of climate change on farmers, the WHS ramifications and what might be done to mitigate risks and ensure the sustainability of the vital agricultural sector.

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