

Chapter 8

Trajectories of Change in Rural Landscapes: The End of the Mixed Farm?

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Introduction

Agriculture in many developed countries has undergone a transformation – becoming both increasingly intensified and specialised. Accompanying this trend has been a decrease in mixed farming systems and the ongoing substitution of labour for capital. This chapter explores these trends in the Australian context where many competing forces are shaping the agricultural landscape. While recognising that economic, technological and food security factors are key forces, the chapter focuses on the role of knowledge intensity as a driver of farmers' decisions to specialise in both commodity production and land use. The growing knowledge intensity of agriculture, accompanied by a concentration in human capital, is putting increased pressure on farm managers to maximise investments



Figure 8.1 Mixed Farm in Central West NSW – A Relic of the Past?

in knowledge and skills by specialising. This specialisation is resulting in a reduction in the number of land uses on individual farms, in turn placing both the traditional mixed-farming system at threat as well as the ecological diversity of agricultural landscapes. This is a new trend as the agricultural industry rapidly undergoes change. Better recognition of the important role of human capital is an urgent challenge, not just for farmers or for sustainability, but for the wider industry as a whole.

Linking Specialisation and Knowledge Intensity in Agriculture

Specialisation is the concentration on a limited number of products or land uses, which can lead to less diverse cropping and/or livestock patterns. Specialisation is often, but not always, associated with intensification (the increasing of productivity through the greater use of energy, capital, chemicals and machines). Agricultural specialisation is occurring in most developed countries. For example Western Europe has been experiencing the intensification, separation and specialisation of agricultural and livestock systems since the middle of the twentieth century (Kirkegaard *et al.* 2011). North America has followed a similar trend where, in places like Iowa, farms have become increasingly specialised grain or livestock producers since the 1950s (Brown and Schulte 2011). Until recently, Australia did not follow this trajectory. Farmers traditionally retained a mix of cropping and livestock enterprises ('mixed farming') as a risk management strategy that gave them the flexibility to respond to climate and market variations. However, in the past two decades, Australia has begun to see a shift. In the rangelands and semi-arid regions where livestock has always dominated, mixed farming continues, but in the higher rainfall areas of the eastern and western wheat/sheep belts (see Figure 8.2), there has already been a swing away from traditional mixed crop-livestock systems towards either crop or livestock systems. From 1992-93 to 2009-10, the area planted to crops (excluding pastures and grasses, and hay) increased by 50 percent, while grazing area decreased by 6 percent (Lesslie *et al.* 2011).

There are a number of reasons why farmers may choose to specialise, with economic explanations predominating. For one thing, specialisation has the potential to allow farmers to maximise product quality and volume through efficiencies of scale (Chavas 2008). Since the 1990s, greater profits have been available from cropping than from either sheep or beef cattle production (Kirkegaard *et al.* 2011). Specialisation is also a rational response to declining terms of trade and the need to improve financial returns through the increased concentrations of inputs such as nutrients, water, energy and management effort (Lesslie *et al.* 2011). Although these are all important justifications, they are not the only reasons for specialisation. Other less tangible factors can influence decisions to specialise – factors such as human capital and the combination

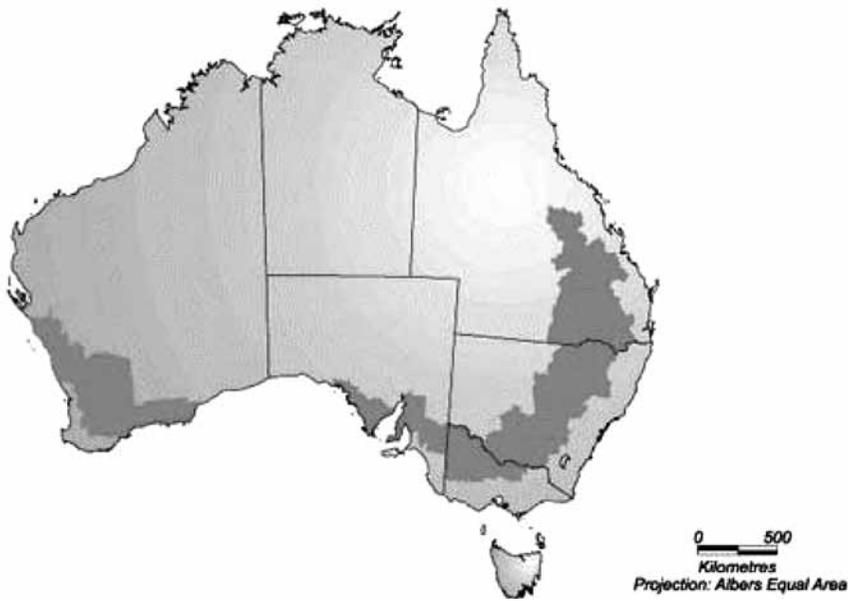


Figure 8.2 Eastern and Western Wheat-Sheep Zones

Source: ANRA 2001

of knowledge and skills (Schultz 1961). The important role of human capital is well recognised in other industries, such as manufacturing and the services sector. While there have been studies on the impact of human capital on farm productivity, little attention has been paid to the role of human capital as a driver of specialisation and hence of land use change in agriculture.

Why are knowledge and skills so significant? Knowledge is not the same as information. It is not simply additive, like data collection, nor is it easily abstracted from its context (Wolf 2008). It can include perceptions, implicit understandings, unconscious motivations and behavioural habits: knowledge cannot simply be given to someone else (Breschi and Malerba 2001). It has to pass through a filter of perceptions and interpretations and it takes time and effort to build (Midgley 2000). Traditionally, farmers' knowledge has been characterised as local, tacit and informal, formed through practical advice from other individuals plus a farmer's own practical experiences (Oreszczyn *et al.* 2010). Today, farmer's knowledge could be classed as global as well as local, formal and scientific as well as tacit and practical. Agriculture is very different now from how it was even a decade ago.

The modern agro-industrial system is frequently characterised as intensive in terms of external inputs and energy use. What is less well known is that modern agriculture is also becoming more knowledge intensive. Agricultural

systems and their management have become increasingly complex, underpinned by expensive capital investments, changing production technologies, volatile markets, social challenges and increased regulation (Kingwell 2011). This has increased management complexity and has placed new and additional demand on farmers' existing knowledge and skills (Kingwell 2011). This greater knowledge intensity is true of both cropping and livestock systems. For example, cropping systems now require specialised skills to manage technical, biophysical, financial and marketing components of the business (Jackson 2010). Increasingly farmers are adopting Conservation Agriculture, the primary feature of which is the maintenance of a permanent or semi-permanent soil cover, either a live crop or dead mulch, which protects the soil from the elements and feed soil biota (Knowler and Bradshaw 2007). It can involve reducing soil compaction through 'controlled traffic farming' or the use of predetermined tracks or 'tram lines' guided by a Global Positioning System (GPS). Many farmers now also manage variable land and soil conditions on a micro-scale through 'precision agriculture', which involves the use of high resolution spatial data and analysis, and tailoring inputs and management accordingly (CSIRO 2011). Even planting a new crop is not simple. Activities such as the management and application of fungicides, herbicides and pesticides and management of subsoil water content, all require detailed knowledge, skills and experience. Alongside these technologically complex processes are post-harvest elements of cropping, namely bulk handling, storage, transport and marketing. Variable returns depend on market destination, choice of terminal or port for grain delivery, forward selling against fluctuating volumes and exchange rates. The timing of sales and contracts plays a key role in an industry that is globally connected and subject to dramatic fluctuations in global commodity prices.

The livestock sector is often viewed as the less sophisticated cousin of cropping, but advances have also occurred in the sector over recent decades, increasing its complexity and the knowledge required by graziers. To transport and sell livestock in Australia, farmers must comply with the National Livestock Identification System (NLIS), which became mandatory in 2006. The NLIS enables individual animals (cattle, sheep and goats) to be tracked from birth to death for purposes of biosecurity, meat safety and market access. Farmers are required to fit each animal with an identity tag and record livestock movements and transactions on the NLIS database. Online auctions, vendor declarations, weighing livestock to cater to weight-specific orders, pregnancy scanning, chemical record management and paddock rotations all add to the complexity of running a contemporary livestock enterprise. Adequate grass for grazing is no longer simply a matter of waiting for rain. Farmers implement different grazing strategies to restore perennial plant density, suppress annual grasses and increase soil seed reserves. To better predict the performance of an animal based on its genetics, an 'estimated breeding value' can now be calculated using software.

Such examples demonstrate the increasing complexity of agricultural systems and the greater investments required by farmers in human capital (knowledge and

skills). This has implications for land use change because investments in human capital create incentives to specialise, since there are fixed costs to knowledge acquisition, regardless of how that knowledge may later be used. To maximise the rate of return on investment, specialized skills and knowledge must be used as intensively as possible. The greater the investment, the greater the incentive.

Evidence from New South Wales

The following section draws examples from research conducted across the wheat/sheep belt in New South Wales (NSW). This research – the NSW study – investigated farmers’ experiences with on-farm innovation, decision making and knowledge management, and was conducted in mid-2009. Purposeful sampling targeted 33 farmers who had a record of innovative land management on 22 broadacre dryland family farms. A relatively small number of farmers were intentionally chosen, facilitating in-depth research across a geographically dispersed area.

“GP versus Your Specialist”

The NSW study demonstrated the impact of knowledge intensity on farm management decisions. Some 16 of the 22 farms were mixed farms in mid-2009; however 21 of the 22 had been mixed farms in the past, with 5 having changed from mixed farms to specialist cropping enterprises since 1993. That trend is consistent with a wider trend in Australia, where cropping has become increasingly important in many farming enterprises, often totally replacing livestock. From an economic point of view, the shift towards cropping in Australia is usually explained by the decline of the sheep industry. Sheep numbers peaked in 1990, followed soon after by the collapse of the wool stockpile in 1991. A crisis in the industry led to the introduction of the Flock Reduction Program, which paid farmers to destroy over 20 million sheep (Rudwick and Turnbull 1993). Farmer #4 had to destroy 2500 sheep, which was the “worst job of my life”. On top of the collapse in market prices, prolonged drought saw breeding herds of sheep and cattle being sold off and eventually replaced with trading stock, such as steers and wethers, which are owned for a much shorter period of time and require less emotional or economic investment than breeding stock. However, after decades of decline, the livestock sector may be experiencing a renaissance. While productivity growth has been higher for cropping specialists than for mixed crop-livestock farmers or livestock specialists for almost 30 years, productivity of livestock specialists has recently begun increasing (Jackson 2010, Mullen 2007, Nossal *et al.* 2009). Beef specialists now achieve the same average performance level as the mixed crop-livestock industry (Nossal *et al.* 2009). Sheep, lamb and meat cattle numbers increased in 2010-11 while farm cash income for the sheep industry has returned to levels not seen since 1989-90.

From a knowledge point of view, it is not surprising then that when making a choice to specialise, farmers are being drawn to the cropping sector because of the greater investments being made in research and development. As Farmer #23 explained:

Cropping – [is] where all the new technology is, where all the bigger toys are, where more money is, greater support infrastructure..... try and find the same level of information and everything else around that is run on the livestock point of view and it is just not there.

These investments have further facilitated crop specialisation through developments like nitrogen fertilisers, herbicides, fungicides and new ‘break crops’ which make continuous cropping possible where previously pests, diseases and nutrient deficiencies would have prevented this approach (Kirkegaard *et al.* 2011). In addition to knowledge availability, knowledge intensity played a role as well. For example, Farmer #2 felt that “it is timing – it is all time dependent” while Farmer #29 explained, “these days, more and more, it is the timing. Timing is the big thing as I understand it. Like, you have got to kick in and do things when they need to be done”. Farmer #15 explained how they had moved from being a mixed farm to just a cropping enterprise because it meant they had “been able to get our timing much better on our cropping” whereas “cattle used to take 60 percent of our labour and make about 20 percent of the money”. Timing and making the most of windows of opportunity provided by seasonal conditions are crucial in cropping. But getting timing right requires knowledge and skills, which is in turn time consuming and an incentive to specialise.

For Farmer #15, it didn’t matter whether farmers chose to be graziers or croppers, but “if you are a grazier, then rather than do a bit of part time cropping, you’re probably better off to be a straight out grazier”. Farmer #10, who had also specialised, argued that “it is very unusual to see a really good cropping manager and a really good stock manager in the same person”. Farmer #7 had a similar view. He likened it to the “GP versus your specialist. If I need brain surgery I don’t want my GP to take it or open heart surgery – there is that level of professionalism now”. Farmer #16 also found it was more effective to concentrate her efforts on one enterprise. She felt that farm management is “not going to be perfected in every area by one person ... you’d be too thinly spread”.

These comments reveal that while diversifying can be a risk management strategy, it can also come at a cost. Human resources must be divided between more land uses, potentially undermining farm management, timing and business viability. In a mixed-farm, resources can be channelled away from the core business to support other secondary efforts (Grande 2011). In contrast to diversification, specialisation had allowed farmers to focus their knowledge and skills on fewer enterprises and to maximise their return on investments in human capital.

Although the agricultural industry has undergone profound changes, several farmers felt that society still held outdated views of what it was to be a farmer –

that the community at large still envisaged farming as a largely outdoors lifestyle involving the man on the land with his horse and his dog. In reality, as much time can be spent planning, researching, marketing and doing ‘paper work’ in the office as is spent outdoors working in the field. And many new machines and gadgets have replaced some of the more traditional roles on the farm. As Farmer #7 said of agriculture today:

It is a sexy industry and no one knows about it... The only thing we need now is lasers and we’ve got satellites and robots and all these other things that every kid wants to work with and they all think we chew straw...

Concentration of Human Capital

Though mixed crop-livestock farming still dominates the major cropping zones in southern Australia, it looks very different from how it once was. In addition to being technologically complex, Australian agriculture is becoming an industry with fewer farmers and bigger farms. It therefore comes as no surprise that farmers share a sense of being too “thinly spread” (F#16). While the knowledge and skill requirements of agriculture have been increasing, the number of people working in the industry has been decreasing. The replacement of human labour with capital and machinery can increase economic efficiency and reduce the burden of some tasks. However, it also concentrates human capital – knowledge and skills – in fewer individuals. Australian agriculture employs fewer people every year; between 2001-2006, employment fell by fully 19 percent (ABS 2008). In the past, family members would have been called on to fill any gaps in labour, particularly during peak times like shearing and harvesting. To some degree, this is still the case. At a global scale, agriculture remains one of the few industries still largely based on a family business model, even in countries like the United States (Alston 2010, Deininger and Byerlee 2012). But these figures can be misleading. In Australia, the proportion of broadacre and dairy farms that are family owned remains constant at between 94-99 percent (ABS 2003, Pritchard *et al.* 2007). However, while the ratio of family to non-family farms remains the same, the number of family farms has actually decreased significantly – by 30 percent between 1986-2006 – involving the loss of approximately 42,000 farms (with smaller farms often being absorbed into larger holdings).

The remaining family farms are getting bigger, but have fewer family members staying on to work on the farm. This can be partly driven by an increased dependence upon off-farm income as the profitability of agriculture declines (Barr and Cary 2000). While off-farm income can have its advantages, again, it has a cost in terms of human capital and farm diversification, not least because non-family farm labour is less readily available than in previous generations (Pfieffer *et al.* 2009). In the NSW study, labour issues were raised by more than half the farmers. As wives have increasingly taken up work off-farm and children have

decided not to return to the farm after finishing their education, farmers have had to perform more tasks on their own. Farmer #28 explained:

I've got three kids and a wife, and unfortunately I don't think any of the kids are going to go on the land. The oldest one definitely won't. The youngest one definitely won't. The middle one is doing business agriculture, but not with a bent to come back on the farm but to be a trader or something along those lines.

With fewer hands available, farmers must work smarter in order to remain viable. Given family dynamics, Farmer #17 was also reconsidering his enterprise mix, being inclined to concentrate more on livestock:

I'm looking to expand the stock area and cut back a bit on the cropping because look, as much as anything, I do the whole thing on my own. I run the whole farm on my own ... it's just a very big job. And my kids are getting a bit bigger and I'm just looking to try and wind back on that cropping a little bit and run more stock.

The reduction in family members working on farms not merely reduces labour availability but also represents the departure of trusted advisors. Family is one of the most important sources of information for farm managers and can play a crucial role in shared decision making. In the NSW study, farmers expressed a strong tendency to rely on family members and other farmers for advice. A 2007 study in Central West NSW similarly found that the most popular individuals for a farmer to seek information and advice from were family members, before other farmers, agribusinesses and agronomists (CSIRO 2007). As more family members work off-farm, their role as financial advisors, confidantes and business partners may be lost, potentially removing an important component of farm success.

Fewer family members remaining on-farm can also mean the loss of skilled labour. Australian agriculture suffers not only a labour shortage, but the absence of a large pool of specialised and skilled labour. Skilled labour tends to reside within the owner/manager. Beyond reductions in family labour, there were difficulties in finding on-going skilled labour needed for day-to-day farm management. With the increasing complexity of agriculture, even day-to-day tasks require significant knowledge and skills. Once employees were found, they then had to be trained in the use of advanced technologies, appropriate management practices such as controlled traffic farming and remunerated appropriately. In the NSW study, farmers were concerned that non-family employees were an insecure investment, since it required the input of significant time and effort to develop their knowledge and skills. There was concern that once an employee had been trained or "up-skilled", there was nothing to stop them leaving and finding work elsewhere. Training family members was a more secure investment. Farmer #4, who had pooled his funds with several



Figure 8.3 Shared Decisions are Important in Farm Management

other neighbouring farmers to jointly employ a skilled farmhand, told how his neighbour was having problems with hiring, particularly at peak times like crop planting:

A neighbour over here, a mate of mine ... I've seen him do 76 hours straight. Where he should be able to get on the phone and say, I need three blokes to drive this machine, 8 hours shifts, go. Can't do it – can't find the workers.

The reliance on family members reveals another dimension to the impact of human capital on decision making – the current crisis in succession. On many Australian farms, the main adjustment to declining profitability has been the abandonment of expectations of intergenerational transfer. There is a lack of young people entering the industry – family members or otherwise (Barr 2004). Older farmers are deferring farm exit, have an increased dependence on off-farm income, and do not expect to transfer the farm to another generation (Barr and Cary 2000, Barr *et al.* 2005). This is an issue among farm families in other developed countries as well, such as the United States, which is also experiencing a delayed transfer of assets to the next generation (Richards and Bulkley 2007). The deferral of farm exit in response to a lack of perceived alternatives has contributed to the increase in the average age of the farm population (Barr and Cary 2000, Barr *et al.* 2005). However, being older doesn't necessarily mean being less successful

or innovative. Within the Australian cropping sector, productivity is highest for farmers aged between 55 and 60 years (Zhao *et al.* 2009). This is in part due to the value of accumulated knowledge and experience that is embodied in these older farmers. However, as ageing farmers retire without successors, knowledge that has been accumulated over generations is potentially lost. As Farmer #15 said:

And all this information is in that head, it's nowhere else. It isn't anywhere else. And that's the trouble. There are a lot of farmers out there with some really good skills but it just gets lost.

Stagnation in succession planning further serves to concentrate human capital in the sector, with cascading impacts on the broader community. In Western Australia, economic restructuring and depopulation are undermining both social capital and the viability of sporting clubs and organisations (Tonts 2005). Farmer #28 echoed these concerns for New South Wales, recalling how:

When I left school, I was playing Aussie rules and we had rules, union and league. And we had soccer players that used to travel away. Now we have got a league team, no union team and no rules team. There's just not the people.

This concentration of human capital, of knowledge and skills, means that individual farmers have to make a choice. They can continue to build expertise and skills in more tasks, or concentrate their efforts and expertise on fewer subjects. Eventually they are going to have to prioritise. This can result in some things being done less well, or in their removal. Consequently, cropping specialists are more likely than mixed farmers to introduce new crop husbandry practices, cultivars and fertiliser/weed/pest/disease management practices (Nossal and Lim 2011). Parallels exist in other countries. In Denmark, Finland, Germany and Greece, the majority (50-60 percent) of farmers who adopted precision farming practices (such as yield mapping) were cropping specialists, rather than mixed farmers (Lawson *et al.* 2011). These specialists are in a better position to adopt advanced technologies than those who were balancing multiple land uses.

A 'Hardening' of the Line Between Cropping and Livestock

The growing demand on knowledge and skills required to optimise farm performance makes specialisation attractive, even with the potential economic risks it can bring. In the past, the balance between cropping and livestock on mixed-farming systems could be varied based on market and climate conditions. The ability to adjust this balance may no longer be as great, due to infrastructure decline. Where infrastructure for either cropping or livestock no longer exists, the reversibility of specialisation and the opportunity to (re)integrate crop-livestock systems is reduced (Hochman *et al.* 2012). For example, in the NSW study, several



Figure 8.4 A Stockpile of Water Troughs and Fencing Materials –
Removed after a Switch from Mixed Farming to Cropping

farmers who had switched to cropping had already removed fences, water troughs and even shearing sheds and sheep yards.

New spatial arrangements on increasingly specialised farms also inhibit flexibility. In the NSW study, 10 of the 22 farms had undergone property redesign. In order to implement controlled traffic cropping, fence-lines were being adjusted to create bigger paddocks (to minimise the number of times a tractor or other GPS controlled machinery has to turn). Grazing paddocks were being made smaller as part of a rotational grazing system that sought to increase the planned movement of stock around a number of paddock cells. Rotational grazing is timed to coincide with the most nutritious stage of the plant growth cycle. Paddocks are rested between grazing events, allowing sufficient time for plants to regrow. The use of electric fences was widespread across the farms which ran livestock, suited to either sheep or cattle. The changing fence-lines reflected more than a lot of labour intensive work, revealing a broader conceptual shift in farm management. A hardening of the line between the two farming systems was occurring. Switching back and forth may not be as easy as it once was.

This ‘hardening’ of the division between land uses is ironically being driven by two practices which seek to increase the sustainability of farm management: rotational grazing and conservation agriculture. Conservation

agriculture places a strong emphasis on the exclusion of livestock to avoid soil compaction. Rotational grazing emphasises the rotation of stock through small paddocks to allow the rejuvenation of perennial pastures. Both essentially require the exclusion of other enterprises. Farms become divided into two zones – the cropping and the livestock zones. The implication of such separation is that synergies or complementarity between the two systems are removed. Separation of the two enterprises can make the final step towards single land use specialisation easier. It also fundamentally changes the dynamics of the mixed farm. Complicating matters further is the fact that enterprise separation was also facilitated by availability of the very thing whose absence can also lead to specialisation – the next generation returning to the farm through successful farm succession. Where there was more than one family member or ‘labour unit’ responsible for farm management (often when a son or daughter returned to the farm), a division of labour was possible. Put simply, while labour shortages could mean specialisation across a whole farm, labour availability facilitated enterprise separation within a mixed farm.

Rediscovering the Mixed Farm

Do the above trends towards specialisation and enterprise separation mean the end of the mixed farm as we know in Australia? Currently mixed-farms are on a trajectory towards distinct zones for cropping and livestock enterprises, either as separate entities within a farm or a single land use enterprises. However, a counter trend is also at work shaping the future trajectory of agricultural landscapes. A renewed awareness is emerging of the importance of mixed crop-livestock systems as a means of improving system diversity, nutrient cycling and other natural processes (Herrero *et al.* 2010, Villano *et al.* 2010). Such awareness may slow the separation of enterprises and instead cause re-integration.

Demand is being generated by farmers themselves for the re-integration of livestock and cropping systems. In the NSW study, re-integration was being driven by farmers’ recognition (and sometimes rediscovery) of the role of livestock in nutrient cycling. While most farmers had adopted the prescriptions for conservation agriculture and had removed livestock from their cropland, several were beginning to question the cost of the separation. They either had plans, or had already begun, to reintroduce livestock into the cropping system or vice versa. They saw livestock as playing a key role in nutrient cycling and ongoing system health. Farmer#14 had decided to reintroduce some livestock into the cropping system because he believed that the soil biology could benefit from “a bit of manure in the system, a few hoofs in there”. Meanwhile, Farmers #2, #3 and #33 were implementing a farmer-developed technique known as pasture cropping.

Pasture cropping involves the direct sowing (without ploughing) of annual cereal crops into living perennial pastures. It creates new synergies between grazing and cropping, as well as flexibility to move between the two. The crop

increases biomass and soil health, whilst also providing forage for livestock and, if it yields enough, seed for harvest. Instead of bringing livestock into the cropping system to graze, this technique involves bringing cropping into the grazing system. As Farmer #33 said of livestock:

You need them to cycle the grasses and promote biology. The crops actually help with the livestock too because they're providing high quality forage and they're providing another choice for animals to mix with dry grass. So they both help each other.

Gains from such integration may become more important as productivity growth slows down. Eventually mixed farms may recover the overlap between livestock and cropping, and create systems where there is greater balance between plant composition, animal density and nutrient cycling.

Specialisation or Sustainability?

These trends towards specialisation can confound alternative visions for sustainable agriculture. One example is the notion of 'multifunctionality' – a vision of agriculture as a source of social, economic and environmental sustainability served by multiple functions (with multiple land uses). In this vision, landscapes are on a trajectory where they evolve from a 'productivist' focus on producing food and fibre into 'post-productivist' places of resource management, biodiversity conservation, and the provision of ecosystem services. There is some sense of inevitability that this is the direction that agriculture will evolve, yet, there is nothing inevitable about such a transition. Rather than moving into more multifunctional or post-productivist modes of agriculture, production in many dryland agriculture areas is in fact becoming more intensified with fewer, not more, land uses.

Understanding knowledge intensity as a driver of specialisation also challenges assumptions that it can be a driver for sustainability. When farmers in the NSW study were asked to comment on an image of a 'future farm' – their responses were largely negative. It was one version of what a 'multifunctional' landscape might look like, with the farm divided into seven different land uses, with income generated through biodiversity credits, carbon offset credits, renewable electricity, certified sustainable timber, water credits, wheat and wool production. The image provoked a common response – that this 'future farm' was unrealistic because it comprised far too many land uses. It was best explained by Farmer #16 who felt that:

To be run by one farmer is near impossible...to be able to cover all the other industries and to be up on all of that knowledge is, for one person, nearly impossible.

Farmer #15 expressed similar sentiments: “the first thing that springs to mind is the fact that you’ve got five or eight different enterprises there and I mean [what are] the chances of one person being able to be totally tech savvy at all of those?”.

If knowledge intensity is driving farmers away from multiple land uses, what does this mean for calls for sustainable agricultural systems based on knowledge intensity rather intensity of inputs such as energy, machinery and chemicals? Would UNCTAD’s (2010) suggestion of transforming high-input industrial agricultural systems into knowledge intensive regenerative agricultural systems be possible? Knowledge intensity doesn’t rule out sustainability (and may in fact be more benign than capital or energy intensity), but the rise in complexity accompanied by a decline in human capital and specialisation may be undermining ecological diversity within agricultural systems. This is true where specialisation results in more intensive land management practices, less diverse cropping/livestock patterns, and negative environmental impacts. However, in other instances, specialisation, for example in rotational grazing for livestock, can lead to increased perennial and native grass species diversity and ecosystem health. The challenge is to ensure that where specialisation occurs, it isn’t to the detriment of broader landscape sustainability. Where intensification must occur, it should be pursued along the lines of ecological intensification, defined as ‘producing more food per unit resource use while minimising the impact of food production on the environment’ (Hochman *et al.* 2013). A key opportunity for ecologically efficient intensification exists through the better integration of crop and livestock enterprises on mixed crop-livestock farms, so returning to the important role of mixed farming.

Conclusion

It is not yet clear which of the many competing forces shaping the agricultural landscape will dominate. Certainly the mixed farm of the future will look very different to farming systems of today, with complex and knowledge intensive management systems an integral part of the farm business. As pressures on mixed-farming accumulate, greater support for the knowledge and skills associated with mixed farming systems will be needed. If greater human capital was available, then more than one type of specialisation (a division of labour) might be possible within individual farms, maintaining land use diversity. Along these lines, mixed-farming itself could become a specialised skill rather than a compromise between enterprises. This would require acknowledging the human capital challenges facing mixed farming. It would also mean renewed focus on research and development challenges. Past efforts have largely focused on single system components or single enterprises. Australian industry organisations are not exempt, and have neglected the interaction between crops and livestock for years. What has resulted is a poor understanding of the complexities of inter-relationships between enterprises on mixed farms. Gaining a renewed appreciation of the benefits of multiple land uses

for productivity will be an important means of not only moving towards a more sustainable agricultural sector, but ensuring that mixed farming systems survive. Only by better understanding the role of knowledge and skills will knowledge intensity become an asset instead of a burden, a driver of diverse agro-ecological landscapes and vibrant family farms.

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