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FORAGE – An online system for generating and delivering property-scale decision support information for grazing land and environmental management

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ABSTRACT

Queensland grazing industries operate in one of the world's most variable climates and face enormous challenges to achieve profitability and sustainability. To assist grazing enterprises, the Queensland Government has developed an operational online information system – FORAGE, to facilitate best management practice for grazing land. The FORAGE system provides land managers with property-scale information relating to rainfall, ground cover, soil erodibility, land types, tree density, seasonal climate outlooks and pasture growth simulated using the GRASP grazing system model. This information is site-specific and tailored to facilitate on-ground management decisions common to Queensland grazing enterprises. The FORAGE system makes complex remotely-sensed data, information from a range of databases and pasture growth models more accessible and relevant to land managers. This paper describes the structure, resources (e.g. software, databases and models), information generating processes, delivery mechanisms and information products of the FORAGE system.

1. Introduction

Grazing lands in Queensland, Australia, account for 85% of the total land area (DAF, 2014) and the grazing industries operate in one of the world's most variable climates (McKeon et al., 2004). Due to the impacts of overgrazing (McKeon et al., 2004), drought and climate change (Henry et al., 2007; O'Reagain et al., 2011), land managers face enormous challenges in maintaining the profitability and sustainability of the grazing systems (Hunt 2008; O'Reagain et al., 2011). These challenges include reduced productivity (Henry et al., 2007), soil erosion (Tongway et al., 2003), woody weed invasion (Gooden et al., 2009) and declines in species diversity (McKeon et al., 2004).

To assist land managers, purpose-built and readily available property (farm) scale decision support information is critical for facilitating on-ground management (Henry et al., 2007; McKeon et al., 2009). For example, land managers require climate and pasture growth information to enable the calculation of feed budgets and to optimise paddock stock numbers (Hunt 2008). Similarly, government agencies also need information to facilitate the implementation of environmental management policies (Hassett et al., 2006). This information may include land condition indicators such as ground cover, soil erosion and weed occurrence.

Quite a few decision support tools have been developed in Australia in the last decade or so and have been considered to be useful in improving grazing land management (McKeon et al., 2009). For example, the online tool Pastures from Space® Plus (http://www.pasturesfromspace.csiro.au/) provides site specific estimates for pasture growth rate in Mediterranean and temperate agricultural zones of southern Australia. The GRAZPLAN (http://www.grazplan.csiro.au/) offers a range of models to estimate pasture growth and nutritional requirements of sheep and cattle for assisting decision-making in grazing enterprises. These decision support systems, though valued by the industry, have not been widely used in rangeland management in northern Australia, mainly due to not being freely available or not being developed for the rangeland communities in the regions.

The Queensland Government, since the 1990s and more recently under the Reef Water Quality Protection Plan (http://www.reefplan.qld.gov.au/), has invested significantly into research, development and extension activities for the grazing land industries to achieve land condition, ground cover and reef water quality improvements. Tools and information sets have been developed to provide assistance to cope with the impacts of drought, overgrazing and climate change on grazing land and natural environments (Henry et al., 2007). These include grazing system models (McKeon et al., 1990), seasonal climate and pasture growth outlooks (Stone et al., 1996), land condition monitoring information (Hassett et al., 2006), historical and projected climate

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databases (Burgess et al., 2012; Jeffrey et al., 2001) and remote sensing based estimates of ground cover, tree density and fire scar information (Danaher et al., 2010). However, despite these tools and information sets have been used by government agencies, extension officers and consultants, they have not been readily available to land managers and wider community users, due to software complexity and limitations in accessing relevant databases. More importantly, the information provided has not always been site-specific or available in a user friendly format and therefore has been difficult to interpret.

To overcome these limitations and to facilitate informed land management decisions, an online information system, FORAGE, has been developed by the Department of Science, Information Technology and Innovation (DSITI), Queensland Government. FORAGE offers property specific information on rainfall, pasture growth, seasonal rainfall and pasture growth outlooks, ground cover, foliage projective cover (FPC, a measure of tree density), soil erodibility, land types and climate projections. Since its development, FORAGE has been used by a range of users to support grazing land management practices in Queensland.

This paper aims to introduce the structure, data and software resources, information generating processes, delivery mechanisms and information products of the FORAGE system.

2. Overview of the FORAGE system

The FORAGE system operates through a public website (http://www.longpaddock.qld.gov.au/forage/). The website is designed to offer simple interfaces for users to submit their requests. When requesting an information product, users only need to provide:

- the location of the property through either a cadastral identifier (e.g. a Lot on Plan) or geographic (latitude and longitude) location;
- an email address for delivering the information products (mainly reports); and
- specific information for a information product (e.g. the time period of interest or a threshold option).

When a request is submitted, FORAGE utilises relevant databases, models and other information resources to generate the required information. In most cases this information is then compiled into a PDF report and emailed to the user. Most of the reports are delivered within 10 min after a request is submitted; more complex requests can take up to 5 h depending on the complexity of the model run and satellite image processing.

FORAGE currently provides 12 reports along with purpose-built satellite images. These reports and satellite images are freely available for all users. Additional information products are currently being developed and evaluated. Due to input data availability, these information products are currently only available for locations in Queensland. A comprehensive User Guide and collection of Frequently Asked Questions (FAQ) are provided on the FORAGE website to assist users in requesting and interpreting the reports.

3. FORAGE structure, resources and processes

3.1. Structure

The FORAGE system has four major components (Fig. 1):

- a web interface;
- a request processing unit;
- an information generating unit; and
- a delivery unit.

When a request is submitted through the web interface, the information entered (such as a user email address and a Lot on Plan) is checked and sent to the request processing unit. The request processing unit conducts a security check on the information received, analyses and sorts the request parameters, and then submits the processed request to the information generating unit. The request processing unit also provides logging and debugging functions.

The main component of the FORAGE system is the information generating unit. All databases, models and other relevant information resources used in FORAGE are linked with this unit. The unit consists of a group of subunits, where each subunit provides functions to produce a specific information product. The main functions of each subunit include querying databases, running models, analysing satellite images, synthesising information, generating graphs and maps and assembling report.

Depending on the size of the resultant information product, the delivery unit determines the electronic delivery methods, with PDF reports being delivered as email attachments and larger size GIS data and imagery being delivered through File Transfer Protocol (FTP).

Apart from the web interface, all other FORAGE components are located on a high performance computing (HPC) server which provides computing capacity for FORAGE to analyse large data sets and process multiple requests.

3.2. Resources

3.2.1. Programming languages

The FORAGE system is written in Python programming language (http://www.python.org) within a LINUX environment (except for the web interface). Python language was preferred due to its portability, flexibility and the modules it offers for conducting data analysis (such as 'scipy' and 'numpy'), plotting ("matplotlib") and manipulating strings. This language also provides the interfaces required to utilise a range of other libraries and programs such as GDAL/OGR (Geospatial Data Abstraction Library, www.gdal.org) and MapServer (http://mapserver.org/) for spatial data processing and visualisation. R (https://www.r-project.org/) is used to conduct statistical analyses.

3.2.2. Database

FORAGE is linked to a historical climate database – SILO (http://www.longpaddock.qld.gov.au/silo/), a projected climate database – Consistent Climate Scenarios (CCS) (Burgess et al., 2012) (https://www.longpaddock.qld.gov.au/climateprojections), a remote sensing database and a GIS database – Spatial Information Resource (SIR).

SILO provides Australian climate data from 1889 to the day before current date, in a number of ready-to-use formats which are suitable for research and climate applications. For any point on a $0.05^{\circ} \times 0.05^{\circ}$ grid (approximately 5 km by 5 km) across Australia, SILO is able to provide historical daily rainfall, maximum and minimum temperature, solar radiation, pan evaporation, vapour pressure (9 a.m.) and estimates of relative humidity. These climate data were developed from interpolating Australia Bureau of Meteorology weather/climate station records (Jeffrey et al., 2001).

The CCS draws on OzClim methodologies (http://www.csiro.au/ozclim) and historical climate data from SILO providing projected daily climate data for 2030, 2050 and 2070 at the same resolution as the SILO database. Change factors from multiple GCM models from the IPCC fifth assessment report are summarized to show mean change and the range of expected changes for the location requested in the FORAGE climate projection report.

The remote sensing database, which was developed by the Queensland Government's Remote Sensing Centre (https://www.qld.gov.au/environment/land/vegetation/mapping/remote-sensing/), offers a range of purpose-built image products derived from Landsat and other satellite imagery. This database provides FORAGE with images of FPC and pasture ground cover, both of which are developed from the Landsat imagery and are available from 1986 to present (Scarth et al., 2006; Danaher et al., 2010).