2022 STEM Challenge - AG2030

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Overview

The Australian Agricultural Sector is currently worth approximately $67 billion and the following report aims to increase this value to at least $100 billion.

To accomplish this challenge, goals were set to ensure specifications were met and solutions determined that comprehensively addressed the key issues at hand.

Goals

1. Increase crop yields per area of land
2. Improve water and farming efficiency
3. Use emerging technologies
4. Protection and restoration of natural environments
5. Balance between intensification and sustainability

Specifications

The above goals will be achieved using a multi-pronged process which focuses on the parts of the agricultural sector that are worth the most money in production value; improving these areas to create an agricultural sector worth $100 billion by 2030.

Split

I. Crop for human consumption

Wheat, fruit, vegetables and nuts.

II. Crop for animal consumption

Coarse grains, fodder crops, crop residues.

III. Livestock

Cattle, sheep, wool and milk.

Crops:

For Human Consumption

In Australia, wheat, fruit, nuts and vegetables account for 23% of the agriculture, fisheries and forestry sectors' total value of production for the 2019-2020 financial year. (*Snapshot of Australian Agriculture 2021 - DAWE*, 2021) As this is a significant proportion, improvements to the way we grow wheat, fruit, nuts and vegetables through the usage of energy efficient vertical farming will have a significant impact on the agricultural sector.

Indoor vertical farming in Australia is an underutilised method of producing crops with only a handful of farms nationwide. (Thaper & Jacob, 2017) Vertical farming can means one acre indoors can produce the same yield as 4-6 outdoor acres, (Silverman, 2007) use between 70-90% less water than traditional farming (Diebel, 2018) and reduce or entirely eliminate pesticide use (Schipper, 2021).

Wheat:

A study of vertical farmings' feasibility for wheat crops, led by Dr. Paul Gauthier in New Jersey demonstrated that vertical farming could increase crop yield from 3.2 metric tons per hectare to around 1940 metric tons per hectare. (Noor, 2020) This utilised optimal artificial light, temperature and carbon dioxide levels to grow the wheat in ideal conditions. This study also showed that wheat indoors required less water, herbicides and nutrient loss to the environment. Using a 10 storey building "the wheat was grown under 20 h per day of light at an intensity of 1,400 μmol/m2/s, totaling 50 MJ/m2/d (with 1 J = 1 Ws), and an atmospheric CO2 concentration of 330 ppm." (Asseng et al., 2020, 19131-19135) The light levels also allowed the wheat to be grown at a faster rate than the control outdoor wheat.

The issue with the study as noted by the authors is the high level of energy consumption required, however through the following strategies this can be overcome.

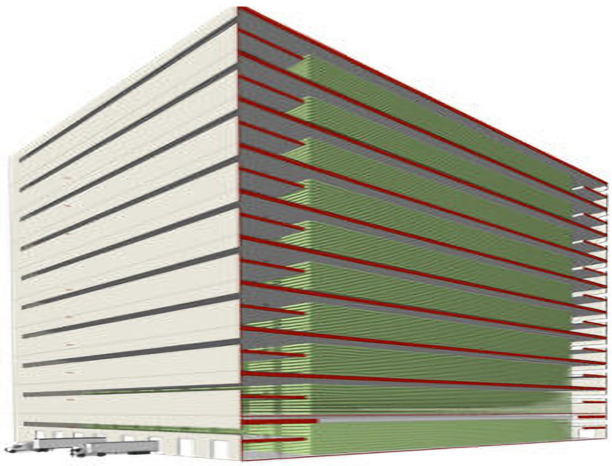
1. A redesign of the building materials

   Instead of the 10 storey models' concrete skyscraper-esque constructionsing, using the idea of *Eden Green Technology* would give the vertical farm translucent walls. This could reduce its light energy consumption by around 90%. These walls can also be made out of recycled plastic bottles further decreasing the impact on the environment. (Martinez, 2021)

2. Using wheat straw to make biomass-based fuel cells

   Currently wheat straw is farm waste that is often burned or fed to cattle. According to Bradley, 2017, "an alternative approach [uses] biomass to drive an electricity-generating fuel cell instead of burning it to drive generator turbines." This creates small-scale biomass fuel cells which have the potential to provide enough electricity to supply the farms. (Montero et al., 2017) (Bradley, 2017) For more information see *Appendix A.*

This results in a vertical farm that looks like this:



-Recycled plastic bottle walls

-LED artificial lighting

-Water efficient hydroponics system

-Ten storeys of area for wheat crops

-CO2 monitor

-Thermostat

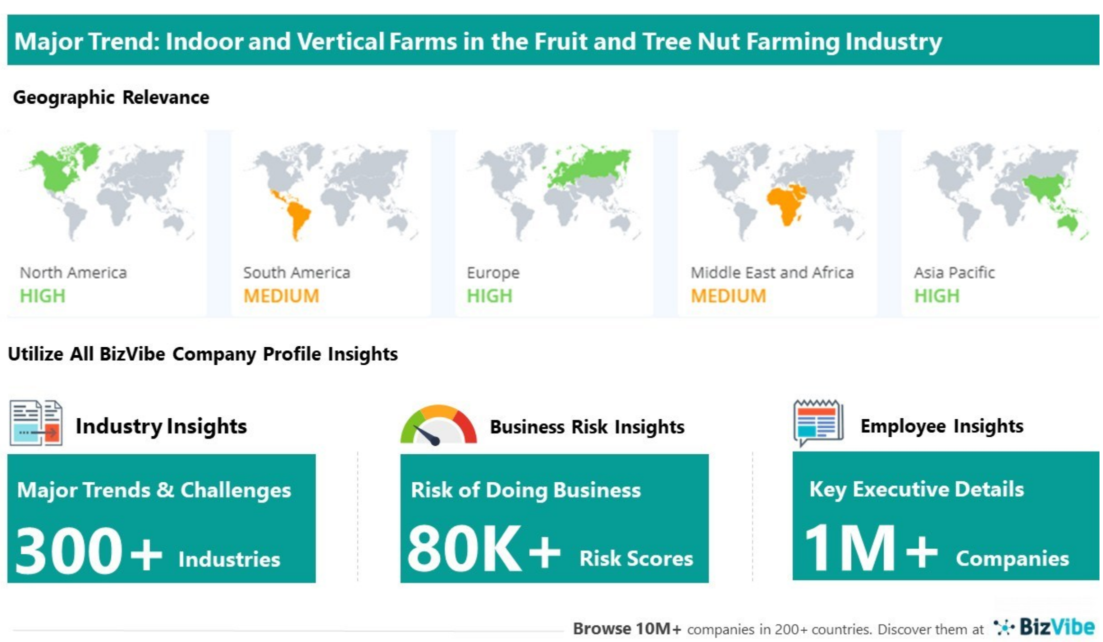
-Bio-fuel cell generators on ground floor

Image sourced from: (Asseng et al., 2020, 19131-19135)

Fruit and Nuts:

Vertical farming for fruit and nuts use an approach similar to that for wheat. It must be noted that there is currently limited data freely available, yet there is still a distinctive market shift towards vertical farming as can be seen in *Figure 1.* (BizVibe, 2021)

Figure 1: BizVibe Fruit and Tree Nut Vertical Farming trend



Fruit and nut trees can be grown in the vertical format with hydroponics, using around 70% less water than traditional farms, (Desjardins et al., 2016) they are also completely pesticide and herbicide free as well as no-longer being seasonal.

Vegetables:

Vertical farming (VF) for vegetables in Australia is currently underutilised in both cities and regional/rural farming areas. There is currently only one VF company commercially growing vegetables in Australia and many opportunities for the traditional farming industry to go vertical. (Thaper & Jacob, 2017) Vegetables can be cultivated vertically with natural and artificial light, rotating beds and either aeroponic, aquaponic or hydroponic growing mediums - used as best suited to the specific vegetable variety. (LeBlanc & Jasperson, 2020) Such VF's are 100% pesticide free, and depending on the choice of aeroponic, aquaponic or hydroponic growing can reduce water consumption by 70-95%. (Avgoustaki & Xydis, 2020, 1-51) These farms can also reduce fertiliser use by up to 50% (feasible to recirculate and reuse nutrient solution) and reduce yield variation by 90% (monitored internal environment). (Avgoustaki & Xydis, 2020, 45-51)

The significant application of such vertical farms is that they are able to be installed on city rooftops. Think of productive, community vertical gardens providing greens to the building's inhabitants. This is especially important as people are drawn closer to cities, and such farms can be powered by food scrap biomass, wind turbines (area dependent) and solar panels installed on the rooftops. Even more efficient, they can be using blackwater to further optimise city resources.

For Animal Consumption

Currently, coarse grains account for 4% of the agriculture, fisheries and forestry sectors' total value of production for the 2019-2020 financial year. (*Snapshot of Australian Agriculture 2021 - DAWE*, 2021) These grains are most commonly used as feed for cattle with fodder crops and crop residues. Improving the quality of these items genetically to better nourish and feed cattle as well as withstand harsh weather will increase cattle value and mean less crop is lost to drought; another option is also using vertical farming on targeted crops.

By genetically modifying feed for livestock, it can become cheaper to grow and create in turn fatter and resultantly more valuable cattle. The modification of coarse grains can be done through genome editing to create crops that are easier for animals to digest. Meganucleases can be engineered to glom onto certain DNA sequences and cut other DNA nearby, this can increase the energy that livestock gain from eating the crops. (Young, 2014) This increased energy not only means that livestock can eat less to obtain the same nutritional value, but farmers will likely not need to buy as much food. (ISAAA, 2022)

Genetically modifying crops for drought hardiness is an additional way that in times of water scarcity there is still food available to feed livestock. There is current misinformation about this topic however, "there is no clear evidence that first generation GM crops affect animal health." (de Vos & Swanenburg, 2018, 3-12) This is an area that is currently underdeveloped in most crops and one that the Australian government would benefit looking into in the future when this technology becomes more affordable and advanced.

Currently, vertical farms are the most viable option for providing reliable, consistent high yields of coarse grains. Similarly to wheat they can be successfully grown vertically, however doing so for all coarse grains is inefficient use of the pre-existing highly arable land in certain regions. Instead, specific coarse grains that produce poor yields in the Australian environment can be targeted and grown vertically. This would ensure livestock has more food security in times of extreme weather and as above the benefits of increased crop yields and less environmental impact.

Livestock:

In the agriculture, fisheries and forestry sectors' cattle, sheep, wool and milk made up 40% of the total value of production for the 2019-2020 financial year . (*Snapshot of Australian Agriculture 2021 - DAWE*, 2021) This significant economic portion means that adjustments to the way farmers track, breed and adapt livestock for the harsh conditions can increase the sector's value.

Cattle and sheep:

On July 1 2005, farmers in New South Wales, South Australia and Western Australia were required by law to electronically tag cattle, so as to track the animals in the event of disease outbreaks and boost Australian exports to international markets. All other Australian states and territories complied with the law in the ensuing years.

The National Livestock Identification System (NLIS) was created, and issued radio frequency identification (RFID) tags, which replaced the traditional tail tags and permitted for individual animals to be tracked through life, to ensure food safety and product integrity (*RFID Tagging of Cattle by Law in Australia*, n.d.). In the case of a disease outbreak, or unhealthy livestock with a property, the NLIS issues an Early Warning (EW) status within the database. The flaw in this system is its inability to identify the cause of the status change or which specific animals should be considered high risk.

A change in this, resulting in more accurate identification would allow for swift action to be taken by property owners, and in the case of a disease outbreak, or effects of drought on particular areas, a rerouting of appropriate resources could be made to the affected area. This prevents the negative effect of inaction and the impacts it could have had on food safety and biosecurity of the entire value chain (*NLIS Early Warning Status*, n.d.). This would also be applicable in the sheep industry, which it is currently not mandatory in. More accurate identification of diseases and unhealthy animals, and the implementation of appropriate resources using the analysis of data would result in less livestock death across the board, which would save money for both property owners and the industries as a whole. (Pretty & Moroz, 2013)

As of August 1 2021, over 60% of Queensland was declared to remain in drought, consisting of 34 entire local government areas, three part local government areas and individual properties in a further eleven areas. This can only be deduced as being a common trend across the nation, and as climate change across the world sees temperature records being broken, one can only assume the continuation of such events.

In the early 20th century in north Queensland, the Droughtmaster, a breed of cattle that is a cross between a Brahman and Shorthorn, was bred. The breed is spread throughout the nation, but the highest numbers of the breed are concentrated primarily between Cape York in far North Queensland, and the New South Wales border. They have a reputation for reasonable fertility, ease of calving and good mothering ability, often under harsh conditions. They are also known as reasonable foragers and to have a tolerance of heat and ticks and a high resistance to bloating (*Cattle Breeds: Droughtmaster*, n.d.). In the ever changing climate where droughts are bound to become more frequent and intense, a further inclusion of the breed to other states around the nation would increase the level of meat going into the market. Reducing cattle deaths from drought, ticks and bloating and increasing meat available for consumption and profits for farmers.

Wool:

Australia for decades has been one of the world's largest producers of wool, with the country producing 25% sold on the global market, with exports in 2016-17 being estimated to be valued at $3.615 billion. Within the country, wool is produced nationwide except in the Northern Territory. New SOuth Wales produces the greatest volume of the textile fibre, followed by Victoria, Western Australia and South AUstralia. It was estimated that over 74.3 million sheep were shorn nationwide (*Wool - DAWE*, 2020). The amount of wool a single sheep produces depends upon its breed, nutrition, genetics, age and gender. For example, a lamb would produce less wool then a mature animal and a ram would produce more wool than a ewe of the same breed, based on its larger size. The most common sheep in Australia is the Merino (*Wool Production*, n.d.). However, harsher climate conditions have been affecting wool stocks, with the Australian Wool Testing Authority reporting in January 2019, that the amount of wool tested was decreased 12% to 151, 013 bales when compared to testing in January 2018. Sheep have been growing less wool due to seasonal conditions, while also being impacted by the forced destocking by farmers (Jeffery, 2019). By introducing the analysis of data collected by RFID tags from the National Livestock Identification System (NLIS), there can be a better distribution of resources across properties and state areas at risk due to climate events such as drought, floods and storms. This would allow for better allocation of money, which would see an increase in profits as the animals would have a higher general health. This means that the production of wool would increase and the Australian Agricultural market would be positively affected.

Milk:

Maximising the amount of milk from cows is critical to producing more from the same land area without having to overpopulate them. Research has shown that giving cows a dry period of between 45-50 days will ensure that the next milk yield does not decrease and that after calving an increased feed intake is crucial for optimum milk production. (Calder Stewart, 2018) Dairy farmers can also benefit from adding calcium solutions or anionic salts to cows feed to ensure they do not experience subclinical milk fever which will reduce milk production. (Penn State Extension, 2016) In other words, prevention of this is key and keeping cows BCS around the recommended targets of 5.0 for mixed age and 5.5 for first and second calvers is critical. This ensures at calving that cows can have good milk production.

According to Dairy NZ, cows can produce more milk postpartum if feed additives; they also recommended supplements having a better ME than the pasture and that vitamins can benefit targeted cows. If Australian dairy farmers work to ensure that all of these factors are met they can have cows theoretically producing more milk!

Conclusion:

Overall, through the implementation of vertical farms, future GMO crops for cattle feed and further utilisation of modern technology to improve livestock, wool and milk yields the goal of Ag2030 can be achieved. The above solutions meet the goals of increased yield per land area, improved water and farming efficiency, usage of emerging technologies and allow for the protection and restoration of the natural environment. They also balance between intensification and sustainability ensuring such agricultural practises are viable for future generations.

Appendices:

Appendix A: *Biomass Based Fuel Cells* (Bradley, 2017)

> The team had previously reported a new type of flow fuel cell that can oxidize biomass directly to generate electricity at low temperature (less than 100 °C). This design uses two different liquid catalysts, based on iron(III) and vanadium(IV), in the anode and the cathode, respectively. The researchers have now developed this setup further to work with wheat straw biomass by employing an aqueous iron(III) oxidant to degrade the biomass at the anode and a simple and readily available vanadium(IV)/vanadium(V) couple with nitric acid-oxygen redox system at the cathode.
>
> This system takes in finely powdered wheat straw, which is first oxidized by the iron ions in the anode tank at approximately 100 °C. The resulting reduced iron(II) is oxidized by vanadium in the cathode. The vanadium species is completely regenerated by oxygen. All the while, the system generates electricity at a rate of 100 mW/cm^2. Importantly, the approach avoids the need for expensive noble metal catalysts.

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