Horticulture transformers: can a modular approach improve grower access to automation?

A think piece by Nick Pickering, University of Waikato.

How does this piece of work deliver on the Aotearoa Horticulture Action Plan?

This think piece contributes to the action:

- Work with local and international technology organisations to build a strong agritech sector.

GROWING TOGETHER 2035

Aotearoa Horticulture Action Plan

THE UNIVERSITY OF WAIKATO

Te Whare Wānanga o Waikato

INTRODUCTION

Agricultural Technology (AgriTech) is transforming the food and fibre sector, but many automation prototypes have not been widely adopted in commercial horticulture due to challenges in performance, ease of use and/or financial viability. To address this, the Modular Agritech Systems for Horticulture (MAS-H) concept explores re-usable automation "building blocks" that can be reconfigured across various crops and tasks year-round.

A range of factors are holding back greater adoption of automation in New Zealand horticulture. These include:

- **Seasonality:** the seasonal nature of crop production limits the viability of equipment dedicated to single tasks that only need to be completed for part of the year (pruning, frost detection etc).
- **Capital constraints:** small and medium-sized businesses often lack the significant capital required to purchase sensors, robotics and automation.
- **Servicing support:** limited support networks for AgriTech hardware create challenges for rapid servicing and repair, especially when built for specific crops or when used in more isolated regions.
- **High complexity at low scale:** the high costs of production of relatively few units mean robotics and similar solutions struggle to deliver return on investment (ROI) in some crops.
- **Data Silos:** despite technical feasibility, data-sharing remains low as companies prioritise competitive advantage.
- **Availability and cost of specialists:** access to specialists can be a limiting factor, particularly those working in robotics, machine learning and software.

Canvassing industry views on the need for automation

To identify the demand for AgriTech in horticulture, a survey was conducted by the University of Waikato and distributed to various horticulture product groups. The survey had 43 respondents, spanning kiwifruit (10), apples (7), vegetables (5), avocado (4), orange (3), feijoa, lemon, strawberry, tamarillo (2 each) and blueberries, cherries, mandarin, onion, passionfruit and tomatoes (all 1 each). The demand was analysed per crop against a variety of technology automation opportunities. An opportunity was deemed applicable to a crop if one of the respondents classified it as a high or essential priority[1].

Drivers

Respondents identified that productivity, yield, quality, labour shortages and health and safety were all drivers of automation. Quality and yield were the greatest drivers as they had the biggest 'very important' percentage.

[1] Due to the low quantity of respondents and the large diversity across crops, the results are to be treated with caution. Notwithstanding that, the trends identify a scope of work for future investigation.

Serviceability expectations

Often horticulture activities need to occur within a time-critical window e.g. when a crop is ready, there is a short timeframe in which it can be harvested. Therefore, it is important that technology can be back in service rapidly if an issue occurs. The survey indicated that apples, avocado, blueberries, cherries, feijoa, kiwifruit, mandarin, passionfruit, strawberry and vegetables would all require a Mean Time To Repair equipment (MTTR) within 24 hours. Specific activities requiring a MTTR within 4 hours include pollination, frost detection, irrigation, harvesting (automatic), harvesting (human assisted transport) and transport e.g. bin carrying. Activities such as soil sampling, weeding, grass cutting, growth prediction / estimates, planting, pruning and pest/disease detection have the lowest repair time requirements of between 1-7 days. To achieve these expectations there is a need to hold spares and build support capability.

Technology development approach

In terms of the best approach, the majority of respondents (62.5%, Figure 1) believed that we should be developing technology together across horticulture. 20.8% did not have an opinion, with 8.3% recommending leaving it to the tech companies, 6.3% preferred developing within their crop. One person answered “other”, recommending including all existing industry stakeholder in the development of solutions.

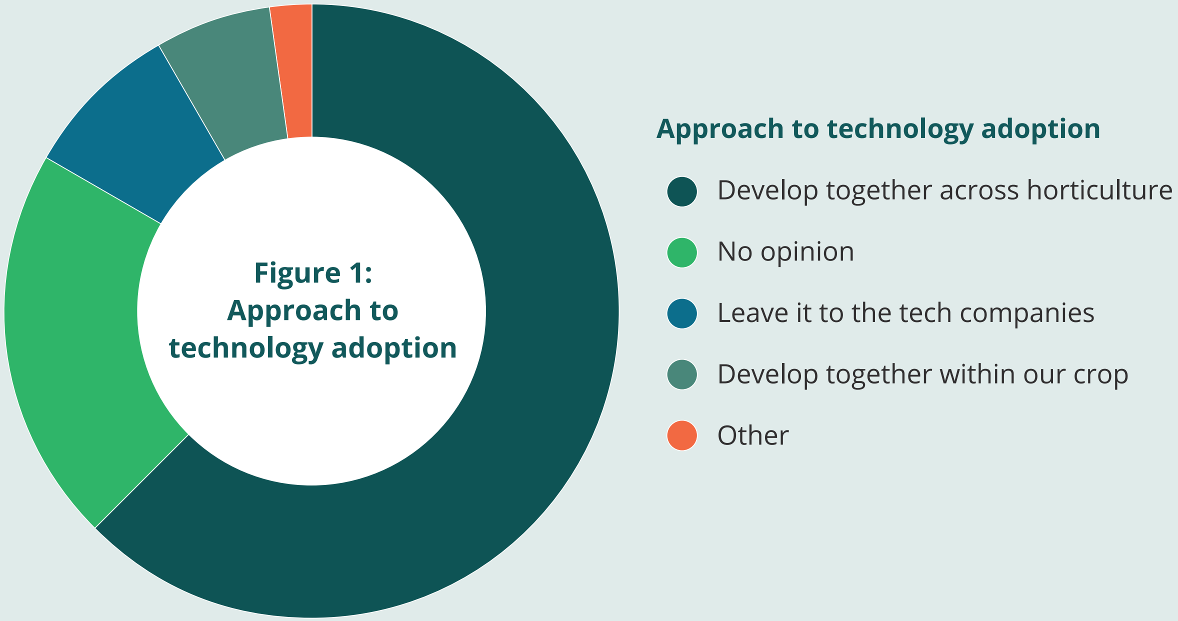


Figure 1: Approach to technology adoption

Table 1: Potential opportunities for collaboration based on activity and interested groups.

Opportunity for automation	Number of crops interested	Type of crops interested
Pest and disease detection	11	Apples, avocado, feijoa, kiwifruit, lemon, orange, potatoes, strawberry, tamarillo, tomatoes (for processing), vegetables.
Spraying	10	Apples, avocado, blueberries, kiwifruit, lemon, orange, potatoes, tamarillo, tomatoes (for processing), vegetables.
Weeding	7	Avocado, cherries, feijoa, kiwifruit, onion, orange, strawberry, tamarillo, vegetables.
Growth prediction / estimates	8	Apples, cherries, kiwifruit, lemon, orange, strawberry, tomatoes (for processing), vegetables.
Irrigation	7	Apples, cherries, feijoa, kiwifruit, strawberry, tomatoes (for processing), vegetables.
Harvesting (automatic)	7	Apples, blueberries, kiwifruit, orange, strawberry, tomatoes (for processing), vegetables.
Human assisted harvesting	7	Apples, avocado, blueberries, kiwifruit, orange, strawberry, vegetables.
Grass cutting	7	Apples, avocado, cherries, feijoa, kiwifruit, lemon, vegetables.
Transport e.g. bin carrying	5	Apples, avocado, kiwifruit, orange, vegetables.
Pruning	5	Apples, blueberries, kiwifruit, orange, tomatoes (for processing).
Pollination	4	Apples, kiwifruit, strawberry, tomatoes (for processing).
Soil sampling	4	Apples, kiwifruit, orange, vegetables.
Fruit and veg thinning	3	Apples, kiwifruit, tomatoes (for processing).
Planting	3	Apples, potatoes, tomatoes (for processing).
Flower thinning	3	Apples, kiwifruit, tomatoes (for processing).
Frost detection	3	Apples, cherries, kiwifruit.

Where automation is needed

To better understand where automation would be beneficial, priority for automation was surveyed across growing activities. Table 1 identifies the activities that at least one respondent from each crop identified as a 'high' or 'essential' priority for automation. The results show areas of interest that are common to multiple crops, and therefore, potential opportunities for pan-sector collaboration.

POSSIBLE SOLUTION

What could a modular approach look like?

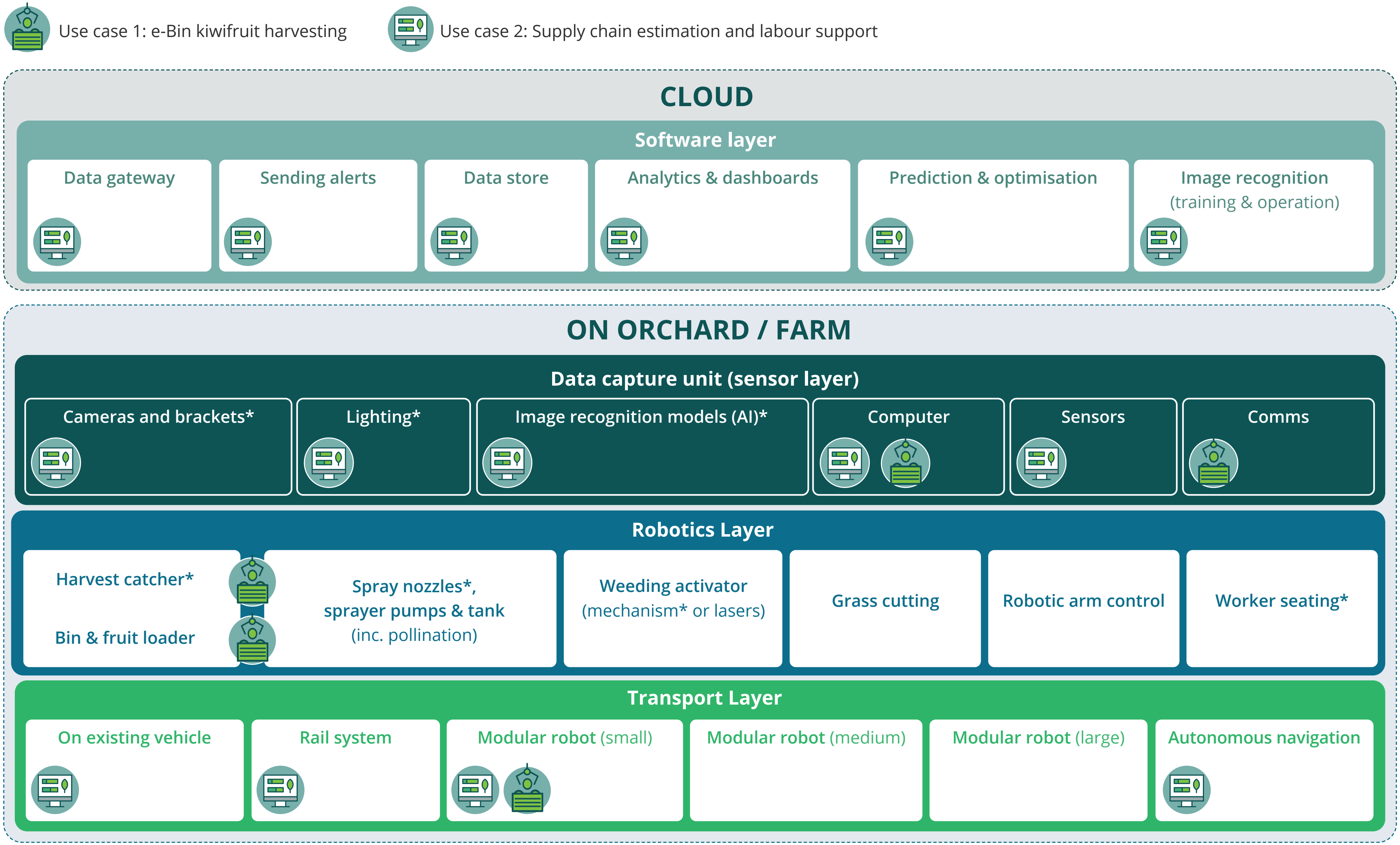
A modular approach would consist of re-usable technology building blocks from a hardware and software perspective. These building blocks take care of the common capabilities, to enable the AgriTech ecosystem to develop crop specific add-ons. For example, a company may utilise the common Data Capture Unit (sensors) and software but build their own specialised image recognition model to detect a disease or predict yield for a specific crop. The building blocks are outlined in Figure 2, consisting of a:

- transport layer (covering five size options to suit different crop architecture, with or without autonomous navigation)
- robotics layer (for undertaking manual tasks)
- data capture layer (for gathering crop information); and
- software layer (for data processing, visualisation and alerting).

The tools within each of these layers can be combined and supplemented by custom equipment for a specific crop[2]. The robotics and data capture tools can be added and removed from different base transport layer options to address servicing and low utilisation challenges. Use of industry standards for interfaces between the modules will allow for interoperability with commercial or custom made local add-ons that.

[2] For more information refer to conference paper Pickering, N., Duke, M., & Au, C. K. (2023, June). Towards a Horticulture System of Systems: A case study of Modular Edge AI, Robotics and an Industry Good Digital Twin. In *2023 18th Annual System of Systems Engineering Conference (SoSe)* (pp. 1-8). IEEE.

Figure 2: Modular AgriTech Systems for Horticulture (MAS-H)



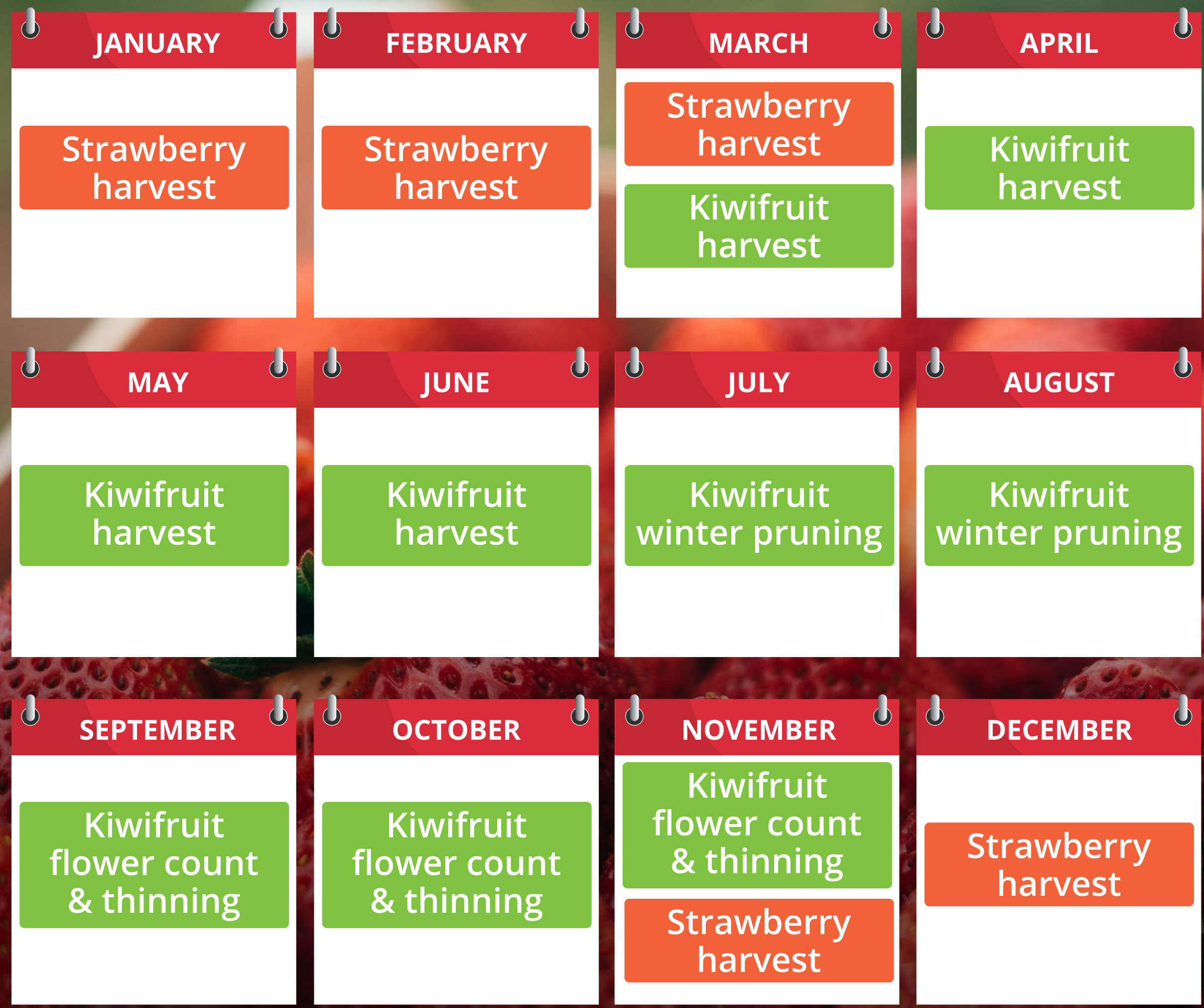
*The implementation can be tailored by the local AgriTech ecosystem to meet any crop specific requirements.

Year-round utilisation

Due to varying growing cycles of fruit and vegetables, automation is often only utilised for a small window of time. Figure 3 demonstrates how MAS-H could be utilised for kiwifruit harvesting (use case 1) from March to June, reconfigured to support pruning in July and August, changed to surveying for flower counting (use case 2) with seats added for thinning during September and October, then reconfigured for towing strawberry pickers. Use across multiple crops allows for year-round utilisation of the base unit.

For those who want to own their own equipment, research and development costs can be saved by building on top of the modules and leveraging the common support capability in terms of people and spare parts.

Figure 3: Timeshare of MAS-H example between kiwifruit and strawberries



How would a modular AgriTech approach make automation more accessible?

Due to the low number of units, rapid repair requirements, long lead times for specialist equipment, high level of support capability required and limited availability of specialists in robotics, machine learning and software, The current approach of everyone custom building everything and holding a suitable quantity of spares and support capability will not be sustainable for many crops. A modular approach would reduce the barriers to AgriTech adoption for many, regardless of whether horticulture businesses own, lease or hire.

Benefits to existing support and AgriTech companies:

- **Develop and support solutions** for the industry without having a high cost of research and development, while retaining IP in their specialist add-on.
- **Leverage academia and government support** or an accelerated transition from research into operation while building a skilled workforce to support it.

Benefits to growers and farmers:

- **Reducing capital constraints** via renting/sharing/leasing options.
- **Servicing support** a common spares pool could be established in-country, based on a modular design that workers can replace on-orchard/in field. Available spare and remote support teams will ensure return to service times can be kept to a minimum.
- **Increased benefits** from AgriTech to improve yield, quality, profitability, sustainability and reduce the impact of labour constraints.

The investigation highlights the potential of modular technology building blocks for re-use across horticulture, focusing on supportability and financial viability. It is hoped that this think piece will generate further discussion. The agnostic Modular AgriTech Systems for Horticulture (MAS-H) approach aims to bridge gaps that currently hinder academia and the AgriTech ecosystem from scaling innovations to benefit the entire horticulture industry.

Use case 1: Kiwifruit human assisted harvesting

Human assisted harvesting in kiwifruit helps to address harvest labour availability risks by expanding the demographic of people who can harvest and allowing picking at night. This approach removed the physicality of harvesting kiwifruit in the heat of summer while carrying around approximately 25kg. While expanding the available pool of workers, unit trials are also looking promising in terms of addressing fruit quality, productivity and worker retention challenges.

The e-Bin utilises the Modular Robot (small), harvest catcher, bin/fruit loader and lighting to expand the picking day. Future work will utilise the navigation tools to provide steering assist and productivity reported remotely to harvest contractors to support worker incentivisation and orchard planning.

The fruit capture at the rear and fruit loader can be removed to act as a standard bin carrier. The side wheel units could be reconfigured to a different wheel base to be utilised for other purposes, such as auto-navigating down strawberry rows while towing ergonomic worker buggies, shuttling trays from harvesters to the chiller or surveying an orchard with the Data Capture Unit (DCU) attached. For more information see the video here. This work was funded by Zespri International and the winner of the Fieldays Prototype Innovation award in 2022.

Figure 4: e-Bin human assisted harvesting

Use case 2: Kiwifruit surveying to support labour decisions

Natural variances in fruit growth based on soil, vine health and weather, combined with labour availability challenges can make flower thinning unpredictable. Autonomous surveying of flower counts can utilise the MAS-H Modular Robot (small), along with the Data Capture Unit (DCU) and soon to be autonomous navigation, (Figure 5) and will provide a dashboard to the orchard manager. They can adjust their desired growing strategy and process workers instructions based on expert knowledge rules, specifying the thinning strategy, location and expected timing per bay.

For more information see the video here.

This work was funded by Zespri International.

Figure 5: Labour Decision Support Survey