EPIC2019

Ethnographic Praxis in Industry Conference Proceedings

Following the Invisible Road Rules in the Field
Using ANT for CTF

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Australian grain growers look to technologies of farming and cropping systems to maximise their productivity. Zero tillage cropping, variable rate inputs, soil moisture probes, and precision planting are a few practices that farmers may adopt to support their farming practices. To implement cropping technologies, and to achieve the outcomes promoted by the technological innovators, farmers need an alignment of machinery, mobile connectivity, knowledge, skills, farm services support, finance and people on the farm to make it happen. This paper shifts the focus beyond binary and hierarchical notions of humans versus technology and human versus nature, to insider research into the farming practice, alliances, and neighbourly relations to specifically examine how agency makes farmers enact a precision farming technique called controlled traffic farming. Using an actor network approach this paper examines what controlled traffic farming is, and why it makes farmers follow the 'invisible road rules' in the field using an actor network approach.

INTRODUCTION

> During harvest, as an observer-researcher sitting in the tractor with my camera, notebook and pencil perched on my knees, sharing the confined cabin space with a farm worker, I saw a precision farming system [a system designed to maximise crop yields] from a very different perspective to that of the designers of such technologies. Leo knew he was being watched. I asked him what he was doing every time he touched a new switch, button, screen or control stick. But then I realised that he was not abiding by the rules of a controlled traffic farming system. I didn't say anything. And this was when I had my 'uh-huh' moment and I could see that no matter how prescribed a technological farming system was, there was room for human error and interpretation. Even with a prescriptive and precise cropping system, together with his employer's instructions and his above average hourly pay rate because farm labour was scarce, technology and science fell short of accounting for everything. The farm worker was not abiding by the road rules in the field set down by the system.

This paper is an analysis of farmer agency in the context of a precision cropping system entitled 'controlled traffic farming'. The paper uses ethnography to look beyond what industry expects from this kind of technologically-driven farming practice, and to offer a more nuanced understanding of how agricultural science and technological systems plays out on farms. With experience as a controlled traffic farming project consultant, as well as my thinking as a landholder and grain grower, I position myself as an insider researcher concerned with the roles and rituals of social interaction on the farm and the practices by which farmers maintain their legitimacy. As a place-based ethnography located in the vast farming spaces of Australia, my research also encompasses the hierarchies, positions, and

ways of thinking that comes with geographical location, rurality and the social isolation within the farming landscape. In what follows, we take up each of these dynamics in turn.

This paper aims to draw attention to farmers' relations with non-humans, like machines, technology and farming methods. Relational ties within the network are thoroughly explored. This approach is related to material-semiotics, but at the same time it remains faithful to ethnomethodology in its detailed descriptions of common farming activities, practices, sequences and the habits that makes Australian farming. Actor network theory offers a powerful approach for capturing the ways in which 'agency' is produced via a heterogeneous network of interactions of human and non-human actors such as knowledge, technology, money, farmland, animals, plants, and so forth, and how these interactions depend on both the quality of the actors and the networked context of interactions between actors (Noe and Alroe 2003). This analytical approach demonstrates that agency can be interpreted as a collective property of humans, non-humans and objects and seeks to present the relationships between things that form an assemblage of agents.

As a heterogeneous product, agency generates effects. The sociology of translation located within actor network theory is used to show where these effects are found. This study works with two farmers from commercial farming businesses to demonstrate that farmer agency exists to exercise control within the agri-food structures, but it requires specialized non-human relations and associations to generate such effects. This paper explores these concepts by interrogating farmer agency in the context of machination and technology for crop production. This research is place-specific in the dryland agricultural zone of the Wimmera Southern Mallee region of Victoria, Australia, however it contributes to a global understanding of how agricultural science and technology is adopted and held in place by agency.

What The… CTF

Controlled traffic farming (CTF) offers insight into how farmers organise their farm practices. Farmers who follow CTF have adopted the concept, by accepting the benefits and making the system fit their farm. This farming system is advocated by a specific group of scientists as well as CTF farm leaders. The Australian Controlled Traffic Farming Association has over 700 members. Some peer-reviewed CTF research includes the whole farm benefits of CTF (Kingwell and Fuchsbichler 2011), soil emissions of nitrous oxide and methane (Tullberg et al 2018), modelling to estimate environmental impacts (Gasso et al 2014), and estimating annual machinery costs for CTF (Bochtis et al 2010). This work aims to contribute to the CTF literature about how CTF science is adopted and held in place by agency constructed as a relational collective. Critical ethnography moves beyond the traditional agronomic perspectives that CTF scientists and farmers offer. This paper can support the innovators and designers of farm machinery and technology by showing that machines, technologies, humans, skills and land are a collective that work together to enact controlled traffic farming.

Controlled traffic farming is a science that enables farmers to potentially be more productive by following the same wheel tracks in fields for every operation. The objective of a CTF system is to minimize soil compaction and achieve all the benefits advocated by CTF scientists such as improved water infiltration, mitigation of randomized machinery passes which cause soil compaction, improved plant performance in non-trafficked zones,

hardened designated wheel tracks for faster field access after rain, and reduced fuel consumption. CTF is a prescription based precision farming system. It relies on global positioning systems (GPS) for real time kinematics (RTK) auto-steering guidance. Axels on the prime mover, whether it be a tractor, combine or a self-propelled sprayer, share the same wheel base width. These are aligned with implements in a ratio to ensure that the machines travel on exactly the same tracks in the paddock for every field operation, indefinitely (see Figure 1). The GPS and the auto-steering software ensure that the implement, like the seeder or the boom-spray, are not overlapping nor underlapping. Machinery accuracy can be as precise as one centimetre.

In an increasingly automated world one may assume that farmers wholly submit and give over to their fully-automated machines and technology for their decision-making. Yet farmers do not give up control. When they apply a controlled traffic farming system they are actively re-shaping a technical system. Soil type, topography, micro-organisms, and knowledge are also part of the system. This work sets out to challenge that farming is more than just a farmer's set of decisions. This work argues that agency is not purely human. Agency is defined as a property of humans and non-humans using an actor network approach to explain how technology and science re-articulate the agential properties of farmers, their machines and the other agents that enter the farming complex.

Controlled traffic farming has been used by grain growers in Australia over the last twenty years. However, not every farmer who grows grain has adopted this system. This article offers two case studies, one farmer who has adopted CTF and another farmer who has not. Empirical evidence is provided to show how agency is distributed as a collective and performed by farmers, machines and other entities. The paper marshals the methodological approach to analyse the social, cultural, material, natural, human and technological elements at play in these case studies. This analysis contributes to a broader understanding of the complex relationship between farmers, technology and their land.

Figure 1. This photograph captures the straight lines and mathematics of CTF ratios. The image shows the wheel tracks and the 12m swath of canola crop remaining to be harvested, parallel to the operating combine harvester. (Photograph taken by the author).

CASE STUDIES: AGENCY IN THE AUSTRALIAN GRAINS SECTOR

This is a story of two farmers who grow grain. These farmers are neighbours who reside in a small rural farming district in the Wimmera Southern Mallee region of Victoria. This rural district, marked only with a hall and a tennis court, is called Telangatuk East. They are aged in their mid-40's and were once class mates at the local primary and secondary schools prior to their senior schooling years. They are both volunteer members of the district Country Fire Authority and occasionally have a hit of tennis in the local social tennis competition.

Tony, our adopter of controlled traffic farming, went to boarding school in Hamilton, a regional hub in the western district of Victoria, about 100 kilometres south of his farm. He did not complete his final year of high school, leaving early to undertake a farm apprenticeship in the Mallee in the mid-1990's. The Mallee is a region, spanning the north western region of Victoria and South Australia that receives low annual rainfall, and features sandy soils and sparse low vegetation. It was on this 2400 hectare farm where he first experienced continuous dryland cropping. After three years he continued his education with a diploma in agriculture, and then he worked extensively in southern Queensland and the Riverina region of New South Wales laser-levelling greenfield zones for irrigation development. Wayne, our non-adopter, completed his secondary education at the state high school in Horsham, the regional centre of the Wimmera, before he commenced a farm apprenticeship in the western district. Wayne worked on a much smaller, intensive mixed enterprise farm, focussing on sheep production, pastures and high rainfall opportunity cropping.

Both Tony and Wayne returned to Telangatuk East around the same time to farm full-time with their parents, but they needed to supplement their farming income with some off-farm work. Over time Tony has undertaken contract windrowing and harvesting, owned a precision-planter and grader board machinery hire business, and managed a consultancy project for a multi-national Malaysian corporation for the re-development of economic land concessions in Cambodia. Wayne continues to operate a canola windrowing contracting business. Both of these farmers have married. They each have two children; all of whom attend the local community school.

Tony continuously crops 1350 hectares, leasing land from another neighbour and his parents as part of the farm succession plan. Tony has implemented a full controlled traffic farming (CTF) system. Tony has a farm worker called Leo who helps him at sowing and harvest times. Wayne crops 630 hectares and has over 2000 cross-bred sheep on 450 hectares. He owns half of the land, and all of the machinery, with a profit-sharing arrangement with his parents as part of their farm succession. Wayne does not practice CTF as he runs sheep as part of his mixed farming enterprise, but he is interested in the system. The fieldwork in this study examines these neighbours by tracing their actions to understand the agents in their actor networks and how they enrol machinery and technology in their farming practices to find meaning in what they do and do not control.

These farms are located in the water catchment of the Glenelg River; a border dividing political representation in the Federal Parliament and a natural division between high and medium rainfall zones in western Victoria. The landscape is diverse with the Black Range State Park to the east (see Figure 3 for aerial image of the landscape). Remnant paddock vegetation, shallow top soil, creeks, and native pest populations of kangaroos, cockatoos and

emus are dominant landscape features. The mean annual rainfall is 550mm. The vegetation density, the undulation and non-arable zones are symbolic of the traditional grazing enterprises. Tony is the only farmer in the district who does not have stock on his property as a risk management strategy and for income diversification. The district population is 50 people. More broadly, the Wimmera Southern Mallee (WSM) region covers just under 34,000 square kilometres with a total population of 47,000 (WSM Regional Partnerships 2017). The agricultural sector accounts for 25% of jobs in the WSM and 47% of all businesses (WSM Regional Partnership 2017). The region has a projected estimated growth rate for the period of 2016–2031 of -0.6% (Wimmera Southern Mallee Regional Growth Plan 2014). Mobile telephone service and mobile data is limited. This locality is marked as a black spot in the detailed local government boundary map of Horsham Rural City Council (see Figure 2).

Figure 2. Map of the Wimmera Southern Mallee region in Victoria (map sourced according to copyright laws from Regional Development Victoria)

This fieldwork took place over four months leading up to and throughout the harvest period of summer 2018 – 2019. The data for this project includes informal conversations, hand written notes capturing farmers' sequences of action. These notes included what they touched or modified, meaning whether they reacted to a situation or if were proactive in what they did, as well as who they talked to and the topic of conversation. Digital images were taken to support the findings. In total 210 images from three different cameras, a DLSR, iPhone and a drone, to support the research methodology by capturing what took place inside machinery cabins, in the field, and from aerial views. The observations focussed on how the participants operated their harvesting machinery and technologies. To protect their identities, Tony, Leo, Walkers Machinery, Bert and Jake are pseudonyms. The results are succinct stories describing farming practices, decision-making and discussion of how CTF influences human agency. Actor network theory is used to examine agents' associations

and to explain from an insider perspective how agency is distributed as a collective and performed by farmers, machines and other entities.

The CTF Farmer

About twenty years ago Tony commenced implementing a CTF system. Back then he was still farming with his father and his younger brother. Tony saw that compacted soils, which was caused by decades of grazing, hay production and cropping, were limiting their crop production. After a bus tour with a grower group to outback New South Wales to meet a CTF farmer, together with expert knowledge from soil scientists from the University of Queensland who were publishing widely in farm extension magazines, Tony gradually introduced CTF to his family farm business. The process started by moving the tractors' axels out to 3m spaces and matching the width of the seeder to the width of the combine harvester's front. Tony removed fences and some tall paddock trees for easier traffic-ability and to reduce the trees' interference with the GPS signal.

At the same time farmer case studies of the successful implementation of CTF were being regularly published for a farming audience. Tony was reading as much about CTF as he could. While modifying his farm and his farming network, Tony had access to new CTF knowledge, some basic farm soil data, a record of their annual yields, and a membership to a grower group.

In these published journal articles the CTF scientists tended to speak on behalf of the non-human actors who could not speak for themselves, such as residue, soil microorganisms, plant roots, rainfall infiltration and soil air pockets. On the other hand the CTF farmers spoke on behalf of their costs, machinery, a quicker return to the field after rainfall, and their crop's performance. By enrolling a number of agents from the farm services sector who too shared Tony's goals, his fields were transitioned to CTF so that machinery could only drive up and back on the same invisible lines across the fields, indefinitely. Tony, his father and his brother, all witnessed an increase in crop yields; controlled traffic farming was a translation in an actor network sense, by enrolling actors, aligning goals and stabilising the network.

Two decades later, in spring 2018 Tony was faced with a new problem. He could not find a new or second-hand combine harvester front to fit his CTF system. This was a moment when Tony could have forgone the CTF system and returned to randomized traffic widths, choosing a cheaper and readily available 10m front. This would have been easy. Instead, he chose to implement a new CTF ratio. In simple Australian language, he was getting bigger gear. This change meant that he would need a new self-propelled boom-spray as well as a new air seeder for sowing season. Paddock trees would need to be removed. Tony viewed the standing paddock vegetation as an obstacle, nonetheless they were still a contributor to his CTF collective. But the actors in his system were agents because they demonstrated agential capacity to translate the CTF science. CTF is a translation of humans, machinery, nature and technological agency, which as a collective enact the benefits of the science on the farm. Transitioning systems, Tony stabilised his cropping practice by replacing CTF agents with new CTF agents.

For a CTF system to be enacted at harvest the auger on the combine needs to extend over the chaser bin. The chaser bin is a cart that is towed behind a tractor, allowing the combine to harvest and empty its grain simultaneously (see Figure 3). The John Deere

dealership had assured Tony that an auger extension kit on his new combine would be long enough for his 12m system. They installed a kit as part of the contract but it failed to reach the required length. This meant that the chaser-bin could not be filled while both machines remained on the CTF wheel tracks. Tony knew that the auger was too short. He said that another extension kit would have to be installed before the next harvest; it was too late this year.

Figure 3. This photograph captures the harvest where the combine's auger is extended over the chaser bin to unload canola in transit. The farming landscape typifies the dry summers at Telangatuk East. (Photograph taken by the first author).

The Farm Worker

Combine harvesters are designed to auger grain into a chaser bin while harvesting to maximize harvest efficiency (see Figure 3). The tractor tows the chaser bin, which is filled with grain, to empty into a field bin or in a truck. This was the job for Leo, Tony's farm worker. Leo was driving the John Deere tractor. He had GPS and auto-steering technology to drive in straight lines. Leo's task was to follow the same wheel tracks as the combine harvesters once they had harvested the crop.

The chaser bin was limited in its technology, but remained mechanically sound and robust. It had no modern features to support Leo's judgement of how full the bin was. It just had one window, like a port hole, for Leo to see the grain through the bin wall. Leo's decision-making was based on his sight and feedback from the combine drivers, as they had a better view into the field bin that he did (see chaser bin alignment in Figure 4).

Leo was working alongside two large capacity John Deere combine harvesters; Tony's combine and a brand new demonstration model. This combine had 3m axels and a 12m front which meant it fitted Tony's CTF system. It featured the latest technologies and modern driver comforts. As a sales pitch the local dealership brought it to Tony's farm to let him experience this new machine, while harvesting his crop and sharing the synced paddock data between both machines.

Figure 4. This photograph captures the tractor and chaser bin aligned with the field bins. The farm worker is auguring the canola from the chaser bin into the field bin with his judgement of sight for accuracy. (Photograph taken by the first author).

The paddock was heavily timbered with 10 remnant Eucalyptus trees. Two trees had dropped limbs which increased the area of the fixed obstacles. Figure 5 demonstrates the vegetated landscape where the combine harvesters were working.

Figure 5. Two combine harvesters, remnant trees and fallen tree limbs are captured in this photograph and demonstrate the complexity that the chaser bin driver must consider. (Photograph taken by the first author.)

Tony had instructed Leo to remain on the new wheel tracks that the combine left behind in the stubble. Leo drove along the headlands and watched the two combines; from a distance they were hard to differentiate. The chaser bin had to be positioned on the combine driver's left side, on stubble only. Leo followed the combine, staying on the new wheel tracks before disengaging the auto-steer software. He had to steer the tractor straight, avoiding the combine on his right side, but staying close enough to collect the grain. He had to use his judgment of where to drive. He then set the speed on the control stick, and steered the tractor over to the combine and into a safe zone to fill the chaser-bin. Over his right-hand shoulder he watched the auger swing out from the combine and over the bin. The grain crept up the window of the bin. Once filled, Leo moved back onto the wheel

tracks. He re-set the auto-steer to guide the direction of the tractor, and slowed down as he no longer had to keep up with the combine.

Leo wasn't abiding by the CTF system. His hand movements were discrete; he switched software off and on, and he pushed the accelerator forward for speed and pulled it back to slow down. The GPS guidance and auto-steer system were over-ridden. He merged the tractor about one metre towards the combine to collect the grain while in transit. Leo was utilising his own relations with machinery and guidance software by operating the tractor manually. Considering a network approach, the actors were all present yet they were fluid. Leo was re-negotiating the assembled collective through the terms of the short auger, because the machine was not realising the full benefits of CTF. Leo wasn't being negligent, disrespectful to Tony, nor sceptical of the CTF system – if he had remained on the CTF wheel tracks as he had been instructed to do, the grain would have fallen on the ground.

The Non-CTF Farmer

Wayne was a mixed farmer. He did not follow a CTF system even though most of his machinery axels were on 3m widths. He relied on GPS guidance and auto-steering at harvest and sowing. Wayne had participated in a local CTF trials with a grower group a few years ago, and he knew that from this small trial CTF showed yield advantages. But Wayne wasn't convinced that it was worth the effort. Wayne equally liked his sheep. He said that he looked to his neighbour Tony for cropping advice, and to Jake, his best friend and a farmer further along the road, for his stock advice. Wayne had employed a former school friend as his crop consultant.

There was 30 remnant native trees scattered across the 25 hectare field of barley. The barley variety was relatively new to Australia, with end point royalties to Seedforce for the intellectual property rights to sell the grain. However, Wayne wasn't selling this grain; it was allocated as his stock feed.

Wayne negotiated his older model Case IH 2188 combine harvester between most of the tree trunks. He disengaged the auto-steering software to avoid the trees. He didn't always resume the auto-steering after by-passing the trunk; Wayne manually steered the combine towards the upcoming trees rather than re-engaging the software. Wayne had not paid for a subscription to unlock the Trimble software to monitor his crop yield. He disclosed how much the annual subscription to the GPS base station costs. Yet he had no way to map his yields despite his alliance with Trimble technology. The combination of paying for a yield monitoring subscription and the fall-back position that his grain will be fed to sheep, demonstrated a different set of relations in his farming practice.

Wayne's father, Bert was driving the John Deere 8220 tractor towing the chaser-bin (see to Figure 6). This chaser-bin had been modified resulting in an ambiguous form of measurement. To unload, Wayne used his UHF radio to call Bert. Bert drove tractor out from under the shade of a tree and lined up next to the moving combine. Wayne's auger extended over the bin and emptied the grain tank. When this was finished Bert returned to his place in the shade. Wayne was counting how many times Bert took the fully loaded chaser bin down the road to empty the barley into the grain shed. This was Wayne's method of estimating the average crop yield from the field.

For Wayne the total grain loss from the combine wasn't his priority because it shared goals with his mixed farming. The grain that was not collected in the combine could be eaten

by the sheep. The dial in the cabin that measured grain loss never moved, suggesting it was ineffective. Stopping the machine, he got out of the cabin to manually adjust the concaves. He made the threshing clearance smaller to reduce the amount of grain which was un-threshed and spread on the ground. Back in the cabin he said that he "is looking forward to a new header so I don't have to do this". Wayne made a comment that he wanted a clean sample for Jake who was coming by later to get a trailer of the grain to feed out. The amount of chaff remaining in the grain sample didn't seem that important to Wayne. If it wasn't for Jake he had no reason to adjust the header settings to create a cleaner sample.

Wayne owned his combine harvester. Wayne spoke about his concerns of transitioning to wider equipment and the need to remove some of the standing vegetation in his fields. He mentioned the state legislative requirements to get a permit to cut down native vegetation. He talked on behalf of the trees and the waterways. Nature offered physical obstacles and abstract barriers through law, but for Wayne these were agents in his collective. Wayne did not give up control over nature, rather he actively worked with the landscape and the laws to determine his size of machinery. He wanted to buy a newer second hand New Holland combine in the coming year with modern technologies, but at the same time it also had to align with his Trimble GPS system and his existing MacDon front from his windrower. His wife was not in favour of trading their Case IH; she did not share Wayne's goals because she was content with the current actors in their network.

Wayne's relations were hybrid. His agency was an assemblage that generated a collective effect; sheep, sheep feed, lower financial commitments, family, land, machinery, technology, cropping inputs and advice were translated for production. He demonstrated both recreational and business relations with Jake as he sold him barley directly from the header rather to a grain buyer. Wayne's wife, Janine was camping with Jake's wife during harvest. Both families bank with the same rural finance company, basing their business on the employee who worked as the regional representative. When this representative was moved to another branch, Wayne was very disappointed. Wayne's agronomist, Peter, was his old school friend. Wayne terminated his former agronomist to allow Peter to give him crop recommendations, based on trust. Wayne looked to enrol people in his network. Wayne assembled agents in his farming network through brand and human loyalty.

Figure 6. The black top third of the chaser bin shows where it has been extended by the owner. (Photograph taken by the first author)

The culture of the Australian grains industry

Modern farmers continue to change and modify their agricultural techniques to keep up with the terms of trade in the global economy. Wayne is looking to increase his machinery size for work efficiency and Tony has implemented CTF for crop yield benefits. Increases in crop yields, decreases in production costs, management of risk and/or improvement in work efficiency are key ways in which farmers attempt to maintain competitiveness. Higgins (2006) states that the agency of farmers is the subject of ongoing conceptual and analytical debate in the critical studies of agriculture and food. The culture of the Australian grains industry, and the structures of the commodity chain, contextualise why farmers refer to science and technology, such as controlled traffic farming, for profitability and productivity advances.

Australian agriculture is structured to enable farmers to produce near-identical bulk commodities. Farming practices are moderated by others even when connections within this chain seem implausible because farmers are legally required to meet extensive quality standards set by regulators and as a consequence many actors are aligned to safeguard production. Agriculture is governed from Australia's capital city, Canberra. Levies are deducted at grain sales and this is matched with government funding to finance the peak industry body, the Grains Research and Development Corporation (GRDC). Australian farmers participate as individuals in a colloquially-named 'global playing-field'. They are not subsidized; their inputs and grain prices are influenced by the value of the Australian dollar and global supply and demand. Grain grown from using a controlled traffic farming technique is not segregated, penalised, nor rewarded; it remains a bulk commodity subject to standard commodity grades, validating the inquiry into why farmers would make such an effort to enact such a practice.

The commodity chain consists of numerous private enterprises engaged in increasing farm productivity and profitability. They are positioned in the economy by farmers' subscriptions, fee for services, retail costs, research funding from levies and so on. Competition exists within the farm services sector to undertake agronomic field research. Controlled traffic farming research is competitive under this governing structure of the industry. Farmers do not receive any premiums or segregation benefits at the point of sale, however levies may be directed to ongoing CTF research if scientists and grower groups are successful in their competitive application for research in this field.

For Australian farmers, global competitiveness comes by supplying high quality grain compliant with the strict market conditions. Farmers feel coerced and powerless to challenge the political conditions under which they operate, hence they rely on new production techniques.

INSIDER RESEARCH ON FARMS USING ANT

Actor network theory (ANT) is a theory, or rather a family of theories within the field of Sociology of Translation and technosciences proposed by Bruno Latour, Michel Callon (1986), and John Law. This work utilises some of the frameworks from within ANT to examine agents' associations and to explain from an insider perspective how agency is distributed as a collective and performed by farmers, machines and other entities.

Hierarchical social orders are also flattened, working from the ontological premise that humans, non-humans and objects are not separate realms. This is founded on the rejection of epistemology and objectivity, by redefining ontology to allow for multiple ontologies (Latour 1999; Latour 1999b; Latour 2005). This approach shows the role played by science and technology in structuring power relationships (see Latour 1987). It is clear that certain entities control others but by remaining agnostic, the power dynamics between humans and non-humans becomes visible. This means that in a farming environment the insider researcher needs to be aware of the agricultural sciences, natural resource sciences, social sciences, technological and information sciences ready for interpretation at every moment. It is the researcher's role to forgo these ontologies and listen to the participants, or agents, as well as the others that they mobilise, in the study. Giving generalised symmetry to actors implies that the researcher must act impartially and refer to the differing protagonists in the same terms, regardless of their effect upon others. Describing the way in which actors are defined, associated and obliged to remain faithful to their alliances is how we determine performative agency.

Agency is a property of a collective. Agency is about moving beyond human notions of conscious action to an actor network approach where human agency is dissolved among many. As a post-human, practice-based method actor networks shape the idea of agents and the performativity of agency. Each performative definition of what society is about is reinforced, underlined and stabilised, by bringing in new and non-human resources (Latour 1986). The method focused on inanimate entities and their effect on social processes (Cresswell, Worth and Sheikh, 2010). Upon this point the notion of power can change, transferring it to the many resources used to strengthen and hold society still.

An actant is an entity that 'performs' in network relations with other actants (Noe and Alroe 2003). The term actant replaces the term actor since the latter implies only human agency (Higgins 2006). Higgins (2006) defines agency as a property of humans and non-humans through the arrangement of relations, not just those which are social relations. Agency is performative in that it is constituted in and by these relations (Higgins 2006). The ways in which actants perform in an actor-network is framed by the actor-network – meaning that among all the ways in which an artefact, or actant, could be performed such as a zip tie or fence, limits the possibilities that are actualised within the particular actor-network. The notion of 'translation' is characterised as the transformation of objects as they are enrolled into the network and mobilise actants of the network (Noe and Alroe 2003).

Approaching these farms as actor-networks there were many elements that were translated and enrolled into the objective of crop production. There were the farmers, tractors, combines, chaser bins, technologies, mobile phones, satellite signal, land, crop, sheep, remnant vegetation, soil, family, farm labour, grain, market prices, knowledge, skills, values, time, stress and so forth, depending on the heterogeneous strategy of each enterprise. The outcome of the sequence of operations required to undertake the practice of farming resulted in the interactions in the actor-network.

Controlled traffic farming as a translation took the form of a black box. Using the actor network infra-language a black box is the term used to describe an alliance for transforming and translating a diverse range of interests so that an object of controversy is no longer subject to contestation and dispute (Higgins 2006). This is not to suggest that controlled traffic farming is a controversy, rather an actor network analysis identifies black boxes at moments when they open and expose the parts which hold them together. The parts were

exposed when the combine auger did not reach the chaser bin, forcing Leo to over-ride the GPS auto-steering guidance system and manually drive beside the moving combine. Black boxes are a consequence of agential capacity of human and non-humans when the relations between these materials hold and generate an effect. Controlled traffic farming demonstrates the agency between the farmer, and his machines, nature and technology to generate effects on soil and crop yield, which allowed Tony to be competitive as a grain grower in the Australian grains sector.

The relationality of entities is that the entities enrolled get their forms and performances through the relations in which they are located (Law 1999, p 4). This re-interprets our understanding of farm enterprises from an ANT approach. To explain further, if Tony planted Trojan wheat in a field, and the following day Wayne borrowed Tony's John Deere disc air seeder to plant this same variety of wheat on his farm, and theoretically both crops were sown at the same seed and fertilizer rates and received the same rainfall during the growing season; the fields will not average the same. To begin, Tony's wheat is translated into a controlled traffic farming network, where different entities are enrolled to produce the crop. Wayne's crop is translated into a mixed farming enterprise, where sheep as an entity are immobilised in the network and generates a different effect. The same kind of difference can be explored for the other entities enrolled such as farm size, software, grain marketing strategies, rural finance and so forth.

The actants enrolled in the networks on the farm can be actor-networks themselves, e.g. controlled traffic farming, GPS auto-steering technology, prime lamb production, John Deere as a global entity, and local John Deere dealerships, Trimble, and Telangatuk East. The networks also enrolled entities not limited to the physicality of the farms. Actor network approaches bring with them a value of time and a stored energy from historic associations. The CTF scientists, farm succession, Tony's brother's labour, the trip to outback Australia to visit a farm with a grower group which Tony no longer subscribes to, all add to complexity of the heterogeneous network. External entities are enrolled and mobilised as actants into the farming processes: seed, machinery dealerships, John Deere's data storage facility in Brazil, education, work experience, and weather forecasts. The kind of entities and actors that are enrolled or not enrolled into the network and how they are enrolled is characteristic of the enterprise (Noe and Alroe 2003). Comparing Tony and Wayne's education, technical training and cropping work experiences prior to their move home, together with the implementation of CTF and yield monitoring references, and the difference in the number of relations in each network can all be used in 'summing up' that Tony's average crop yields will be different to Wayne's average yields.

The sociology of translation relies on observations and artefacts. Farmers' motives are not really known but they can be inferred by what remains behind. Latour (1999) defines the program of action as a series of goals to undertake operations. Tony and Wayne's goals may have begun by determining the crop types and varieties based on the paddock rotation, market demand and price, balancing nitrogen against the climate outlook, using retained seed, and/or keeping production costs low. Wayne may have considered achieving ample stockfeed for his stocked rate, with surplus grain to sell to Jake.

Social research on farms typically seeks the barriers of adoption suggesting that farmers have limited choice in their actions. Noe and Alroe (2003 p.6) oppose this idea, offering that actor networks are built on choices, but there is no master plan prescribing the mobilisation of the network and there is no platform for making these choices rationally because the

network must establish its own schema of rationality. They interpret this as when you ask a farmer why the farm is organized in the way it is, the researcher will often get the answer that it is because it is the only rational way to do it, because of … etc. And the argument leads to a place where there was no choice (Noe and Alroe 2003). Only through a reflexive communicative process of the actor-network, the fact of choice becomes visible (Noe and Alroe 2003).

Latour (1986) states that society is not what holds us together, it is what is held together. "Social scientists have mistaken the effect for the cause, the passive for the active, what is glued for glue" (Latour 1986 p.276). The Australian agricultural sector, led by the Agriculture Minister, do not hold farmers, commodities, trade partners and companies together. Practices, as an act of doing, are privileged over ideas. So rather than assuming that structures exist or actions will occur, associations locate knowledge in activities, events, processes and sequences. Power is not something a human may possess nor hoard; either they have it in practice or not, as others have it. Latour (1986) identifies two sources of power. When someone has power – *in potentia* – nothing happens and they are powerless. When they exert power – *in actu* – others are performing the action and not the subject. Power over something or someone is a composition made by many people (Latour 1986 p.265) and for farmers this composition is extended to their machinery and technology. The amount of power exercised varies not according to the power someone has, but to the number of other people who enter into the composition.

Controlled traffic farming consists of a composition of actants. Power over something or someone is a composition made by many (Latour 1986). Controlled traffic farming had power as it made Tony, Leo and the staff from the local John Deere dealership abide by the invisible road rules in the field. Wayne knew that if he wanted to implement a CTF system he would have to remove some trees. As a performative behaviour, it gave Tony identity, and it made the local machinery dealership strive to translate his farm in their own network strategies by demonstrating the new combine in the aim to make a sale. Controlled traffic farming enrolled the GPS guidance, software, farmers, machinery widths, machinery manufacturers and made them follow the system even during a period of transition; there was little room for creativity and self-expression. Only momentary decision making occurred to disengage from guidance to steer around the remnant paddock trees to avoid collision and turn at the end of the paddock during operations.

Like power, agency as a composite produces an effect. Controlled traffic farming is a pre-determined system created by others for farmers to follow through modifications to machines and utilisation of technologies. Agency is what has to be explained by the action of others who enrol. This is evident by the memberships to Australian Controlled Traffic Farming Association, the diversity of CTF research projects, the financial risks to farmers to adopt CTF, the factory standard machinery to fit CTF multiples, and the after-market axel and auger extension kits to keep the system alive. All of these effects support the hypothesis that CTF as a collective assemblage of actants have agency. Agency was a product that was distributed among many.

Agricultural robotics is nearby, removing farmers from their machinery and placing them elsewhere in the network. It's predicted that farm operations will be undertaken by swarm-like micro-machines. This work demonstrates that farmer agency will not be lost when robotics become normal practice. The assumption that farmer agency disappears as technology replaces manual work is not correct. Creativity and freedom in open fields may

decrease, and research and development may be left to the experts, but farmer agency, when we understand this in relational terms as a collective assemblage to generate effects, will always remain.

CONCLUSION

Controlled traffic farming is a networked assemblage of agents that generates effects. Controlled traffic farming brought with it collective action which held power in a two-fold effect; it supported farmers' grain production and yield advantage, and secondly, it enrolled farm machinery manufacturers to supply objects to fit the system. Yet farmers' power remained on the farm. The grain grown with a CTF system and traded as a bulk commodity was not segregated nor awarded premiums. This brings ethnographers to ask the fundamental question of 'why should farmers bother?'

Farmers' actions are rooted in economics as much as they are ideology. Grain growers increasingly look to technology and science to enhance their productivity. Actor network theory is an insightful tool to show that farmer-agency is reliant upon those far away from their farm, including CTF scientists and the innovators in farm machinery and agricultural technologies. As a practice, controlled traffic farming can be assimilated with any innovative farming technique that brings automation, machination, technology, robotics, humans and land together; where farmers' agency is not purely human but will always be present.

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Acknowledgements – special thanks to my support crew from Federation University: Professor John McDonald and Professor Keir Reeves – both for providing invaluable drafting advice and solid guidance for this paper and for the trust in my work to date. Thanks also to EPIC curators: Professor Tania Lewis from RMIT University, and Dr. Dan Perkel from IDEO for drafting advice. This research would not have been possible without the generous sponsorship from Regional Development Australia - Grampians Region and Federation University Australia. Amity Latham is supported by a Research Training Program scholarship administered by FedUni Australia on behalf of the Department of Education and Training. All views and opinions in this paper are those of the author alone.

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