MELBOURNE'S FOODPRINT

What does it take to feed a city?

A Foodprint Melbourne Report

June 2016

VEIL victorian eco innovation lab
LORD MAYOR'S CHARITABLE FOUNDATION
THE UNIVERSITY OF MELBOURNE
msd Melbourne School of Design
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DEAKIN UNIVERSITY
SUSTAIN THE AUSTRALIAN FOOD NETWORK

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Version 1.2

Sections 4.1 and 5.1 of the report have been amended to clarify the use of long-term (from 1946 to now) urban density trends to calculate agricultural land lost to accommodate a growing urban population.

Section 3.7 of the report has been amended to remove references to 'inedible waste from food processing' in order to facilitate accurate interpretation of the data. Inedible by-products from food waste are not included in our estimates of food waste. Table 2 in this section has been amended by removing the row on 'Inedible waste from food processing'. Figure 9 in this section has been amended by removing the bars for 'Inedible waste from food processing'.

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SECTION 1

Executive summary

This report explores Melbourne's 'foodprint' – the environmental footprint of feeding the city. It takes a lot of land, water and energy to feed a rapidly growing city like Melbourne, and a significant amount of food waste and GHG emissions are generated as a result.

As supplies of the natural resources underpinning food production become more constrained, the city will need to explore new approaches to increase the sustainability and resilience of its food supply. This report aims to provide an evidence base to support this process. The principal findings of this research are:

- It takes over 475L of water per capita per day to feed Melbourne, around double the city's household usage
- 16.3 million hectares of land is required to feed Melbourne each year, an area equivalent to 72% of the state of Victoria
- Feeding Melbourne generates over 907,537 tonnes of edible food waste, which represents a waste of 3.6 million hectares of land and 180 GL of water
- Around 4.1 million tonnes of GHG emissions are emitted in producing the city's food, and a further 2.5 million tonnes from food waste
- Melbourne is likely to grow rapidly between now and 2050, and its foodprint will increase significantly as a result
- Melbourne's city foodbowl could play an important role in increasing the resilience and sustainability of the city's food supply
- The city foodbowl has significant capacity for production of fresh foods. It also has access to recycled water and organic waste streams, and could reduce the city's dependence on distant sources of fresh foods
- Key vulnerabilities in Melbourne's regional food supply include loss of agricultural land, water scarcity and the impacts of climate change
- Potential strategies to increase the sustainability and resilience of Melbourne's regional food supply include increasing urban density, shifting to regenerative agriculture, increasing the use of recycled water for agriculture, reducing food waste and modifying our diets
- Multiple strategies are likely to be needed to increase the sustainability and resilience of Melbourne's regional food supply
- Around 10% of the available recycled water from Melbourne's water treatment plants would be enough to grow half of the vegetables that Melbourne eats
- Increasing urban density as Melbourne grows could reduce urban sprawl by about 50% over the next 20 years, saving 180,000 hectares of land in Melbourne's foodbowl – an area equivalent to almost 5 times Victoria's vegetable growing land

SECTION 2

The Foodprint Melbourne project

2.1 About the Foodprint Melbourne project

The Foodprint Melbourne project is led by the Victorian Eco-Innovation Lab at the University of Melbourne in collaboration with Deakin University and Sustain: The Australian Food Network. The project is funded by the Lord Mayor's Charitable Foundation. The Foodprint Melbourne project has three parts.

Part 1: Melbourne's Foodbowl - Part 1 investigated Melbourne's'foodbowl'. It explored what grows in Melbourne's foodbowl and the capacity of the foodbowl to feed Melbourne[1] now and as the city expands in future. The report for Part 1 was released in December 2015 and can be found on the VEIL website.

Part 2: Melbourne's 'FoodPrint' - Part 2 explores what it takes to feed Melbourne, now and as the city grows to a population of 7 million. It investigates how much land, water and energy are required, and the greenhouse gas emissions and waste generated. Part 2 also investigates the vulnerabilities in Melbourne's food supply, and the opportunities for strengthening the resilience and sustainability of Melbourne's regional food supply.

Part 3: Melbourne's regional food economy – Part 3 will explore the economic contribution made by Melbourne's foodbowl, and the potential costs and benefits of increasing consumption of food from the foodbowl. It will also investigate policy approaches to increasing the sustainability and resilience of Melbourne's regional food supply.

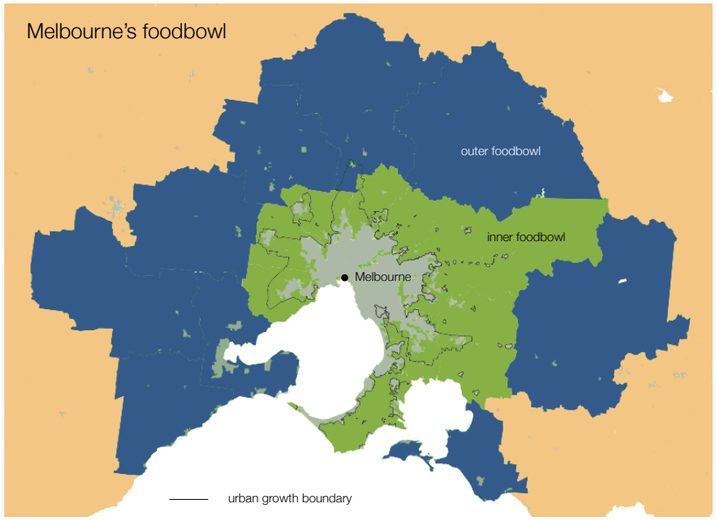


Figure 1: Melbourne's foodbowl

2.2 About this report

This document presents an evidence base about what it takes to feed Melbourne.

It explores the natural resources that are required to feed Melbourne now and with a population of 7 million in 2050. It also highlights some of the vulnerabilities in Melbourne's food system, and some strategies for addressing the vulnerabilities to create a more sustainable and resilient regional food supply. It is one of the first studies of its kind for an Australian city. The Sydney Food Futures project is conducting a similar investigation into food production on the fringe of Sydney[2].

1 The project explored the capacity of Melbourne's foodbowl to feed Greater Melbourne. Greater Melbourne was defined as the Local Government Areas within the Urban Growth Boundary, including the urban and 'interface' councils. For the full list of Local Government Areas included in Melbourne's foodbowl, see Appendix 1 of Sheridan, J., Larsen, K. and Carey, R. (2015) Melbourne's foodbowl: Now and at seven million. Victorian Eco-Innovation Lab, The University of Melbourne

2 Sydney Food Futures (2015) 'About us', http://www.sydneyfoodfutures.net/about-the-project/

SECTION 3

Melbourne's foodprint – now and at 7 million

3.1 Introduction

Food consumption accounts for a significant proportion of our environmental impact. Previous studies have suggested that food consumption makes up around 28% of Victorians' total ecological footprint[3], and is responsible for 45.9% of Australians' water footprint, and 48.8% of our land footprint[4].

This project investigates the environmental impacts of food consumption in Melbourne, exploring three aspects of the city's food system:

- The city's 'foodprint' – the natural resources required to feed Melbourne now and with a predicted future population of 7 million
- Vulnerabilities in the city's regional food supply due to emerging environmental challenges
- Opportunities to address the vulnerabilities and increase the sustainability and resilience of the city's food supply

Melbourne is fed by a complex global food system, and its foodprint extends far beyond Victoria to other states of Australia and to other countries.

The ability to source food for Melbourne from other states and countries contributes to the resilience of the city's food system; that is, to its capacity to withstand and recover quickly from disruptions to food supply due to shocks, such as extreme weather events (storms, droughts and floods), sudden spikes in food prices or the impacts of climate change.

However, a strong regional food supply is also an important part of a resilient city food system. It can lessen the impact of shocks to national and global food supplies, including the impacts of climate change, and reduce dependence on distant sources of food[5].

A strong regional food supply can also increase the sustainability of city food systems, offering opportunities to harness urban waste streams as inputs to food production (e.g. waste water and organic waste), reduce GHG emissions associated with food transportation and maximize use of the limited natural resources available for food production.

This report focuses specifically on the sustainability and resilience of Melbourne's regional food supply.

A strong regional food supply is an important part of a resilient city food system

3 EPA Victoria (2008) Victoria's Ecological Footprint. Melbourne: EPA Victoria and the Commissioner for Environmental Sustainability

4 Australian Conservation Foundation (2007) Consuming Australia: Main findings. Sydney: Australian Conservation Foundation

5 FAO/RUAF (2015) City region food systems. Rome: FAO

3.2 Our approach

This 'foodprint' for Melbourne assesses the environmental impact of feeding the city by quantifying the natural resources that are required to feed Melbourne's population now and when the city reaches a predicted population of 7 million (in around 2050)[6].

The foodprint draws on the idea of an environmental footprint[7], and is inspired by similar international projects, such as the 'Foodprinting Oxford' project[8] in the UK, and the 'Foodprints and Foodsheds' project[9] in the US. This foodprint assessment estimates how much land, water and energy is required to feed Melbourne, and the amount of greenhouse gas (GHG) emissions and waste generated. Some of these natural resources come from Melbourne's city foodbowl and from regional Victoria, but some of the land, water and energy required to feed Melbourne comes from other places that supply Melbourne with food.

The assessment draws on data from a study of Australia's national food security funded by the Australian Research Council - 'Modelling policy interventions to protect Australia's food security in the face of environmental sustainability challenges', a joint project from the Victorian Eco-Innovation Lab (at the University of Melbourne), Deakin University and the Australian National University. Our foodprint assessment draws on data generated by this project about Australian diets and the impacts of environmental challenges to Australia's food supply. It also uses the same underlying modelling framework, based on the CSIRO-developed Australian Stocks and Flows Framework (ASFF). One of the aims of this project is to evaluate the use of the ASFF framework for modelling challenges to food supply at city region scale. Lessons learned are discussed in section 6 and in an earlier project report on Melbourne's Foodbowl[10].

The Australian Stocks and Flows Framework[11] is a platform for assessing environmental sustainability challenges in Australia and modelling potential solutions. It tracks the supply of resources – like land, water and minerals – and it models the physical processes by which those resources are converted into food, housing or other goods in the Australian economy. It can highlight tensions, where the supply of resources is insufficient to meet demand for goods in the economy (e.g. where the withdrawal of water to meet demand for food will exceed water availability), and it can also be used to explore scenarios that might resolve tensions, so that demand does not exceed supply. ASFF has similarities to both input-output analysis and Life Cycle Analysis, which have been used elsewhere for foodprinting, but it is different to both[12].

6 This is a conservative estimate for Melbourne's population growth, based on projections from the DELWP Projections for Melbourne's population at 2050 vary from 7 million to almost 8 million, with different fertility and migration assumptions underpinning the various figures.

7 EPA Victoria (2008) As above.

8 See http://www.oxfordmartin.ox.ac.uk/publications/view/1004

9 See http://foodprintsandfoodsheds.org/foodprints/

10 Sheridan, J., Larsen, K. and Carey, R. (2015) As above.

11 Turner, G., Hoffman, R., McInnis, B., Poldy, F. and Foran, B. (2011) A tool for strategic biophysical assessment of a national economy: The Australian stocks and flows framework. Environmental Modelling & Software 26 1134-1149.

12 For an explanation of the differences between ASFF, Input-Out Analysis and Lifecycle Analysis, see Turner, G. et al (2011) As above.

The key elements of our approach were as follows:

- Food consumption in Melbourne was modelled based on data from a 2010 national survey of food consumption[13]. We assumed that food consumption in Melbourne followed national consumption patterns
- Detailed 'diet profiles' were developed to determine how much of each type of food needed to be produced in order to meet these consumption patterns
- As Australia is largely self-sufficient in food[14], we assumed for the purposes of modelling that Melbourne's food was sourced from within Australia
- ASFF was used to model the amount of land, water and energy used to grow food for Melbourne, based on these consumption patterns, and also to estimate associated GHG emissions and food waste. This generated Melbourne's 'foodprint'
- ASFF findings about Melbourne's foodprint were validated against external sources of data, such as industry and government reports, and data sets from the Australian Bureau of Statistics. Findings were also validated through expert consultation. This process was used to make further changes to modelling assumptions in ASFF
- Vulnerabilities in the sustainability and resilience of Melbourne's regional food supply were identified, based on Melbourne's foodprint and review of other external data sources
- ASFF was used to model approaches to resolving tensions and addressing vulnerabilities in the sustainability and resilience of Melbourne's regional food supply. In some cases (e.g. to explore the potential of recycled water for food production), localized sources of data were used to model strategies outside ASFF

13 Australian Bureau of Statistics (2014) 4364.0 - Australian Health Survey: Nutrition, 2011-12, Canberra: Australian Bureau of Statistics.

14 PMSEIC (2010) Food security in a changing world. Canberra: The Prime Minister's Science, Engineering and Innovation Council.

Melbourne's population requires around 15,080 tonnes of food to be produced each day - approximately 3.45kg per person

3.3 Melbourne's food consumption

This foodprint assesses the natural resources required to feed the population of Greater Melbourne - that is, the Local Government Areas within the Urban Growth Boundary, including the urban and 'interface' councils[15].

Greater Melbourne's population of around 4.37 million requires around 15,080 tonnes of food to be produced each day – approximately 3.45 kilograms per person. This 3.45 kilograms is significantly more than the 1.2 kilograms of food physically eaten by the average Melbournian each day, as food is wasted throughout the food chain, and inedible parts are discarded.

By 2050, Melbourne's population is likely to grow by at least an additional 2.63 million people to reach a population of around 7 million[16]. If Melbournians eat the same diet as they currently consume, this population of 7 million will require around 24,132 tonnes of food per day. In light of the increasing rate of obesity in Australia[17], this is likely an underestimate of Melbourne's future food consumption.

Melbourne's food consumption was estimated using data from the Australian Health Survey 2011-12[18]. In other words, we assumed that Melbourne's diet was the same as the typical Australian diet. The amount eaten by the average Melbournian is estimated in table 1.

Australian food preferences are constantly changing, and current trends in dietary patterns, such as increasing chicken consumption and decreasing red meat consumption, were taken into account in estimating the food needs of Melbourne's future population in 2050.

The amount of waste for each type of food was also taken into account in estimating the required food production for Greater Melbourne's population. Food losses through processing and inedible components are different for each type of food. The amount of food required each day to feed Melbourne is detailed below[19].

15 For the full list of Local Government Areas included in our definition of Greater Melbourne, see Appendix 1 of Sheridan, J., Larsen, K. and Carey, R. (2015) As above.

16 This is a conservative estimate for Melbourne's population growth, based on projections from the DELWP. For further detail on how Melbourne's population growth has been estimated, see Sheridan, J., Larsen, K. and Carey, R. (2015) As above.

17 Walls, H., Magliano, D., Peeters, A. (2012) Projected Progression of the Prevalence Of Obesity In Australia. Wiley-Blackwell; Australian Bureau of Statistics (2014) As above.

18 Australian Bureau of Statistics (2014) As above.

19 For further detail on how Melbourne's food consumption was calculated, see Sheridan, J., Larsen, K. and Carey, R. (2015) As above.

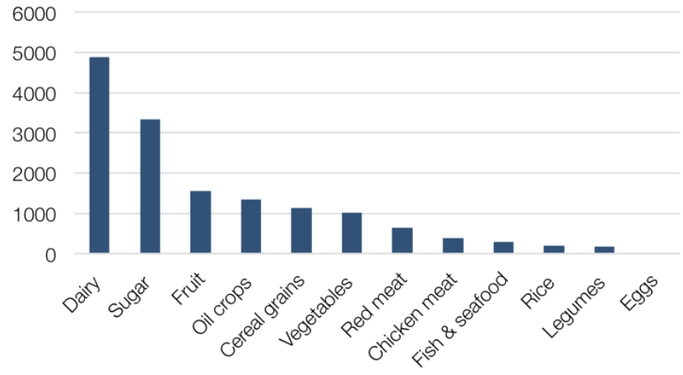


Figure 2: Tonnes required each day to feed Melbourne

Foodstuffs	Grams eaten per person per day
Dairy	322.4
Fruit	218.8
Vegetables	184.8
Cereal grains	144.3
Sugar	76.2
Chicken meat	51.7
Beef & veal	48.1
Eggs	29.7
Pig meat	26.7
Seafood	26.6
Oils	23.2
Rice	19.4
Legumes	16.9
Mutton & lamb	11.1
Nuts	8.4
Salt	2.0
Total food:	1210.2

Table 1: Per capita food requirements in the typical Australian diet

Australia's large per capita land foodprint

In international footprint comparisons, Australia has by far the highest per capita agricultural land footprint. A previous study estimated Australia's land footprint for food consumption at 3.2 hectares per person[22]. Comparable cities in the UK and USA have land footprints for food consumption of around 1 hectare[23,24], while cities in more sparsely populated countries tend to have a higher footprint e.g. Calgary in Canada has a per capita footprint of 2.6 hectares[25]. Australia's high per capita land footprint for food consumption is due to its production systems for beef and lamb production, which primarily involve pasture-based grazing systems, rather than feedlots, with animals at low stocking densities over large areas of land.

3.4 Land

Feeding Melbourne's population of around 4.37 million people for one year takes around 16.3 million hectares of agricultural land. This area is equivalent in size to almost three-quarters of the state of Victoria[20], but represents just 4% of Australia's agricultural land[21].

This is the amount of land needed to grow the fruit, vegetables, grains and pulses that Melbourne eats, as well as the land on which livestock are raised for meat, dairy and eggs. It also includes the land used to grow feed for these animals. Melbourne's land foodprint is higher than the typical land foodprint in many other parts of the world.

Different food groups have different land requirements. Vegetable production for Melbourne is responsible for just 0.1% of the city's land foodprint, although vegetables make up 15% of Melbournians' food needs. The vast majority of Melbourne's land footprint for food consumption – around 90% - is related to beef and lamb consumption, although beef consumption makes up just 4% of the city's diet. This is due to beef and lamb production systems in Australia, in which most animals graze on pasture over large areas of land at low stocking densities. Much of this land is unsuitable for other types of food production[26].

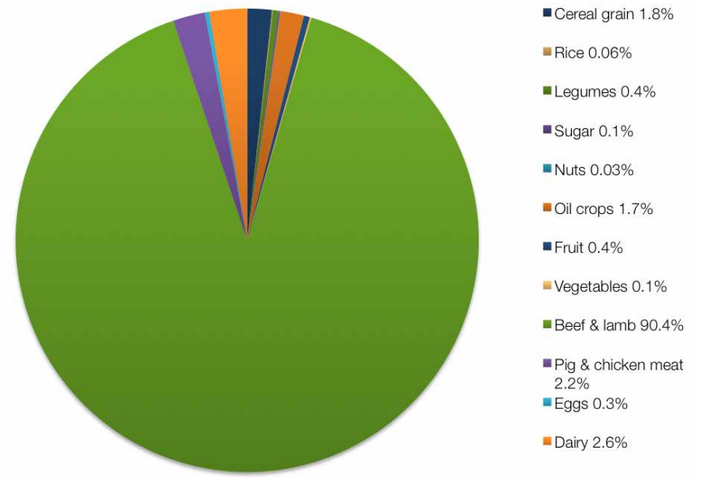


Figure 3: Proportion of the land footprint attributed to different food groups in the typical Australian diet

20 Australian Bureau of Statistics (2012) 4609.0 - Land Account: Victoria 2012, Canberra: Australian Bureau of Statistics.

21 Australian Bureau of Statistics (2013) 7121.0 - Agricultural Commodities, Australia, 2010-11, Canberra: Australian Bureau of Statistics.

22 Lutter, S., Burrell, L., Giljum, S., Patz, T., Kernegger, L., Rodrigo, A. (2013) 'Hidden impacts: How Europe's resource overconsumption promotes global land conflicts' Vienna: Global 2000 and Sustainable Europe Research Institute.

23 Moore, D (2011) Ecological Footprint Analysis San Francisco-Oakland-Fremont, CA, Oakland: Global Footprint Network.

24 World Wildlife Fund (2007) 'City Residents Ranked by Size of Their Food Footprint' http://www.wwf.org.uk/filelibrary/pdf/food_footprint.pdf [accessed 1 March 2016]

25 Kuzyk, L., Hummel, M., Rockley, M., Green, B., Hall, J.W., St Arnaud, N. (2014) 'Ecological Footprint and Land Use Scenarios, Calgary, Alberta' Calgary: The City of Calgary Land Use Planning & Policy.

26 Wiederman, S., McGahan, E., Murphy, C. and Yan, M. (2016) Resource use and environmental impacts from beef production in eastern Australia investigated using life cycle assessment. Animal Production Science 56: 882-894.

By 2050, when Melbourne has a population of around 7 million people, the land required to feed the city will have almost doubled to 32.3 million hectares. The city's per capita land foodprint is likely to have increased from 3.8 hectares to around 4.6 hectares.

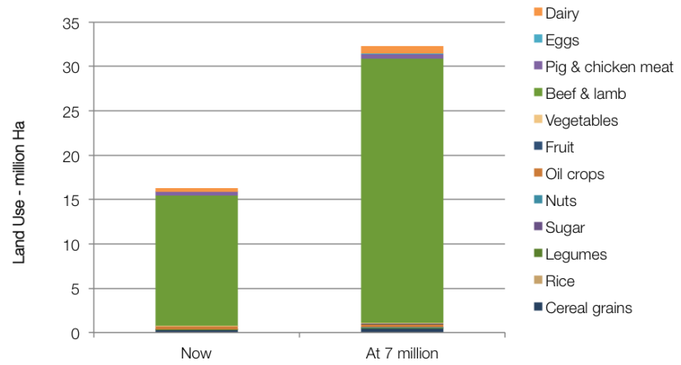


Figure 4: Land required to feed Melbourne now and with a population of 7 million

Feeding Melbourne's population requires around 16.3 million hectares of agricultural land per year

When Melbourne has a population of around 7 million people, the land required to feed the city will have almost doubled to 32.3 million hectares

This 24% increase in the city's per capita land foodprint is due primarily to land degradation and the impacts of climate change, so that more land will be required by 2050 to produce the same amount of food. When land is used intensively, the soil degrades[27]. Raising more animals on a piece of land than it can naturally support also requires the use of fertilisers and other inputs to maintain productivity, and this increases over time[28].

In 2015, Melbourne required the equivalent of almost half of Victoria's vegetable growing land to meet the city's vegetable needs. By 2050, the city is likely to require the equivalent of over 80% of Victoria's vegetable growing land to meet the population's need for vegetables[29].

27 PMSEIC (2010) As above.

28 Turner, G.M., Dunlop, M., Candy, S., (2016) 'The impacts of expansion and degradation on Australian cropping yields—An integrated historical perspective', Agricultural Systems 143: 22-37.

29 Calculated using Australian Bureau of Statistics (2015) 7121.0 – Agricultural Commodities, Australia, 2013-14, Canberra: Australian Bureau of Statistics.

It takes over 475 litres of water per day to grow food for each person in Melbourne

3.5 Water

To grow food for Melbourne's population takes over 758,000 million litres of water per year (758 gigalitres). This is around double Melbourne's household usage, which is approximately 376 gigalitres per year[30]. It is equivalent to 475 litres per person per day or 173,375 litres per person per year.

This is an under-estimate of the total amount of water used to grow food for Melbourne, as it includes only the irrigation water that is used to grow crops and animal feed, as well as drinking water for animals. Irrigation water is sometimes referred to as 'blue water'. 'Green water' - the water that falls directly onto crops as rain - is not included in this figure, because it is not tracked in Australia's water accounts[31].

Agriculture in Australia is predominantly dryland agriculture, reliant on green water. Only 1% of Australian farmland is irrigated[32]. This is slightly higher in Victoria, where 5% of farmland is irrigated[33]. Other research has estimated that considerably more green water than blue water is typically used in producing food[34].

Our estimate of the amount of water required to grow Melbourne's food also excludes water used at other stages of the food supply chain, such as food processing. However, other research indicates that water use in food processing in Australia represents less than 2% of the water used in agricultural production[35].

As Australia is largely self-sufficient in food[36], our estimate of the amount of water needed to grow food for Melbourne draws on data about the amount of water applied to food crops in Australia[37]. Different types of food require different amounts of water. For example, 18% of the average Melbournian's diet is fruit[38], but only 0.5% of the water used to grow their food is attributed to fruit. Three quarters of the typical Melbournian's water foodprint is attributed to livestock products - 26.3% to beef and lamb and 53% to dairy products. More water is used to produce dairy products than red meat, because dairy production in Australia typically takes place on irrigated pastures, while most beef and lamb production takes place on dryland ranges and is rainfed (this 'green water' has not been included in our estimate of the water used to feed Melbourne).

30 Melbourne Water (2015) 'Enhancing Life and Liveability', Melbourne: Melbourne Water.

31 Australian Bureau of Statistics (2015a) 4610.0 – Water Account 2013-14, Canberra: Australian Bureau of Statistics.

32 Table 4.8 in Australian Bureau of Statistics (2015a) As above.

33 Australian Bureau of Statistics (2015a) As above.

34 Mekonnen, M., Hoekstra, A. (2011) 'A Global Assessment of the Water Footprint of Farm Animal Products' Ecosystems 15: 401-415

35 Water use in food processing in Australia has been estimated at 215 gigalitres per year, compared to water use in agriculture of 12,000 gigalitres a year – Wallis, D., Brook, P. and Thompson, C. (2007) Water sustainability in the Australian Food Processing Industry. Australian Food Statistics 2007. Canberra: Department of Agriculture, Fisheries and Forestry.

36 PMSEIC (2010) As above.

37 Calculated from ABS (1993-ongoing) 4610.0 - Water Account, Canberra: Australian Bureau of Statistics.

38 ABS (2014) As above.

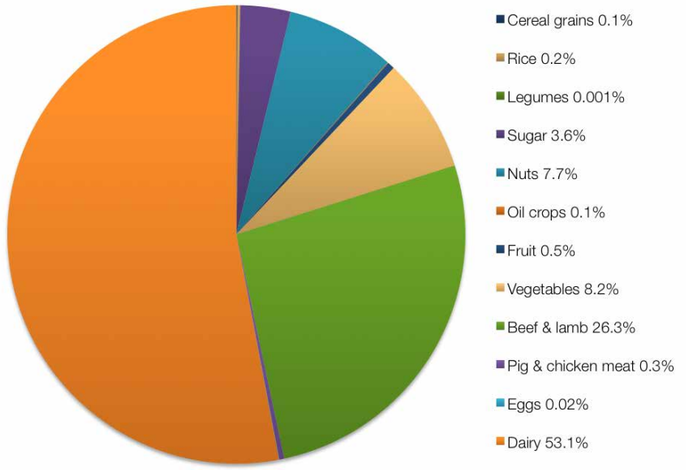


Figure 5: Proportion of water used to feed Melbourne by food group

When Melbourne grows to a population of around 7 million by 2050, approximately 1598 gigalitres of water will be needed per year to grow food for the city. This is around 627 L per person per day, a 32% increase on the amount of water currently required per capita to grow Melbourne's food.

More water is likely to be needed to grow each person's food as a result of land degradation and the impacts of climate change. Due to land degradation, more land is likely to be required to produce the same amount of food (see section 3.4), and more water will need to be applied to irrigate that land. More irrigation water is also likely to need to be applied as the climate dries due to the impacts of climate change[39].

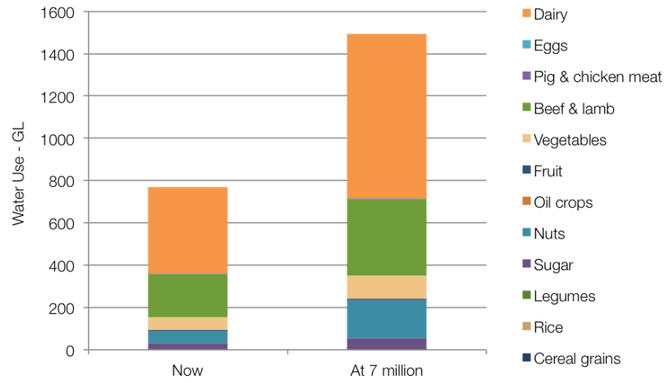


Figure 6: Water required to feed Melbourne now and at 7 million

39 Turral, H., Burke, J., & Faures, J. (2011) Climate change, water and food security. Rome: FAO. http://www.fao.org/docrep/014/i2096e/i2096e.pdf

Melbourne's food consumption accounts for over 0.9 tonnes of GHG emissions per capita per year

3.6 Energy and GHG emissions

Melbourne's food consumption accounts for over 0.9 tonnes of GHG emissions per capita per year, which is 4.1 million tonnes (megatonnes) in total for Melbourne. These are the emissions associated with food production on farm only. They do not include emissions generated in the processing, refrigeration, transport, cooking or waste of food, and are therefore an under-estimate of the total food-related emissions for Melbourne (see section 3.7 for GHG emissions associated with food waste). GHG emissions associated with food production represent around 4% of per capita emissions[40].

Around 58% of the GHG emissions associated with Melbourne's food production are due to red meat production (beef and lamb), and a further 21% of emissions are associated with dairy production. This is mostly due to enteric emissions from ruminant livestock, the vast majority from cattle rather than sheep. This is a conservative estimate of emissions due to meat consumption. It assumes 14 kg per capita beef consumption per year, based on data from a 2011 national survey of consumption[41]. However, industry sources estimate per capita beef consumption to be considerably higher[42].

Other sources of emissions related to food production come from cropping and fertilizer application, soil carbon loss due to grazing, and emissions from the use of farm machinery.

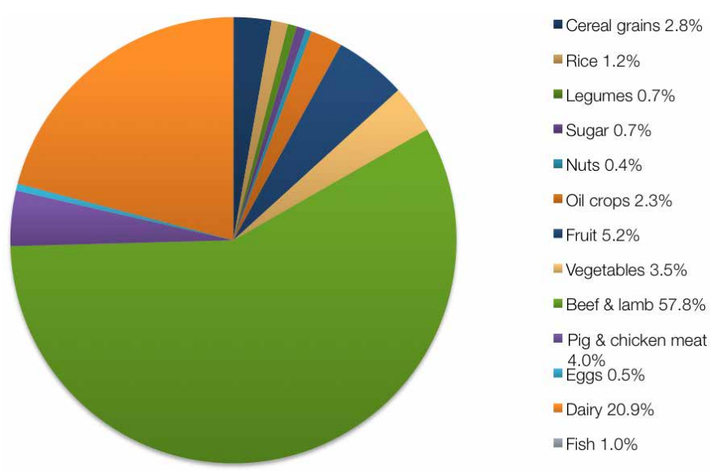


Figure 7: GHG emissions from Melbourne's food consumption by food group

40 Per capita emissions in Australia are 22.7 T per year - Department of the Environment (2016) Quarterly Update of Australia's National Greenhouse Gas Inventory: September 2015. Canberra: Commonwealth of Australia.

41 Beef consumption in the 2011-12 Australian Health Survey: Nutrition, (Australian Bureau of Statistics, 2014), was estimated to be 17.5 kg per capita. A continuing declining trend in beef consumption was also assumed, generating an estimate for 2014 of 14 kg beef consumption per capita per year.

42 Meat and Livestock Australia (2015) Fast facts: Australia's beef industry. Canberra: Meat and Livestock Australia.

As Melbourne's population grows, GHG emissions due to food production will increase. By 2050, when Melbourne reaches a population of around 7 million, the city's total GHG emissions due to food production are likely to increase to around 7.4 megatonnes. Per capita GHG emissions are also likely to increase around 13% to 1.1 tonnes. This projected increase in per capita emissions is due to an increase in the amount of land required to produce food, as a result of land degradation, and an increase in the number of livestock required to meet Melbourne's meat needs, due to the impacts of climate change, including the effects of heat stress on livestock[43].

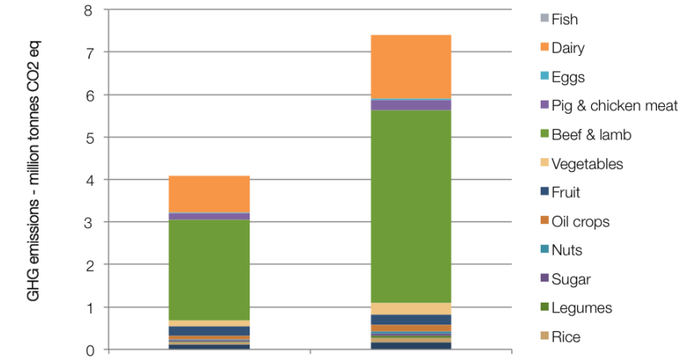


Figure 8: GHG emissions from feeding Melbourne now and at 7 million

Melbourne's food consumption also has a high energy footprint. This energy footprint considers only on farm fuel use. On farm fuel use to produce Melbourne's total food consumption is around 114 million litres (megalitres) per year[44]. Most of this fuel use is associated with beef consumption, as a result of the fuel required to produce animal feed, primarily from the use of farm machinery.

Agriculture is responsible for a relatively small proportion of Australia's energy use, accounting for just 1.7% of the nation's industrial energy consumption[45].

43 Brown, J et al. (2016) In 30 years, how might climate change affect what Australians eat and drink? Bulletin of the Australian Meteorological and Oceanic Society 29: 22-27.

44 This figure excludes fuel use for forestry and other non-food uses.

45 BREE (2014) Energy in Australia. Canberra: Bureau of Resource and Energy Economics.

Melbourne generates around 207 kg of food waste per person per year

3.7 Food waste

The 1.9 million tonnes of food that Melbourne consumes each year generates around 907,537 tonnes of edible food waste through the food supply chain. Around 32% of edible food is wasted in total. This amounts to around 568 g food waste per capita per day (or 207 kg of food waste per capita per year).

Stage of the food supply chain	Tonnes per year
Pre-farmgate waste	217,287
Waste from processing and distribution	319,276
Post-consumer waste[46]	370,974
Total edible waste	907,537

Table 2: Total food waste from Melbourne's food consumption - waste through the food supply chain*

Of the total edible food waste, around 370,974 tonnes – or 41% - is 'post-consumer' waste generated by households and in restaurants and cafes, around 24% is pre-farmgate waste (that occurs before food leaves the farm), and 35% occurs during food processing and distribution.

There is little available data on food waste through the food supply chain in Australia, with the exception of household waste[47], so these estimates of food waste in Melbourne are based on estimates from the United Nations Food and Agriculture Organisation (FAO). FAO estimates of food waste in the North America/Oceania region (which includes Australia) have been used in ASFF to model the amount of food waste generated as a result of food consumed in Melbourne. This data may not reflect recent efficiency gains in some Australian industries in reducing and re-using food waste.

Different types of food incur waste to differing degrees along the food chain. Figure 9 shows waste throughout the food system for each food type. Losses of inedible material are also incurred during food processing. For some crops there is a substantial loss of this material - when raw sugar is converted into refined sugar for example, oil seeds into oil, or raw milk into dairy products, such as cheese and butter. These inedible losses are not included in our estimation of Melbourne's food waste footprint.

* Table 2 and Figure 9 have been altered from the original by removing data on 'Inedible waste from food processing'. This has been done in order to facilitate accurate interpretation of the findings. Inedible by-products from food processing are not included in our estimates of food waste.

46 Post-consumer waste includes waste from households, restaurants and cafes.

47 Sound local data exists for household food waste, but not for food waste at other stages of the food supply chain. Sustainability Victoria has estimated that households in Victoria throw out around 400,000 tonnes of food waste - Sustainability Victoria (2014) Food waste research - http://www.lovefoodhatewaste.vic.gov.au/about-us/food-waste-research [accessed 24/4/16]

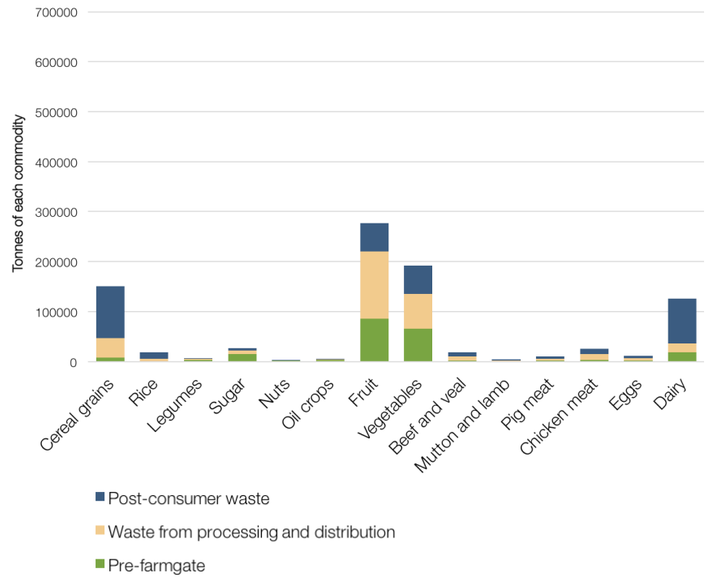


Figure 9: Food waste from Melbourne's food consumption by food type - waste through the food supply chain*

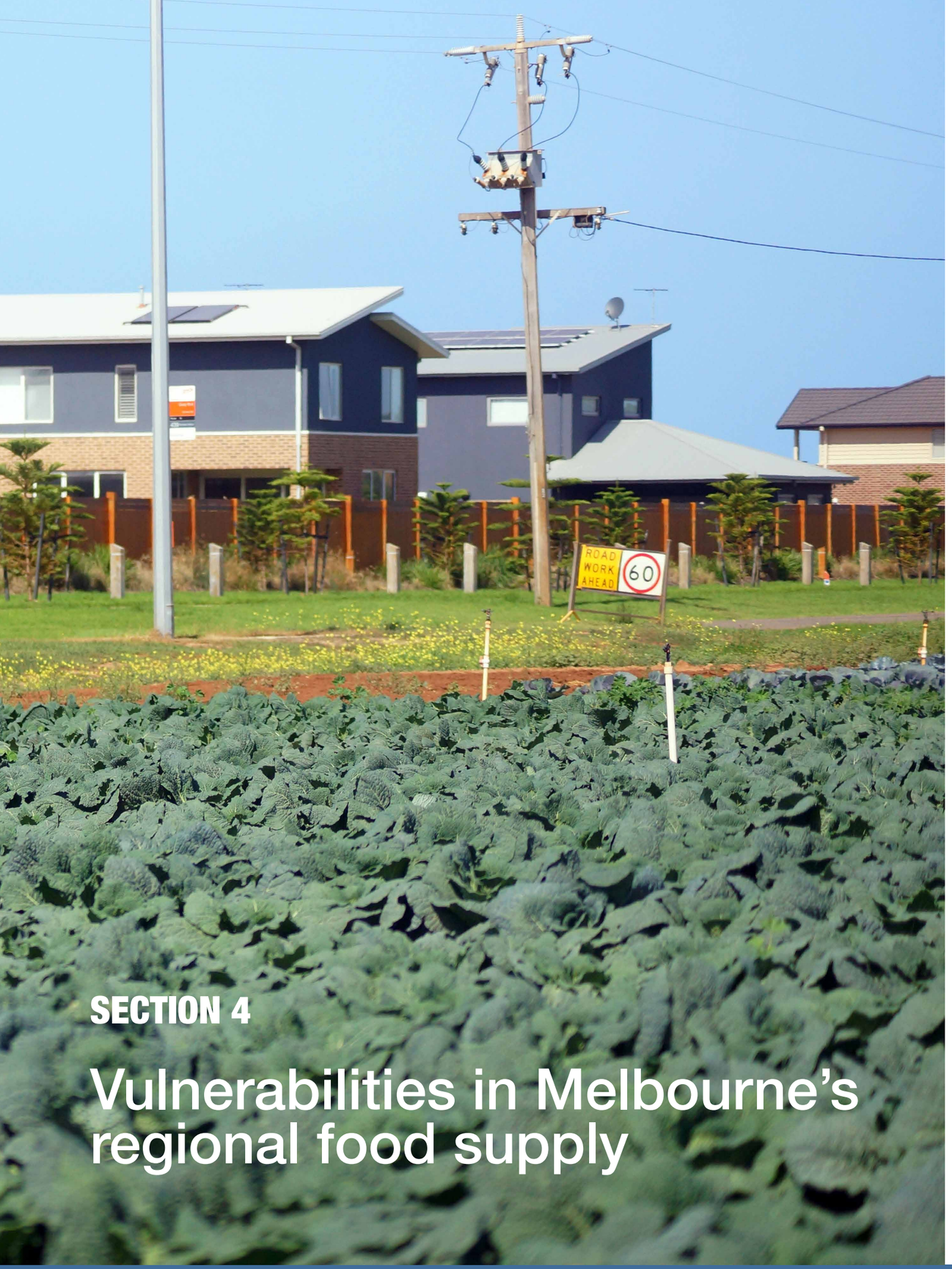
Food waste from Melbourne's food consumption leads to around 1.5 million tonnes of GHG emissions per year from food waste in landfill

The FAO estimates that around one third of all food produced globally for human consumption is lost or wasted[48]. Food waste is not only a waste of the land, water, and energy used in the production and distribution of food. It is also a significant source of avoidable GHG emissions from food waste in landfill. Ranking food waste against the top GHG emitting nations, it would represent the third highest emitter, behind only the USA and China[49].

Food waste from Melbourne's food consumption leads to around 1.5 million tonnes of GHG emissions per year from food waste in landfill, which is 0.3 tonnes per person per year. Food waste as a result of Melbourne's food consumption also represents the waste of around 3.6 million hectares of land and 180 gigalitres of water, and producing that extra food generates around 1 million tonnes of GHG emissions.

48 FAO (2011) 'Global food losses and food waste'. Rome: FAO

49 FAO (2013) 'Food wastage footprint: Impacts on natural resources - Summary report' Food and Agriculture Organisation of the United Nations.



SECTION 4

Vulnerabilities in Melbourne's regional food supply

Melbourne is fed by a complex global food system that draws on food supplies from other parts of Australia and other countries[50]. However, Melbourne is also blessed with a strong regional food supply that currently has significant capacity to contribute to feeding the city[51].

Maintaining a strong regional food supply is likely to become increasingly important in the context of pressures on the global food system. However, Melbourne's regional food supply faces challenges, including the impacts of climate change and decreasing availability of the natural resources on which food production depends.

This section identifies vulnerabilities in the environmental sustainability and resilience of Melbourne's regional food supply, while section 5 explores strategies to address these vulnerabilities.

One of the most significant vulnerabilities in Melbourne's regional food supply is the loss of productive agricultural land

4.1 Loss and degradation of farmland

One of the most significant vulnerabilities in Melbourne's regional food supply is the loss of productive agricultural land due to urban expansion and soil degradation.

The first phase of the Foodprint Melbourne project highlighted that if the city continues to expand at its long-term rate of urban density, 16% of farmland in Melbourne's foodbowl is likely to be lost by 2050 in order to accommodate population growth[52]. At the same time, the demand for food will increase by 60% to meet the food needs of an extra 2.63 million people. As a result, the foodbowl's capacity to meet the food needs of Greater Melbourne's population is likely to fall from 41% in 2015 to 18% by 2050.

The greatest impact is likely to be on food production in the inner foodbowl, where higher population growth will occur. The foodbowl's capacity to meet Melbourne's vegetable needs is likely to be particularly affected, as the inner foodbowl accounts for 36% of the state's vegetable growing land (while the outer foodbowl contains an additional 15%)[53]. Several other studies have also pointed to potential vulnerabilities in fruit and vegetable supply in Victoria and other areas of Australia due to urban expansion[54].

50 Although Melbourne's food supply draws on global food sources, the vast majority is sourced from within Australia. Around 93% of Australia's food needs are met by Australian farmers - PMSEIC (2010) As above.

51 Melbourne's city foodbowl currently has the capacity to meet 41% of the food needs of Greater Melbourne. See Sheridan, J., Larsen, K. and Carey, R. (2015) As above.

52 Sheridan, J., Larsen, K. and Carey, R. (2015) As above.

53 Calculated from ABS (2013). As above.

54 Larsen, K., Turner, G., Ryan, C., Lawrence, M. (2011) Victorian Food Supply Scenarios: Impacts on availability of a nutritious diet. Melbourne: Victorian Eco-Innovation Lab; Sobels, J. (2010) Summary of research into the long-term physical implications of net overseas migration to Australia in 2050. Adelaide: National Institute of Labour Studies.

Food production depends on healthy soils, and Australia's ancient soils are particularly susceptible to degradation through intensive agricultural activity[55]. Degradation of productive agricultural land in Victoria is occurring as a result of salinity, soil acidification and erosion[56]. Data on the extent of soil degradation in Victoria is poor, but estimates suggest that around 60% of the state's soils are vulnerable to erosion and decline in soil structure, and that 2% of Victoria's area of dryland (non-irrigated) agriculture is affected by salinity[57].

4.2 Pressures on farming

In order to maintain the productive capacity of Melbourne's foodbowl, farmland on the city fringe must be actively farmed. However, farmers on Melbourne's fringe are under pressure, as they are elsewhere in Australia, and some are choosing to leave their farms. Between 2006 and 2011, the number of family farmers in Australia fell by 11%[58].

Farmers are caught in a cost-price squeeze. The cost of farm inputs – like fertilisers, fuel and pesticides – has been rising faster than the prices they receive for their produce[59], and supermarkets have put downward pressure on farmgate prices.

Farmers on the city fringe face other pressures, such as the encroachment of residential and other land uses[60], conflicts with residents over farm practices, and the high cost of land and water[61]. These challenges add to the pressures of climate change and the limited availability of natural resources.

4.3 Climate change

Climate change is likely to have a range of impacts on food production in Melbourne's foodbowl. Strong drying and warming is expected in Southern Australia[62], and significant drying has already occurred in Victoria[63].

Climate change is likely to reduce the capacity for food production across Australia, including in Melbourne's foodbowl[64]. Crop production is expected to be affected by rising temperatures, reduced water availability, extreme weather events, increasing pest activity and changes in the production windows for crops[65]. Fruit and vegetable production is particularly sensitive to climate impacts. In 2009, a heatwave in Victoria resulted in the loss of 20-25% of the apple crop and 60-80% of the strawberry crop in the Port Philip region[66].

Climate change will affect food production in many parts of the world and is expected to make global food supplies more vulnerable to disruption[67]. Regional foodbowls could play an important role in increasing the resilience of city food supplies to shocks in national and global food systems from extreme weather events or rapid rises in food prices. Their ready access to secure sources of recycled water could also make city foodbowls particularly important in the context of increasing water scarcity.

Regional foodbowls could play an important role in increasing the resilience of city food supplies to shocks

55 Australian Bureau of Statistics (2002) Measuring Australia's progress 2002. Canberra: Australian Bureau of Statistics.

56 Commissioner for Environmental Sustainability Victoria (2013) 'Victoria State of the Environment Report 2013, Science Policy People' Melbourne: Commissioner for Environmental Sustainability Victoria.

57 Commissioner for Environmental Sustainability Victoria (2013) As above.

58 Australian Bureau of Statistics (2012a) 4102.0 - Australian Social Trends. December 2012.

59 The Treasury (2008) Media release. ACCC examination of fertilizer prices. 22 August 2008.

60 Parberry, P (2008) Square pegs in green wedges? Landholders and natural resource management in Melbourne's rural hinterland. Melbourne: Department of Primary Industries.

61 OSISDC (2010) Inquiry into sustainable development of agribusiness in outer suburban Melbourne. May 2010. Outer Suburban/Interface Services and Development Committee.

62 Reisinger et al. (2014) Australasia. In Barros et al. (eds) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

63 Bureau of Meteorology (2014) State of the Climate Report, Bureau of Meteorology, Australia.

64 Reisinger et al. (2014) As above.

65 Gunsakera, D., Kim, Y., Tullah, C. and Ford, M. (2007) Climate change: Impacts on Australian agriculture. Australian Commodities 14 (4) December quarter 2007.

66 DPI (2009) cited in Hughes, L., Steffen, W. Rice, M. and Pearce, A. (2015) Feeding a Hungry Nation: Climate Change, Food and Farming in Australia. Climate Council of Australia.

67 Porter, J R et al (2014) Food security and food production systems. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Recycled water is likely to be one of the most secure sources of water for food production during prolonged drought

4.4 Water scarcity

One of the main ways that climate change will impact food production is through water scarcity[68]. Water availability for food production is also falling as a result of increased demand for water and the need to restore environmental flows in river systems[69].

Recycled waste water is likely to be one of the most secure sources of water for food production during times of water scarcity, such as prolonged drought. Cities have abundant access to sources of waste water from city water treatment plants.

Some of Melbourne's best horticultural land is located close to the city's two main water treatment plants, the Eastern and Western Treatment Plants. The Werribee Irrigation District, situated next to the Western Treatment Plant, grows around 10% of the vegetables produced in the state of Victoria. The importance of recycled water in this district became clear towards the end of Australia's Millennium Drought (which lasted from 1996 to mid-2010), when river flows dropped to unsustainable levels, and recycled water became the main source of water for vegetable growers in the area, enabling production to continue during the drought[70].

There is potential to extend and improve the infrastructure that supplies recycled water in areas near the city's water treatment plants in order to develop them as 'drought-proof' foodbowls (see section 5.3.1).

4.5 Limits to other natural resources

Water and land are not the only inputs to food production that are in limited supply. Inputs based on fossil fuels, such as energy and nitrogen-based fertilisers are also in increasingly short supply.

The global food system is dependent throughout the food supply chain on fossil fuels – for fertilisers, pesticides, transportation and refrigeration. The food sector accounts for around 30% of the world's total energy consumption.[71] However, the evidence now suggests that 80% of global coal reserves, half of gas reserves and a third of oil reserves need to be left in the ground if global warming is not to exceed 2 degrees.[72] Food system inputs derived from fossil fuels are therefore likely to be in increasingly short supply in future.

Food production is also dependent on phosphorous as a critical input for conventional fertilisers. Phosphorous is a non-renewable resource derived from phosphate rock, and there is evidence to suggest that global reserves of phosphorous may be depleted in 50-100 years.[73]

The global food system will need to look to alternative sources for these inputs to food production.

68 Reisinger et al. (2014) As above.

69 Molden, D. (ed.) (2007) Water for Food, Water for Life: A comprehensive Assessment of Water Management in Agriculture. London: Earthscan, and Colombo: International Water Management Institute.

70 Southern Rural Water (2009) Regional Environment Improvement Plan: Werribee Irrigation District Class A Recycled Water Scheme. Melbourne: Southern Rural Water.

71 FAO (2011a) Policy brief: The case for energy-smart food systems. Rome: FAO.

72 McGlade, C. and Ekins, P. (2015) The geographical distribution of fossil fuels unused when limiting global warming to 2 degrees. Nature 157: 187-193.

73 Cordell, D., Drangert, J. and White, S. (2009) The story of phosphorous, global food security and food for thought. Global Environmental Change 19: 292-305.

SECTION 5

Opportunities to strengthen Melbourne's regional food supply

This section investigates strategies for addressing vulnerabilities in the environmental sustainability and resilience of Melbourne's regional food supply.

It explores a number of 'what if' scenarios about actions that could be taken to address vulnerabilities and their potential effectiveness in reducing the environmental impacts of Melbourne's food consumption and strengthening Melbourne's regional food supply.

5.1 Protecting Melbourne's foodbowl

Melbourne's foodbowl currently has the capacity to meet around 41% of Melbourne's food needs. However, if the city continues to sprawl at its long-term rate to accommodate population growth, up to 16% of farmland in Melbourne's foodbowl could be lost by 2050, including up to 77% of farmland in the inner foodbowl, a region that includes farming areas such as Werribee South and the Mornington Peninsula[74]. As a result, the capacity of Melbourne's foodbowl to meet the city's food needs could fall to 18%.

If Melbourne were able to grow instead in a way that retains the capacity of the city's foodbowl, it could contribute to a more sustainable and resilient food supply for the city.

We modelled the potential impact on Melbourne's foodbowl of increasing urban density. If urban density were increased so that 80% of residential units became multiple dwelling units (townhouses and apartments) and the footprint of new buildings was reduced by 30% (see scenario summary for further details), urban sprawl could be reduced by about 50% by 2050 and 180,000 hectares of land in Melbourne's foodbowl could be saved. This area of land is equivalent to almost 5 times Victoria's vegetable growing land.

Scenario summary

The potential impacts of increasing urban density on land loss in Melbourne's foodbowl were modelled in ASFF. The scenario assumed that 80% of dwellings became multiple rather than single dwelling units (townhouses and apartments, rather than separate houses) and that the overall footprint of buildings was reduced by 30%. This change was phased in over 20 years between 2016 and 2036.

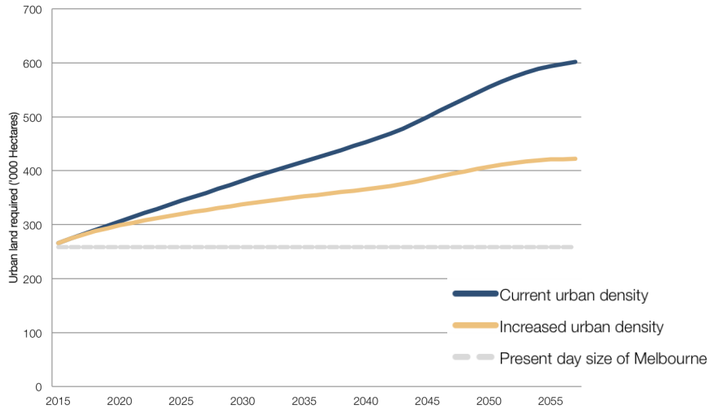


Figure 10: Potential impact of increasing urban density on the amount of land required to accommodate Melbourne's population growth.

74 Sheridan, J., Larsen, K., Carey, R. (2015) As above.

75 Planning Panels Victoria (2014) Moorabool Planning Scheme Amendment C62. Bacchus Marsh Urban Rezoning. 10 July 2014.

76 Moorabool Planning Scheme (2014) Municipal Strategic Statement. Bacchus Marsh. 21.07 09/10/2014 C72.

Case Study: Bacchus Marsh

Bacchus Marsh is around 50 km to the North-West of Melbourne in Moorabool Shire. The town has an area of intensive irrigated agriculture on its outskirts that is an important source of fresh produce, particularly fruit and vegetables. The Bacchus Marsh Irrigation District is also an important source of local jobs, employing almost 600 people in 2009[75].

Bacchus Marsh has experienced rapid population growth and pressure on agricultural land in the irrigation district due to urban encroachment from Melbourne's west. However, Moorabool Shire Council has protected the area from urban expansion by maintaining its agricultural zoning and through clear statements in the Shire's planning scheme[76] that the irrigation district should be maintained as an area of horticultural production and protected from urban expansion.

Scenario summary

Our scenario assumed that 50% of farmers introduced regenerative agriculture practices over a transition period of 10 years (2016 to 2026). Regenerative agriculture practices involved a shift from conventional cropping to a mixed livestock-cropping system, which incorporated perennial pastures (dominated by native grasses) for livestock feed and soil conditioning. We assumed that livestock would be grazed for 4 out of 5 years, and crops produced in the 5th year. The stocking density on native pastures was also reduced from 7 DSE (dry sheep equivalents) to a more sustainable stocking density of 5 DSE.

5.2 Regenerative agriculture

One approach to addressing land and soil degradation is regenerative agriculture. Regenerative agriculture is an approach to sustainable agriculture that rebuilds soil condition and prevents further degradation by matching the use of the land to its capability.

Regenerative agriculture involves mixed cropping and livestock grazing. Livestock are grazed on perennial pastures dominated by native grasses, so that bare soil is not exposed. Interspersing years of crop production with grazing enables native grasses to replenish soil structure, water and nutrients for future crop rotations[77]. No-till cultivation is also practiced to reduce soil erosion and degradation[78]. Regenerative agriculture has been successfully used in broadacre farming in Australia[79].

The evidence suggests that regenerative agriculture practices could enable crop yields to be maintained, while regenerating soil health and reducing some of the negative impacts of conventional agricultural practices, such as over-application of fertilisers[80]. There is also evidence to suggest that regenerative agriculture practices could increase soil carbon[81].

We modelled the potential impacts of a shift to regenerative agriculture on Melbourne's foodprint.

Our modelling suggests that a shift to regenerative agriculture could have an impact across a number of elements of Melbourne's foodprint. The amount of (irrigation) water required per capita to produce food for Melbourne could reduce significantly – by around 45% – as cattle grazing on farms practicing regenerative agriculture would graze mainly on native pasture, rather than other forms of pasture or feed that are irrigated. More crops would also be grown in the mixed cropping-grazing system (see the scenario summary), reducing water use further.

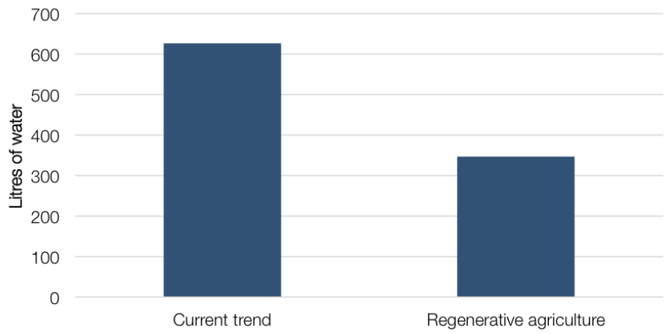


Figure 11: Water required per capita per day for food consumption in 2050 with a shift to regenerative agriculture

77 Kemp, D and Dowling, P. (2000) Towards sustainable temperate perennial pastures. Australian Journal of Experimental Agriculture 40: 125-132.

78 Millar, G. and Badgery, W (2009) Pasture cropping: a new approach to integrate crop and livestock farming systems. Animal Production Science 49: 777-787.

79 Seis, C. (2006) Pasture cropping as a means to managing land. Australian Organic Journal, Winter 2006.

80 Seis, C. (2006) As above.

81 Gould, S and Jehne, W (2011) Regenerating our landscape to transition Australia to a low-carbon future. Soils for life, http://www.soilsforlife.org.au/resources.html [accessed April 17 2016]

The GHG emissions associated with per capita food consumption would also fall slightly – by around 7% – if there were a shift to regenerative agriculture. Soil carbon increases with regenerative agriculture, and no till practices reduce emissions.

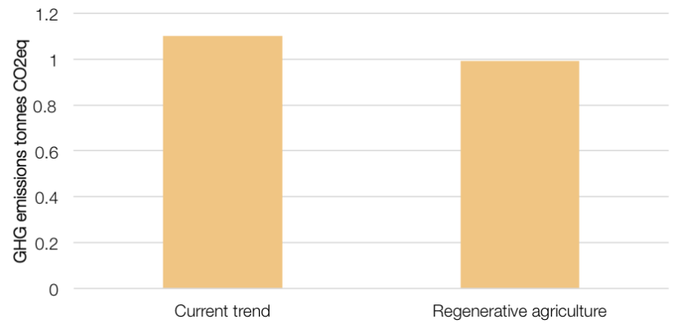


Figure 12: GHG emissions per capita per year from food consumption in 2050 with a shift to regenerative agriculture

Around 7% more land would be required per capita to produce food for Melbourne under a regenerative agriculture scenario. This is because the stocking density of livestock on pasture is reduced (fewer animals per hectare of land), so more land is required to produce beef and lamb for Melbourne. However, the total land area required is equivalent to just 8% of Australia's current farmland, and the negative impacts of the land use would be reduced.

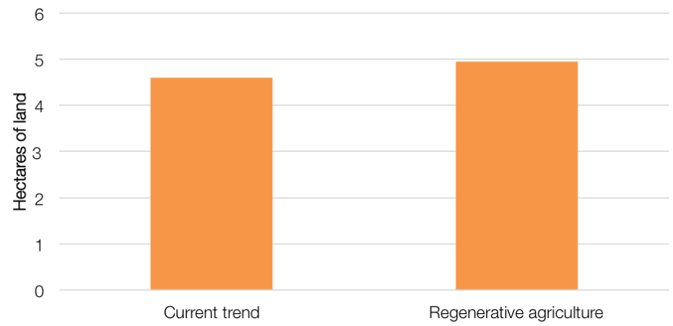


Figure 13: Land required per capita per year for food consumption in 2050

Soil condition would improve under a regenerative agriculture scenario, and this leads to some improvement in crop yields. Crop yields would still reduce over time to 2050, due primarily to the impacts of climate change, but the decreases in crop yields are slightly lower with regenerative agriculture than in a 'business as usual' scenario, and less fertilizer needs to be applied.

Case Study: Regenerative Farming

Colin Seis is an internationally renowned pioneer of a form of regenerative agriculture known as ‘pasture cropping’. He combines a mixed system of merino sheep and grains on his family’s 2000-acre New South Wales property.

In conventional cropping, grains are sown into stubble or bare soil, leaving a period during which soil is exposed to erosion and degradation. Under the pasture cropping system, perennial pastures that have already been grazed are planted with annual grains to take advantage of different ecological processes in the plants’ root systems. Colin has also trialed multi-species cropping with a combination of forage and grain crops alongside perennial pasture. In this system, the plants’ traits work together to create a succession of uses that require fewer inputs – such as herbicides – and that improve soil structure and water filtration[82].

A key focus of regenerative agriculture is not just maintaining soil condition but – as the name suggests – regenerating soil condition. Evaluations on Colin’s farm suggest that soil carbon has increased significantly, and that soil nutrient content has also increased across a broad range of nutrients. The shift to perennial grasslands has also led to a reduction in weeds, as they have been outcompeted by native grasslands. In 1999, pastures on the farm consisted of 60% weeds and 10% native perennial grasses. By 2012, pastures were just 5% weeds and 80% native grasses[83]. These native grasses have lower superphosphate requirements than annual pastures, requiring less fertilisers.

Colin reports that it now costs $120,000 less per year to achieve the same average crop yields on the farm. The change has led to improvements in wool quality and has created new income streams through the harvest and sale of native grass seeds.

82 http://www.pasturecropping.com/pasture-cropping

83 http://www.pasturecropping.com/images/PDF/Winona%20Case%20Study.pdf

Image courtesy of Soils for Life www.soilsforlife.org.au

5.3 Water reuse for agriculture

In the context of a drying climate and increasing demands on water resources, recycled water from city water treatment plants, desalination plants and stormwater run off could provide an increasingly secure source of water for food production in Melbourne’s foodbowl.

5.3.1 Recycled water

Recycled water can be used to produce food if treated to a high standard[84]. The areas of food production close to Melbourne’s two main water treatment plants, the Eastern and Western Treatment Plants, have access to recycled water to produce vegetables during drought[85]. Schemes using recycled water for agriculture also exist near some of the smaller water treatment plants around Melbourne, such as the Boneo Treatment Plant in the South-East (see case study on page 35).

Although there are schemes using recycled water from both of the city’s main water treatment plants, there is significant unused capacity in recycled water, particularly as a result of an upgrade of the Eastern Treatment Plant in 2014.

The Eastern and Western Treatment Plants (ETP and WTP) together treat just over 300 gigalitres of water each year. Around 6% of this recycled water is currently used to grow food, 10% is used in other ways, while 84% is unused and disposed of at sea (see table 3 on following page)[86].

84 Coliban Water (2011) Recycled Water Class Definitions. Bendigo: Coliban Water http://www.coliban.com.au/site/root/operations/documents/CW_Rec_Definitions_2012-version2.pdf [accessed 24/4/16]

85 Melbourne Water (2015a) Using Recycled Water, Melbourne Water. http://www.melbournewater.com.au/whatwedo/recyclewater/Pages/Using-recycled-water.aspx [accessed 24/4/16]

86 Melbourne Water (2015) As above.

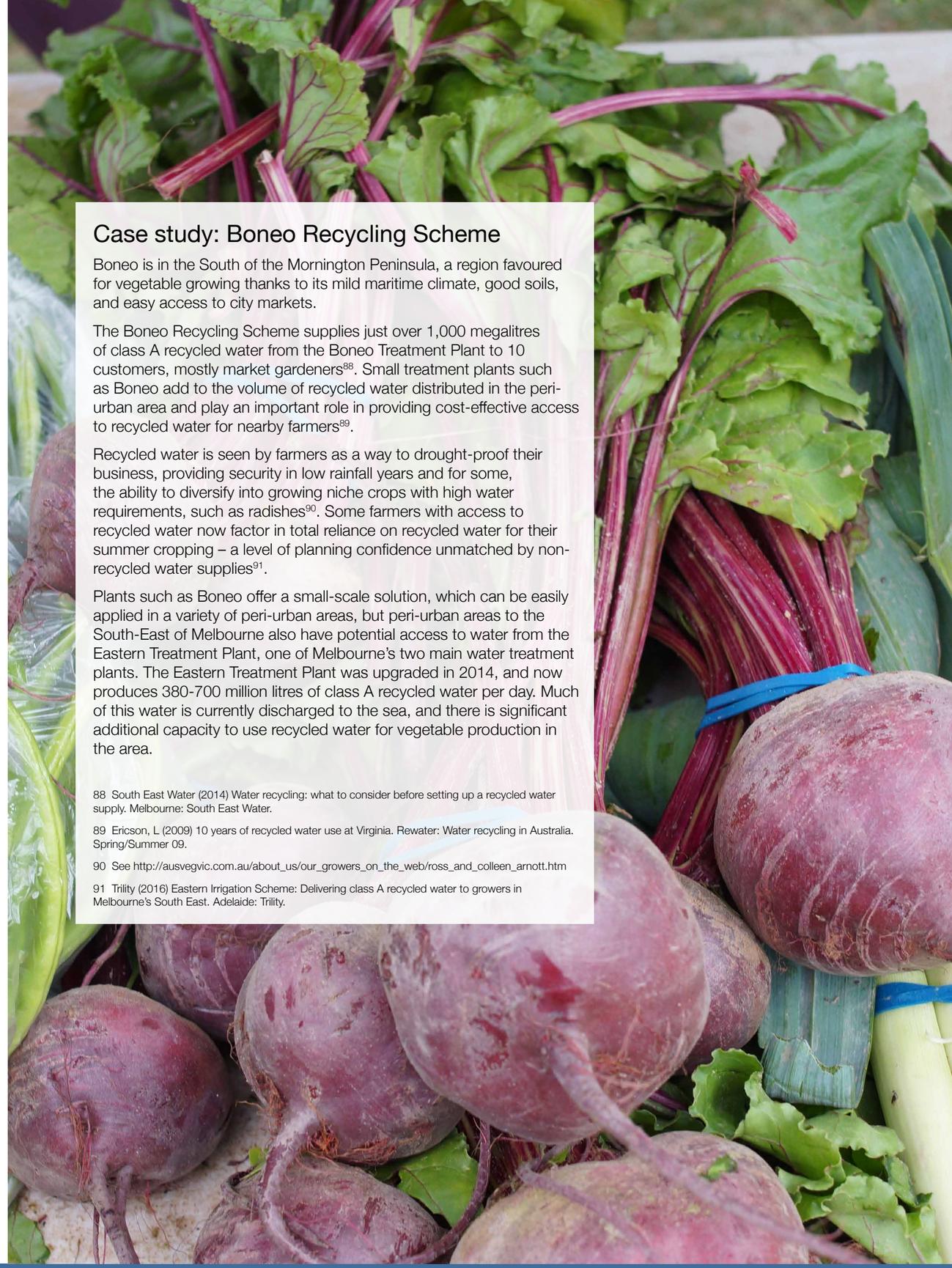
	2013/14	2014/15
Total treated wastewater available for recycling (GL/yr) (This figure is based on sewerage inflows to the treatment plants less losses for evaporation and in plant use during the treatment process.)	312	295
Total amount of recycled water currently supplied to non-agricultural uses from ETP and WTP (GL/yr)	34	28
Total recycled water already made available to agriculture from ETP and WTP (GL/yr) (MPH Agriculture, Werribee Irrigation District, Eastern Irrigation Scheme)	16	19
Total unused recycled water discharged into the ocean (GL/yr)	278	267

Table 3: Recycled water supply in Melbourne[87]

Not all of the unused recycled water produced by the water treatment plants can currently be used for agriculture, because some of the water is produced during winter outside of the growing season when farmers can make use of it, and because of a lack of the necessary infrastructure to store recycled water and to pipe this water to farmers in some areas.

It is unclear exactly how much of the unused recycled water could be diverted to agriculture, but just 10% of the available recycled water would be enough to grow half of the vegetables that Melbourne eats, 15% of the available recycled water would be double the amount of water needed to produce all of the lamb eaten by Melbourne, and 20% of the water would be enough to produce 70% of the nuts eaten by Melbourne.

87 Melbourne Water (2015) As above.



Case study: Boneo Recycling Scheme

Boneo is in the South of the Mornington Peninsula, a region favoured for vegetable growing thanks to its mild maritime climate, good soils, and easy access to city markets.

The Boneo Recycling Scheme supplies just over 1,000 megalitres of class A recycled water from the Boneo Treatment Plant to 10 customers, mostly market gardeners[88]. Small treatment plants such as Boneo add to the volume of recycled water distributed in the peri-urban area and play an important role in providing cost-effective access to recycled water for nearby farmers[89].

Recycled water is seen by farmers as a way to drought-proof their business, providing security in low rainfall years and for some, the ability to diversify into growing niche crops with high water requirements, such as radishes[90]. Some farmers with access to recycled water now factor in total reliance on recycled water for their summer cropping – a level of planning confidence unmatched by non-recycled water supplies[91].

Plants such as Boneo offer a small-scale solution, which can be easily applied in a variety of peri-urban areas, but peri-urban areas to the South-East of Melbourne also have potential access to water from the Eastern Treatment Plant, one of Melbourne's two main water treatment plants. The Eastern Treatment Plant was upgraded in 2014, and now produces 380-700 million litres of class A recycled water per day. Much of this water is currently discharged to the sea, and there is significant additional capacity to use recycled water for vegetable production in the area.

88 South East Water (2014) Water recycling: what to consider before setting up a recycled water supply. Melbourne: South East Water.

89 Ericson, L (2009) 10 years of recycled water use at Virginia. Rewater: Water recycling in Australia. Spring/Summer 09.

90 See http://ausvegvic.com.au/about_us/our_growers_on_the_web/ross_and_colleen_arnott.htm

91 Trility (2016) Eastern Irrigation Scheme: Delivering class A recycled water to growers in Melbourne's South East. Adelaide: Trility.

5.3.2 Stormwater

In addition to recycled water, an estimated 400-550 gigalitres of stormwater runs off Melbourne's urban catchment annually, and less than 0.25% of this stormwater is currently diverted for use[92].

Stormwater contains pollutants, and harvested stormwater is generally cleaned before storage. The cost of cleaning large quantities of stormwater can be high. However, Melbourne has a number of options to increase rainwater capture, which could reduce the amount of polluted water reaching stormwater drains[93]. When last investigated, less than 1 gigalitre of rainwater was collected across Melbourne, and strategies were put in place to increase this[94]. Increasing the amount of rainwater collected could alleviate some stormwater-related flooding issues.

The potential of stormwater reuse for agricultural production in Melbourne's foodbowl is currently unclear. However, options for stormwater reuse are under investigation in Melbourne[95] and other Australian cities[96], including reuse for agriculture.

92 Victorian Parliamentary Environment and Natural Resources Committee (2009) 'Inquiry Into Melbourne's Future Water Supply,' Melbourne: Victorian Parliament.

93 Victorian Parliamentary Environment and Natural Resources Committee (2009) As above.

94 Yarra Valley Water (2008) 'Water Supply Demand Strategy for Melbourne 2006-2055,' Melbourne: Yarra Valley Water.

95 Melbourne Water (2013) Stormwater strategy: A Melbourne Water strategy for managing urban and rural run off. Melbourne: Melbourne Water.

96 SA Department of Water (2011) Stormwater strategy: The future of stormwater management. Adelaide: Department of Water.

5.4 Modifying our diets

The findings of this research indicate that our current dietary patterns have a considerable environmental impact. One approach to creating a more sustainable and resilient food system is therefore to modify our diets. There is an increasing international focus on 'sustainable diets'[97] as part of the solution to making food systems more sustainable[98].

There are some uncertainties about exactly what a sustainable diet would look like, particularly in an Australian context, as this is an emerging area of research. The environmental sustainability of our diets depends on the amounts and types of foods that we eat and the way that those foods are produced[99]. There are also questions about what constitutes a sustainable and healthy diet[100]. A healthy diet is not necessarily always a sustainable diet[101]. However, a growing body of evidence concludes that we can develop diets that meet nutritional guidelines and are more sustainable than current diets[102].

General principles are emerging about what constitutes a healthy, sustainable diet,[103] and some countries have drawn on these principles to integrate advice into their national dietary guidelines about how to eat sustainably[104]. The evidence suggests that healthy, sustainable diets include consumption of a diverse range of fruits, vegetables, legumes and wholegrains, with low consumption of meat and fish, moderate consumption of dairy products and very limited consumption of processed foods that are high in fat, salt and sugar[105].

97 For a definition of sustainable diets, see FAO (2010) Report: International Scientific Sympo-sium, Biodiversity and Sustainable Diets, United Against Hunger, Rome 3-5 November 2010.

98 UNEP (2012) Avoiding future famines: Strengthening the ecological foundation of food security through sustainable food systems. A UNEP synthesis report. Nairobi: UNEP. FAO (2010) As above.

99 Garnett, T. (2014) What is a sustainable healthy diet? A discussion paper. Oxford: Food Climate Research Network.

100 Macdiarmid, J. (2013) Is a healthy diet an environmentally sustainable diet? Proceedings of the Nutrition Society, 72: 13–20

101 Macdiarmid, J. (2013) as above; Vieux F, Soler L-G, Touazi D, Darmon N. (2013) High nutritional quality is not associated with low greenhouse gas emissions in self-selected diets of French adults. American Journal of Clinical Nutrition 97:569–83.

102 Garnett, T. (2014) As above.

103 Garnett, T. (2014a) Changing what we eat: A call for research and action on widespread adoption of sustainable healthy eating. Oxford: Food Climate Research Network.

104 Ministry of Health of Brazil (2014) Dietary Guidelines for the Brazilian Population. 2nd Edition. Ministry of Health of Brazil, Primary Healthcare Department; Livsmedelsverket National Food Agency (2015) Find your way to eat greener, not too much and be active. April 2015. Livsmedelsverket.

105 Garnett, T. (2014a) As above.

5.4.1 Reducing meat consumption

The findings of this research indicate that consumption of animal protein (as meat and dairy products) accounts for a significant proportion of the environmental footprint of feeding Melbourne (see section 3). These findings are consistent with a growing body of evidence that consumption of animal products accounts for a large proportion of the environmental footprint of contemporary diets[106] and that livestock production has a range of significant environmental impacts[107].

Australian livestock production systems are different to those elsewhere in the world, because of their greater use of outdoor grazing rather than feedlots. Much of this grazing land cannot be used for other types of food production[108].

There is some evidence that the environmental impacts of beef and lamb production are different, as a result of these different production systems, and that the water footprint of beef production in Australia may be lower than elsewhere in the world[109]. Grazing systems are typically associated with a higher land footprint though, and may also generate higher GHG emissions[110]. Our research indicates that meat's contribution to the environmental footprint of Melbourne's food consumption is considerable, regardless of differences in production systems.

The role of meat consumption in sustainable, healthy diets is complex. Meat consumption has nutritional benefits. It is a valuable source of protein, as well as iron and other essential nutrients[111]. Culturally, meat is also an important part of our diet. However, high levels of red meat consumption, particularly processed meats, have been associated with colorectal cancer[112].

One approach to reducing meat consumption that is becoming more common around the world is a 'Meatless' or 'Meat Free' Monday[113]. This is a global initiative to go meat-free one day a week.

106 See Low Carbon Oxford (2013) Foodprinting Oxford: How to Feed a City. Oxford: Low Carbon Oxford/ LandShare; Eschel, G., Shepon, A., Makov, T., Milo, R. (2014) Land, irrigation water, greenhouse gas, and reactive nitrogen burdens of meat, eggs, and dairy production in the United States, PNAS 111, 33: 11996-12001; Macdiarmid (2013) As above.

107 Garnett (2014) As above.

108 Wiederman, S., McGahan, E., Murphy, C. and Yan, M. (2016) As above.

109 Wiederman, S., McGahan, E., Murphy, C. and Yan, M. (2016) As above.

110 Peters, G., Rowley, H., Wiederman, S., Tucker, R., Short, M. and Schulz, M. (2010) Red meat production in Australia: Life cycle assessment and comparison with overseas studies. Environmental Science and Technology 44: 1327-1332.

111 NHMRC (2013) Eat for Health. Australian Dietary Guidelines: Summary. Canberra: National Health and Medical Research Council.

112 World Cancer Research Fund/American Institute for Cancer Research (2011) Continuous Update Project Report. Food, Nutrition, Physical Activity, and the Prevention of Colorectal Cancer.

113 See http://www.meatlessmonday.com

Case study: Meat Free Monday

Meat Free or 'Meatless' Monday is a global movement to go meat-free one day a week. The initiative started in 2003 in association with the John Hopkins Bloomberg School of Public Health to raise awareness about the health benefits of reducing high levels of meat consumption. It has since gathered momentum as a way of also reducing the environmental impacts of food consumption, including the climate impacts of GHG emissions from ruminant (e.g. beef and lamb) production.

Meatless Monday is now a worldwide movement that involves schools, university campuses, hospitals and cities that promote meat free Mondays. Cities that have committed to promoting Meatless Mondays include US cities such as Los Angeles, San Francisco and Washington DC, as well as European cities, such as Ghent in Belgium and Barcelona in Spain. For more information, see the Meatless Monday website.

Scenario summary

A Meat Free Monday was modelled by removing a day's worth of meat consumption from Melbourne's diet and replacing it with legumes in portion sizes recommended by the Australian Dietary Guidelines[114]. This involved decreasing each person's weekly meat consumption by 123 g and increasing their legume consumption by 185 The impact of this dietary change on Melbourne's foodprint was modelled in ASFF as an immediate change taken up by the population of Greater Melbourne.

Our findings indicate that if Meat Free Monday was taken up now by Melbourne's population, it could reduce the city's per capita footprint for land, water and GHG emissions by around 8%.

We modelled the potential impact of a Meat Free Monday on Melbourne's foodprint.

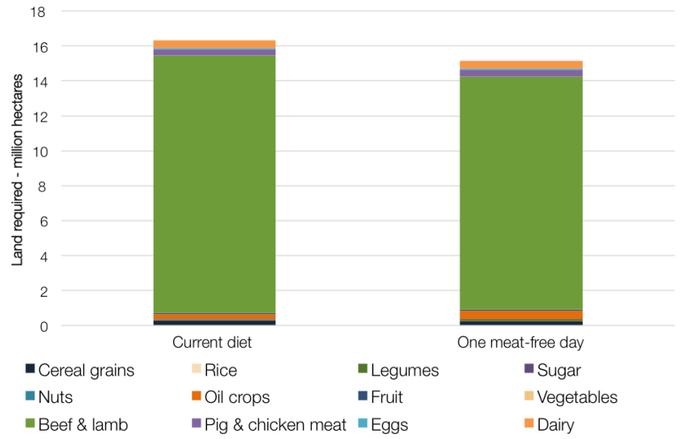


Figure 14: Change in current per capita land foodprint with one meat free day

This would reduce the city's total land footprint due to food consumption by around 1.3 million hectares (see figure 14) and its current GHG emissions by around 319,200 tonnes (see figure 15). The 'saving' in GHG emissions is equivalent to the transport emissions of around 100,000 Melbournians[115].

The reduction in land footprint from the introduction of a Meat Free Monday is due to the large land footprint of beef cattle (see section 3.4) and the reduction in GHG emissions is due to the high GHG emissions from enteric fermentation in beef cattle and sheep (see section 3.6).

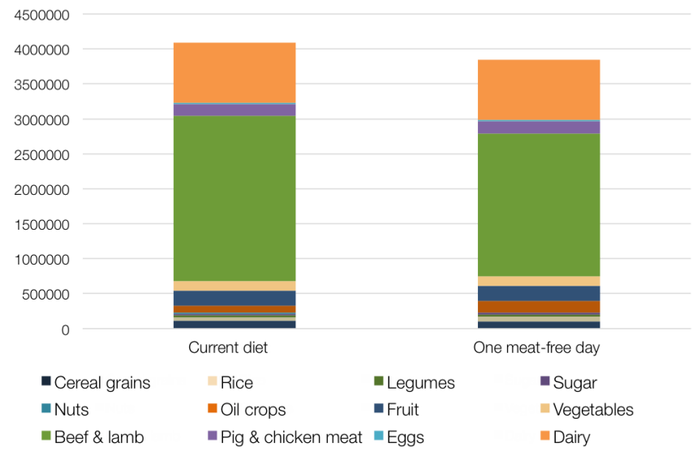


Figure 15: Change in current per capita GHG emissions with one meat free day

114 NHMRC (2013) As above.

115 Per capita transport emissions for Melbourne were 3.1 tonnes per year in 2013. See Stanley, J. and Loader, C. (2008) Road transport and climate change: Stepping off the greenhouse gas. Report prepared for BusVic, the Bus Industry Confederation. April 2008.

The impact of a shift to a Meat Free Monday would be more significant over time. For a Melbourne population of around 7 million in 2050, the reduction in land foodprint from take up of a Meat Free Monday would be around 4.3 million hectares, and the reduction in GHG emissions around 650,000 tonnes[116]. Avoiding meat consumption on two or more days would have a more significant impact, while still meeting recommended nutrient guidelines if meat was replaced by plant-based alternatives from recommended food groups[117].

5.5 Recycling organic waste

Cities generate abundant supplies of under-utilised organic waste that can be converted to compost and used for food production in place of conventional fertilisers. Organic waste includes the biosolids generated by humans, animal manure, food waste and 'green waste', such as garden waste and some types of paper.

For some crops, particularly vegetable crops, organic waste can be a valuable substitute for artificial fertilisers, and can meet plants' nutrient needs, while reducing water requirements and improving soil health[118]. However, organic fertilisers are currently more expensive than synthetic fertilisers for a range of reasons, including transport costs. This suggests that application as close as possible to their point of production is a sound option.

Creating fertilisers from organic waste could lead to significant reductions in GHG emissions[119]. However, there are still substantial data gaps about the impact of recycling cities' food and green waste for fertiliser substitution, including questions about crop uptake of nutrients from organic fertilisers.

116 The large impact on land footprint occurs because the 2050 total land foodprint for Melbourne is significantly higher than the current foodprint, due to land degradation and because more livestock are needed to produce the same amount of meat per capita, as a result of the impacts of climate change on meat production, including heat stress on livestock.

117 NHMRC (2013) As above.

118 DPI (2011) 'Cost Benefit Trial of Using Compost in Vegetable Growing' Sydney: NSW Department of Primary Industries.

119 PSD (2012) 'Biosolids snapshot' Canberra: Department of Sustainability, Environment, Water, Population and Communities.

5.6 Reducing food waste

Melbourne's food consumption generates a significant amount of food waste – over 200 kg per capita per year. High levels of food waste undermine food security and represent a waste of increasingly limited natural resources, such as land and water, as well as being a significant source of GHG emissions[120]. There is therefore an increasing focus worldwide on initiatives to reduce food waste.

A target has been set in the 2015 Sustainable Development Goals to halve per capita global food waste at the retail and consumer levels (e.g. in households, restaurants and supermarkets) by 2030[121], and to reduce food waste at other stages of the food supply chain. The United States has set a national target to reduce food waste by 50% by 2030[122], and Australia is also currently developing a National Food Waste 2025 Strategy[123].

We used ASFF to model the potential impact on Melbourne's foodprint in 2020 if post-consumer food waste (food waste in households, restaurants and cafes) was reduced by either 30% or 50%. The results are shown in the table below.

	Impacts in 2020 – with current food waste habits	Impacts in 2020 – with 30% less post-consumer food waste	Impacts in 2020 – with 50% less post-consumer food waste
Land – hectares per person per year	4.52	4.35	4.25
Water – litres per person per day	577	554	539
GHG emissions from food production – tonnes per person per year	1.03	0.99	0.96
GHG emissions from food waste in landfill – tonnes per person per year	0.33	0.27	0.24

Table 4: Impact of reducing post-consumer food waste on Melbourne's foodprint in 2020

120 Garnett (2014a) As above.

121 United Nations General Assembly (2015) Resolution adopted by the General Assembly on 25 September 2015. Transforming our world: the 2030 agenda for sustainable development. New York: United Nations.

122 USDA (2015) News release: USDA and EPA join forces with the private sector to set nation's first food waste reduction goals. Washington DC: USDA.

123 United Nations Information Centre Canberra (2015) Tripartisan support for food waste reduction by Australian Political Parties announced at Think.Eat.Save event in Canberra, Australia. 4 June 2015. http://un.org.au/2015/06/04/tripartisan-support-for-food-waste-reduction-by-australian-political-parties-announced-at-think-eat-save-event-in-canberra-australia/ [accessed 22 April 2015].

We also modelled the impact of reducing food waste by 30% or 50% at all stages of the food supply chain. Most food waste initiatives focus on reducing waste in households, but almost 60% of the food waste from feeding Melbourne occurs at earlier stages of the food supply chain (see section 3.7).

If food waste generated on-farm and during food processing was also reduced by 30% or 50%, the 'saving' in natural resources and reduction in GHG emissions would be far higher, because waste would be addressed at all stages of the food supply chain and because the impacts are cumulative.

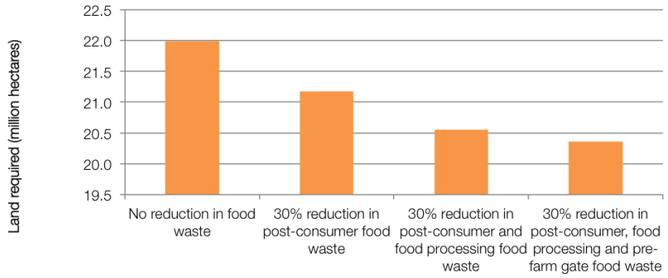


Figure 16: Land required to feed Melbourne in 2020, if food waste were reduced by 30% across the food supply chain

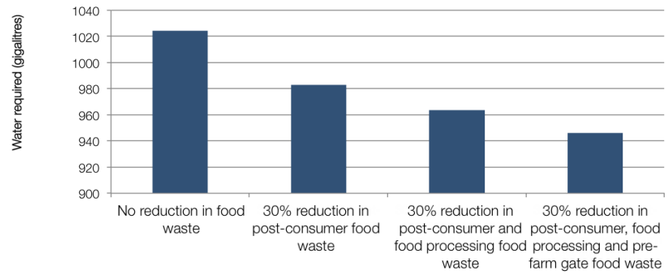


Figure 17: Water required to feed Melbourne in 2020, if food waste were reduced by 30% across the food supply chain

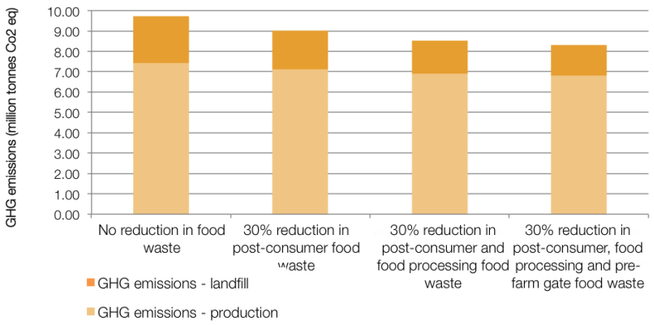
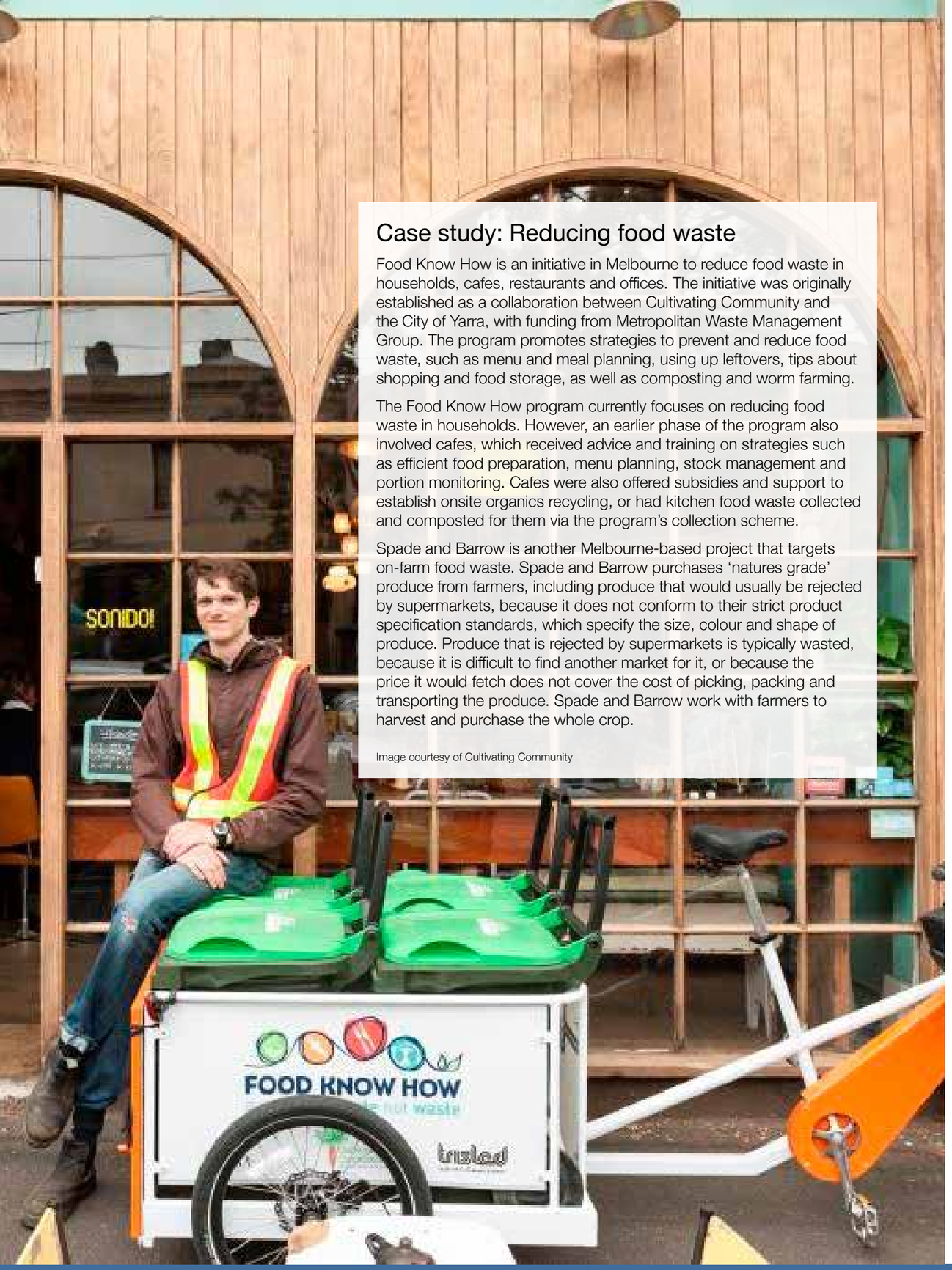


Figure 18: GHG emissions generated by production of food for Melbourne and Melbourne's disposal of food waste in 2020, if food waste were reduced by 30% across the food chain



Case study: Reducing food waste

Food Know How is an initiative in Melbourne to reduce food waste in households, cafes, restaurants and offices. The initiative was originally established as a collaboration between Cultivating Community and the City of Yarra, with funding from Metropolitan Waste Management Group. The program promotes strategies to prevent and reduce food waste, such as menu and meal planning, using up leftovers, tips about shopping and food storage, as well as composting and worm farming.

The Food Know How program currently focuses on reducing food waste in households. However, an earlier phase of the program also involved cafes, which received advice and training on strategies such as efficient food preparation, menu planning, stock management and portion monitoring. Cafes were also offered subsidies and support to establish onsite organics recycling, or had kitchen food waste collected and composted for them via the program's collection scheme.

Spade and Barrow is another Melbourne-based project that targets on-farm food waste. Spade and Barrow purchases 'natures grade' produce from farmers, including produce that would usually be rejected by supermarkets, because it does not conform to their strict product specification standards, which specify the size, colour and shape of produce. Produce that is rejected by supermarkets is typically wasted, because it is difficult to find another market for it, or because the price it would fetch does not cover the cost of picking, packing and transporting the produce. Spade and Barrow work with farmers to harvest and purchase the whole crop.

Image courtesy of Cultivating Community

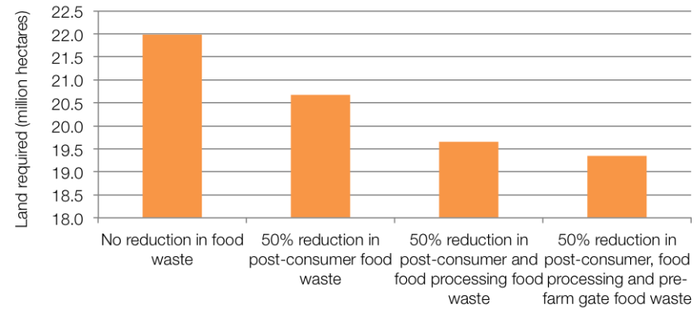


Figure 19: Land required to feed Melbourne in 2020, if food waste were reduced by 50% across the food supply chain

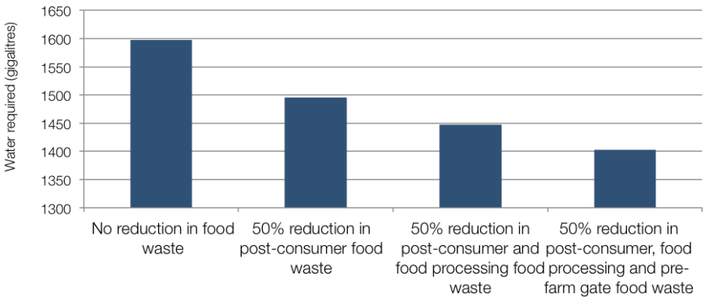


Figure 20: Water required to feed Melbourne in 2020, if food waste were reduced by 50% across the food supply chain

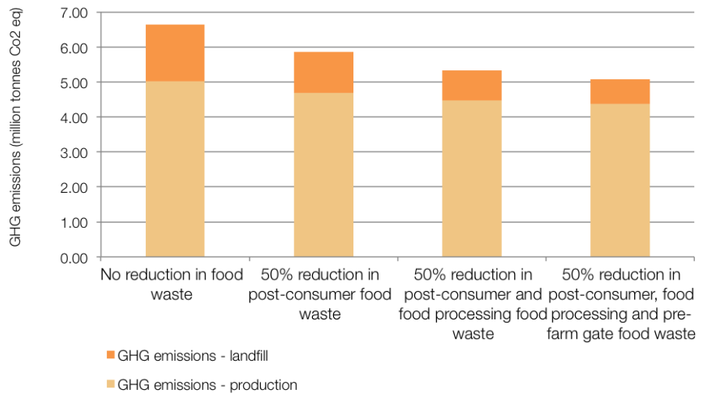
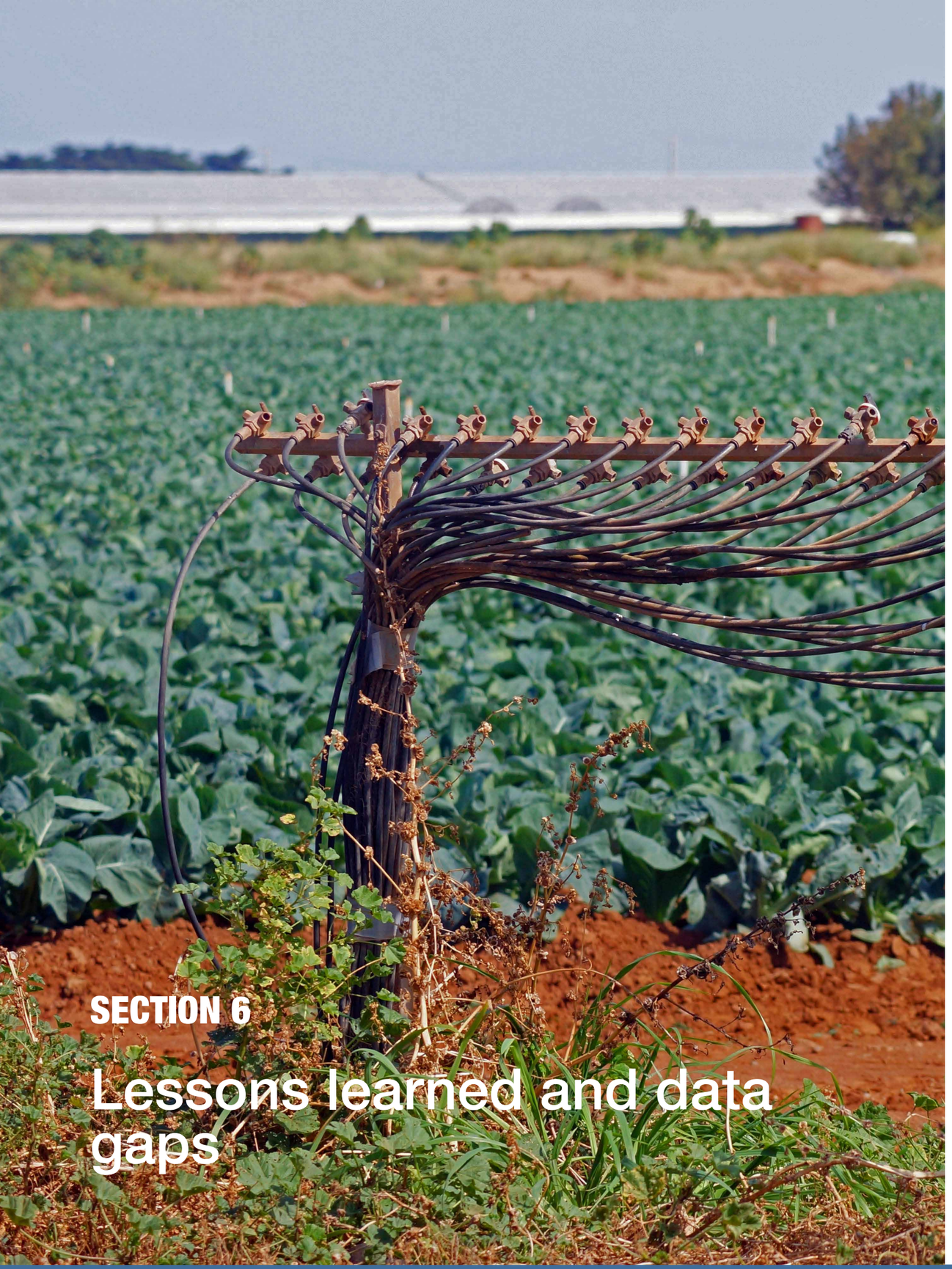


Figure 21: GHG emissions generated by production of food for Melbourne and Melbourne's disposal of food waste in 2020, if food waste were reduced by 50% across the food chain



SECTION 6

Lessons learned and data gaps

6.1 Data gaps

This research identified a number of gaps in the evidence base to support the development of a more sustainable and resilient regional food system for Melbourne.

Lack of data about the following impeded aspects of the research:

- **Freight** - there is a lack of publicly available data about freight movements of food both within and between states in Australia, which makes it difficult to determine where Melbourne's food comes from. Given the potential impact of freight on some foodprint measures (e.g. GHG emissions), more information about food freight movements would contribute to a better understanding of the contribution of food transportation to Melbourne's foodprint
- **Food processing** – there is little publicly available data about the quantities of produce that are transformed from raw commodities into processed foodstuffs, and the freight movement of processed foods around Australia
- **Food waste** – while there is sound evidence about the extent of household food waste in Victoria, there is little publicly available data in Australia about food waste during earlier stages of the food supply chain (pre-farmgate, food processing and retail) or food waste in restaurants and cafes
- **Recycled water –** there is little publicly available information about the availability of recycled water for agriculture, or the availability of infrastructure to support storage and delivery of recycled water for agriculture
- **Stormwater reuse** – further work is needed to improve our understanding of how changes to Melbourne's stormwater management could affect the availability of water for agriculture
- **Organic fertilisers** – there are significant gaps in data to support an understanding of the potential use of organic waste as fertilisers on farm. Information gaps include the volumes of waste generated, the movement of waste and the uptake of nutrients from organic fertilisers
- **Sustainable diets** - further work needs to be done to determine what a sustainable and healthy diet could look like in an Australian context

6.2 Applying the Australian Stocks and Flows Framework at city region scale

One aim of this project was to trial the CSIRO-developed Australian Stocks and Flows Framework (ASFF) for food system modelling at city region scale. The ASFF is a scenario modelling platform that draws on Australian national data sets. It can be used to compare the long term impacts of trends and to construct scenarios that attempt to resolve negative impacts from those trends.

Lessons learned in applying ASFF at city region scale include:

- The framework is designed for long term scenario comparison. In order to compare results from a particular year (e.g. to compare 2015 and 2050), some smoothing of data trends was required in order to present figures that were in line with overall trends and to overcome data anomalies in specific years
- In order to create scenarios that modelled the local context for Melbourne appropriately, some settings in the model needed to be changed at times to reflect local conditions (e.g. when investigating the impact of Melbourne's fast-growing population and urban sprawl)
- There were differences at times between national and local methods of food production that needed to be taken into account e.g. differences between southern and northern Australian beef production systems, or the different amounts of water applied to crops in southern and northern production systems

SECTION 7

Conclusion

Feeding Melbourne has a significant environmental footprint:

- 16.3 million hectares of land is required, an area equivalent to 72% of the state of Victoria
- Over 758 gigalitres of water is used, double Melbourne's household usage
- Over 907,537 tonnes of edible food waste is generated, which represents a waste of 3.6 million hectares of land and 180 GL of water
- Around 4.1 million tonnes of GHG emissions are emitted in producing the city's food, and a further 2.5 million tonnes from food waste (1.5 million from landfill and 1 million from producing the wasted food)

The majority of the land, water, and energy required to feed Melbourne is due to meat and dairy consumption, as well as the majority of the GHG emissions generated from producing the city's food. A sizeable portion of Melbourne's environmental foodprint is also due to food waste.

Melbourne is likely to grow rapidly between now and 2050. Its population is predicted to increase by at least 60% to become a city of over 7 million people, with a significantly larger environmental footprint.

Supplies of the natural resources that underpin Melbourne's food supply – including land, water, fossil fuels and phosphorous – will become more constrained in future. Pressure is also likely to increase to reduce GHG emissions associated with food production and consumption.

Melbourne's city foodbowl could play an important role in increasing the resilience and sustainability of the city's food supply in the context of climate change and constraints on supplies of the natural resources underpinning food production.

The city's foodbowl has significant capacity for production of fresh foods, particularly fruit and vegetables. It also has access to recycled water and organic waste streams, and it could reduce the city's dependence on distant sources of fresh foods. However, this research has also identified a number of vulnerabilities in Melbourne's regional food supply, including loss of agricultural land and water scarcity.

The research has explored a number of potential strategies for increasing the sustainability and resilience of Melbourne's regional food supply, including increasing urban density, reducing food waste, modifying our diets, shifting to regenerative agriculture and increasing use of recycled water for food production. All of these approaches have the potential to increase the resilience and sustainability of Melbourne's food supply and all are likely to be necessary to some degree.

The next phase of this research will explore policy approaches to increasing the resilience and sustainability of Melbourne's regional food system, focusing particularly on the city foodbowl. It will also explore the economic contribution made by Melbourne's foodbowl, and the potential costs and benefits of increasing food consumption from the city foodbowl.

SECTION 8

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