Manaaki Whenua
Landcare Research

Moving the Middle

Empowering rural land managers to act in complex landscapes

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Changing farm practice and causal diagrams

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INTRODUCTION

A conceptual framework drawing on farm management theory, social practice theory and system dynamics was developed to (i) provide a foundation for integrating the research across the Moving the Middle Research Programme, (ii) and to guide the identification and testing of leverage points in the programme. The framework is summarised in Appendix A.

Farms are classified into trajectories in the framework: rigid, robust, and elastic. These trajectories characterise the degree to farms are locked into practices because of the impact that changing practice would have on the strategic and tactical flexibility that farms need to survive the turbulence in their business, social and biophysical environment. Depending on the degree to which farms are locked into practices by their trajectory, changing practice can be categorised into types of strategic, tactical, complex, or incremental change. Each of these types of change has different consequences for the interaction between the farmer, the farm system, and the world outside the farm.

The framework is being used to identify some of the systemic factors (internal and external to farms) that influence the adoption of practices that affect the environmental performance of farms. In this report we document how these systemic factors differ between farm trajectories by constructing a causal loop model. The causal loop model provides a means for identifying:

- potential leverage points for each farm,
- commonalities that exist across the systems that affect farmers,
- and potentially critical leverage points in additional to those being investigated with in the programme.

In the next section we provide a brief description of how farmers make decisions about changing farm practice. The processes and/or pathways of influence followed by those who make decisions in systems external to the farm – yet which affect the farm – such as policy makers, financiers, and agents of change (all of which are being investigated in the programme). We then consider how the factors that influence farmers decision-making about changing farm practice can be represented in causal diagrams. We go on to describe a causal diagram that represents how the types (strategic, tactical, complex, and incremental) and rates, of practice change, can be influenced by factors external to farms. See Appendix B for a brief explanation of how to read a causal diagram.

BACKGROUND[1]

Changing farm practice, including the adoption of agricultural technologies, can be characterised as a form of high involvement purchase where farmers engage in complex decision-making when deciding whether they will change practice or not (Bewsell & Kaine 2004; Bewsell et al., 2007; Kaine 2008). Complex decision-making entails deliberate and systematic evaluation of the merits of the practice prior to adopting it. The farmer's perception of the merits, or otherwise, of the new practice derive from the degree to which they believe it will create benefits when implemented in the context of their existing farm system.

The process of identifying benefits requires farmers to invest effort in learning about the attributes of the practice. This means farmers must invest time and 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. They must be able to visualise how the practice will interact with their farm system. 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. All that we know about our world is based on models – all maps, statistics, books, databases, equations, and computer programmes are abstractions of reality. So too are the ways that we picture the world in our heads – how we *think* the world works. These are our mental models (Meadows, 2008). Much of our decision-making is based on such mental models.

Hence, the use of complex decision making in high involvement decisions such as changing practices implies that farmers develop explicit chains of reasoning to guide their decision making. This is consistent with general psychological theories of the fundamental logic of decision-making (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).

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 screening entails the use of non-compensatory criteria (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 with, and complexity of, the choice, significance and irreversibility of the outcomes, and the decision-maker's motivation (Beach and Connolly 2005). See Longley et al. (2012). See Kaine & Niall (2001), Kaine et al. (2002), Kaine et al. (2006) and Court et al. (2007) for some examples of non-compensatory screening of alternatives in relation to changing practices on farms.

REPRESENTING INFLUENCES ON INDIVIDUAL FARMER DECISION-MAKING WITH CAUSAL DIAGRAMS

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 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 explanation (which is influenced

[1] The content in this paper borrows heavily from Kaine (2008).

by, and influences, their mental models) which is then used to evaluate the extent to which the alternatives will meet their farming needs and upon which a decision is finally made (Cooksey 1996).

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 diagrams that incorporate characteristics of the farm systems and relevant external characteristics. These can help us to understand the inter-related nature of influence and causality and if/where feedback loops exist between farmer's and policy maker's goals and their efforts to achieve them (Bagozzi 2006, Kaine et al., 2013).

For example, public irrigation schemes in Victoria originally relied on gravity to distribute irrigation water to farms using open channels (Boland et al. 2005; Kaine et al. 2005; Kaine et al., 2008). The use of low-flow, micro-irrigation systems require a water supply that is continuously available and pressurised. Consequently, access to a water supply with these characteristics is a prerequisite for converting an orchard from flood or furrow irrigation to micro-irrigation.

The causal diagram in Figure 1 summarises the situation. In this example, the adoption of micro-irrigation would be facilitated by converting the public irrigation infrastructure from open channels to pressurised piping. Hence, policy regarding public irrigation infrastructure is seen as a potential leverage point for promoting the adoption of micro-irrigation.

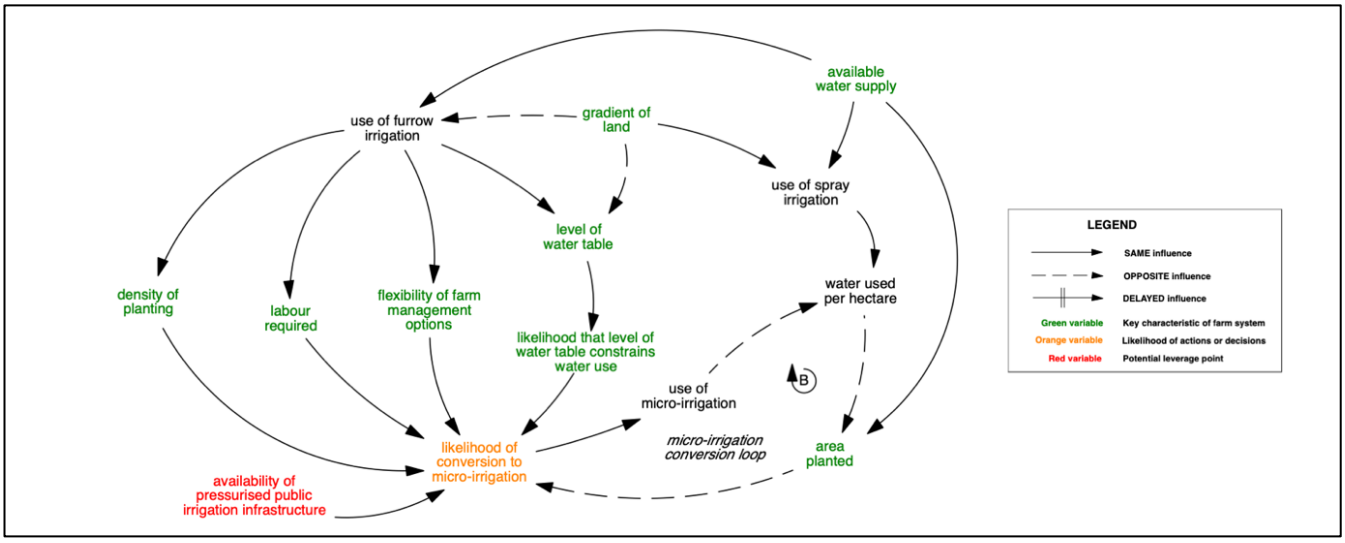

Figure 1. Causal diagram demonstrating factors influencing the likelihood of adoption of micro-irrigation by orchardists.

Notes: Green text denotes key characteristics of the farm system. Orange text denotes likelihood of actions or decisions. Red text denotes potential leverage point.

Source: Based on Boland et al. 2005 and Kaine et al. 2005.

REPRESENTING INFLUENCES ON THE DECISION-MAKING CONTEXT OF INDIVIDUAL FARMERS

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 and constructing causal diagrams provides a starting point for:

- Assessing the impact of the policy measure on farm practice, and
- Identifying the key external influences on implementing or responding to the policy measure.

This is illustrated in Figure 2 with respect to constructing wetlands on farms which is based on Kaine & Polyakov (2023).

The factors in the farm system that influence the decision as whether to construct a wetland include, among others, the presence of a wet area on the property, whether the wet area supplies good quality pasture, whether fencing it would create a choke point regarding the movement of livestock around the property.

If the creation of the wetland involves earthworks or stream diversions, then a resource consent may be required from the relevant regional council. The requirement for a resource consent may prompt the farmer to abandon construction of the wetland depending on their opinion of the regional council. For example, farmers may fear that involving the regional council may mean they lose control over the siting of the wetland, its design, and increase the costs, time and effort involved in constructing the wetland (Kaine & Polyakov 2023).

This causal diagram has been expanded in Figure 3 by linking the level of biodiversity, which is impacted by farmer's actions, to the policies of regional councils. This creates a feedback loop linking on farm activity and the council's activity. Assuming regional councils have increasing biodiversity on private land as a policy objective then the decisions of farmers to construct wetlands will affect the achievement of this objective. Since farmers' decisions about constructing wetlands depend, at least in part, on the need for resource consent, a feedback loop is created between council policies regarding resource consents and farmers' decisions about establishing wetlands and creating biodiversity. In these circumstances, the policies of councils (and their translation into the need for, and conditions of) resource consents become a potential leverage point with respect to the scale and rate of creation of biodiversity on private land.

Another causal diagram in Figure 4 shows how farmer's actions may fit in relation to policies of regional councils and policies of the central government. In this example Regional Councils are assumed to have policies to (i) increase biodiversity on private land and (ii) to increase riparian planting on private land to improve water quality. Central government is assumed to have a policy to promote carbon sequestration through an emissions trading scheme.

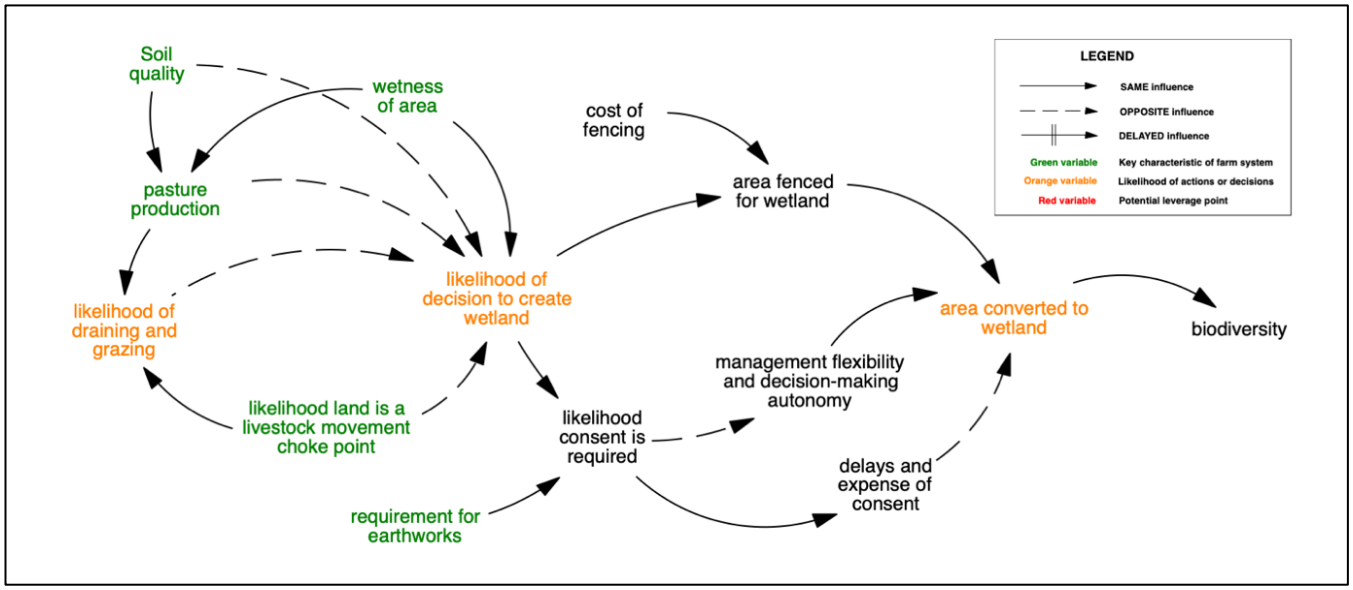

Figure 2. Causal diagram for creating wetlands.

Notes: Green text denotes key characteristics of the farm system. Orange text denotes likelihood of decision to proceed to create wetland or not, or the area eventually converted to wetland.

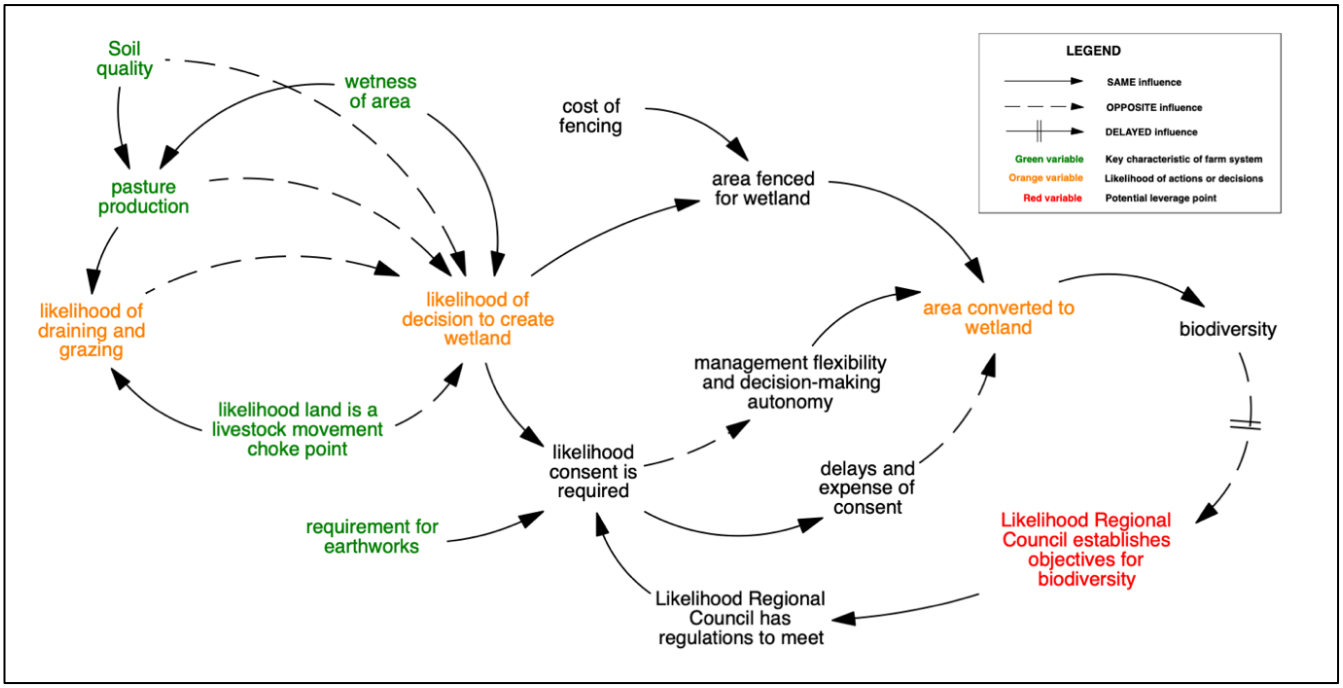

Figure 3. Causal loop diagram for creating wetlands.

Notes: Green text denotes key characteristics of the farm system. Orange text denotes likelihood of decision to proceed to create wetland or not, or the area eventually converted to wetland. Red text denotes potential leverage point.

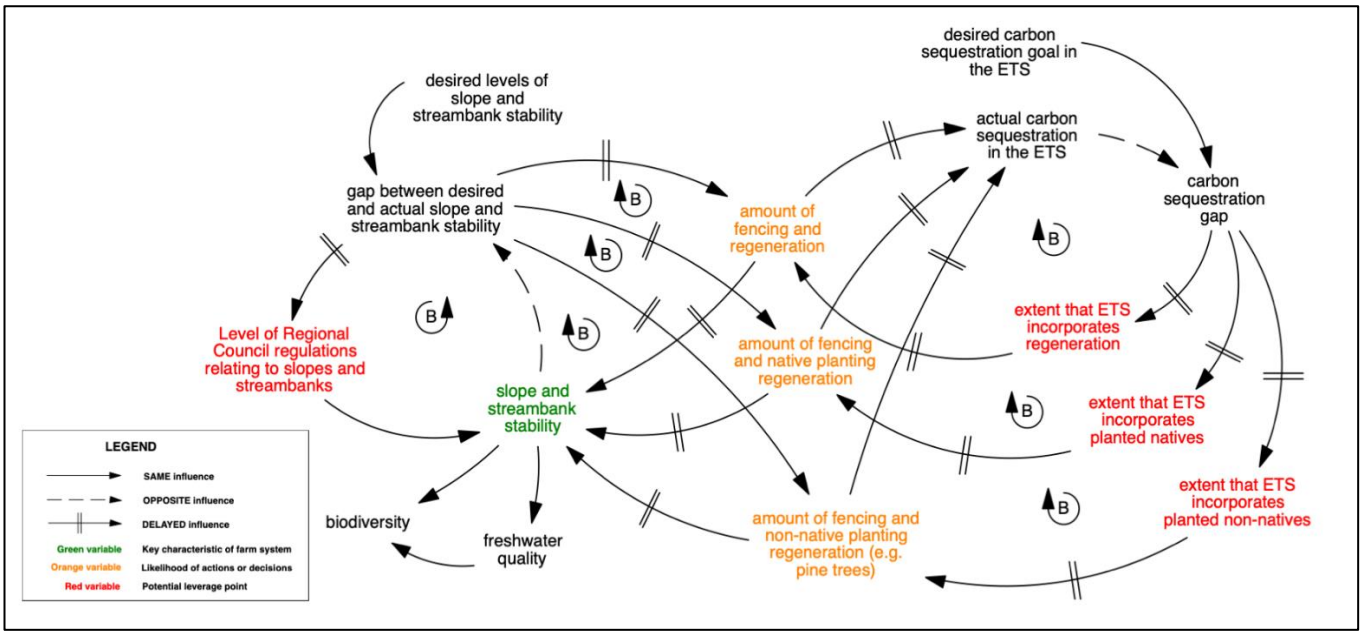

Figure 4. Causal loop diagram for increasing biodiversity and improving water quality.

Notes: Green text denotes key characteristics of the farm system. Orange text denotes farmer's decision to proceed to plant trees and shrubs or not. Red text denotes leverage point.

Farmer's decisions to plant native trees to stabilise slopes and streambanks, and their decisions to plant riparian strips to improve water quality will depend, at least in part, on the reward for sequestering carbon by planting native trees relative to and non-native trees (Kaine 2021; Edwards et al. 2022). That is, it is not dependent on Regional Council policy alone. If the return to planting native trees is less than the return to planting non-natives,

then farmers may simply postpone planting, or they may choose to plant non-natives. Both options have the potential to hinder improvement on water quality and biodiversity. Hence, in this example, the policies of the central government in relation to the recognition of, and reward for, carbon sequestered by planting native and non-native trees in the design of the emission trading scheme becomes a potential leverage point with respect to the scale and rate of improvements in water quality, and the scale and rate of creation of biodiversity on private land.

A GENERAL CAUSAL DIAGRAM REPRESENTING THE CONCEPTUAL FRAMEWORK USED IN THE MOVING THE MIDDLE

A variety of causes can trigger changes in farm practice including:

- 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 such as access to public infrastructure and changes in seasonal conditions and climate.
- changes in practices of relevant external parties such as financial institutions, input suppliers and purchasers of farm outputs

Here we show how these influences can be represented in a general causal diagram to illustrate the feedback loops that may arise between government policies and farmers' decisions and responses, depending on how policies influence the need for strategic, tactical, complex, and incremental changes on farms.

The model is summarised diagrammatically in Figure 5.

First, the categorisation of potential adopter farmers into the different change types (strategic, tactical, complex, and incremental) moves the farmers from the **blue shaded areas** on the left-hand side to the relevant box (or stock) representing the type of change required at the left of the **orange shaded area** in the middle of the diagram. The influences that do this are captured in the **dark and light blue shaded areas** of the diagram.

The essential factors and feedback loops that influence the movement of farmers from their categorised type of adoption through to actual adoption, are captured in the **orange shaded area** of the diagram. These arise from the reactions of policy makers to the difference, if any, between the desired rate of change in farm practice and the actual rate of change in farm practice and the reactions of farmers to the measures that policy makers enact.

These policy interventions are in turn based on the perceived level(s) of environmental health which, if not at an appropriate level, over time lead to greater awareness of an issue and resulting pressure for action. This is shown in the **green area of the diagram and the loops around the outside of the shaded areas**.

Within the orange shaded areas of the diagram, when the actual rate of practice change falls sufficiently below the target rate, policy makers may:

- Invest in research that enables farms facing a strategic change to switch to a tactical change (and so potentially change more quickly) by creating new technologies that either create substitutes for the critical input or increase the efficiency with which the critical input is used. This is shown by the 'investment in innovation' factor and associated loops.
- Invest in research that enables farms facing a complex change to switch to an incremental change (and so change more quickly) by creating new technologies that better suit the relevant farm systems. This is also shown by the 'investment in innovation' factor and the associated loops.
- Develop policy guidelines for farms facing a complex or incremental change that allow them to change more quickly by relaxing the conditions, or simplifying processes, for obtaining a resource consent. This is shown by the 'likelihood resource consent conditions relaxed' factor and associated loops.
- Offer incentive programmes that assist farms facing a complex or incremental change to change more quickly. This is shown by the 'likelihood of incentives to adopt' factor and associated loops.

- Offer compensation programmes that assist farms facing a strategic change to change more quickly. This is shown by the 'likelihood of compensation to support farm adoption' factor and associated loops.
- Implement regulations making practice compulsory for farms facing complex or incremental change. This is shown by the 'likelihood of regulation to require adoption' factor and associated loops.

Hence, in this diagram, factors that influence the actual rates of adoption of the practice change are potential leverage points. This qualitative diagram does not suggest which may be more powerful.

Note that factors that influence the rate of adoption of the different types of change in the orange section, will help increase the total rate at which adoption occurs. These factors include economic conditions (commodity prices, interest rates, logistics, labour costs), the regulatory environment (animal welfare, labour welfare, environmental policy), climate and social conditions (farmers' aspirations). The overarching political environment and resulting political targets for farm change and adoption, may be influenced by political agendas and the pre-existing regulatory environment.

CONCLUSION

We have constructed a causal diagram that reflects the conceptual framework that was developed to guide the Moving the Middle programme. The trajectories that characterise the degree to which farms are locked into practices, and the types of change required to change practice, are represented in the model. In this model we have focused on the feedback loops that arise from the reactions of policy makers to the difference, if any, between the desired rate of change in farm practice and the actual rate of change in farm practice and the reactions of farmers to the measures that policy makers enact. The target rates of practice change set by policy makers (which are often implicit) emerges as a key leverage point in this model. We plan to extend and refine the model during the programme.

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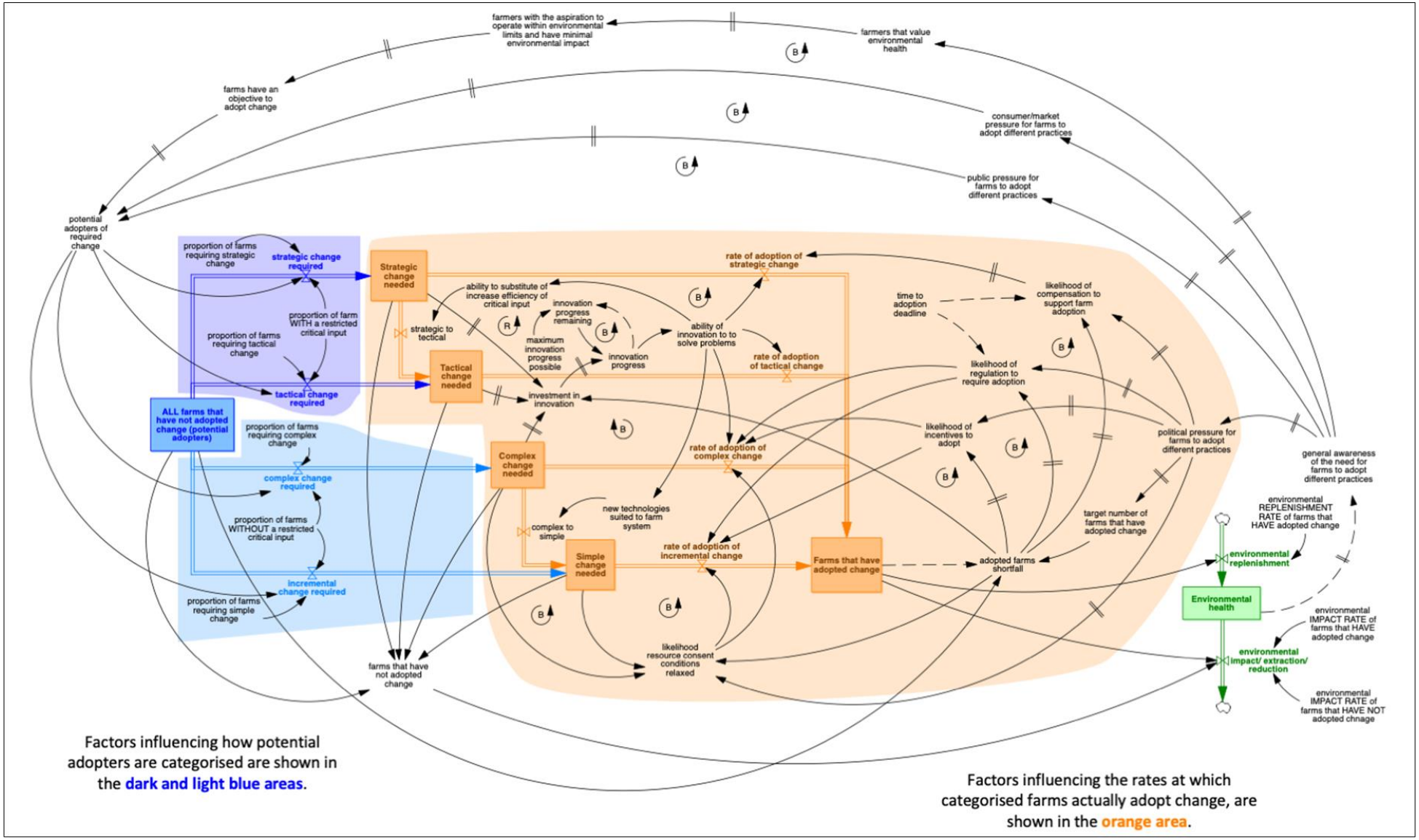

Figure 5: Causal diagram capturing the conceptual framework used for the Moving the Middle project.

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APPENDIX A: SUMMARY OF THE CONCEPTUAL FRAMEWORK

MOVING THE MIDDLE CONCEPTUAL FRAMEWORK

BACKGROUND

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. A conceptual framework for Moving the Middle 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 A1 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.

Table A1. 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.

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.

SOCIAL PRACTICE THEORY[2]

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 A2).

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.[3]

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

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

Table A2. 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. [4]

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

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

modifiable, mechanistic characteristics such as taxes, incentives and standards, or physical elements of a system, 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 A3. 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 signaled by the extent to which the change restricts access to critical inputs.

Table A3. 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
	Buffer stocks	Silage, cash, overdraft, grain stores, water availability
	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.
		Farmer
	Power to transcend	

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.[5] 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, nutrient, pastures) 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.[6] The resulting conceptual framework with hypothetical examples is presented in Figure A1.

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).

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

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

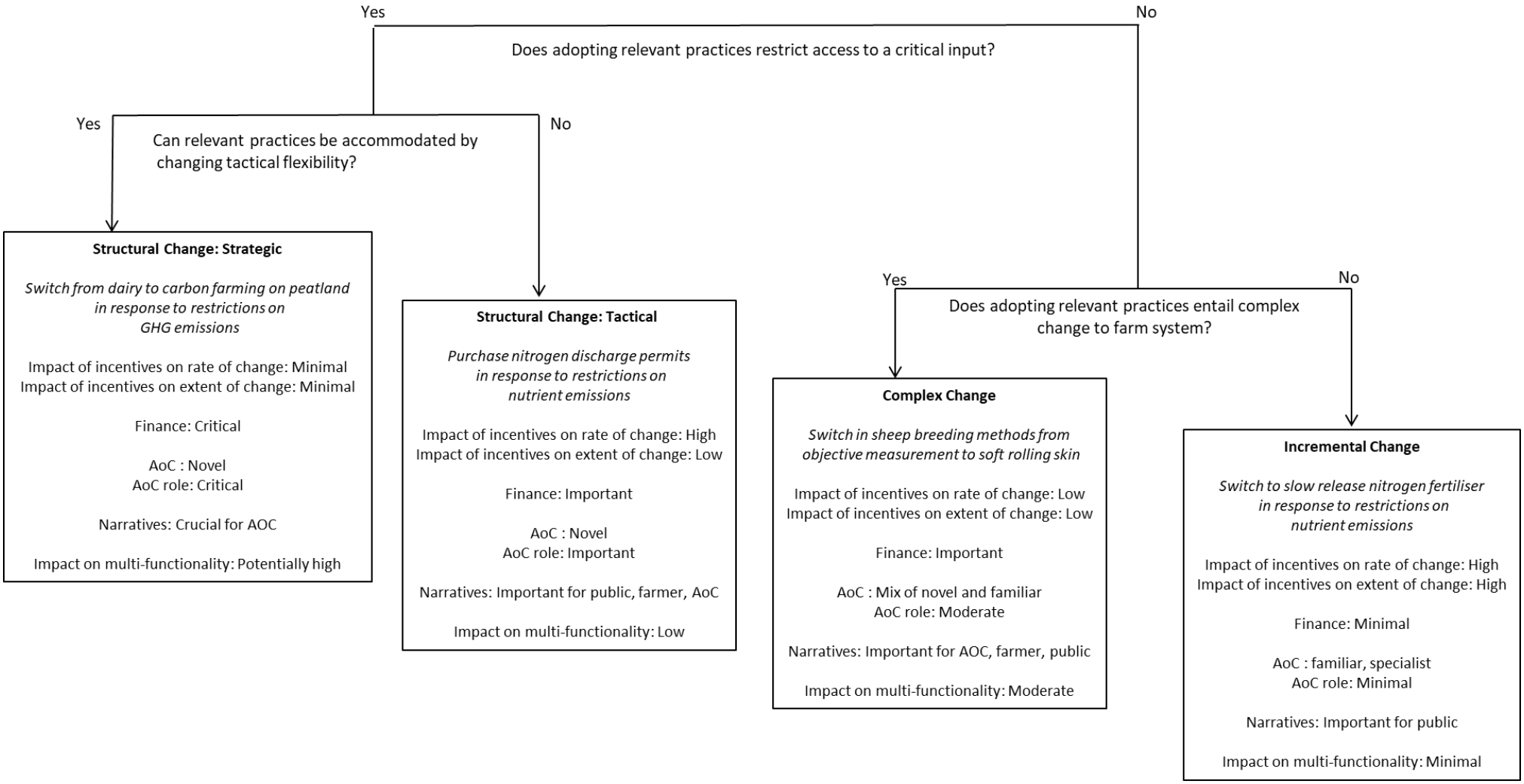

Figure A1. Diagrammatic summary of conceptual framework

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. 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. [7]

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.

How quickly the switch to a superior practice happens depends on characteristics of the practice itself (e.g. complexity, observability, ease of trialing, 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.

[7] 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.

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).

Appendix B: HOW TO READ A CAUSAL DIAGRAM THAT INCLUDES STOCKS AND FLOWS.

THINK LIKE A BATHTUB

A useful analogy used in systems thinking is the bathtub analogy. This helps to conceptualise important parts of your focus: where do things build up or decline? Or, where do things accumulate and decumulate?

In a metaphorical bathtub, the level of the bathtub is the level of something that you are interested in. This level can build up or decline. A bathtub (sometimes called stocks) might be anything that we are interested in – number of people, quality of water, level of morale, etc. In the diagrams in this summary report, it is farms or farmers who may be or are potential adopters of change.

The level in the bathtubs can ONLY increase through more inflow (the tap over the metaphorical bathtub), and ONLY decrease through more outflow (the drain in the metaphorical bathtub). This applies for whatever you are interested in – just like the level of water in a bathtub. See Figure B1.

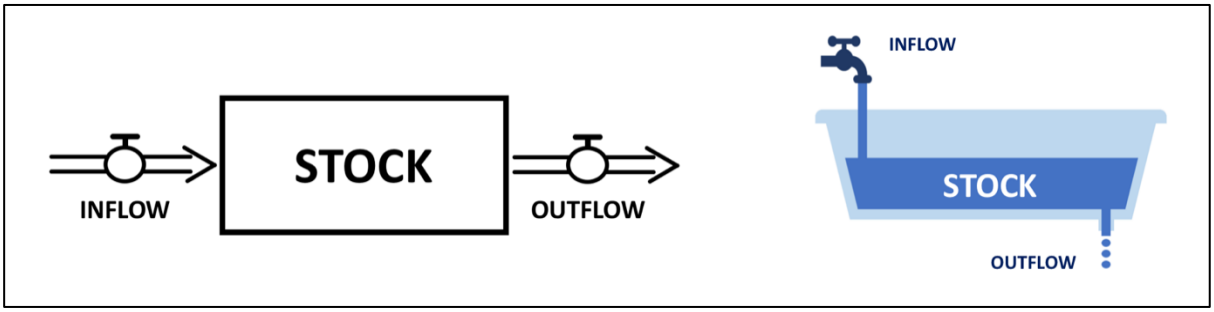

Figure B1. How the 'bathtub analogy' is used to represent accumulation in a causal diagram.

The inclusion of a conceptual bathtub in a causal diagram allows a greater level of insight to understand whether a change in a key variable (bathtub) is due to a change in inflow (tap) or a change in outflow (drain).

FEEDBACK LOOPS

Feedback loops are the basic building blocks of causal diagrams and are how circular causality is represented. There are two types: reinforcing and balancing.

In a reinforcing feedback loop, influence transfers around the loop and back on the original factor in the same direction. That is, if it goes up, it will continue to go up, or vice versa. This reinforces the direction of the original influence, and any change will build and amplify. Reinforcing loops can operate in both upward or downward directions. They drive growth or decline in a system.

For example: (untouched) money in the bank will earn compounding interest and grow; or rust will expose more metal to corrosion and thus more rust.

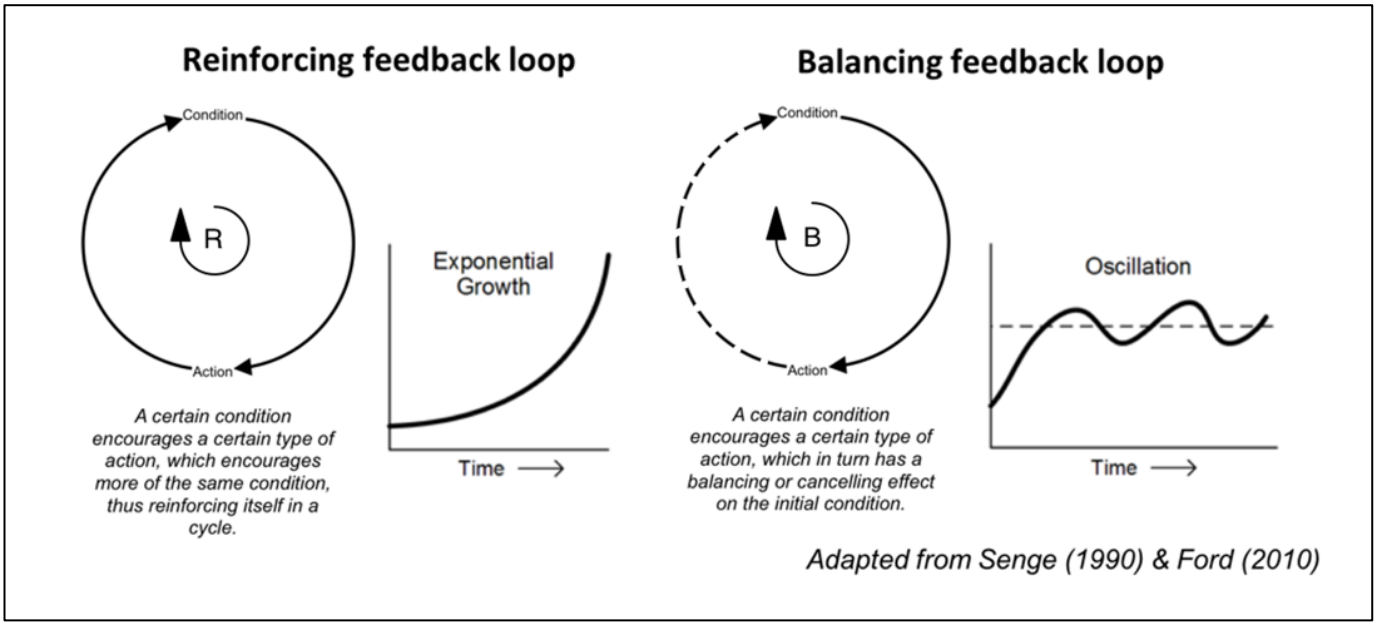

Figure B2. The two types of feedback loops

In a balancing feedback loop (Figure B2), influence transfers around the loop and back on the original factor in the opposite direction. This, if it goes up it will then go down, or vice versa. This balances the direction of the original influence. They create control, restraint or resistance in a system.

For example: a thermostat connected to a heater will turn on if the room is cold, this will heat the room then turn itself off. The room will then cool until the thermostat turns on again and the cycle begins over again.

A NOTE ON HOW ARROWS ARE LABELLED IN CAUSAL DIAGRAMS

Causal diagrams (and feedback loops) are made up variables connected by arrows representing causal influence. There are two kinds of causal influence (Figure B3):

Same influences are when change in the direction in one variable leads to a change in the same direction in the next variable. i.e. if A goes up, then B goes up (or vice versa). Same influences are arrows with a solid line.

Opposite influences are when change in the direction in one variable leads to a change in the opposite direction in the next variable. i.e. if A goes up, then B goes down (or vice versa). Opposite influences are arrows with a dashed line.

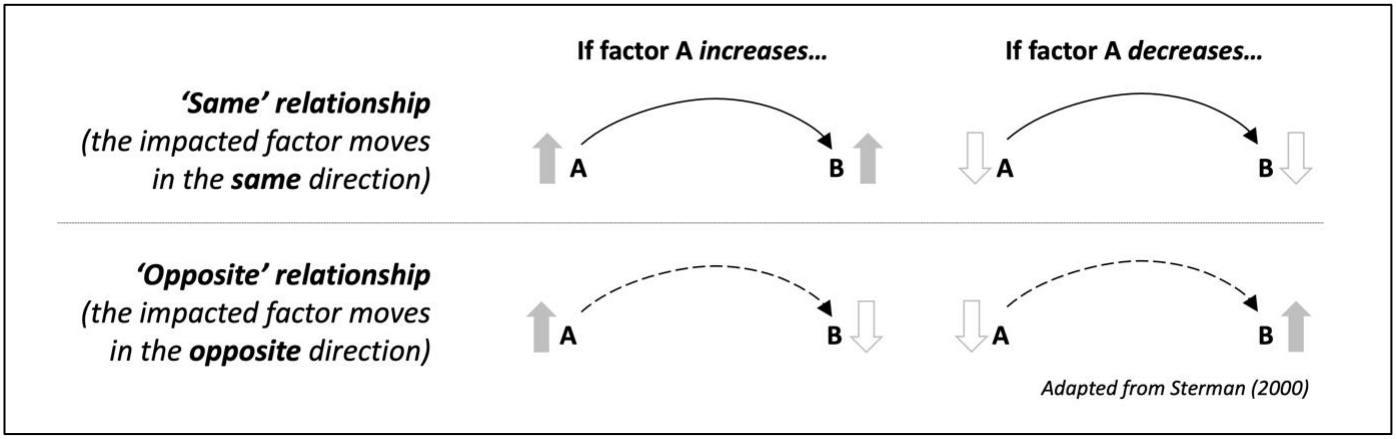

Figure B3. The two types of influence in a causal diagram

Delays are there a delay between cause and effect, for example change occurs in variable A yet it takes time to present in variable B. These are represented by short double lines across an arrow. In causal diagrams delays are relative, i.e. this time take to present is longer relative to others shown in the Figure B4.

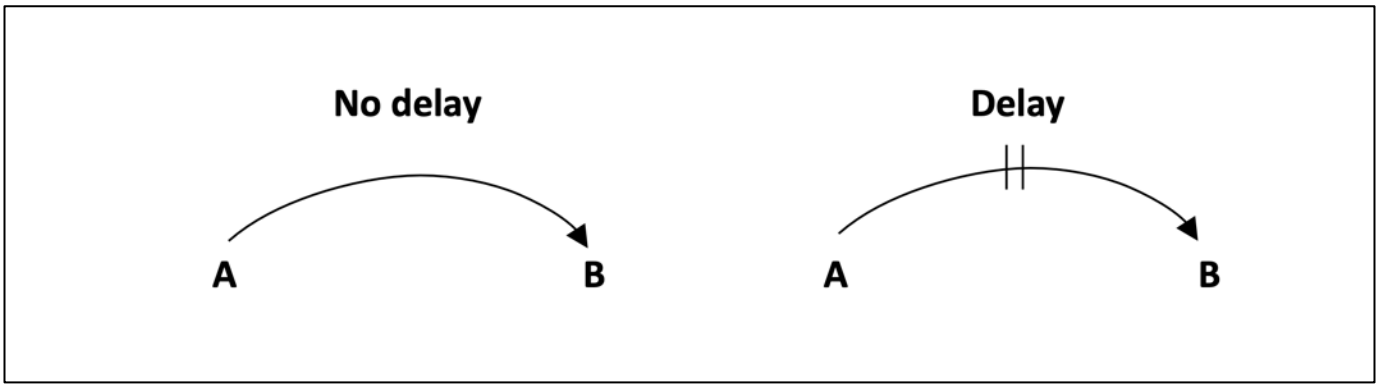

Figure B4. How conceptual delays are represented in a causal diagram