Sustainable Walnut Farming

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Executive Summary

Climate change imposes unprecedented risks upon all economic sectors, including agriculture which is essential for feeding a growing global population, a significant proportion of whom also rely on the agricultural communities for their homes and livelihoods. Developing sustainable and resilient farming methods is critical for mitigating climate change impacts and ensuring food security.

Farmers are increasingly struggling with unpredictable weather patterns and the broader unfolding effects of global warming. Extreme weather events such as droughts, heavy rainfall and damaging storms are directly affecting crop yields and quality. Moreover, warmer winters disrupt the bloom cycles of deciduous fruit trees, including walnuts, impacting their productivity.

The walnut industry faces increasing challenges from climate change, including insufficient chill units and extreme weather events, which threaten crop yields, nut quality and orchard viability. Legislative changes in the EU regarding the use of certain chemicals domestically and on imports also pose potential risks and challenges to Australian walnut cultivation and exports.

This report explores sustainable farming practices, focusing on regenerative agriculture (RA) as a key strategy to mitigate climate impacts and enhance soil health. This approach supports biodiversity, reduces chemical input, and boosts the resilience and profitability of farms. European case studies, such as Italy's walnut Farm (Valier), demonstrate the successful integration of sustainable practices, showcasing resilience despite strict regulations. These examples offer actionable strategies for Australian farmers to enhance long-term sustainability and adapt to increasingly stringent global standards.

The need for adaptation is highlighted by ongoing research into climate-resilient and pest-resistant tree cultivars. While waiting for these solutions to become commercially viable, immediate resilience can be fostered through the adoption of improved soil health practices, precise nutrient management, and technological advancements.

Ensuring the sustainability of the walnut industry is a crucial component of the broader Australian and global challenge in meeting future food security demands amid changing climatic conditions. This report provides a comprehensive investigation into the challenges and opportunities within the industry, underscoring the need for continued innovation and the adoption of regenerative practices to ensure the viability and growth of walnut production in Australia and beyond.

Keywords: Sustainable farming, regenerative agriculture, walnut industry, farm to fork, soil health

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Foreword

Coming from the Canary Islands in Spain, I embarked on a transformative journey to Australia in early 2011, having completed my bachelor's degree in chemical engineering from the University of las Palmas de Gran Canaria. Initially drawn to Australia for the purpose of cultural and language immersion, my trajectory took an unforeseen turn when I secured employment in a picturesque pecan orchard situated in Moree, New South Wales. Commencing as a stick picker—tasked with clearing debris from the orchard to facilitate harvesting—my initial exposure to the job was arduous, yet I developed an affinity for the orchard's serene environment and an eagerness to dig deeper into horticulture.

Returning the subsequent year to participate in the harvest, this time accepting the role of a sweeper driver, marked a pivotal moment in my career. As my visa expiration loomed, I seized the opportunity to request an internship at the Toowoomba factory from our Managing Director, Ross Burling. The intention behind this move was to gain hands-on experience in processing, augmenting my prospects of securing employment upon my return to Spain as a qualified chemical engineer.

However, I realised a newfound passion for agriculture. Opting to relocate to the Moree farm, I pursued a master's degree in agricultural engineering, later culminating in a Ph.D., all while maintaining evolving roles employed with Stahmann Webster. Presently, I reside in Bundaberg, where I serve as the Chief Scientist for Stahmann Webster, overseeing research and development programs for walnuts, pecans, macadamias, and almonds throughout our Australian orchards.

During my tenure in the industry, I've realised that crop production faces escalating challenges due to increasing pest pressures, volatile climatic conditions featuring more extreme events, and the withdrawal of chemicals due to safety concerns and resistance build-up. Among the crops under our management, walnuts stand out as particularly reliant on chemical interventions to address the challenges. Consequently, this project will concentrate on walnuts, with the anticipation that the findings will have broader applicability to other horticultural systems.

Table 1. Miriam Travel Itinerary

Travel date	Location	Visits/contacts
October 7-10, 2022	Australia: New South Wales Eltham	Pecan Growers Association Conference

November 7-9, 2022	Australia: Queensland Gold Coast	Australian Macadamias Conference.
February 20-23, 2023	Australia: South Australia Adelaide	EvokeAG Conference
May 22-26, 2023	United Kingdom: London	International Nut Council conference
May 29- June 4, 2024	Italy: Venecia, Rovigo, Rome, Torre Greco.	Walnut Farm visits
June 5 – 11, 2024	France: Grenoble	IX International Symposium on Walnut and Pecan. Walnut orchard visits in France.
June 12- 26, 2024	Spain/Portugal: Seville, Madrid, Redondo.	Walnut/ Almond farms
September 10 – 17, 2023	Argentina	GFP
September 17 – 24, 2023	Ireland	GFP
September 24 – October 1, 2023	France	GFP
October 1 – 7, 2023	Poland	GFP
March 4-9, 2024	Australia Canberra	Pre- CSC
March 8-17, 2024	Brasil Campo Grande, Bonito	CSC

Acknowledgements

This study would not have been possible without the invaluable support of numerous organisations and individuals who helped me. Over the course of my Nuffield journey, I have had the privilege of forging connections with individuals whose positive influence has shaped my trajectory.

Heartfelt thanks to Nuffield Australia and my invested supporters Public Sector Pension Investment Board (PSP) for providing me the opportunity to further explore the intricate realms of sustainable farming. This invaluable support has not only empowered me to draw more deeply on my passion for agriculture but has also enabled me to contribute meaningfully to the ongoing discourse on reducing the dependence on inputs and chemicals in crop production. I am sincerely grateful for their commitment to fostering knowledge, innovation, and sustainable practices in farming, and I am eager to utilise this opportunity to make a lasting impact on the future of agriculture.

Foremost, I express my gratitude to Stahmann Webster for their unwavering support in facilitating the execution of this research. A special acknowledgment is extended to Ross Burling, the MD of Stahmann Webster, whose consistent encouragement to challenge conventional wisdom, question assumptions, and research into unexplored areas has been truly motivating. Thank you also to those who have assisted in proof reading and providing feedback on this report.

I extend my thanks to my husband, Stuart King, for his unwavering support in my academic pursuits, unconditional encouragement and willingness to listen. His contributions, ranging from shared meals to caring for our kids, Oscar and Molly, have been invaluable in enabling me to travel around the world and to spend time writing this report.

I would like to offer special thanks to my father who, although no longer with us, continues to inspire me in my personal life and career. Last, but not least, to my mother, Isabel; a courageous woman who taught my sisters and me to follow and fight for our dreams. Thank you for always having the courage to face any adversity, and for moving ever forward regardless of the obstacles. You have taught me the best lessons in life.

Glossary

BOT	Botryosphaeia
AWIA	Australian walnut Industry association
PFA	Pistillate flower abortion
BMP	Best management practice
NPD	Non-pollination drop
RA	Regenerative agriculture
CU	Chill units
AI	Artificial intelligence
SDG	Sustainable development goals
EU	European union
IPM	Integrated pest management
ESG	Environmental, social, governance

Introduction

Background

Historically valued for their nutritional benefits, walnuts have been part of human diets since prehistoric times. (Calcagni, 2006; Salas-Salvadó et al., 2011). Today, they are celebrated not only for their versatility in culinary applications but also for their substantial health benefits, which include promoting heart health, supporting weight management, and reducing the risk of chronic diseases such as type 2 diabetes and cardiovascular diseases (Lockyer et al., 2022). Walnuts are particularly noted for their high content of omega-3 fatty acids, antioxidants, and phytosterols, which contribute to their cholesterol-lowering and anti-inflammatory properties (Ros et al., 2018).

The global demand for walnuts has seen a consistent rise, driven by their recognised health benefits and increasing use in diverse food products ranging from bakery goods to snack foods. This demand has positioned walnuts as a significant commodity in agricultural export markets worldwide. Over recent years, Australia has ramped up its production capabilities, with walnut orchards expanding across regions known for their favourable climatic conditions for walnut cultivation.

Australia's walnut production is characterised by its adherence to high-quality standards and sustainable farming practices. As of 2023, the tree-nut industry generates approximately AUD$721.1 million production value, with a contribution from walnuts of AUD$20 million in 2023. A value 40% lower than previous season (Hort Innovation, 2023), this reduction was a consequence of heavy rainfall, which resulted in high disease pressure. The growth trajectory of Australian walnuts is particularly impressive, with projections indicating that the industry could reach annual production value of AUD$95 million by 2030. This growth is supported by strategic initiatives aimed at enhancing production efficiency and expanding market reach. Approximately 40% of the walnuts produced in Australia are destined for export, serving markets in the northern hemisphere with fresh product during their off-season. This strategic positioning helps Australian walnuts capture premium prices and build a reputation in international markets as a reliable supplier of high-quality nuts (Australian nut Industry Council, 2022). Approximately ninety per cent of Australia’s walnuts are grown in the Riverina region of NSW near the towns of Leeton and Griffith. The climate in this region is semi-arid, with hot dry summers and cool winters but relatively little rain compared to other walnut growing regions. Other growing regions in Australia include northern Victoria (for example, near Shepparton and Mildura), Western Australia and Tasmania (Simpsoms, 2021)

Traditionally, Australia has been a net importer of walnuts, but a significant proportion of its crop now reaches European markets. As of the end of 2023, approximately 45% of Australian walnut exports were sent to Europe (Figure 1). The European Union's Green Deal, particularly through its 'Chemicals for Sustainability', 'Farm to Fork', and 'Biodiversity' strategies (European Parlament, 2023), is in the process of reviewing various chemicals, some of which are used in walnut cultivation. This legislative review by the European Parliament in 2023 could potentially affect Australia's future export capabilities to the region.

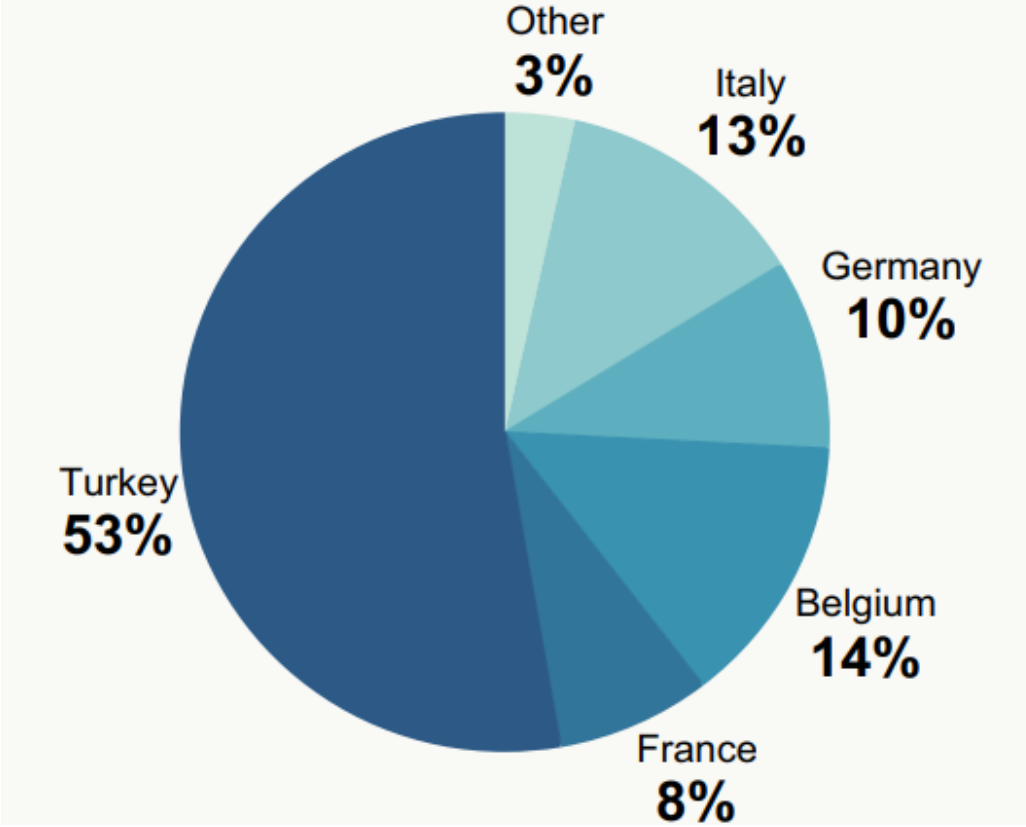

Figure 1: 2022/23 walnut export by country (Hort Innovation, 2023)

A major concern within the industry is around the challenges posed by global warming. Walnut crops are increasingly experiencing insufficient chill units (CUs) required for adequate flowering. Additionally, extreme weather events such as floods, storms, and droughts are exerting further pressure on flowering and subsequent crop yields. Disease pressures, including blight and Botryosphaeria (BOT), significantly impact final yields and challenge sustainable pest management strategies. Furthermore, there is growing advocacy for stricter agrochemical use regulations and pressures from rising input costs.

The effects of climate change on tree nut production are expected to intensify, emphasising the need for research focused on sustainable farming practices and the cultivation of healthy, diverse, and stable orchard ecosystems. Gauthier and Jacobs (2011) research examined how walnut trees manage environmental stresses and their potential for adapting to climate change. The study highlighted significant uncertainties regarding the impact of climate change on walnut trees. Findings suggest the potential for a severe outcome where walnuts might struggle to cope with climate change. Especially concerning are projections of warmer, drier summers and increased extreme weather events, which could critically threaten the survival and cropping efficacy of walnut trees.

Objectives

The overarching aim of my Nuffield scholarship is to explore deeply how various farming communities across the globe are responding to and adapting to the numerous challenges presented by climate change and increasingly stringent environmental regulations.

While the scope of my study encompasses a broad examination of walnut operations worldwide, there is a specialised focus on the transition towards using agrichemicals that are less hazardous. This focus is particularly sharp in the context of Europe due to its rigorous regulatory framework which strictly limits the availability and use of certain chemicals, driving a significant transformation towards sustainable agricultural practices.

In Europe, the regulatory environment is not merely restrictive but proactive, encouraging the adoption of innovative farming techniques that are less reliant on traditional chemical inputs. This has led to pioneering developments in sustainable farming, making European farms ideal subjects for my study.

The insights gained from these farm visits are invaluable, providing a blueprint for reducing chemical dependency and enhancing ecological sustainability. These practices are not only pertinent to enhancing the resilience of walnut farming but also have broader applications across various types of agriculture in Australia and beyond.

Walnut cultivation challenges & opportunities

Botany

Walnuts are part of the Juglandaceae family, which also includes pecans. Species found in temperate climates are deciduous, while those from subtropical areas tend to be evergreen. Walnut trees are monoecious, meaning they have both male (Figure 3) and female (Figure 2) flowers on the same tree (McGranahan et al., 2009). Male flowers, or catkins, appear in the spring on older wood, whereas female flowers develop on new shoots at the tips of branches in terminal-bearing cultivars, and from side spurs in lateral-bearing cultivars. Walnuts are wind-pollinated and can self-pollinate, provided the timing of pollen release coincides with the receptivity of the female flowers.

Once fertilised, the female flower enlarges over the summer into a green, egg-sized fruit (Figure 4). As the season progresses, the shell beneath hardens, the kernel matures, and by autumn, the green husk splits open allowing the nut to drop to the ground.

As autumn progresses, the leaves lose their green tint, the golden foliage gradually sheds, and the tree enters dormancy by winter.

Figure 2: Female flower with stigma (Stahmann Webster, 2023)

Figure 3: Male buds, catkins (Stahmann Webster, 2023)

Figure 4: Walnut in husk (Stahmann Webster, 2023)

Pollination and fruit set

Fruit set and flower abortion in walnuts are critical determinants of crop yield and quality. The intricate process of pollination in walnut trees is critically dependent on the synchronised timing of pollen release and flower receptivity. In the lifecycle of walnut cultivation, flower loss predominantly occurs due to two phenomena: pistillate flower abortion (PFA) and non-pollination drop (NPD). PFA manifests as a premature stop of development and subsequent shedding of pistillate flowers, which generally takes place a few weeks post-bloom when the flowers are roughly 2-3mm in diameter. The process typically involves an interruption of growth, followed by necrosis, and finally, abscission, resulting in the flowers drying up and falling off. PFA substantially diminishes potential yields by decreasing the number of flowers available for maturation into fruit.

Research suggests that PFA may be precipitated by an excess of pollen, which overloads the flowers with ethylene, potentially triggering a sequence of physiological responses that result in flower abortion (McGranahan et al., 1994). Environmental stressors, particularly variations in temperature and humidity, also exert influence over PFA by impacting ovule viability and the overall conditions necessary for maintaining pollen viability and effective fertilisation.

In addition to PFA, dichogamy significantly affects the timing necessary for pollination, thereby escalating the risk of NPD—a challenge that has been studied by Cosmulescu et al. (2010). The duration of bloom overlap, crucial for pollination, is sensitive to climate conditions and variations, notably temperature fluctuations as documented by Luedeling et al. (2009). NPD, linked to extreme temperature spikes during the flowering stage (Hendricks et al., 1998), is notably acute in late-blooming walnut cultivars situated in semi-arid environments, making these varieties more susceptible to NPD owing to the environmental conditions they encounter during their pivotal reproductive phases.

Pollen Viability and Transfer: Effective pollination relies on the viability of pollen and its successful transfer to stigmas. Pollen viability can be affected by environmental stressors such as temperature extremes and humidity levels, which can alter pollen tube growth and fertilisation success (Ehlers, 1999; Wesselingh, 2007).

Fertilisation and Genetic Factors: Successful fertilisation is contingent upon the compatibility of pollen and stigma, which is influenced by the genetic makeup of the trees involved. Selective breeding and genetic research are vital for enhancing compatibility and increasing the chances of successful fruit set (Taylor & Whitelaw, 2001).

Resource Allocation: After fertilisation, the availability of nutrients and photosynthates is crucial for the development of the fruit. Limitations in these resources can lead to fruit abortion if the developing seeds cannot sustain growth (Wesselingh, 2007)

Environmental Stressors: Temperature and moisture are significant abiotic factors that influence fruit set. Optimal conditions allow for regular developmental processes, while deviations can cause stress to flowers and developing fruits, leading to higher abortion rates. Strategies to mitigate these effects include the use of frost protection

techniques and regulated irrigation systems to maintain appropriate moisture levels during critical growth phases.

Ideal growing area

The climate and specific microclimate of an orchard site are crucial factors to consider. Elements such as spring frost, intense summer heat, fog, insufficient winter chill, unexpected rainfall in late spring or early autumn, and wind all play significant roles in selecting varieties and setting up a new orchard.

Walnuts thrive in fertile, deep, well-drained loams and require excellent soil drainage. When planted in less ideal soils, walnuts demand more precise management to thrive. Additionally, irrigation is critical for walnut cultivation. A consistent source of high-quality water is essential for a thriving walnut operation. Walnuts are particularly sensitive to soluble salts like sodium and chloride, and they cannot tolerate excess boron.

In many regions, the potential for walnut production is constrained by inadequate winter chill. Most varieties need approximately 800 hours of winter temperatures below 7°C. Insufficient winter cold can lead to delayed and uneven bud break, reduced yields, and branch dieback. Cooler summer temperatures may diminish kernel size and result in underfilled nuts, while extreme summer heat can cause sunburn, darkening of kernels, or shrivelling, especially under moisture stress.

Pest and Diseases

Diseases such as walnut blight and pests can disrupt the fruit-setting process by harming flowers or immature fruits. In Australia, walnut production is primarily affected by diseases like blight and Botryosphaeriaceae (BOT). Other significant concerns in the walnut industry include Phytophthora and crown gall. Implementing integrated pest management (IPM) strategies is crucial for addressing these challenges. IPM involves the use of biological controls, maintaining proper sanitation, and the careful application of fungicides and pesticides. This approach helps manage these threats effectively while reducing chemical residues and mitigating environmental impact.

- **Walnut Blight Challenges and Management:** Walnut blight, caused by the bacterium *Xanthomonas arboricola pv. juglandis*, poses a major threat to walnut orchards worldwide, significantly reducing both yield and nut quality. In recent years, Australia has seen up to 80% of its walnut production impacted by this disease. The management of blight has involved the use of copper-based pesticides combined with Mancozeb. However, concerns over the environmental impact of excessive copper use, particularly its effects on soil health, have increased. Furthermore, the EU's ban on Mancozeb complicates reliance on this effective treatment strategy, prompting a need for alternative solutions.
- ***Botryosphaeria* (BOT):** In the context of walnut trees, fungi from the *Botryosphaeriaceae* family are responsible for causing Botryosphaeria canker and blight, which is a serious disease affecting walnut orchards. This fungal infection leads to symptoms such as dieback in branches, shoots, and buds. It

also causes direct damage to the nuts themselves by infecting them, significantly reducing yield and quality. The impact is particularly severe as it can lead to the death of the fruiting wood, escalating losses with each subsequent harvest. This condition, if not effectively managed, can potentially lead to total crop failure, emphasising the need for vigilant disease management in walnut cultivation.

- ***Phytophthora* and crown rot***: It* is a genus of plant-damaging organisms known as water moulds, although they were historically classified as fungi. These organisms are notorious for causing extensive damage to a wide range of plant species, leading to diseases such as root rot, dieback, and damping-off. The name "Phytophthora" literally means "plant destroyer" in Greek, which is indicative of their severe impact on agriculture and natural ecosystems. Phytophthora species thrive in moist and wet conditions, spreading through waterborne spores that infect plant roots and other tissues. This disease may be carried to new sites by farm equipment and irrigation water and can cause the decline and death of walnut trees. Early symptoms of infection are poor growth, small chlorotic leaves and premature leaf senescence. This is followed by twig die-back, partial defoliation and, finally, tree death.
- **Crown gall** is a plant disease caused by the soil-borne bacterium *Agrobacterium tumefaciens*. This bacterium infects plants through wounds in their roots or lower stems, often caused by pruning, grafting, or mechanical damage during cultivation. Once inside the plant, the bacterium inserts a portion of its DNA into the plant's genome, causing the plant cells to proliferate uncontrollably and form tumorous growths called galls. These galls can appear at the crown of the plant (where the stem meets the roots), on the roots, or at the base of the stem. They disrupt the normal flow of nutrients and water within the plant, which can stunt growth and weaken or even kill the plant. Management of crown gall focuses on preventive measures, such as using disease-free planting material, avoiding injuries to plants, and applying proper sanitation practices.

Challenges

During my travels, I've observed that the challenges faced by walnut farming mirror our own challenges in many ways:

- Global warming is leading to insufficient winter chill periods, crucial for walnut growth and crop production;
- Rising input costs are becoming increasingly burdensome;
- Extreme weather events are becoming more frequent and severe;
- Pest and disease pressure are increasing, exacerbated by further restrictions in agrochemical treatments and limited biological/IPM strategies.

Furthermore, soil health is a continuous concern. The cyclical use of agrochemicals to treat diseases can adversely affect the soil biome. This disruption can weaken the trees' natural resilience, potentially making them more susceptible to pests and diseases.

Regenerative Agriculture

Introduction

Regenerative agriculture (RA) is a holistic approach to farming that aims to improve and regenerate the health of the ecosystem, rather than simply maintaining it. This method focuses on enhancing the overall vitality of the land, leading to healthier crops, improved soils, and a more balanced environment.

Faced with rising input costs and declining agricultural prices, there's a growing recognition of the need to focus on overall profitability rather than just production volumes. Interestingly, most farmers I spoke with that have implemented regenerative practices, initially adopt them to cut costs, only to discover that the benefits far exceed their expectations. Moreover, there's increasing consumer demand for products that not only sustain but improve the land they come from.

RA aims to enhance soil health and increase biodiversity both above and below the surface. By improving soil and plant health through biodiversity and the accumulation of organic matter, this approach boosts the resilience of crops to pests and diseases while reducing the need for inputs, thereby enhancing profitability. It restores degraded soils with techniques grounded in ecological principles, such as increasing soil organic matter and diversity, which leads to healthier, more productive soil that withstands drought and flooding better, reduces chemical usage and pollution, and enhances wildlife habitats.

These practices also contribute to producing nutritionally richer foods and sequestering carbon in the soil (Montgomery et al., 2022), which helps combat climate change. While regenerative agriculture is commonly associated with rangelands or croplands, the same principles are applicable to a wide variety of agricultural contexts. Successfully integrating regenerative practices into conventional agriculture involves understanding traditional farming principles and incorporating soil health-enhancing practices.

Traditional research has shown that controlling under-crop vegetation and applying fertilisers and irrigation promote growth and yield. However, these studies primarily focused on soil type without considering soil health and long-term outcomes. Implementing regenerative strategies such as planting disease-resistant cultivars, using cover crops, and adopting IPM can reduce chemical use and enhance farm health. Additionally, employing alternative fertilisation methods can further soil regeneration and create a sustainable nutrient management plan for farms, ensuring that crops are not over fertilised and supporting optimal production.

Soil Principles

Soil health is intrinsically linked to the health of our entire food system, impacting plant health and human well-being. RA focuses heavily on nurturing soil health while also maintaining high standards for animal welfare and ensuring fairness for farm workers. The aim is to create agricultural systems that work in harmony with natural processes, improving the quality of life for all involved. Observations from natural ecosystems have identified five fundamental principles essential for sustaining healthy soil. These

principles are vital for maintaining balance and functionality in the soil, which in turn supports robust plant health:

- Maintain Soil Coverage: Always keep the soil covered to protect it from erosion and to retain moisture.
- Minimise Soil Disturbance: Limit tilling and other disruptive activities to maintain soil structure and microbial integrity.
- Promote Diversity: Foster a mix of plant species to increase biodiversity and improve soil health.
- Ensure Year-Round Plant Presence: Strive to have living plants in the soil all year to continuously nourish and protect it.
- Integrate Livestock: Use livestock grazing as part of land management to naturally recycle nutrients and enhance soil fertility.

Opinions on these soil health principles vary worldwide, with many United Kingdom and European farmers already implementing some of these methods alongside other sustainable farming practices. A notable example is Top Farms, in Poland (Case Study Top Farms and Terra Nostra, Poland), which is working towards having all of their farms meet regenerative farming registration standards set by Terra Nostra, a foundation promoting this type of sustainable development in the EU.

Certification

Top Farms- Terra nostra approach, Poland

There is significant interest from food processors, such as Nestlé, in transition to purchasing RA products (Nestle., 2023). Top Farms have seen the benefit on implementing these practices, but are going a step further to develop standards that includes other important aspects. Their program has five components, the 5 C's: calcium (nourish your soil), cultivation (do not disturb your soil), carbon (provide energy for your soil), cover crop (keep roots alive) and culture (live in symbiosis with your environment).

Currently, Top Farms growers are encouraged but not required to go through a certification program for regenerative farming. However, the vision for the future is for each grower and third-party grower to undergo these processes in a verified manner. While these methods are strongly encouraged for now, there may be a mandatory transition period in the future.

There is an expectation that adopting these practices could yield higher value, largely dependent on the commitment of processors. Additionally, EU payments are increasingly geared towards rewarding verifiable environmental practices. Thus, the more precise the data and record-keeping undertaken by a company, the greater the dual benefits of enhanced cost-effectiveness in production and the attraction of payments incentivising environmental improvements.

Leading Harvest

It's important to recognise that while RA focuses primarily on environmental benefits, it may not fully address social and governance aspects of comprehensive

Environmental, Social & Governance (ESG) frame-worked sustainable business practices. It is worth considering additional or other certifications to assure compliance across the broader sustainability spectrum of ESG-aligned standards.

Certifications like Leading Harvest offer a broader, ESG-aligned scope that ensures businesses adhere to sustainable practices across multiple domains. Leading Harvest, a non-profit organisation originating in the United States, manages a certification process designed to standardise and enhance sustainable practices across diverse farmland and agricultural operations. This certification, known as the Leading Harvest Farmland Management Standard, is scientifically based and involves rigorous third-party audits to ensure adherence to sustainable farming practices.

The Leading Harvest certification is notably flexible, designed to be applicable across various geographical regions and farming systems, and emphasises outcome-based rather than prescriptive practices. It covers a comprehensive range of sustainability principles including soil health, water protection, biodiversity conservation, and community engagement, among others.

The Farmland Management Standard includes 13 core principles aimed at promoting sustainable agriculture, improving soil health, protecting water resources, managing energy use, supporting local communities, ensuring fair labour practices, and more. These principles ensure that the certification is not only practical but also capable of evolving with advancements in agricultural science and societal expectations, promoting continuous improvement in environmental stewardship. This broad, outcomes-based approach adopted by the Leading Harvest Standard and authentication processes, establishes it as a powerful framework and toolset in effecting progressive aspirational change, with the 13 core principles also able to be mapped to United Nations Sustainable Development Goals (SDG’s) for organisations seeking this alignment.

Travel case study

As previously noted, Europe's stringent regulations mean that EU farmers face more limitations regarding the use of agrichemicals, and that those limitations also extend to imported products including from Australia. In the following sections, I will present several case studies demonstrating how EU farmers have turned the challenges posed by a changing climate, political instability, and fluctuating input costs into opportunities for sustainable farming there and what we can learn from it for Australian farming.

Walnut farming in Europe

Walnut production in Europe has seen significant changes over the past century. Originally, the continent produced about 150,000 tonnes of walnuts annually a century ago, but this figure has dropped to approximately 50,000 tonnes in modern times due to various factors. Key walnut-producing countries in Europe include Spain, Italy, Germany, and Greece, each adapting their agricultural practices to changing economic and environmental conditions (Calcagani, 2023).

Spain and Greece have transitioned some of their walnut orchards to more profitable crops like almonds and pistachios. In Italy, the production has shifted focus towards hazelnut cultivation. In Germany and Austria, walnut farming remains on a smaller scale, often as a secondary income source for farmers.

The quality of European walnuts has been impacted due to aging orchards and the small scale of farms, which are typically managed as secondary sources of income.

- **Innovation and Adaptation:** Italy is transitioning from older varieties like 'Sorrento' to newer, more robust types such as 'Chandler' and 'Lara'. Efforts are ongoing to rejuvenate and expand walnut cultivation in new areas like the Balkans, Hungary, Moldova, Ukraine, Poland, and Serbia. Reflecting a broader trend towards diversification and adaptation in response to market demands and climatic conditions.
- **Sustainable Practices and Market Trends:** Europe faces challenges with disease management, particularly with the restrictions on the use of certain chemicals like Mancozeb. Furthermore, the European market is shifting towards sustainability, with consumers willing to pay more for quality and sustainably produced nuts.
- **Breeding and Innovation:** There is minimal work going into breeding new varieties in Europe, except in France. Most innovations focus on cultivation techniques and disease management to improve yield and quality. For instance, pruning techniques vary by variety, contributing to the health and productivity of the orchards.

Case Study Valier farm- Italy (Rovigo)

Valier Farm, located at a latitude of 45 degrees north, is a prime example of successful walnut production that leverages the principles of RA to its fullest. Approximately 70-80% of its production is processed, packed, and sold in-house, demonstrating a strong, integrated value chain from production to consumer. The farm confronts typical

challenges such as dealing with late spring frosts that can affect up to 10% of its output in some years, and disease pressure.

Valier Farm stands out as an exemplary business in the agricultural sector due to its commitment to innovation and sustainability. The owners display a genuine care for the land and the quality of the products they produce, embodying the spirit of RA. This approach not only helps in maintaining soil health and ecosystem balance but also enhances the farm's resilience against various challenges.

Despite facing restrictions on the use of certain chemicals, which could hinder disease management and pest control, the farm's advanced practices in conscious walnut husbandry allow them to successfully overcome these obstacles. Their efforts are geared towards maintaining the health of their walnut trees through natural and sustainable methods, minimising chemical inputs while maximising the health and productivity of the farm.

This proactive and innovative management style at Valier Farm showcases how RA practices can be effectively implemented to yield high-quality produce while ensuring environmental stewardship and sustainability.

Case Study Top Farms and Terra Nostra, Poland

Top Farms

Top Farms International, operating under Spearhead International, has significantly expanded its operations since its inception. Initially established as Green’s Farming in the United Kingdom 50 years ago, the company ventured into post-Soviet regions where it successfully tendered for 1,200 hectares amidst the privatisation of state farms. Spearhead International was formed out of a merger in 2000, growing to manage 80,000 hectares of farmland across Central and Eastern Europe by 2018.

The company's operations are segmented into establishment (up to 2008), growth (up to 2012), and diversification (2013 onwards). Following a change of ownership in 2021, Top Farms has divested in some areas due to high land prices, assisting a strategic shift to mitigate the risks associated with agricultural variables such as market fluctuations and climate impacts. This includes a significant investment in precision farming technologies since 2009, enhancing input measurement, yield tracking, and ensuring traceability from seed to shelf, meeting high food safety standards.

In the United Kingdom, Top Farms leases 2,000 hectares, specialising in seed potatoes grown in controlled environments to maintain high hygiene standards. In Poland, the preference for leasing over owning land reflects the high costs associated with land purchases, coupled with regulatory restrictions that favour local farmers. Similarly, in Romania, the company deals with fragmented land ownership and challenging climatic conditions, focusing on irrigation systems partly funded by the EU to support agricultural productivity.

The company is also steering towards regenerative farming practices, with a focus on meeting standards set by Terra Nostra. This shift is partly driven by the need to diversify income streams and reduce dependency on commodity crops, aiming for a

higher proportion of specialty crops. Top Farms is also aligning with the EU's move towards incentivising environmentally friendly practices, anticipating future requirements that may necessitate certified regenerative farming methods for all its growers.

Top Farms, in its commitment to sustainable development, is actively aiming to align all its operations with regenerative agriculture principles. This commitment is part of a broader strategy to adapt to changing agricultural practices that emphasise not only environmental stewardship but also the enhancement of soil health and ecosystem biodiversity. By adopting regenerative practices, Top Farms seeks to rebuild organic matter and living biodiversity in soil, which helps cycle nutrients naturally, improves water retention, and could potentially reverse the effects of climate change on their farmlands.

Their strategy includes integrating crop rotations, cover cropping, reduced tillage, and organic inputs which foster a healthier soil ecosystem and increase crop resilience against pests and diseases. The move towards RA is also seen as a way to improve yield stability and farm profitability in the long term, by creating a more resilient farming system that can better withstand the pressures of climate variability and market fluctuations.

Top Farms' engagement with the Terra Nostra foundation further highlights their commitment to sustainable farming practices across Europe. This foundation promotes RA through education, certification, and by influencing policy to support sustainable practices. Top Farms is not only looking to meet current sustainability standards but also anticipating future regulatory requirements and market demands that favour environmentally responsible farming practices.

By focusing on these regenerative principles, Top Farms is positioning itself as a leader in sustainable agriculture, with the goal of enhancing the sustainability of their operations while also providing a model for other farms to follow. This initiative is expected to contribute significantly to their overall sustainability targets, including reducing carbon footprints, enhancing biodiversity, and improving soil health across their extensive farming operations.

Top Farms is also deeply invested in mentoring and encouraging local farmers about the benefits of sustainable farming. This initiative is part of their broader mission to promote RA practices and enhance the overall sustainability of farming in their operating regions. By sharing their knowledge and experiences, Top Farms aims to foster a community of farmers that are well-informed about sustainable practices that can lead to healthier soils, increased biodiversity, and improved yields.

This outreach and education effort complements their own adoption of sustainable practices, such as crop rotations, reduced tillage, and organic inputs. By acting as a mentor, Top Farms not only advances their sustainability agenda but also contributes to the growth of sustainable farming practices across the region. This collaborative approach helps create a more resilient agricultural sector that can better adapt to environmental and market changes, ultimately benefiting the wider community and ecosystem.

Terra Nostra Foundation

Terra Nostra is a sustainability certification entity that has evolved from an initial focus on regenerative farming practices. The foundation was established in 2019 to address the growing need for sustainable agricultural practices that are both ecologically sound and economically viable. With roots in Top Farms, where its journey began in 2010, Terra Nostra has developed into a leading organisation in the EU for certifying RA.

- **Mission and Operations:** Terra Nostra was started by a former employee of Top Farms, driven by the recognition that sustainable farming required a deeper understanding and management of soil health. The foundation's mission has been to spread knowledge about sustainable practices and foster a shift in agricultural paradigms. This includes rigorous soil analysis and the adoption of regenerative techniques that not only enhance farm productivity but also reduce production costs.
- **Partnerships and Certifications**: In partnership with Bureau Veritas, Terra Nostra has successfully implemented standards that certify farms across the EU. Starting with large farms and expanding to cover over 180,000 hectares, the foundation has demonstrated that regenerative practices can be scalable and beneficial. The success has established a robust reputation for the certification, encouraging wider adoption among farmers.
- **Expansion and Challenges:** Terra Nostra has initiated programs in the United Kingdom and has established operations in Romania and Lithuania. Despite the challenges associated with often lower yields in organic farming, the foundation promotes regenerative farming as a profitable alternative, capable of fetching premium prices from major buyers like Goodman Fielder and Danone. This strategy addresses the economic concerns of lower yields by focusing on the environmental benefits that can command higher market prices.
- **Standards and Training:** The foundation has developed explicit standards that apply to entire farms, using measurable metrics. This approach ensures that the sustainability practices are comprehensive and verifiable. Training and auditing are key components, with continuous improvement encouraged through detailed feedback and actionable insights based on farm audits.
- **Future Directions:** Looking ahead, Terra Nostra plans to integrate more comprehensive components, including social and governance aspects, into their certification process. This expansion is in response to the demand from companies and regulatory bodies for a holistic approach to sustainability that includes measurable outcomes on greenhouse gas emissions and other environmental impacts.
- **Community and Corporate Engagement:** The foundation is actively engaging with corporate entities to define and standardise what regenerative farming entails, providing a clear framework for companies to meet their sustainability goals. This collaborative approach helps align corporate objectives with practical agricultural practices, fostering a broader movement towards sustainable agriculture. Terra Nostra's efforts are exemplified by their proactive approach to education and advocacy, including hosting conferences like the BIO_REACTION conference to disseminate knowledge and best

practices in regenerative agriculture. Terra Nostra is a pivotal player in transforming the agricultural landscape by advocating for, certifying, and teaching regenerative farming practices that are scientifically backed and economically beneficial. Their work not only impacts the immediate agricultural community but also contributes to global sustainability goals.

Sustainable Farming Practices

The tree nut industry and in particular the walnut industry challenge is the rate by which we can adopt new improvement practices. Trees are planted with permanency or long term in mind, so changes that require new infrastructure or that could have a transformative benefit like variety selection are costly in resources to implement, particularly in waiting time to commercial yield.

- **Cultivar Selectio*n:*** Strategically selecting cultivars is essential for establishing a walnut orchard, given the long-term commitment required due to the longevity of the trees. The economic feasibility of replacing existing varieties with new ones needs careful assessment. The ongoing walnut breeding program focuses on developing varieties that are more resilient to pests and diseases and require fewer chill hours. This strategy aims to adapt to changing climatic conditions and improve orchard sustainability by ensuring the chosen cultivars can thrive under the evolving environmental pressures. UC Davis is leading the field in trying to develop new cultivars that produce good yield and quality nuts whilst being resistant to diseases. Working on blight resistant varieties, so far successful in finding resistance, however the quality of the kernel is not desirable. The new UC Wolfskill walnut variety, recently released by the University of California, Davis, Walnut Improvement Program (Brown et al., 2020), is part of a broader effort to enhance the California walnut industry. This program focuses on developing improved scion cultivars and new rootstocks that exhibit resistance to pathogens and abiotic stresses, while also enhancing the understanding of walnut genetics. The breeding efforts aim to produce new cultivars with better disease and insect resistance, varied harvest dates, and characteristics like increased yield, early maturity, good kernel colour stability, and high yield of kernel halves. The Walnut Improvement Program also continues to refine DNA markers for traits like lateral bearing, precocity, and leafing date in seedlings, which aids in the rapid development of new cultivars.
- **Soil Management:** Implementing RA soil practices in a walnut orchard involves a holistic approach focused on improving soil health, increasing biodiversity, and enhancing the ecosystem. Here are some steps to guide the implementation:

  Cover Cropping: Planting cover crops between the rows of walnut trees can help improve soil structure, enhance organic matter content, and suppress weeds. Cover crops such as vetch, clover, or mustards are beneficial for fixing nitrogen in the soil and providing habitat for beneficial insects.
    - Reduced Tillage: Minimising tillage in the orchard helps preserve soil structure, enhance water infiltration, and reduce erosion. This practice also helps increase the soil's organic matter content and microbial activity by not disturbing the soil biology.
    - Compost Application: Applying high-quality compost helps add organic matter to the soil, which improves soil fertility and water retention. Compost also introduces and feeds beneficial microorganisms that help break down organic material into nutrients that almond trees can absorb. Earth worms help move part and completely composted organic matter deeper into the soil profile, depositing metabolisable

nutrients into the feeder root zone and enhancing soil structure leading to better rainfall and irrigation ingress, moisture retention and excess drainage.
    - Mulching: Using organic mulches like wood chips or straw around the base of the trees can also conserve moisture, reduce weed pressure, and add organic matter to the soil as they decompose. This further helps in moderating soil temperature.
    - Monitoring Soil Health: Regularly testing the soil for nutrients, organic matter content, and other indicators of soil health helps guide management decisions and adjustments in cultural practices.

- **Integrated Pest Management (IPM):** Employing IPM strategies reduces the reliance on chemical pesticides, promoting a healthier orchard ecosystem. This includes using biological control agents and managing pests through mechanical and cultural techniques.
- **Diversifying Plant Species:** Introducing a variety of plants within and around the orchard can enhance biodiversity, improve pollination rates, and provide habitat for beneficial insects and wildlife. This could include planting flowering plants that attract pollinators or other types of trees that provide additional economic benefits.
- **Water Management:** Efficient irrigation systems that reduce runoff and optimise water use are crucial. Drip irrigation systems deliver water directly to the root zone of the trees, which conserves water and reduces the leaching of nutrients.
- **Microclimate Management:** Adjusting orchard microclimates through the use of windbreaks, reflective mulches, establishing an interrow cover crop and pruning strategies, can stabilise temperature and light conditions, thereby supporting better flowering and fruit set conditions.
- **Nutritional Interventions:** Tailored fertilisation programs based on soil and leaf nutrient diagnostics can ensure that trees receive the necessary nutrients at optimal times, promoting robust flower development and successful fruit set.
- **Phenological Monitoring:** Using modern technologies to monitor plant phenology and adjust agricultural practices in real-time can significantly enhance the timing of interventions, such as pest control and fertilisation, to align with critical developmental stages of walnut trees. Understanding and managing these factors comprehensively ensures not only the maximisation of fruit set but also the sustainability of production, aligning with environmental conservation efforts and ensuring the long-term viability of walnut orchards.
- **Strategic Disease Management:** Crop protectants used for managing walnut blight, are predominantly based on mixtures of copper + mancozeb. However, tolerance or resistance of the walnut blight pathogen to copper biocides, and the withdrawal, or potential withdrawal of Mancozeb registration from many walnut growing countries and/or regions requires the development of new crop protectant substances and/or behaviours. In Europe, Mancozeb has now been withdrawn, so the management of these diseases have shifted towards more sustainable practices, such as IPM strategies, which involve monitoring disease levels, optimising application timing based on environmental

conditions, and using targeted treatments to minimise the use of broad-spectrum chemicals. This strategic approach not only aims to control pests and diseases effectively but also reduces the environmental footprint of orchard management practices, promoting healthier orchards and sustainable agriculture. Developing new crop protectants and complementary behaviours such as focusing on timing of application by using models, is key.

Conclusions

The success of the walnut industry in Australia will depend on its ability to innovate in response to environmental challenges, adapt to legislative changes, and satisfy the growing demand for healthy, sustainably produced food. This will require ongoing investment in research, a steadfast commitment to regenerative farming practices, and an adaptive business strategy that emphasises environmental health alongside economic viability.

- **Expansion Driven by Demand**: Historically, the expansion of walnut cultivation in Australia has been propelled by increasing global demand and the recognised health benefits of walnuts. This Australian expansion has helped establish walnuts as a significant commodity in the global agricultural export markets. Embracing sustainable and regenerative behaviours in growing and value chains presents opportunities to better value-add Australian walnuts into growing demand for these credentials.
- **Challenges from Climate and Regulations:** The growth of the industry is countered by significant challenges, including climate change and stringent regulatory environments in key markets such as Europe. These challenges impact critical aspects of production, such as flowering and fruit set, and complicate agrochemical usage. Regenerative farming practices present opportunities in countering these threats and challenges.
- **Resilience Against Environmental Stressors:** Environmental stressors that affect flowering and fruit yield test the industry's resilience. However, the industry also sees opportunities to capitalise on its commitment to high-quality and sustainable farming practices, which could open doors to premium markets, whilst also working to mitigate environmental stressor risks.
- **Advocacy and Research for Sustainability:** Initiatives like the Nuffield scholarship highlight a proactive approach to addressing industry challenges, emphasising the need for increased funding and partnerships with research entities to support a sustainable transition.
- **Embracing Regenerative Agriculture**: The transition toward RA is a pivotal strategy to mitigate the impacts of climate change, enhance ecological sustainability and create new and added value. This approach focuses on improving soil health, increasing biodiversity, and reducing reliance on chemical inputs, enhancing the resilience, profitability and value of walnut orchards.
- **Technological Advancements in Irrigation:** The industry has been proactive in adopting advanced technologies for efficient irrigation, helping farmers optimise water usage to enhance crop efficiency. These are complemented by regenerative practices, particularly cover crops, soil structure, biota and organic matter improvements.
- **Circular Economy Practices:** The industry is leveraging the circular economy, particularly through the recycling of harvest and shell waste into biochar via pyrolysis. This practice improves soil structure and contributes to overall soil health, whilst simultaneously sequestering carbon for 100+ years, reducing and in some cases eliminating net greenhouse gas emissions from walnut orchard enterprises, including processing.

Recommendations

Threats challenge us to mitigate them, to find ways of managing the risks of negative outcomes from a changing climate and our constantly evolving physical, economic and social environment. The Nuffield Scholarship has not only exposed me to different ways of thinking about sustainable walnut farming, but also the aspirational challenge of extending that to a deeper regenerative mindset. I have found in my Nuffield travels and research, further reinforcement of the value of comprehensive initiatives such as those already implemented by my employer Stahmann Webster, and also their leadership towards finding "better ways" in a deliberate process of continuous improvement. They supported and encouraged me to undertake this Nuffield project, however my recommendations I hope have broader industry value and even learnings for other nut industries and agriculture as a whole. There are many recommendations that can be made from my learnings in undertaking this research project, however I believe there are six key recommendations for the Australian walnut industry:

1. **Stretch Sustainable to Regenerative**
   As much as sustainable farming practices seek to halt broad declines in our environment, particularly our climate, soils and biosphere, I have learnt that regenerative farming seeks to not only halt but reverse the damage and create better outcomes from farming. Walnuts are an ancient super food, naturally and sustainably packaged in their own biodegradable shell "wrapper", and that same shell can be simply processed through pyrolysis into biochar, sequestering carbon in solid form for extremely long periods of time whilst simultaneously building soil fertility and biodiversity. This is an example of upscaling a sustainable mindset into a regenerative one and can be implemented in all walnut enterprises and probably most other agricultural systems that produce wastes that can be converted to biochar, with renewable energy a by-product and energy source for the pyrolysis process. Pyrolysis processes can be very simple and low scale or more complex and large scale. The conversion of agricultural wastes to biochar also presents significant tangible carbon and waste reduction strategies to help mitigate climate risk regulatory obligations.

2. **Adopt Authentication and ESG Frameworks**
   It is not enough to apply sustainable and regenerative practices in farming enterprises. Not only do regulatory and export market access/value protocols require an independently verified adherence to a certifiable standard or system of behaviour, the strategic and organisational change processes benefit significantly from the application of systematic frameworks. ESG-aligned farm management standards like that of Leading Harvest and regenerative certifications like Terra Nostra's establish not only a credible method of authenticating sustainable and regenerative product and enterprise claims, but also a systemic methodology around which to build and implement strategies. ESG-alignment where implemented, ensures broader holistic sustainability and regenerative objectives in social and governance spaces are engaged with the same intent as environmental principles. Adopting a suitable standards-based approach with the rigour of independent audit and certification/verification will

address on-farm sustainability/regenerative behaviours, regulatory compliance and market access/recognition of value which not only can open access to new markets and value opportunities but can help differentiate positively within existing markets.

3. **Develop new walnut varieties to adapt to climate change**
   The long cycle of plant breeding and orchard tree replacement adds even greater urgency to the need to incorporate climate adapted traits into new walnut varieties and cultivars, alongside ongoing general yield optimisation and disease resistance trait plant breeding focus. Specifically: (a) improving walnut genetic adaptation to shorter and less consistent winter chill periods; (b) improving genetic adaptation to extreme weather events becoming more frequent and severe; (c) improving genetic adaptation to increasing pest and disease pressure, whilst simultaneously adapting to restrictions on agrochemical treatments.

4. **Accelerate biological and soil regenerative initiatives**
   Soil health is a significant concern in many established walnut orchards in choosing sustainable and regenerative priorities that have significant benefits, soil health and biome, is probably the number one focus. The improvements and benefits are cumulative over time, so the sooner action is taken, the better. As part of soil health initiatives, developing new and improved biological/IPM strategies will be very helpful to the walnut industry and will complement plant breeding advances.

5. **Enhance industry support for research and sustainability/regenerative initiatives**
   Industry support for Nuffield and other research-based projects could be further complemented by better co-ordination of university research, industry funding and enterprise access support. This will better focus collective resources to accelerate and enhance our knowledge of the functional morphology of walnuts in Australian landscapes and how we can better support and adapt walnut orchards to unfolding challenges, including climate change.

6. **Invest in emerging technologies and innovation**
   Investing in emerging technologies and innovations is crucial for enhancing efficiencies in agriculture. Throughout history, technological advancements have significantly influenced the development of agricultural practices. Today, these innovations are essential for achieving the SDG's and transforming agrifood systems into more efficient, resilient and sustainable models.

- Irrigation Technologies: Advanced irrigation systems can mitigate the impact of drought on nut production by optimising water use. Efficient water management not only conserves this vital resource but also ensures consistent crop yields under varying conditions.
- Robotics: The implementation of robotics in nut farming, including robotic harvesters, drones for crop monitoring, and autonomous machinery for spraying, holds significant potential. These technologies can streamline labour-

intensive tasks, reduce production costs, and enhance overall operational efficiency. Robotic solutions also ensure precise and consistent agricultural practices, leading to higher-quality nut yields.

- Artificial Intelligence (AI): AI technologies have the potential to revolutionise farming practices through data-driven insights and predictive analytics. Machine learning algorithms can analyse vast datasets, including soil composition, weather patterns and pest dynamics. This analysis facilitates informed agricultural decision-making. AI-powered systems for crop forecasting, disease detection, and yield prediction empower farmers to navigate uncertainties, increase productivity, and mitigate risks, and hence, enhancing the resilience of nut farming enterprises.

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