GAP-a-Farm: A tool to support GAP compliance and information based decision making in horticulture

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Abstract. Adoption of information technology in horticulture is low, especially in developing countries. Governments across the world issue new regulation to govern the application of good agricultural practices affecting production, storage and selling activities, while certification program require that farmers keep detailed records of farm events, for auditing purposes. These changes in the context of horticultural practices, represent an opportunity to test whether a compliance and decision support systems can shift farmers processes to utilize technology incorporating data and expert advice. GAP-a-Farm is a tool to ease record keeping, and to turn recorded data into alerts and advice. This chapter documents the key aspects of the system's design, and reports on preliminary discussions with end-users that take part in a pilot study in Argentina.

Keywords: GAP Compliance, Decision Support System, Technology Adoption, Horticulture

1 Introduction

Compliance certifications are one method of raising the bar on food quality, yet many farms lack the existing processes to reliably track their crops from seed to harvest along with pesticide applications. As multigenerational farms are sometimes slow to innovate and adopt technology, they may collect such data by hand or by using spreadsheets. Understanding the barriers to technology use for farmers, as well engaging with them to improve their confidence in information technology (IT), is crucial in order to remove cultural constraints on technology adoption and foster their economic growth. Research on decision support systems identified compliance as an effective way to deliver solutions with decision support with improved adoption rates [18].

In October 2018, the Argentinean government issued new regulation [17] to govern the application of good agricultural practices (as defined by FAO, the Food and Agriculture Administration of the United Nations) in the context of fruit and vegetable production. This regulation affects production, storage and selling activities that take place in the confines of the farm. In relation to chemicals used in the farm, regulation states that farmers must comply with the recommendations and restrictions of use stated in the product label by the manufacturer, and that all applications must be recorded (article 2.2.1). Farmers can only use chemicals, fertilizers, and soil additions that have been registered at SENASA, the National Agrifood Health and Quality Service (article 2.2.2 for chemicals, article 2.6.1 for the case of fertilizers and soil additions). Compliance with this regulation is mandatory from January 2020 for fruits, and from January 2021 for vegetables. [17].

Based on conversations with local farmers, many farms either do not use software tools to assist with decisions and farm management. Some have begun to actively seek research and development opportunities such as RUC-APS [13] to improve their farming practices to deal with the multitude of challenges they experience such as traceability, a volatile market, manual labor requirements and pests. Adopting technology and IT systems can help to mitigate risks that the challenges pose and ensure farming practices are compliant [11]. Compliant crops should begin to increase the value of farmer's products, help secure trade deals with supermarkets and gain access to international markets for export.

This chapter discusses key aspects in the design of GAP-a-Farm [15], a tool to simplify the recording of farm events, and to offer alerts and advice for the application of agricultural best practices. The tool is introduced as support for decision making and compliance software for farmers in the horticultural belt of La Plata, in Argentina. It is a farming area of approximately 6000 hectares with over 1000 farms that provide fresh vegetables to a large part of the population of the Buenos Aires province [19].

2 Related work

DSSs are designed to aid users make better decisions by guiding users through decision stages and presenting the likelihood of various outcomes resulting from different option [18], [4]. These can be dynamic software tools that provide suggestions according to the user's inputs and record data and analyze it to provide data-driven insights [18]. Despite wide availability of software for agriculture, studies show that uptake has been disappointingly low. One study looking at lessons learned from previous DSSs and their reasons for low uptake identified key factors for effective DSS design and delivery from interviews with 78 farmers and advisers including usability, cost-effectiveness, performance, relevance to user and compliance demands [18]. As farmers in the region of La Plata are relatively technology-averse, the authors will attempt to embody these guidelines, focusing primarily on bottleneck processes with high-level of risk for the farmer to justify the use of technology. Record keeping for compliance can be a tedious process for many farmers with mistakes easily made, warranting the use of a software that can reduce compliance risk.

Software currently exists that supports record keeping from seed to harvest for compliance, in the form of enterprise resource planning (ERP) tools in industry such as Farmbrite [8] and Artemis [1]. These tools are expensive and can be a leap for the technologically illiterate, especially when software is only available in English. Two major reviews have been conducted on agricultural DSSs in academia: 10 years ago on 70 crop protection DSSs in Europe [2] and 15 years ago on a taxonomy of all 624 DSSs in published works in 2004 [14]. Neither of which mention DSSs to support compliance. A more recent review on apps for sustainable agriculture identifies some apps for compliance-related inspection, but found that they do not integrate farmer knowledge or practical solutions [5]. Similarly, the review concluded with the need for software emphasizing knowledge exchange to identify evidence-based practices that improve indicators of sustainability, as well as involving end-users early and throughout the software development. Finally, a review from 2015 of farm management information systems (FMIS) found that 19% and 16% of FMIS software had features for tracking traceability and providing best practices respectively [10]. The analysis states that both traceability and best practice functions are still in their infancy commercially and that these attributes directly influence food quality and could be used to enhance value of farm products [10]. There remains an opportunity, based on lessons learned and the lack of DSSs to support record keeping for compliance, to develop software as a vehicle for improving farmer's confidence in technology solutions.

3 General approach

Design and development of the GAP-a-Farm tool started in late 2019, in response to a demand from a Farmer that needed help with record keeping in spreadsheets. The farmer's original request was to customize a complex Excel workbook he had found on-line, that consisted of multiple connected pages. Following an agile approach as reported in [20], a set of key functionalities was agreed. After a series of meetings with farmers and agronomists (as depicted in Figure 1), it was decided that a building from scratch a minimalist web-application would solve the immediate need of simplified record keeping. It was also considered that such tool would become the conduit for more advance decision support, and for the dissemination of agricultural best practices. The tool (which is called GAP-a-Farm), focuses on supporting record keeping, raising awareness regarding the use of phytosanitary products, and delivering targeted news to farmers.

3.1 Record keeping

Record keeping in the farm serves various purposes. From the perspective of farm management, record keeping allows the farmer to plan, to evaluate what works and what doesn't, and to do forecasting. Detailed records help the farmer

Fig. 1. Tool design workshop at one of the participating farms

assess the performance of the implemented practices, the yields of the different farming sectors and crops, and provides input to monitor the health of the farm. Moreover, record keeping provides information for expenditure control and budgeting. Not all farmers keep records with the same level of detail. Extremes are not frequent; most farmers do keep some records focusing that which bring them the most value with less effort. During interviews with farmers, the authors learned that most of them keep paper notes regarding harvesting (when, what, how much). This is frequently bound to the fact that employees are paid in relation with the product they harvest. Detailed records of pests or diseases, and detailed records regarding the application of phytosanitary product are scarce.

Government regulation and certification programs such as Global G.A.P. [12] set minimum levels of records that farms must collect. These records are used as evidence during auditing visits. In the case of horticulture in Argentina, the recommended information to record includes planting/seeding, identification of pests and diseases, phytosanitary treatments, harvesting, and sales. This minimum set of records was taken as the basis for the design of the tool.

3.2 Safe use of phytosanitary products

The CODEX Alimentarius[7], regularly published by FAO, includes a database reporting on the maximum residue levels (MRL) of pesticides legally allowed on products of agricultural origin [6]. Similarly, the governments of various countries publish their own, adjusted lists. Although the format of these publications, and the specific details may vary, they generally comprise the following elements: a) the name of the active ingredient (e.g. Abamectin), the functional class (e.g., fungicide), the product or commodity it applies to (e.g. Tomato), and the maximum residue level (commonly in mg/kg for countries that use the metric system).

Farmers must only apply approved products, making sure that residue levels when the product reaches the market is below the MRL dictated by applicable regulation. Looking at the list of approved products per crop and per functional class can helps farmers make a first decision. The tool includes an up-to-date catalog of approved products according to the Argentinean regulation for horticultural production. The catalog can be consulted by farmers in advance to application; moreover, the systems limits the application of pesticides to only allowed cases.

The presence of pesticides on agricultural products decays with time, depending on the application and farming conditions. Farmers need to be aware not only about the allowed pesticides, but also about the waiting time before harvesting. Waiting times are determined experimentally, and depend on each specific formulation and application strategy. Given its variability, this information is not included in as part of the Argentinean government regulation. On the contrary, farmers obtain this information looking at the product's label, or asking an expert advisor. When farmers fail to comply with waiting time, they risk certification and endanger human health. To increase awareness about the waiting times, and to minimize the risk of non-compliance, the tool includes a database of withdrawal times. Given that such information is not publicly available for all products, the database is updated by an expert agronomist, based on the most frequently used products in the target community of farmers. The tool combines the information from the database of phytosanitary products with the records of applications to keep the farmer aware of the required waiting periods.

3.3 Limit the lock-in effect

The tool has been designed as a web application running on a centralized public server. It could be installed for a single farm (both as an on-premise or as a cloud server controlled by a single farm). However, most of its power derives from shared knowledge. First and foremost, when a GAP-a-Farm installation is shared by a group of farms, the farms share the effort of the supporting expert. When the expert updates the list of phytosanitary products or publishes targeted news all farms benefit from it.

Many cloud computing services are designed to generate customer dependency, a phenomenon known as "customer lock-in´´. Customer lock-in is characterized by the difficulty of a potential migration to an alternative provider. Lock-in occurs as a consequence of systems being designed to be incompatible with those from other vendors, or using proprietary standards, or using restrictive licensing schemes. Although customer lock-in is good for the vendor, it can have negative effect on service adoption [16].

Seen that farmers are already reluctant to adopt computing technologies, reducing the perceived lock-in effect was paramount in the design of the tool. Two strategies were combined with this objective in mind. Firstly, the tool is released as open source[9], with the permissive MIT License. Secondly, as some farmers are accustomed to using spreadsheets for data recording, the tool includes comprehensive export to CSV functionality. Farmers can, at any time, export all event records of their authoring. This functionality allows the farmer to conduct further analysis with external tools, to migrate to other cloud services, and to generate printed reports for audit purposes.

3.4 Minimize effort and highlight value

One of the tool's purpose is to help researchers understand record keeping customs in the horticultural area of La Plata, to identify burdens to the adoption of recording practices, and arrive to proposals for the introduction of information technology that have value for farmers. In preparation for a limited pilot study with the tool, the researchers interviewed prospective participants. Only a few recorded events with the help of computer systems (spreadsheets), and mainly for events that had a strong connection to economic results such as harvesting and sales. For those that keep records, paper forms are the most frequent strategy. Some farmers indicated that they have attempted replicate the existing paper records in computers systems, but this only last for as long as the day to day of the farm lets some spare time. They indicated that given the perceived effort of the data collection and data entry tasks, they would need a person solely responsible for them. In response to this perception, the tool focuses on the set of features that are either a requirement in preparation of certification programs such as GLOBAL G.A.P., or that evidently turn into decision support tools.

To reduce effort and maximize gain, the tool has been designed to support a group of farmers, recording events in a common shared repository. Farmers only have access to their own records. Each deployment of the tool is served by a group of expert agronomists (which could be only one, for a small group of farmers). The tool uses all events in the repository to create aggregated reports for the experts. Common reports include crops currently in production, recent infestations, and applied pesticides. Experts use this information to identify training needs of the farmers, and to assess potential risks. In response to reports, experts can publish news posts (a form of internal micro-blogging). Visibility of posts can be configured for a given time-frame, and for farmers with certain characteristics (i.e., the crops the plan, the products they apply, etc.).

To make the value of digital data recording evident, the tool offers a dashboard where important aspects of the state of the farm are highlighted. Using the information provided by the farmer when planting was recorded, a widget in the dashboard alerts about upcoming harvesting dates on specific plots. This is specially important so the farmer avoids using using pesticides that may delay harvesting due to waiting time restrictions. Another widget in the dashboard clearly alerts on the plots where pesticides have been applied and harvesting should not take place. These two widgets contribute to minimizing the risk of impact to consumed health, and of non compliance with regulations. An additional widget shows the progress of the harvesting, comparing the actual (ongoing) yield to the expected one. As information from the farmers becomes available, additional widgets can be created and deployed (such as a comparing the farmers yield for a crop to that of other farmers). In this way, the researchers expect to navigate the space of value added functions of the system.

4 System design

The system consists of two important data models; the models of events and the model of the catalog of authorized phytosanitary products. Figure 2 provides an overview, in the form of a UML class diagram, of the main abstractions that model events. The granularity for recording of events is defined by the Plot. Plots have unique id (which implies that the farmers first needs to produce a map of the farm with fixed ids), surface (in square meters) and a description (normally regarding the characteristics of the plot). Mandatory input is kept to a minimum as unnecessary work may hinder adoption. All events must be timestamped, with the date and time corresponding to the moment the event took place (which allows recording of past events), and refer to a plot. Planting and harvesting events are linked to a crop, application events are linked to a substance, and adversity reports are linked to a type of adversity from a fixed list. When planting, quantities can be expressed in kilograms of seeds, or in number of pants. When harvesting, quantities can be expressed both in kilograms and in a unit of choice or the farmer (e.g., number of baskets). When planting, the farmer can optionally indicate the expected date of harvest, the duration o the harvest, and the expected yield. The tool uses this information to update widgets in the dashboard and to offer decision support. This fields are defined as optional after the fact that farmers do not always know or record this information, but it will result valuable in showing the potential of these tools.

With use, a plot¡s history contain events of the present harvesting cycle as well as of past cycles. To make this distinction clear, and to focus alerts and targeted news, the system computes the current harvesting cycle based on simple heuristics.

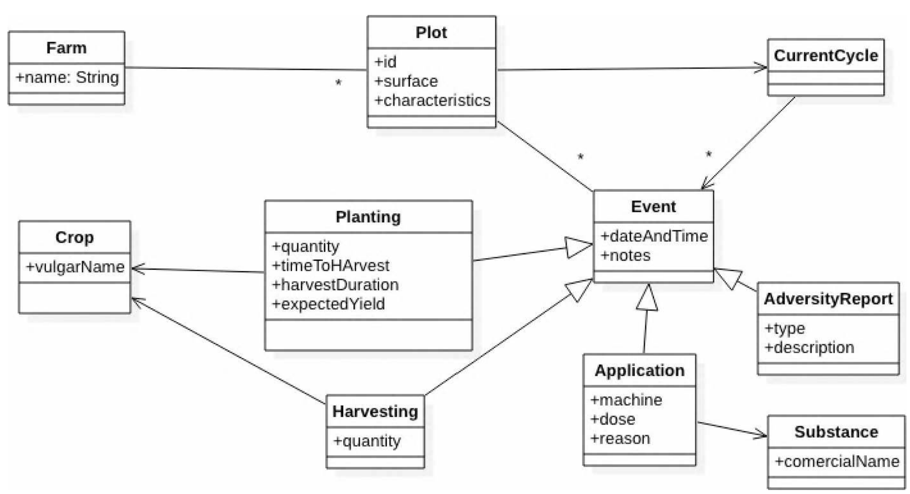

Fig. 2. Overview of data abstractions concerning the recording of events

The phytosanitary catalog comprises information about maximum residue levels, and about the recommended withdrawal time after the application of a product on a crop. Figure 3 depicts the part of the system's design that models such information. Every time the Argentinean authorities publish new regulation regarding the maximum residue limits, the information is imported into the system as multiple MRL records connecting an active ingredient with a crop, an MRL value, and a functional class. Each record is labeled after the document (source) it originated from. Withdrawal recommendation are entered and updated by the experts that advice the farmers.

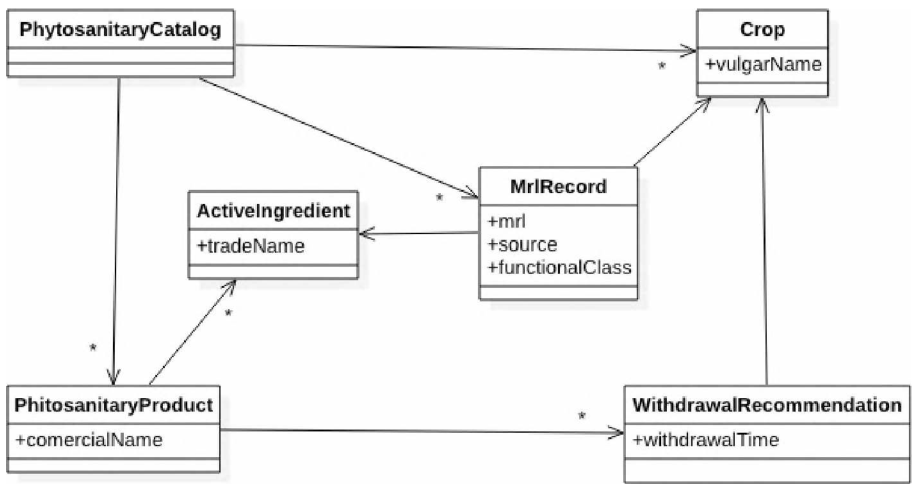

Fig. 3. Overview of data abstractions modeling the phytosanitary catalog

After signing in, farmers are taken to the dashboard screen. Figure 4 depicts the dashboard as seen by a farmer. On the left side (top to bottom) there are links to the various views and data entry screen. The first block (the farm today) offers access to the dashboard (currently active), the plots overview, the crops overview. The second block (events) offers links to the event recording forms, and to the chronology view. The third block (administration), offers functionality to add and edit plots, to manage the inventory of phytosanitary products of the farm, to record sales (only offering basic functionality for traceability), and to exporting data to CSV.

Widgets in the dashboard become active when there is something to show. In the figure, the farmer is presented with a block for the news, the list of plots in withdrawal (to avoid harvesting), the lists of crops that are soon to be harvested, and the progress of the harvest.

When a user enters the systems as an expert (attending a group of farmers) the dashboard provides an summary of activity for the last week and month. One

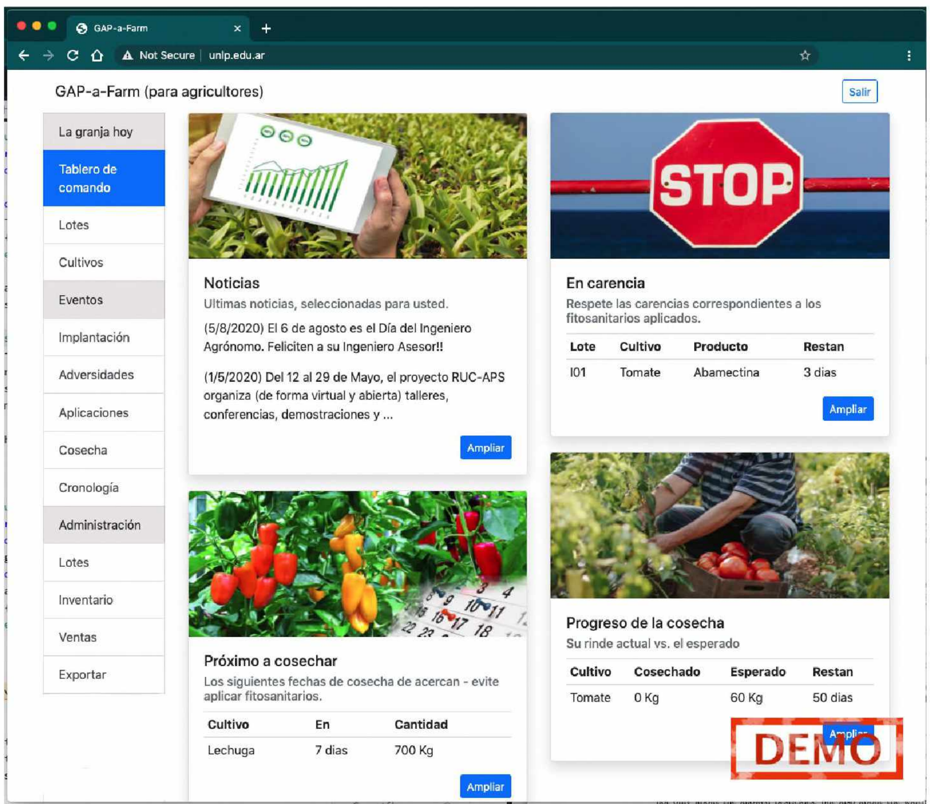

Fig. 4. Dashboard screen as seen by a farmer

widget offers a summary of planting by crop, another widget offers an overview of the reported adversities, and another widget provides an summary of applied phytosanitary products. The expert uses this information to decide if the farmers may need any specific advise. If that is the case, the expert navigates to the news section (via a link on the left) to publish news, targeting farmers by criteria such as used pesticides, crops planted, etc.

On the left menu, the expert has access to the list of active principles (as imported from the database of MRL), and to the list of phytosanitary products and fertilizers. It is in this later list that the expert adds new products for the farmers to use, and updates the withdrawal times.

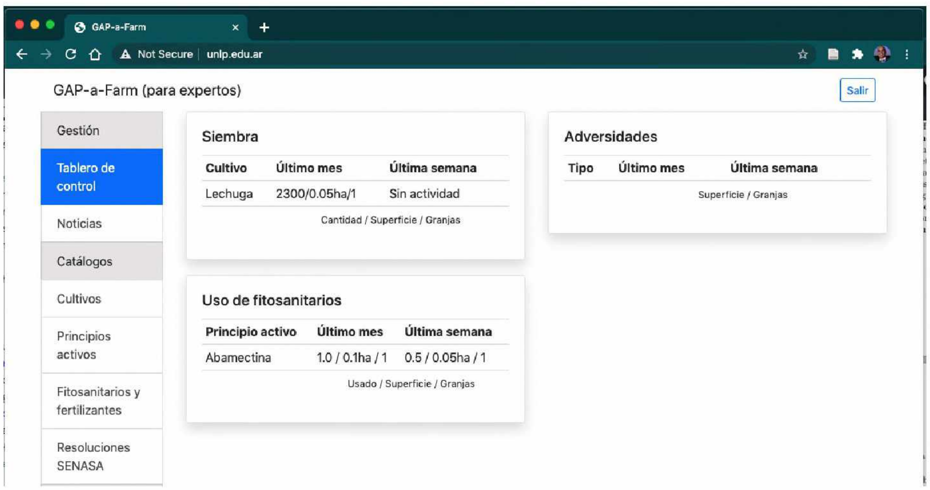

Fig. 5. Dashboard screen as seen by an expert

5 Pilot study

GAP-a-Farm went through a series of testing cycles to ensure alignment to end-users objectives and usability requirements. The researcher's strategy towards adoption is to present the tool as simplified support for record keeping as required by GAP.

The tool transparently learns from many farmers and turn this into group decision support (for example, by showing trending issues or by comparing a farm's yield to the average all farm's using the system). A pilot study is currently underway to assess the farmer's stance towards the provided decision support, and towards the (anonymous) use of the information they provide to benefit other farmers. In order to evaluate the user-experience and maturity of the software the study included a system usability scale [3] questionnaire.

The pilot started in August 2020, and is underway at the time of this writing. Eight middle size farmers take part. They were interviewed to learn about their current record keeping and decision making strategies, and to asses the level of adoption of IT tools. One of the farms is Global G.A.P. certified. As part of the certification process they were required to record plantation, use of pesticides and harvesting. They did it mostly in paper forms, which they indicated was sub optimal. Another farmer kept detailed records (mostly in paper forms, that are later translated to word documents) of harvesting, application of pesticides and water use. The rest of the participants kept some form of records (in paper) for applications and harvesting. A special case was that of farms that outsourced harvesting and pesticide application to external workers, as each action was recorded by the worker to claim payment. In most cases, farmers indicated that it is difficult to keep up with recording when the day to day work of the farm consumes most of the time.

6 Conclusions and outlook

The introduction of new agricultural regulation by the Argentinian government is an opportunity to test whether a compliance-based DSS can increase technology adoption rates by integrating software into required record keeping. The authors built and deployed a tool that supports farms that follow the GAP compliance scheme, with the expectation of wider adoption when legislation is enforced for vegetable growers in 2021. A pilot study is underway. If successful, the authors plan to scale the software for farms nationally. A follow-up study is then needed to evaluate if farms begin using other IT solutions as a consequence of using this DSS to see if tool helped to improve technology adoption rates acting as a gateway.

Early feedback from farmers shows both that farmers were positive about the value of the tool, but that at the same considered the task of record keeping to be time consuming and secondary. Time will show if the value added by having historical records that are turned into decision advice outweighs the effort of data recording. Moreover, research is underway to reduce the perceived effort of data recording. In this regard, heuristics based on models for the behavior of crops, and machine learning methods are used to pre-load event forms and to proactively create event reports that the farmer later confirms.

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