Live sensor data for environmental monitoring and improvement

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Executive Summary

This project was intended to investigate the potential uses of remote sensor environmental data by farmers to help them improve their environmental outcomes. This could promote innovative management practices whilst making compliance easier for farmers.

The concept of 'outcome-based' regulation as well as environmental monitoring through sensors has been explored with some good applicable literature from case studies available to study.

Several common themes emerged from this literature around benefits and risks as well as the importance of the system design.

Due to their nature of basing regulation around outcomes farmers can self-manage their environmental outcomes, removing managerial restrictions to not only allow, but encourage farmers to innovate and achieve better and more cost-effective results.

European researchers have noted farmers improve their skills over the duration of result-based schemes and form new social connections between conservationists/ecologists due to their common goals. It was also theorised that change may also occur in the relationship between farmers and the public, with farmers assuming the responsibility for management practices and the credit for environmental improvements as opposed to merely meeting government requirements.

Better environmental monitoring data would be hugely beneficial to both regulators and farmers as the feedback would allow for better prioritisation of actions and funds. To maximise these benefits, it has been shown that the timing and frequency of water sampling is of great importance. Water quality varies greatly around storm events, within seasons and between years. Data needs to be amassed over several years to fully understand the real impact of land management practices.

The risks of outcome-based regulation have come through the literature as:

- The need for careful establishment of desired outcomes, how they are benchmarked and how they are measured.
- Possible lack of effective mitigation options and farmers exposure to events beyond their individual control e.g., large flooding events
- The issue of data ownership and how it is used and/or shared

The success of any outcome-based scheme would be greatly dependant on the identification and development of indicators. These should be carefully considered, and a balance needs to be struck between minimising the scheme complexity and having sufficient indicators to represent the objectives. If this cannot be achieved a combination of regulatory approaches may be necessary.

The last risk identified is the need for a better understanding on how farmers are likely to respond to result oriented approaches. Past examples have shown many benefits, these are mainly concerning agricultural subsidies and a switch to compliance may change the results.
With this technology still in its earlier stages of development, the cost and availability of sensors combined with poor rural connectivity make the possibility of widespread adoption purely theoretical, at least currently.

I conclude that it is too early for New Zealand to incorporate an outcome-based regulation system. Given the substantial benefits which may be achieved I don't believe the idea should be completely abandoned and I have recommended further trails to understand and quantify any potential efficiencies. As technology develops further and becomes less prohibitive a hybrid model of 'action' and voluntary 'outcome' based regulation may be created reducing the cost of compliance and helping farmers to be seen as part of the solution and not part of the problem.

My main recommendations are as follows:

1. Address data ownership and use issues. Any increase in data capture and reporting requires a data strategy addressing data ownership and how it is to be used. In order for farmers to voluntarily give their own environmental data to a regulatory body there would need to be assurances made to address any concerns in this area.
2. Begin environmental data collection. Early trial work by regulators would provide feedback and learnings from live sensor data. This would help in designing required actions for environmental protection. It would also have value if data can be incorporated into existing models to strengthen their validity.
3. Identify indicators for monitoring. Designing a system of effective indicators should be carefully considered and would need to involve a high degree of consultation. If an environmental outcome cannot be monitored simply and effectively then an outcome-based scheme may not be appropriate for that measure.
4. Start small, proof of concept trials. This might suit larger high-country properties where it can be safely assumed that water entering the grazed areas is of high quality. Water leaving the property could then be monitored to establish agricultural impacts. This would have benefits as the cost to fence off all water ways on these properties would likely be uneconomic if required under an action-based scheme.
5. Explore options for a hybrid model between action and outcomes based environmental legislation.
6. Allow voluntary data use. Live sensor data could well be incorporated as a voluntary component of a digital farm plan, creating a 'hybrid' model allowing innovative farmers and regulators to test the approach before wholescale adoption.
7. Factor in future technological advances in writing regulation. Currently the technology looks to make this option cost prohibitive. Legislation could be written now to allow for its use in the future.

1.Introduction

1.1 Objective of project

Recent developments in the Internet of Things (IoT) and in particular water quality sensors are beginning to enable live, reliable, and auditable water quality data.

This project was intended to investigate the potential uses of remote environmental sensor data by farmers. Initially the thought of using this data for regulatory compliance was just a part of this however it became more of a focus as I discovered the existing global work looking into what was called “result” or “outcome” based systems.

By improving land manager knowledge of freshwater contamination sources, timing and loads my hope was that mitigation efforts might be directed more effectively to achieve improved outcomes. As an example, if a property’s main contaminant source is nitrogen leaching from a shingle wintering pad, then time and money spent fencing off waterways may not generate the highest degree of environmental improvements possible.

If farming businesses could use data collected as a part of meeting their legislative requirements the business case for using sensors would be strengthened. The idea could encourage innovation and productivity whilst making compliance easier for farmers.

I have chosen to focus more on potential benefits and risks and a little less on the technical feasibility of sensor capability. This is due to the rapidly changing landscape and an acknowledgement that any information provided will quickly be out of date.

Farmer and regulator behaviours and drivers were always going to be important as any idea that doesn’t have sufficient buy-in will not succeed.

My research question looked to weigh up these risks and benefits.

1.2 Background

The National Policy Statement for Freshwater 2020 provides local authorities with direction on how they should manage freshwater under the Resource Management Act 1991 (Ministry for theEnvironment, 2021).

At a legislative level the requirements focus on outcomes, however when implemented at a local authority level, prescriptive actions (or restrictions) are generally used.

The Freshwater NPS is one of four pieces of national direction for managing New Zealand’s freshwater. Local authorities are also required to give effect to:

- National Environmental Standards for Freshwater
- Stock exclusion regulations
- Water measurement and reporting regulations.

(Ministry for theEnvironment, 2021)

The favoured way of assessing farm businesses is through the use of farm environment plans (FEP’s), there is work underway to digitalise these plans which will enable them to be ‘working’ documents rather than an assessment at a single given point of time.

With increased use of digital FEP’s comes the possibility of incorporating live sensor data to measure actual environmental outputs rather than using estimates based on modelling. Farms have many

variables such as soil water content, rainfall, aspect and slope, pasture covers, stocking rates and policy, soil fertility and downstream mitigations to name a few. A single, modelled quantity of contaminant will have multiple actual possibilities dependant on the complex interactions between the many influencing factors. Actual measurements will accelerate farmer learnings and quantify efforts to encourage constant improvements, farmers generally want to do better, and this could be a tool to enable that.

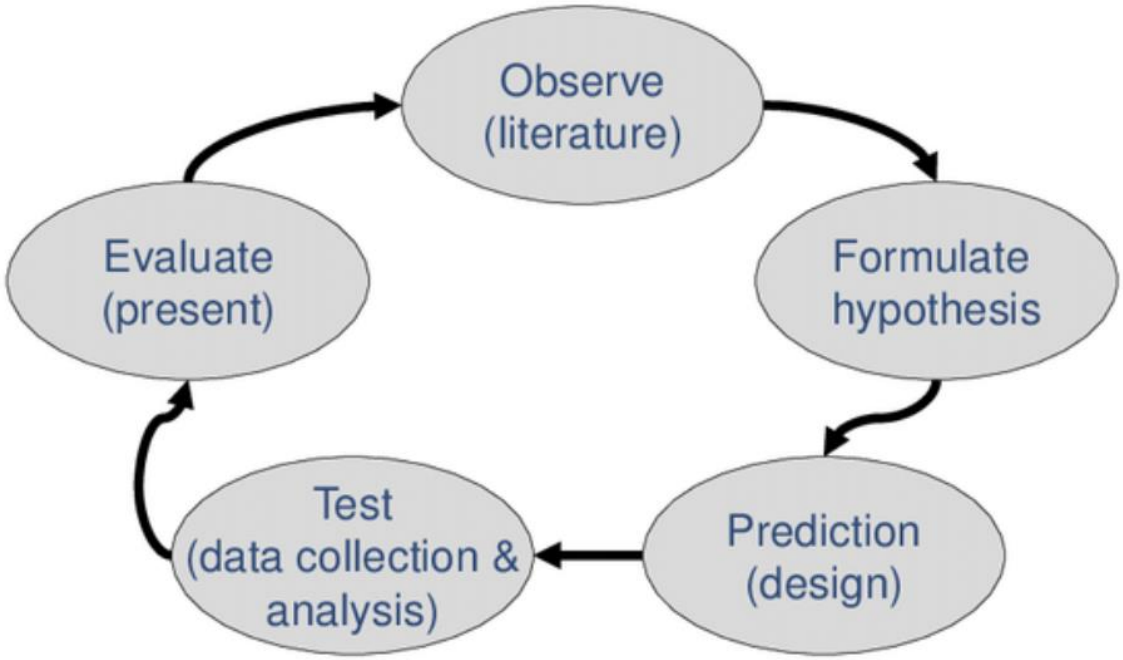
2. Methodology

The methodology for this research project included a literature review consisting mostly of past research papers referring to case studies.

Several common themes emerged and using the hypothetico-deductive model (Figure 1), I was able to deduct a hypothesis and comment of some design requirements.

FIGURE 1

The hypothetico-deductive cycle commonly used in hypothesis testing



(Wicherts, 2017)

Initially I intended to then interview farmers and rural professionals but as the subject became increasingly theoretical, I looked further into the implications found from existing trials.

As technology develops further investigations would be required to determine specific farmer attitudes towards this topic, this is where surveys might be of more value but relevance of any such survey at this point would be questionable.

3. Case Studies

3.1 Timing, frequency of sampling affect accuracy of water-quality monitoring

This research paper looked at some technical standards and issues around water quality monitoring off California's 'rangelands', defined as "*…are distinguished from pastureland by the presence on them of native vegetation, rather than of plants established by human societies, and by their management principally through the control of the number of animals grazing on them, as opposed to the more intensive agricultural practices of seeding, irrigation, and the use of fertilizers"* (The Editors of Encyclopaedia Britanica, 2018). This environment is comparable to much of New Zealand's South Island high country and could give valuable insights into management, and monitoring options in this sensitive area. California's water resource has come under pressure in recent years from multiple groups, many with concerns around the effects of grazing rangelands on water quality. The paper noted, "*the listing of various anadromous fisheries on the Federal Endangered Species List, development of numeric standards (Total Maximum Daily Loads) for nonpoint source constituents and litigation concerning grazing impacts on watersheds that provide municipal drinking water ensure that this interest will not diminish soon. Sediment, nutrients, pathogens and increased stream-water temperature are the primary water-quality concerns on California rangelands"* (Kenneth W. Tate, 1999).

The authors used both water quality and quantity sampling to assess and demonstrate the variability of water quality across years, within a single year and around significant weather events.
They found that "*timing and frequency of water sampling from the storm to the annual time scale play an extremely significant role in water-quality monitoring and suggest that a minimum sampling strategy should include sampling before, during and after storms. Samples must be collected over a period of several years to account for variability among years"* (Kenneth W. Tate, 1999).
Some common needs highlighted in this example and New Zealand's current Freshwater Management legislation are included below:

- *Key to an effective water-quality monitoring program is the establishment of well-planned and concise monitoring objectives.*
- *A common monitoring objective of ranchers and managers is to determine pollutant levels in water bodies that pass-through lands they manage and to identify possible contributions resulting from their management activities.*
- *Watershed groups and funding agencies are often interested in assessing improvements in water quality following implementation of best management practices (BMPs) such as erosion-control structures or improved grazing management.*
- *Regulatory agencies charged with developing Total Maximum Daily Loads (TMDLs) are required to document reductions in pollutant concentrations and loading for several decades into the future.*
- *…difficulties with funding, logistics, technical skill and the inherent variability of nonpoint source pollution on rangeland watersheds can make it extremely difficult to achieve monitoring objectives.*
- *inherent temporal variability of several important nonpoint source constituents at the individual storm event, seasonal and annual time scales from experimental rangeland watersheds in Northern California.*

(Kenneth W. Tate, 1999)

This paper concluded that:

- *Our data illustrate that the timing and frequency of sampling from the storm to the annual time scale play an extremely significant role in determining the ability of monitoring to meet any of these objectives.*
- *One year, even several years, of data are often not enough to distinguish confounding temporal and weather influences from the real impact of land use or BMPs.*
- *At a minimum, significant and consistently collected data both before and after a specified treatment are required to document the causal relationship between water-quality parameters and management changes.*
- *Timing is everything when it comes to designing a proper water-quality monitoring program.*

(Kenneth W. Tate, 1999).

These findings provide valuable insights into the opportunity of live sensor data and the risks associated with current monitoring practices.

3.2 Outcomes-based environmental regulation: an Australian Government perspective

The Australian Department of the Environment was looking at an outcomes-based environmental approval system and considering how it could design and implement an outcomes-based approach to environmental regulation. This information was presented at the EIANZ (Environment Institute of Australia and New Zealand) Annual Conference 2014.

- *Globally, the preferred approach to regulation is changing over time*
- *Outcomes-based regulation needs to be applied in the right circumstances*
- *Outcomes-based regulation creates risks for business and regulators in the EPBC (Environment Protection and Biodiversity Conservation) Act context*
- *The Department's current approach to regulation has its own risks and does not necessarily achieve good environmental outcomes*
- *When the risks are managed outcomes-based approvals can be a better practice approach which provide significant scope to reduce and simplify environmental approval conditions*
- *Designing successful outcomes-based regulation relies on trust and good relationships with business*
- *It is essential that outcomes are measurable and enforceable*
- *Trusted proponents could access a faster assessment process if they engaged early in the design process*
- *A regulator can assess the overall risk of the action in order to determine the most appropriate approach*
- *Public accountability for outcomes is a key element of a successful outcomes-based system*
(Australian Government - Department of the Environment, 2014)

The presentation acknowledges that there is potential to improve the regulatory system to achieve better environmental outcomes and that an outcome-based system could have applications for this. The issues with this approach follow some common themes with other case studies including:

- *Available data (on a project basis and a whole of system level) remains an obstacle for many projects*
- *A key message from both business and departmental officers is that it is necessary to have accurate baseline data to measure outcomes*
- *This may be difficult for greenfield projects and those referred early in the development process*
  (Australian Government - Department of the Environment, 2014)

As stated, *"A combination of regulatory approaches may be necessary"* (Australian Government - Department of the Environment, 2014), the use of reliable and accurate environmental sensor data could help overcome some of the stated risks and make an outcomes-based approach more feasible in the future.

3.3 Result-oriented agri-environmental schemes in Europe and their potential for promoting behavioural change

Rob J.F. Burton[a,*], G. Schwarz[b]

This paper reviews and discusses the implementation of 'Result-oriented schemes' in the European Union (EU), with respect to agricultural subsidies and environmental objectives.

Traditionally 'action-orientated approaches' have been used by the EU to legislate and enact on environmental and conservation values with farmers being paid for the delivery of land management practices rather than desired outcomes.

While by some measures, the 'action-oriented' approach has been "*exceptionally successful*" (Rob J.F. Burtona, 2013), there is an acknowledgement that the EU may not be getting the best return on investment with this approach. With budget pressures being a constant political concern, one option which has been considered in the EU is the implementation of result-orientated schemes.

As mentioned in the paper, a 2010 communication on future challenges in the food, natural resource and territorial areas pushed further in this direction in observing the "paramount importance" of developing new, more cost-effective, delivery mechanisms for environmental goods and noting that a more outcome-based approach "would best steer the policy towards EU priorities and show what it actually achieves" (Rob J.F. Burtona, 2013).

Further benefits outlined in the paper include the development of new skills and knowledge by encouraging farmers to innovate to improve environmental performance.

Some additional issues with action-based schemes, beyond cost efficiency, are mentioned as "outcomes in terms of both targeted species protection and general biodiversity are often rather poor" and "the practice of restricting farmers' behaviour does little to foster commitment to nature conservation. In fact, restrictions on behaviour are often viewed with resentment and/or act as a disincentive for scheme participation" (Rob J.F. Burtona, 2013).

Two key points were noted as 'problem areas' towards Result-orientated schemes – increasing risk for farmers and the need to develop effective indicators. These factors remain relevant in a New Zealand environmental regulation setting, perceived or otherwise. Any sensor data would need to be rigorous and proven enough to be used as effective indicators.

As mentioned in the paper, action-oriented approaches continue to be the commonly used, as is the current and proposed case in NZ. They are relatively easy to implement and monitor, are easily understood by farmers and are often the only feasible option.

This paper concluded that while there are many positives to result-orientated schemes, many of these are theoretical and the associated risks may easily out-weigh the benefits.
The risks include:

- *there may be situations where result-oriented schemes are simply not effective in meeting the provision-goals, in particular when it is not possible to develop simple, reliable and self-monitorable indicators*
- *very little experience has so far been generated in applying result oriented AEMs for environmental objectives other than biodiversity conservation or enhancement*
- *the question of how widely these approaches can and should be applied remains an open one*
- *there is as yet neither sufficient understanding of the processes for implementing such schemes, nor any certainty of the environmental outcome – especially at wider scales.*
- *In particular, we need more empirical studies into how farmers are likely to respond to result oriented approaches before initiating major changes to current policies*

The authors conclude "*we contend it would be a mistake to jump into result-oriented provision without making a major attempt at the EU level to understand exactly what is required for success and what the long-term environmental, economic and social outcomes are likely to be* (Rob J.F. Burtona, 2013)". Result-oriented schemes were seen as having the potential to complement current action-oriented approaches, it is hard to imagine this concept being not having potential applications in New Zealand's future environmental regulation.

4. Findings and Discussion

4.1 Current state

Water quality issues are currently an important consideration of consumers and the general public and this is being addressed by the current government through the National Policy Statement for Freshwater Management (NPS-FW). In addition to freshwater there are several other environmental issues which are becoming more prevalent and regulated towards, these include Greenhouse gasses, Soil health and Biodiversity loss.

This project will focus on fresh water, but it is important to acknowledge the other issues as they are likely to be incorporated into Farm Environmental Plans (FEP's). Local Government agencies, who are tasked with 'on the ground' regulation and compliance are given direction from the National Policy Statements on how they should manage environmental issues and so far, the approach has been an action-based system via FEP's. Local governments have several challenges in enforcing the NPS-FW including the cost of monitoring and coming up with rules which have been constantly challenged by farmer groups in the Environment courts.

FEP's are now widely accepted by the farming community and have potential for greater use, as identified by a large supplier of FEP templates FarmIQ found:

"The government's fresh-water regulations are close to being fully in place, and most in the primary sector acknowledge regardless of which government is in power, the rules will by and large remain in play. Included within them is the need for all farms to complete a farm environment plan (FEP), identifying the farm business's land management units and how environmental risk within them will be managed and mitigated...

…FEPs have to be more than a compliance driven "box ticking" exercise and need to deliver real benefits not only to the environment, but to farmers' profitability, given the time and commitment required to complete them. Already some processors are requiring farmers to furnish an FEP as part

of their supply agreement, and in return offer premium level payments for extra evidence of sustainable practices. Digitising the FEP and doing away with volumes of paper is vital to farmers only want to enter their data once. Keeping it digitised and accessible also maintains the FEP's role as a "living document", easily adjusted to allow for inevitable changes in the biological system it records.

Putting the FEP on a digitised platform means it can be shared among multiple parties including compliance organisations like councils, and farm advisors or key staff. As the plans become an integral part of a farms ability to operate, having a digitised FEP means there is no risk of loss of institutional knowledge around it when key staff depart or the property is sold (FarmIQ, 2021).

4.2 Opportunity

This project looks at the opportunity to use live environmental data gathered remotely by sensors to enable more of an outcome-based regulation system. The initial driver of this for me was the opportunity for positive impacts on farmer behaviours which was described in the paper "*Result-oriented agri-environmental schemes in Europe and their potential for promoting behavioural change*", they stated:

Result-oriented schemes create common goals between farmers and conservationists, leading to cooperation between two conflicting groups. Increasing cooperation between stakeholders in this manner is likely to result in ecological improvements as well as the infusion of previously incompatible values into agricultural production.

Change may also occur in the relationship between farmers and the public. In particular, result-oriented schemes can communicate the extent to which farmers contribute environmental services to society and, consequently, help to justify financial support to the farming community. By assuming the responsibility for management practices, credit for providing an attractive and biodiverse landscape may be attributed to the land manager rather than being perceived as a regulated management requirement of the government (Rob J.F. Burtona, 2013).

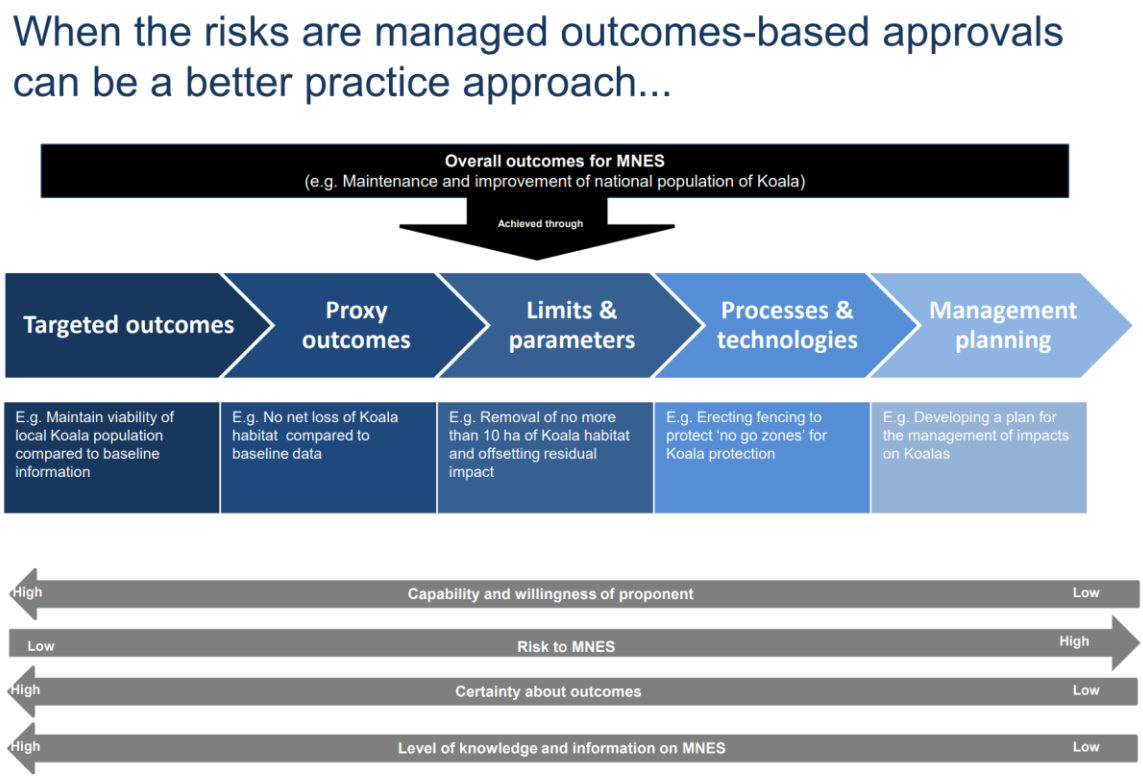
With the use of FEP's already established it would take a great need to change this approach. This does not mean there cannot be improvements made and as stated by the Australian Department of the Environment "*Management plans do not necessarily lead to good environmental outcomes*" (Australian Government - Department of the Environment, 2014). Live sensor data could well be incorporated as a voluntary component of a digital farm plan, creating a 'hybrid' model allowing innovative farmers and regulators to test the approach before wholescale adoption.

Some strong themes have come through the case study literature around both the benefits and the risks of an outcome-based regulation approach. The use of live environmental data from sensors could be the technological advance needed to mitigate some concerns raised in previous 'outcome' or 'result' based schemes. I will discuss these concerns further in "Risks" and what part live sensor data might play in enabling a different approach to environmental legislation.

Internationally outcomes-based regulation is being explored as an option to reduce the cost of monitoring and compliance and to enable improved outcomes. In addition to the EU's interest in result-oriented schemes, *other countries such as the USA and Canada have increasingly explored outcomes-based approaches to different regulatory regimes in recent decades and The Australian Productivity Commission recommends that, where possible, outcomes-based conditions be the default approach* (Australian Government - Department of the Environment, 2014). They also found that an outcome-based approach also had benefits to Multinational enterprises as shown in figure 2.

FIGURE 2

Prescriptive v's Outcomes-based approval benefits and risks



(Australian Government - Department of the Environment, 2014)

4.3 Benefits

Of particular interest to myself, and the main driver behind this project topic is allowing farmers to manage their business operations with a higher degree of autonomy than what is currently being proposed as regulation.

The following three points made here illustrate how incorporating some outcome-based regulation could reduce the cost to regulators of setting effective policy and monitoring compliance, empower farmers to innovate and maintaining profitability and improve environmental outcomes.

4.3.1 Value for money / cost

In the EU there is some concern that action-based schemes may not be providing value for money and that "currently we may not be getting the best environmental return for our investment" (Rob J.F. Burtona, 2013).

The main economic advantage from sensor data use in digital farm plans initially appears to come from a reduction in the costs of administration and compliance to regulators. This has been demonstrated in limited European examples such as paying farmers in the Netherlands per clutch for preserving meadow birds. This was more cost-effective than paying them to manage the environment (Rob J.F. Burtona, 2013).

Further to this, a potential for 21–36% cost effectiveness gains for a biodiversity project in Germany has been estimated (Rob J.F. Burtona, 2013) which is significant enough to warrant further investigation.
Due to outcome-based regulation being in its early stages there is still little proof of its cost effectiveness which is mostly theoretical.
As stated in Result-oriented agri-environmental schemes in Europe and their potential for promoting behavioural change, *"the prototype schemes currently in existence have relatively high administration and transaction costs for establishing and monitoring as scheme implementation and operation cannot build on previous experience, and schemes often lack economies of scale"* (Rob J.F. Burtona, 2013).

4.3.2 Farmer Behaviour and innovation

While I wouldn't infer that the result-oriented approach fails there appears to be potential improvements, primarily when considering farmers ability to innovate and improve in a non-prescriptive manner.
While action-based methods have their advantages, (this will be covered below in "Risks") namely their simplicity and acceptance by farmers one of the key problems with is their failure to promote long-term behavioural change. In contrast, "there are a number of characteristics of result-oriented schemes that, we contend, make them more likely to induce positive changes" (Rob J.F. Burtona, 2013). The initial uptake rates of result-oriented approaches In the EU have been very positive suggesting, at the very least, the schemes are as attractive as action-oriented approaches despite the increased risks (Rob J.F. Burtona, 2013).

By allowing farmers to self-manage environmental outcomes and removing managerial restrictions or costs outcome-based schemes not only allow but encourage farmers to innovate and draw on their own experience and local knowledge to achieve better and more cost-effective results (Rob J.F. Burtona, 2013).
European researchers have noted farmers improve their skills over the duration of result-based schemes and form new social connections between conservationists/ecologists, other farmers and the purchasing organisations (regulators) (Rob J.F. Burtona, 2013).
This must be seen as a major benefit as there seems to, at times, be a gap in trust and cooperation between these parties.
Some farmers may not initially possess the desired knowledge or resources to implement adequate change however immediate feedback from live sensor data would support land use change or best practice development bespoke to individual farming systems.

There has been much commentary on a growing urban rural divide and seemingly lack of understanding from both sides. The introduction of a degree of outcome-based regulation could benefit this relationship
This notion is well explained in the paper "Result-oriented agri-environmental schemes in Europe and their potential for promoting behavioural change". *By making knowledge of how to improve conservation on farms important, result-oriented schemes create common goals between farmers and conservationists, leading to cooperation between two conflicting groups. Increasing cooperation between stakeholders in this manner is likely to result in ecological improvements as well as the infusion of previously incompatible values into agricultural production. Change may also occur in the relationship between farmers and the public. Result-oriented schemes can communicate the extent to which farmers contribute environmental services to society. By assuming the responsibility for management practices, credit for providing an attractive and biodiverse landscape may be attributed to the land manager rather than being perceived as a regulated management requirement of the government* (Rob J.F. Burtona, 2013).

By taking what might be seen as a risk by farmers by exposing actual, measured results they may endear themselves to a public and consumer who is increasingly demanding more information and better outcomes for our shared environment.
Farmers would also be better equipped to place internal social pressure on each other, a study on self-monitoring of conservation activities by farmers in Australia suggests that while initially farmers are reluctant to apply sanctions to each other, this changes once farmers feel they have met their management responsibilities while others are not meeting theirs (Rob J.F. Burtona, 2013).

4.3.3 Improved outcomes

Previous examples and experiences in result orientated schemes have indicated that, in addition to the afore mentioned benefits of better cost efficiency and enabling farmer leadership in this space, there is a strong case to be made for better environmental outcomes from result-based systems over action based due to more specific goal setting and targeted delivery, *"There is a general belief that result-oriented approaches will be able to deliver better ecological outcomes than action-oriented approaches"* (Rob J.F. Burtona, 2013).

This has more applications in areas such as biodiversity where, rather than completing certain actions to comply with regulations farmers could be encouraged to focus on achieving the same goals which lead to the regulation in the first place. Where a farmer might retire an area of native bush as a habitat for wildlife, outcomes might be improved in some cases while maintaining some economic productivity of the same land. One example is using green fields between bush blocks as a habitat for kiwis to socialise and mix, this land can still be grazed by a farmer (with small restrictions) and adds to the kiwi conservation efforts (Australian Government - Department of the Environment, 2014).
Currently water quality is based mainly on modelling combined with some sample monitoring. This has limitations in that often the sampling can be expensive and as stated in "Timing, frequency of sampling affect accuracy of water-quality monitoring", "*timing and frequency of water sampling from the storm to the annual time scale play an extremely significant role in water-quality monitoring and suggest that a minimum sampling strategy should include sampling before, during and after storms. Samples must be collected over a period of several years to account for variability among years"* (Kenneth W. Tate, 1999), this approach is not feasible under current local government resourcing levels. Better benchmarking and monitoring would be hugely beneficial to both regulators and farmers as instantaneous feedback would allow results to be better understood, actions prioritised, and funds directed more efficiently.

Outcome based systems allow for more competitive market forces to influence appropriate environmental land management, the Australian Department of the Environment stated this system as:

- *Offering a tailored approach rather than 'one size fits all'*
- *Encourages innovation: businesses are able to develop their own solutions to deliver an outcome*
- *Potentially faster and/or simpler assessments and approvals for proponents*
- *Private sector utilised to collect environmental information through baseline surveys and ongoing monitoring*

(Australian Government - Department of the Environment, 2014).

When farmers are paid according to outcomes, there is an incentive to use land for production that will produce the best environmental results (Rob J.F. Burtona, 2013). If this principle, originally based on EU subsidies, was incorporated into NZ's legislation it could provide a valuable benefit for New Zealand agriculture when considering land use and the protection of sensitive environmental areas through market forces and not expensive compliance monitoring.

The Australian Department of the Environment have included some conditions on outcome-based approvals should include public accountability mechanisms in three categories, Monitoring, Reporting Non-compliance, and Reporting. They have put more responsibility on the approval holder (or farming business as it could be) to meet requirements such as:

- *Establishing parameters for assessing the achievement of outcomes.*
- *Establishing a monitoring network which demonstrates progress against those parameters.*
- *The approval holder must inform the regulator if monitoring indicates that outcomes may not be achieved as required by these conditions.*
- *The approval holder must provide full details to the Department in writing of any non-compliance with any condition and,*
- *must ensure that compliance reports are prepared and published on its website annually, including all related documentation.*
- *The approval holder should make monitoring data publicly available.*
- *Allow the public to see how the approval holder is tracking.*
- *Data can help the regulator to build a more comprehensive overview of the status of a particular MNES (Multinational enterprises).*
- *Members of the public can use the data for research.*

(Australian Government - Department of the Environment, 2014)

Whilst these guidelines may not apply in a New Zealand agricultural setting, they do demonstrate the different options available in creating or incorporating an outcomes-based system of regulation.

4.3.4 Data Sharing/use

Another huge potential benefit are the applications from amalgamating and analysing data at a catchment scale. Actual environmental benefits could be accelerated by using this data to direct and prioritise efforts towards the higher sources of pollutants.

A study at Poyang Lake, China investigated *"optimizing a new sampling network for future implications of more efficient and precise water quality sampling and routine monitoring".* The paper proposed an *"optimal sampling strategy using a remote sensing, big data and spatial sampling integrated approach for sampling design".* They found, *"it is practically essential to optimize the sampling locations using limited sampling numbers to obtain the most comprehensive water quality monitoring results considering both the spatial and temporal dynamics"* (Jian Lia, 2021).

Results showed that *"total suspended sediment (TSS) estimation errors of the whole lake were reduced by 18.11% and 29.34% on average when compared to systematic and stratified sampling under the same sample size. Remote sensing showed great potential as ideal means to provide spatially contiguous and comprehensive data"* (Jian Lia, 2021).

In order to improve water quality in the fastest and most cost-effective manner it is important that we have the most accurate and timely information available as possible.

4.4 Risks

New Zealand freshwater management regulation is action-oriented, this approach is common worldwide for several reasons:

1. they are relatively easy to implement and monitor
2. are, in general, acceptable to farmers (often because they involve little actual change to farming practices
3. and we currently lack any feasible alternative.

(Rob J.F. Burtona, 2013)

There would be several associated risks if outcomes-based regulation become a part of our regulatory system. Whether the benefits would outweigh these would need to be considered and might support a gradual, and voluntary, introduction of an outcome-based system.

The following themes have come through the literature as risks of result or outcome-based regulation.

- The establishment of desired outcomes, how they are benchmarked and measured
- Lack of effective mitigation options and farmers exposure to events beyond their individual control
- The issue of data ownership and how it is used and/or shared

4.4.1 Establishment of desired outcomes, how they are benchmarked and measured

The Australian Department of the Environment stated the following risks associated with the establishment and enforcement of outcome-based regulation.

- Compliance risk to business if outcomes are set too high
- Difficulty enforcing ambiguous outcomes/conditions
- Outcomes can be difficult to define in some circumstances
- It can be difficult to define outcomes for MNES (Multinational enterprises)
    - Enforcement risks for regulators
    - Compliance risks for business
    - Risks to MNES

(Australian Government - Department of the Environment, 2014)

The 'Data Quality from a Community-Based, Water-Quality Monitoring' Project in the Yukon River Basin found *"despite evidence that Community-based Monitoring (CBM) data can equal professional data in quality, continued scepticism implies that scientists and policy makers remain less likely to trust conclusions based on CBM.*

…. with consistent protocols and participant training, community-based monitoring projects can collect data that are accurate, precise, and reliable" (Nicole Herman-Mercer, 2018).

Care would need to be taken to avoid or minimise these risks as much as possible, particularly where outcomes cannot be measured accurately and reliably. The main challenge appears to lie in the difficulty of developing suitable indicators of success.

4.4.2 Lack of mitigation options, exposure to events beyond individual farmer control

With action-based schemes, if a farmer meets the prescribed measures, they are not responsible for any subsequently poor environmental outcomes. To change this would expose farmers to some factors outside of their control – in particular, climatic conditions and the behaviour of neighbouring farmers (Rob J.F. Burtona, 2013).

The choice and design of desired outcomes and sensitivities would be important in ensuring fairness, an effective sensor network could identify and differentiate performance between land-use and ownership. Many businesses may sometimes find it easier to implement prescriptive conditions and some Small businesses may not have capacity to develop their own solutions (Australian Government - Department of the Environment, 2014).

Researchers in the EU have suggested *"a number of means of reducing the risk including offering a base payment to compensate for actions, and a bonus payment for outcomes, making remuneration dependent on a combination of the agent's actions and a weather variable allowing farmers to undergo subsequent checks to avoid sanctions after extreme weather events"*. This is in reference to agricultural subsidies, but a similar approach could be taken in New Zealand where certain actions such as fencing off waterways to a sufficient level might protect farmers from poor outcomes, or non-compliance from measurements due to an unusually large storm event.
These risks are focused from the farmers perspective but there are also risks mitigation for the regulator through outcome measures. As has been proposed, fixed dates for re-sowing to be completed in the spring would restrict a farmer's ability to respond to weather events and even market forces if it rules out certain crops. The outcome focus could lead to greater improvements over time as "u*nlike in action-oriented schemes where risk is relatively constant, the risk associated with result-oriented payments declines with increased experience as farmers learn more about the production function, develop new skills, expand their knowledge, and forge new social capital with others"* (Rob J.F. Burtona, 2013).
Although farmers risk profiles would change under a different way of approaching environmental compliance, it might be considered an acceptable option, *"some evidence suggests that farmers desire the flexibility result-oriented schemes bring. In a 2010 study of German farmers, a third stated they would prefer an exclusively result-oriented scheme to retain flexibility – while only 7% preferred rigid conditions and a secure premium. They also found that of the 27% that had failed to meet the required number of indicator species, only 13% were affected by factors beyond their control and only a total of 5% were deterred from the project by the risk of a negative outcome"* (Rob J.F. Burtona, 2013).

4.4.3 Data sharing/use/ownership

A concern which has been raised by farmers is that of data ownership and use. There is a certain degree of mistrust with government (Fuller, 2019) and allowing access to potentially sensitive information. If an outcome-based approach was taken, then farm characteristics and managerial performance could conceivably impact land values, data would need to be sufficiently secure and managed.
Some EU researchers have noted that, again regarding subsidies, *engaging as a provider of public goods opens the farm up to closer public scrutiny. As the farmer is now selling a public good, access to information about the farm must be made available, increasing the risk of public disclosure of incriminating information about farm management practices* (Rob J.F. Burtona, 2013).
There is a very real and valid fear from farmers that voluntarily giving additional information to governments could expose them to greater scrutiny and litigation.

4.5 Feasibility

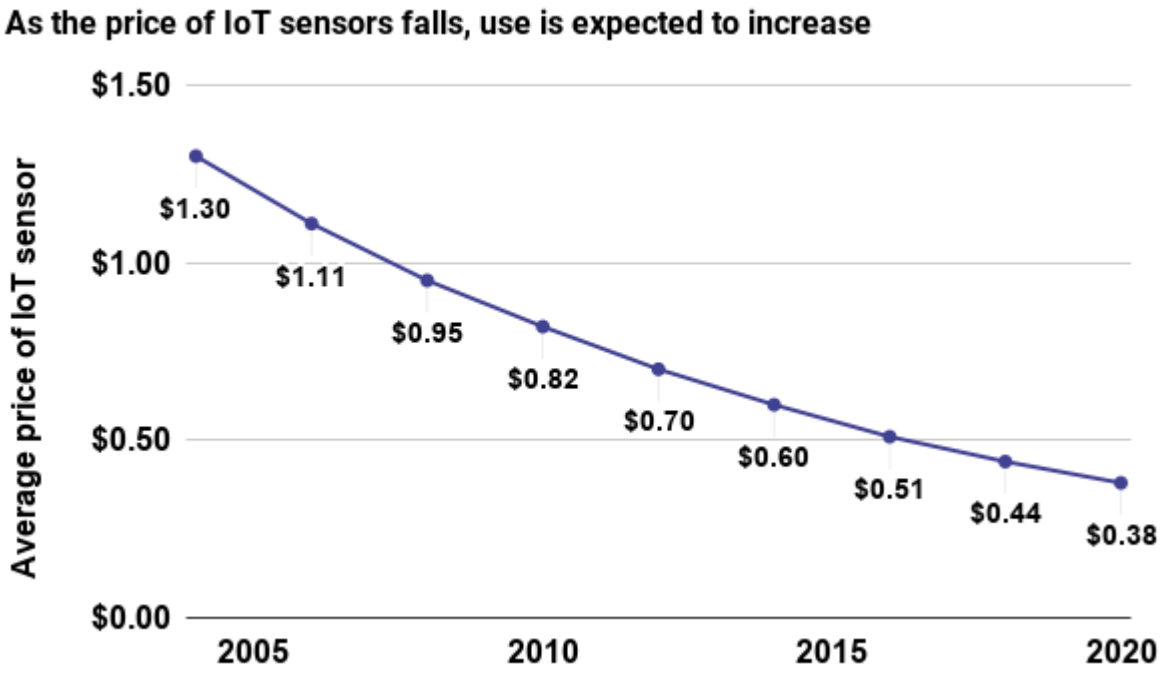
4.5.1 Technology/cost

One of the key advantages of using live sensor environmental data is that it enables more use of outcome or results-based regulation. For this to happen the sensors need to be at a price level, reliable and accurate enough to be trusted by both farmers and regulators. This technology is still in its early stages of development with individual unit prices needing to reduce for this to be a realistic option for most farmers. In the freshwater space, it might be common for a single farm to have multiple entry and exit points of water and as such multiple sensors would be required to correctly report on overall farm effects on water quality.

Figure 3 illustrates the price of Internet of Things (IoT) sensors dropping overtime and becoming more accessible for common use. It was estimated by Microsoft that by 2021 there would be 36.13 billion connected IoT devices (Leonard, 2019).

FIGURE 3

Average price of IoT sensors over time



(Leonard, 2019)

4.5.2 Connectivity

A connected network of live environmental sensors providing data to farmers and regulators all have one thing in common, the need for internet connectivity at some point.

New Zealand's rural internet connectivity is often poor and without this barrier being removed any compliance which is reliant on connectivity would be impossible. While the connectivity situation is improving there will need to be major improvements, perhaps the time for this to take place will

allow for further improvements and cost reductions in sensor technology, a lot of which is still in the research and development stage.

One example of technological advances enabling more sensor technology and consequently more outcome-based regulation is "Starlink" by SpaceX. Starlink uses a network of satellites to provide internet connectivity across the globe, by passing the current difficulties of needing costly 'built' infrastructure on the ground. Starlink is "*ideally suited for areas of the globe where connectivity has typically been a challenge. Unbounded by traditional ground infrastructure, Starlink can deliver high-speed broadband internet to locations where access has been unreliable or completely unavailable*" (Starlink, 2021).

Until advances such as this example become common place the cost of widespread sensor networks by individual farming businesses would be too prohibitive for anything other than voluntary schemes.

4.5.3 System design

The success of any outcome-based scheme would be greatly dependant on its design and a combination of regulatory approaches may be necessary (Australian Government - Department of the Environment, 2014).

The Australian Department of the Environment identified several key factors for success as:

1. Public accountability for outcomes is a key element of a successful outcomes-based system
2. Reporting - both compliance and non-compliance needs to be reported
3. It is essential that outcomes are measurable and enforceable

They also noted that data should be made publicly available this allows the public to see how the approval holder is tracking, can help the regulator to build a more comprehensive overview of the status of a particular business and that the regulator can provide support and assistance to approval holders to ensure outcomes are achieved (Australian Government - Department of the Environment, 2014).

While these conditions may not all be valid in a New Zealand agricultural sense, they do provide some interesting points to consider.

The European examples also emphasised the importance of setting up a system with effective indicators of achievement.

In some cases, indicators may be relatively simple. For example, where schemes promote breeding success in large carnivores or easily recognisable bird species the indicators can be singular (presence/absence) and are likely to be easily recognisable to farmers (Rob J.F. Burtona, 2013). Of course, this example would not apply to NZ systems but the idea of water quality sensors providing clear and easily understood measurements as a simple indicator might be all that is required in some cases. Other stated qualities of indicators which are valid in a NZ setting are;

- **Indicators should be measurable and identifiable.**

  Measurability and identifiability are critical requirements for selecting indicator species. Measurability is necessary to promote ease of monitoring and should be comparable over the contract period. Species should be easily identified as, in the majority of result-oriented schemes, farmers have a role in monitoring their levels of provision

  To make this easier, it is beneficial if the species' appearance is consistent throughout the year

- **Indicators should not conflict with agricultural goals.**
  To be acceptable to farmers and fit in with conventional farming systems it is beneficial if indicator species do not damage conventional agricultural production particularly where the species are considered 'weed species'
- **Indicators should be consistent with ecological goals.**
  Indicators should be consistent with the ecological goals of the project as far as is possible. For example, indicator species known to host beneficial insects should be selected above those that, while representative of the desired habitat, do not play an important ecological role
- **Indicators should reflect the effort of participating farmers.**
  As with crops, some indictors are likely to be more difficult to propagate than others. Thus indicators (and payments for indicators) need to reflect the management effort required for production

(Rob J.F. Burtona, 2013)

The identification and development of indicators should be carefully considered and involve a high degree of consultation, particularly in earlier trials to allow the possibility of success. A balance needs to be struck between minimising the number of indicators on the list in order to minimise scheme complexity and having sufficient indicators to represent the objectives (Rob J.F. Burtona, 2013).

Economic success or failure of schemes will rest on the quality of the indicators employed. Consequently, if it is not possible to develop relatively simple, self-monitorable, indicators as may be the case in some instances, the result-oriented remuneration approach may not be an appropriate means of achieving desired outcomes (Rob J.F. Burtona, 2013).

5. Conclusion

New Zealand agricultural environmental impacts are becoming increasingly regulated, this is primarily done through Farm Environmental Plans.

The use of live environmental data collected remotely from sensors to enable 'outcome-based' regulation would have several potential benefits including more cost-effective regulation and compliance, enabling farmer innovation and outcome-based behaviours and more targeted environmental improvements.

Despite the general positive nature of the assessment there are, of course, many potential problems involved in implementing result-based measures and however 'good' the theory and promising the initial results, there remains the prospect that it will fail (Rob J.F. Burtona, 2013).
Data ownership and usage are likely to be an issue for farmers who may be asked to provide data which could potentially prove non-compliance.
Current internet connectivity and technologies also lead to this option being cost prohibitive; this is however likely to change in the near future.

Considering the above points, I agree with (Rob J.F. Burtona, 2013) in that "*we contend, the immediate implementation of 'strong' forms of result-orientation to meet all environmental objectives might be a mistake. Although ultimately the stronger the result-orientation the more likely it is to encourage innovation, weaker forms are likely to be more effective in the initial stages before cultural and social capital has been established. The risks may be too high to make the approach attractive to farmers, and, simultaneously, the risks of a failure of provision and consequent environmental damage too high for funders and the public"* (Rob J.F. Burtona, 2013).

Given the substantial benefits which may be achieved, and how important the design of outcome systems is I don't believe the idea should be completely abandoned. The use of initial trials leading to a hybrid model of actions and/or outcomes may create New Zealand a regulatory system of global envy.

Farmers need to remain profitable for them to continue in environmental improvement, as is being required. It is my hope that in the future, the incorporation of voluntary options for 'outcome-based' regulation may help reduce the costs of compliance and help farmers in being seen as part of the solution and not part of the problem.

6. Recommendations

I believe that in the future the concept or outcome-based regulation will be available and will encourage innovation and productivity whilst making compliance easier and achievable for farmers. To prepare for this I would recommend the following actions:

1. Identify indicators for monitoring. Designing a system of effective indicators should be carefully considered and would need to involve a high degree of consultation. If an environmental outcome cannot be monitored simply and effectively then an outcome-based scheme may not be appropriate for that measure.
2. Begin environmental data collection. Early trial work by regulators would provide feedback and learnings from live sensor data. This would help in designing required actions for environmental protection. It would also have value if data can be incorporated into existing models to strengthen their validity.
3. Address data ownership and use issues. Any increase in data capture and reporting requires a data strategy addressing data ownership and how it is to be used. In order for farmers to voluntarily give their own environmental data to a regulatory body there would need to be assurances made to address any concerns in this area.
4. Start smaller, proof of concept trial work. This might suit larger high-country properties where it can be safely assumed that water entering the grazed areas is of high quality. Water leaving the property could then be monitored to establish agricultural impacts. This would have benefits as the cost to fence off all water ways on these properties would likely be uneconomic if required under an action-based scheme.
5. Explore options for a hybrid model between action and outcomes based environmental legislation.
6. Allow voluntary data use. Live sensor data could well be incorporated as a voluntary component of a digital farm plan, creating a 'hybrid' model allowing innovative farmers and regulators to test the approach before wholescale adoption.
7. Factor in future technological advances in writing regulation. Currently the technology looks to make this option cost prohibitive. Legislation could be written now to allow for its use in the future.

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