If you want to go far, go together

The future of open source agtech

A report for

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Executive Summary

Most software and data platforms developed for agriculture are copyrighted and thus closed in nature. There are very few projects where the source code for these products is freely available to users, referred to as open source. Many other software sectors have embraced this open source model.

This report investigates the open source software options available to agriculture, discussing how these projects could benefit the agricultural sector and detailing the challenges or barriers to adoption.

This report found that there were a limited number of open source projects available that could be adopted easily by industry, but many more that could be adopted with some further investment.

It was also found that there are many more benefits to the industry than just free software. Adoption of an open source culture in agricultural software and data will increase the value of that data to stakeholders, by allowing easier sharing and analysis of that data. This can speed research outcomes by improving researcher access to on-farm data sources, though a simpler data sharing system, which would enable access to a larger and more diverse dataset for research use.

The adoption of an open source ecosystem will benefit all stakeholders in the agricultural data value chain, from farmers to developers, manufacturers and Research Development Corporations (RDC).

Open source software provides growers with the opportunity to take control of their data and also their data infrastructure. Whether they choose to outsource or self-manage, the choice is theirs.

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Foreword

I come from a fifth generation, broadacre cropping farm near Crystal Brook in South Australia. Our farm is 100% cropping with a rotation including wheat, barley, lentils, canola and oaten hay. Our business has been an early adopter of many Precision Agriculture (PA) technologies, moving into yield mapping, two-centimetre autosteer and variable rate technology, in the late 1990s.

Something that has always been common to agricultural technology is its closed nature and the reluctance of manufacturers to collaborate for fear of losing their Intellectual Property (IP) or market share. This caused much frustration on our farm and was the catalyst for the creation of the Southern Precision Agriculture Association (SPAA), aimed at improving the compatibility of PA equipment between brands and machines.

I have spent many hours troubleshooting various pieces of PA equipment on our farm and have found the support for these systems is largely limited to the manufacturer, and even then only a few people have an in-depth knowledge of the systems.

I have also learned to code at a very basic level and build some basic electronic devices. I set up my own public Long Range Wide Area Network (LoRaWAN) connected to The Things Network (TTN) and built a sensor to measure temperature inversion conditions. All this was achieved using information found on various web pages and forums.

This led me to pose the question: if all of this was available for users of regular technology, why was it not available for users of agtech? The answer is that most of these regular technology items were built on open source platforms such as Arduino or Raspberry Pi. As such, all the information about these products was freely available so that anyone could become an expert and then share that knowledge.

When I originally applied for a Nuffield Scholarship, I wanted to look at the potential uses for the Internet of Things (IOT), but I soon found that there were limited applications for non-irrigated broadacre agriculture. Must uses involved improving the way we already sense our environment, not creating novel applications.

If you want to go fast, go alone. If you want to go far, go together. - Proverb

I feel this proverb sums up the current agtech climate well. There many companies rushing to be the first and the greatest; rushing to generate returns for their venture capital (VC) backers, and keeping their cards close to their chest in a market where many will fall by the wayside. While I was looking at IOT I found some other projects hidden behind the money-intensive, marketing-driven and VC-funded agtech startups.

These hidden projects were the open source projects that had been started to solve a problem for one farmer or a group of farmers, and were quietly serving a purpose, not looking for a purpose. These were groups of like-minded farmers and developers working together to solve issues that impacted them collectively. These projects looked like the answer to much of the frustration I had previously experienced when dealing with our current PA equipment. I instead chose to focus on the projects that were championing a new era in agtech by bringing open source solutions to farmers.

This Nuffield project has allowed me to meet people I never thought I would have met and pushed me outside of my comfort zone. It has allowed me to talk to the people that are maintaining and driving these open source communities and to show these projects to a wider audience who were previously unaware of their existence.

Acknowledgments

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I am grateful to my family for their support and understanding throughout this journey. My parents, Malcolm and Jane for held the fort at home while I was away for a large part of our growing season. My partner, Lauren for her understanding and patience throughout the last 12 months.

I would like to thank all the people that I visited during my travels for their hospitality and for the time that was so freely given. It is the people that I have met throughout these travels that made the Nuffield experience so uniquely rewarding.

I would also like to thank Marie Groenhof and Martijn Kuiper from Achmea, Netherlands, for organising and escorting me on two days of visits in the Netherlands, whilst I was still finding my way at the beginning of my studies.

Abbreviations

AOG	AgOpenGPS
CRC	Cooperative Research Centre
DIY	Do It Yourself
GNSS	Global Navigation Satellite System
IOT	Internet of Things
IP	Intellectual Property
LoRaWAN	Long Range Wide Area Network
MIT	Massachusetts Institute of Technology
NTRIP	Networked Transport of RTCM via Internet Protocol
OADA	Open Ag Data Alliance
OATS	Open Ag and Technology Systems
OSRF	Open source Robotics Foundation
OSS	Open source Software
PA	Precision Agriculture
RDC	Research Development Corporation
ROS	Robot Operating System
RTCM	Radio Technical Commission for Maritime Services
RTK	Real Time Kinematic
SPAA	Southern Precision Agriculture Association
TTI	The Things Industries
TTN	The Things Network
UI	User Interface
VC	Venture Capital

Objectives

This project has five separate but closely connected objectives, which are to:

- Identify some of the prominent open source projects currently available tor agricultural producers.
- Investigate the challenges and barriers to adoption for using these systems.
- Investigate the benefits of adopting an open source ecosystem.
- Identify funding models to encourage continued support of these projects.
- Identify potential opportunities to grow the use of open source tech in agriculture.

Chapter 1: Introduction

Currently, nearly all PA technology is provided by large manufacturers or private companies. These companies have, until very recently, operated inside their own ecosystems. Company A's products would not integrate well with Company B, and if a farmer wanted to access the benefits of a particular device, they would often have to buy the associated devices from the same manufacturer. Essentially users were locked into a particular vendor. This made it difficult for growers to choose tools based on their merit, rather than the compatibility with their own systems.

Compare this to the consumer technology world, where a photo can be taken on a smartphone, then opened in any image editing software and then printed on any printer with ease. The current agtech systems are like the early Microsoft and Apple operating systems, where it was difficult to transfer data between these systems. Further improvements in the industry have meant that a file can now be sent from one system to the other, without the need for any intermediate software.

Open source is not open data. Open source refers to the source code for the software, which is freely available without a licensing fee. The data held within that software can be as available or tightly held as the user likes.

In 2018 there was over US$1.6 billion invested in agtech (Kukutai et al., 2018). This was predominantly in startups and private companies. Each investment tends to be separate from another, which invites the question: is there potential to invest in a foundation or a framework which provides a base and standards for these investments to leverage?

The Data to Decisions Cooperative Research Center (CRC) recommended that the 15 Research and Development Committees (RDCs) collaborate to establish an open standards hub where standards can be suggested, considered, implemented and catalogued in an open forum (Skinner et al.,, 2017). Finally, it is inevitable that all ad hoc digital and big data projects will be delivered into value chains by the RDCs. As these products and services become established, it will become harder for the participating RDCs to collaborate on common platforms to optimise value for their industries and levy-payers (Skinner et al., 2017). Similarly, as products and services are delivered by private industry, it will also become harder to collaborate, if collaboration is not a primary consideration when designing these platforms. It is important that RDCs are active in this area while the big data industry is becoming established in agriculture. They can provide guidance and a framework to ensure that big data protocols are established which promote simple and efficient collaboration and compatibility moving forward.

Perrett et al. (2017) found that the unconstrained implementation of decision agriculture would result in a lift in the gross value of agricultural (including forestry and fisheries) production of AU$20.3 billion. The challenge for developers is ensuring products are relevant to farmers' needs, are simple and easy to use, and perhaps most importantly, deliver a return on investment (Perrett et al., 2017). Ault et al. (2018) suggest that, unless open source collaboration can be implemented by industry and academia, we will all continue to lament the limited utility and limited size of the ag-data market.

"*If a farmer gave away their harvests for free, they would be unable to pay their expenses, their workers, and themselves. Farming takes limited resources (soil, inputs, labour) and transforms them into a limited product (food). Software is different. It still requires limited resources to create (the hours and attention of a programmer), but once the code is written it can be copied for free*. *Proprietary software licences put restrictions on this ability to copy in order to turn an unlimited product into a limited one, so that it can be sold at a premium. A free software licence, on the other hand, explicitly allows users to copy, modify, and redistribute the software without restriction."* (Stenta, 2019).

It is for these reasons that this report has investigated the potential uses of open source in agriculture.

Chapter 2: Open Source Projects

While Open Source Software (OSS) projects are common in other computing areas, the move towards OSS in PA technology has been relatively recent, with many projects only established in the last five years. As a result, there are not large numbers of OSS projects directly related to PA, but they are beginning to gain momentum. Searching AgOpenGPS on Google in 2016 returned zero results (Tischler 2016). That search in 2020 returns nearly 6,000 results. Open source projects traditionally arise from a real and identifiable need (Eghbal 2016).

Open source software still has licensing and copyright requirements. There are differing levels of open source licensing, some more restrictive than others in regard to the use of the code. The two main types are the permissive licence and copyleft licence. For the purpose of this report, the term open source refers to permissive licensing, such as the MIT (Massachusetts Institute of Technology) licence. The intent of the MIT licence is defined by Opensource.org (2020) as "*users may deal in the software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicence, and/or sell copies of the software*".

The other main type of open source licence is referred to as a copyleft licence. These licences require that any software that uses that source code must also use the same licensing requirements and make any modifications available back to the original source. This type of licence is becoming less popular as it does not allow companies to build on top of the original open source code without losing the IP rights to the code they add. When it comes to build versus buy, most companies would rather build software from scratch in-house than risk using software with a copyleft licence (Gerkey 2019).

Some of the more common open source projects related to agriculture are outlined below.

2.1 AgOpenGPS

AgOpenGPS (AOG) began when Brian Tischler of Mannville, Alberta, needed a way to know where he had planted; the long stripper stubble from the previous year prevented him from seeing the cultivated ground, so he turned to a technology solution and began developing AgOpenGPS.

"Well it seems I have had some time on my hands with it snowing so here goes. Have a peak! Its a bit like watching paint dry, but I think the application has promise - considering its free. AB line,

*up to five sections GPS control, fully configurable and it actually works extremely well. Cannot fool the section control as it gives very good recognition of unapplied areas." (*Excerpt from the introduction of AgOpenGPS, Tischler 2016).

AgOpenGPS is an open source autosteering system, that runs on any Windows tablet and allows users to set up their own autosteer system using generic off-the-shelf components and create a fully functional system for a fraction of the cost of current proprietary systems. It has many of the same features as its proprietary counterparts with improvements added regularly, thanks to an active community of farmers and developers.

Figure 1: AgOpenGPS autosteer boards ready to ship. Source: A. Ortner 2020

2.2 FarmOS

FarmOS is a web-based application for agricultural management, planning and record keeping. There are at least 200 users of FarmOS currently, according to their Drupal usage statistics. These are spread across at least 14 countries. It was developed by Mike Stenta of Hartford, Connecticut, while he was working on some small diversified vegetable farms in 2014. As these vegetable farms have a diverse range of crops, the paddock management can be quite complex. Stenta saw a need for a system to record the history of all the operations carried out on these farms. As well as recording their paddock operations, FarmOS now allows growers to record data from proprietary or do it yourself (DIY) on-farm sensors. Growers can also choose to share their data with other users and control the level of sharing.

2.3 Vinduino

Vinduino began as an open source irrigation management system by Reinier van der Lee, to better manage the water usage of his vineyard in Temecula, California. His system measures soil moisture using gypsum blocks and temperature in the vineyard. Information is then sent to the cloud via a LoRaWAN network. From there, the data is sent to the eVineyard platform that provides the water usage information and schedules irrigation timings based on evapotranspiration and soil moisture data. Reinier's initial product, the R3 sensor station, is still open source, but later products and the eVineyard platform are now closed source.

2.4 ROS Agriculture

ROS Agriculture was founded by Matt Droeter from Dallas, Texas in early 2017. The community's main goal is to empower farmers to work with robotic tools, based around using the Robot Operating System (ROS), which allows farmers to create their own robots. (Laird 2018) describes ROS Agriculture as a way for farmers to create their own innovation. ROS is OSS that was created in the late 2000s by researchers at Stanford and Willow Grove to allow them to study robotics, without the cost and learning curve needed when working with different proprietary systems. Much of the development of ROS has been focussed on service and industrial robots, which means that some of the functionality required for robots in an agricultural setting is not available. One of the goals of ROS Agriculture is to make packages with this functionality available (Laird 2018).

2.5 FieldKit

While not specifically aimed at agriculture, Conservify is developing an open source platform called FieldKit. Fieldkit is a standardized open source software and hardware platform that gives individuals and organizations the tools to collect and share field-based research data, and tell stories through interactive visualisations for conservation, science, exploration and education (Conservify 2018). Many aspects of conservation and agriculture overlap, and these tools could also be useful deployed in an agricultural scenario. FieldKit consists of a hardware platform for collecting various weather and environmental data, as well as a software platform to store and interpret that data.

2.6 OATS Center

Purdue University has been proactive in promoting open source PA projects. Purdue has set up the Open Ag and Technology Systems (OATS) centre to address the issues caused by the lack of an open source culture in agriculture. They believe that the data exchange among systems, people and projects is the most critical component for achieving data-driven sustainability goals, and that this can be solved by using open source data and algorithm exchange paradigms. The OATS centre has several projects aimed at making agricultural data more accessible and more usable.

One of these projects is ISOBlue, endeavouring to facilitate the data acquisition process through the development of an open source hardware platform and software libraries to forward ISOBUS (ISO 11783) messages to the cloud (Layton et al., 2014). Combined with some of their other projects, the Open Agriculture Data Alliance (OADA) and TrialsTracker, farmers can view real time harvested yield data in the machine or anywhere.

2.7 The Things Network and Chirpstack

The Things Network (TTN) and Chirpstack are two open source projects that support the establishment of LoRaWAN networks. LoRaWAN is a networking protocol that allows IoT devices to communicate over long distances using minimal power. Unlike other IoT network protocols such as Sigfox, or cellular connections such as NB-IOT or Cat-M1, that rely on a provider to establish a network and provide a service. Users are able to install their own LoRaWAN gateway to create a network where required, similar to being able to setup your own wifi access point but not build your own phone tower.

ChirpStack is a project that allows users to set up their own private LoRaWAN network server. This enables users to connect a LoRaWAN end device, such as a soil moisture sensor, to the internet. This is accessed via a LoRaWAN gateway and the ChirpStack network server; from there they can forward the data to any storage or visualisation platform.

TTN functions in a similar way, except that it has established a global public network. All gateways connected to the TTN public network server are part of the same network. This allows the gateways to work together to cover a wider area and reduce duplication of infrastructure. The data that is transferred on the public network is still private and encrypted. TTN also allows for users to run their own network server and have a private network if they choose.

Chapter 3: Open Source Challenges and Barriers

3.1 Funding

It is important to recognise that software does take some effort, both to create it and to maintain it (Stenta 2019). The biggest challenge to OSS is finding the funding to continue maintenance and development of the project. As the code is provided at no charge to be freely used, depending on the licence, it is hard to generate an income stream. While it might be acceptable at the beginning when the project is small, a developer may manage to spend a few hours a month working on it. As the project grows and becomes more demanding, the developers cannot dedicate the time required without some form of remuneration.

Vinduino was a project that faced this problem. As the project user base increased, so too did the support requests. As the software was open, users could modify the code to suit their needs, resulting in some users breaking the code and requiring assistance. As Reinier released newer products that were more complex, he made the software closed source. This was partially to protect the Intellectual Property (IP), but also to prevent people creating issues by modifying the code (van der Lee 2019). Unfortunately, Vinduino had not developed the active support community around the product that some other projects had, which could have lessened the burden on Reinier to provide support.

3.2 The Learning Curve

For a user of OSS, the systems that are currently available require extra input from the user to set up than the proprietary equivalent. For example, AgOpenGPS requires the user to source all the hardware components from different suppliers, assemble the hardware and then install and configure it. There are some users that are now pre-assembling the components and selling the ready-made units to allow other farmers to adopt the system more easily. Farmier offer a hosting service for FarmOS, which means a grower only needs to pay a hosting fee and they can use FarmOS immediately, without having to set up their own server.

3.3 Trust

Some people still believe that open source is not as secure as proprietary software. Eghbal (2016) states that today nearly everyone uses open source code, including Fortune 500 companies, government, major software companies and startups. It can appear that if the source code is available to all, rather than locked down by a company, that it somehow is not as secure. In reality, it is potentially more secure as there are a greater number of people able to view the code and find flaws or security issues.

Chapter 4: Benefits of an Open Source Ecosystem

4.1 Harder, better, faster, stronger

Free software is directly responsible for today's current startup renaissance (Eghbal 2016). Embracing an open source culture allows companies to develop software faster and cheaper than if they were to develop it from scratch themselves. By being able to use OSS for their own systems, companies can reduce overheads as well as build on top of existing OSS for their products.

"*Open source became a movement — a mentality. Suddenly infrastructure software was nearly free. We paid 10% of the normal costs for the software and that money was for software support. A 90% disruption in cost spawns innovation — believe me*." (Suster 2011)

4.2 Driving innovation

Anybody with an idea, passion and talent anywhere in the world can contribute to the innovation culture. More minds mean more ideas and more creativity (Ault et al., 2018).

Ault et al., (2018) propose that, if current developers are able to share their ideas with the wider community, it will inspire others to work in agriculture and help to attract the great minds that are so desperately needed to address the issues facing agriculture in the future.

4.3 Building community

While some OSS have the option of a paid support service, such as Linux RedHat, many OSS are supported by an online community through a forum or chat group. These online groups allow collaboration on new ideas as well as support for issues. As there are no geographic restrictions on the use of OSS, there are members from around the world allowing the potential provision of 24-hour support and access to many ideas when trying to solve a problem. The chat groups create a sense of community, as they allow users to exchange experiences and challenges. This community is critical to the ongoing success of the project as they not only provide support for other users, but also a platform for the generation of ideas and development for the project itself.

4.4 Making data usable

The current proprietary environment makes transfer of information difficult, at worst it is impossible, but at best it requires every company to develop an interface to work with each other's company.

Brian Gerkey from Open source Robotics Foundation (OSRF) develops software for the ROS, for whom the majority of work they do is released as open source. Commercial companies will contract them to develop a feature that they need for ROS. If that feature is not their market differentiator, they will then open source it to be added to the main ROS project. The benefit of this is that they do not need to maintain that feature, because the global community will (Gerkey 2019). This allows the company to focus on the parts that do differentiate them in the market. Many companies outside of agriculture have found sharing, rather than building proprietary code, to be cheaper, easier, and more efficient (Eghbal 2016). These same principles apply to agricultural data.

This same principle could be applied to agriculture. Currently each platform develops their entire system and it is closed and restricted to that system, meaning that farms and paddocks have to be created and operational records entered for each system separately. This creates an extra task for the farmer to enter and maintain these records for each platform, before a useful result can be obtained. If that lower level infrastructure were open source then all companies could use the same data and build their product on top, saving work for the farmer entering records and saving time and money for the company developing the software. This would also make it easier for smaller startups to enter the market, as they would also have access to that same basic platform, fostering innovation. The OADA framework fits in between the current systems we have now and a solution with a common infrastructure.

4.5 Security

Open source software is independent of commercial entities and can be hosted locally by the farmer. This alternative allows farmers concerned about the security of their information to have greater control over the use and distribution of their data.

4.6 Academia

To ensure that the greatest value is derived from limited research dollars, open source is a logical decision, especially in the case of public funds. By using open source when a researcher wishes to continue, recreate or build on a colleagues work, they do not start with what the author says about his or her work, they start with the actual work - the actual code, the actual test cases and even the actual data (Ault et al., 2018). In this way, they can easily exactly replicate the previous outcomes, to then test different hypotheses or build further research. OSRF has found that government agencies in the United States are delighted with their approach of releasing their research as open source, as this approach is more in line with their long term goals of building common infrastructure that can be used and really move the industry forward (Gerkey 2019). This contrasts to Australia, where research funding has been steadily decreasing and research organisations have been forced to try to capture IP to monetise, sometimes at greater cost than the IP returns.

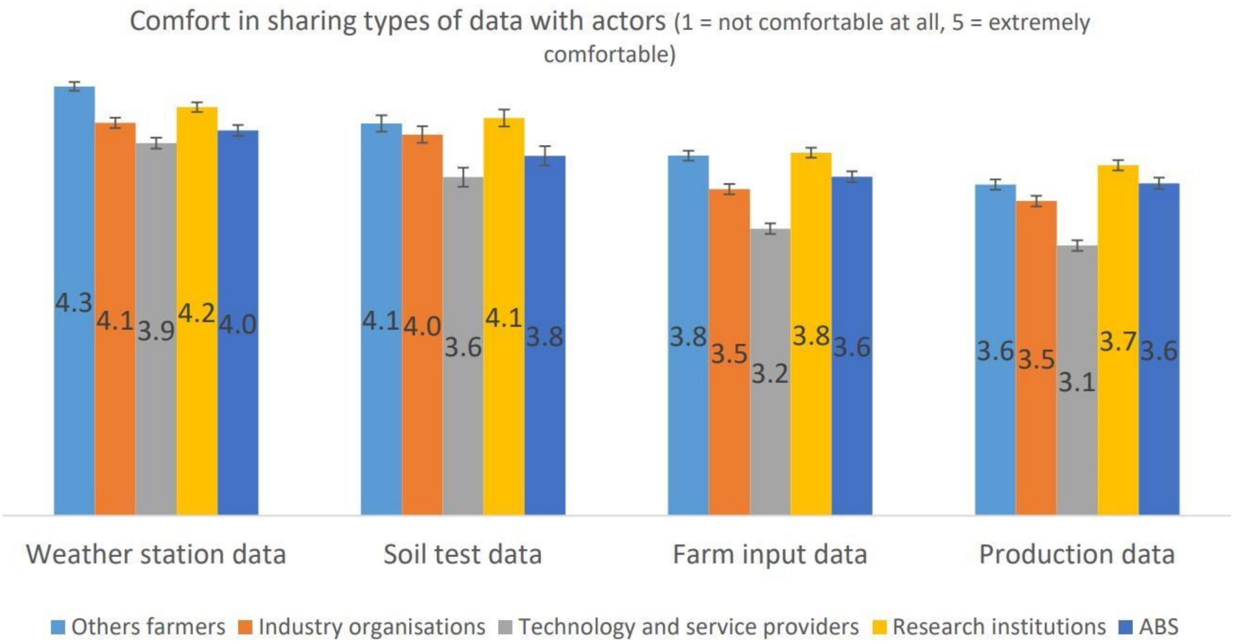

Figure 2: Farmer comfort in sharing data. Source: (Zhang et al., 2017) CSIRO

Figure 2 shows the willingness of farmers to share data with various stakeholders. Farmers are very willing to share data with other farmers and research institutions. A simplified and standardised method of accessing and sharing usable data would reduce the workload to collect datasets for research.

4.7 Commercial integrators

Recently some companies have formed as not-for-profits to tackle the issue of cross compatibility between different equipment brands. JoinData and Agrirouter are two examples of such companies. These companies provide a service to help farmers control how they share their data, how much and to whom. However, the companies that provide the data, like manufacturers and the apps that receive the data, must be members of JoinData or Agrirouter for the farmer to use these services.

These services are helping to address the challenges of data sharing and compatibility but adds another step in the data sharing process and comes at an additional cost to growers. In the case of JoinData, the app provider is charged a yearly fee per farmer and that is passed on to the farmer (Sener 2019). Agrirouter charges a flat annual fee per connection to the grower (Sonnen and Moller, 2019). These services provide an independent, secure and simple pathway for growers to share data between their different devices and suppliers. However, they also require the grower to use the machinery manufacturers cloud service as well, to get the data from the machine to the cloud. This creates another layer of cost to the grower as they must use the cloud service and the sharing service to move their data.

4.8 Reducing duplication

When Real Time Kinematic (RTK) autosteer with a 2cm accuracy was introduced into agriculture approximately 20 years ago, a local base station was required to provide a correction signal to each vehicle Global Navigation Satellite System (GNSS) receiver. Each manufacturer had their own type of base station to provide the required correction signal to their vehicles. The range of these base stations was typically around 20km. This meant that for a given area there would be several base stations overlapping the same area, each providing a correction for a specific brand of GNSS receiver. Most manufacturers now incorporate the ability to use a common type of correction message called Radio Technical Commission for Maritime Services (RTCM) messages. RTCM messages can be distributed by a radio link or cellular network using Networked Transport of RTCM via Internet Protocol (NTRIP). This has eliminated the need for overlapping RTK networks and as the RTCM protocol is open, it has allowed open source base stations to develop. This has resulted in the ability to use fewer, simpler, and lower cost base stations.

A similar situation is developing now as IOT is gaining momentum in agriculture, with network connectivity being required for these devices. Telecommunication companies are rolling out IOT connection services using the cellular data network, while some other operators are rolling out their own private networks using LoRaWAN. The two network infrastructures, cellular and LoRaWAN are complementary and each has a fit for particular users.

Due to the design of LoRaWAN, having multiple networks overlapping can be detrimental to the radio performance of the devices; however multiple overlapping gateways on the same network can greatly improve radio performance. Consequently, it is more efficient to have one LoRaWAN network that all devices can use, than overlapping networks that degrade performance. The implementation of TTN that all devices and users can access could possibly ensure the most efficient use of infrastructure.

Unlike software, costs for hardware are accrued per unit and hardware requires replacement at some stage. This makes the business model for a public LoRaWAN network difficult. While there are great benefits for a public network, how to monetise it is a problem still to be solved. A solution that could still deliver some of the benefits of one network is packetbroker.org. This service allows data to be transferred between private networks, thus effectively appearing as one network, whilst allowing network operators to charge for the data that they forward to other networks. It would allow current operators to gain better value from their current infrastructure and provide efficiencies for the network as a whole.

Chapter 5: Sustaining Open Source Opportunities

5.1 Funding

As mentioned earlier in this report, at some point, funding is needed to maintain an open source project. Finding a business model to support OSS is difficult. For many project maintainers, impact is a primary motivator, as they see how their direct efforts positively affect other people's lives (Eghbal 2016).

AgOpenGPS is maintained, using a purely altruistic approach, by Brian Tischler who has a desire to give back to agriculture and enjoys helping other farmers. Farming helps support this model, with many hours of programming completed while on a tractor or at home after a day's work.

ROS Agriculture is maintained by Matt Droeter, who consults full time to users of ROS or people looking to become users of ROS in agriculture. This allows him to support the ROS Agriculture project.

FarmOS uses a combination of funding sources to support its development. It develops specific modules for niche use cases of FarmOS as a fee for service, provides a hosting service for farmers FarmOS instances in the cloud, and accepts donations.

FieldKit is purely philanthropically funded. As their projects are mainly targeted at conservation projects, they align well with many philanthropic organisations' goals. However, these sources of funding are finite, with no guarantee of renewal after the granted project finishes.

TTN is managed and maintained by The Things Industries (TTI). TTI is a commercial entity that provides LoRaWAN network services for a fee. By providing the TTN as a free community project, TTI has been able to establish global coverage and test and perfect their network software. The TTN is provided without any service level guarantee, as can be expected from a free service. To obtain higher service level agreements, businesses can use TTI for a fee, which also allows access to some features that are not available to the community network.

No one strategy will work for all projects, as strategies vary depending on the project's goal and where it fits in as infrastructure or user software. For example, a company may decide to develop a plugin that sits on top of FarmOS or OADA. In this case they would have an incentive to support

FarmOS as it affects them directly. This would be more difficult for AgOpenGPS, as it is more of an end product, however farmers that use it may be inclined to support it, as it can potentially save them tens of thousands of dollars.

5.2 Critical mass

To see real change towards an open source culture in agtech, critical mass is needed. There are indications that this is starting to occur, Purdue has established the OATS centre and there are more open source projects appearing targeted for agriculture. In a recent newspaper article by (Belz, 2020), Mark Stock commented that the increased record prices paid for older farm tractors was due to the fact that any time something breaks on newer tractors, a dealer's computer is required to fix it. (Bruisma, 2019) commented that the work that was being done by Purdue was amazing and just lacked the critical mass to have it fully available. One way to influence the companies offering PA solutions to embrace an open source culture, aside from the benefits it offers them, is to get enough farmers using an open source alternative, to achieve the critical mass needed to initiate change.

5.3 Partnerships with proprietary

Partnering with proprietary software will likely be the most sustainable solution going forward. While open source has many benefits, some things need a monetary incentive. It is not about free technology but open technology and a pragmatic approach is required (Bruisma, 2019). Open source the things that can be open and keep the sensitive IP closed.

To develop new technologies requires financial investment. To justify that investment there needs to be a financial return. This is essential for agriculture to keep driving innovation forward but partnering with open source platforms allows that innovation to happen faster, by focussing on what is important. Open source platforms provide business opportunities for anyone to build a service that adds value. If there are enough businesses building add-on services, then they will be inclined to support it as they depend on it (Gerkey, 2019).

If agricultural data is readily accessible and easy to integrate, it then provides opportunities for ideas from anywhere to get a start. Startups do not need large amounts of capital as the basics are already available to them. Real innovation and on a budget: that makes sense (Laird, 2018).

Chapter 6: Case Study: AgOpenGPS

As mentioned earlier, AgOpenGPS is an autosteer project that was created by Brian Tischler. It is supported by an active global community, through a Telegram chat group and Discourse forum. It is hard to quantify the number of users of the software, as it can be freely obtained from the GitHub repository (https://github.com/farmerbriantee/AgOpenGPS). Currently there are 268 active members in the English-speaking Discourse forum and over 500 in the German-speaking Telegram group. The forum provides a location for users to obtain assistance from the community when installing and setting up AOG, as well as log bug reports and suggesting new features. The Telegram groups are useful for quick short messages discussing development ideas.

Figure 3: Brian Tischler, creator of AgOpenGPS in AgraBot. Source: A. Sargent 2019, Canada

There are several members contributing back to the project, depending on where their skill sets lie. Some are assisting with the improvement of the main software; others are developing hardware for vehicles, while others write documentation to help new and future users. Due to the collaborative nature of open source, there are new features added regularly in response to requests from users. Farmers have access directly to the developers of the software, allowing feedback to get quickly to the people who need it. Depending on the complexity of the feature, some new features are added within a week or even a day of the request. This agility cannot be matched in a proprietary system.

The software currently runs on a Windows tablet and uses any GNSS receiver. The tablet interfaces with the steering sensors and actuators through an Arduino or ESP32 microcontroller. This part requires the user to assemble their own steering hardware and electronic components, however there are now some users offering to sell ready-made control boards to simplify installation.

AgOpenGPS has features that rival many proprietary systems on the market. It has the ability to steer straight and curved lines, generate lines and headland patterns from a predefined boundary and turn the vehicle at the end of the row and onto the next line, in a feature called Uturn. As part of the Uturn, the system can operate end-of-row functions, such as hydraulic lift. As the paddock is worked, a coverage map is generated which allows the system to manage section control of 16 sections, display worked area, overlap and the actual area remaining. The software also includes a NTRIP client that allows RTK correction messages to be forwarded to the GNSS receiver providing 2cm accuracy. The software can control a semi-autonomous vehicle AgraBot, but due to risk and safety concerns that functionality has been removed. All this has occurred in a project that is not even four years old yet.

Conclusion

Smith (2019) of Wine Australia suggests that the industry needs a step-change in the way agtech innovation is managed and look to non-traditional partners. Embracing the open source culture could be part of that solution. It would help break down some of the barriers traditionally stifling the advancement and adoption of agricultural data. This puts farmers in the front seat to develop and influence solutions that work for them.

Open source software is a viable alternative to the current business models used in agtech. Most websites are built on open source software and many other industries and companies have already embraced the open source culture. Agriculture needs to catch up in order to realise the gains promised by agtech and big data and move past the current proprietary stalemate.

There are great opportunities for startups and existing software providers to embrace open source and build more universal solutions on top of an open platform, allowing growers greater flexibility in how and where they use and share their data, while also allowing the providers to capture a larger market share through a more universal and easily adopted platform. An open source ecosystem would reduce the barriers to entry for new entrants to the agtech and big data industry, as there would be ready-made platforms for them to build from, encouraging innovation in this area.

There are open source offerings available now for agriculture that are usable and provide real value to growers. While there are many more that are nearly ready to be widely adopted, they need a little more investment and support. The community aspect to the open source culture is vital. This community provides the ideas and the bug reports allowing for rapid development of new features. The community also carries the burden of the development work and documentation. Without an active and enthusiastic community contributing back to the project, it is incredibly difficult for an open source project to thrive. As these projects are more widely adopted, there will be a greater need for funding and suitable funding models will need to be identified and implemented.

There is an opportunity now for RDCs and grower bodies, in consultation with growers and with the support of the agtech industry, to guide the future of agtech and big data. This can be facilitated by promoting the reference architecture that was established by the 'Precision to

Decision' project and encouraging the creation and adoption of an open source data sharing and storage model. This would allow the real value of agricultural data to be realised.

There is an opportunity for growers to establish their own network infrastructure for the IoT. If this is approached collaboratively and uses existing on farm infrastructure, a robust network could be established in farming areas. This network could be implemented independent of telecommunications companies and with a relatively small financial investment.

Open source is not the answer for all the problems facing agricultural data, as there will always be a need and a place for proprietary systems. However, there is much more that can be done to incorporate open source culture into agtech, so that the promised value of agtech and big data can be realised.

Recommendations

- Manufacturers and software developers should look to adopt open source ideals in their products.
- Manufacturers needed to provide growers access to their agronomic data from a machine level, without subscriptions.
- Farmers need to insist that they have free access to their data at the source, in a format that is open and easily transferable.
- Farmers should consider incorporating open source projects on farm and contribute to those projects in some way through time, money or support.
- A collaborative approach to data formats should be adopted and built on open standards, facilitated by industry bodies.
- Industry bodies need to establish a data repository to store all farm data, built on an open source platform.
- Any funding for agricultural research should preference projects with open source release of research material.
- A collaborative approach to infrastructure should be considered by farmers and grower groups.

Appendix 1: Summary of Terms

Acronym	Full Name	Description	Purpose
GNSS	Global Navigation Satellite System	Refers to all satellites that provide navigation services, including GPS, Galileo, GLONASS, BeiDou	The system allows devices to locate themselves in a 3 dimensional space
IOT	Internet of Things	Refers to physical objects that are embedded with sensors and software which are connected to the internet	It is an internet that has devices which do not require human interaction
LoRaWAN	Long Range Wide Area Network	Is a Low Power, Wide Area networking (LPWAN) protocol that allows or the connection of battery powered devices to the internet	Allows a low cost and energy efficient means to connect IoT devices to the internet
NTRIP	Networked Transport of RTCM via Internet Protocol	Is a protocol that allows for the transmission of GNSS correction signals over the internet, rather than direct radio link between the base and rover	Allows GNSS corrections to be received anywhere there is an internet connection, removes the limitations of a radio at the location of the base station
ROS	Robot Operating System	Is a collection of tools, libraries and conventions to provide a flexible framework for writing robot software	It reduces the burden of writing robot software by facilitating a collaborative approach developing robotic solutions
RTCM	Radio Technical Commission for Maritime Services	Is a non profit organisation which developed a standard for GNSS messages	Their standard is used across most GNSS devices for RTK correction data
RTK	Real Time Kinematic	It is a GNSS correction system used to improve the accuracy of GNSS	Allows GNSS receivers in mobile applications to

		signals in real time while moving	resolve their position to +-2cm accuracy
TTI	The Things Industries	A company that provides a network server and support for IoT devices using LoRaWAN	To provide an IoT connectivity solution to businesses
TTN	The Things Network	The community arm of TTI that provides a network server free of charge to users wishing to setup their own LoRaWAN network	To provide an open source IoT connectivity solution

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Plain English Compendium Summary

Project Title:	If you want to go far, go together The future of open source agtech
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Scholar:	Andrew Sargent
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Objectives	• Identify some of the prominent open source projects currently available for agricultural production. • Investigate the challenges and barriers to adoption for using these systems. • Investigate the benefits of adopting an open source ecosystem. • Identify funding models to encourage continued support of these projects. • Identify potential opportunities to grow the use of open source tech in agriculture.
Background	Most software and data platforms developed for agriculture are copyrighted and thus closed in nature. There are very few projects where the source code for these products is freely available to users, referred to as open source. Many other software sectors have embraced this open source model.
Research	This report investigates the open source software options available to agriculture, discussing how these projects could benefit the agricultural sector and detailing the challenges or barriers to adoption. Research was conducted in the USA, Canada, Netherlands, Germany, Austria and Australia using a combination of interviews, farm visits, conferences, presentations and personal study.
Outcomes	Industry needs a step-change in the way agtech innovation is managed and look to non-traditional partners. Embracing the open source culture could be part of that solution. It would help break down some of the barriers traditionally stifling the advancement and adoption of agricultural data. This puts farmers in the front seat to develop and influence solutions that work for them. There are open source alternatives emerging. These offer the potential for greater compatibility and more efficient systems. They can provide lower barriers for entry for new developers and provide lower cost solutions, while improving the value generated from agricultural data.
Implications	This report highlights options that are available now for growers and other stakeholders in the agricultural data sector. It also identifies other projects that could be incorporated to establish an open data sharing and storage platform for agricultural data.