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Barriers to adoption of win–win mitigation farm practices: evidence from New Zealand pastoral farmers

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Abstract

This paper uses survey data from 167 New Zealand sheep/beef and dairy farmers to explore the non-financial barriers that affect their decision-making when deciding whether or not to adopt or expand particular on-farm greenhouse gas (GHG) emissions mitigation practices. We focus on six practices that have the potential to reduce the carbon footprint of animal operations, four of which have been defined by New Zealand scientists as win–win, or what we call "no-cost" practices. We identify barriers following the typology of Jaffe (2017) and find that 12 different barriers preclude the decision to adopt/expand practices, even after the farmers have perceived the practice as "no-cost". Of the identified barriers, "Unsureness about practicality" appears as the main cause for under-adoption across all farmers, while "Salience bias" and "Principal-agent or split-incentive problems" are the main barriers noted by sheep/beef farmers and dairy farmers, respectively. We discuss these findings from the perspective of policy makers to provide insights on how these barriers could be confronted so as to enhance the adoption or expansion of win–win practices.

JEL codes

Q10; Q19; Q52; Q54

Keywords

Barriers to adoption; GHG mitigation practices; pastoral systems

Summary haiku

Farmers are unsure
if no-cost practices are
practical for them.

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1 Introduction

Win–win, or no-cost, practices can reduce on-farm biological GHG emissions while maintaining (or even increasing) farm profits (Moran et al. 2013). These options are the set of investments, technologies, or practices that reduce the carbon footprint of farming without affecting profitability (conventionally defined as financial profitability). Although these no-cost practices have been identified for pastoral farming, they are reported to be under-adopted in New Zealand (Reisinger et al. 2018). Jaffe (2017) developed a typology for assessing the existence and significance of barriers to the adoption of "no-cost" agricultural GHG emissions mitigation practices. In this study we use Jaffe's typology to investigate which barriers influence the decision-making of New Zealand farmers in relation to the adoption or expansion of no-cost practices.

Jaffe (2017) refers to barriers as "any factor that might explain why farmers might eschew a no-cost option" and groups them in seven categories: "Arguably efficient", "Information", "Market structure and institutions", "Regulation and policy", "Risk and uncertainty", "Externalities", and "Behavioural factors". These categories are shown in Figure 1 and the specific barriers within each category are listed and described in Appendix Table 1.

This paper complements the study of Cortés-Acosta et al. (2019), which uses interview results to analyse the existence of barriers to the adoption of no-cost practices by New Zealand pastoral farmers. In this study, we address a similar question using a bespoke survey of New Zealand livestock farmers. The survey was designed to assess whether farmers determine particular practices to be no-cost and to identify the occurrence of barriers when farmers under-adopt no-cost practices. Specifically, the survey aimed to record the perceptions of sheep/beef (SB) farmers for three different agricultural practices, and those of dairy (D) farmers for three different agricultural practices.

For sheep/beef farmers, the practices explored were:

- higher live-weight gains in lambs/calves (SB1);
- increasing scanning percentage (SB2); and
- use of dairy beef animals to replace beef cows (SB3).

For dairy farmers, the practices were:

- reducing current stocking rates (D1);
- limiting the use of nitrogen (N) fertiliser in favour of other practices (D2); and
- adopting a "once per day" milking system (D3).

Four of these practices (SB1, SB2, D1 and D2) fulfil the no-cost criteria described above according to de Klein and Dynes (2017). Practices SB3 and D3 may or may not fulfil these criteria and were included for their potential to lower emissions and improve the sustainability of those sectors in the medium term (Reisinger et al. 2018).

Two main findings arose from the results of the survey. The first is that a relatively high percentage of farmers believe that the six evaluated practices can be defined as no-cost. The vast majority of sheep/beef farmers believed practices SB1 and SB2 are indeed no-cost. Among dairy farmers, 60% believe D1 to be no-cost and 43% believe D2 to be no-cost. As expected, less than 40% of respondents believe either SB3 or D3 to be no-cost.

Second, even among those farmers who consider a practice to be no-cost, many have not adopted that practice. In these cases we identify a set of barriers causing the under-adoption. Barriers are identified in mainly three sub-groups of farmers among those who believe a practice is no-cost: group 1) farmers who have used the practice in the past but do not do so anymore; group 2) farmers who do not adopt the practice but state that they will in the future; and group 3) farmers who state that they will not (or were unsure to) adopt the practice at all. We found four barriers for group 1, five barriers for group 2, and eight barriers for group 3, which we summarised in Table 4. In group 3, the barrier "**Unsureness about practicality**" was most frequently selected by farmers overall, while "**Salience bias**" and "**Principal-agent or split-incentive problems**" were the barriers most frequently selected for sheep/beef famers and dairy farmers, respectively.

The remainder of this paper is structured as follows. Section 2 briefly presents Jaffe's (2017) typology of barriers to adoption, and Section 3 describes our research methods. Section 4 presents our results, and Section 5 discusses these in line with their policy implications. Finally, Section 6 provides some concluding remarks.

2 Barriers to Adoption

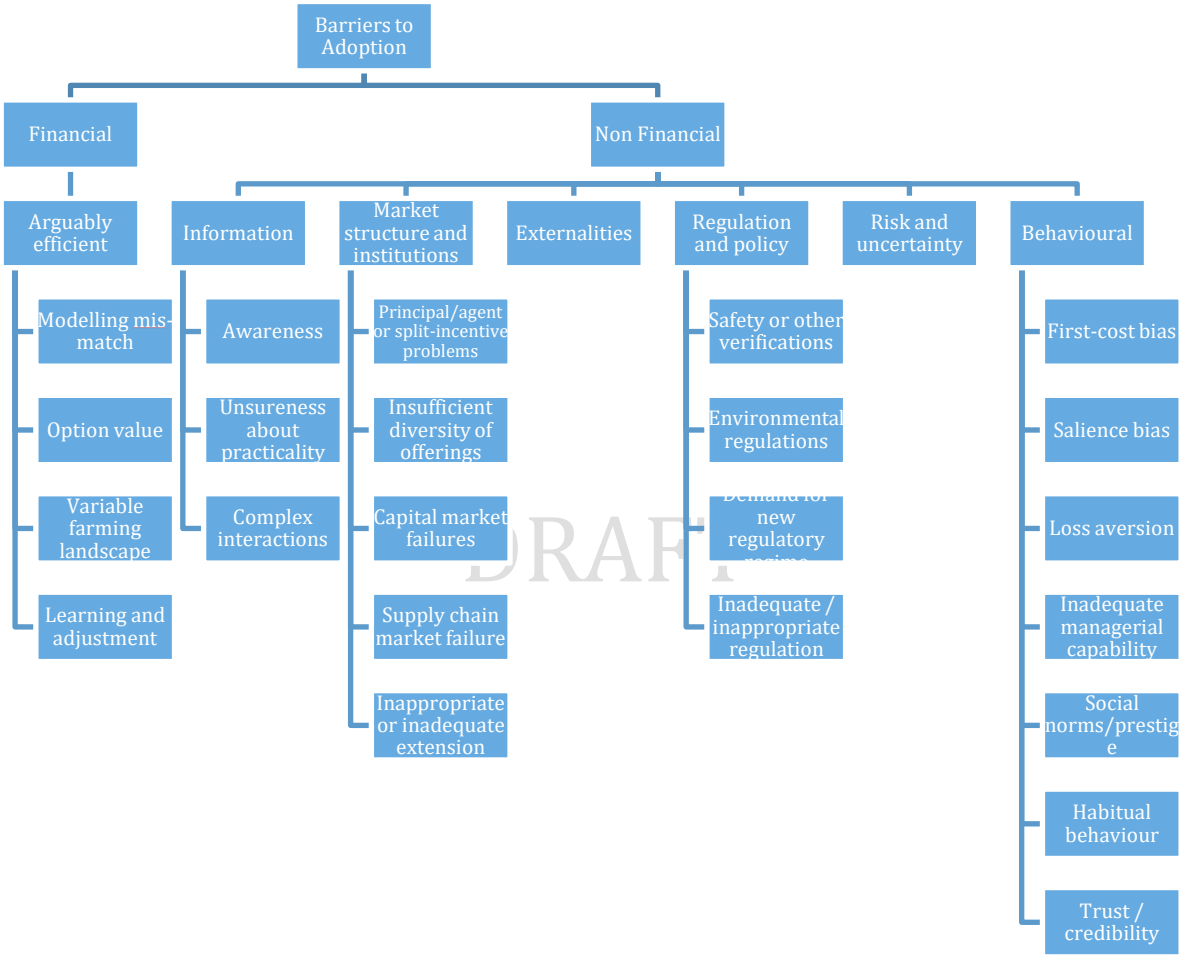
There is limited research focusing on identifying barriers for adoption of no-cost mitigation measures in New Zealand. Previous studies (e.g. Niles et al. 2015; 2016) highlight the need for further research into the behavioural barriers that farmers face in the adoption of mitigation practices. There is however, no coherent framework applied to assess the variety of barriers to adoption, nor is there a study focusing specifically on the adoption barriers associated with no-cost mitigation practices in New Zealand, specifically.

Therefore, we use Jaffe's (2017) framework to be able to identify a wide range of potential barriers to adoption. The seven different categories that we use to group the barriers to adoption are shown in Figure 1. The barriers in the first category, "Arguably efficient", include those that can be considered "financial", as they reflect cases in which farmers perceive that the financial costs of adopting or expanding a given practice outweigh the benefits. This perception can be a product of two effects: (1) formal financial profitability tests fail to measure correctly the economic impact of the practice on the farmer, who faces costs that reduce his/her profits, i.e. mitigation practices suggested by an analyst may in fact impose important short- or long-term financial burdens on the farmer; or (2) the farmer might incorrectly perceive a financial cost when in reality the practice would be profitable, at least in the medium term. The barriers in the "Arguably efficient" category thus straddle financial and non-financial aspects as they stem either from unconsidered financial costs in modelling scenarios or from incorrect perceptions of financial costs versus benefits.

The barriers in the other six categories can be defined as "non-financial" in nature. The "Information" barriers occur when adoption is not implemented because of imperfect availability of information. "Market structure and institutions" barriers relate to failures in these areas that inhibit adoption, e.g. a lack of training programmes or extension. "Regulation and policy" barriers are those that derive from existing or potential constraints from public policy or the law. These last two categories are generally external barriers to adoption in farming contexts, as it is not within the power of the farmer to change them, e.g. biosecurity regulations that unnecessarily delay the introduction of a new crop or food safety regulations that aren't developed quickly enough to be applied to new products. Conversely, the category "Risk and uncertainty" applies to farmers who think that moving to less intensive GHG emissions operations (such as once per day systems) is risky because, for instance, they perceive commodity price as being uncertain. "Externalities" are barriers in which the full costs and benefits of an action are not exclusively borne by the decision-maker. For example, if farmers do not regard mitigation policies as being viable in the long term and thus don't fully internalise the cost, actual adoption rates will fall short of those modelled. Finally, "Behavioural factors" relate to intrinsic barriers that farmers may develop as part of their formation, experience, and culture. Among these, barriers such as "First-cost bias" (when decision-makers tend to place a

disproportionately large weight on the initial cost) or "Habitual behaviour" (when farmers may perceive that transitioning is too disruptive to existing routines) can limit adoption (Jaffe, 2017).

Figure 1. Categories of barriers to adoption in farming contexts.



Source: Adapted from Jaffe (2017).

3 Methods

The empirical analysis in this study is based on a sub-sample of sheep/beef and dairy farmers who responded to the large internet-based Survey of Rural Decision Makers (SRDM) in 2017.[1] From the total sample, 300 farmers were invited to complete our survey focused on no-cost practices and barriers to adoption. A total of 167 (56% out of the 300 invited) farmers responded, of which 83 were sheep/beef farmers and 84 were dairy farmers.

The survey included questions on farmers' perceptions of whether they consider particular practices to be no-cost and on barriers affecting their decision to adopt or expand the use of no-cost practices. The flow diagram provided in Appendix Figure 1 shows the survey

1 The Survey of Rural Decision Makers is conducted bi-annually by Landcare Research. Its sample covers both commercial production and lifestyle farming in all 16 regions in New Zealand. For more details, see Brown (2017).

design. We first asked whether farmers believed it is possible to maintain or increase profits under each of these practices. Those who responded "no" signalled that no adoption is a consequence of perceived financial costs.

For farmers who believed that it is possible to maintain or increase profits while using these practices, we asked whether they had implemented the practice (and whether they were either not using the practice at all or were using it in a non-optimal way).[2] The non-optimality was elucidated by asking in the survey if the farmer believed the practice could be expanded (applied more) in a farm similar to theirs without affecting profits. A group of farmers affirmed they are currently using the practice. To this group of farmers we tested the presence of potential barriers by asking whether they would recommend the practice to others. In the main analysis we conduct in this paper, for each practice we exclude from the sample farmers reporting that they are applying the practice as well as those that did not believe the practice was no-cost, which leave us farmers who are not adopting a no-cost practice as consequence of non-financial barriers (see Appendix Figure 1 to see this in the survey flow). We further divided, these farmers into three groups: Group 1) those who had adopted the practice in the past but were no longer doing so; Group 2) those who stated they would adopt the practice in the future, but not just yet; and Group 3) those who were unsure about adopting a practice at all. We then asked these farmers to explain why they were not adopting the practice, using several answer options reflecting the barriers from Jaffe's (2017) typology and an additional comment window after the option "other" to allow farmers to expand on the reason (with their own words) in case they were not satisfied with the provided answer options.[3] In all cases, farmers were allowed to tick up to three options.

The analysis of the responses was conducted for each practice separately. Hence, farmers could fall into several groups depending on which practices they are not adopting.

The wording used in the survey was derived from Jaffe (2017) and Cortés-Acosta et al. (2019), and is provided in detail in Appendix 1 of this paper.

As described in Section 2, the perceptions of no-cost status and of barriers were assessed in the survey for four ostensibly no-cost mitigation practices (SB1, SB2, D1 and D2) (fully described in de Klein & Dynes 2017), and two practices that have been proposed to support the mitigation of GHG but are not considered no-cost (SB3 and D3) (Reisinger et al. 2018).

2 In the remainder of the paper we refer to these two cases as "no adoption".
3 As shown in Appendix Table 1, our survey covered most, but not all, barriers in Jaffe's (2017) typology. The exclusion of some barriers was done mainly to avoid a lengthy survey that could have jeopardised our response rate. For more details, see the Appendix.

4 Results

4.1 Are practices perceived as no-cost?

At the start of the survey, sheep/beef farmers were asked whether they believe it is possible to increase live-weight gains in lambs/calves (SB1), increase scanning percentage (SB2), or use dairy beef animals to replace beef cows (SB3), while at the same time maintaining or increasing profitability. Results are reported in Table 1. Nearly all (98%) respondents agreed that SB1 could be used to improve or maintain current profits, suggesting that the practice is indeed a no-cost option for mitigating GHG emissions. Similarly, 86% of farmers believe that SB2 may be used more intensively without sacrificing profitability, again suggesting that increasing scanning percentage is a valid no-cost option for mitigating GHG emissions for many farmers. Conversely, only 39% agreed that SB3 could be used more intensively without adversely affecting profits, while 36% disagreed and 25% were unsure that doing so was possible, indicating (as expected) more uncertainty about whether using dairy beef animals is truly a no-cost option for mitigation.

Dairy farmers were asked whether they believe it is possible to reduce current stocking rates (D1), limit the use of N fertiliser in favour of other practices (D2), or adopt a once per day milking system (D3) while at the same time maintaining or increasing profitability. Results are provided in Table 1. Only 60% of dairy farmers in our sample agreed that D1 was consistent with maintaining or increasing profits, while 29% disagreed. For D2, 43% of respondents agreed, while 33% disagreed and 24% were uncertain. For D3, 29% agreed, 49% disagreed, and 22% were uncertain.

Table 1. Agreement with the statement "This practice can be applied more intensively while improving (or maintaining) current farm profits".

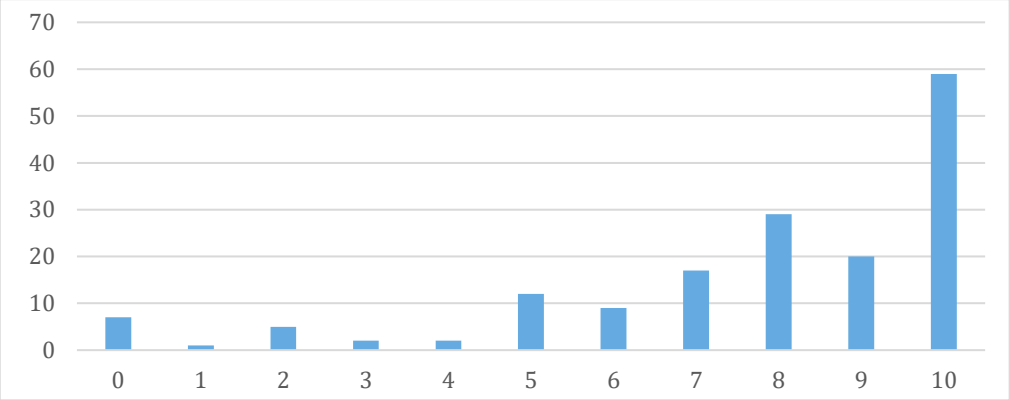
Practice	Agree	Disagree	Unsure
Higher live-weight gains in lambs/calves (SB1)	98%	2%	0%
Increasing scanning percentage (SB2)	86%	6%	8%
Use of dairy beef animals to replace beef cows (SB3)	39%	36%	25%
Reducing current stocking rates (D1)	60%	29%	11%
Limiting the use of N fertiliser in favour of other practices (D2)	43%	33%	24%
Adopting a "once per day" milking system (D3)	29%	49%	22%

Respondents who disagreed with the statement "This practice can be applied more intensively while improving (or maintaining) current farm profits" (Table 1) do not believe that the practice is no-cost. Financial barriers are dominating their perceptions, so the role of non-financial barriers is secondary. Given this, we do not evaluate the perceptions of this group of farmers in this study any further.

Results of Table 1 imply that there is a possibility for the evaluated practices to be further applied given farmers' perceptions with regard to the financial benefits they can generate. To gain further insight into farmers' perception of climate change and the willingness to take up no-cost practices, we asked "if clear technology options to reduce your GHG emissions at no additional financial cost for your farm existed, how interested would you be in implementing them on a voluntary basis?". Results are shown in Figure 2. Results point out that a large proportion of farmers would be interested in applying "no-cost" practices.

Related to this question we asked whether they believe that agriculture should act to mitigate GHG emissions. Among respondents, 47.5% replied "no" and 52.5% replied" yes". We further discuss this finding in section 5.

Figure 2. Farmers' interest in implementing no-cost technology options on a voluntary basis



Note: Answers were coded with a scale from 0 (not interested at all) to 10 (very interested).

4.2 Barriers to the adoption of no-cost practices

Farmers who agree that a given practice can be increased or used more intensively while increasing or maintaining profits were asked whether that practice is currently being applied on their farm, whether it was previously applied but this is no longer the case, or whether it has never been applied. The results are presented in Table 2.

Table 2. Percentage of responses to the question of whether or not the stated no-cost farm practice was applied on the farm.

	SB1	SB2	SB3	D1	D2	D3
I currently apply this practice	78%	75%	72%	49%	77%	75%
I have applied this practice in the past but am no longer doing so	14%	9%	6%	31%	3%	13%
I have never applied this practice	9%	17%	22%	20%	20%	13%
Number of farmers who believe practice is no-cost	81	71	32	49	35	24

Notes: Percentages are of the total number of farmers who believe the practice is no cost (totals shown in last row). Percentages are rounded, so they might sum to 101. SB1 = higher live-weight gains in lambs/calves. SB2 = increasing scanning percentage. SB3 = use of dairy beef animals to replace beef cows. D1 = reducing current stocking rates. D2 = limiting the use of N fertiliser in favour of other practices. D3 = adopting a "once per day" milking system.

For five of the six practices, between 72% and 78% of the farmers who agree they are consistent with increased or maintained profits on similar farms currently apply that practice on their own farm. The only exception is the practice of reducing stocking rates (D1), in which more than half of dairy farmers who consider it a no-cost option are not applying it. It is worth highlighting that a third of the farmers have applied this practice in the past but are no longer doing so, suggesting that a third of farmers have increased the stocking rate of their farms in comparison to previous rates. The reasons for this and the barriers affecting the use of lower stocking rates are discussed below.

4.2.1 Would you recommend this practice to a fellow farmer? (barriers to "promotion")

We asked the group of respondents who believe in the profit potential of a practice and are currently applying it whether they would recommend that practice to other famers. While most respondents stated "yes", some farmers said that they would not recommend the use or expansion of a given practice. To those replying "no", we asked why – using an open-ended response format. With this question, we aimed to observe whether there exist barriers for the promotion of mitigation practices. Specific responses (direct quotes) and our interpretation of them in line with barriers include the following:

"*It's not for everyone. M. bovis would make me not recommend it presently*" (about SB3). This reasoning relates directly to two barriers: "**Variable farming landscape**", in the sense that the farmer implies the practice would be no-cost for him/her but not for others; and "**Risk and uncertainty**", in the sense that bringing animals from other farms is currently perceived as highly risky because of *Mycoplasma bovis* cattle disease.

"*It requires a coordinated approach to make it work. The standard of pasture management needs to be improved with greater attention to detail and not every farm has the capability to*

achieve this. Applying more N is simpler and hence more effective for just some people/systems" (about D2). This reasoning is a combination of two barriers: "**Inadequate managerial capability**", as indicated by the lack of capability; and "**Unsureness about practicality**", as indicated by the suggestion that, because of ease and convenience, others may avoid the practice).

"*The level of management skill required to run a low-stocked farm and achieve high performance is not there in most cases*" (about D1). As noted below, an important barrier to reducing stocking rates is "**Inadequate managerial capability**".

"*Everyone farms different systems. You can only explain your results*" (general). This relates to the barrier "**Variable farming landscape**", which in some extent it also linked to the barrier "**Complex interactions**", as for the farmer it is hard to identify in advance if the practice will work in other farms given the lack of information.

4.2.2 Reasons for ceasing or reducing the application of an apparently profitable practice

Across all six mitigation strategies, a significant share of farmers who believe that adopting a given practice can increase or maintain profits (i.e. who believe that a given mitigation strategy is indeed no-cost) have either yet to adopt it or have stopped using it. The latter group of respondents (described in the methods section as Group 1) was asked to select reasons for their decision to stop or reduce the practice. The options provided in the survey for these reasons were based on the framework outlined in section 2, but we also provided an option to allow respondents to indicate whether the previous application was unsuccessful (option "did not see a payoff").

Directly related to this last point, seven respondents (two in SB1, three in D1 and two in D3) stated that they had stopped applying the practice because they "did not see a payoff". This statement seems to relate to an "**Arguably efficient**" type of barrier, as the particular practice did not generate the expected benefits.

In relation to non-financial barriers, two respondents reported that the barrier "**Complex interactions**" (too much hassle) was a cause to stop applying the practice SB1. One respondent stopped applying D3 because it was too risky ("**Risk and uncertainty**" barrier) and one because employees on the farm objected. We classify the latter as a "**Principal-agent or split-incentive problems**" barrier because it reflects non-financial costs borne by the employees (e.g. uncompensated extra work) and not necessarily the decision maker. Finally, another respondent stated that he/she stopped maintaining a low stocking rate because his/her investors objected, which we also classify as the barrier "**Principal-agent or split-incentive problems**" (see Appendix Table 1).

Several farmers listed the reason for ceasing a practice as "other". Among these, the main reasons for SB1 were "did not need the extra numbers" and "got where we wanted to go". These options do not directly reflect a particular barrier but rather perceptions that operations are already nearly optimal. Whether or not this is the case is not the subject of this paper, although incorrect perceptions of optimality are likely to occur in cases in which similar farms in the same region also under-adopt particular practices. In this sense, the barrier "**Habitual behaviour**" cannot be ruled out. Similarly, one dairy respondent reported that for D1 "[we] had reduced stocking rates over previous three seasons and now feel that we are at the correct stocking level, therefore no need to keep applying it".

Also, one dairy farmers stated, *"Reduced stocking rates also requires a higher standard of pasture management. In my experience, a lower rate only works with a more experienced and capable farm manager",* pointing clearly to the "**Inadequate managerial capability**" barrier.

4.2.3 Why delay adoption?

Farmers who believe that a mitigation strategy is indeed no-cost but have never adopted the given practice (Group 2) were asked whether they plan to adopt that practice in the future. Six out of seven (85.7%) farmers who agree that SB1 is no-cost but who have yet to adopt it do plan to introduce the practice. Analogous figures for SB2 and SB3 are seven of 12 (58.3%) and six of seven (85.7%). Eight out of ten (80%) farmers agree that D1 is no cost and have yet to adopt it but do plan to introduce the practice. Analogous figures for D2 and D3 are four of seven (57.1%) and two of three (66.7%).

Three sheep/beef farmers stated that "other priorities" was a reason to delay applying SB1, while one farmer stated this option for SB3. This "other priorities" argument relates to the typology barrier of "**Option value**", as respondents delay adoption because other, more cost efficient practices might be applied first.

Another reason for delay highlighted by one respondent for SB1 and one for SB3 was "limited budget". This response relates to the typology barrier "**Supply chain market failure**", as cash constraints impede the adoption of the practices.

Several dairy farmers also stated "other" as a reason for delaying adoption. One farmer stated, with respect to D1, "*Concentrating on herd improvement to be in the best position to maintain profitability when stock numbers are reduced*". This reasoning relates to the barrier typology "**Learning and adjustment**", as it states that the respondent has delayed adoption because his/her animals are not good enough to establish a profitable system based on lower stocking rates. Thus, this is not a barrier to adoption, but rather a barrier for delaying adoption.

Another farmer for D1 stated, "*No confidence in industry or government successfully working to recognise, differentiate and market pastoral value advantage inherent to NZ*". This reasoning relates to the barrier "**Inadequate or inappropriate regulation**" as it points to a lack of regulatory framework to recognise mitigation efforts on the part of farmers. It also points to

the barrier "**Trust or credibility**", as it clearly indicates a lack of confidence in the regulatory framework. Farmers respond to incentives, so if these are not obviously in place then the adoption of particular mitigation options will not happen.

Finally, with respect to D2 one famer wrote, "*lack of time. Putting on N is quick*". This relates to the barriers "**Habitual behaviour**" and "**Unsureness about practicality**" because it points to the unwillingness of the farmer to change a practice that he/she is comfortable using. Changing the practice will affect the ease and convenience he/she obtains from current practice.

4.2.4 Reasons for not adopting (or expanding) no-cost practices

Finally, the survey asked respondents who consider a given management practice to be no-cost, but who had not applied it in the past and did not plan to do so in the future (Group 3), to identify up to three reasons for their decision. Responses for all barriers recorded for these cases are shown in Table 3.

Table 3. Number of times that barriers were selected by farmers who state that a practice is no-cost, but who have not applied the practice in the past and are not interested in doing so in the future

Barrier	SB1	SB2	SB3	D1	D2	D3	No. of times barrier is mentioned
Unsureness about practicality		2	4	2	2		10
Salience bias*	1	4					5
Habitual behaviour*	1	1	1		1		4
Principal-agent or split-incentive problems				1	1	2	4
Risk and uncertainty			2		1		3
Inadequate managerial capability*	1	1	1				3
Complex interactions		1	2				3
Inappropriate or inadequate extension		1			2		3

Notes: Sorted by total frequency. Blank cells indicate no answer. SB1 = higher live-weight gains in lambs/calves. SB2 = increasing scanning percentage. SB3 = use of dairy beef animals to replace beef cows. D1 = reducing current stocking rates. D2 = limiting the use of N fertiliser in favour of other practices. D3 = adopting a "once per day" milking system.

The results presented in Table 3 clearly indicate barriers to the adoption of no-cost practices, i.e. they explain why farmers have not and will not adopt practices that they themselves consider to be no-cost.[4] Even though the frequency of responses reported in Table 3 are low, they provide important insights into understanding which barriers are relevant to farmers for each of the evaluated practices.

[4] The option "other" was selected eight times by farmers, but an analysis of the quotes provided show not clear reference to any barriers.

Although no barrier was selected more than once for SB1 by sheep/beef farmers, it is worth noting that only behavioural barriers are highlighted in this case (with the exception of "other"). In contrast, the barrier "**Salience bias**" is disproportionately identified as the barrier for SB2, indicating that multiple farmers perceived the potential cost savings or extra benefits of increasing the scanning rate at their farm as too small vis-à-vis the extra efforts and precautions required. Finally, for practice SB3, the barrier "**Unsureness about practicality**" was disproportionately selected, indicating that the use of dairy beef animals is not believed to an option that can work well in the farmer's current system. In SB3, the barriers "**Risk and uncertainty**" and "**Complex interactions**" were also named by multiple farmers, pointing to the risks and information complexities associated with the practice by some farmers.

Among dairy farmers who believe that a given practice is consistent with maintaining or increasing profitability but who have not adopted that practice, "**Unsureness about practicality**" is also identified as barrier to adopting D1 and D2. This result points to the notion that some farmers are reluctant to adopt given practices because they are not convinced that they will work well on their own farms. Interestingly, for practice D2, the barrier "**Inappropriate or inadequate extension**" was also reported by multiple farmers, highlighting the importance of tailored extension for the adoption of this and similar practices. Finally, for D3, the barrier "**Principal-agent or split-incentive problems**" was selected two times out of a total three responses, which suggests that the potential lack of support from investors and/or shareholders may inhibit the adoption of a once per day milking system even when the farm manager is convinced that it could yield equal or higher profits.

5 Implications for Policy Making

The first point to highlight from our findings is the relatively high percentage of farmers who believe that the different practices surveyed are indeed no-cost. These include practices SB3 and D3, which have not been defined by scientists as no-cost. The 39% and 29% of farmers perceiving practices SB3 and D3, respectively, as no-cost (Table 1) is telling because it shows space to grow the adoption of these practices that have been proposed as effective options for reducing farm-level GHG emissions (Reisinger et al. 2018). More and better evidence with respect to their potential profitability could be assessed and promoted.

A second important finding for policy makers is the relatively low perception among dairy farmers that D1 and D2 are no-cost (in contrast to sheep and beef farmers' perceptions of SB1 and SB2). Both of these dairy practices have been promoted by scientists as no-cost options, but the reality is that a significant number of farmers surveyed (29% and 33%, respectively) rejected them as such (Table 1). An additional point is that more than half of farmers who perceive D1 as no-cost are not currently adopting the practice. This is a remarkably different result from the other evaluated practices, in which three-quarters of farmers were applying a

practice they considered no-cost. These points suggest that there is wide room for improving awareness of the no-cost nature of D1 and D2, and that addressing barriers to the adoption of D1 could lead to significantly higher rates of adoption.

Table 4 summarises all the identified barriers in this study. For D1, we show that farmers stopped using the practice of low stocking rates because of "**Inadequate managerial capability**". This finding indicates that more and better farm management training on aspects related to low stocking systems could help to maintain (and increase) the adoption of the practice. Previous literature on the adoption of new practices has shown that extension initiatives focused on farmer learning and practice change can address barriers related to "**Inadequate managerial capability**", complexity and risk (Sewell et al. 2017). This barrier was also highly relevant for adoption of D1 in the findings from Cortés-Acosta et al. (2019), who identify different challenges that farmers face when moving towards lower stocking rate systems. Low stocking rate systems are more viable on some farms than others, so more and better tailored (e.g. catchment-specific) analysis of stocking rate optimums would be beneficial for promoting less intense systems and achieving better mitigation.

Another important policy consideration with respect to D1 is given by the barriers identified by the question "Why delay adoption?". In this case, one farmer stated, "No confidence in industry or government successfully working to recognise, differentiate and market pastoral value advantage inherent to New Zealand" (Table 4) as a reason for not applying a low stocking rate at the current time. This opinion strongly relates to the barriers "**Inadequate or inappropriate regulation**" and "**Trust or credibility**" and needs to be considered in policy discussions. If higher adoption rates of climate-friendly practices are expected, then regulation or clear political signalling about their benefits is desperately needed.

In relation to sheep/beef farming practices, an important finding was the barrier "**Risk and uncertainty**" in SB3 as a consequence of the *M. bovis* outbreak. This was identified as a barrier for farmers' willingness to recommend the practice of using dairy beef animals to replace beef cows to fellow farmers, showing the important role of government in promoting sustainable practices in cases like this. Farmers will be reluctant to promote practices that might be perceived as too risky by others (especially after shocks like the *M. bovis* case), which is a void that the government could try to fill. Farmers might be keen to experiment on their own farm but might not feel confident about the results on other farms, opting to be cautious about promoting certain practices.

With respect to other policy implications for the barriers summarised in Table 4, our discussion proceeds on two fronts: barriers that are intrinsic to the farmer and barriers that are shaped by external factors, i.e. that are beyond the farmer's control. With respect to the first, the following implications can be noted:

- "**Salience bias**" seems to be an important barrier for sheep/beef farmers. This barrier could be overcome by providing more information about cost savings and rewarding farms that strategically opt for practices involving lower environmental costs. Although Ghadim & Pannell (1999) do not explicitly use the term "Salience bias", they highlight such themes in the adoption of agricultural innovations.
- "**Habitual behaviour**" is another common behavioural barrier that may be hard to overcome in the field. However, one option to reduce this barrier is to support and expand the role of "model farmers", who can contribute direct knowledge to their peers about the operability and benefits of certain practices (Brown et al. 2016).
- "**Inadequate managerial capability**" is a barrier repeatedly reported by sheep/beef farmers and is not only relevant to keep low stocking rates in dairy systems, (as discussed above), but also for sustaining low nitrogen pastures (D2). Skill enhancement and training programmes could support the reduction of this barrier.

Barriers that cannot be overcome by individual farmers are even more relevant to policy makers as public or coordinated private interventions (or a combination of both) could be pursued in order to reduce them. With respect to such external barriers, our findings suggest the following policy implications:

- The barrier "**Inappropriate or inadequate extension**" was also recorded in two different practices. This finding is in line with Cortés-Acosta et al. (2019), who identified the presence of this barrier from farmers' interviews and relevant literature in New Zealand. This barrier may potentially be overcome by improving extension (Sewell et al. 2017). However, doing so may not be straightforward as GHG emissions do not directly affect the surrounding environments of farms, making the relation between climate change and on-farm activities a topic that is difficult to understand (Geoghegan & Brace 2011). This position is confirmed by the respondents, in which only half of the farmers indicate that their on-farm activities can help to address climate change. Hence, extension services need to be able to address the void between the farmer decision-making today and the seemingly distant effects in the future. As this barrier is addressed, it will also support overcoming the barrier "Inadequate managerial capability".
- The "**Principal-agent or split-incentive problems**" barrier was recorded in all three dairy practices evaluated here, reflecting the different interests of farm managers and either the farm executive board (the farm owners) or the employees of the farm (or both), which on occasions may not necessarily align. This mismatch of interests is not exclusive to dairy operations, but it is important to investigate in this context as different targeted interventions are needed in order for farm owners' (and/or employees') interests to

become better aligned with those of farm managers seeking to adopt or expand environmentally friendly practices.

Other barriers noted in Table 4 and discussed in previous parts of this paper are also important to consider and identify in future public climate change mitigation interventions. Some of these barriers could be addressed with straightforward approaches (e.g. incorporating mitigation practices in extension programmes to reduce both "**Inappropriate or inadequate extension**" and "**Inadequate managerial capability**" barriers). As straightforward as some approaches may appear, however, they are not without complexities and challenges. In this respect, integrated frameworks and approaches could support more and better policy design to change behaviour and to intervene in certain areas in order to reduce barriers.

Finally, our aim is not to emphasise whether any one barrier is statistically more significant than another as our small number of observations does not allow us to draw conclusions on this. Rather, we want to highlight that even when farmers consider a practice to be no-cost, the barriers summarised in Table 4 may prevent them from doing so. All the barriers identified here should be considered as relevant in the New Zealand context as they were clearly identified by the farmers surveyed over other options provided. Thus, from the barriers listed and discussed by Jaffe (2017), our evidence suggests that:

- At least 12 different barriers from Jaffe's (2017) typology stymie the use or expansion of no-cost practices (rows 2-4 in Table 4).
- Four barriers need to be addressed if the promotion of practices by farmers is to be encouraged (row 1 in Table 4).
- "**Principal-agent or split-incentive problems**" seems to be an important barrier to confront if higher adoption rates of once per day milking systems is an objective in New Zealand.
- Some barriers also appear affecting the willingness of farmers to promote specific mitigation practices. In this analysis, we found that "**Variable farming landscape**" appears to be an important reason for farmers to not promote mitigation practices.

Table 4. List of all barriers identified and selected quotes in relation to identified no-cost practices.

	Barrier (practice)
Barriers for not recommending the practice to other farmers*	Variable farming landscape/Risk and uncertainty (**SB3, D2**) Inadequate managerial capability (D1, D2) Variable farming landscape/Complex interactions (G) Unsureness about practicality (D2)
Barriers for delaying adoption	Learning and adjustment (D1) Inadequate or inappropriate regulation/Trust or credibility (D1) Habitual behaviour/Unsureness about practicality (D2) Option value (SB1, **SB3**) Capital market failure (SB1, **SB3**)
Barriers for ceasing adoption	Habitual behaviour (SB1, D1) Complex interactions (SB1) Principal-agent or split-incentive problems (D1, **D3**) Inadequate managerial capability (D1)
Barriers for not adopting at all	Unsureness about practicality (SB2, **SB3**, D1, D2) Salience bias (SB1, SB2) Habitual behaviour (SB1, SB2, **SB3**, D2) Risk and uncertainty (**SB3**, D2) Inadequate managerial capability (SB1, SB2, **SB3**) Complex interactions (SB2, **SB3**) Inappropriate or inadequate extension (SB2, D2) Principal-agent or split-incentive problems (D1, D2, **D3**)

Notes: * This group of farmers stated that they are applying the no-cost practice, but affirmed that they are not willing to promote it to fellow farmers, therefore these are barriers to 'promotion' rather than to 'adoption'. Practices provided in parentheses. SB1 = higher live-weight gains in lambs/calves. SB2 = increasing scanning percentage. SB3 = use of dairy beef animals to replace beef cows. D1 = reducing current stocking rates. D2 = limiting the use of N fertiliser in favour of other practices. D3 = adopting a "once per day" milking system. G = general, i.e. no specific practice.

6 Final Remarks

This paper explores the occurrence of barriers in the decision-making of farmers when facing agricultural GHG mitigation practices that scientists claim to be no-cost, i.e. they are practices that could lead to higher (or maintained) levels of profit while simultaneously reducing the GHG-emission intensity of the farm (Jaffe 2017; de Klein and Dynes 2017). In particular, we explore four scientifically tested no-cost practices and two extra practices that purportedly may be used to reduce GHG emissions on pastoral farms – in total, three practices for the sheep/beef industry and three practices for the dairy industry.

Two main findings yield important take-away messages: (1) a relatively high percentage of farmers believe that the six evaluated practices can be defined as no-cost; and (2), among those farmers who consider a practice to be no-cost, several are not adopting it. For the latter, we find a set of barriers causing this under-adoption. These barriers are identified in mainly three sub-groups of farmers within those who believe a practice is no-cost: 1) farmers who have used the practice in the past but do not anymore; 2) farmers who do not adopt it but state that they will in the future; and 3) farmers who state that they will not (or were unsure to) adopt it at all. We found four barriers for group 1, five barriers for group 2, and eight barriers for group 3 – in total, 12 different barriers (summarised in Table 4). In group 3, "**Unsureness about practicality**" was the barrier most frequently selected by farmers, while "**Salience bias**" and "**Principal-agent or split-incentive problems**" were the most frequently selected barriers for sheep/beef famers and dairy farmers, respectively.

We also found that some barriers affect the promotion that farmers applying mitigation practices can make about the practice to other fellow farmers. In this case, the barriers "**Variable farming landscape**" and "**Risk and uncertainty**" (especially in relation to the *M. bovis* outbreak and the practice SB3) were important reasons farmers stated for being hesitant to promote mitigation practices.

Finally, it must be noted that the findings in this paper are only an initial step towards addressing an issue that has received inadequate attention in the past. A larger, periodic survey could be established to better understand which barriers are in place in particular contexts as mitigation efforts expand across New Zealand. For this to happen, industry support is key in encouraging farmers to express their perceptions on practices and options, the benefits and costs of these, and the factors limiting their adoption/expansion. The evidence provided here indicates that several barriers are important in New Zealand pastoral systems. As mitigation awareness, regulation and options expand in the country, these barriers will need to be addressed and evaluated over time. Different approaches to reducing barriers deserve debate and scrutiny from planners, industry and scientists.

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Appendix 1: Survey design and sampling

Appendix Table 1 provides the specific wording used in this paper and the related wording and definitions used in Jaffe (2017) and Cortés-Acosta et al. (2019). The blank cell in the third column of the "Option value" and other barriers means that these barriers were not directly included in the survey. As mentioned in footnote 3 of this paper, these barriers were omitted to avoid an overly complex survey that could have negatively affected our response rate. The decision on which barriers to include was made by the authors after defining the most relevant in the New Zealand context according to the literature review and interview analyses provided in Cortés-Acosta et al. (2019).

1. Barriers to the adoption of farm practices or options: Typology definition and non-technical language used with farmers.

Barrier	Technical definition adapted from typology (Jaffe, 2017)	Non-technical definition used in Cortés-Acosta et al. (2019)	Non-technical definitions used in the survey (this paper)
1. Arguably efficient			
1.1 Modelling mismatch	Barrier arisen from incorrect assumption in modelling	The practice does have greater costs than benefits!	Although the practice can work, it cannot lead to improved (or maintained) profits Will result in more work
1.2 Option value	A "value" of waiting to get a lower price	I'll try it one day, but not yet	
1.3 Variable farming landscape*	The possibility that a no-cost option works for some farms but not others due to heterogeneity	The model doesn't reflect the landscape of my farm	It's too different from how my farm works, so profits will be negatively affected
1.4 Learning and adjustment	If adaptation costs are high enough or the learning period is long enough, the eventual benefit may not justify bearing these costs	It pays off only once we have learnt how to do it, but the learning process is too expensive	Learning how to do it is too expensive
2. Information			
2.1 Awareness	Farmers are not aware of the existence of no-cost options	We just didn't know	

Barrier	Technical definition adapted from typology (Jaffe, 2017)	Non-technical definition used in Cortés-Acosta et al. (2019)	Non-technical definitions used in the survey (this paper)
2.2 Unsureness about practicality	Information on context-specific performance might be weak	It doesn't seem practical	The practice would not be practical on my farm The practice might not work well on my farm system
2.3 Complex interactions	Farmers do not know the bottom-line impact or are not sure about some unintended consequences due to a complex interaction during adoption	It wouldn't mesh well with other farming systems	The practice might not mesh well with my farm system
3. Market structure and institutions			
3.1 Principal-agent or split-incentive problems	Lack of right incentive to adopt mitigation options	I'd like to try it, but my investors/suppliers wouldn't	My investors/shareholders/manager wouldn't approve the use of this practice Employees objected
3.2 Insufficient diversity of offerings	The market offers an insufficient number of variants	There isn't enough diverse choice of options	I can't access the right products (animals, fertilisers, etc.) to make this work
3.3 Capital market failure	Inability to finance investments	The upfront money for the investment is too hard to get out of banks	I wouldn't be able to raise the initial capital without affecting my profits in the medium term Limited budget
3.4 Supply chain failure	External factors (e.g. demands from up or down the supply chain) may preclude use of some options	I can't access the options	Limited options to purchase inputs
3.5 Inappropriate or inadequate extension	Extensions may fail to meet the needs of farmers	The government seminars and information aren't clear about this	I haven't had advice (or seen evidence) about how this practice could be used effectively I haven't had good advice about how to adopt this practice
4. Regulation and policy			
4.1 Safety or other verifications	Some regulations may require costly verification when a new option is introduced	There is a conflict with occupational health and safety requirements	

Barrier	Technical definition adapted from typology (Jaffe, 2017)	Non-technical definition used in Cortés-Acosta et al. (2019)	Non-technical definitions used in the survey (this paper)
4.2 Environmental regulations	An option may have environmental side effects that are restricted by the existing regulations	Maybe there are side effects modellers don't consider, which are regulated by government	
4.3 Demand for new regulatory regime	New option may need some new regulatory structure before implementation	Same as above	
4.4 Inadequate or inappropriate regulation	Existing regulation may be a disincentive to the adoption of a new option	The regulation does not support its use (of the option)	Uncertainty about government regulations
5. Risk and uncertainty**	The benefits and costs of an option may vary over different conditions	It's too risky or uncertain	It was too risky It is too risky, so I don't see a clear profit gain
6. Externalities	Farmers may not get (or pay) the modelled benefits (or costs)	Costs or benefits aren't just borne by me, but also by someone else	
7. Behavioural factors			
7.1 First-cost bias	Farmers may put a considerably large weight on the initial cost	The first cost is too high, even though it pays off over time	
7.2 Salience bias	Potential cost savings may be overlooked by farmers	The benefits are too small to be worth the effort	The profit gains could be too small compared to the extra effort involved
7.3 Loss aversion	Farmers may put disproportionate weight on avoiding losses	I can't risk the loss, even though it's not probable	
7.4 Inadequate managerial capability	Using a new option may require some specific skills	There is no one available who is trained to manage the farm through this	Necessary inputs/capability are not available It requires skills that we don't have Insufficient managerial capability
7.5 Social norms and prestige***	Adoption of certain no-cost options may go against social norms or prestige	It's too different from what farming has been about	
7.6 Habitual behaviour	Farmers may be reluctant to change their old ways of doing things	We don't want to change our routines and habits	Will disrupt current management The practice would mean changing my way of doing things

Barrier	Technical definition adapted from typology (Jaffe, 2017)	Non-technical definition used in Cortés-Acosta et al. (2019)	Non-technical definitions used in the survey (this paper)
7.7 Trust or credibility	The source of information about no-cost options is untrustworthy	The source of information is not coming from someone who I know and trust, and who knows about me and my farm	

Notes: * Includes the barriers "Heterogeneity of preferences or conditions" and "Variability and model incompleteness", as defined in Jaffe (2017). ** Includes the barriers "Risk aversion", "Uncertainty of regulatory constraints", "The benefits and costs of an option may vary over different conditions" and "There may be fundamental uncertainty about the magnitude of the overall net benefit", as defined in Jaffe (2017). *** Also includes the barrier "Standard practice", as defined by Jaffe (2017).

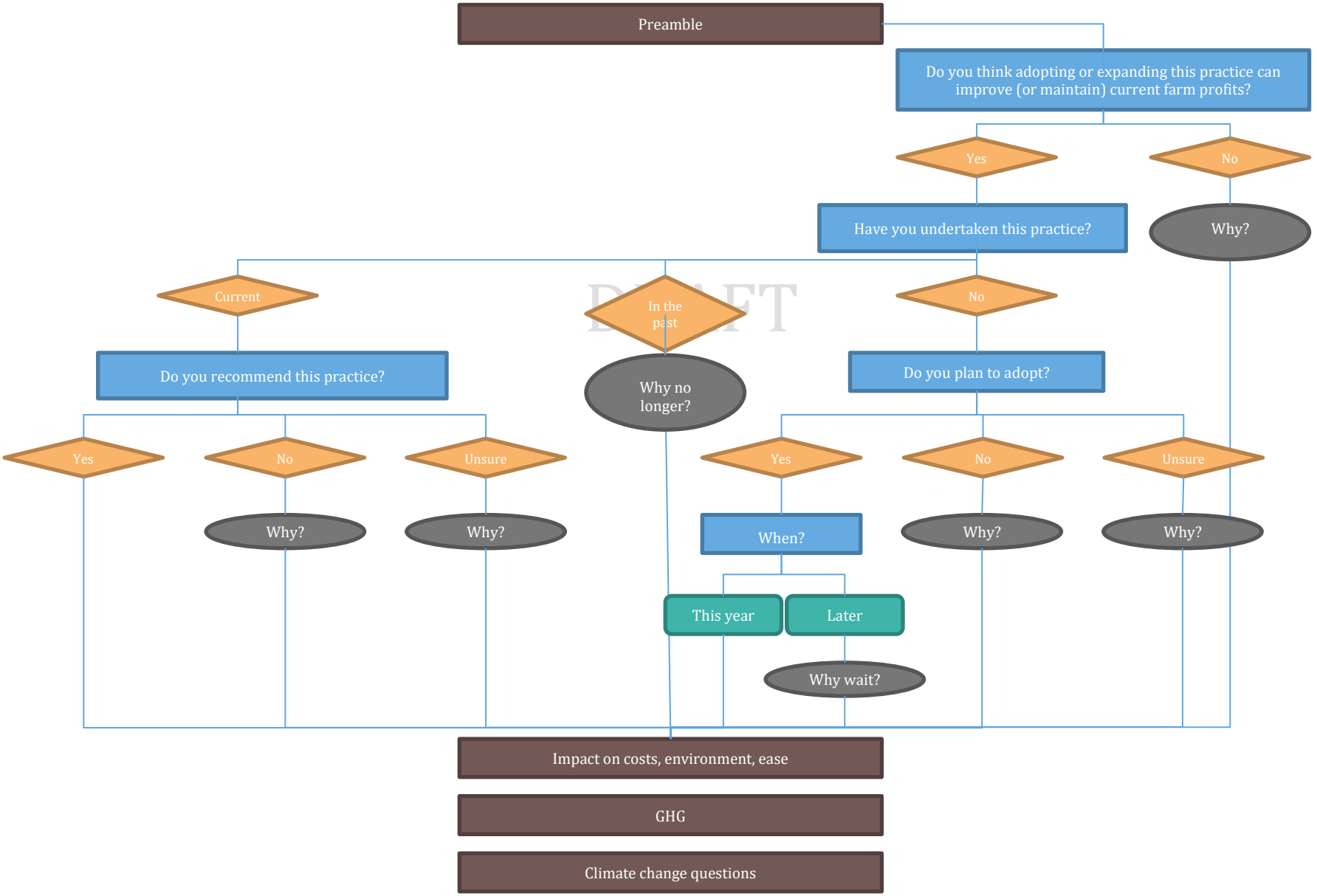
During our survey, we occasionally used a different wording to describe the barriers. This was done mainly to adapt the option to the answer provided by the farmer – barrier options were given as answers to different questions, as seen in Appendix Figure 1. This figure shows the flow chart used in the survey design, where each green oval node denotes a section where a barrier was identified. With respect to the representability of our sample in the New Zealand pastoral context, the following can be stated.

- For sheep/beef farmers, 7.2% of farmers classify themselves as high country, 38.6% classify themselves as hill country, 6.0% classify themselves as intensive finishing, 34.9% classify themselves as finishing breeding, and 13.3% classify themselves as mixed finishing. Beef+Lamb New Zealand (2018) estimate that South Island high country and North Island hard hill country comprise 11.3% of sheep/beef operations, that hill country comprises 39.4% of operations, that intensive finishing comprises 22.7% of operations, that South Island finishing breeding comprises 22.2% of operations, and that South Island mixed finishing comprises 4.4% of operations. Although Beef+Lamb New Zealand (2018) do not include North Island finishing breeding or North Island mixed finishing classes, 22 of 29 respondents who classified their operations in the survey as finishing breeding and 7 of 11 respondents who classified their operations as mixed finishing reside in the North Island. Intensity of inputs varies across operation classes, with high country and hill country operators having the lowest input use. Some 71.1% of sheep/beef farmers who responded to the survey operate primarily in the North Island, compared to 52.9% of North Island sheep/beef farmers reported in Beef+Lamb New Zealand (2018), indicating a potential North Island bias in our analysis.

- For dairy farmers, 25.3% are classified under System 1 in DairyNZ's classification system (DairyNZ 2017), 28.9% are System 2, 32.5% are System 3, 9.6% are System 4, and 3.61% are System 5.5 While farms may change systems even within a season, the DairyNZ 2016–17 Economic Survey (DairyNZ 2017) reports that 5–10% of owner-operated herds are System 1, 20–25% are System 2, 35–40% are System 3, 20–25% are System 4, and 0–10% are System 5. Hence, Systems 1 and 2, which DairyNZ (2017) consider to be low-input systems, are over-represented in our data, while System 4, considered to be a high-input system, is under-represented. Overall, 69.9% of dairy farming survey respondents reside in the North Island, a figure that is close to DairyNZ's (2018) report of 74.3% of all dairy herds being located in the North Island.

5 The five production systems broadly reflect when feed is fed to dry or lactating cows and, secondarily by the amount of imported feed and/or off-farm grazing. In System 1, no feed is imported and no supplemental feed is provided to the herd except supplement harvested off the milking area. In addition, dry cows are not grazed off the milking area. In System 5, up to 55% of total feed is imported and is used throughout the year for both dry and lactating cows. See https://www.dairynz.co.nz/business/the-5-production-systems.

Appendix Figure 1. Survey flow. Barriers were identified at the grey oval nodes.

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