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Design Thinking and Compliance as Drivers for Decision Support System Adoption in Agriculture

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ABSTRACT

To respond to increasing demands for good agricultural practices (GAP) and food safety, governments globally are introducing stringent regulations to govern agricultural compliance that affect production, storage, and sales activities. New legislation in Argentina to enforce GAP is an opportunity to test compliance as an incentive to adopt technological solutions. This research aims to determine whether compliance software is an effective gateway to shift farmers' decision-making strategies from intuition-based to evidence-based, improving agricultural productivity through technology. Integrating technology can be a significant hurdle for farms but is also a steppingstone towards more reliable processes. To address this, the authors prototype a decision support system (DSS) for greenhouse farmers in La Plata, Argentina, to help farmers keep traceable records of their crops and treatments to reduce compliance risk. The project incorporates lessons learned from previous DSS projects and utilises design-thinking strategies to involve the end-user in the development.

KEYWORDS

Agricultural Compliance, Agriculture, Decision Support System, Design-Thinking, RUC-APS, Technology Adoption

INTRODUCTION

Technology and decision support systems (DSSs) have potential to improve food safety, production efficiency and therefore profits for agricultural business especially in developing countries (Fuglie et al., 2019). Their low adoption rates proves a significant hurdle for productivity improvements (Fuglie et al., 2019; Parker & Campion, 1997; Rossi et al., 2014), however studies suggest that compliance and end-user participation in design could be effective to increase sector-wide use (Parker & Campion, 1997; Rose et al., 2016; Rossi et al., 2014). This study will explore these drivers further through developing a compliance-focused DSS within a developing economy that is introducing new food safety regulations. The authors introduce the study first through: (i) background of agriculture and

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technology adoption, (ii) the context of this study conducted in Argentina and (iii) aims and objectives to address the aforementioned challenge.

BACKGROUND

The agriculture landscape is changing. The past five decades have seen a global shift in the field of agriculture from resource-driven growth to productivity-driven growth (Fuglie et al., 2019). Previously, farms have improved agricultural output through the expansion of land, use of pesticides, more fertilisers and other inputs. Now, most farms prioritise the improvement of resource and labour efficiency alongside good agricultural practices (GAP) and technology (Fuglie et al., 2019). Agricultural productivity has been lower in economically developing countries compared to advanced economics, impeding their convergence. Whilst much of the world has embraced technology with open arms, agriculture has adopted it more gradually (Fuglie et al., 2019). Technology and innovation are crucial to accelerate improvements in the sector and embody state-of-the-art practice (Fuglie et al., 2019). The knowledge capital contained within software and hardware can transform farm owners' businesses through improved connection to customers, streamlined supply chains and enhanced yields (Fuglie et al., 2019).

DSSs, a type of software solution designed to aid users make better decisions (Dicks et al., 2014), have shown success in both private and public sectors such as healthcare, banking and engineering (Papathanasiou et al., 2016). They have the potential to benefit farmers by presenting the likelihood of various outcomes from different options (Dicks et al., 2014; Rose et al., 2016) and can guide users through decision stages by providing expert advice that automatically corresponds to the user's inputs and recorded data for analysis (Been et al., 2009). The analysis conducted by such tools provide data-driven insights which may have otherwise been inaccessible or prone to human error. Despite a wide variety of DSSs for agriculture, studies indicate a disappointingly low uptake (Parker & Campion, 1997; Rose et al., 2016; Rossi et al., 2014) which is amplified in developing countries due to reasons such as technology and software being considered 'risky' by farmers (Fuglie et al., 2019). DSSs have barely contributed to practical agriculture due to this 'problem of implementation' which has been ascribed to technical limitations of software and farmers attitudes towards DSSs (Rossi et al., 2014). There are numerous detailed analyses on reasons for failure and non-adoption (Parker & Campion, 1997; Rose et al., 2016; Rossi et al., 2014) that will be examined more closely in the related works section.

The adoption of technology in agriculture in developing countries could help provide improvements that do not solely tackle production efficiency but also raise the bar of food quality for higher-value exportable products (Fuglie et al., 2019). This can be a significant growth opportunity for small-holder producers in order to meet the standards of other markets and ultimately catalyse impact on their triple bottom line: social well-being, environmental protection and economic value (Slaper & Hall, 2011).

Compliance has been identified as an incentive factor for adoption of DSSs in agriculture (Rose et al., 2016). Compliance certification schemes, such as global GAP (GAP, 2019), are a method of ameliorating aspects of supply chain traceability and food quality, yet many farms lack the existing systems and processes to reliably track crops from seed to harvest. This includes logging of pesticide treatments that have been approved by local regulatory bodies. Multigenerational farms, and the farms included within this study, can be slow to innovate and they may collect necessary data with pen and paper and transfer this data to spreadsheet tools. McKeever et al (2009) declare "the reliability of spreadsheets are essentially the accuracy of the data it produces and is compromised by the errors found in approximately 94% of spreadsheets". These errors are common, non-trivial and can be unforgiving in directly causing catastrophic loss of institutions and companies (Croll, 2008; Panko, 2008). In the context of Agriculture, data may be incorrectly inputted causing noncompliance and revocation of a contract when perhaps data was inserted correctly but the programme was unable to highlight a breach of compliance enabling swift preventive action.

Through first understanding and then addressing these barriers to technology for farmers, technology developers can improve their confidence using information technology (IT) which is crucial to overcome cultural constraints on technology adoption. Such advancements have the potential to improve labour efficiency, reduce risks and therefore sustain economic growth. Although available software solutions have struggled with low adoption rates (Rose et al., 2016), many lessons learned from agricultural decision support systems (DSSs) have been identified. One of these is that compliance is an effective means to deliver expert decision support (Rose et al., 2016). This is the issue that requires further investigation and that this article aims to explore.

Case Study in La Plata, Argentina

To evaluate whether compliance incentivises technology adoption the authors have designed a study with farmers to take advantage of new regulations. The participants and farmers involved in this study were based in La Plata, Argentina, a horticultural farming region covered with 6000 hectares of greenhouse occupied area with more than 5700 producers (Ferraris & Ferrero, 2018). In the last quarter of 2018, the Argentinean government enacted new regulations to govern the application of Food and Agriculture Organisation of the United Nations (FAO)-defined good agricultural practices (FAO et al., 2007) in the context of vegetable and fruit production (RESFC, 2018). This set of regulations affects the production, storage and sales activities that take place for commercial farms. With regards to chemical applications, the regulation states that farmers are obligated to comply with the recommendations and restrictions of use on the product labels by manufacturers and record any and all applications (under article 2.2.1). Chemicals, soil-additions and fertilisers must be approved for use by SENASA, the National Agri-food Health and Quality Service (see article 2.2.2 for chemicals and 2.6.1 for fertilisers and soil additions) (RESFC, 2018). These changes, that will come into force from January 2020 (for fruits) and January 2021 (for vegetables), represent a unique opportunity to test how a compliance DSS, that addresses the new legislative changes, is able to provide maximum benefit whilst shifting farmers operating protocols to incorporate technology whilst concurrently embedding expert advice and risk mitigation strategies. With this context in mind, this project has been developed as a part of the Risk and Uncertain Conditions for Agriculture Production Systems (RUC-APS) project (RUCAPS, 2020) and working with several horticultural greenhouse farmers in the region of La Plata, Buenos Aires, Argentina.

Aims and Objectives

The authors put forward the hypothesis that a compliance software built with a participative mindset is an effective strategy for the development and adoption of agriculture DSSs and technology solutions. This project aims to integrate lessons learned from previous DSS projects (Rose et al., 2016; Rossi et al., 2014) to enable the incremental introduction of technology into a farm's processes with continuous end-user feedback and design-thinking strategies. This paper will lay the groundwork for a follow-up study investigating whether an accessible compliance software is an effective gateway for shifting farms decision-making to technology and from intuition-based to evidence-based, improving agricultural productivity. The objectives of this project are as follows:

1. To review the literature and existing software tools for similar functionality, guidelines and reasons for low adoption.
2. To select a suitable methodology that includes user-participation within the software development process.
3. To develop a DSS prototype, GAP-A-Farm, with farmers in La Plata to address recently introduced compliance regulations and serve as a probe to study adoption.
4. To test prototypical features with decision support to examine receptiveness of farmers to expert advice.
5. To acquire end-user feedback during the development cycle with farm owners and managers.

The paper addresses the objectives in chronological order. *Related Works* presents the approach and the main outcomes of a literature investigation whose goal was to identify the key influencing factors regarding record keeping and decision making in horticulture. The literature investigation also covers existing software tools available on the market and their limitations. *Participative DSS Design* discusses how Design Thinking (Razzouk & Shute, 2012; Rowe, 1987) was adopted in this project as a suitable methodology for participatory design. Design-thinking is a methodology for innovation rooted in people centred design and is based on direct observation and user participation as the means to gain a solid understanding of what users want and need. *System Overview* provides an overview of the main features of the resulting DSS system. The system overview discusses inputs such as harvesting, adversity, phytosanitary applications, as well as data about products allowed by local regulation. It also covers outputs detailing how it offers advice to reduce the chance of non-compliance due to the use of unauthorised phytosanitary residues or to the presence of residues in the harvested crops. *Initial Evaluation* presents the results of an initial evaluation based on a survey and a pilot (which is currently underway). Finally, the last section presents the *Conclusions and Future Works*.

RELATED WORKS

The authors conducted an investigation into the literature most relevant to DSSs in agriculture (with particular focus on guidelines and compliance), barriers to their adoption and compliance software tools available to farmers. Firstly, an analysis of literature on DSS was conducted to identify various functions of DSS and reasons for low adoption through searching keywords 'Agriculture Decision Support Tools/Systems', 'Agriculture Apps', Agriculture DSS Low Uptake and 'Review of Agricultural DSS' in Google search engine and Scopus. Secondly, the initial search results yielded thousands of results therefore searches were refined to articles that mentioned barriers to adoption, review of DSS and compliance. Thirdly, a non-exhaustive list of DSS and commercial software tools that address agricultural compliance was collated through searching on iOS/Google app stores and Google search engine for 'farm compliance software/DSS' in both English and Spanish.

Many analyses have been conducted to examine the reasons for DSS low uptake and their failures in agriculture to provide guidelines for future projects (Hochman & Carberry, 2011; Magarey et al., 2002; McCown, 2002; Parker & Campion, 1997; Rose et al., 2016; Rossi et al., 2014). Most technological issues associated with DSS use have been significantly reduced due to increased availability of computers, access to the internet and development of web-based DSSs (Jones et al., 2010). Two prominent and relevant studies examined previous DSS projects and uncovered reasons for low uptake and concluded key factors for effective design and delivery of such tools (Rose et al., 2016; Rossi et al., 2014). They described common issues which align with previous studies, that include:

- Failure to consider key aspects of interconnected crop production (Rossi et al., 2014).
- Lack of incentives for continued use (McCown, 2002; Rose et al., 2016).
- Poor usability with overwhelming amounts of information (Rose et al., 2016).
- Time intensive due to tedious input requirements and data processing (Parker & Campion, 1997; Rossi et al., 2014).
- Information is delivered to users at time intervals that are not compatible with decision-making (Rossi et al., 2014).
- DSSs are not regularly maintained and updated (Rossi et al., 2014).
- Lack of IT education (Rose et al., 2016).
- General avoidance of technology (Rose et al., 2016).

Typically, if the benefit of use outweighs the cost and effort, then there is an incentive, however there are many DSS systems that require inputs that growers struggle to provide with little indication

of cost benefits (Parker & Campion, 1997). With the common issues described, the costs of effort can be high (outdated software, investment into learning or unnecessary data collection). Decisions in agriculture are also multidimensional and many programs tend to focus on one specific problem instead of considering how production is interconnected. Also, farmers want to make main decisions, requiring assistance rather than being replaced as a decision-maker (Rossi et al., 2014).

Relevant drivers to adoption that the authors for this study aim to incorporate in their DSS development include: usability, relevance to user and compliance demands (Rose et al., 2016). The guidelines proposed within the study by Rose et al. (2016) suggest that if a developer focuses on time-consuming processes with substantial risk, such as compliance, then it warrants time and effort dedicated from a farmer. From several major reviews on agricultural DSSs, two of which have no mention of DSSs that support compliance (Been et al., 2009; Eichler & Dale, 2019). One review in 2019, that covered apps for sustainable agriculture, identified software for compliance-related inspection of farms but found that they make no effort to integrate farmer knowledge (Eichler & Dale, 2019). Eicher and Dale (2019) state the lack of any emphasis on knowledge exchange of evidence-based practices to improve sustainability practices and a disconnect between developers and end-users in early-stages of software development. Another review of farm management information systems in 2015 highlighted that only a few DSSs had features for tracking traceability and providing best practices, however these were in their infancy commercially (Fountas et al., 2015). Despite this, commercial software solutions have begun to emerge to support record keeping from seed to harvest, in the form of enterprise resource planning (ERP) tools for compliance and these have been discussed in Table 1. These tools can be expensive, have limitations such as available languages and can be a leap of faith for traditional farms with potentially technologically illiterate users that require support.

This non-exhaustive review reveals an opportunity to involve end-users in the early development of a compliance based DSS as a vehicle to improve the confidence of farmers in technology solutions. The key takeaways from this review are: (1) that DSSs struggle with low adoption rates, (2) tracking compliance is a time-consuming and laborious process that software tools can make more efficient, (3) compliance and end-user involvement has been listed as a driver towards adoption. There is no

Table 1. Software packages available which can be used for agriculture record keeping

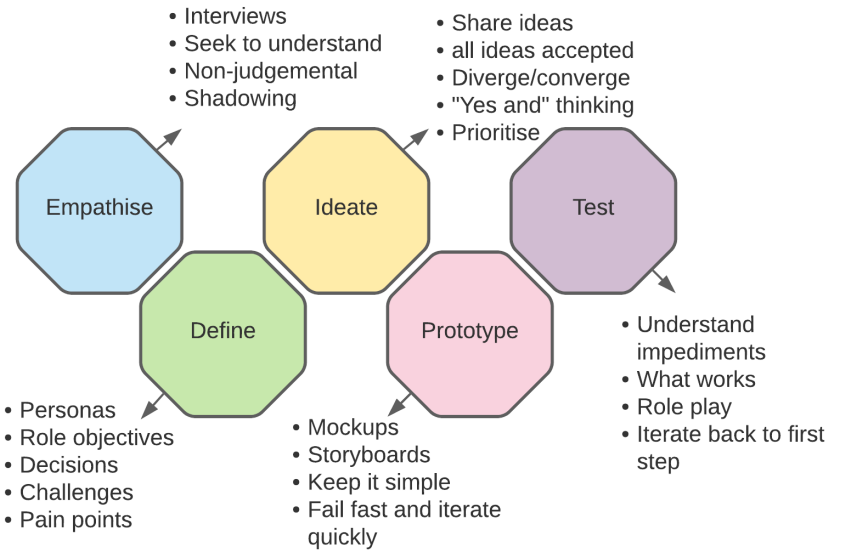
Software title	Description	Limitation	Website
Artemis	An application enables growers to optimise facilities and manage people, plants, processes and compliance. Available in multiple languages	Expensive, difficult to implement and data and sensor integration may not be suitable for less technologically minded farms.	https://artemisag.com/
Farmbrite	Web-based software developed by farmers and records seed-to-sale to improve farm management, help with certifications documentation and accounting. Integrates weather forecasts, includes grazing animals interactive maps Able to build online e-Commerce stores	Not available in multiple languages and does not provide local or group decision support based on regulations. Additional features such as E-commerce which may not be necessary.	https://www.farmbrite.com/
SmallHoldr	Global solution tailored for smallholder farms to gain data-driven agronomic advice to achieve higher yields and establish a credit history	No fixed pricing model or free trial. UK-based company with no website translation.	http://www.smallholdr.com/
Microsoft Excel	Spreadsheets are highly customisable and allow for organisation, analysis and storage of data in tabular form. They have been used on farms for decades and are able to handle static data with formulas coded by the user.	Prone to human error with no automation, poor communication of lack of real-time data. No data science integrations and cannot scale.	https://www.microsoft.com/en-gb/microsoft-365/excel

research done to date isolating compliance as a driver and testing whether technology addressing record-keeping and regulations can change farmers' attitude towards technology. There is a large opportunity to reduce this pain-point for farms and this is evident by new businesses selling web-based software for record keeping and farm management optimisation. This has become more apparent with the coronavirus pandemic, highlighting ways that technology can aid in farm management with a reduced workforce as well as optimisation in normal circumstances (Kopf, 2020).

PARTICIPATIVE DSS DESIGN

Design thinking, as proposed by Razzouk & Shute (2012), is generally defined as "an analytic and creative process that engages a person in opportunities to experiment, create and prototype models, gather feedback, and redesign". The strategy involves a set of processes which can be broken down into initial divergent phases and convergent phases that are iterated. The approach sequentially follows through the five phases: *empathise, define, ideate, prototype and test.* These phases utilise common techniques which are illustrated in Figure 1. The goal of the first phase is to gain an empathetic understanding of the user's needs. Through such techniques like interviews, surveys and journey mapping the developers understand some of the core challenges that the farmers encounter regularly. During the definition phase, the designers and stakeholders analyse the information they obtained during the empathise phase, and synthesise the core problems (in the case of our DSS, the core decisions) that need to be supported, enabling clear objectives for the system to emerge. This is followed by sharing of ideas (the ideation phase), thinking of possible solutions and prioritising viable concepts. A minimum viable product (MVP) is created and evaluated by the end-user through mock-ups or storyboards in order to get rapid feedback to validate the software. The MVP mitigates the risk of unnecessary features being developed for the software ensuring its receptibility by the target market. The last step, *test*, allows the developers to find what works and what does not so that unnecessary features can be removed, and the useful features can be improved/added. This approach was iterated over four two-week sprints with several greenhouse farm owners, a senior software developer and a junior developer.

Figure 1. Design-thinking phases with actions (adapted from (Stanford Design School, 2020))



Following the outlined design-thinking approach, the designers met multiple times with farmers. To complement the interviews and to better identify and define key decisions to support, a short survey with ten participants owning farms between 0.5 to 30 hectares was conducted to identify the key challenges for local indoor farmers, which compliance schemes they follow, their key performance metrics and their existing technological capacity (i.e. number of computers and internet access). The results highlighted that all participants thought technology would be helpful in their processes, however many of them were not sure how they would integrate software and it was clear that they were underprepared to deal with regulatory changes. All the participants agreed that a software would be useful to record traceability and crop planning and they were accustomed to using smartphones to access the internet on their farm, however 70% of those farms did not have access to a desktop computer. 50% of the farms do not track any key performance metrics (indicating intuition-based decisions) and all farms would find comparing their farms to others helpful. The authors concluded that the best solution would be a web-based group DSS to support the necessary compliance processes, provide decision support around authorised substances, premature harvest warning after a chemical application and comparison metrics.

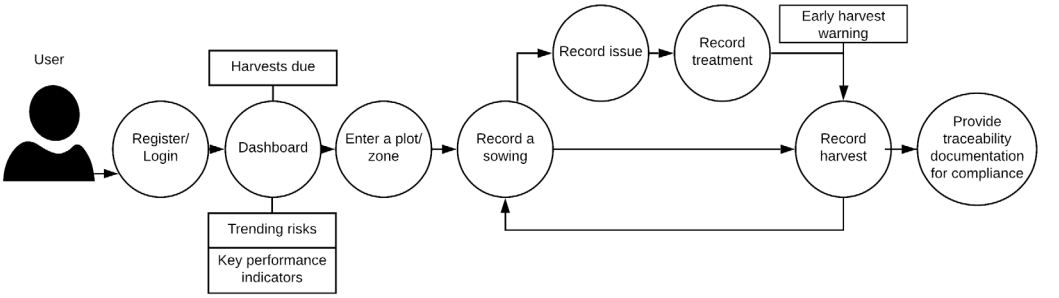
After an examination of how farms think about technology, data and desirable features; additional interviews were conducted with several greenhouse farm businesses that follow existing compliance schemes (primarily Global GAP). These interviews included a series of workshops, the first of which was a journey mapping session to analyse their workflows over harvest cycles and highlight pain points in tracking crops and their treatment plans (Urbieta et al., 2021). The interview sessions enabled a clear definition of the software requirements to adequately record the data for SENASA (the local government organisation) and GAP. The user requirements were agreed to cover the following:

1. Plots can be entered with a history log.
2. Plant batches can be sown or harvested within a plots.
3. Adversities like pest outbreaks can be reported for batches.
4. Treatments like pesticide applications can be reported for batches.

Concerns were raised by farmers about whether it would be possible to retrospectively change the logged dates for treatments which indicates that mistakes may be commonly made and records back-dated for compliance. For these reasons, additional features were included such as a warning system to ensure chemical applications are only applied to approved crops by SENASA and crops are not harvested prematurely after a treatment.

After identifying the core functionality of the DSS, an ideation phase followed which resulted in a set of prioritised ideas. Concepts that were discussed through a series of workshops included risk registers, baseline graphs for metrics (yields and pesticide use) utilising group decision support system mechanics, harvest estimation (date and yield) and incorporating a database of SENASA's accepted treatments. The MVP of each of these functions was discussed to see whether they would assist users with decisions they make and determine their benefit. Simple features were then incorporated into a dashboard mock-up and a user journey-map illustrated in Figure 2 to get end-user feedback. After accessing the system, farmers are presented with the dashboard. The dashboard offers decision support regarding harvesting dates that are near, trending risks (e.g. pests) in the form of news provided by expert advisors (and based on the reports of multiple farmers), and key performance indicators such as a harvesting progress in relation to plans, and time until the next harvesting starts. From the main screen, farmers can access the details of events in each plot, and can report sowing, adversities (issues), treatments, and harvesting. Information about the products applied during treatment is taken into account to provide decision support previous to harvesting (to avoid harvesting before the mandatory waiting times of the applied products). At all times, farmers can browse and export detailed events records to support the compliance certification processes.

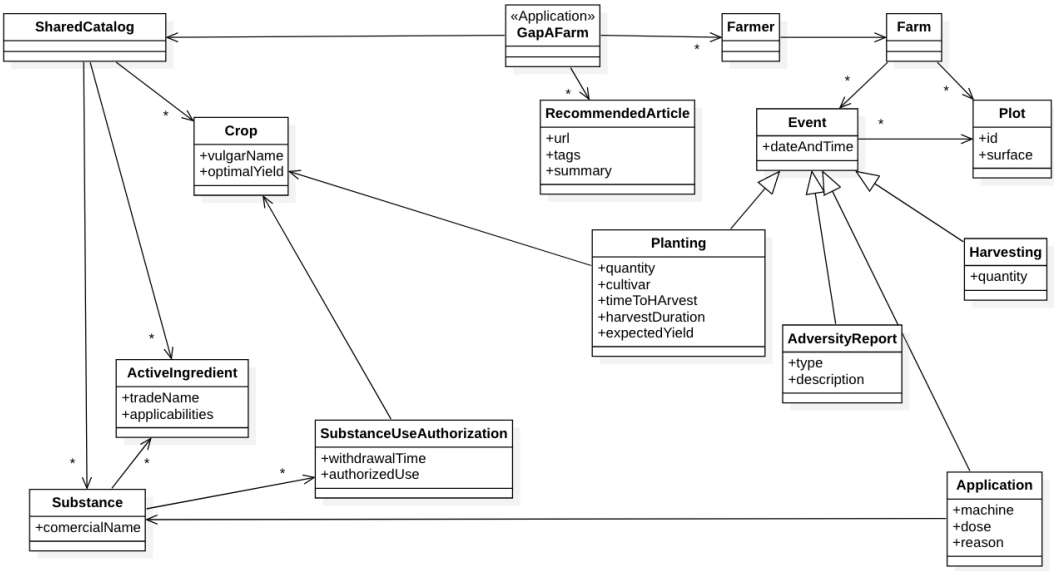
Figure 2. User journey (farmer) for MVP developed with the end-users



SYSTEM OVERVIEW

The prototype tool, GAP-a-Farm, was implemented at the National University of La Plata, and is available under a general public license (GPL) v3.0 on Github (accessible via https://github.com/cientopolis/gap-a-farm) (Fernandez, 2020). It foresees two user profiles: experts and farmers. Experts access the system mainly to align the shared catalogue of crops and authorised substances with the information obtained from product labels, and from SENASA. Farmers access the system to record when they plant or discover adversities in the farm (e.g. pests), when they apply chemicals and fertilisers, and when they harvest. This replaces the paper forms or spreadsheets they currently use. Moreover, as farmers use the system, they will discover additional support for decision making, specially focused on GAP compliance. Figure 3 provides an overview of the key design abstractions (the data model) that make up GAP-A-Farm. Farms are organised in plots that interact with events and a catalogue of substances and crops aligned to the information provided by the government body, SENASA.

Figure 3. Key design abstractions in GAP-A-Farm



After an initial phase whereby the farmer registers the plots in the farm, most of the interaction of the farmer with the system involves recording relevant events. Events are connected to plots (plots are the minimal unit of analysis). Four types of events are currently available: *Planting*, *Adversity Report*, *Harvesting* and *Application*. In all cases, date and time are recorded.

When planting, the farmer records the crop (choosing one from the shared catalogue), the quantity (as number of plants or kg of seeds), the time to harvest, the harvest duration, and the expected yield. This information is later turned into dashboard alerts regarding upcoming harvests, to provide targeted news (recommended articles), and to compare expected vs. actual yield.

Upon recording an adversity, the farmer provides a short description (normally the name of a pest) and a classification from a predefined taxonomy (i.e. *Infestation*, *Disease*, *Nutrients Deficiency* or *Other*). Reported adversities are currently used to offer targeted news to farmers and to build a dashboard report of "trending" adversities (that summarises what farmers report). In the future, this would work as a collaborative system providing additional advice as soon as an adversity is reported if farmers share their information.

Recording the application of chemical products and fertilisers is central for compliance. When the farmer records the application of a substance to a plot, the system checks in the shared catalogue that the given substance has been authorised by SENASA for the crop in that plot. Note that the farmer applies the substance under the advice of the farm's agronomist (which can consult the shared catalogue), and it is not up to the system to offer such advice. Moreover, in case SENASA indicated a minimum waiting time before harvesting after application, the system marks the plot as "not to harvest before [date]". This aims to prevent errors in practice rather than requiring the user to change entries retrospectively.

When the harvesting period starts, the farmer records every harvest from every plot. The harvesting event includes information regarding the quantity, both in kilograms, and in a customised unit selected by the farmer (e.g. no. of crates or no. of baskets). Whereas the later was included to reflect common practices, the former is used to update the dashboard report that compared expected to actual (up to date) yield.

As a result of an explicit decision, driven by agility and in pursuit of a MVP, the design has been limited to the data pieces that farmers need to record for compliance certification. The only exception to this rule is the *Planting* event where additional information regarding time to harvest, harvest duration, and expected yield is requested. Although it became clear that farmers do not normally record this information, it was included to assess, during the pilot study, the willingness of farmers to do the extra work if they see how it provides data-driven decision advice.

To ease its deployment and maintenance, the system has been implemented as a web application. This limits its use to farms with internet access, at least. in the management office (which is the case for many farms). It was built using responsive technologies which means that it can be used from both desktop and mobile devices. However, initial discussion with the farmers that will take part in the pilot study suggest that the system will be mainly accessed via desktop computers.

Once the prototype was finished, it was tested with respect to properties such as completeness and internal consistency of the artefacts built; which are a prerequisite to move forward to an evaluation of impact in a follow-up study. GAP-A-Farm went through a series of early testing cycles to ensure alignment to end-users' objectives and usability requirements (efficiency, effectiveness and satisfaction). This meant bringing interactive user-interfaces and mock-ups of additional features to conduct role-play sessions with the end-user. These sessions highlighted challenges in user-flow and additional fields that would be useful (i.e. a notes section for event and customisable units). At the end of the testing phase, a fully functional prototype was available, that included the key functionality for record keeping.

INITIAL EVALUATION

The goal of the research, to determine whether compliance software is an effective gateway to shift farmers' decision-making strategies from intuition-based to evidence-based, requires a comprehensive

and longitudinal evaluation of impact. A longitudinal study has not been conducted as this research is in its preliminary stages, however, initial evaluation was conducted which lays the foundation for future assessment. The primary goal of this initial evaluation is to learn whether widespread adoption of the tool (and sustainable record keeping practices) is possible. This would indicate a first step towards evidence-based decision making. For this initial evaluation, two instruments were combined. Firstly, a demonstration and training session was conducted alongside a survey. Secondly, a pilot was set up as an introduction of the system in real settings. This is currently underway and results are being collected.

Survey

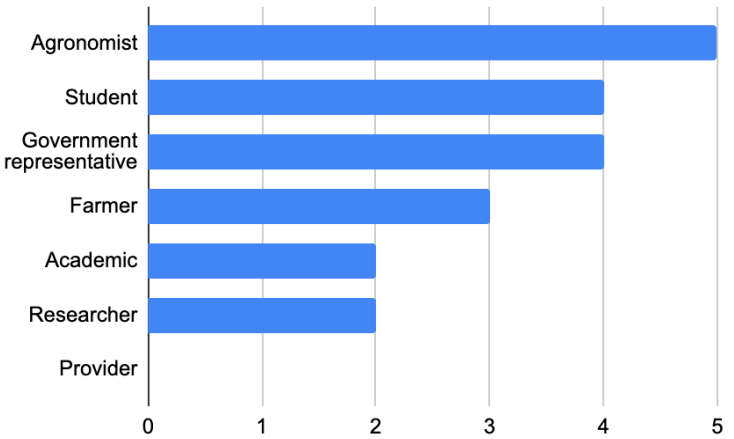
A one-hour online training session was conducted in May 2020. The training session had 39 participants, most of them located Argentina, Chile, Spain and Italy, and with varied backgrounds. The session started with a presentation of the objectives and main features of the system, and a video demonstration followed by a round of questions and answers. Following the training session, participants were invited to participate in a survey aimed at eliciting the participant's opinion with respect to the system. The survey consisted of one multiple selection question, and five short text open questions:

- Which of the following options best describes your function/role/occupation?
- Do you think there is a need/opportunity for tools like GAP-a-Farm?
- Which are the major challenges to take into account if the researchers are to move forward with GAP-a-Farm?
- What do you think are the strengths of GAP-a-Farm?
- What do you think are the weaknesses of GAP-a-Farm?
- If GAP-a-Farm were a cloud service (a web-site where you can record information about your farm), who would be trusted to manage it?

In total, 14 participants completed the survey. Figure 4 presents the profile of respondents; they represent the academic, industry and government sector (some participants belong to more than one category).

Participants were asked if they considered there was a need/opportunity for a tool like GAP-A-Farm, all respondents answered yes. Respondents identified tool dissemination, adoption, and

Figure 4. Profile of survey respondents



commitment to use as the main challenges moving forward. Then, the survey asked participants to identify strengths and weaknesses of the tool. The researchers encoded the free text responses (short answers) in the main themes shown in Figure 5. Respondents perceived the reduction of the data recording effort, and the ease of use of the tool as two of its strengths. In contrast, they perceived the need to manually record the data as the biggest weakness. These results may appear contradictory at first; however, they can be explained as the recognition of the significant improvement the tool represents when compared to other methods, while still making a claim for further work along this trajectory. Next in order of importance, respondents identified support for the implementation of GAP and for the systemisation of event recording as strengths. The provision of alerts and recommendations, and supporting expert-farmer collaboration were noted as strengths. Still, the lack of usage experience of the tool, and the need for training in GAP and in the usage of the tool are a source of uncertainty about its impact and therefore a weakness. Two responses pointed to missing functionality as a weakness, one of which was related to recording of the use of manure and fertilisers. Although such functionality came up during the design workshops, it was left out of the prototype to limit the scope of the development (that focuses on the application of phytosanitary products affected by government regulation). The other missing functionality report referred generally to "farming machinery" which was interpreted as an interest in the integration of the system with smart machinery, and which requires further analysis.

GAP-A-Farm depends on the centralisation of all recorded data in a single repository. Researchers perceived, in preliminary conversations, that farmers might be reluctant to give other institutions access and control over recorded data. With this in mind, the survey asked participants to indicate which institutions they would entrust their data to. Figure 6 summarises their responses. The university represents their first choice, followed by a farmer's organisation and a government agent.

Pilot Study

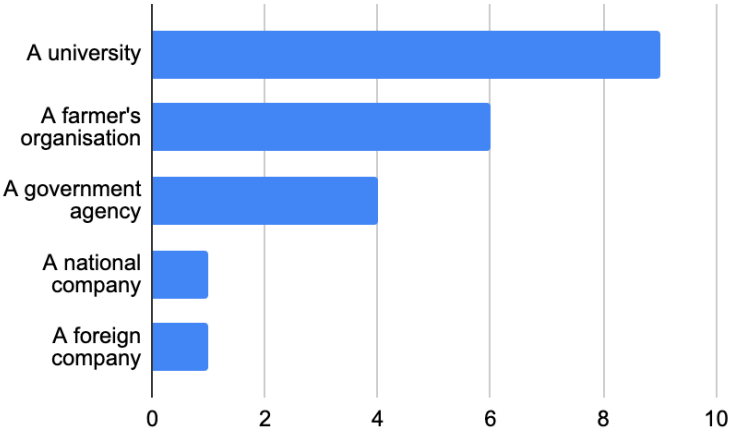
During the second half of 2020, a pilot study was developed with the objective to collect preliminary data regarding the impact of the use of GAP-a-Farm on the farm's event registry. At the time this article is written, the pilot is underway. Due to the coronavirus pandemic, interaction with participants was limited to what could be conducted on-line. The participants of the pilot include 10 medium horticultural farms from the horticultural green belt of La Plata. Prior to the pilot, representatives of the 10 participating farms were interviewed to discuss their practices and future vision on registration of events and the role of IT. Below, some conclusions obtained from these interviews are summarised.

The first obstacle to event recording is the lack of a map with the layout of the farm, where plots can be identified and georeferenced. Often plots do not have a label/name, so it is impossible to record the events that take place in each one of them. Then, there is also a lack of records of events, and a lack of an orderly management within them. The activities are not explicitly planned, they are executed without being decided and analysed, and therefore they are not evaluated once they are finished in

Figure 5. Main strengths and weaknesses grouped thematically according to the survey respondents (number of responses on the right)

Strengths		Weaknesses	
Effort reduction	8		
Perceived ease of use	4	Manual data recording	6
Support of BPAs	4	Missing usage experience	4
Systematisation	4	Training and adoption	2
Alerts and recommendations	3	Missing functionality	2
Expert-farmer collaboration	3		
Decision support	2		

Figure 6. Survey results evaluating who farmers would entrust their information to



a concrete way. The vast majority of activities are done intuitively and by tradition (almost always the practices are repeated continuously without a justified reason), and this is one of the causes why existing data is not recorded.

The producers of intensive horticulture develop innumerable daily tasks, many of which are not within organisation charts or production planning. Although these tasks are not formally thought or planned, all of them must be executed for the operation of the productive establishment and to fulfil the objective of the establishment, which is to produce the volume of vegetables needed to maintain the economy of the establishment in question. All these activities or events are carried out by the producer or operators, and sometimes occur without keeping a record of them, or keeping records of very few of them.

The sowing dates are useful to know the crop cycles and the yield by season, but for farmers in the pilot it is difficult to take and analyse data. Many times, sowing is performed by operators, who do not record the data anywhere with the subsequent difficulty of its recompiling from memory. When, where and what is sown, typically does not exist as data. If the farmer is not present during the implantation, the farm plants frequently, and grows multiple crops types, registration is even more difficult: these data are lost without being recorded.

To observe and register adversities, one has to know how to identify them and know how to quantify their damage. In this sense, for producers to carry out these records, training is required for this purpose. This is another activity that is done intuitively or by eye. For this reason, applications of phytosanitary products are carried out by frequencies of calendar time (weekly, every ten days, and not under a diagnosis). A few producers have adversity advisers or monitors, and they carry out tighter sanitary programs. Producers who use biological control or who do organic production include monitoring as a diagnostic tool, quantify the damage and use these indicators to make decisions about the application of phytosanitary products.

The harvest of each batch provides potential insights into the yield of the crop, and the incidence of all the variables on the crop in question. The challenge with this registry is that some crops are harvested at staggered times and, in addition crops that come from different lots can overlap, resulting in the confusion of the clear identification of the origin. With quality assurance systems or quality certification systems, the registration of these data is strictly necessary to ensure traceability, a mandatory condition for any type of food certification.

The registration of events is not instilled in the behaviour of the producers, since the horticultural producers do not have training in business, commercial or more professional management. The

training of the producers of La Plata is almost entirely based on expert-apprentice experiences within the family. They developed their work history by executing the activities, without programming or analysing them, but rather developing them intuitively, or by family tradition. Producers "know from experience" the result of each activity carried out: soil work, planting the crop, yield, phytosanitary applications, without having evaluated precise data, but rather roughly.

Horticultural production almost always works against the clock with increasing risks, due to climate issues (drought, excess rainfall, soil issues and temperature changes). There are always reasons to work quickly and consequently there is no time to dedicate to recording data. Another problem resides in the fact that, in this type of horticultural establishment, there is not always the data that can be used for decision-making in the different links of the establishment's value chain. Counterproductively they think data is unnecessary, since the activity works under a lot of risk and uncertainty and consider it "waste of time". Therefore, in general, events are not recorded in mixed farms in horticulture because there is no custom, the importance of the data is not believed, it is not known what to use it for and there is no certainty that it will be useful for making decisions. Decisions are often thought to be the correct ones due to their custom, tradition and intuition.

Record keeping was perceived as an important matter, but still secondary in priority to the core activities. The novel coronavirus disease made this gap in relevance even more apparent with urgent action required. Still in this context, most pilot participants confirmed their interest in participation. In one case, the farm hired a person to be in charge of record keeping.

Different strategies for record-keeping will have varying results in terms of efficiency (less effort), effectiveness (fewer errors) and overall satisfaction of the registrant. GAP-A-Farm aims to improve in these aspects, compared to other observed strategies (mainly paper and spreadsheets). Preliminary observations of the loading practices of one of the participants in the pilot project indicate that, when the information to be recorded is available, recording times of each event requires 1 to 2 minutes. In an observed case (an organic producer), 578 events were registered, for which a time investment in the registry of 9 hours is estimated (without considering the data preparation time). For this producer, the records made actually represent less than 15% of what should have been recorded per month. This is a substantial sink of time, especially for producers with many records, because they may have a great variety of crops. The time required to record in GAP-a-Farm and generation of useful data would involve approximately two hours per week of man-hours in labour. However, if the monitoring effort is considered, the time required for the preparation of the data, and the context switching cost (that is, dropping everything else the farmer is doing to sit in front of the computer) the total perceived time for the task is much higher. This could be substantially reduced by utilising mobile app technologies so that there is a distributed way to input into GAP-A-Farm rather than centralised in an office.

CONCLUSION AND FUTURE WORK

The introduction of new agricultural regulation regarding GAP has represented an opportunity to investigate whether compliance software is an effective gateway to shift farmers' decision-making strategies from intuition-based to evidence-based, improving agricultural productivity through technology. Literature confirms that that DSSs struggle with low adoption rates, tracking compliance is a time-consuming and laborious process that software tools can make more efficient, and compliance and end-user involvement have been listed as a driver towards adoption. Design thinking was found to be an effective strategy to involve farmers in the conception of a cloud based, event recording decision support system focused on GAP compliance. Although the study was limited to farmers in La Plata, in Argentina, it already received positive feedback from a wider community through the global RUC-APS (2020) project. The resulting tool, GAP-a-Farm has been released as open source (under GPL3 license and available at: https://github.com/cientopolis/gap-a-farm). A pilot study is now underway involving 10 farms. Early reactions to the pilots evidence two key barriers to methodical

record keeping. Firstly, record keeping is perceived as an important but secondary task for farmers; this means they will only conduct it in periods of low farm activity or when record keeping becomes critical (e.g., near the date of a compliance auditing). Secondly, data collection points are scattered and unreliable, consequently increasing the effort and difficulty of the whole event recording process.

One way to balance the scale towards record keeping is to further reduce the effort it represents. Even though farmers recognise that GAP-a-Farm is an improvement, they still indicate data input as a burden. During the pilot, the researchers have observed that certain patterns may exist that would allow form autocompletion, or input prediction. Although at this point it is not clear now much of a time reduction it would imply, these techniques are a clear line for future work. In this regard, techniques such as those proposed by Troiano et. al. (2017) can be applicable. Additionally, taking a strategic approach to compliance and aligning it with business priorities is an important step to cultural change. One method to do this would be to employ someone whose primary job is to spreadhead the integration of the software and record keeping into the farm processes.

GAP-a-Farm was designed as a web application serving a large community of farmers. This design decision enables collaborative decision support, as data from various farms can be combined and turned into alerts, predictors, advice and baselines for comparisons. Farmers have demonstrated high interest regarding alerts, and moderate interest regarding advice, and baseline comparisons. The pilot has not still reached the point where enough data is available to enable and evaluate such functionality. Future will focus on adjusting collaborative decision support functionality, and learning about the value it delivers to farmers. A longitudinal study is also required to be able to see whether it was a catalyst for further technology integration into farms. The authors expect that such additional value will increase the farmer's motivation to record events.

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