Submission to The Committee of the House of Representative of the Federal Parliament of Australia inquiring into and reporting on the role of technology in increasing agricultural productivity in Australia.

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1. Context

Why is it necessary to improve the productivity of agricultural practices?

World population is increasing by some 200,000 people per day [1] and together with increased wealth per head, this is expected to increase demand for food by at least 70% by the year 2050 [2]. At the same time increased urbanisation, currently greater than 50% worldwide, will lead to more people relying on imported food either from local or international suppliers rather than producing it themselves [3]. Total food reserves worldwide over recent years have been estimated to vary from between 57 and 74 days at the lower end to 107 and 116 days at the higher end [4, 5]. **The saying** [6] **that "the distance between order and chaos is 7 meals" illustrates the need to increase food supplies dramatically to minimise the breakdown of societies in the future.**

Since the development of city states **food supply has been used as a weapon of mass destruction**. In developed economies the vast majority of **current decision makers in all sections of society have no direct experience of food being used as a weapon of war**, having been born after 1950. However **ISIS and similar groups are currently using food and water depravation as highly effective weapons of war**.

Although with globalisation it is considered that food can trans-shipped to areas of need, this is far too slow in cases of sudden and catastrophic disruption. We need innovative ways to manage food supplies for people in situations when major disruptions to electricity, water or transport happen or when war and natural disasters occur to ensure food supplies are available to meet short term, high priority and local needs.

In the light of the above **there are 2 issues that need to be solved**:

First, the subject of this Parliamentary review: there needs to be **a strategy to increase food supplies** through research and innovation to meet increasing demand;

Second there needs to be **a strategy to manage fluctuations over scales involving a range of time and place**. It must be remembered that both 10% too much or too little production are both disastrous. Too much sends prices tumbling and farmers broke whilst too little leads to food shortages, potential mass starvation and the breakdown of societies. The requirements at national levels should be regarded as of similar importance to the need for fuel reserves. However as this is not part of increasing production through innovation it is not considered further here.

Assuming that we avoid total dislocation of current trends, then **increased population, middle class wealth and the demand for better and more varied diets means that if we can increase food production significantly there is a major economic opportunity for Australia**.

2. Options for increasing food supplies.

There are 3 situations worth considering that apply at both local and global scales.

First; because of insufficient investment in R and D and/or innovation yields per unit area do not increase. The effects of this will be increased levels of atmospheric CO_2 associated with land clearing, increased soil degradation and a major increase in the area of cultivation. This will occur in a situation of diminished water supplies for irrigation and an increased requirement for fertilisers as less fertile land is brought into cultivation. Species losses occur when habits change; clearing land for farming is the classic example of a change that leads to major biodiversity loss. At the same time "free" environmental services supplied by natural systems will be reduced and pollution from agricultural activities likely to be increased. None of these outcomes is desirable.

Second; due to climate change the net level of production per unit area falls as the weather becomes increasingly variable and larger extremes are experienced. To counter the falling yield will require either an even greater area of land clearing than would be the case in situation 1 above or significant innovation in production systems must occur to ensure that yields are maintained at current levels or if possible increased.

Third; as with the green revolution of the 1960's and 1970's, we develop new technologies that allow major increases in yield per unit area with little or no increase in land under cultivation. This is a major challenge, for as the world becomes increasingly urban there is also increased competition from cities for land for housing, industry and infrastructure. Traditionally most cities have developed on land of high quality for agriculture. This means innovation must also improve yields on less fertile land.

3. What areas of technological innovation are needed to ensure long term increases in yield per unit area?

Whilst the technological areas listed in the call for submissions are important and are areas of interest to farmers, **the underlying driver of all agricultural production is the conversion of CO_2 and water into food by plants using sunlight as the primary energy source**. This reaction sustains nearly all life. Whilst the efficiency of conversion of plant material into animal production is also significant, I will not consider it here for 2 reasons, first it depends on the primacy of plant growth and second my experience and expertise is not in this area.

To optimise plant growth requires an understanding of the potential ways to improve the ability of plants to convert light energy into food and how to manage the growth and development of plants in different and fluctuating environments so that we maximise light fixation and its partitioning into food and other useful products. Whilst climatic zones are usually well understood, **the actual**

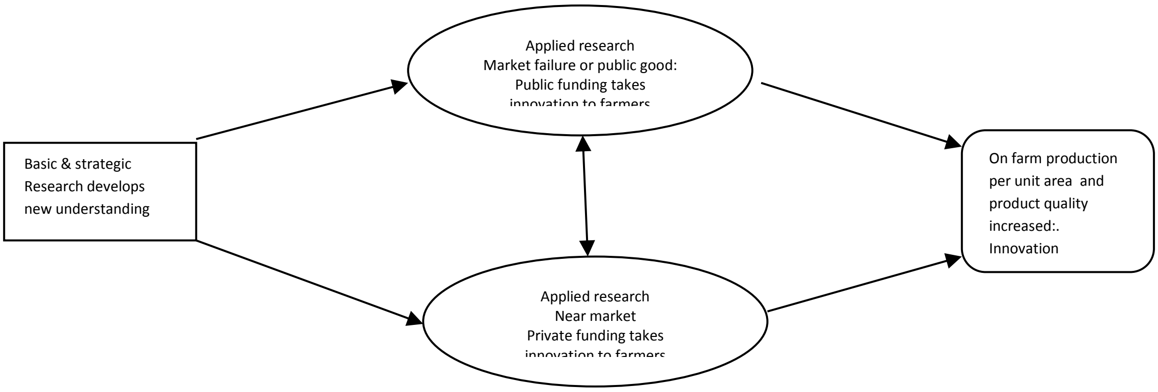
sequence of weather events in relation to crop development, are random and not well understood. To increase their productivity, crops need to be buffered against environmental uncertainty, which besides the physical factors of soil type, water availability, fertility etc. also cover pests, weeds and diseases. All these factors can reduce plant growth**. This requires an understanding of plant growth at several levels; at the gene, cell, organ, plant, crop and ultimately at the market level. Environmental variability, in its many aspects, interacts with all these processes.** It is only within this framework that we are likely to be able to increase crop yields to the levels needed to ensure that we do not need to clear large new areas of native vegetation for food production.

Few organisations have the range of skills needed for the holistic understanding of crop production outlined above. Even if the skills area available there are often other barriers to the adequate integration of the knowledge required for innovation to occur on farms to ensure increases in production per unit area. These include institutional, IP, funding, reward and personal barriers.

Much of the knowledge required for this increase in production will fall within the areas of public good, market failure or fundamental science and is not be easily capturable. Once the basis of the interaction between plants and their environment are better elucidated then opportunities arise in the near market area for private enterprise to develop improved varieties and products that lead to increased yield per unit area**. Links between basic researchers, agricultural scientists, industry and farmers need to thrive to ensure that novel research leads to farm innovation**.

Note that many important innovations in agriculture were initially developed by farmers and not by scientists or business e.g. identifying and cultivating plant species, selecting local varieties, irrigation, crop rotation etc. Science has explained why these were successful and have added an understanding of the mechanisms involved, allowing generalisation. However the only way to ensure that we have enough food in the future in a period of rapidly reducing resources for agriculture and increasing population will be via research and innovation at a deep scientific level with enough experienced people who are capable of taking innovation into the complex and interactive world of a farm business.

The line of development of innovation in agriculture is shown the figure below:



So how do we ensure that we have adequate science to allow major innovation in agriculture? My views on this topic are based on personal experience working in agricultural research at a range of levels for more than 50 years spanning both hands on research and its administration [7].

4. Factors that allow effective hands on research:

1. An interesting area of research

2. A clear objective

3. Somebody else worrying about resources and people management

4. A simple reporting system

5. Lively and stimulating interactions with colleagues

6. A wide range of technical interests allowing cross linking of ideas

7. Not perpetually looking over one's shoulder about job security

5. An approach to managing research and innovation:

1. Clearly define group/organisation objectives

2. Get the best people possible and have a system that retains them. Then keep them informed of all developments; technical, administrative, organisational

3. Minimise their administrative load

4. **Take a significant and ongoing interest in what they are doing and let them know it is appreciated; remember that they, not management, are the key to success**

5. Good scientists are highly creative people, do not restrict them to just the tasks at hand but allow flexibility in approach as in research it is never certain where the next big jump is coming from.

6. **Trust staff until there is good reason not to, then deal with these individuals. Do not add burdens onto the trustworthy with endless regulations. These will never stop a determined miscreant but foster resentment amongst the honest and have a high opportunity cost in enforcement as well as affecting enthusiasm and research productivity. These costs are usually much greater than the actual actions of untrustworthy individuals.**

7. Encourage staff to be self and organisationally critical but do not take their comments personally and take note of and if appropriate, act on issues raised.

8. Good scientists are like good hounds, once their nose is on the scent they run and run all day

I believe that this management style is highly effective and from all stages of my administrative career have attempted to apply it. I have had former colleagues, years later. telling me that our time working together was the golden age in their research careers.

6. Personal experience of creative periods in my career

I have had two periods of high research creativity; the first was as a young scientist when I was involved in a wide range of activities that lead to several important publications [8-12].

The second period I believe is now that I am retired.

In both periods most of the criteria outlined in 4 above were/are met. In the latter period I have personally funded most of my research activities [7].

7. How to take research knowledge to farmers and have an impact on agricultural innovation? An example with the lupin extension package in Western Australia

When I arrived in WA in 1977 the recently established lupin industry had fallen from a maximum area of 110,000 ha to about 35,000 ha. Farmers were losing confidence in the industry. My job was to mechanise the lupin breeding program and improve crop disease resistance. At this time most lupin research of the then Western Australian Department of Agriculture was run out head office by scientists involved in different components of growing lupins. The programme was implemented by the research station and district office staff. There was much confusion about how to grow lupins depending on the success or failure of local trials and much blame was placed on the quality of the varieties breed by Dr. John Gladstones; the father of the lupin industry in Australia and at that time the most effective breeder of lupins in the world. I had the privilege of working in his group. Because of my expertise in running field trials and because we needed to test potential new varieties in a wide range of environments I had personal experience of planting, managing and harvesting lupins from Geraldton to Esperance a distance by road of more than 1100 kms. Whenever a trail failed, I could tie the result back to the way we managed the crop rather than on the genetic potential of the variety.

Based on this experience and together with Peter Nelson, a crop adviser based in Geraldton, we devised a series of demonstrations including both farmers who had dropped out of lupin production and those who remained enthusiastic. Six sites were used and at each site the demonstration involved the 5 key factors that illustrated correct and incorrect management of the crop. All 32 potential combinations were grown each site with 2 replications, one arranged systematically so that the impact of different management practices were easily compared. We told the farmers what we were going to do before planting and predicted the outcome. At the same time once a month during the growing season we opened the trials to farmers and had lively discussions with them**. At harvest the average yield on farm in the region was 0.3 t/ha which was the same as when we got all 5 production factors wrong** [13]**. When we got them all right our yields increased 5 fold to 1.5. t/ha**.

Note this was not part of my job description as a lupin breeder but I was not constrained by the organisation from carrying out these demonstrations and joining with Peter Nelson in a major extension push. Over the next few years the area of lupins increased from 35,000 ha to 1.1 million and yields doubled [13]. During this time I had the privilege of developing and leading a research team and using the methodology developed for lupins had a similar success in increasing wheat yields in the Geraldton region.

I have always found farmers very willing to take up new technology provided that they can see the benefits. The ides and the reasons underlying them need to be clearly explained and they have trust the person encouraging innovation. Never waffle at farmers if you do not know the answer to a question, but say you do not know but will find out and get back to them. **My experience is that farmers are highly innovative and are prepared to take adoption risks** before the scientists have a full understanding of the science behind the innovation!

8. Some comments on innovations listed in the terms of reference from the Committee.

Telecommunications: In the developing global economic and knowledge environments, decent communications will allow farmers to optimise their production systems in terms of inputs and outputs and allow them to remain competitive in world markets.

Due to the dispersed nature of the farming industry, particularly in Australia, ways must be found to ensure farmers have **access to this technology on an equitable and cost effective basis**. Determining an equitable cost is a political decision and effectiveness is basically a commercial decision of the providers. These are **relatively simple and peripheral issues to resolve as compared to making sure farmers have access to the genetics and farming systems that allow them to produce enough food of appropriate and high quality to meet the future market demands needed feed people.**

Drones: Drones , combined with appropriate sensors will allow farmers to more closely monitor their crops and in some situations allow better management of limiting factors. Suitable drones are already available. The decision for farmers on **their use will involve, cost, technical interest and**

particularly the development of cheap, appropriate, accurate and lightweight sensors. As these are developed I anticipate that they will be rapidly taken up by farmers if the information adds value to their farm activities and lives.

Plant genomics: Plant genomics are widely used by crop breeding organisations, however much of the development work is done under highly controlled conditions and there are likely to be major IP issues in their use. Results obtained under these conditions may not be of predictive for complex characters (e.g. yield) that are being expressed in the highly variable environments encountered on farm between seasons and sites. **Also theoretical work by Rosielle and myself [9] from a long time ago suggest that the genomic results will only be partially successful and may be totally unsuccessful in predicting plant responses on farm**.

For direct application of genomics on farm their role is in animal breeding. Uptake is strong in some industries (eg Dairy, Pigs and Poultry) but is likely to be very slow in merino wool stud industry if past experience is anything to go by. Genomics may also have a role in identifying plant diseases well as between different races of a particular disease. However this is most likely to be done at a centralised laboratory with the information being rapidly communicated to the farming community.

Agricultural chemicals: Agricultural chemicals are an important component of farming. They cover a range of materials such as fertilizers, growth promoters and pesticides. It is in the latter that major issues arise.

Australia is a small market for these products when compared to the USA, Europe, Russia and China and parts of South America for the multinational companies that develop these compounds. New compounds by law have to be registered for local use in Australia. **This is a significant cost for manufactures, often for a very small market** (e.g. disease control in raspberries). This often leads to **novel and valuable compounds being unavailable to our farmers**. This is an area where a review and simplification of the registration system should make more compounds that solve problems faced by farmers available to them. **Dan Ward [14] has developed the theory of the simplicity cycle** that applies to almost every endeavour but applies particularly well to complex systems including law making and agriculture as well as the more general issues of product development, innovation and use. He has summarised his ideas in 4 pages and simple language [14]. I **recommend it to the committee as it will provide a powerful intellectual framework for their thinking on this and many other projects.**

8. Take home message for the committee on the barriers to the adoption of emerging technology relevant to the agricultural sector

To meet future demands for food we must develop plants that are more efficient in the use of light, water and nutrients that are grown in the most sustainable farming systems possible. If these plants can be developed I believe they will be rapidly adopted as they will add significant value for farmers and consumers. Currently we do not have the components of the system available to do this.

The key agricultural issue for both Australia and the world **is how to meet the greatly increased demand for high quality food? Success or failure in this endeavour has major implications for our**

political stability, social equity and defence of the nation. The issues identified **for submission to the Committee, although important are relatively trivial and simple in comparison to the one identified here.** At a time of need for significant research effort to allow the innovation of a step change in food production**, Australia and just about every other nation is running down its capacity to deliver. In Australia this includes Federal, State and education organisations across the country**. Australia is too small a market to encourage multinational companies to fill the near market gap.

It is hard to imagine a better way to stifle innovation in an industry that is a major contributor to the well being of this country and of people overseas who buy our products.

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