Increasing farmer awareness of the impact of agriculture on water quality with the 1622WQ™ app

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Abstract
In many regions of the world, farmers need to change management practices to reduce discharge of chemicals and nutrients to marine and aquatic ecosystems. However, they rarely appreciate the link between their practices and water quality, something which is necessary for them to change management. Existing water quality information systems are not designed to raise farmer awareness and facilitate improved management. We developed an application, 1622WQ (https://wq.1622.farm/), using user experience design principles to provide farmers with real-time, high frequency information on nitrate concentration and other contextual variables in creeks and rivers of Great Barrier Reef catchments. The app is having impact. It attracted >1,000 users within a few months of being launched, with that engagement being maintained, and there is evidence it is changing farmers' attitudes about local water quality and their practices. The Queensland Government is adopting it to communicate their data to farmers and advisors. There is also demand for it in pesticide monitoring activities, with a version being developed for that purpose.

Keywords
Sugarcane, Great Barrier Reef, Nitrogen fertiliser, Pesticides, Environment

Introduction

The health of the Great Barrier Reef (GBR) is under pressure from dissolved inorganic nitrogen (DIN) discharged from adjacent catchments, with the main source of DIN being N fertilisers applied to sugarcane cropping (Thorburn et al., 2013). To protect GBR ecosystems, the Australian and Queensland governments have developed targets for reduced DIN discharges (Waterhouse et al., 2017) and invested substantial amounts on the adoption of improved management practices to achieve those targets (Anon, 2021). Despite these efforts there is still scepticism amongst sugarcane farmers about the link between farm management and water quality[1] with one result being that changes to crop management are not occurring fast enough to meet DIN discharge reduction targets (Anon, 2021).

For farmers to engage in actions to improve water quality, they need to be aware of the link between crop management and water quality. Sugarcane farmers are particularly interested in local water quality data to help "see" that link (Davis et al., 2021; Fielke et al., 2021). For DIN in GBR catchments, the main sources of that information have been technical publications (e.g. Waterhouse et al., 2017; Napel et al., 2019) summarising monitoring of DIN in rivers and creeks near sugarcane farms. These sources are not "farmer-friendly", both in their format and the delay between data collection and reporting. Thus we hypothesise that having these data readily available in real-time will allow farmers to see and appreciate the link between crop management and DIN concentrations, and thus evaluate the impact of their recent farming practice (e.g. fertiliser application) on water quality.

To this end we developed 1622WQ™, a web-based app that provides real-time data on stream water quality. This paper describes the development of the app for displaying nitrate concentrations in catchments draining to the Great Barrier Reef, some issues faced in development, user feedback, and the impact of the app.

1622WQ™ development

The vision for 1622WQ was that it be a device-independent (i.e. desktop and mobile), online application, with no installations required, and that kept network requests to a minimum allowing us to partially address

[1] https://www.theguardian.com/environment/2019/aug/23/sugarcane-farmers-support-group-working-to-undermine-great-barrier-reef-science?CMP=Share_iOSApp_Other

internet connectivity issues in rural Australia. The name “1622” comes from the height of Mount Bartle Frere, Queensland’s highest mountain that overlooks the Russell-Mulgrave catchment where much of the design work was undertaken. The app was developed in two phases, a prototype then a robust application, in a process shaped by user experience (UX) design principles (Stitzlein and Mooij, 2019). The design process, software engineering and data sources are outlined below, with full details given by Vilas et al. (2020).

“UX” design process

The UX design process was based on both formal and informal user experience workshops and “hallway” testing (testing with various individuals). These activities were mainly undertaken in the Russell-Mulgrave catchment (immediately south of Cairns), the location of two farmer-led water quality monitoring projects (described below). The process started in May 2017, when a context assessment was undertaken through structured interviews with 10 farmers to identify their desires and needs regarding water quality information. These interviews confirmed their desire for readily accessible information and revealed the basic features the farmers wanted in the application, such as the format of data display (e.g. line graphs) and the preferences about information displayed on the main page. These interviews also revealed that farmers were interested in rainfall data, to see how nitrate concentrations varied after falls of rain. The project team investigated commercially available data display systems, such as the Grafana dashboard (https://grafana.com/grafana/), but none of these filled the needs of the farmers. Thus, we decided to develop an original piece of software.

A prototype (v1.0) with a map-based interface (Figure 1a) was developed (Apr 2018) based on this feedback and tested with a group of seven farmers. From this we identified the need for a list of sensor locations to be presented to users, as well as the map interface, to facilitate the selection of the sensors. Prototype-v1.1 incorporated these features and was released in October 2018 to a group of 12 farmers, selected for their interest in water quality, through one-on-one interactions. Usage data (from Google Analytics) and informal interviews 3 months later revealed that most of the farmers had not accessed the prototype-v1.1, and those that had did so rarely. When asked for specific feedback on the prototype these farmers indicated that the two-step registration/activation process (which involved contacting the app manager to register and then logging-in to activate the account) was a substantial barrier to its use. They also stated a desire for contextual information to help them interpret the data. In addition, latency when loading data and data errors (e.g. negative nitrate concentrations, discussed below) further diminished their interest in using the app. These issues were addressed in the move from the prototype to the 1622WQ application.

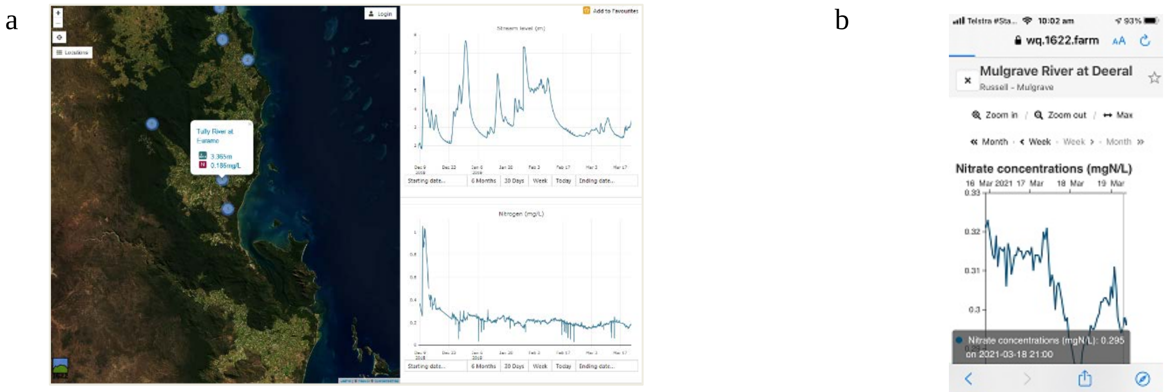

Figure 1. Screen shot of the 1622WQ™ app in the (a) prototype version and (b) the current version of the web application available through https://wq.1622.farm/.

There were several versions of the 1622WQ application. Version 1.0 (app-v1.0), completed in Feb 2019, was developed so that data could be visualised rapidly (facilitated by the caching and architecture of the application) and implemented a streamlined registration/activation process. It also included the mean nitrate concentration for the past 30 days to help farmers interpret the data and techniques to handle erroneous and missing data (described below). Schematics were made of the next interface design and feedback solicited through “hallway” testing with ~10 stakeholders in May. The application was re-designed (app-v2.0) based on their feedback. Additional hallway testing was undertaken (Sep 2019) and the app updated to app-v2.1 with improved interaction with the map interface. Also, local rainfall data were included as requested by the farmers. Version 2.1 (Figure 1b) was completed in Dec 2019 and publicly released the following month with coverage of the launch in print and television media in GBR catchments.

Software/Development

(a) Prototype

A prototype version of 1622WQ was developed using the Shiny package (https://shiny.rstudio.com), an open source R package for rapidly building web applications using R (https://cran.r-project.org). Qualitative feedback from farmers in local water quality monitoring projects indicated they did not want their data available publicly, so access to the app was restricted by user identification.

(b) Application

The 1622WQ application was developed as a React SPA with a Django microservice-based backend (https://www.djangoproject.com) and a PostgreSQL database (https://www.postgresql.org). These were implemented for speed and utilise all open source frameworks and libraries. The features of the app in Version 2.1 included: (1) Automatic discovery of new data sources (i.e. newly installed sensors) for the app administrators, which they can add to the app if desired; (2) the ability to restrict external access to specific data sources, enabling the display of publicly available data and establishment of private user groups; (3) limited user tracking through Google Analytics, complying with European privacy standards; (4) filtering of erroneous data; and (5) infilling missing data.

Data

When the app was publicly released there were three programs/projects providing water quality data for 1622WQ. The first was the Queensland Government's Great Barrier Reef Catchment Loads Monitoring Program (Napel et al., 2019). Nitrate and water level data were displayed from 11 stations monitoring 10 river catchments draining into the GBR. These data are referred to as "Queensland Government" data in the app. Data also came from two projects in the Russell-Mulgrave catchment aiming to inform farmers about variation in water quality in that area. The projects were "Project 25" (Davis et al, 2021) and "Cane to Creek" (Billing, 2017), with the latter focussing on the Figtree Creek sub-catchment of the Mulgrave River catchment. In all three projects water sampling was automated with measurement intervals ranging from 10 to 60 min. Data from all three sources are transmitted in real time to a cloud-based platform (Eagle.io, https://eagle.io) and then transmitted to the Eagle.io database behind the app.

Data filtering and infilling

Errors and anomalies are commonly found in real-time water quality data (Zhang and Thorburn, 2021b). Erroneous measurements are a result of sensor malfunction, sensor-database communication failures, etc. For the nitrate concentration data these problems manifested themselves as negative concentrations, unrealistically rapid changes in nitrate concentrations, along with gaps in data streams. Some of these problems are indicated by an 'error code', generated by the sensor, accompanying the data. These data were removed from the streams displayed. A data filter was developed to remove negative nitrate concentrations. It also removed data associated with unrealistically rapid changes in concentration, defined as exceeding the 98% quantile for a specific location. Gaps in data up to five consecutive values were infilled by linear interpolation. Methods for infilling larger gaps were developed based on state-of-the-art sequence-to-sequence deep learning architecture (Zhang et al., 2019; Zhang and Thorburn, 2021a), although these have yet to be implemented in the publicly available version of the app. All data filtering and infilling is conducted in the Amazon Web Service Lambda platform.

Discussion

Use

There were >1100 users of the 1622WQ app in the five months after the public launch (compared with ~1400 sugarcane farms in the region), and this level of use has been subsequently maintained. Over 70% of users interact with multiple pages in the app, as opposed to visiting the landing page and leaving. This is a high degree of web page/app engagement by IT industry standards. These use statistics starkly contrast the experience following the release of prototype-v1.1, highlighting the benefit of the UX-based design and successive prototyping processes overcoming the barriers to uptake of the earlier versions.

Impact

The impact we sought from developing and deploying the 1622WQ app was to have farmers understand that there is a relationship between the management of their farm, in particular nitrogen fertiliser management, and nitrate concentrations in nearby creeks and rivers. Following the launch, semi-structured interviews were held with farmers in the Russell-Mulgrave catchment (Fielke et al., 2021), and the responses provide insights into whether the app was on track to achieve the desired impact. A comment from a water quality scientist working in the regions suggest that the app is starting to have an effect:

> *"Since its recent launch, I am regularly contacted and queried by influential growers in my study catchment as to particular water quality events occurring in their local waterways (often before I am even aware of them myself). This development demonstrates a major paradigm shift in how farmers can engage with water quality monitoring in their local environments, and one that cannot be understated."*

And that conclusion is supported by a comment from a farmer:

> *"I think it's* [the app] *proven that you've got to get your timing right… like with your fertiliser… and we can take that out to the growers, and they're understanding it..."*

Future

The 1622WQ web app is becoming recognised as a valuable communication tool in farmer-oriented water quality monitoring. Not only are the project teams behind the data streams displayed in the app still using it in their communications with farmers, it is acquiring an expanded base and new developments. It is being used by the Queensland Government's Catchment Loads Monitoring Program to provide real-time data from greatly expanded nitrate monitoring in the Burdekin and Herbert catchments, and the Program continues to provide us with access to data from sensors in other areas. A version is being developed for pesticides for use in farmer-led monitoring in the Mackay and Burdekin regions. "Behind the scenes" the development team is improving back-end process, including making small improvements to the display and simplifying establishment and management of project groups. Improving the efficiency and quality of back-end process will reduce the ongoing cost of maintaining and delivering the app. We are also making data filtering better and less time-consuming to set up and looking at more sophisticated infilling of data gaps. These initiatives will underpin greater and more timely access by farmers and interested communities to more relevant local water quality data, improving their engagement in efforts to protect Great Barrier Reef ecosystems.

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