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A Gateway for Technology Adoption in Agriculture: a Design-Thinking Approach for a Compliance Decision Support System

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ABSTRACT

Globally, consumers are becoming more conscious of unsustainable farming practices. The appetite for safely produced, compliant and pesticide free crops is increasing. In response to these demands, the Argentinian government has issued new regulation to govern the application of *good agricultural practices* affecting production, storage and selling activities. This legislation is an opportunity to incentivise farm owners to adopt technology for recording mandatory information which has previously proven difficult. This project aims to test whether compliance software is an effective gateway for shifting farmers decision-making to technology, and from intuition-based to evidence-based, improving agricultural productivity. Understanding and integrating technology into their existing practices is a substantial challenge for many farms. Consequently, the authors prototype a decision support system (DSS) for greenhouse farmers in Argentina that can trace batches of crops and their treatments to reduce compliance risk. Incorporating lessons learned from previous DSS projects, the authors utilise design-thinking strategies to include end-users in the development of the system. Through such a tool, the authors can trial innovative features to test receptiveness of farm owners to utilise information technology solutions for decision-making and identify barriers to data collection and technology adoption.

Keywords: Agricultural Compliance, Decision Support System, Technology Adoption, Design-Thinking, Agriculture

INTRODUCTION

Background

Over the past five decades there has been a global shift in agriculture from resource-driven growth to productivity-driven growth [1]. Previously, farms have increased agricultural output through expansion of land, water use, and other inputs. Most farms now prioritise improving resource and labour efficiency alongside better farming practices and technology [1]. Agricultural productivity is lower in developing countries compared to advanced economies, impeding their convergence. Technology and innovation are fundamental to drive improvements and acceleration in the sector, embodying state-of-the-art practice and "knowledge capital" that can transform farm owners' businesses [1]. Improving farm productivity not only involves efficiency and yields improvements, but also raising quality of food for higher-value and exportable products [1] . This can be an important growth opportunity for small-holder producers to meet the standards of other markets, ultimately improving their impact on economic prosperity, environmental protection and social well-being.

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, they may collect such data by hand or through using spreadsheets. Understanding the barriers to technology 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 catalyse their economic growth. Many software solutions have struggled with low adoption rates [2] and lessons learned from previous agricultural decision support systems (DSS) identified compliance as an effective way to deliver decision support [2].

Scenario

In October 2018, the Argentinean government issued new regulation [3] to govern the application of good agricultural practices (as defined by FAO) 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 Agri-food 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. [3]

The approach described in this paper aims to seize the opportunity to test whether a compliance DSS addressing new legislative changes can shift farmers processes to incorporate technology whilst embedding expert advice. The project is developed in collaboration with several horticultural greenhouse farmers in La Plata, Argentina, a farming area of approximately 6000 hectares with over 1000 farms that provide fresh vegetables to a large part of Buenos Aires province [4]. Based on conversations with local farmers, many farms 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 [5] to improve their farming practices to deal with the multitude of challenges they experience such as traceability, a volatile market, manual labour requirements and pest management. Adopting technology and IT systems can help to mitigate risks that the challenges pose and ensure farming practices are compliant to help secure trade deals with supermarkets or for international exports [1].

Aims and Objectives

The authors propose a prototypical DSS, GAP-A-Farm, to incrementally integrate technology into a farm's compliance processes using a design-thinking approach for continuous end-user feedback and incorporating lessons learned from previous DSS projects [2, 6]. The authors aim to demonstrate the effectiveness of whether an accessible compliance software is an effective gateway for shifting farmers decision-making to technology, and from intuition-based to evidence-based, improving agricultural productivity. The objectives of this project are as follows: (i) review the literature and existing software tools for similar functionality and guidelines, (ii) apply design-thinking principles for software development to develop a minimum viable product (MVP) DSS for compliance and traceability, (iii) prototype features with decision support and (iv) acquire end-user feedback during the development cycle with farm owners and managers in La Plata, Argentina. The paper addresses the objectives in chronological order and is concluded in the last section with plans for a pilot study.

RELATED WORKS

DSSs are designed to aid users to make better decisions by guiding users through decision stages and presenting the likelihood of various outcomes resulting from different option [2, 7]. These can be dynamic software provide suggestions according to the user's inputs and record data for analysis to provide data-driven insights [8]. Despite wide availability of DSSs for agriculture, studies show that uptake has been disappointingly low [2]. One study, looking at lessons learned from previous DSSs and their reasons for low uptake, identified key factors for effective DSS design and delivery including usability, relevance to user and compliance demands [2]. Guidelines suggest focusing on time-consuming processes with substantial risk for the farmer to justify the use of technology [2]. Software is available to support record keeping from seed to harvest for compliance, in the form of enterprise resource planning (ERP) tools in industry such as Farmbrite and Artemis [9]. These tools can be expensive and are a leap for the technologically illiterate, especially when they are only available in English.

Several major reviews have been conducted on agricultural DSSs, two of which do not mention DSSs to support compliance [8, 11]. A review from 2019 on apps for sustainable agriculture identifies some apps for compliance-related inspection but found that they do not integrate farmer knowledge [11]. It concluded that DSSs lack emphasis of knowledge exchange to identify evidence-based practices that improve indicators of sustainability, as well as involving end-users early and throughout the software development [11]. Finally, a review of farm management information systems (FMIS) in 2015 found that few FMIS software had features for tracking traceability and providing best practices, and these were in their infancy commercially [12]. There remains an opportunity to develop a DSS as a vehicle for improving the confidence of farmers to use technology solutions.

APPROACH

A design-thinking approach was taken to involve end-users in the development of the DSS to assist farm-owners that are typically technology averse. Design-thinking 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" [13]. It encompasses a set of strategies which can be broken down into initial divergent phases and convergent phases which are iterated. The approach starts with "emphasising" through journey mapping and interviews to understanding some of the core challenges that the farmers encounter regularly. The problem-solvers then "define" the challenges and decisions that need to be supported, enabling objectives of the system to emerge. The "ideate" phase consists of sharing ideas, thinking of possible solutions and prioritising viable concepts. The “prototype” phase involves a MVP that is 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 a software that has unnecessary features or is not suitable for the 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.

EMPHASISE/DEFINE – INTERVIEWS AND SURVEYS

In order to determine the best-fit solution for greenhouse farmers in the region, the authors conducted a short survey with ten participants owning farms between 0.5 hectares to 30 hectares in La Plata. The aim of the survey was to determine the challenges local indoor farmers experience, the compliance schemes they follow, their key performance metrics and their current technological capacity (no. of computers and internet access). The results showed that all participants thought technology would be helpful in their processes and most participants were underprepared to deal with regulatory changes. All participants agreed that a software would be useful for “recording traceability” and “planning”. Although all farms were accustomed to using their smart phones to access the internet on their farm, 70% of 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 wanted to compare their performance to other farms. The authors concluded that the best solution would be a web-based group DSS to support existing compliance processes, providing decision support around authorised substances, premature harvest warnings and comparison metrics.

Interviews were then conducted on several greenhouse farmers that follow compliance schemes proceeding a journey mapping session which highlighted pain-points in tracking crops and their treatments [14]. These interview sessions enabled a clear definition of the software requirements in order to adequately record the data necessary for SENASA and GAP. The following user requirements were agreed: (i) plots can be entered with a history log, (ii) plant batches can be sown or harvested within a plots (iii) issues like pest outbreaks can be reported for batches, (iv) treatments like pesticide applications can be reported for batches. Concerns were raised about being able to retrospectively change the dates of treatments, indicating mistakes may be made whilst back-dating compliance. Therefore, additional features were suggested such as a warning system to ensure that pesticide is only applied to approved crops by SENASA and that crops are not harvested prematurely once pesticide has been applied.

IDEATE/PROTOTYPE – BRAINSTORMING AND PROTOTYPING

After identifying the core functionality of the DSS, and ideation phase followed which resulted in a set of prioritized ideas. Concepts that were discussed through a series of workshops included risk management, 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 Fig. 1 to get end-user feedback.

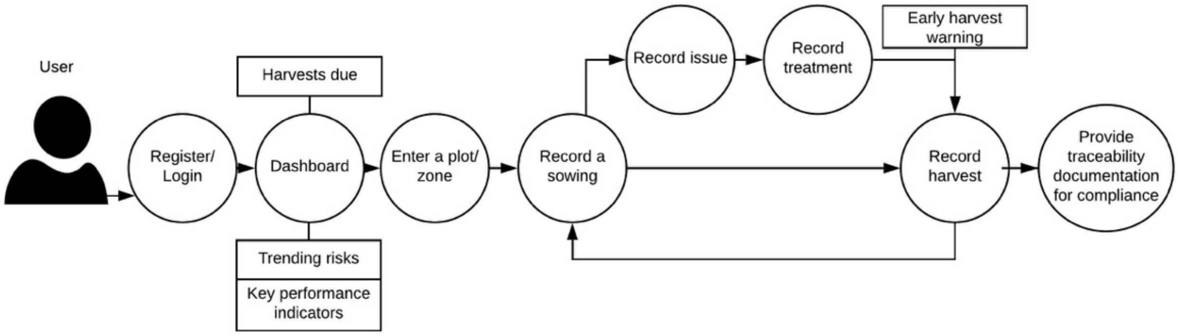

Figure 1 User journey (farmer) for Gap-A-Farm developed with the end-users

A prototype was developed for evaluation. Gap-A-Farm 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, when they discover issues in the farm (e.g. pests), when they apply chemicals and fertilizers, and when they harvest. In this sense, the system replaces the paper forms or spreadsheets they currently use. Moreover, as farmers use the system, they discover support for decision making focused on GAP compliance.

After an initial phase where the farmer registers the plots in farm, most of the interaction of the farmer with the system involves recording relevant events. Events are connected to plots (the unit of analysis). Four types of events are currently available: Planting, Issue reporting, Harvesting, Application. In all cases the date and time are recorded. When planting, the farmer records crop type (selecting from the shared catalogue) , quantity (no. of plants/kg of seeds), time to harvest, harvest duration, and expected yield. This information is processed as alerts on the dashboard such as upcoming harvests and to compare expected vs. actual yield. When recording an issue, the farmer provides a short description and a classification from a predefined taxonomy (i.e. Infestation, Disease, Nutrients deficiency, Other). Reported issues are currently used to offer targeted news to farmers whilst collating "trending" issues to be summarised on the dashboard (in the future additional advice could be offered upon logging). Recording the application of chemical products and fertilisers is central for compliance. When an application of a substance to a plot is recorded, it is cross-referenced with the shared catalogue to ensure its authorization by SENASA for the crop type in that plot (note: substances are applied under the advice of the farm's agronomist who can consult the catalogue). If a minimum waiting time prior to harvest after an application is required, the system marks the plot as "not to harvest before". Once the harvesting period begins, every harvest is recorded from each plot in the form of events (including the quantity, both in kilograms and/or in a customized unit). Whereas the latter is used to reflect on common practices, the former is used to update the dashboard, comparing expected to actual yield.

As a result of an explicit decision, driven by agility and in pursual 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 farmers do not normally record this information, it is included to assess the willingness of farmers to provide extra information, evaluating how it may prompt decision advice. Finally, Gap-A-Farm transparently learns from many farmers and turn this into group decision support (e.g., showing trending issues or comparisons of a farm's yield performance to averages of other farms using the DSS).

To ease its deployment and maintenance, the system has been implemented as a web application, limiting its use to farms with internet access. It was built using responsive technologies to enable compatibility for both from desktop and from mobile devices. However, initial discussion with the farmers from the pilot study suggest that the DSS will be primarily accessed via desktop computers.

TESTING

Gap-A-Farm went through a series of 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). The tests were necessary to determine whether record keeping with the system clearly outperformed paper handwritten forms and spreadsheets. Assessing this contribution is the first goal of the pilot studies to be conducted in the next phase of the project. The systems also offer advice (alerts, warnings) to help farmers recognise and avoid the most frequent causes of non-compliance, namely: using a substances that was not approved by SENASA, and harvesting before the mandatory waiting time after an application has elapsed. A second goal of the pilot study will be to assess the tools contribution to reducing the risk of non-compliance. The third goal of the pilot will be 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 how well the software solves the problem intended, the authors will conduct user-experience testing such as the system usability scale questionnaire.

CONCLUSIONS

The introduction of new agricultural regulation by the Argentinian government is an opportunity to test whether a compliance-based DSS, Gap-A-Farm, can increase technology adoption rates by integrating into required record keeping. The authors use design-thinking strategies to develop Gap-A-Farm prototype that supports farms that follow the GAP compliance scheme with the aim to help other farms more widely when legislation is enforced for vegetable growers in 2021. Four iterative two-week cycles have been completed, gathering feedback on the prototype system from several farmers. This approach of combining learnings from the agricultural DSS literature and design-thinking to take advantage of recent legislative changes may be a crucial opportunity to prompt agricultural practices in developing countries to evolve into the digital age. The pilot study with five farmers to formalise end-user feedback on DSS is now underway and will demonstrate whether Gap-A-Farm achieves its objectives. Features found to hinder the usability can be removed. 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 Gap-A-Farm acted as a gateway to improve technology adoption rates.

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