with stock on the crop, there is an added component to soil loss risk depending on grazing management and stock type.

A consistent response across all themes was the necessity to “Make sure you do it properly to make sure you get a good crop”, “you can’t cut corners”.

It was clear from the interviews that the detail of successfully establishing crops devolved to the farm level based on the quality of decisions such as fertiliser requirements in relation to soil nutrient levels and crop type, and potential for weed and pest impacts. The choice of crop was determined by the type and/or class of animal for which it was targeted, with the area determined by both availability and crop volume to sustain or grow animals. Differences in the pattern of seasonal rainfall dictated when to establish a helicrop, and were based on soil moisture rather than a calendar event. Delaying a decision until soil temperatures were suitable was clearly outweighed by considerations of soil moisture and ensuring the crop was established well before the soils dried out.

The preceding dialogs record the experiences of the four interviewees at a time when all have come through the initial learning experiences for helicropping. Attention needs to be paid to their experiences and what might be done in the future if other hill country farmers are to take up the practice of helicropping with confidence.

Conclusions
All four respondents reported profitable returns from their experiences with helicropping. Combined with their experiences of reliable crop establishment this has convinced these early adopters that the practice is a good fit within their farming practices and did not conflict with their obligations as environmental custodians looking to preserve hill country soils. Their experiences fit well with the Pastoral Industry Forage Strategy themes of forage improvement and on-farm innovation (Forage Strategy 2016).

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Information required from research programmes when introducing legume forage systems into challenging environments

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Abstract
The use of legumes to increase animal performance is well known, but why are sheep and beef farmers not using a legume forage system in New Zealand hill country, and what information do they need before introducing a legume forage system? A co-innovation process was started to explore the challenges sheep and beef farmers face introducing a legume forage system into hill country and their information needs. The first step in this process, reported here, was to run eight workshops throughout New Zealand which 105 farmers and agribusiness representatives attended. Results showed that getting the right information from trusted sources was the highest priority for farmers looking to introduce a legume forage system. Information provided by the science community and industry needs to be region specific as the range of knowledge around legume species differs across regions. Some of the information required by farmers is already well documented, but may not be in the hands of the right people.

Keywords: challenges, forage, farm system, information requirements, knowledge, legumes, sheep and beef farmers

Introduction
Evidence is emerging that pasture production in New Zealand hill country has declined in the past 10 to 15 years (Mackay & Costall 2016), especially on some slopes and aspects. So while maintaining advances in productivity and profitability by utilising more of the feed grown (Fennessey et al. 2016), this option is rapidly running out. New technologies are required to maintain productivity and profitability into the future. Hill country development and sustainability are hampered by limitations of soil nitrogen and water. Legumes, by fixing atmospheric N, increase water use efficiency, and supply high quality feed to ewes and lambs and cows and calves, providing stock for red meat supply at premium times. Previous science developing forage legumes has often failed as farming practices have not changed to capture the benefits of feed quality, improved water use efficiency and feed quantity, that are proven to increase animal production (Stevens et al. 2012).

The use of legumes to increase animal performance is well known (Lambert & Litherland 2000), however, sheep and beef farmers are not adopting legume forage systems in New Zealand hill country. What information do they need before introducing such a system? This research reported aimed to understand the perceived challenges farmers face when introducing a legume forage system and what information requirements they needed to adopt such a system. This paper reports on the first step towards providing researchers with information that farmers need to know to be able to make a change to their farm system. Such information will help researchers incorporate these needs into research programmes.

Methods
For complex issues, such as changing a farm system, a co-innovation approach can assist with change (Turner et al. 2014). This approach involves a number of people and organisations working together in the design and implementation of research. A co-innovation process was used to explore the challenges and information requirements when introducing a legume forage system into hill country. A benefit of ‘co-innovation’ is better understanding of the problems as a result of involving more people and organisations, which in turn provides greater confidence that the solutions will be successful (Rijswijk et al. 2015). People and organisations, through a process of interaction and social learning, become aware of the values and needs of participants in the co-innovation system. Ideally, this enhances each person’s moral and knowledge perspectives and increases their respect and opportunity for developing a solution that attempts to satisfy the needs of all (Hounkonnou et al. 2012; Klerkx et al. 2012; Klerkx & Nettles 2013). The hypothesis was, if people and organisations from all parts of the system are involved in specifying the problem and co-developing a solution, then that solution is more likely to be fit-for-purpose and be adopted by the end-users (who helped develop it) than would otherwise be the case.

Workshops
Eight farmer workshops were held throughout New Zealand focusing on the information required for farmers to adopt legume forage systems. Each workshop involved between 10 and 15 participants from sheep, beef and dual-purpose properties. The workshops were conducted under a co-innovation process (Rijswijk et al. 2015) and led by experienced facilitators.

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Zealand to provide understanding of what challenges to legume use are present in different environments. The location of the workshops were based on eight distinct geo-climatic regions, five in the North Island and three in the South Island. An open invitation was sent to local sheep and beef farmers through the Beef + Lamb New Zealand network. In total, 105 self-selected participants attended the workshops. All workshops had a farm systems scientist as the primary facilitator and a social systems scientist as the primary facilitator and a social systems scientist as the primary facilitator and a social systems scientist as the primary facilitator and a social systems scientist as the primary facilitator and a social systems scientist as the primary facilitator and a social systems scientist as the primary facilitator. The question on how to tailor information was explored in an open discussion session. Results (Table 1) indicated that there were three main layers to the way farmers viewed information. The first was the type of information that was required. This reflected the challenges that were identified and that providing information would alleviate or solve the problem. However, much of the discussion about information was not about the lack of information, but rather how the information needed to be delivered and who should be involved. Farmers wanted to know what legumes work for which farm system, followed by on-farm field days and workshops. The role of rural professionals and agribusiness personnel was identified as key to ensuring that messages were consistent and of high quality, enabling farmers to make appropriate decisions. The concept of ensuring that information was tailored to local farming systems and conditions was recognised as an important role for local agribusiness and rural profession groups. Training to ensure that local professionals understood the technology and practices associated with legume forage systems was highlighted as a need.

**Information requirements**

**Economics**
- Grazing management
- Animal health
- Weed and pest control
- Animal nutrition
- Farm systems design
- Environmental impacts
- Economics

**Management guidelines**
- Supportive network
- Training of rural professionals
- Demonstration
- Consistent messages
- Local examples
- Appropriate language
- Field days
- Workshops

**Who needs to be involved**
- Farmers
- Agribusiness
- Scientists
- Trainers
- Industry support

Figure 1 Challenges that face farmers when implementing legume forage systems.

Grazing management was of greatest importance in the practical implementation realm, although weeds and pests and establishment were also highly represented. Other areas that were considered important included the base resources of soils and climate, particularly the response to variability in the weather.

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**Discussion**

The complexity of changing to a legume forage system has limited the impact of previous research. Investigations of end-users needs and the information they require, will inform the design of future extension programmes and help define rates of adoption of complex technologies. Changing to a legume forage system has major consequences many of which add value to the farming system and individual, while some may not.

The complexity that came out of the workshops was that many of the biophysical factors like grazing management, weeds, pasture management and pests are all inter-related, as were the economics and flexibility of the farming enterprise. So while each of the issues can be defined in isolation it is only when they are combined that a legume forage system can be designed. It is important to realise that while the identification of challenges provides some insight into information needs, the relative representation may not necessarily represent their real importance. The greater the number of representations of a category, the more likely they were to be represented in different regions. The occurrence of some of the challenges, e.g. animal health and species selection, may represent the lack of familiarity of the group with legume forage systems. However, some others, such as weeds and pests, reflect direct experience with these challenges that were yet to be resolved. Regulations and public opinion were noted infrequently, but if regulation prevents practice then meeting other requirements such as grazing management, will not change the outcome.

While some challenges were specific to some regions, most were evident in all regions. The challenges also demonstrated overlap between the initial categories. Information provided by the science community and industry needs to be region specific as the range and depth of knowledge around legume species is different across regions. The types of issues and how farmers view the use of legumes also varied across the regions.

Information requirements were the greatest recognised challenge. This included current knowledge that is not available at the local level, but also further knowledge that may be required across the range of categories. There are two parts to information requirements. The first is what information is known and can be provided immediately to farmers and their agribusiness support systems? The second is what information is unknown, which defines the science needs? The current knowledge needs to be identified and developed into appropriate packages for both farmers and agribusiness support. Agribusiness support, through seed representatives, contractors, consultants and veterinarians need to be engaged in the process to co-develop material and delivery programmes.

Some of the information, like requirements for clever establishment, are already well documented, but may not be in the hands of the right people. In regions where oversowing is not regularly practised, there is a need for more people and some training, to make sure that best practices are implemented.

A lack of or a need to acquire more knowledge was the highest rated social risk. This recognises the need to understand new management systems when implementing legume forage systems. The risk of some farmers attempting to implement legume forage systems without changing current thinking was also strongly recognised. More labour also means more people management skills are needed so staff can also understand how to operate a legume forage system.

Understanding the challenges farmers face when implementing a legume forage system is only the first step in tailoring information packages. Farmers need information before they need to implement a decision. Information needs to be provided in a way which farmers understand. Suggestions included practical on-farm demonstrations in a climate that was similar to their farming system, and information presented in a clear, simple way. Workshops participants noted that getting the right information from trusted sources was their highest priority. Providing farmers with rural support networks, such as seed and fertiliser system representatives, contractors, consultants and veterinarians need to be engaged in the process to co-develop material and delivery programmes.

Some of the information, like requirements for clever establishment, are already well documented, but may not be in the hands of the right people. In regions where oversowing is not regularly practised, there is a need for more people and some training, to make sure that best practices are implemented.
representatives, armed with correct and relevant information was identified as vital. Some of the information required to address the noted challenges is already well documented, but needs to be transferred to the relevant farmer networks.

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Abstract
The effects of increased use of brought-in feeds were evaluated across 25 dairy farms in central Waikato. Farms were classified into low, medium and high feed-input categories based on <500, 500-1200 and >1200 kg DM/cow, covering a range typical of that in the main dairying regions of New Zealand. Average milksolids (MS)/ha was 1087 and 1900 kg in the low and high feed-input categories, but total land-use/tonne MS was the same when all off-farm land was accounted for. Average estimated on-farm nitrogen (N) leaching increased from 26 to 30 kg N/ha/year between the low and high feed-input categories, but off-farm leaching sources were equivalent to an increase of 20 and 64%, respectively. Greenhouse gas emissions (GHG) for the off-farm component of the whole system were 61% higher on high feed-input farms, but the carbon footprint and N leaching per tonne MS were similar across feed-input categories. High feed-input farms used feed-pads and increased effluent area (66 versus 21% of farm) to increase nutrient efficiency. Mitigation analyses indicated that N leaching could be decreased by optimising effluent area, reducing N fertiliser rate and utilising low-N feeds.

Keywords: nitrogen leaching, whole farm system, greenhouse gases, land use

Introduction
Dairy farming in New Zealand has intensified in recent decades, with increased milk production per hectare associated with the use of nitrogen (N) fertiliser, irrigation and increased use of brought-in feeds. For example, the average use of dry matter (DM) in brought-in feed on NZ dairy farms was 970 kg DM/ha in 2004/2005 and 2550 kg DM/ha in 2014/2015 (source: ProfitWatch and DairyBase from DairyNZ). The increased feed intake will be associated with increased nutrient intake and excretion by animals, which potentially could lead to greater losses of N and phosphorus (P) to waterways. However, various management practices that affect nutrient losses, such as farm dairy effluent (FDE) management, have improved over time (e.g. PCE 2012). Farmlet research trials in Waikato have shown large increases in N losses with increased use of N fertiliser, relatively small changes on farmlets (milking platform only) with brought-in maize silage and large potential reduction in N leaching with farm management and mitigations (e.g. Ledgard et al. 2006; Shepherd et al. 2017).

The aim of this study was to evaluate productivity, nutrient losses and wider environmental indicators at on-farm and whole system levels for 25 case study dairy farms in central Waikato with varying levels of use of brought-in feeds.

Methods
Twenty-five case study dairy farms from the Taturaunui area of central Waikato were selected and classified into low, medium and high feed-input levels based on brought-in feed of <500, 500-1200 and >1200 kg DM/cow/year. Farm numbers in each category were 6, 11 and 8, respectively. Farm records were collected from each farm for 2014 and 2015 and cross-checked with farmers. Thus, it uses real farm data but the wider representativeness for New Zealand in relation to level of brought-in feeds is uncertain.

Data from farms were modelled using the OVERSEER® nutrient budget model version 6.2.3 (hereafter called OVERSEER; Wheeler et al. 2003) to estimate N and P losses, and a life cycle assessment (LCA) model that complied with International Dairy Federation (IDF 2015) guidelines to estimate total greenhouse gas (GHG) emissions. The LCA accounted for all emissions from production, transportation and use of inputs including fertilisers and feeds. Modelling accounted for the dairy farm (milking platform), as well as land used for rearing replacements off-farm (based on the MPI intensive beef monitor farm data) and growing crops for the brought-in feed. For the latter, average published data on crop yields and inputs (e.g. Ledgard & Falconer 2015) were used with associated N leaching calculated for crop systems using OVERSEER or from published data (Schmidt 2007). Excretion of N by animals was calculated in OVERSEER from the difference between N intake and N output in products. The FDE component of this calculated in OVERSEER was based on the relative time cows spent in the dairy farm, yards and feed-pad areas. The remaining excreta-N was deposited.