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Moving the Middle

Empowering rural land managers to act in complex landscapes

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Moving the Middle Conceptual Framework

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BACKGROUND

The rights, roles and responsibilities of Māori are stated in many of New Zealand's legislative frameworks. The National Policy Statement for Moving the Middle is based on the proposition that most land managers (farmers) are not altering their farming practices to improve environmental outcomes around water quality, GHG emissions and biodiversity as quickly as is desirable. The argument in the proposal is that …

> '… many land managers are simply overwhelmed by information overload, and by the complexity of the multiple systems and pressures they face.'

Therefore, a conceptual framework for Moving the Middle must describe the complexity of farm systems and the circumstances in which this complexity creates hesitancy in decision-making by farmers. In principle, those circumstances provide clues about the kinds of policy interventions that would reduce hesitancy. The conceptual framework must also describe the complexity of systems beyond the farm that influence farm practice, and the circumstances in which complexity in those systems can constrain decision-making by farmers.

The overall conceptual framework we will use to guide our research in Moving the Middle draws on Social Practice Theory and Farming Systems Theory. Social Practice Theory (SPT) is the fundamental conceptual framework for Moving the Middle because it provides a coherent logic for investigating the emergence, persistence and decline of practices, including agricultural practices, in socio-economic systems. SPT has the advantages of generating insights into how systems beyond the farm, as well as farmers themselves, and the farm system itself, influence farming practice. See Table 1 for a brief description of the key concepts used in the conceptual framework.

SPT instead recognizes that, like all practices, farming practice is undertaken within settings. Farmers' behaviour is constrained therefore, by the context-specific and dynamic complexities of specific farm systems and their inter-related parts, as well as by numerous factors beyond the farm. Behaviour change from an SPT perspective is thus distributed across social systems and material infrastructures that influence 'what makes sense to do'.

SPT 'takes collective social practice as the unit of analysis and, in so doing, reduces the scope and ordering power of [individual] reason' (Schatzki 2017:5). SPT has the advantage of generating insights into how systems beyond farmers and their farms can influence farming practice.

Farming Systems Theory (FST) provides a theoretically sound, empirically grounded approach to investigating how the farm system itself (including the farmer), influences farming practice. FST can be viewed as a special case of SPT where the analysis has usually been limited to the farm system itself (which includes the farmer) and identifying external factors that influence the system. Unlike SPT, FST does not analyse practices within which those external factors are embedded.

Methodologically, the SPT approach to understanding (and changing) practice can involve zooming in on the composite elements of a specific practice in a context, or it may involve following the practice beyond the farm gate to appreciate factors beyond the farm that shape the dynamics of farm practices. It may also involve exploring the ways in which more intangible elements – socio-cultural narratives – may also shape 'what makes sense to do' and, therefore, a practitioner's receptivity to practice modification, substitution or practice switching.

Table 1. Key concepts

Concept	Description	Comments
Practice	Composed of materials, competencies, meanings	Incremental change is a change in materials
Practice architecture	The way materials, competencies, meanings link together	Modular change is change in materials and architecture of practice
Practice bundle	Set of practices that are related because they share materials/competencies/meanings	
Bundle architecture	The way practices link together to form a bundle	Architectural change is a change in the architecture of one or more bundles
Farm system	Suite of inter-related and overlapping practice bundles	Radical change is a change in component practices and architecture of a bundle
Practice ecosystem	The constellation of practice bundles beyond the farm that link to the farm system	The farm system is managed to meet a purpose (intent). The ecosystem is not managed to meet a purpose and the farm system is, practically speaking, unable to modify practices in the ecosystem
Critical input	An input that that, if restricted, disrupts the operation of dampening feedback loops such that the achievement of the farmer's goals is compromised (system intent). The intent of the farm system and the suite of practice bundles (and the relationships between them) that constitute the system determine which inputs are critical, and which are not.	Environmental requirements that alter access to critical inputs in a way that threatens realising the system intent. They will require radical changes to practice bundles and architectures (or changes in system intent) unless new tactics can be created. Environmental requirements that alter access to inputs without threatening system intent can be accommodated by reconfiguring relevant practices, practice bundles or practice architectures.
Strategic/tactical flexibility	The capacity of the farm system to absorb variation in critical inputs without changing practice bundles or bundle architecture. Strategic flexibility is the capacity to vary outputs. Tactical flexibility is the capacity to substitute inputs.	This capacity depends on the suite of practice bundles (and the relationships between them) that constitute the farm system.
Farm trajectory	Characterisation of the strategic and tactical flexibility of the farm system and the intent of the farm system.	The capacity to exercise strategic or tactical flexibility is constrained by the suite of practice bundles that constitute the farm system.

SOCIAL PRACTICE THEORY[1]

The unit of analysis in SPT is a 'practice'. A practice is composed of materials, meanings, and competences (Shove et al. 2012). A practice can be conceptualised as a system of these related elements purposely enacted by the practitioner (farmer) regarded as a carrier of practice. In more extreme forms of SPT analyses, there is very little human agency because individuals are regarded primarily as carriers of (collective) social practice.

In this way, an examination of 'fencing' as a farming practice shows how it is shaped not only by the farmer's individual choice, but by the availability and types of fencing materials, budget constraints, knowledge of how to build a fence, an understanding of why the fence should go here but not there given farm topography, the types of animals being kept in or out, the location of other relevant resources such as water supplies and shelterbelts, flood risk, how good the fence has to be to fulfil the socio-cultural requirements of a good fence and a good farmer and so on (see Table 2).

SPT is thus able to identify opportunities for change both in *how* practices are performed and in *why* they are practiced in particular ways. SPT does not target individuals or information deficits; rather, SPT asks how and why a practice is successful (or not) at recruiting and retaining practitioners.

ARCHITECTURAL 'BUNDLING'

Practices do not exist in isolation. Often, one or more elements of a practice (materials, meanings, and competencies) serve as elements in other practices. Furthermore, practices may themselves constitute the materials, competences, and meanings of other practices. Consequently, practices occur in bundles, the practices within a bundle being inter-related such that a changing one practice entails some degree of change in other, related practices. Hence, what appears to be a single practice that should be easy to change is often part of an intricate network of other, *related* practices which makes change more difficult (Moreham 2021).

A bundle of practices can also be said to have an architecture because the practices within a bundle are inter-related and mutually supportive. A farm system can, then, be conceptualized using SPT as a collection of inter-related practice bundles, with different farm systems being composed of different practices, different architectures creating different practice bundles, and different relationships between bundles generating different bundle architectures. Identifying and mapping practice bundles and bundle architectures has been an important subject of study in FST.[2]

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[1] See Appendix A for a fuller description of SPT.

[2] See Appendix B for a description of farms as systems

Table 2. SPT analysis of the practice of fencing

Elements of Practices	Practice Architecture
Project Control the location and movement of livestock	**Practice landscape** Farmers design fencing plans, choose and purchase fencing materials, erect fences and install related infrastructure. Contractors may be employed to undertake these activities subject to oversight and approval by the farmer. Funding, resource availability and supplies, paddock purpose also play a part. The project purpose may be to change animal movements from keeping animals in place, to keeping them out (of, say a waterway).
Sayings Livestock productivity depends on pasture productivity, and both can by increased by managing stocking rates, grazing rotations, and conserving feed.	**Cultural-discursive** In NZ context post and wire fences are common but stone fences, hedges or shepherding is rare. Livestock containment is acceptable/accepted method of controlling animal movement. Certain types of fencing imply a permanent and enduring boundary (e.g. excluding livestock from water bodies).
Doings Purchase fencing materials Planning fence layout Erecting fences Installing/modifying related infrastructure such as gates, watering systems and tracks	**Material-economic** Topography, farm boundaries, watercourses, land class, soil types, farm track and water infrastructure Stock type Fencing materials Fencing equipment Fencing skills
Relatings Contractual	**Socio-political** Contract law Relevant regional council consents (e.g. watercourses) Tension between farmers and regulators Farmer to farmer tension/alliance New funders and relationships with, for example, community groups interested in riparian planting
Dispositions Skills in fencing; knowledge and skills in relation to pasture and livestock management; knowledge and expertise in relation to seasonal pasture growth and production across the farm	**Practice traditions** Low tensile fencing with closely spaced droppers on hill country High tensile fencing with strainer posts, widely spaced support posts without droppers on extensive flat country Cooperate/compete with neighbours

Based on Kemmis et al. (2014: 39)

So, for example, fencing as a practice is not simply a matter of putting in some posts and connecting these with wire; rather, it has implications for water supplies and animal movements to and from waterways, milking or shearing sheds, feed management etc. In short, putting a fence 'there' could affect numerous other farm operations and overall farm performance and functionality. As in any complex system assessing the (sometimes subtle) implications for other practices of changing one practice involves careful consideration and judgement. This has two important implications:

(1) that any requirement to apply decontextualized, generic 'best practice' ignores, *in practice*, the complex reality of situation at hand.

(2) that a change in practice may be more, or less, difficult depending on the complex reality of situation at hand.

This bundling of practices creates helps us to understand why farmers may engage and persist in behaviours that are inconsistent with their (apparently relevant but personal) values and attitudes or that may seem, from an external perspective, irrational or unreasonable. What may seem a reasonable or rational request when assessed against one criterion (or a limited set of criteria) may not *make sense* when key relationships between practices are considered. Like the legs of a table, one practice 'props up' another in an on-going architectural achievement. Thus the scope for farmers to exercise discretion in changing practices is very limited; often there are few, if any, alternatives that will 'work'.

FST has demonstrated that while values and beliefs, and therefore attitudes, have a role to play in farmers' decision-making - especially in relation to strategy and defining an acceptable degree of variability in farm performance - the presence of practice bundles creates complexity of a farm system which, together with the need to ensure the farm business remains viable, can severely constrain what farmers do. It is at this level where practices are bundled, and bundles interact, that a farmer must attempt to resolve sometimes contradictory pressures around profitability, animal welfare, human resources, environmental aspirations, etc.

Importantly, the consequences of changing practice within a bundle can be exceedingly difficult to anticipate. This means that, despite the normative thrust of recent National Policy Statements, it is important to consider the active sense-making that accompanies practice as *the right thing to do*. This right thing to do is not the kind of decontextualised rule-following of 'best practice'; rather it depends on contextualised and intuitive expertise, that is, praxis, wisdom, and skill (Flyvbjerg 2001). Therefore, the 'right thing to do' is not about optimising on a single criterion but about satisficing (Simon 1956) across several, possibly competing, criteria. This means that, to voluntarily contemplate changing practice, the benefits of the change (the relative utility or relative advantage) must be obvious and achievable. This also means that if regulations compelling a change in practice create an obvious disadvantage, they will be strenuously resisted, challenged, and avoided. This can lead to unintended and perverse effects. [3]

Since the 'right thing to do' is based on judgement and practical wisdom generated through experience and sense-making then farmers themselves, the practitioners, become the source of expert information on practices and practice bundling. Consequently, identifying the constituents of practices, their architecture, and how practices interact to form bundles, requires interviewing famers using techniques such as convergent interviewing and laddering.

PRACTICES, PRACTICE BUNDLES AND LEVERAGE POINTS

Meadows (1999) proposed that systems contain a hierarchy of leverage points and that the transformational capacity of an intervention to change the system depends on the characteristics of the leverage point(s) in the hierarchy that the intervention acts on. Meadows identified twelve leverage points ranging from 'shallow'—places where interventions are relatively easy to implement yet bring about little change to the overall functioning of the system—to 'deep' leverage points that might be more difficult to alter but potentially result in transformational change.

Meadows' leverage points can be aggregated into four broad types of system characteristics that interventions can target (from shallowest to deepest): parameters, feedbacks, design, and intent (Abson et al. 2017). Parameters are modifiable, mechanistic characteristics such as taxes, incentives and standards, or physical elements of a system,

[3] See Appendix C for a discussion of farmer decision-making

such as sizes of stocks or rates of material flows (Abson et al. 2017). Feedbacks are the interactions between elements within a system of interest that drive internal dynamics (e.g. dampening or reinforcing feedback loops) or provide information regarding desired outcomes such as the effectiveness of an incentive scheme (Abson et al. 2017). Design characteristics relate to the structure of information flows, rules, power, and self-organisation (Abson et al. 2017). Finally, intent characteristics relate to the norms, values and goals embodied within the system of interest and the underpinning paradigms out of which they arise. These may be explicit or implicit. (Abson et al. 2017).

Farm system examples of the four different types of leverage points are presented in Table 3. In the table we have also highlighted the correspondence with the elements of practices (materials, meanings, and competencies). In the context we are considering (changing farm practice to improve environmental outcomes) a fundamentally important implication of Meadows' conceptualisation of leverage points in a system is that practice changes that entail modifying the design and intent of a farm system will be qualitatively different in terms of effort, resourcing and risk from practice changes that entail modifying parameters and feedbacks.

PRACTICE BUNDLES AND PRACTICE CHANGE

Given that farm systems consist of interlocking and overlapping bundles of practices, a change in the same practice (or its elements) can, in principle, have qualitatively different consequences, entail qualitatively different processes, and encounter qualitatively different constraints depending on the farm system. These qualitative differences may be anticipated by considering first, the extent to which the practice change might threaten the intent of the farm system (Meadows 1999), which is signalled by the extent to which the change restricts access to critical inputs.

Table 3. Systems and leverage points

Leverage point	Description	Farm system example
Parameters	Constants Numbers	Gestation periods, tractor horsepower, livestock growth rates feed conversion rates, fertility rates, lambing rates, germination rates, product and input prices, labour regulations, animal welfare standards, OH&S standards, environmental standards, payment rates for biodiversity incentives, riparian fencing incentives, tree planting incentives, farm size, topography, soil type, labour, livestock type, nutrient emissions
		Silage, cash, overdraft, grain stores, water availability
	Buffer stocks	
	Structure	Farm layout, water dynamics, nutrient dynamics, pasture, and livestock growth dynamics
Feedbacks	Delays	Production horizons (e.g. annual crop cycles), tractor capacity, time to crop germination
	Dampening feedback loops	Grazing management, parasite control, irrigation management, pest management
	Reinforcing feedback loops	Productivity improvements, erosion dynamics, remnant vegetation loss, greenhouse gas warming, water quality dynamics
Design	Information flows	Pasture status, soil tests, pregnancy tests, water quality tests, milk quality tests, milk production per cow, cattle condition scores, soil moisture tests, pest traps
	Rules/incentives	Productive farms reflect competency, productive land should be used for food and fibre production, making an income from food and fibre production is legitimate
	Constraints	Honour debts
	Power to change structure	Farmer, technology advances, government
Intent	Goals	Acceptable variation in net income, family support, lifestyle, organic production, dairy production, beef production
	Mindset	Independent, individual, private ownership and exclusive use of land, multi-functionality.
	Power to transcend	Farmer

Adapted from Abson et al. (2017)

Note: Green=materials, Blue=competencies, Red=meanings

In broad terms, changes in practice that do not threaten the intent of the farming system can, in principle at least, be accommodated by restructuring practice bundles and bundle architectures. Changes in practices that have the potential to threaten the intent of farm system cannot be accommodated simply by restructuring practices, practice bundles and bundle architectures. They require either the creation (by technology or policy) of substitute for the practice change or they require a conscious changing of the intent (and therefore parameters, feedback, and design) of the farm system. In both cases, the role of incentives, finance, agents of change and narratives is likely to be qualitatively different compared to their respective roles regarding practice changes that do not threaten the intent of the farm system.

Second, the extent to which the practice change entails changes to the constituents of a practice, changes to practice architecture and changes to practice bundles. In broad terms, incremental changes are limited to modifications that only affect practice elements, modular changes are modifications that affect practice elements and architecture, architectural changes alter the relationships between practices within a practice bundle while radical change alters practices within

a bundle and the relationships between them.[4] Qualitative differences in the nature of the change in the farm system required to accommodate the change in practice signal differences in the scale of planning, resourcing, change management and knowledge acquisition that will be needed to implement the change in practice, with consequent implications for the role of incentives, finance, agents of change and narratives.

These considerations suggest that classifying farm systems into trajectories with respect to their flexibility to respond to restrictions on critical inputs (such as water, fertiliser, pasture) would be useful. This is because the concepts of strategic and tactical flexibility, and what constitutes acceptable variability in farm business performance, are fundamental in defining the agency farmers have in changing farm systems. Such a categorization is useful both in terms of highlighting qualitative differences in their capacity to adopt changes in practices, and in highlighting differences in the nature of the role that incentives, finance, agents of change and narratives may play in contributing to change.[5] The resulting conceptual framework with hypothetical examples is presented in Figure 1.

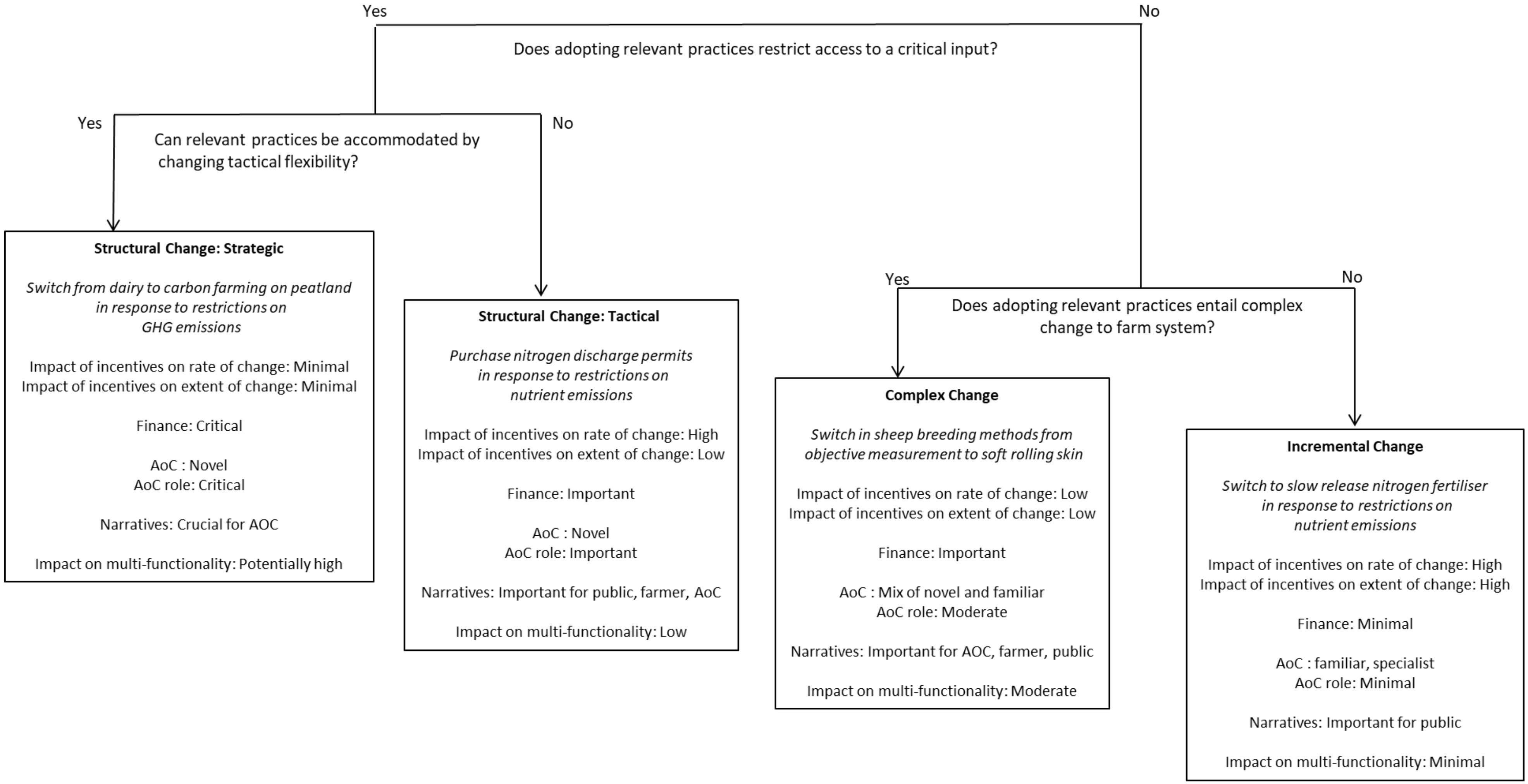
For our purposes, in terms of Meadows (1999), a critical input can be defined as an input that, if restricted, disrupts the operation of feedback loops such that the achievement of the farmer's goals is compromised (system intent). The implication being that the change in availability of the input is beyond what the farm system can absorb by exercising tactical and strategic flexibility. When this happens either:

- Tactical flexibility can be expanded, perhaps by using a policy instrument to create new tactics (e.g. markets in transferable water or nutrient entitlements).
- The suite of practice bundles and bundle architectures that form the farm system must be radically modified by changing strategic flexibility and/or intent (e.g. introducing a new enterprise such as farm tourism or switching to carbon farming)

[4] See Appendix D for a typology of practice change in farm systems

[5] See Appendix E for a typology of farm system trajectories based on sensitivity to restrictions in critical inputs

Figure 1. Diagrammatic summary of conceptual framework



Both responses will incur substantial transition costs and are likely to require support of one kind or another from systems beyond the farm such as the finance sector, government, agents-of-change and the possibly the public. Such support may entail corresponding changes in practices in those systems, which in turn, may require changes in the narratives underpinning the intent in those systems.

PRACTICE BUNDLES AND CHANGING PRACTICE

The SPT approach to changing practices means interrogating not the individual nor addressing their knowledge deficits but, rather, investigating the ability of a practice to 'recruit' practitioners based on its relative utility in terms of one's reputation, the 'comfort, cleanliness, convenience' of a practice (Shove 2003), or 'conformance and care' provided by and to others, (Clarke 2021), as well as a more tangible aspects like cost, consistency of inputs, speed/efficiency of operation, the time of day or the season. When relationships to other practices in a bundle are considered in context, choosing practices based on optimising one criterion may be less prudent – or make less sense - than satisficing across several criteria.

Judgement of the relative utility of alternative practices shapes 'what makes sense to do' which means following a practice, often beyond the farm gate, to explore the broader systemic levers, narratives and agents of change that shape the dynamics of practices. We can follow the practice, or practice architecture to explore the terrain of discourse, plans, policies, contracts and qualifications that shape on-farm practice or bundling dynamics. We do not need an in-depth appreciation of every farming practice on every farm. We do not need to know in detail what practices 'are'. More important is to understand how they hang together - or not – and what combination of levers need to be pulled to shape the relational dynamics of farming practice elements (e.g., materials, meanings, competences) or practice architectures (bundles of practices).

Consider, for example, the relative utility of making an incremental practice change (reconstituting or reconfiguring the elements of a practice) such as switching to a slow-release fertilizer to reduce nutrient emissions. If slow-release fertilisers (materials) are only available intermittently farmers are likely to remain committed to a reliably available conventional alternative. In this example, change does not occur because there are factors beyond the farmer's control influencing the 'sensible' choice. Identifying these factors, and the suite of practices in the environment beyond the farm gate that give rise to them, places the farm practice of interest within a broader 'ecology of practices' (Kemmis et al. 2014).

This broader ecology may include practices in relation to:

- policy-making that changes parameters or design in farm systems,
- financial institutions that influence parameters, constraints, and goals in farm systems,
- agents-of-change that can support changing parameters, feedback, design, and intent in farm systems,
- narratives that that can support changing feedback, design, and intent in farm systems.

SPT can be applied, in turn, to describing the dynamics of practices in these domains and identifying potential leverage points for change. [6]

SPT, by providing a framework that encourages following a farm practice beyond the farm gate, encourages exploration beyond the farm to identify systemic levers, narratives and agents of change that shape the dynamics of farm practices. Consequently, rather than just providing more information to individuals about the benefits of changing to an alternative practice, SPT identifies whether it is necessary to intervene in *the 'balance of competition between practices'* (Spurling and McMeekin 2015: 81).

DISTINGUISHING THE SCALE OF CHANGE FROM THE RATE OF CHANGE

At this point it is worthwhile to distinguish the factors that influence whether a voluntary change to farm practice is worthwhile, from the factors that influence how quickly a change will be implemented, given the change is worthwhile. Whether a change to farming practice is worthwhile largely depends on the relative advantage the new practice offers, that is, the superiority of the new practice relative to current practice. Superiority fundamentally comes down to improving the productivity of an input, in particular a constraining input. Here, structure (e.g., policy, rules, resources) is the key determinant of change.

[6] See Appendix F for a characterisation of agricultural practice change that can be described by causal loop modelling and enables the identification of leverage points for change.

How quickly the switch to a superior practice happens depends on characteristics of the practice itself (e.g., complexity, observability, ease of trialling, compatibility with values) and characteristics of the farm manager (e.g., investment priorities, innovativeness, resources available to support change including finance). Hence, how quickly change occurs depends on the practitioner (e.g., farmer competencies, identity, attitudes, beliefs) as well as the broader practice infrastructure.

This distinction is important as efforts to increase practice change that effect information gathering and search behaviour such as promotion, education, small incentives, and nudges only influence the pace of practice change. They do not influence the relative advantage of the practice, and so do not alter the potential scale of change (Doole et al. 2019).

Policy measures that clearly change the relative advantage offered by a practice such as regulations, construction of infrastructure, significant subsidies and penalties, and market mechanisms, can alter the potential scale of change (Doole et al. 2019).

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APPENDIX A: SOCIAL PRACTICE THEORY

FARMING AND SOCIAL PRACTICE THEORY

In traditional attitude-behaviour theory the unit of analysis is the individual and an individual's actions are governed by their attitudes which are, in turn, seen as functions of relevant values, beliefs, and social norms. Behavioural models based on attitudes are exemplified by Schwarzer (1992), Witte (1992), Janz and Backer (1984), Petty and Cacioppo (1979), Ajzen and Fishbein (1977), Bandura (1977), Rogers (1975) and others. One implication of the reasoning underpinning these theory of planned behaviour models is that a change in the set of relevant values, beliefs or norms should lead to a change in behaviour. Yet, in spite of many refinements to these models (e.g., locus of control, self-efficacy) over the years, a considerable body of research has found that this attitude – behaviour change (or ABC) model does not always, or often, work[7].

Another common approach often used in public administration assumes that people do not do as they should because they lack the appropriate information. The reasoning here is that if people knew more about the benefits of, for example, good nutrition, they would eat better. If they knew more about the health and environmental benefits of active transport, they would cycle to work. This information deficit model underpins many public policy campaigns but, as with the theory of planned behaviour above, more – and better – information does not appear to mobilise significant change. Many people still engage in practices and behaviours that appear irrational and even harmful despite increasingly sophisticated information campaigns.

As a result, we argue that a new approach is needed that does not necessarily focus on individual decision-making but, instead, attends to the constraints and enablers that shape what people *actually do*. Social Practice Theory is a suitable option because it recognizes that what people do is not decided 'in the mind' but is negotiated in and through everyday practice, undertaken in particular settings. As Sayer (2013, p. 168, italics added; see also Wittgenstein, 1980) notes, 'it is one thing to *decide* what to do, and another to *actually do it*'. SPT seeks to understand how what people do – their practice - is constrained by the context-specific and dynamic complexities of, for example, specific farm systems and their inter-related parts, as well as by the numerous factors beyond the farm gate. Behaviour change from an SPT perspective is therefore an endeavour distributed across social systems and material infrastructures that influence 'what makes sense to do'.

PRACTICES AND PRACTITIONERS

In a radical departure from an enquiry that prioritises information, evidence, values, beliefs and attitudes in shaping what actually people do, Social Practice Theory (SPT) takes collective *social practice* as the unit of analysis and, in so doing, reduces the scope and ordering power of [individual] reason' (Schatzki, 2017, p. 5). To misquote Wittgenstein, sense-making and deciding what to do does not happen in the mind… *it is part of life*. There is thus a distinction between cleansed, decontextualized and rationally determined accounts of what should be done, and the way we practically navigate daily life with limited resources, pursuing competing or conflicting ambitions, in settings that are constantly shifting. In this way, I may 'know' that it is better for the environment to bike to work and I may even decide to cycle to work…but only on days when I do not have to drop my kids to school on the way, and do the groceries on the way home when it is forecast to rain. Social Practice Theory engages not so much with *decisions* as the *sense-making* that shapes practice.

This raises questions about what is [social] practice? In one of the simpler accounts of SPT, Shove et al (2012) suggest a practice is comprised of materials, meanings and competences. Others have a slightly different framing or have added nuance to particular elements; thus a good deal of scholarly debates centres on what are the constitutive elements of practice and what is their relationship. While the focus on the elements of practice is often forefront, SPT analyses also recognise that these elements are 'integrated when practices are *enacted'* (Shove et al., 2012, p. 21, italics added). It is in the doing that the various elements of practice come together in a socially recognisable form. Shove et al. (2012, p. 7) note:

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[7] For a critique of the ABC approach to 'behaviour' change see Shove, E. (2010). Beyond the ABC: Climate change policy and theories of social change. Environment and Planning A, 43, pp. 1273-1285 and Strengers, Y. and Maller, C. (2015). Social Practices, Intervention and Sustainability. London/New York: Routledge/Earthscan.

> … practices exist as *performances*. It is through performance, through the immediacy of doing, that the 'pattern' provided by the practice-as-an-entity is filled out and reproduced. It is only through successive moments of performance that the interdependencies between elements which constitute the practice as entity are sustained over time.

Thus, while no two sandwiches or sandwich-making sessions are exactly alike, 'making a sandwich' is a socio-culturally recognisable activity with (perforated) parameters that distinguish it from 'making a soup' not only materially but also in terms of the skills needed and the reason(s) for making it. Reckwitz (2002, p. 249) thus describes a practice as:

> a routinized type of behaviour which consists of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge.

These accounts are interesting in that they address the components or elements of a practice and assess, ontologically, *what practices are, in practice*. Others are as much interested in the purpose of practice that gives them fuller shape and arguably examines in more detail the complexities of meaning and meaning-making in and of practice. This speaks to the idea that when doing something, one may be doing multiple things. Making a sandwich, for example, may also be a way of caring for others, being a good parent, or failing one's keto-diet ambitions. As Schatzki (2002, p. 87) points out, a practice can be seen as:

> a temporally evolving, open-ended set of doings and sayings linked by practical understandings, rules, teleo-affective structure, and general understandings.

Practical understanding combines recognizing which actions are appropriate at any given time and having the know-how or ability to conduct that action. *Rules* include codified oughts, thou shalts, and laws, whereas *teleo-affective structures* are a complex and indefinite notion comprising of 'the ends, purposes, emotions, and moods found acceptable within a practice' (Lammi, 2018, p. 82). It is acceptable, for example, to accept a gift with a word of thanks and a feeling of gratitude. *General understandings* pertain to shared values, morals, beliefs, concerns and virtues (Lammi, 2018, p. 80).

In addition to these social rules, values and general directedness towards others, SPT explicitly reconfigures what are often cast as *individual* behaviours and individual choices as *collective* accomplishments. According to Kemmis et al. (2014 p.31):

> … practice is a form of socially established cooperative human activity in which
>
> characteristic arrangements of actions and activities (doings) are comprehensible in terms of arrangements of relevant ideas in characteristic discourses (sayings), and when the people and objects involved are distributed in characteristic arrangements of relationships (relatings), and when this complex of sayings, doings and relatings 'hangs together' in a distinctive project….

Social practice therefore accentuates not just what people (decide to) do, but also their artefacts and infrastructures that constrain and enable any future performance of that practice. In this way, an examination of 'fencing' as a farming practice shows how it is shaped not by the individual farmer and their decision, but by a complex and extended relational web comprising the availability and types of fencing materials, training around how to build a fence, an understanding of why the fence should go here but not there given regulations and social expectations of the 'good farmer', farm topography, the types of animals being kept in or out, other paddock resources such as water supplies and shelterbelts and so on.

This material suggests a continuum of SPT thought about what practices are, and the role of the practitioner. Given the fencing example detailing an extended ecosystem of constraints and enablers of practice, at one extreme, SPT demotes individual agency almost entirely, suggesting instead that people are merely carriers of practice. This is consistent with the idea of the 'practice as entity' taking on a life of its own, and analyses in this tradition often centre on how some practices are more successful than others at recruiting practitioners. This recruitment might be the result of policy settings aimed at behaviour change but may also occur due a material shortage, new technology or skill.

At the other extreme is a more humanistic 'practice as performance' approach. Here, practitioners retain their importance – and a degree of agency - because, as Schatzki notes (2017, p. 5) 'Practice thought never countenances macro determinations that are impervious to the intervention of individuals'. Each time a practice is performed, there is scope for the individual to modify and mould practice. There may be strong drivers – convenience, comfort, care or conformance – that, ultimately, shape broader social movements.

If the role of the practitioner is subject to debate, the answer to the question 'what is *a* practice' is no more straightforward though many would agree that, basically, there are material elements (the bike, the road, the bread, the cheese, the posts and wire) reconfigured by a more or less competent practitioner, for a particular purpose, that hangs together to form a socially recognizable verb: cycling, fencing, cooking. While this highlights key concepts in SPT, when thinking about how and why practices changes or how and why new practices are more or less successful than others at recruiting practitioners, it often becomes apparent that focusing on 'a' practice may only be the start of any enquiry. It may also be necessary to examine how different practices relate or bundle together to promote stability or enable change.

ARCHITECTURAL 'BUNDLING'

SPT analysts use various terms, but most recognize that while 'a' practice such as 'fencing' is made up of elements like materials, meanings and competences, the practices are themselves bundled with other practices to enact a broader practicescape (Moreham, 2021). Fencing, then, is not just a discrete activity that involves putting in some posts and connecting these with 7 strands of wire; rather, it has implications for water supplies (irrigating), animal movements around the farm (milking and feeding out), preventing animal access to waterways (erosion control) and so on. Putting a fence 'there' will affect *numerous* other farm practices and operations, and impact on overall farm performance and functionality.

As in any complex system where the parts and practices interact, you never just do one thing. Because 'a' practice does not exist independently of other practices, a change in one practice usually has important, though sometimes subtle, implications for other practices. Often, these can only be understood in context. Consequently, the requirement to apply decontextualized, generic 'best practice' ignores, *in practice*, the complex relational realities of the situation at hand. Kemmis et al. (2014) invoke an 'ecology of practice' metaphor to help us understand this relational web.

This also helps us understand why people may engage and persist in behaviours that are inconsistent with their values and attitudes, or that may seem irrational or unreasonable. What appears to be a reasonable or rational request when assessed against one criterion (or a limited set of criteria) does not *make sense* when key relationships between practices are considered in context. If 'fencing off a waterway' necessitates significant modification to other farm practices (tactical change), or compromises functionality or profitability (strategic change), the practice will likely find it difficult to recruit practitioners. Like the legs of a table, one practice 'props up' another in an on-going architectural achievement. Thus the scope for farmers to exercise discretion in changing practices is very limited; when viewed with an architectural lens, it becomes apparent that a seemingly simple directive become part of a complex juggling act with the result that, often, there are few, if any, alternatives that will actually 'work'.

How, then, is change promoted or enabled? Consistent with this architectural framing, Spurling and McMeekin (2015) suggest we can either change the [constituent] elements, substitute practices or change how practices interlock. As with systems thinking involving 'elements, interconnections, and function or purpose' (Meadows, 2008, p. 11) the whole is more than the sum of its parts and, therefore, the 'relatings'[8] (Kemmis) comprise an essential feature of a system's functionality.

Given the normative thrust of recent National Policy Statements, it is also important to consider the active sense-making that accompanies practice as *the right thing to do*. This right thing to do is not the kind of non-situational

[8] You think that because you understand "one" that you must therefore understand "two" because one and one make two. But you forget that you must also understand "and." —Sufi teaching story (in Meadows, 2008, p. 12).

rule-following of 'best practice'; rather it acknowledges contextualized and intuitive expertise (praxis, phronesis (wisdom) and techne (skill)).[9] Like Flyvbjerg (2001), Kemmis et al. (2014, p. 26) note:

> We confront uncertain practical questions more or less constantly, in the form "what should I do now/next"?. They are concerned 'not [*only*] with a kind of rule-following [best practice], or producing an outcome of a kind that is known in advance… but rather action whose consequences are more or less indeterminate, but that can only be evaluated in light of the consequences - in terms of how things actually turn out. This kind of action is "praxis".

This is akin to Schatzki's (2010, p. 114) practical intelligibility which 'animates or informs the frequent redirections and restarts that mark the flow of conduct' shaping what is done next in the consequential ebb and flow of life. For Nicolini (2012) these are the preoccupations that makes social practice theory truly social: we are not just concerned with ways of doing, but of doing it the 'right' way. The 'right thing to do' is not based on disembodied or decontextualized knowledge about the environment or the consequences of particular actions; rather it is based on judgement, practical wisdom or phronesis[10] (Flyvbjerg, 2001) generated through experience and sense-making overtime.

Sense-making and practical intelligibility is not about optimisation against one criterion but, rather, 'satisficing' or doing enough across multiple considerations, in the on-going balancing act of competing demands on time and resourcing. The concept of 'satisficing' has a long history[11] in the planning and public policy fields. The very idea of rational decision-making was challenged by the likes of Simon who claimed (1956, p. 136) that decision-makers have

> neither the senses nor the wits to discover an "optimal" path—even assuming the concept of optimal to be clearly defined—we are concerned only with finding a choice mechanism that will lead it to pursue a "satisficing" path, a path that will permit satisfaction at some specified level of all of its needs.

As Moreham (2021) has carefully detailed in his commuter cycling analysis, this involves weighing up the *relative utility* of various bundling options (see Figure A1). His work illustrates, first, how information has been widely disseminated about the benefits of commuter cycling in terms of health and bio-physical environmental benefits. These 'meaning making' information campaigns about the benefits of cycling have been accompanied by significant investment in material public infrastructure and a range of bike options from private retailers. Learn to ride 'competency' schemes have become a standard part of the primary school curriculum. In essence, enormous effort has been poured into commuter cycling materials, meanings and competence…but for – arguably - only marginal gains. Commuter cycling as a practice has failed to recruit large numbers of practitioners.

The explanation involves looking to those commuting options relative to the bike; when it comes to commuting, 'the rise of automobility cannot be separated from the decline of velomobility. The increasing domination of the car is as much about defection from cycling as it is about recruitment to driving' (Watson, 2013, p. 123; Moreham, 2021). For example, if any eco-friendly practice (cycling to work) is *relatively* less convenient or appealing than a less eco-friendly one (driving a car), the latter will prevail. Consequently, rather than providing more information to individuals about the benefits of cycling, it is actually necessary to alter *the 'balance of competition between practices'* (Spurling and McMeekin, 2015, p. 81) and *reduce the relative utility of the car*. This may be achieved by increasing car parking fees or reducing the number of car lanes. For the 'middle' cohort of commuters, it is only by

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[9] According to Nicolini (2012, p. 26), Aristotle distinguished between three 'dispositions of the intellect': episteme (scientific knowing generated through analysis), phronesis (wisdom) and techne (skill or instrumental rationality). Nicolini suggests the purpose of phronesis is to 'produce praxis or action informed through knowledgeable …deliberations; the aim of techne …is poiesis… or the creation of durable artefacts…with the end different from the making itself. Praxis refers to a doing in which the end is nothing else than doing things well 'morally, politically or ethically'. Nicolini concludes that the history of the European intellectual tradition has been a process of 'practical displacement' in favour of contemplation of the divine favoured by Christianity.

[10] For the ancient Greeks, this referred to the type of understanding a leader's 'practical governance' such as how to extract the maximum amount of tax without causing an uprising.

[11] See also Lindblom's (1959) *The Science of Muddling Through* and, more recently, Flyvbjerg (1991) who demonstrated that what is 'rational' is significantly shaped by power dynamics. Gladwell (2005) provides another variation of sense-making taking place in the blink of an eye.

targeting the car that it starts to 'make sense' to cycle in different contexts. 'Levers' include, for example, disincentives, the creation of new markets, 'influencers', policy instruments and so on.

In examining how to change a practice architecture – which is beyond a single, isolated practice, but where the relationships or bundling pf practices is evident - Schatzki (2013) suggests we explore how 'coalesence' (where norms, rules and understandings combine), hybridization (practices merge) or bifurcation (diverge) might occur. Emphasising relationships between practices is extremely useful as Moreham's (2021) work showed. One key issue with making transport more sustainable is actually the relative utility of the car rather than any intrinsic deficiency of the bike. Bikes are wonderful …they are just not as wonderful as cars. Thus, in addition to exploring the reconstitution or reconfiguration of practice elements, practice bundles and bundling dynamics provide another useful line of enquiry that may explain why and how some practices successfully recruit practitioners or not.

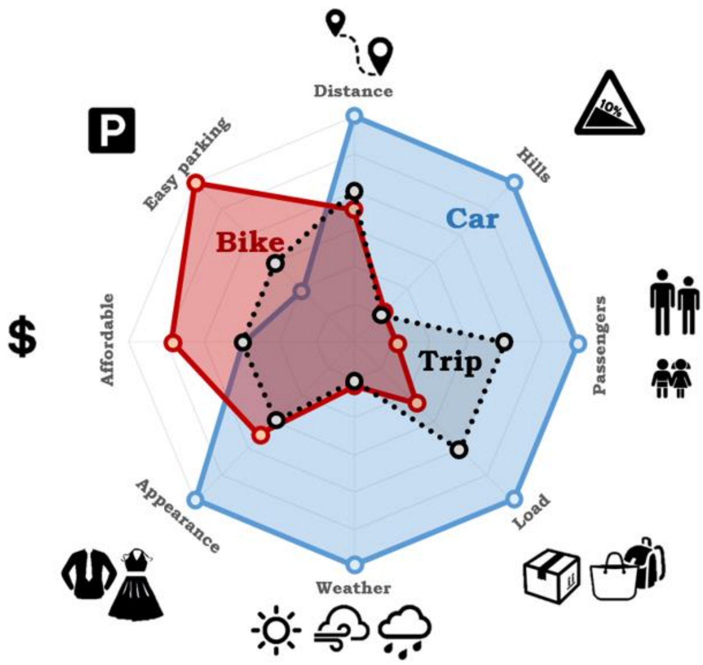

Figure A1. A schematic representation of the utility envelope, where the needs of a particular trip are matched against the capabilities of the car and the bike.

THE 'NET' OF ECOSYSTEM DYNAMICS

In practice, there is an ongoing need to assess many, inter-related and idiosyncratic contextual or *site-specific* factors. Yet there are also many factors beyond the farmer's control beyond the farm gate including the price of milk, time of day, availability of materials, care for the environment, immigration requirements shaping labour availability, disease, internet connectivity, the regard of peers and the broader community, compliance requirements etc. These indicate the broader ecosystem dynamics that reconfigure as well as reconstitute elements and architectures of practice.

In taking account of the idea of an ecology of practices, Kemmis et al. (2014, 31) define a practice as:

> a form of socially established cooperative human activity in which characteristic arrangements of actions and activities (doings) are comprehensible in terms of arrangements of relevant ideas in characteristic discourses (sayings), and when the people and objects involved are distributed in characteristic arrangements of relationships (relatings), and when this complex of sayings, doings and relatings 'hangs together' in a distinctive project….

The ‘hanging together’ is essential in both emphasizing the need to synthesise or synchronise various practices and their elements in functional relationships, as well actually shaping what a distinctive practice is. As shown in Table A1, if we apply a framing developed by Kemmis et al. (2014) to a farming example (a) individual and collective *practice* such as fencing livestock, milking cows or sowing seeds is influenced by (b) *practice architectures* of site specific cultural-discursive, material-economic and socio-political spaces so that (c) the *sayings*, *doings* and *relatings that* characterise the practice hang together in *projects* that in turn shape and are shaped by (d) *practice traditions* that promote reproduction through a ‘collective memory’ of the practice, such as ‘agri-culture’ or our collectively practiced art and science of cultivating plants and animals.

Consequently, it is possible to follow a practice or practice architecture beyond the setting within which they are performed, and explore those levers, combinations of levers, agents of change and sense-making narratives that shape practice dynamics. Drawing again on Moreham’s (2021) commuter cycling, he showed although ‘increased commuter cycling’ was the goal, unless effort is directed towards making the car less desirable *relatively speaking* through tolls, taxes, reduced car parking, increased petrol costs, the uptake of commuter cycling will remain low. While this may seem obvious in this case a) it was not initially apparent that increasing cycling was *so much* influenced by the appeal of the car and b) robust evidence of the relative utility is required before system and practice dynamics are modified. Beatson et al., (2020) similarly found consumers’ aspirations for ‘green consumption’ were influenced as much by *post-consumption* disposal (reduce, reuse, recycle) as much as production. If this approach of following a practice and practice switching/bundling is adopted, it can either illuminate obscure levers or add rigor to obvious but unproven ‘intuition’ that underpins practice.

STUDYING PRACTICE

While most SPT approaches recognize the relational elements (whether materials, meaning or competencies (cf. Shove), or architectures of cultural-discursive, material-economic and social-political arrangements (cf. Kemmis et al), there are various approaches to researching, managing and promoting practice change. Different research methodologies are used according to whether one is ‘zooming in’ or ‘zooming out’ but some key foci (cf. Gherardi, 2019; but also Van Manen, 2016; Nicolini, 2012; Moreham, 2021) include:

- Practice as accomplishment; Instead of asking what fencing ‘is’, the question is how is fencing accomplished collectively?

Table A1: SPT analysis of the practice of fencing

Project Control the location and movement of livestock	**Practice landscape** Farmers design fencing plans, choose and purchase fencing materials, erect fences and install related infrastructure. Contractors may be employed to undertake these activities subject to oversight and approval by the farmer. Funding, resource availability and supplies, paddock purpose also play a part. The project purpose may be to change animal movements from keeping animals in place, to keeping them out (of, say a waterway).
Sayings Profitability,responsibility, acceptability, availability.	**Cultural-discursive** The scale of farm operations means shepherding is impractical. In the NZ context 7 strand fence is common but stone, hedges or shepherding is rare. Livestock containment is acceptable/accepted method of controlling animal movement (i.e. keeping them in rather than keeping them out). Certain types of fencing imply a permanent and enduring position re keeping livestock contained/excluded from water bodies
Doings Purchase fencing materials Planning fence layout Erecting fences Installing/modifying related infrastructure such as gates, watering systems and tracks Managing stocking rates, grazing rotations, and conserving feed	**Material-economic** Topography, farm boundaries, watercourses, land class, soil types Stock type Fencing materials, equipment Fencing skills Fencing funding New water sources must be found (if fencing excludes animals from water sources) New animal movements from A to B must be managed Where to fence a moving waterbody
Relatings Contractual If this, then that. If this fence is installed here, this means ,,,, Livestock dependence and vulnerability	**Socio-political** Contract law Relevant regional council consents (e.g. watercourses) and compliance Tension between farmers and regulators Farmer to farmer tension/alliance New funders and relationships with, for example, greenies interested in riparian planting Banks and finance
Dispositions Skills in fencing; knowledge and skills in relation to pasture and livestock management; knowledge and expertise in relation to seasonal pasture growth and production across the farm	**Practice traditions** Low tensile fencing with closely spaced droppers on hill country High tensile fencing with strainer posts, widely spaced support posts without droppers on extensive flat country Water bodies may move/flood/become blocked Cooperate/compete with neighbours

Practice as performed where knowledge is embodied in performance rather than cognition. Examples are kicking a ball at a goal, hammering a nail, driving a tractor. Here, each rendition of a practice provides opportunity for change and allows more agency to the practitioner. Schatzki's work on 'teleo-affectivity' emphasises the extent to which 'what we do' is future focused and directed toward others (see also Clarke, forthcoming).

- Practice as (sociomaterial) entity; The social and the material are co-constitutive and relational. For example, 'phones' enable new work practices and have become an extension of our bodies, exerting energy and agency (see also Wallenborn, 2013). At its extreme, this sees practitioners as 'carriers of practice' with very limited agency. A key question here might be 'how do new practices recruit practitioners'.
- The rules of practice; akin to grammar and the correct way of using language inhabiting the formal lexicon, and language games, slang or everyday use that bring language to life. The notion of praxis where practice – putting in a good fence – is judged in terms of practical outcomes is useful here.
- Practices as socially sustained; What is a 'good practice' – or praxeology – is assessed against broadly held values, social norms and cultural constructs.

CHANGING PRACTICE

The somewhat diffuse reading of SPT outlined here sees changing practice as taking place through rearranging or switching a) the elements of a practice b) changing the practice architecture c) changing the ecosystem dynamics or d) the practitioners. For the most part, while farmers *may* have limited agency to manage certain elements or slightly modify the architecture of practice, transformative change to the ecosystem (dynamics) is beyond the ability of individual famers. This puts firm parameters around the utility of information campaigns aimed at changing behaviour. It raises questions about who or what makes for an appropriate 'unit of analysis' when seeking transformative change.

Following Nicolini's (2012, p. 224) zoom in/zoom out approach, zooming in involves examining:

> The mundane practical concerns which ostensibly orient the daily work of the practitioners. What matters to them? What do they care about? What is their main practical concern when they go to work? What do they worry about in practice? Where do they direct their efforts?

In a sense, much of this can be gleaned by asking about the practical concerns and preoccupations of farm management but especially some of the 'trickier' aspects that separate seasoned farmers from the novice. Which practices are most perplexing in terms of their teleoaffectivity? Which practices demand heavy and inflexible investment in meaning, materials or competency? Which practices cause the most cognitive dissonance or debate over and beyond the farm gate? Why is a desirable practice unable to recruit practitioners? Is changing this practice a matter of changing an *element* of it?

Or, to understand 'this' practice, is it necessary to consider the relative utility of *other* practices? What other practices comprise an architecture of relationships that essentially keeps 'the' practice in place? Or are there opportunities for coalescence (where norms, rules and understandings combine), hybridization (practices merge), bifurcation (diverge), substitution or switching. This allows analysis of the *work* 'that goes into making associations come about' (Nicolini, p. 230). What is needed, for example, to switch one practice for another? And what kind of investments are needed across finance, infrastructure, strategy, skills and so on.

We can then follow the practice, or practice architecture even further to explore the terrain of discourse, plans, policies, contracts and qualifications that shape on-farm practice or bundling dynamics. We do not need an in-depth appreciation of every farming practice on every farm. We do not need to know in detail what practices 'are'. More important is to understand how they hang together - or not – and what combination of levers need to be pulled to shape the relational dynamics of farming practice elements (e.g. materials, meanings, competences) or practice architectures (bundles of practices). We need to understand how certain practices successfully recruit their practitioners and appreciate how the relative utility can be shaped to promote different practices.

APPENDIX B: A DESCRIPTION OF FARMS AS SYSTEMS[12]

FARMS ARE OPEN SYSTEMS

Farms can be conceptualized as open systems. They have a structure consisting of a set of components (for example, soil, livestock, and physical structures) that are linked together by relationships (for example, farm practices and strategies). The structure interacts with the salient components of broader natural, economic, and social environments beyond the farm. It is these interactions that lend the farm its open-system character. Within this framing of the farm system, the farmer is implicitly a part of the system through the decisions they make regarding farm management practices and strategies (Cowan et al. 2012).

FARMS ARE MANAGED TO ACHIEVE A PURPOSE

Further, farms can be conceptualized as purposeful systems that interact with the relevant elements of the environment to achieve goals. The purpose of a farm system, like all businesses, is fundamentally to achieve a profit. Farmers seek to achieve this purpose by consuming inputs from the task environment in the farm system to create outputs.

How farmers seek to achieve this purpose can be described within a hierarchy of plans. In this context the task environment consists of the bio-physical, socio-economic systems and settings (such as banking policies, policy settings and relevant community expectations) that impinge on the operation of the farm system. Also, the term 'inputs' is to be interpreted in the broadest sense and include by-products of agricultural activities that generate externalities such as nutrient emissions that damage the environment and greenhouse gas emissions.

A HIERARCHY OF PLANS ARE USED TO MANAGE FARMS

This hierarchy of plans begins at the highest level with the farm business strategy, which is the fundamental decision of what the business is going to produce and for whom. This farm business strategy leads to decisions regarding how the farm production system is going to be organized to produce outputs. Once the farm business strategy is defined, increasingly elaborate and specific descriptions of how the business is to achieve its purpose are created. Importantly, all points in the hierarchy of plans below the purpose can be revisited and altered.

Running parallel to this hierarchy of plans is a hierarchy of goals, which describes why the business operates as it does. Hence, higher-order goals determine the selection of, or constrain, subordinate goals. A higher-order goal in farming is the survival of the farm business. Beneath this higher-order goal of survival, subordinate goals are determined from the needs of the farm. These lower-order goals change as the needs of the farm change, so long as they are consistent with the purpose of the farm and higher-order goals.

PLANS CONSIST OF STRATEGIES AND TACTICS

Strategies and tactics exist within the hierarchy of plans and are quite distinct from each other: the way each is formulated and implemented is very different to the other. Strategies in farm businesses are decisions about what is going to be produced and how the business is going to be organized to produce it. Once a farm has been organized to produce a set of outputs identified by strategy, tactics are used to translate inputs from the task environment through production processes to produce these outputs. Tactics are chosen from alternatives, all of which can serve the strategy under certain circumstances.

STRATEGIES AND TACTICS FOR MANAGING VARIABILITY

Variability in the physical productive performance of the farm can affect profitability, potentially threatening the survival of the business. Variable farm performance reflects, in part, the variability of the environment. To seek a consistent business performance, a farmer must manage this variability in the task environment. A farmer manages variability by organizing the structure of the farm system so that the range of behaviors of the farm matches the range of relevant variability in the task environment. In other words, ideally, farmers make strategic decisions regarding what to produce and how to organize the farm production processes to produce it, so that the system's

[12] The content in the following sections borrows heavily from Cowan et al. (2012)

behavioural options can sufficiently prevent variability in inputs from negatively affecting farm financial performance. The capacity of a farm system to absorb variability is the extent to which the farm can continue to produce its output to generate sufficient profit without requiring change to system structure.

ADAPTATION BY CHANGING FARM STRUCTURE

When a farmer has to change the structure of the farm system to return it to a state where it can absorb variability adequately, this is adaptation from a general systems perspective. In other words, adaptation can be described as a change in strategy, or what is being produced and the way the business is organized to produce it. When changes in the state of the task environment require structural change to the farm system such that the farm business strategy is no longer viable, the system must transform into a new system or fail. This aligns with a common economic policy conceptualization of adjustment in agriculture.

A change in structure is defined as changing components and/or relationships within the system in a way that alters their functioning within the farm system. All change in structure comes at a cost, including once-off switching costs and constraints on future decisions.

See Cowan et al. (2012) for further discussion of the distinction between strategies and tactics, and changes in structure.

MANAGING VARIABILITY

There are two fundamental ways that farmers absorb variability in critical inputs. One way is to alter the use of the critical input within a production cycle. The other is to change the outputs that are produced from the set available within the existing farm system to reduce reliance on the critical input, which we describe as changing the output mix. This is usually carried out from one production cycle to another.

The capacity to alter the use of critical inputs in farm systems and change the output mix of farm systems is constrained in three ways:

- the long production cycle characteristic of agriculture limits the opportunities available for farmers to make investment and management decisions.
- asset fixity can cause considerable costs to arise when changing an investment
- technical constraints imposed by technology and the characteristics of location will constrain opportunities for altering the use of inputs or changing output mix

APPENDIX C: *RATIONALITY IN FARMER DECISION-MAKING*

These arguments are consistent with the assessment in the farming systems literature that farmers are intentionally rational in the way they formulate strategy and manage their farming operations, including their choice of practices and technologies (Cramb 2005). Farmers are not, and need not be, hyper-rational agents engaged in optimising behaviour when contemplating the adoption of agricultural innovations and changing farm practices (Wright 1986; Murray-Prior & Wright 2004; Campbell 1995; Kaine et al. 2007, Kaine et al. 2013).

As Crouch (1981) observed, the decision to change practice is often a matter of practical sense as the scope to adopt practice changes is restricted by the mix of technologies and practices adopted previously, resource constraints, and management strategies of the producer.[13] Consequently, the choice is usually stark: the decision not to change practice is often a simple matter of elimination rather than a question of optimisation based on finely balanced criteria.

Furthermore, the complex interrelationships between technologies, practices, resources, and strategies in farming systems means farmers must be confident that the benefits a change appears to offer will be realised to justify the necessary investment in adjustments to their farm systems as well as investment in the practice change itself. Hence, practice changes that appear to offer only a marginal relative advantage are unlikely to be considered as deserving candidates for adoption.

In addition, the complexity of farming systems, together with the inherent unpredictability of elements that are critical to performance, such as commodity prices and seasonal conditions, means that there is a perceived risk associated with the adoption of any agricultural practice change. Consequently, changes in agricultural practice that only offer a marginal benefit in terms of technical advantage must be perceived as virtually risk free to merit consideration for adoption. This is most likely to be the case with incremental practice changes which, by definition, are likely to be highly compatible with the farming system (Henderson and Clark 1990). Hence, the decision to adopt incremental practice changes that offer a marginal relative advantage is more likely to depend on simple calculation than on complicated, finely balanced optimisation.

A systems perspective on the adoption of agricultural practice changes supports the conclusion that farmers need not be hyper-rational in this regard. From this perspective the adoption of agricultural practice changes is largely a matter of system improvement rather than system redesign (van Gigch 1974). Consequently, the adoption and integration of practice changes into a farm system is a process of identifying and realising infra-marginal gains rather than optimisation of marginal benefits through refinement of system design.

HOW DOES THIS EXPLAIN FAILURE TO CHANGE

The preceding reasoning about changing farm systems leads to the conclusion that voluntary adoption of an agricultural technology or practice will only occur when the benefits of doing so, the advantage offered by the new technology or practice relative to present technology or practice, is obvious and substantial. This is especially the case with novel technologies and practices that constitute architectural and radical changes to farm sub-systems. The consequence is that the widespread adoption of agricultural technologies and practices can take years to occur (Kaine et al. 2012; Kaine & Wright 201; de Oca Munguia et al. 2021), even when the technology or practice offers clear benefits (see Table C1).

Farmers will evaluate practice changes (and policy measures) with respect to their potential to contribute to better farm performance. Hence, the failure of farmers to adopt practice changes is most likely to occur when farmers are not persuaded that they will realise the benefits claimed for the practice change. This is consistent with Rogers (1995) conceptualisation of economic advantage as the key factor influencing innovation diffusion and with the observations of Lindner (1987) that self-interest is the key motivation influencing the adoption of innovations in agriculture. By the same reasoning farmers will avoid voluntarily complying with policy measures that do not directly benefit their businesses.

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[13] This suggests that, in many instances, agricultural practice changes will fail to pass the screening associated with producers' strategic image (Beach and Connolly 2005). See section on 'How farmers make decisions to change practice'.

Policy measures define some of the parameters in the task environment of farms by, for example, setting standards for production systems and prohibiting or restricting the use of certain inputs. Typically, such measures detract from, rather than, improve farm performance. They entail a loss of income and (perhaps) tactical or strategic flexibility. Logically then, farmers will seek to postpone, preferably avoid, responding to policy measures when:

- Those measures considerably modify their tactical or strategic flexibility (e.g., restrictions on using a critical input or constraints on output)
- Those measures undermine their capacity to maintain farm performance within acceptable bounds (restrictions on nutrient use)
- Those measures necessitate architectural or radical changes to farm systems (restrictions in grazing management)
- There is uncertainty about the precise requirements of a measure (e.g., limits on nutrient or GHG emissions)
- Two or more measures are implemented concurrently

The preceding reasoning about changing farm systems also leads to the conclusion that farmers will prefer autonomy of choice in complying a policy measure (that is, freedom to make their own choice as to how to reconfigure the farm system) and will prefer making a change that enables them to comply with two or more policy measures concurrently (e.g., renovating a wetland to offset carbon emissions and protect biodiversity).

The adoption of practice changes in agriculture is, essentially, a high involvement purchase for farmers and this means the personal values of farmers can play a pivotal role in their decision to adopt some practice changes (Kaine et al. 2004). Farmers will be more likely to adopt practice changes that appear consistent with their personal values and less likely to adopt practice changes that appear inconsistent with, or challenge, their personal values.

Table C1: Trying and adopting technologies and practices

Technology or practice	Time to trying (Months)	Time to adopting (Months)	Complexity
Slow-release nitrogen fertiliser	12.0	4.9	1.93
No nitrogen fertiliser applied in winter	45.2	13.3	2.61
New pasture varieties	22.3	52.5	2.16
Different breed of livestock	84.0	59.0	2.19
Feeding palm kernel	64.1	36.2	1.91
Different calving period (e.g. split calving)	36.0	3.6	3.18
Artificial Insemination	105.2	75.1	2.14
Grazing heifers off-farm	97.3	84.6	2.11
A feed pad	74.3	34.2	2.96
Increased land area for effluent	18.0	4.3	2.20
Install 90-day effluent storage	17.7	2.3	2.70
Fencing stock out of waterways or wetlands	53.8	46.1	-
Constructing a wetland	126.9	62.0	-

Note: Time to adopting is period of time elapsing between trying and committing to using.
Note: Red text indicates technology or practice installed because of regulation.
Source: (Kaine & Wright 2016)

Consequently, policy measures that detract from, rather than, improve farm business performance may challenge the personal values of farmers, which may further aggravate farmer's unwillingness to comply with policy measures.

Generally, farmers place a priority on tradition, conformity, self-direction, and achievement (Cary and Holmes 1982; Frost 2000; Gasson 1973; Holmes and Day 1995; Kerridge 1978; Walder et al. 2019). Consequently, changes in agricultural practice that are designed to improve the business performance of agricultural enterprises are consistent with the personal values of most farmers. Commercial agricultural practice changes, unlike many consumer products, cannot be regarded as value-expressive in the usual sense that consumer products can be. Basically, agricultural practice changes are intended to contribute functionally to improving farm performance.

To the degree that farmers place a high priority on conformity, self-direction, and achievement the adoption of practice changes designed to improve farm performance simply signals competence to other producers rather than self-identity (Burton 2004, Kaine et al. 2004). Hence the failure to associate social typologies of farmers (farming styles) with the adoption of specific technologies and practices (Howden & Vanclay 2000). Farmers, like other consumers, tend to express their personal values and signal their identity through their choice of career and lifestyle and through the purchase of consumer products such as clothing, cars, and leisure activities.

As most farmers place a higher priority on conformity, self-direction, and achievement than on universalism and self-transcendence (Walder et al. 2019) they are unlikely to find policy measures that are designed to enhance the environment intrinsically appealing, especially if compliance with those measures is likely to lower business performance. Such measures could be regarded as 'value challenging' in the sense that the implementation of policy measures purely for the environmental benefits they create is inconsistent with the personal values of many producers. This is because farmers tend to exhibit an individual good social orientation (Parminter & Perkins 1997, Robinson et al. 2003, Walder et al. 2019).

People whose social values are orientated towards individual good tend to place a high priority individual self-reliance, physical and economic security hard work and individual freedom (Inglehart 1990; Schwartz 1994). This social orientation is grounded in three key beliefs about the relationship between individuals and the societies in which they live. The first is that it is the individual members of society that create wealth. The second is that the wealth of society is equal to the sum of the wealth generated by each individual member of society. The third belief is that the wealth of society is maximised in circumstances where individuals are free to create wealth with minimal interference from government (Sandall et al. 2001).

The individual good value orientation is associated with two key beliefs about the natural environment. The first is that the interests of humans should take priority over the interests of the natural environment (Stern & Dietz 1994). The second is that the natural environment is a source of resources and commodities which individuals have a moral obligation to manage efficiently and productively (Merchant 1990). Thus, people with an individual good value orientation are likely to favour solutions to environmental issues that provide individuals with appropriate and enforceable rights to the resource in question (Merchant 1990). These beliefs also suggest that people with an individual good value orientation are most likely to support environmental protection when they are personally affected by environmental degradation and the personal benefits to them from ameliorating this degradation outweigh the personal costs (Stern & Dietz 1994; Stern et al. 1995).

This has several implications for compliance with policy measures promoting natural resource management. First, few farmers are likely to be motivated to observe measures designed to benefit the environment simply because the environment (Parminter & Perkins 1997, Kaine & Bewsell 2003a). Furthermore, efforts to encourage farmers to adopt such measures by promoting their environmental benefits are, in the absence of incentives and other supporting measures, likely to meet with limited success because farmers are unlikely to be persuaded that such benefits are themselves intrinsically appealing (Bewsell & Kaine 2003, Kaine & Bewsell 2003b).

Second, farmers are likely to be motivated to observe measures that benefit the environment when they perceive those measures as contributing to improving the performance of their farm businesses (Whitten & Bennett J 1999, Bewsell & Kaine 2006, Bewsell et al. 2007, Burton & Wilson 2006, Sherren et al. 2011, Ecker et al. 2012, Marr & Howley 2019, Czajkowski et al. 2021). For example, the development of resistance and the level of pest infestation are key factors influencing the adoption of integrated pest management techniques by fruit growers in Australia and grape growers in New Zealand (Kaine & Bewsell 2003a, Bewsell & Kaine 2004 respectively). Farmers who do adopt a practice change for commercial reasons that also results in an environmental benefit may well regard themselves as ‘good’ environmental stewards (Burton & Wilson 2006, Small et al. 2015), though that view may not be shared by people with an environmentalist value orientation.

Third, if farmers do adopt a practice change for commercial reasons that results in an environmental benefit then they may be less likely to observe other measures that generate environmental benefits (Thorgerson 2012, Truelove et al. 2014). Where farmers have, for commercial gain, changed to a practice that generates an environmental benefit they may use this change to justify the rejection of adopting other measures that benefit the environment on the grounds that they are already engaging in environmentally friendly behaviour. This effect may also occur where farmers have adopted a practice that has little commercial impact on the farm business but signals environmentally friendly behaviour to others (such as planting of trees around the margins of their property).

Relatedly, if farmers do adopt a practice change for commercial reasons that is intended to also generate an environmental benefit then they may, if the opportunity is available, implement the practice in ways that increase productivity but are counter-productive from an environmental perspective and so diminish the environmental benefits. This is highly likely in circumstances where there is considerable scope for use variety in implementing practices (Kaine & Higson 2006, Micheletti Cremasco et al. 2021).

Another implication concerns farmers’ beliefs with respect to use of resources. To the degree that the personal values of farmers differ from those of other groups in the community, the criteria they use to make judgements about how desirable a behaviour is will differ from the criteria used by others in the community. For example, Sandall et al. (2001) found that farmers’ judgements about the appropriate use of different landscapes differed from those of conservationists and policy makers, and that the differences were attributable to differences in social values. This means that disagreements between farmers and other groups in the community over the proper use of natural resources are more than struggles over shares in economic wealth. They are disputes about how to judge what is desirable. Such disputes can be characterised by protracted and passionate disagreements as the parties involved hold fundamentally different beliefs about what is a desirable state or mode of behaviour. Such disagreements often cannot be resolved by negotiation or consensus.

Policy measures that restrict access to critical agricultural inputs for the purpose of environmental benefit could be argued to be value challenging for many, if not most, farmers. On the arguments above, farmers are unlikely to embrace such measures. They will seek to delay, and weaken, the imposition of such measures and avoid complying with them for as long as possible. To the degree compliance with these measures entails adopting architectural or complex practice changes, and changing the structure of the farm system, their desire to postpone action will be heightened accordingly.

We have argued here that farmers will sensibly avoid changing practice when the change is:

- Inconsistent with the farm system
- likely to undermine farm business performance
- entails architectural or radical changes to farm sub-systems(s)
- is inconsistent with farmer’s social values

In circumstances where farm managers are required to change practices across several interacting farm sub-systems in response to concurrent policy initiatives (e.g. animal welfare, greenhouse gas emissions, nutrient emissions, water use efficiency) change becomes entirely problematic. The resulting difficulty in reconciling external demands for change with perceived threats farm lifestyles and livelihoods, together with the complexity of change required, means that farm managers may experience feelings of frustration, helplessness, anxiety, and depression (Marcom et al. 2018, Heo et al. 2020).

The apparent recalcitrance of farmers to respond to environmental policy measures may be misunderstood by those outside of agriculture (including policy makers) resulting in the characterisation of farmers as environmental vandals, resulting a loss of status (Tall & Campbell 2018). Feelings of frustration and helplessness will be exacerbated by policy measures that restrict the independence and flexibility of farmers in making decisions. Farmer’s feelings of anxiety and frustration will also be heightened to the degree that farmers feel that their competence is questioned, directly or indirectly, in the judgements of others.

APPENDIX D: TYPES OF CHANGE IN FARM SYSTEMS[14]

Farms consist of inter-related sub-systems. The more tightly these sub-systems are coupled together the greater the likelihood that a change in one sub-system will trigger a cascade of changes in other sub-systems. Consequently, the time and effort entailed in changing farming technologies and practices depends on the extent to which the new technology or practice alters the functioning of the relevant sub-system and related sub-systems.

Changes to systems, can be classified into four types based on whether the change entails altering the components or the architecture of the system.[15] The four types, which have progressively greater impact on the system, are incremental, modular, architectural, and radical. The four types are defined as (Henderson & Clarke 1990):

Incremental practice changes introduce relatively modest changes to the components of a product leaving the links between components, that is, the product architecture, largely unchanged (Henderson and Clark 1990). Incremental practice changes exploit the potential of an established design and tend to build on existing skills and knowledge. Converting from overhead spray to drip irrigation is an example of incremental practice change (see Table D1).

Modular practice changes introduce relatively substantial changes to the components of a product in that at least some existing components become obsolete because the new components are based on new design concepts (Henderson and Clark 1990). The architecture linking the components together remains largely unchanged with modular practice change. New skills, competencies, and processes may be required to manufacture and install the new components. Consequently, modular practice changes may enhance or destroy competence depending on the history of the specific organisation (Gatignon et al. 2002). Converting from traveling spray to mini sprinkler irrigation is an example of modular practice change (see Table D2).

Henderson and Clark (1990) define an **architectural** practice change as changing the way the components in a system link together. Architectural practice changes entail relatively minor changes in the components. Knowledge about the way components link together becomes embedded in the organisational procedures, processes, and structures over time (Henderson and Clark 1990). Consequently, architectural practice changes have been shown to create serious disruptions to organisations because they require changes in the operating procedures, processes, and structures of the organisations, as well as the acquisition of new skills and competencies. Converting from conventional to Reduced Deficit irrigation is an example of architectural practice change (see Table D3).

Finally, **radical** practice changes involve a new set of design concepts that are embodied in new components that are linked together using a new architecture (Henderson and Clark 1990). Radical practice changes are based on completely different scientific and engineering principles to the principles that were used in the products they supersede. With radical practice changes many areas of organisational knowledge and competence are rendered irrelevant, consequently an organisation may have to consider new ways of thinking to adopt a radical practice change (Smith 2000). Converting from furrow to pressure irrigation is an example of radical practice change (see Table D4).

See Kaine et al. (2008) for detailed applications of these concepts to agriculture.

Clearly, the time and effort required to anticipate and plan for the consequences of change increases, while the opportunity to experiment and change plans decreases, moving from incremental to radical change. Likewise, the potential impact on tactical and strategic flexibility increases moving from incremental to radical change. Consequently, architectural, and radical changes to farm systems may take longer to implement than incremental changes, and uncertainty about the benefits of change may also delay the implementation of architectural and radical changes to farm systems considerably more than incremental changes.

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[14] The content in this section borrows heavily from Kaine et al. (2008)

[15] Note that this is simply a classification of innovations (changes), it is not intended to be a description of the processes (creative or otherwise) that generate the innovation.

Table D1: Incremental practice change – conversion from overhead sprinkler to drip irrigation

(Red text indicates differences in components and architecture)

Overhead sprinkler irrigation		Drip Irrigation	
Component	**Component principle**	**Component**	**Component principle**
Pump	Mechanism for compressing water		Unchanged
Valve	Mechanism to control the flow of water in a pipe		Unchanged
Timer	Mechanism to open or close valves at a preset time		Unchanged
Sprinklers	Water outlet that emits water at high volume	Drippers	Water outlet that emits water at low volume
Pipes	Round, sealed receptacle used to contain water		Unchanged
		Filter	Mechanism to remove impurities from water
Tensiometer			Unchanged
Architecture	**Architectural principle**	**Architecture**	**Architectural principle**
Sprinkler irrigation	Irrigation system is a fixed structure		Unchanged
	Water moves through system from high pressure to low pressure		Unchanged
	Irrigation scheduling based on physiological requirements of crop		Unchanged

Table D2: Modular practice change – conversion from travelling irrigator to mini-sprinkler irrigation

(Red text indicates differences in components and architecture)

Overhead sprinkler irrigation		Drip Irrigation	
Component	**Component principle**	**Component**	**Component principle**
Pump	Mechanism for compressing water		Unchanged
Valve	Mechanism to control the flow of water in a pipe		Unchanged
Timer	Mechanism to open or close valves at a preset time		Unchanged
Sprinklers	Water outlet that emits water at high volume	Mini sprinklers	Water outlet that emits water at low volume
Carriage	Traveling structure with wheels and rotating pipe		Not required
Hose	Flexible, round, sealed receptacle used to contain water that attaches to the carriage	Pipes	Fixed, round, sealed receptacle used to contain water
Cable	A strong wire rope that guides the carriage		
		Filter	Mechanism to remove impurities from water
Tensiometer			Unchanged

Table D2 (continued): Modular practice change – conversion from travelling irrigator to mini-sprinkler irrigation

(Red text indicates differences in components and architecture)

Architecture	Architectural principle	Architecture	Architectural principle
Mobile sprinkler irrigation	Irrigation system is a moveable structure	Fixed sprinkler irrigation	Irrigation system is a fixed structure
	Water moves through system from high pressure to low pressure		Unchanged
	Irrigation scheduling based on physiological requirements of crop		Unchanged

Table D3: Architectural practice change – conversion from travelling irrigator to mini-sprinkler irrigation

(Red text indicates differences in components and architecture)

Conventional sprinkler irrigation		Reduced deficit sprinkler Irrigation	
Component	**Component principle**	**Component**	**Component principle**
Pump	Mechanism for compressing water		Unchanged
Valve	Mechanism to control the flow of water in a pipe		Unchanged
Timer	Mechanism to open or close valves at a preset time		Unchanged
Mini sprinklers	Water outlet that emits water at low volume		Unchanged
Pipes	Fixed, round, sealed receptacle used to contain water		Unchanged
Filter	Mechanism to remove impurities from water	Filter	Unchanged
Tensiometer			Unchanged
Architecture	**Architectural principle**	**Architecture**	**Architectural principle**
Conventional	Irrigation system is a fixed structure	Reduced deficit	Unchanged
	Water moves through system from high pressure to low pressure		Unchanged
	Irrigation scheduling based on physiological requirements of crop		Limiting water during specific stages of crop development changes crop characteristics

Table D4: Radical practice change – conversion from furrow irrigation to mini-sprinkler irrigation

(Red text indicates differences in components and architecture)

Furrow irrigation		Pressure Irrigation	
Component	**Component principle**	**Component**	**Component principle**
Gate	Mechanism for releasing water into a channel		
Furrow	Narrow channel in soil for directing water		
Siphon	Mechanism for directing water from channel into furrow		
		Pump	Mechanism for compressing water
		Valve	Mechanism to control the flow of water in a pipe
		Timer	Mechanism to open or close valves at a preset time
		Mini sprinklers	Water outlet that emits water at low volume
		Pipes	Fixed, round, sealed receptacle used to contain water
		Filter	Mechanism to remove impurities from water
Spade	Mechanism for subjectively assessing water content of the soil	Tensiometer	Mechanism for measuring water content of the soil
Architecture	**Architectural principle**	**Architecture**	**Architectural principle**
Gravity irrigation	Irrigation system is an earthen structure	Pressure irrigation	Irrigation system is a fixed pipe structure
	Water moves from high to low elevation under the influence of gravity		Water moves through system from high pressure to low pressure
	Irrigation scheduling based on physiological requirements of crop		Unchanged

APPENDIX E: MANAGING VARIABILITY USING TACTICS

One way that farmers can manage variability in a critical input is by using tactics to alter the use of the input. Tactics are pre-programmed actions available to the farmer that do not involve having to make changes to the structure of the farm system. Timely activation is crucial for a tactic to be effective; therefore, tactics tend to be more tightly coupled within the farm system to enable a quick response (Glassman, 1973). Tactics are here defined as input-specific responses built into the farm production processes.

A farmer can alter the use of a variable input in three ways: by altering the timing of the use (within the day or throughout the season), by substituting another input for the variable input and by reducing the use of the input. Tactical flexibility refers to the portfolio, or repertoire, of pre-programmed actions, at a point in time, available for the farmer to activate as needed in response to a change in a critical physical input.

The tactical flexibility of a farm system depends on the average capacity of tactics to match the variability of an input and the number of tactics available. Hence, the larger the portfolio of tactics available for an input, given at least a fixed average capacity of tactics to match the variability of an input, the greater is the tactical flexibility of the farm system. Tactical flexibility is a measure of the extent to which variability in an input can be absorbed without changing the structure of the farm system. Tactical flexibility does not measure the capacity to change the portfolio of tactics.

Changing the portfolio of tactics requires a change in the structure of the farm system, and therefore, the capacity to change the portfolio of tactics is a component of adaptive capacity (Nelson et al., 2010). Logically, a farmer may increase the farm's tactical flexibility by expanding the portfolio of tactics to match the variability of an input. This would require some change in the technologies or practices used in the farm system. Given the more tightly coupled relationships of tactics to other components of the system, expanding the portfolio of tactics would entail changing the structure of the farm system.

Put another way, when a farmer uses the existing portfolio of tactics to respond to a change in a critical input, this is absorbing the change. When a farmer modifies the portfolio of tactics to better absorb a change in a critical input, this is adapting the farm system because this is changing the farm's structure.

The input-specific character of tactics means that an individual farm production system may have little tactical flexibility in relation to one input and have considerable tactical flexibility in relation to another. Given many sources of variability, a farmer will need to include a portfolio of tactics into the farm system for each input. For example, a grape grower may use an existing on-farm dam as a tactic to manage a variable surface water allocation. The same grower may use existing overhead sprayers as a tactic to manage extreme temperature days, not necessarily using water from the dam.

MANAGING VARIABILITY USING STRATEGY

A farmer has a farm business strategy and corresponding structure to produce a set of outputs; although the number of outputs in the set differs among farm systems (for example a dairy farm is likely to have only one output whereas a mixed-cropping farm may have several outputs available). Changing the set of outputs the farm business can produce would require a change in structure. For some farms, what is produced at any given time may be a subset of those that can be produced using the current farm system structure. For example, a vegetable grower may select a subset of crops to sow based on output prices.

Also, the production emphasis can vary within some farm systems. For example, a mixed livestock and cropping producer may float between emphasizing cropping and livestock, such as moving from 70% cropping and 30% livestock to 30% cropping and 70% livestock. This manifestation of outputs as a subset and with a changing emphasis is what we describe as the 'output mix'. In addition to using tactics to alter the way an input is used, farmers can respond to variability in an input, usually from one production cycle to the next, by changing the output mix to reduce reliance on the input.

The capacity of a farmer to deliberately vary the composition of their output mix in response to variation of an input, without changing strategy, is a measure of the farm's strategic flexibility. The greater is the capacity to alter the mix of outputs of the farm system without having to change system structure, the greater is the strategic flexibility of the system. Put another way, some farmers develop a farm business strategy that deliberately includes some plurality in output focus. Such a strategy requires loose coupling among the components of the farm system. This enables the farmer to change components and/or function of components within the farm system without affecting the whole system.

Strategic flexibility is a way for the farm system to absorb variability in key inputs. A farmer may increase strategic flexibility by changing their farm business strategy. Fundamentally, this would require the addition of a new output to the set of outputs available to the farm system. Such a change would entail a change in farm system structure and therefore be adaptation. This is not to suggest, however, that all change in strategy is about increasing strategic flexibility.

Tactics are subordinate to strategy. Hence, the portfolio of tactics available to a farmer is predetermined by their farm strategy. Because a change in the farm system that determines how an output will and can be produced is also a change in strategy, investments to alter system structure to expand tactical flexibility can be strategic in nature.

In short:

- A farm system has a set of outputs that can be produced within the current production system.
- The outputs produced at a given time can be a subset and can have a changing emphasis; this is the 'output mix'.
- Strategic flexibility is the capacity of the farmer, within the current strategy, to change the output mix to reduce reliance on a variable critical input.
- The greater the capacity to deliberately alter the mix of outputs of the farm system, the greater is the strategic flexibility of the system.

Strategic flexibility is a measure of the extent to which variability in an input can be absorbed by changing output mix, but not the structure, of the farm system. Strategic flexibility does not measure the capacity to change strategy. Changing strategy requires changing the structure of the farm system, and therefore, the capacity to change strategy is a component of adaptive capacity (Nelson et al., 2010).

A CLASSIFICATION OF FARMS BY THEIR STRATEGIC AND TACTICAL FLEXIBILITY

Differences between farms in their strategic and tactical flexibility provide one criterion for identifying qualitatively different farm trajectories as differences in flexibility determine the nature of farmer's responses to changes in their task environment. Again, the task environment consists of the bio-physical, socio-economic systems and settings that impinge on the operation of the farm system.

Rigid farm systems have low tactical flexibility and low strategic flexibility. Farmers with these systems can only maintain system viability by using tactics to absorb variability in inputs. Even so, the portfolio of tactics available to rigid systems tends to be relatively small. An example is provided in Attachment 1 and summarised in Table E1.

Robust farm systems have high tactical flexibility and low strategic flexibility. The manager of a robust farm system attempts to maintain the current strategy by using a relatively broad portfolio of tactics to absorb variability. Robust systems have more tactical flexibility than rigid systems. This greater tactical flexibility implies that the financial consequences of a given level of input variability are expected to be smaller for robust systems than they are for rigid systems. An example is provided in Attachment 2 and summarised in Table E2.

Elastic farm systems have high strategic flexibility but low tactical flexibility. Elastic systems have some capacity to change output mix to manage variability, while maintaining the farm business strategy. Farmers with this type of system can change the mix of outputs so that they are less impacted upon by inputs whose variability has increased. The ability of the elastic type to switch between outputs requires that these systems have infrastructure that is less enterprise specific overall, as infrastructure that is enterprise specific impedes the ability to easily move between outputs. This feature of a farm's infrastructure is a function of both the demands of the specific outputs produced and the farmer's willingness to trade technical efficiency for flexibility. Elastic systems parallel, roughly, the idea of diversified farm systems. Note that elastic farm systems, as defined here, encompass the farm system described as plastic by Rodriguez et al. (2011). Examples of elastic farm systems, which are summarised in Tables E3 and E4, are provided in Attachments **3 and 4.**

Table E1: Flexibility in rigid farm system - irrigated wine grapes

Strategic flexibility	No capacity to vary output mix without making changes to the farm production strategy	
Tactical flexibility	Changing timing of use	Having access to water when needed is crucial; hence, altering the timing of watering is not an option
	Substitution	Manage canopy to protect the fruit from intense western sun exposure. Purchase temporary water
	Reduction in use	Reduce water on red grape vines, but not on white grape vines

Source: Cowan et al. 2013

Table E2: Flexibility in robust farm system – pasture and cut-and-carry dairy

Strategic flexibility	No capacity to vary output mix without making changes to the farm production strategy	
Tactical flexibility	Changing timing of use	Having the capacity to water early and late in the season is vital, so little capacity to change the timing of use
	Substitution	Carryover water used to ensure early season water Purchase feed Buy temporary water Dryland cropping for cut and carry
	Reduction in use	Take paddocks out of production as needed throughout the season Reduce herd size

Source: Cowan et al. 2013

Table E3: Flexibility in elastic farm system – drip-irrigated mixed farming

Strategic flexibility	Existing production strategy allows farmer to swap between various cropping and livestock outputs. Decisions on what to produce are determined by relative prices of crops, livestock, and water	
Tactical flexibility	Changing timing of use Substitution Reduction in use	Buy temporary water

Source: Cowan et al. 2013

Table E4: Flexibility in elastic farm system – flood-irrigated mixed farming

Strategic flexibility	Existing production strategy allows farmer to swap between irrigated pasture for various stock and dryland crops. Decisions on what to produce are determined by the prices expected for the product, how it will fit in with her rotation, the effect on the soil and water availability	
Tactical flexibility	Changing timing of use	Buys temporary water
	Substitution	Uses bore water
	Reduction in use	Installation of pipes and risers may offer some capacity to reduce use

Source: Cowan et al. 2013

Plastic farm systems have high strategic flexibility and high tactical flexibility. Given the practical constraints on farming such as asset fixity (e.g. specialised machinery), long production cycles and technical constraints, plastic systems are not likely in farming.

The concepts of strategic and tactical flexibility provide criteria for defining farm trajectories because the concept operationalises the potential of the farm to a absorb challenges (including changes in policy settings) originating from the task environment without exceeding the bounds of acceptable variability in farm performance.

Since the need for tactical/strategic flexibility is conditional on what constitutes acceptable variability in farm performance then profound differences in the bounds of acceptable variability in farm performance might constitute another criterion for defining farm trajectories. Acceptable variability in performance depends on goals of the farm owner/manager(s). Differences in goals may arise from differences in cultural aspirations, family circumstances or governance differences mechanisms. Differences in goals may also reflect constraints imposed by relevant actors in the task environment (such as lending criteria and debt servicing requirements).

The concepts of strategic and tactical flexibility, and what constitutes acceptable variability in farm business performance, are important as they are fundamental in defining the agency managers have in changing farm systems.

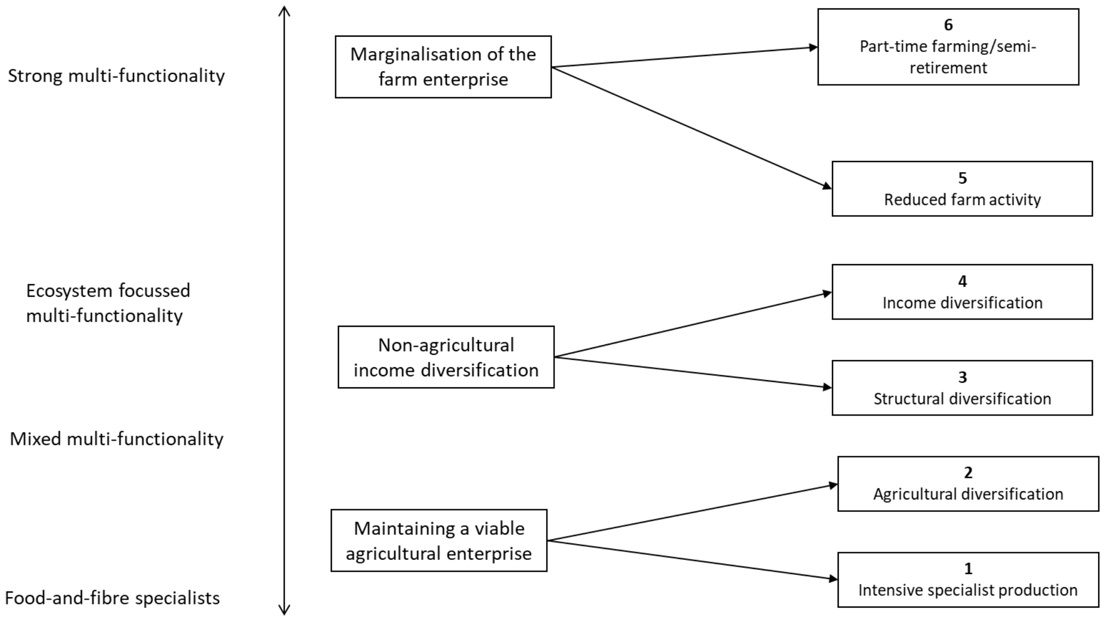
DEFINING FARM TRAJECTORIES

Farms can be classified into trajectories in a variety of ways. Wilson (2007) offers a useful way of classifying farms based on the concept of multi-functionality. Recognising that all farms are, to a degree, multi-functional in the sense that they provide products and services such employment, aesthetics, and environmental conservation, as well as producing food and fibre, Wilson (2007) proposed that farms can be classified along a continuum reflecting different emphases in the nature of their multi-functionalism (Fig. E1 and Table E5). This classification is particularly useful with respect to Moving the Middle as it recognises that agricultural multi-functionalism includes the provision of services to protect the environment by farms that either directly or indirectly concerned with food and fibre production (as most farms in the 'middle' are likely to be, at least at present).

The opportunities for farms that are currently food and fibre specialists to change the focus of their multi-functionality by shifting to supply ecosystem services will depend on:

- their tactical and strategic flexibility as these flexibilities will constrain the potential necessity for, and degree of agency farmers have to, reconfigure their farm systems to be more multi-functional (see discussions below).
- fundamental differences in acceptable variability in farm business performance arising from differences in the values, preferences, and consequent goals of farmers including fundamental differences in the ownership and governance of farms
- fundamental differences in the constraints on what constitutes acceptable variability in farm business performance arising from the values, preferences, and practices of markets, and communities
- government policies and practices in relation to agriculture, natural resources, and the environment.

Figure E1. Multi-functionality and diversification



Adapted from Wilson (2007, 231)

Table E5: Multifunctionalism in farming

Functional characteristic	Specialist food and fibre	Mixed multi-functional	Ecosystem-focussed
Strong focus on food and fibre production	High	Moderate	Low
Intensity of agricultural production	High	Variable	Low
Income diversification	Low	Some	High
Environmental sustainability	Low	Moderate	High
Focus on providing ecosystem services	Low	Moderate	High

Adapted from Wilson (2007, 229).

Some possible trajectories to be explored include:

- Rigid, robust, or elastic farm systems that are food-and-fibre specialists such as dairy and sheep-beef farms
- Rigid, robust, or elastic farm systems that are mixed multi-functional in that they earn income from the provision of environmental services as well as producing food and fibre such as dairy and sheep-beef farms with conserved remnant vegetation and riparian strips
- Rigid, robust, or elastic farm systems that are food-and-fibre specialists or mixed multi-functional and based on organic or regenerative agricultural principles and practices such as organic dairy and horticulture.
- Rigid or robust farm systems that are ecosystem focussed specialists that provide ecosystem services such as carbon capture (peatland farms with dairy grazing).
- Kaitiakitanga farms. These may be rigid, robust, or elastic farm systems where acceptable variability in performance is based on kaitiakitanga principles and Māori governance
- Community farms. These are more likely to be elastic farm systems where acceptable variability in performance is based on community governance

See Crouch (1981), Kaine et al. (1994), Cowan et al. (2013) and Chantre & Cardona (2014) for examples.

There is a distinction between a diversified farm business strategy and a diversified family business strategy. Diversification with respect to <u>farm</u> business strategy entails producing a mix of agricultural outputs but farms remain food-and-fibre specialists (Wilson 2007). Diversification with respect to <u>family</u> business strategy entails producing a mix of agricultural and other outputs. For example, operating a bed and breakfast or having off-farm employment, this is mixed multi-functionalism (Wilson 2007).

FARM TRAJECTORIES AND RESPONSES TO POLICY MEASURES THAT RESTRICT CRITICAL INPUTS

Rigid farm systems

- Reduce production
- Purchase additional input from other agricultural enterprises (e.g. emission markets)
- Acquire substitute inputs (e.g. purchase feed as substitute for pasture)
- Change structure to robust by modifying relevant production systems to produce substitute inputs (e.g. implement cut-and-carry feed system)
- Change structure to elastic by introducing new land use
- Adopt technology that increases productivity of critical input

Policy measures that support rigid systems include measures that facilitate transfer of critical inputs such as market mechanisms and offset mechanisms, measures that encourage changes in land use and research to create technology that increases the productivity of critical inputs.

Rigid farm systems are especially sensitive to policy measures, such as regulations, that unilaterally restrict the use of critical inputs.

Robust farm systems

- Exercise tactical flexibility
- Reduce production
- Sell surplus critical input to other agricultural enterprises (e.g. emission markets)
- Change structure to elastic by introducing new land use
- Adopt technology that increases productivity of critical input

Policy measures that support robust systems include measures that facilitate transfer of critical inputs such as market mechanisms, measures that encourage changes in land use and research to create technology that increases the productivity of critical inputs.

Elastic farm systems

- Exercise strategic flexibility by changing product mix
- Reduce production
- Sell surplus critical input to other agricultural enterprises (e.g. emission markets)
- Adopt technology that increases productivity of critical input

Policy measures that support elastic systems include measures that facilitate transfer of critical inputs such as market mechanisms and research to create technology that increases the productivity of critical inputs.

The above is summarised in Figures E2 through E4.

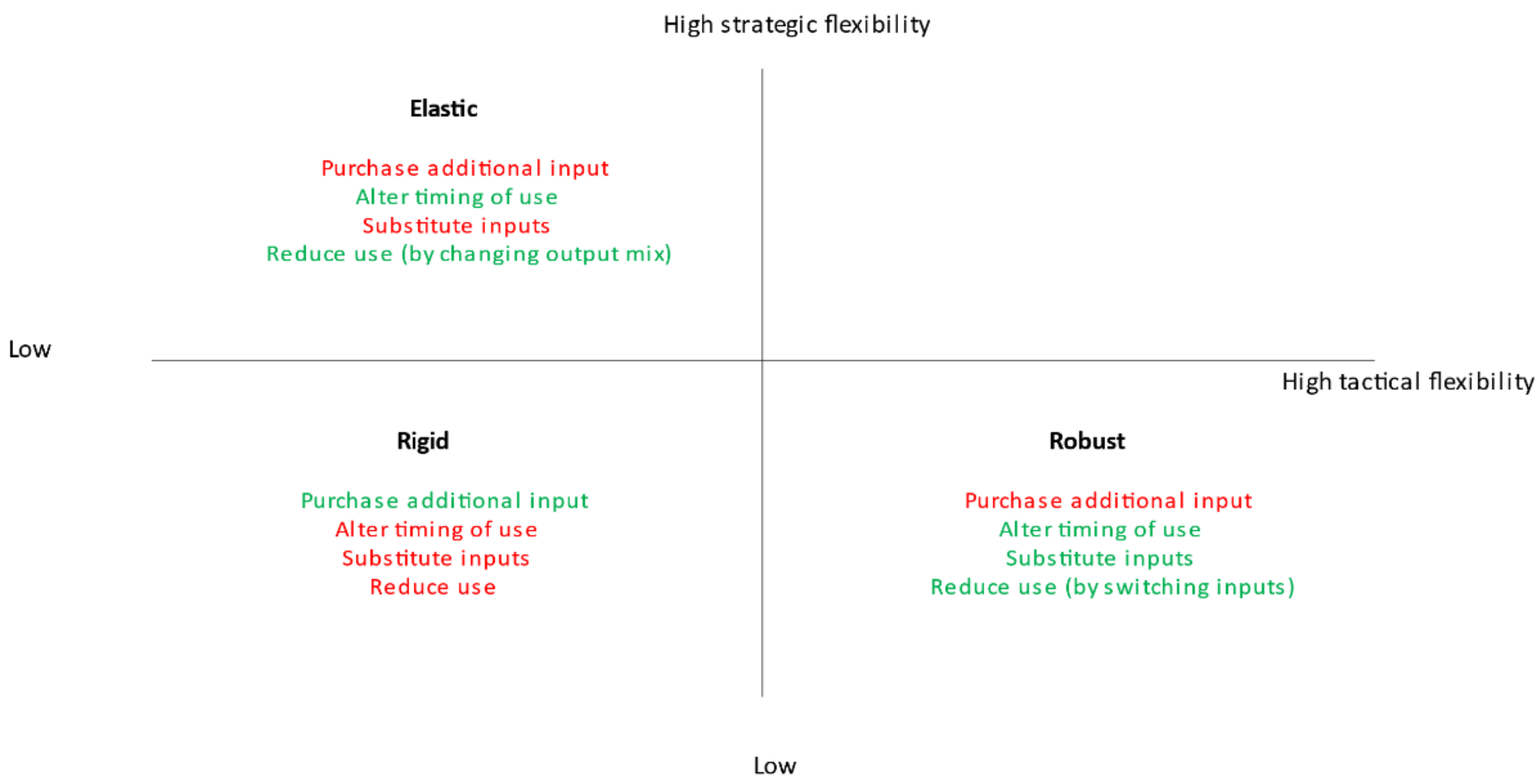


Figure E2. Farm trajectories and options for exercising strategic and tactical flexibility

Note: Options in red text are not available

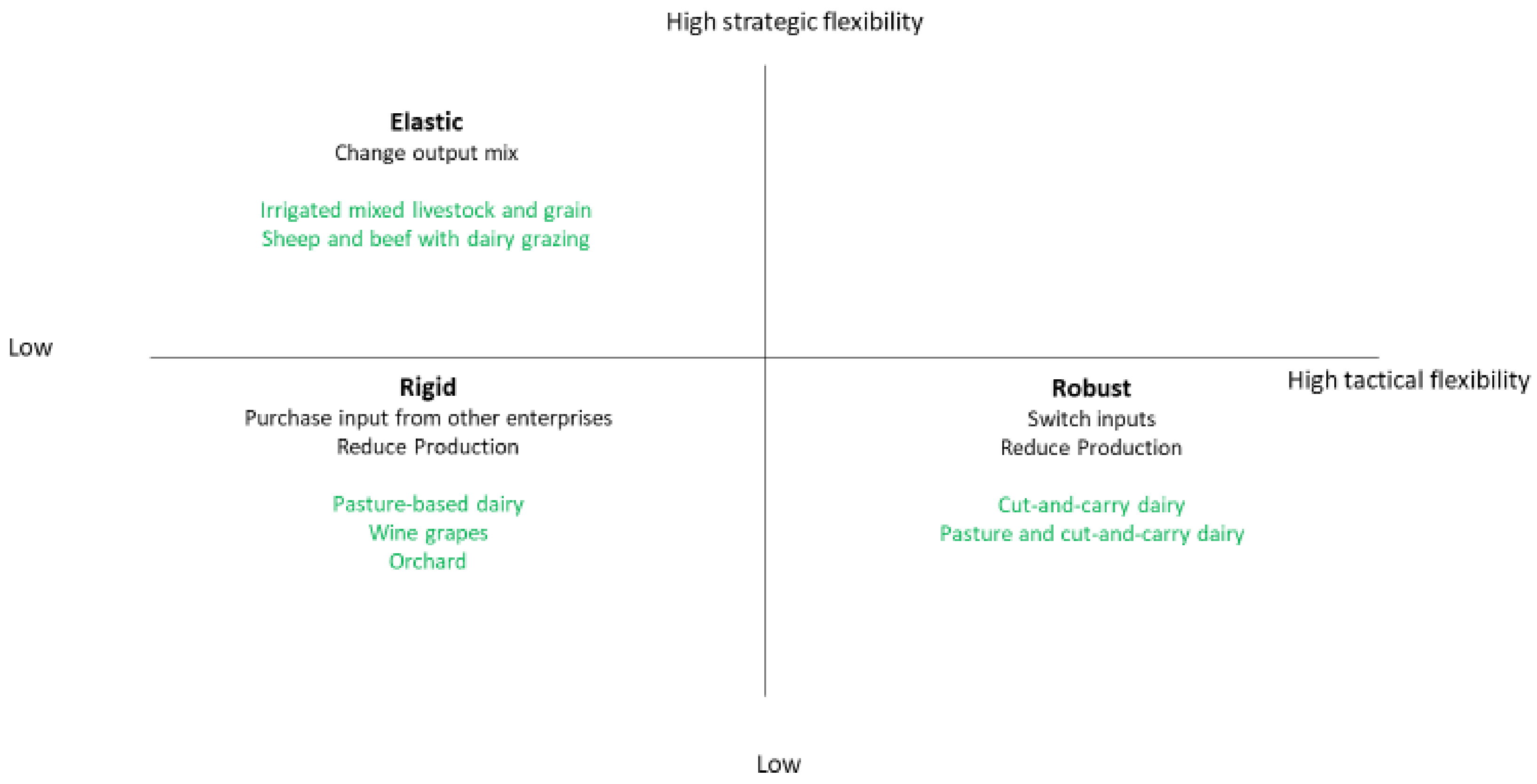


Figure E3. Examples of farms in each trajectory

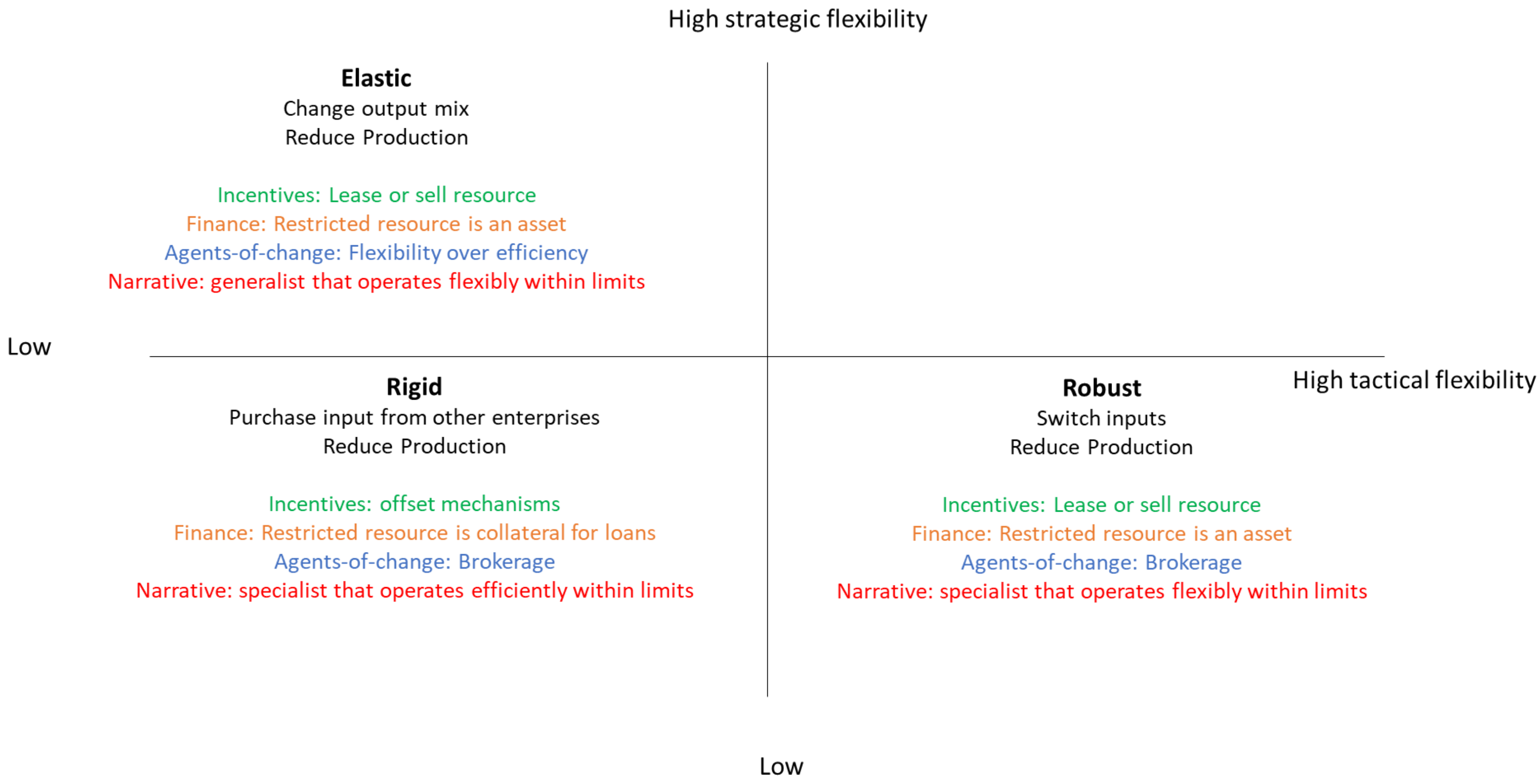


Figure E4. Potential differences in incentives, finances, agents-of-changes and narratives across farm trajectories

Kaitiakitanga elastic farm systems

- Exercise strategic flexibility by changing product mix
- Reduce production
- Sell surplus critical input to other agricultural enterprises (e.g. emission markets)
- Adopt technology that increases productivity of critical input

Policy measures that support Kaitiakitanga elastic systems include measures that facilitate transfer of critical inputs such as market mechanisms and research to create technology that increases the productivity of critical inputs.

FARM TRAJECTORIES, PRODUCTIVISM AND MULTI-FUNCTIONALITY

In principle, rigid, robust, and elastic farm systems may span the continuum between productivist and multi-functional agriculture (Wilson 2007, Renting et al. 2009, Wilson & Burton 2015), at least in the sense that any of these farm systems may offer eco-system services in addition to supplying agricultural outputs, while operating with in environmental constraints. Multi-functional agriculture refers to the potential for agricultural activity to, in addition to providing food and fibre, having other functions such as the management of renewable natural resources, landscapes, conservation of biodiversity and contribution to the socio-economic viability of rural areas Renting et al. 2009).

Rigid, robust, and elastic are descriptions of the flexibility of systems and the principles may be applied to multi-functional agricultural activities. For example, restrictions on the emission of greenhouse gases may trigger a pasture-based dairy system (rigid) on peatland to convert (wholly or in part) to supplying a carbon sequestration service, and potentially a nutrient mitigation service, depending on the extent to which the restrictions constrain herd size. Similarly, incentives for retaining remnant native vegetation may trigger a pasture-based beef-sheep system (elastic) on hill country to supply a biodiversity conservation service (Rolfe et al. 2017).

The possibility arises that such restrictions may trigger switches in farm trajectories from rigid to a robust (restructuring the farm system to incorporate greater input flexibility), or rigid to elastic (restructuring the farm system to produce one or more additional outputs in the form of ecosystem services).

LINKING FARM SYSTEMS TO SOCIO-ECONOMIC SYSTEMS IN THE TASK ENVIRONMENT

Broadly speaking, farms systems are linked to the task environment through:

- Demand for farm outputs which determines product characteristics and revenue
- Supply of farm inputs and methods of production
- External constraints on what constitutes acceptable variability in performance

These three links couple the farm system to the broader economy and community. Note that the task environment (or at least key elements within it) may differ in causal texture across different agricultural sectors, and possibly farms within each sector. Some task environments may be classified as placid, random whereas others may be disturbed, reactive or even turbulent (Emery & Trist 1965). Consequently, differences will also arise in the responsiveness of sectors (and the farms within them) depending on the causal texture of the task environment.

APPENDIX F: HOW FARMERS MAKE DECISIONS TO CHANGE PRACTICE AND CAUSAL LOOP MODELS[16]

In characterising changing practices, including the adoption of agricultural technologies, and as a form of high involvement purchase, farmers will engage in complex decision-making when deciding whether they will change practice or not. Complex decision-making entails deliberate and systematic evaluation of the merits of the practice prior to adopting it. The merits, or otherwise, of the new practice derive from the degree to which it is perceived by the farmer to create benefits when implemented in their farm context. The process of identifying benefits requires farmers to invest effort in learning about the attributes of the practice.

The process of identifying benefits also requires farmers to invest effort in developing an understanding of the elements in their farm system that are functionally related to the practice, and in developing an appreciation of the likely consequences of implementing the practice. These considerations suggest that farmers are likely to have formed comprehensive mental models of their farm systems and to draw on these when seriously contemplating changing practices. Hence, the use of complex decision making in high involvement decisions such as changing practices implies that the farmer develops explicit chains of reasoning to guide their decision making. This is consistent with general psychological theories of the fundamental logic of decision-making such as image theory (Beach and Mitchell 1987; Beach and Potter 1992; Beach and Connolly 2005) and theories of specific decision-making processes in particular circumstances such as explanation-based decision theory, where the focus is on "reasoning about the evidence and how it links together" (Pennington and Hastie 1989).

Image theory treats decisions as social acts and recognises that decision-makers come to a decision with a store of knowledge which influences their decisions and guides their behaviour (Beach and Potter 1992; Nelson 2004). This knowledge can be metaphorically classified into three categories or images. These are the value image which consists of knowledge about what truly matters and is based on beliefs and values (of the farmer in this case), the trajectory image which consists of knowledge about what constitutes a desirable future and is based on goals, and the strategic image which consists of knowledge about how to go about securing that future and is based on plans (Beach and Mitchell 1987; Beach and Strom 1989; Beach and Potter 1992; Beach and Connolly 2005).

Plans in the strategic image have two aspects: tactics and forecasts. Tactics are concrete behaviours while forecasts focus on the outcomes of those behaviours. The various plans in the strategic image must be coordinated so that they do not interfere with each other, and the decision-maker can pursue their goals in an orderly fashion (Beach and Connolly 2005). The relevant constituents of these images (principles, goals, and plans) are employed to frame a situation; that is, to interpret a situation and imbue a decision with meaning.

There are two kinds of decisions in image theory: progress decisions and adoption decisions. Progress decisions are decisions about whether a plan is making progress towards achievement of its goal (Beach and Connolly 2005). These decisions rely on forecasts as to whether the anticipated outcome plausibly includes achievement of the goal or not. If the forecast does include goal achievement the plan is retained. If not, the plan is abandoned and a new or amended plan must be adopted (Beach and Connolly 2005).

Decisions to change practice entail acquiring new knowledge and concern adding new principles to the value image, new goals to the trajectory image or new plans to the strategic image (Beach and Connolly 2005). The criterion for adding a new goal or plan is whether it is compatible with existing principles and consistent with existing goals or plans of the decision-maker. If a goal or plan is sufficiently incompatible with existing principles or interferes with existing goals or plans then it is rejected.

Importantly, decisions to change farming practice are accomplished by screening options in the light of relevant principles, goals, and plans (Beach and Mitchell 1987; Beach and Strom 1989; Beach and Potter 1992). Note that compatibility criteria are non-compensatory (Beach and Strom 1989). This limits the need for making a choice between options to those situations where two or more options survive screening. When two or more options pass screening the decision-maker may call on one or more of a repertoire of decision strategies to make a choice depending on the circumstances of the choice. These circumstances include characteristics such as unfamiliarity

[16] The content in this section borrows heavily from Kaine (2008).

with, and complexity of, the choice, significance and irreversibility of the outcomes, and the decision-maker's motivation (Beach and Connolly 2005).

In terms of image theory, the adoption of a new practice is an adoption decision in the image theory sense because it involves the incorporation of a new tactic, in the form of the practice change and associated changes to the farm system, into relevant plans in the farmer's strategic image. The practice change is screened by considering the compatibility of the amended plans with the value image and the consistency of the amended plans with the trajectory image. If the amended plans fail the screening test then the change in tactics is rejected as is the practice change. If the amended plans pass the screening test then the change in tactics is implemented and the practice change is adopted. See Longley et al. 2012 for some examples of non-compensatory screening of alternatives within the strategic image. See Kaine & Niall (2001), Kaine et al. (2002), Kaine et al. (2006) and Court et al. (2007) for a detailed example of practice change in sheep breeding that illustrates the non-compensatory interaction between the trajectory and strategic images.

Arguably, the constituents of the value, trajectory and strategic images that are relevant to farmers' screening of agricultural practice changes are what have previously been defined as the elements in the farm system that influence the intensity of the technical improvement an agricultural practice change offers, the relevance of the improvement to farmers' objectives, and the compatibility of the improvement with their values, experiences and needs ultimately translate into the constituents of the strategic, trajectory and value images respectively of farmers.

The addition of a new principle to the value image is rare for adult decision-makers except in the case of cultural, revolutionary, or other deep, longer-term change. In this case, a dire or extreme threat to the survival of an organisation (e.g. farm) may be sufficient to generate modifications in the value image of the farmer.

WHAT TRIGGERS CHANGES TO FARM PRACTICE

Changes in farm practice will be triggered by:

- the emergence of new technologies or practices that render current practice obsolete
- policy initiatives such as the imposition of restrictions or bans on inputs or practices
- policy initiatives such as the imposition of technology or process standards
- changes in resource endowments including infrastructure and climate
- changes in resource requirements and endowments triggered by changes in family life cycle
- changes in practices of relevant external parties such as financial institutions, input suppliers and purchasers of farm outputs

Clearly, policy initiatives and changes in the practices of input suppliers and product purchasers may reflect changes in community aspirations and expectations.

FARMER DECISION-MAKING AND CAUSAL LOOP MODELS

In addition to being broadly consistent with image theory, which presents a general model of the fundamental logic of decision-making, complex or extensive decision making is also broadly consistent with explanation-based decision theory (Pennington and Hastie 1989). Explanation-based decision theory provides a description of the specific mechanisms that are employed to make important, non-routine decisions in everyday life in circumstances where a large base of implication-rich, conditionally dependent pieces of evidence must be evaluated as a preliminary to choosing a course of action and, as well, important dimensions of the decision may be unknown (Hastie and Pennington 2000).

In essence this theory proposes that the construction by the decision-maker of causal models or explanations linking evidence and consequences is central to the decision process in these circumstances and that the primary focus for the decision-maker is on reasoning about the evidence and how it links together (Cooksey 1996). Confidence in the explanation, and the subsequent decision, depends on the narrative comprehensiveness of the explanation, which is the capacity of the explanation to link evidence together completely, consistently, and plausibly, and the uniqueness of the explanation which to the potential for other equally plausible explanations

(Hastie and Pennington 2000). In short, the idea is that farmers gather evidence on the attributes of the technological alternatives available to them. This evidence is processed into a coherent causal model, an explanation, which is used to evaluate the extent to which the alternatives will meet their farming needs and upon which a decision is finally made (Cooksey 1996). In other words, farmers build their own, idiosyncratic, versions of causal loop diagrams.

For example, willingness to adopt a new technology or practice will depend on the whether it improves the functioning of one or more farm sub-systems. Hence, the benefits of changing a practice or technology will be conditioned by the presence (or absence) of key elements within the relevant sub-systems. These key elements are those components and relationships in the farm system that interact with the technology or practice to influence the functioning of relevant sub-systems. These key elements describe the farm context for a technology or practice (Crouch 1981) and, usually, can only be identified empirically.

These key elements provide the foundation to build causal loop diagrams of farm systems which can then be linked with causal loop diagrams of relevant external systems in the task environment. See Figure F1 for a simple example of a causal loop diagram of an orcharding system with respect to adopting micro-irrigation. In this example the adoption of micro-irrigation would be facilitated by installing pressurized public irrigation infrastructure.

Assuming a policy measure can be translated into a change in input use or a change in technology or practice, then identifying the farm context(s) for that change provides a starting point for:

- Assessing the impact of the policy measure on farm performance
- Classifying the policy measure as a type of change
- Identifying the impact of the policy measure on tactical and strategic flexibility
- Identifying the impact of the policy measure on variability in farm performance
- Identifying alternative management actions (if any) to counter any undesirable effects of the policy measure
- Assessing the compatibility of the policy measure with the values of farm managers
- Assessing the incentive to delay responding to the policy measure
- Identifying the external systems that have a key influence on implementing or responding to the policy measure

This is illustrated in Figure F2 for a pasture-based dairy farm (rigid) operating on drained peatland. A policy restricting methane emissions from agriculture is being contemplated. The various options the farm manager might consider in responding to such a restriction are illustrated in the diagram, with the attractiveness of each option depending, in part, on the farm context (e.g. proportion of property that is peatland) and the nature of the policy measures associated with the policy.

If a high proportion of the farm is drained peatland then the restriction on methane emissions creates a situation where a substantial reduction in the size of the dairy herd size is required. One possibility is to restructure the farm system by reducing stock numbers and converting the drained peatland to crop production and using the remaining area of the farm for dairy grazing. This means converting from a rigid farm system with limited tactical and strategic flexibility (dairy production) to an elastic system with some output flexibility (diversified crop and grazing).

Alternatively, there may be potential to reduce stock numbers and use the farm to sequester carbon by returning the property to peatland. This means converting from a rigid farm system with limited tactical and strategic flexibility (dairy production) to an elastic system with some output flexibility (multi-functional carbon sequestration and grazing). This possibility requires that a revenue stream can be generated from carbon sequestration. This in turn requires some recognition of property rights with respect to carbon sequestration, and methods for measuring and pricing carbon sequestration (see Fig. F3). Hence, the feasibility of this alternative depends on appropriate practice ecologies in the government and financial sectors (at a minimum).

Both alternatives entail radical, in a systems sense, changes to the practice ecology of the farm system. The choice between these two alternatives and other less radical options will depend on both the farm context and constraint imposed by government policy, financial practices, etc. For example, differences between relying on tactical flexibility to absorb restrictions on methane emissions and changing the structure to adapt to restrictions on methane emissions are shown in Figure F4. Note that none of the options for change may generate an acceptable level of variability in farm profit (business performance).

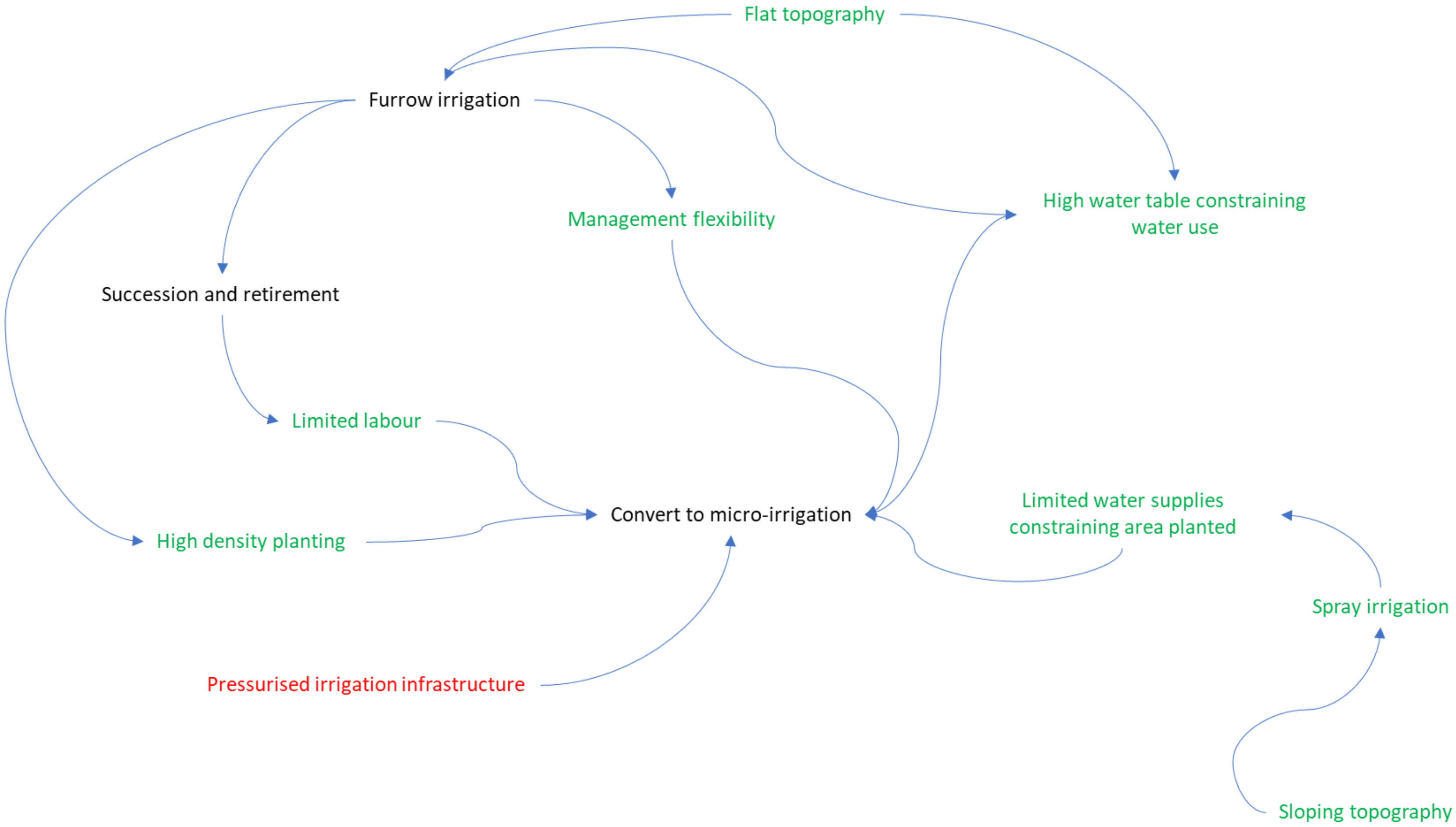


Figure F1. Causal loop diagram for the adoption of micro-irrigation by orchardists (based on Boland et al. 2005 and Kaine et al. 2005).

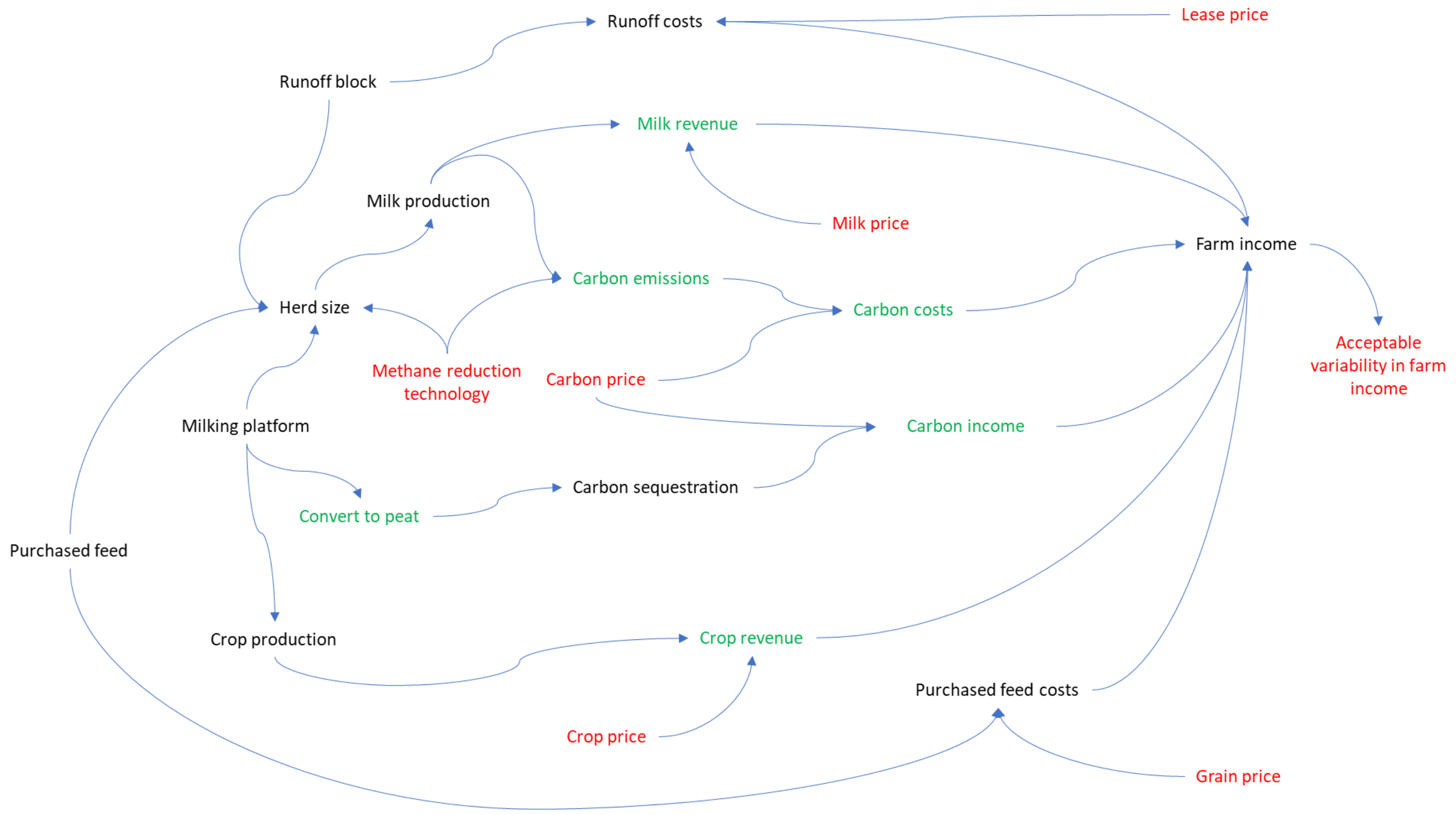


Figure F2. Causal loop diagram for responses to pricing carbon emissions – pasture-based dairy system on peatland (rigid system)

Items in red are potential leverage points

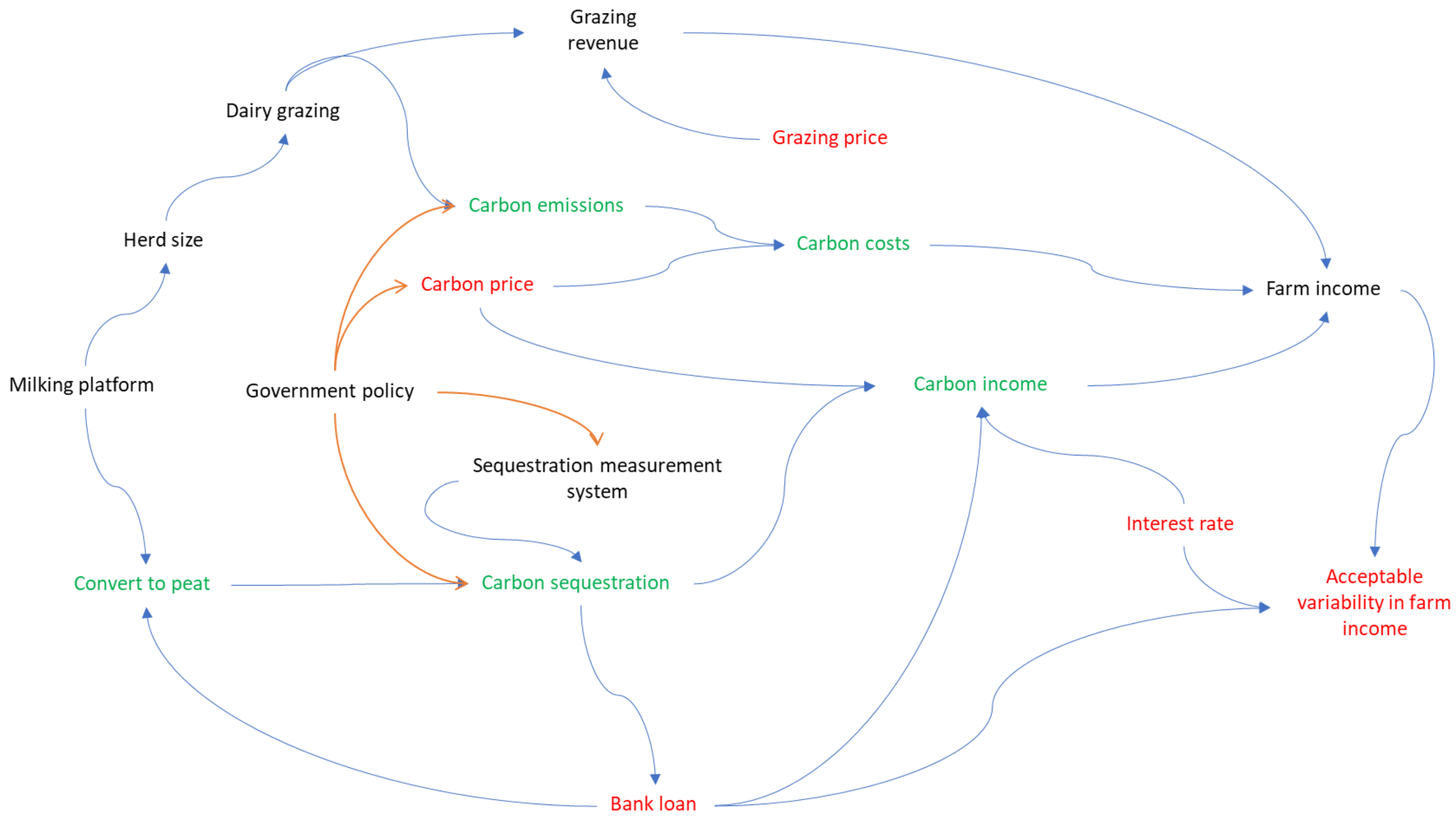


Figure F3. Causal loop diagram for responses to pricing carbon emissions – pasture-based dairy system on peatland converting to multi-functional carbon sequestration-grazing system (elastic system).

Note: Green is provision (or use of) an ecosystem service. Potential leverage points in red.

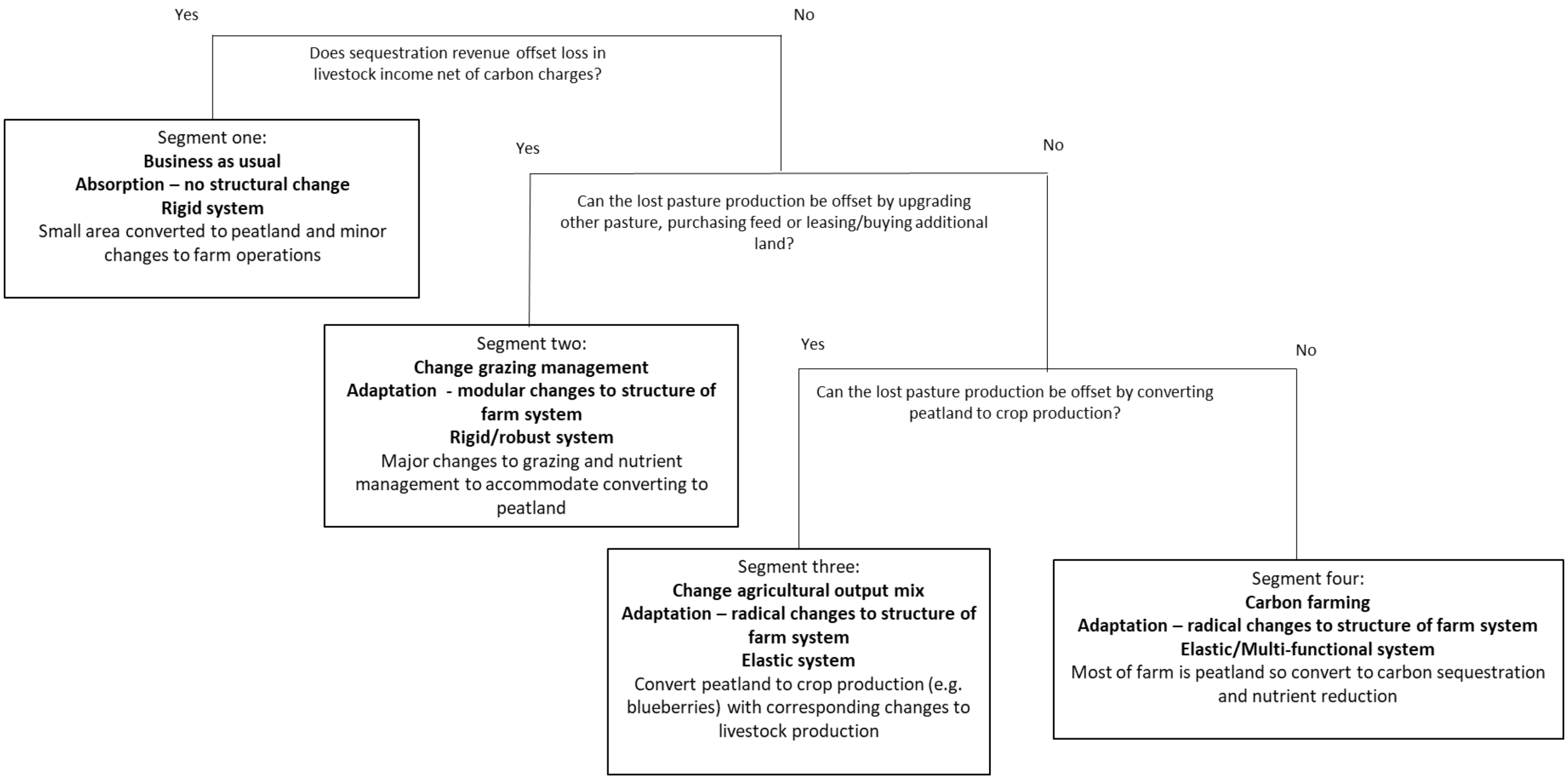


Figure F4. Tree diagram for responses to pricing carbon emissions – pasture-based dairy system on peatland converting to multi-functional carbon sequestration-grazing system (elastic system).

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ATTACHMENT 1. RIGID FARM SYSTEM

Wine Grapes

Sam and Sarah grow grapes on a 16-ha property in the Goulburn Valley. The enterprise is a part of a family business that includes wine making and running a vineyard cafe. They produce premium wines for their own label using the grapes they grow as well as producing commercial clean-skin wine for clients in Melbourne, using grapes from other sources. They also process grapes on contract for other wineries. Sam and Sarah bought the vineyard, with 10 acres of vines on drip irrigation, in 2004. Because they process the grapes they grow for their premium wine label, the emphasis in the management of the vineyard is on the quality not quantity of grapes.

Sam and Sarah generally use between 12 and 16 ML of their 50 ML water right in a season, so a 30% water allocation is sufficient to meet their needs in most years. Even so, water availability has been a problem for the past 5 years. They initially reduced water use by irrigating their vines with less water. The results were mixed. The health of the reds was unaffected, but the health of the whites suffered. Consequently, they have had to increase water to their whites.

Sam and Sarah could prune their grapevines to reduce fruiting which, in turn, would reduce water use. If they retain the right ratio of leaf cover to fruit, they can increase or reduce fruit production year to year without harming the vines. However, pruning decisions are made in the winter before information is available on water allocations for the coming season. This means Sam and Sarah have no choice but to prune according to the yields they want to achieve.

During the growing season, Sam and Sarah can adjust their trellises to alter canopy cover on the west-facing side to protect the fruit from intense afternoon sun. However, this has little impact on water use.

Sam and Sarah have had to buy water twice in the past 5 years, although only 3 or 4 ML in total each time. The cost of doing so was 'small compared to other business costs'. They said that even if they had to go to the market to buy all their water they would do so, as they could afford to buy whatever was needed to ensure production and make sure their vines are kept healthy.

For Sam and Sarah, having timely information about what their water allocation will be, and when it will be available, is crucial to their decision making. They would prefer having a larger allocation announced earlier, with fewer increments through the season, to having many piecemeal announcements throughout the season. Having enough water early in the season to irrigate early was particularly important. They described how, a couple of years ago, the weather was very hot early in the season, before the irrigation season started, and being unable to irrigate, the hot weather had an extremely detrimental impact on production that year.

Sam and Sarah do not have the capacity to vary their output mix, such as changing grape varieties, without making changes to their farm production strategy; hence, their strategic flexibility is low. The options available to Sam and Sarah for altering the use of water, without having to make adaptations to their farm system, are limited as well. Having access to water when they need it is crucial; hence, altering the timing of watering is not an option for them.

They can manage their canopy to protect the fruit from intense western sun exposure as a substitute for water. They can also purchase more water on the temporary market. They can reduce the use of water on their red grape vines, but not on their white grape vines. This means that their tactical flexibility is low. Consequently, we classified their grape-growing enterprise as a rigid farm system.

ATTACHMENT 2. ROBUST FARM SYSTEM

Pasture and Cut-and-Carry Dairy

Jane and John bought their 135-ha dairy farm 5 years ago. They were new to Australia and decided to buy an irrigated property in northern Victoria because it was a secure area regarding water. They milk 250 cows at present but could milk up to 300 cows given that they can produce 12 tonnes of dry matter per hectare and need 5.5 tonnes of dry matter per cow.

They have a 400-ML surface water right and a groundwater bore, but because the groundwater is of reasonably poor quality, they have had to shandy it with surface water. Even with the groundwater Jane and John need very high surface water allocations to be able to fully irrigate the farm.

Since they purchased the property, the supply of water has been poor with allocations well below 100%. In addition, the water table has dropped below the intake of the bore. Water prices have been so high that Jane and John have not been able to afford to buy enough water to irrigate the whole property. Consequently, they have had to move to a cut-and-carry system to remain in business. They could invest in drilling deeper and buying new pumps if they wanted to continue using the groundwater. However, they think this is unwise as, given the need to shandy it, they would have to receive reasonable allocations of surface water to make the investment worthwhile. In short, Jane and John buy in feed because they cannot afford to buy water. To them, it is all about buying mega-joules of energy, whether it comes from water through pasture, or from grain off the back of a truck. It all comes down to which method offers the best value, and this is a constant balancing act. In fact, over the last 2 or 3 years, they sold some water and bought feed, as this was cheaper than growing their own.

For the last 2 years, Jane and John have rented some nearby land for dryland cereal cropping. A contractor plants and harvests the crop, and then they use it for silage. Having a feed source within 5 km of the farm has really brought the cost of feed down. Jane and John have put in a simple rock-based feed pad and troughs. This has reduced feed waste by 10% to 12%. The pad paid for itself within a season. They have also been soil testing and changing their fertilizer use because buying feed and bringing it onto the farm adds nutrients to the soil.

For Jane and John, being able to irrigate early in the season is vital. A good consistent diet is important for their cows, between calving in August and joining in October, to ensure high fertility. This means water is worth more to them early in the season. Also, pasture growth is a lot higher in the spring, so they get more feed produced for water applied. This means the value of water changes through the year for Jane and John. Consequently, when their water allocation is low, they irrigate as much of their pasture as possible early in the season. They then take paddocks out of production over the 2 to 3 months of summer, feeding the cows on the feed pad. They aim to re-sow dry paddocks every autumn to annual grasses, which means that having some water available around August can also be important so they can re-establish pastures. Jane and John are expecting carryover water to be an effective tool for ensuring they have water available early in the season.

They said that they have secured 6–7 months' worth of feed for the next season by carrying over water from this season. They think that having carryover will put pressure on the water authority to ensure the season opens on time. They feel this pressure is important because they fear the authority will try to shorten the season by pushing the start of the season back a couple of weeks into September. This could badly affect their ability to get good pasture growth in early spring. Jane and John do not have the capacity to vary their output mix without making changes to their farm production strategy; therefore, their strategic flexibility is low.

Jane and John do have some options for altering the use of irrigation water on their farm. Because timing of the use of water in the season is important, meaning starting the season late or ending it early would have negative outcomes for them, they use carryover water as a substitution tactic. They can also substitute purchased feed and grow dryland cereals for irrigation water and pasture production. This allows them to buy and sell water depending on the relative prices of water and grain and the allocation for the season. They can reduce their use of water by taking paddocks out of production as the season progresses and feeding their cows on a feed pad. They can also reduce their herd size. This means that their tactical flexibility is relatively high. Consequently, we classified their dairy enterprise as a robust farm system.

ATTACHMENT 3. ELASTIC FARM SYSTEM

Drip-Irrigated Mixed Farming

Andy has been farming for over 30 years. His farm covers 254 ha across three locations. The farm business includes a 16-ha orchard planted to peaches, apples, and pears. Andy's brother manages the orchard independently of the irrigated mixed enterprise business managed by Andy.

Andy has a 758-ML water right. His water use varies from 900 to 1200-ML/year, depending on summer rains. The farm started as flood-irrigated cattle grazing enterprise. Andy moved into growing tomatoes not long after he started farming because it offered higher profits. However, Andy stopped growing tomatoes this year because it is no longer as profitable as other crops. Tomatoes can only be grown on the same site for a year or two before problems arise with soil disease and organic matter. To avoid these problems, Andy used to move the tomato enterprise regularly to a fresh location on the property and replant to pasture for cattle production.

Initially, Andy grew tomatoes using short-row furrow irrigation. He then moved to long-row furrow irrigation using siphons and then eventually installed subsurface drip tape. The need to move the tomato enterprise regularly to a fresh location meant that it was common practice to lift and shift the drip tape every 2 years. Because this was particularly costly, Andy decided to try leaving the drip tape in place and follow the tomatoes with a crop rotation. This meant gradually expanding the area of sub-surface drip tape to maintain tomato production. Andy now has 200 ha of sub-surface drip. His only problems with the tape have been damage from insects and mice, mechanical damage, and root intrusion, all of which he can control through management.

Andy estimates that he saves 2 ML/ha by using the drip tape. Electricity use is his biggest cost as it requires considerable energy to get the pressure needed for the system to function effectively. Andy now grows a variety of crops including lucerne, maize, clovers, and cereals such as wheat and chickpeas. This season Andy has decided to fatten lambs on his irrigated lucerne as he thinks he will get a better price for lambs. He has run beef cattle in the past and provided agistment for dairy farmers. He decides what he wants to grow each season depending on the relative prices of crops, livestock, and water.

Andy tries not to over-capitalize in machinery purchases. He only buys machinery if he expects he is going to be using it for the next 5 years. Otherwise, he uses contractors for planting and harvesting. Andy is always able to buy some temporary water so dry weather does not worry him. Drier conditions are better for his business as a lower allocation means there is greater demand for his products and fewer competitors.

Andy said that knowing likely allocations at the beginning of the season is particularly important for some farmers so they can make sensible decisions, such as when ordering tomato seedlings in August for planting in October.

Andy said that mechanisms such as carryover do not really affect his decision making. He will buy (or sell) water depending on the price of water relative to crop prices. Andy has a high level of strategic flexibility because his existing production strategy enables him to vary his output mix easily by switching between crops (lucerne, maize, clovers, and cereals) and livestock production (prime lamb, beef cattle and dairy herd agistment). By using contractors and leasing machinery, he avoids adding to his infrastructure. His options to alter the use of water, without altering his output mix, are limited; fundamentally, his only option is to buy water if he needs more. Therefore, Andy has low tactical flexibility. Consequently, we classified Andy's irrigated mixed farm as an elastic farm system.

ATTACHMENT 4. ELASTIC FARM SYSTEM

Flood-Irrigated Mixed Farming

Patricia has a 300-ha mixed-production property that has been in her family for over 90 years. The farm began as a sheep (prime lamb and wool), horse, cropping and dairy business. It currently produces prime veal, prime lamb, cereal crops (wheat, oats, and barley) and lucerne (fodder and seed). Patricia runs the farm as a combination of irrigated pasture for stock and dryland cropping.

The farm has an 850-ML surface water entitlement. A few years ago Patricia put in a groundwater bore. The bore water is shandied when used on the paddocks. Patricia generally uses bore water on weekends during the irrigation season when electricity prices are lower. Patricia has a 50-ML reuse dam on her property, and she sometimes buys temporary water to irrigate her annual and perennial pasture.

Patricia has a mixed-farm business because diversifying helps her to maximize productivity. She is constantly thinking about the output mix and changes the mix regularly depending on the price she will get for the product, how it will fit in with her rotation and the effect on her soil.

Patricia's decision making has been greatly affected by low water allocations over the last 10 years. When water is scarce, she can change her production system to increase dryland cropping and reduce irrigated pasture. For example, in 2005, Patricia converted 50 ha of permanent pasture into crops because of limited water. Her plan is to convert back into pasture or lucerne when water allocations increase.

When switching between pasture and cropping, Patricia highlighted a few considerations. She needs to decide by early February if she is going to convert pasture to crops; otherwise, the soil will be too dry to remove the pasture. Rye grass is not used in the paddocks as this requires spraying when converting to cropping.

Switching back to irrigated pasture from cropping is a bit more difficult and requires confidence that there will be enough water to get it established. Patricia has converted a couple of cropping paddocks back to lucerne, which is the first step to going back into pasture. Patricia can also change her mix of stock when water is scarce, or market prices change. For example, lack of water in 2004/2005 led her to increase her sheep and reduce her cattle as sheep could be run on poorer-quality pasture than vealer cattle. Patricia is considering growing sorghum for hay and silage if water stays scarce, as it is compatible with her equipment. She has also thought about growing more barley, a short-season crop that requires a lot less water. She saw someone irrigating barley on bore water last year with fairly good results.

Patricia is in the process of upgrading her farm irrigation system to include more pipes and risers, which will reduce channel maintenance requirements and provide water savings.

Patricia has a high level of strategic flexibility because her farm production strategy enables her to vary her output mix by switching between dryland cropping and irrigated livestock production. Also, she has the capacity to shift emphasis within her pasture-based stocking enterprises between vealer cattle and prime lambs. She avoids changing her infrastructure by using contractors and leasing machinery. Patricia has limited tactical flexibility; she can use bore water or buy temporary water to substitute for her irrigation water allocation. Patricia is improving her tactical flexibility to a limited degree by installing pipes and risers. Consequently, we classified Patricia's irrigated mixed farm as an elastic farm system.