SOiL CRC

Performance through collaboration

TECHNICAL REPORT

Supporting farmer decision making for soil stewardship and profitability

Program 1 – Investing in high performance soils

INTRODUCTION

Farming is a 'human activity system'. The farmer decides how they will manage their soils to optimise their wide range of social, economic and environmental goals. Farmers make those decisions based on their values, capacities and experience, as well as a range of information, and advice, including decision support for particular ends. This document identifies existing (2018) systems and tools designed to assist farmer decision making associated with soil management, comments on their currency and considers the potential for the Soil CRC to further evaluate them and/or use them to assist farmer decision making in the future.

Decision Support Systems (DSS) encompass a range of programs, or projects, with information, guidance and rules of thumb designed to assist farmers make management decisions for certain goals. Decision Support Tools (DST) are documents, checklists, apps or computer programs that offer specific information to help decision making. Conceptually DSS and DST are closely related, as eventually all decisions are made by humans within the human activity system.

AN INVENTORY OF DSS AND DST

The Inventory of DSS and DST presented below was compiled by Programs 1 and 4 of the Soil CRC. It includes some DSS and DST designed specifically for soil management, but many others are DSS for a farming enterprise, with a soil component.

The DST inventory was sorted into three categories

1. DST primarily intended for research purposes;
2. DST intended for 'expert' users or those considered to be specialist advisors; and
3. DST primarily intended for Australia's 85,000 farmers to use directly. The latter category is evaluated below.

The main providers of farmer focused DST listed in the inventory included:

- Research and Development Corporations (RDC) e.g.
    - Meat & Livestock Australia - Making More from Sheep (MMfS) and More Beef from Pastures (MBfP)
    - Australian Wool Innovation - MMfS
    - GRDC
    - Dairy Australia
- State Departments of Primary Industries e.g.
    - SoilPak
- Cooperative Research Centres or national research programs e.g.
    - Evergraze
- Private consulting services e.g.
    - Back Paddock

EXAMPLES OF DST FROM THE INVENTORY

There are many DSS and DST listed in the inventory. The following selection indicate typical approaches.

MORE BEEF FROM PASTURES AND MAKING MORE FROM SHEEP (MMFS)

Launched in 2004, the More Beef from Pastures extension program and underpinning decision support system was originally designed by selected groups of experts and farmers employing a Hazard Analysis Critical Control Point (HACCP) methodology (for example, see Ropkins & Beck, 2000) to identify the most important decision making processes for optimising the profitability and sustainability of southern Australian beef cattle enterprises.

The subsequent 'HACCP manual' was presented as an online decision support program with eight modules representing the Critical Control Points. The pasture growth module included soil management. Each module documented the decision making process or 'Standard Operating Procedure (SOP)', the measurements and/or data required, critical limits or 'action thresholds' and corrective actions. The design was such that while the SOP would not require revision, any number of tools or technologies could be employed to make measurements or acquire the required data inputs. The system was purposely designed to provide multiple modes of user interface including online, hard copy manual, supported learning activities and be upgradeable and/or adapted as new technologies or 'best' management practices became available from research and development.

A formal evaluation of the MMfS program was undertaken in 2017 (Wagg and Howard, 2017). The program engaged 20,361 participants in 1,035 activities over the total life of the project, and achieved a Benefit Cost Ratio of 5.6:1. Practice change and adoption extended to 56% of participants of MMfS program events.

A common feature of the RDC programs identified is that they are all maintained as current. All the RDC's programs provide decision support on whole farm enterprise management, with components associated with management of soils being subsidiary. Most were to an extent co-created by researchers, advisors and farmer end-users and are able to be adapted to individual contexts or modified as new technologies or practices arise. To a varying degree all programs comprised tools intended; 1. for ongoing use in a decision making process, or 2. to facilitate learning or 'mastery' of a decision making process by the farmer.

SOILPAK

The original concept of SOILpak™ was prompted by yield declines attributed to soil compaction (Daniells, Larsen, McKenzie, & Anthony, 1996). SOILpak aimed to provide collated and accessible soils information as a module of SIRATAC, a cotton pest management computer program that was to provide management advice to an audience that rarely read scientific literature. The module was to be called 'Compu-Clod'. Following a soil management training program delivered by NSW Agriculture in the late 1980s (Abbott, 1991), feedback from soil advisors revealed that they would prefer to receive the information in a physical, updatable binder with loose leaf pages.

The SOILpak manual originated through researchers in the Macquarie Valley, NSW collaborating with farmers and advisory staff. Experiments and subsequent management recommendations were summarised and these were built on to include findings of experiments in the Namoi Valley. All SOILpaks were based on extensive consultation and collaboration between researchers, extension officers and landholders.

The creation of SOILpak comprised two separate projects: the production of a manual and the development of diagnostic methods. Daniells and Larsen (1991) state that an important

feature of the SOILpak approach was the cooperation between individuals and agencies in providing knowledge and in organising soil management workshops. While a team from NSW Agriculture (now the Department of Primary Industries) wrote the manual, information relevant to the Australian cotton industry came from research and extension officers in Queensland Department of Primary Industries, CSIRO, universities, private consultants and cotton growers. The result was the production of the first SOILpak manual for cotton (Daniells & Larsen, 1991).

The success of the Cotton SOILpak manual provided the impetus for more manuals following the same format but relevant to other cropping systems and other soil types:

- Northern Wheatbelt SOILpak™: A Soil Management package for Dryland Farming in the Summer Rainfall Zone (Daniells & Larsen, 1991)
- Southern Irrigators SOILpak™ (Hughes & Evans, 1999)
- SOILpak™ for Dryland farmers on the Red Soil in Central Western NSW (Anderson, McKenzie, & Friend, 1999)
- SOILpak™ for Vegetable Growers (McMullen, 2000)
- Southern Dryland SOILpak™ (Brown & Green, 2001)

All the publications comprise sections on diagnosis of soil issues (including how to complete a SOILPak description sheet), management options with background information on district specific soil descriptions and problems.

All the SOILpaks, aside from the Cotton SOILpak, are currently out of print and unavailable. The resources to maintain them and keep them current are significant and have not been made available. The demise of the SOILpaks has coincided with a decline in government extension services for agriculture in NSW. The expertise and willingness to allow the significant effort required has not been forthcoming and as a consequence they are no longer supported.

Cotton SOILpak™ is still available. The original Cotton SOILpak manual has been updated regularly and is in its third edition. It has been promoted by Cotton Info, the Australian Cotton Industries' joint extension program and incorporated into a wider best management practice program. It has also had the benefit of one of the original project team, Dr David McKenzie, remaining active in its upkeep. The most recent edition, however, is 20 years old (McKenzie, 1998) and the loose leaf format is outdated. Although the visual assessment procedure has been published in peer reviewed literature (McKenzie, 2001), without further updating, it is likely to also decrease in relevance.

BACK PADDOCK

Back Paddock (http://www.backpaddock.com.au/) is representative of a number of private providers of farm management decision support services which collect data from clients, undertake some form of analysis and recommend management actions for a fee. Some of these services also sell the farm management software through which data is collected

EVALUATION

The inventory of DST demonstrates solid investment from Australian governments and research institutions in decision support, and DST in particular. Review of the inventory shows that many of these are not updated, or are no longer used, and some are no longer even available. Reviews of such systems identify persistent non-adoption and 'dis-adoption' (Donnelly et al., 2002; McCown, Brennan, & Parton, 2006; McCown & Parton, 2006), something also observed in other developed countries (Rose et al., 2016).

RECOMMENDATIONS

The experience of the authors suggests that any DST must be designed from the *user* perspective, not that of the soil scientist, or policy makers, or the short term funding provider. The DST must fit into the long term working environment of the person who is expected to either implement it on-farm or the person who is advising that person on soil management. It must also have a long term plan for its ongoing support and regular review to maintain currency. This is unlikely to be encouraged by having a DST as a stand-alone Milestone requirement of a funded project.

REFERENCES

Abbott, T. S. (1991). Soil management training for advisors to cotton growers. Final report to cotton research and development corporation. Orange: NSW Agriculture.

Anderson, A. N., McKenzie, D. C., & Friend, J. J. (1999). *SOILpak for dryland farmers on the red soil of Central Western NSW*: NSW Agriculture.

Brown, N., & Green, T. (2001). *Southern Dryland SOILpak*: NSW Agriculture.

Daniells, I., & Larsen, D. (1991). SOILpak: a soil management package for cotton production on cracking clays. Narrabri, NSW: NSW Agriculture.

Daniells, I., Larsen, D., McKenzie, D., & Anthony, D. (1996). SOILpak: a successful decision support system for managing the structure of Vertisols under irrigated cotton. *Australian Journal of Soil Research, 34*(6), 879-889.

Donnelly, J. R., Freer, M., Salmon, L., Moore, A. D., Simpson, R. J., Dove, H., & Bolger, T. P. (2002). Evolution of the GRAZPLAN decision support tools and adoption by the grazing industry in temperate Australia. *Agricultural Systems, 74*(1), 115-139.

Hughes, J. D., & Evans, L. H. (1999). *Southern Irrigation SOILpak*: NSW Agriculture.

McKenzie, D. C. (1998). *SOILpak for cotton growers* (3rd ed.). Orange: New South Wales Agriculture.

McKenzie, D. C. (2001). Rapid assessment of soil compaction damage I. The SOILpak score, a semi-quantitative measure of soil structural form. *Australian Journal of Soil Research, 39*(1), 117-125. doi:10.1071/SR99116

McCown, R. L., Brennan, L. E., & Parton, K. A. (2006). Learning from the historical failure of farm management models to aid management practice. Part 1. The rise and demise of theoretical models of farm economics. *Australian Journal of Agricultural Research, 57*, 143-156.

McCown, R. L., & Parton, K. A. (2006). Learning from the historical failure of farm management models to aid management practice. Part 2. Three systems approaches. *Australian Journal of Agricultural Research, 57*, 157-172.

McMullen, B. J. (2000). *SOILpak for vegetable growers*. ?: NSW Agriculture.

Ropkins, K., & Beck, A. J. (2000). Evaluation of worldwide approaches to the use of HACCP to control food safety. *Trends in Food Science & Technology, 11*, 10-21.

Rose, D. C., Sutherland, W. J., Parker, C., Lobley, M., Winter, M., Morris, C., . . . Lynn, V. (2016). Decision support tools for agriculture: Towards effective design and delivery. *Agricultural Systems, 149*, 165-174.

Wagg and Howard (2017). *Development, implementation and evaluation of the project 2005–2016:* Australian Wool Innovation and Meat and Livestock Australia Limited

		Farmer Intended DSS	
Program	**Provider**	**Weblink**	**Brief description**
Making More from Sheep	MLA/AWI	http://www.makingmorefromsheep.com.au/	Whole farm management/planning DSS. Module 5 Natural Assets, 6 Healthy Soils, 7 Grow Pasture directly associated with soil management. Describes decision making procedures. Provides (or refers to) tools available to carry out the procedure/s.
More Beef from Pastures	MLA	https://www.mla.com.au/extension-training-and-tools/more-beef-from-pastures/	Whole farm management/planning DSS. Module 2 Pasture Growth, 3 Pasture Utilisation directly associated with soil management. Describes decision making procedure. Provides (or refers to) tools available to carry out the procedure/s
Resources for Farm	Dairy Aust.	https://www.dairyaustralia.com.au/	Range of tools/calculators refer: Feedbase & Animal Nutrition, Land Water Carbon. Includes: Fert$Smart, DairySAT
SoilWaterApp	GRDC	https://grdc.com.au/resources-and-publications/apps	App to predict soil water
Soils	NSWDPI	https://www.dpi.nsw.gov.au/agriculture/soils	Comprehensive information package specific to soil management but limited to publications.
Evergraze	???	http://www.evergraze.com.au/	May not be accessible now. Contained a range of DST

Ute guide for Vegetable Growers	LWA	http://lwa.gov.au/products/pn22243	Soil management guide in a small spiral bound book specifically targeted at vegetable growers. Developed under the Land and Water Australia Healthy Soils for Sustainable Farms program. May no linger be available. Developed in conjunction with an accredited course for interpreting soil problems.
Salinity Glovebox Guide	NSW DPI	https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0016/312334/salinity-glovebox-guides-order-form.pdf	Three glovebox guides were produced covering much of NSW: Murray and Murrumbidgee catchments; Namoi, Border Rivers and Gwydir Catchments; and Lachlan and Macquarie catchments as part of the NSW Salinity Strategy. These were produced in conjunction with accredited training (see below). The NSW DPI Salinity extension team were also contracted to write a glovebox guide for Tasmania.
SOILpak for vegetable growers	NSW DPI	https://www.dpi.nsw.gov.au/agriculture/horticulture/vegetables/sil-management/soilpak	The last of the SOILpak series, published in 2000. A soil management manual to diagnose and manage soil problems in soils used by vegetable growers.
SOILpak for Cotton Growers	NSW DPI	https://www.dpi.nsw.gov.au/agriculture/soils/guides/soilpak-series/soilpak	SOILpak soil management manual written for farmers growing cotton, mostly for Vertosols. Actively promoted by the cotton industry, this manual is still widely promoted. https://www.cottoninfo.com.au/publications/soilpak. Very well regarded worldwide as a comprehensive soil management manual.
Other SOILpak Manuals.	NSW DPI	N/A	Four other SOILpak manuals were written: SOILpak for Dryland Farmers on the Red Soils of NSW, Northern wheatbelt SOILpak, Southern Dryland SOILpak and

			Southern Irrigated SOILpak. All are 'in hibernation' waiting for resources to update them.
LANDSCAN	NSW DPI	https://www.dpi.nsw.gov.au/content/agriculture/tocal-skills-training/courses/landscan	This course assists farmers and land managers to assess natural resources, to better match land use to land capability and to balance production, profit and sustainability.
Manage Soils - Online	NSW DPI	https://www.dpi.nsw.gov.au/content/agriculture/tocal-skills-training/courses/manage-soils	This course covers how to conduct research about soils, including interpreting soils tests, develop soil improvement programs and undertake soil monitoring and collectively will enable you to document a soil management plan.
eSpade	NSW OEH	http://www.environment.nsw.gov.au/topics/land-and-soil/soil-data/espade	eSPADE is a Google Maps-based information system that allows free, easy access to a wealth of soil and land information from across NSW on both desktop and mobile devices. The data accessible through eSPADE is sourced mainly from the NSW Soil and Land Information System.
Northern rivers Soil health cards	SoilCare and NSW DPI	https://www.soilcare.org/soil-health-card.html	1 generic card followed by development of 5 industry focused card (mostly horticulture) supporting instructional resources; how to video and printed instructions.
Nutri calc	SRA and nat center for engineering in Ag (NCEA)	https://sugarresearch.com.au/wp-content/uploads/2017/02/IS13020-NutriCalc.pdf	Online nutrient management tool for sugarcane for developing nutrient management plans for use on-farm and part of the SRA SIX EASY STEPS nutrient management package.

SIX EASY STEPS nutrient management program in SMARTcane	SRA and QLD DPI	http://elibrary.sugarresearch.com.au/bitstream/handle/11079/16812/CaneConnection%20Winter%2017%20Pg12-13.pdf?sequence=1	Integrated nutrient management tool that enables the adoption of best practice nutrient management on-farm. It consists of: 1. Knowing and understanding your soils. 2. Understanding and managing nutrient process and losses. 3. Regular soil testing. 4. Adopting soil-specific nutrient management guidelines. 5. Checking on the adequacy of nutrient inputs (e.g. leaf analyses). 6. Keeping good records to modify nutrient inputs when and where necessary. Delivered to industry through a grower-orientated short-course entitled 'Accelerating the adoption of best-practice nutrient management.'
Soil Quality	GRDC UWA	http://www.soilquality.org.au/	Allows users to compare data and examine soil relationships which hopefully leads to a greater understanding of the health of soil through Using the tools provided on the website GIS enabled. Uses traffic light symbols to indicate priority for action. not overly well supported nationally
Making better fertiliser decisions for grazed pastures in Aust.	Vic DPI, MLA	http://www.asris.csiro.au/downloads/BFD/Making%20Better%20Fertiliser%20Decisions%20for%20Grazed%20Pastures%20in%20Australia.pdf	Interpretation of soil tests and a method for assessing nutrient loss in grazed pastures. Old published 2007
Soil Matters	APSRU GRDC	https://www.apsim.info/Portals/0/APSoil/Soil%20matters.pdf	Manual says it provides details of basic soil properties and processes and is a comprehensive guide to soils sampling, analysis, synthesis of information and practical application of results. Monitoring soil water and nutrients in dryland farming. A lot of technical info for how to collect and monitor soil characteristics, some

			more technical than others both farmers and advisor readers.
Saltland Genie website	Sustainable Grazing of Saline Lands (SGSL), national program with state depts of Ag & AWI	website is now unavailable	This enormous website was meant to house all the findings from the national SGSL program, research and producer groups. Huge investment, now lost. Yet again, enormous DSS gone to waste. When SGSL funding finished, some $ were allocated to support the website, but looks like it has been allowed to die.

DSS TOOLS AND APPS

DSS/tool.app name	Web link if known	Brief description
Soil water APP	http://soilwaterapp.net.au/	A virtual soil water sensor. basically the how leaky soil water model with a simple UI and a fixed selection of soils
Yield Prophet	https://www.yieldprophet.com.au/yp/Home.aspx	A tool hosted by BCG, uses APSIM for modelling cropping systems. Growers or consultants can design their paddocks. Offered as a fee for service

soilmapp	http://www.csiro.au/en/Research/AF/Areas/Sustainable-farming/Decision-support-tools/SoilMapp	An ioS app to help find out about the likely types of nearby soils. learn about the likely soil types on your property view maps, photographs, satellite images, tables and graphs of data about nearby soils, uncover your soil's physical and chemical characteristics, including acidity (pH), soil carbon, available water storage, salinity and erodibility, get soil information to put into the farm computer model Agricultural Production Systems SIMulator (APSIM), a model that can help with management decisions on crops and project likely crop yields, access the app anywhere there is wireless or internet connection to your iPad.
N fertiliser calculator	http://www.climatekelpie.com.au/manage-climate/decision-support-tools-for-managing-climate/nitrogen-fertiliser-calculator	The Nitrogen Fertiliser Calculator determines the optimum nitrogen fertiliser application for cereal crops, for a range of potential yield outcomes.

Yield and N estimation for dryland cropping	http://www.msfp.org.au/resources/mallee-calculator-2	A tool to calculate yield and nitrogen requirements of cereals and canola
MySoil	https://www.agric.wa.gov.au/mysoil	MySoil summarises thousands of soils into 15 broad soil types.
Deep P calculator	http://www.armonline.com.au/deepp/#!/	Statistical model that deals with the deep soil placement of P on vertisols
ARM online	http://www.armonline.com.au/#/	4 tools available, 3 are relevant, fallow arm, crop arm and nitrogen arm. Essentially the web version of woper cropper
Making Better Fertiliser Decisions (BFDC) for Cropping Systems In Australia	http://www.bfdc.com.au/interrogator/frontpage.vm	Statistical model using datasets of soil fertility experiments. Useful for making N, P, K and S fertiliser decisions
Dairy Nitrogen Fertiliser Advisor Tool	http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/nitrogen-advisor	Statistical based models of pasture N fertiliser response
Fertiliser Calculator	https://www.agric.wa.gov.au/fertiliser-calculator	fertiliser calculator
Mallee N calculator	http://www.msfp.org.au/resources/mallee-calculator-2	fertiliser calculator
Wheat yield constraint calculator	https://www.agric.wa.gov.au/grains-research-development/wheat-yield-constraint-calculator	Based on a modified French and Shultz equation. This tool estimates water-limited yield

		potential to account for soil plant available water capacity (PAWC), stored soil water at sowing and the gross amount of seasonal rainfall
SYN [Select Your Nitrogen]	Available on CD	fertiliser calculator
Acid Cost	https://agex.org.au/project/soil-acidity/	Excel download form this website
Lime cheque	https://agex.org.au/project/soil-acidity/	Excel download form this website
Maintenance lime rate calculator	https://agex.org.au/project/soil-acidity/	Excel download form this website
Mallee Sustainable Farming Nitrogen Management Tool	http://www.msfp.org.au/resources/msf-n-tool	not sure how this is deiferent from the mallee N calculator but apraently it is
Soil Compaction Calculator	https://play.google.com/store/apps/details?id=com.soilcompactioncalculator.android&hl=en	this one is an App
Multi-criteria analysis (MCAS-S)	http://www.agriculture.gov.au/abares/aclump/multi-criteria-analysis	land resource evaluation
Ranking options for soil amendments tool	https://www.agric.wa.gov.au/managing-soils/ranking-options-soil-amendments-tool	Still under development, can get a beta version
Gypsy Program	https://www.jcu.edu.au/college-of-science-and-engineering/academic-groups/environmental-management-old/gypsy-program	Focused on Sugar cane

SAFEGAGAUGE for nutrients for grains and pasture	http://www.proceedings.com.au/extending-safegauge-for-nutrients-to-high-rainfall-cropping-in-australia/ https://www.mssanz.org.au/modsim2015/B4/thayalakumaran.pdf	The tool estimates nutrient loss risks in grain and pasture systems
HowWet	https://www.apsim.info/how/howwet/how%20wet.htm	HowWet? is a computer program which uses farm rainfall records to estimate, How much Rain has been stored as Plant Available Water, how much Nitrogen has been mineralised in soil and how much Erosion was caused by runoff water during the fallow period
SAFEGAGAUGE for nutrients for sugarcane	https://www.researchgate.net/publication/282334491_Safegauge_A_web-based_decision_support_tool_for_informing_nutrient_management_in_the_Queensland_sugar_industry	SafeGauge for Nutrients is a web-based decision support system (DSS) that combines embedded site-specific basic soil data (permeability, drainage, infiltration and erodibility characteristics sourced from soil survey data) and long term rainfall data
Hydrotech	https://www.feedingknowledge.net/home?p_p_id=1_WAR_feeding_knowledgeportlet&p_p_lifecycle=2&p_p_state=pop_up&p_p_mode=view&p_p_cacheability=cacheLevelPage&_1_WAR_feeding_knowl	Hydro-tech is an integrated decision support system for sustainable irrigation management

	edgeportlet_cmd=serveAttachment&_1_WAR_feeding_knowledgeportlet_stepAttachmentId=21093	
Mallee Calculator	http://www.msfp.org.au/resources/mallee-calculator-2	Spreadsheet based DSS by CSIRO for Mallee region to estimate Soil N and yield
CottBase	https://www.cottassist.com.au/CottBASE/Default.aspx	DSS based on OZCOT for cotton to predict various crop outcomes
CottonLOGIC	https://ac.els-cdn.com/S0308521X02000197/1-s2.0-S0308521X02000197-main.pdf?_tid=22f10d88-d943-11e7-a518-00000aab0f6b&acdnat=1512426983_7556481e4213638c2633fde18a562298	cotton management tool
WHEATMAN	http://www.sciencedirect.com/science/article/pii/S0308521X02000185	designed for winter cropping decisions in the northeastern Australian Grains-belt
BP SodiCalc	http://downloads.backpaddock.com.au/tools/BPSodicalcWeb/BPSodicalcWeb.htm	platform to estimate the soil amendment requirement where a soil is found to be dispersive
The P tool	https://www.mla.com.au/extension-training-and-tools/tools-calculators/phosphorus-tool	P fertiliser tool
Tool to help determine soil texture	http://mbfp.mla.com.au/Pasture-growth/Tool-23-Assessing-soil-texture	A simple flow chart tool
FARMSCAPE	http://bob-mccown.com/?page_id=697	simulation models for farmers

Salinity Training Manual	http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/519632/Salinity-training-manual.pdf	Training manual for practical management of salinity. Developed as part of the NSW Salinity Strategy by NSW DPI.
Biophysical Strategic Agricultural Land (NSW)	http://www.planning.nsw.gov.au/Policy-and-Legislation/Mining-and-Resources/Safeguarding-our-Agricultural-Land	Biophysical Strategic agricultural Land (BSAL) developed to identify high quality agricultural land for policy decisions in NSW. All coal and petroleum projects in NSW are required to determine if there is any BSAL through a site verification (http://www.planning.nsw.gov.au/Policy-and-Legislation/Mining-and-Resources/~/media/ED7BE8EE5FC34A71889FE89CF744D846.ashx) as part of the Mining SEPP. Mapped BSAL layer based on
Strategic Cropping Land (Queensland)	https://www.business.qld.gov.au/running-business/support-assistance/mapping-data-imagery/maps/strategic-cropping-land	Similar to BSAL in NSW.
Land and Soil Capability (NSW)	http://www.environment.nsw.gov.au/soils/20120394lsc2spubslandingpage.htm	Mapping of land capability in NSW. Used, particularly by the Office of Environment and Heritage to gauge capability of land vs land use. Spatial map data available at http://data.environment.nsw.gov.au/dataset/land-and-soil-capability-mapping-for-nsw4bc12

SODICS		Drainage and salt leaching tool
LNB	DSS commercialised years ago. Sold with CD and instruction booklet	LNB (Lime and Nutrient Balance) is a computer software package that calculates the lime required to achieve a target soil pH and requirement of nitrogen and phosphorus to achieve target crop yields. The Nutrient budget component of the software is designed to indicate the nutrient-related sustainability of the system through a ten year crop and pasture sequence. Over 400 copies have been sold to farmers, advisers and universities for education. The lime component was based on Limit3 model which is another more soil-acid specific model. There are 13 major soil types are built in Lime3 and LNB.
SIX EASY STEPS nutrient management program in SMARTcane	http://elibrary.sugarresearch.com.au/bitstream/handle/11079/16812/CaneConnection%20Winter%2017%20Pg12-13.pdf?sequence=1	Integrated nutrient management tool that enables the adoption of best practice nutrient management on-farm. It consists of: 1. Knowing and understanding your soils. 2. Understanding and managing nutrient process and losses. 3. Regular soil testing. 4. Adopting soil-specific nutrient management

		guidelines. 5. Checking on the adequacy of nutrient inputs (eg leaf analyses). 6. Keeping good records to modify nutrient inputs when and where necessary. Delivered to industry through a grower-orientated short-course entitled 'Accelerating the adoption of best-practice nutrient management. Integrated into https://www.smartcane.com.au/home.aspx
N Budget	http://www.ini2016.com/pdf-papers/INI2016_Herridge_David2.pdf	The N management package (manual and DS tool) developed during 2010 - 2011. The 87-page manual 'Managing Legume and Fertiliser N for Northern Grains Cropping' published in November 2011. CD Attached to each manual with MS Excel files for 'NBudget' for winter cropping and 'NBudget' for summer cropping. calculator not available online
back paddock SoilMate	http://www.backpaddock.com.au/products/back-paddock-soilmate/	Back Paddock SoilMate deeply integrates the agronomic function into the Back Paddock System, an easy to use farm management tool for production planning at the business, farm, paddock and

		management zone levels. SoilMate includes: Automated Interpretation against benchmark evaluation tables Automated Fertiliser Recommendation Advanced Relational Database structure designed for year-on-year Trend Analysis

MODELS

Model name	Web link if known	Brief description
APSIM	www.apsim.info	Whole farm system model with crop, soil and livestock components. contains a dynamic soil that represent water, carbon and N dynamics, maybe P, limited pH
BiosEquil	Raupach, M.R., Kirby, J.M., Barrett, D.J., Briggs, P.R., 2001a. Balances of Water, Carbon, Nitrogen and Phosphorus in Australian Landscapes: (1) Project Description and Results, CSIRO Land and Water Technical Report 40/01, Canberra.	Mass balances of water, carbon, nitrogen and potassium fluxes

MSM-BIGMOD	Close, A.F., Mamalai, O., Sharma, P., 2004. The River Murray flow and salinity models: MSM-BIGMOD, 1st National Salinity Engineering Conference, 9e12 November 2004, Perth, Western Australia.	Monthly simulation model for daily flow and salinity routing
PERFECT	Littleboy, M., Freebairn, D.M., Hammer, G.L., 1992b. Impact of soil erosion on production in cropping systems, II. Simulation of production and erosion on production in cropping systems, II. Simulation of production and erosion risks for a wheat cropping system. Australian Journal of Soil Research 30, 775e778.	Productivity, erosion and runoff functions to evaluate runoff functions to evaluate conservation techniques
SWAGSIM and SWAGMAN farm	http://www.colyirr.com.au/swagmanfarm/allUser/SwagFarm.asp Prathapar, S.A., Meyer, W.S., Bailey, M.A., Poulton, D.C., 1996. A soil water and groundwater simulation model: SWAGSIM. Environmental Software 11, 151e158. Meyer, W., Prathapar, P., 1992. SWAGMAN: Salt, water and groundwater management.	Soil water and groundwater simulation model

	Agricultural Systems and Information Technology 4 (2), 23e31.	
SCUAF	http://aciar.gov.au/files/node/2278/tr41_pdf_15097.pdf	SCUAf predicts the effects on soils of specific land use systems under given environmental conditions with a focus on agroforestry
SWAT	https://www.ncbi.nlm.nih.gov/pubmed/26616430	models the effect of land on agricultural watersheds
CropSyst	http://modeling.bsyse.wsu.edu/CS_Suite/cropsyst/index.html	Biophysical whole farm system model (Like APSIM)
CENTURY	https://www.nrel.colostate.edu/projects/century/index.php	The CENTURY Model Version 4.0 embodies our best understanding to date of the biogeochemistry of Carbon, Nitrogen, Phosphorus, and Sulphur. The primary purposes of the model are to provide a tool for ecosystem analysis, to test the consistency of data and to evaluate the effects of changes in management and climate on ecosystems. Evolution of the model will continue as our understanding of biogeochemical processes improves.
GRAZPLAN (Grassgro)	http://www.grazplan.csiro.au/?q=node/1	A simple soil model, but includes P cycling, no N. Model needs to be purchased
GRAZPLAN(AusFarm)	http://www.grazplan.csiro.au/?q=node/3	a modelling environment to couple APSIM and GRAZPLAN. It has capability to model nutrient cycle (N,P) and water cycle between rotations systems, and pasture-crop, animal-soil. Model needs to be purchased

HYDRUS	https://www.pc-progress.com/en/Default.aspx	A soil physics simulator, a numerical model (finite element), is used in irrigation, drainage, and soil compaction research. The 1D version of the model is free, 2D version needs to be purchased
HowLeaky	http://www.howleaky.net/	A simple water balance model, as far as I know not numerical. Widely used in QLD for paddock scale research. Suitable for modelling soil water and a simplified N. A good soil erosion simulator (USDLE) and a good model for pesticide fate simulation.
AgroC	Herbst, M., H.J Hellebrand, J. Bauer, J.A. Huisman, J. Simunek, L. Weihermüller, A. Graf, J. Vanderborght, H. Vereecken, 2008. Multiyear heterotrophic soil respiration: evaluation of a coupled CO2 transport and carbon turnover model. Ecological Modelling, 214, 271-283. Bauer, J., L. Weihermüller, J.A. Huisman, M. Herbst, A. Graf, J.M. Sequaris, H. Vereecken, 2012: Inverse determination of soil heterotrophic respiration dependency on temperature and water content under field conditions. Biogeochemistry, 108, 119-134.	a numerical model for simulating the 1-dimensional flux of soil heat, soil water and carbon in agricultural systems. it is an open source and relatively old model

DSSAT	https://dssat.net/	A crop simulation models for over 28 crops. A whole systems model (essentially the US counterpart of APSIM)
HERMES	http://www.zalf.de/de/forschung_lehre/software_downloads/Seiten/default.aspx	A model to describe plant growth and water and nitrogen dynamics in the soil-plant system.
MONICA	http://monica.agrosystem-models.com/en/overview/crop-growth-in-monica	A dynamic, process-based simulation model which describes the transport and bio-chemical turn-over of carbon, nitrogen and water in agro-ecosystems.
SWAP	http://www.swap.alterra.nl/	SWAP simulates transport of water, solutes and heat in the vadose zone in interaction with vegetation development. In principle it is similar to HYDRUS and AgroC
Sol Virtuel	http://www6.inra.fr/vsoil/The-Project	This is a modelling environment (platform) developed by INRA for coupling different models. It is a counterpart of AusFarm (CSIRO) but with more capabilities.
John Thompsons Nematode model	Thompson, J. P. (2015) Modelling population densities of root-lesion nemaotde (Pratylenchus thornei) from soil profile temperatures to choose an optimum sowing date for wheat in a subtropical region. Field Crops Research, 183. pp. 50-55. ISSN 0378-4290	Currently a series of equations in a paper, However is being implemented into APSIM Next Gen by CSIRO

WatBal	http://www.tandfonline.com/doi/abs/10.1080/07900629650041902	Tipping bucket water balance model with Priestley-Taylor method for computing potential evapotranspiration. Freely available
GrowEst	https://dl.acm.org/citation.cfm?id=1235988	Water balance model designed to integrate the major climatic determinants of potential plant growth at broad geographic scales. Freely available
Topog_Yield	https://www.researchgate.net/publication/220274213_Review_of_soil_water_models_and_their_applications_in_Australia	The Topog_Yield model is a transient model of unsaturated-saturated flow and an application module in the Topog modelling framework (Beverly 1992, Vertessy et al. 1993). Freely avalible
WAVES	https://research.csiro.au/software/waves/	WAVES (Dawes and Short 1993, Hatton et al. 1995) is a biophysical model which predicts the dynamic interactions within the soil-vegetation-atmosphere system. Freely available
CLASS	https://toolkit.ewater.org.au/Tools/CLASS-U3M-1D/PublicationDetail.aspx?id=1000045&publicationID=1000043	Catchment scale multiple land use atmosphere soil water and solute transport model (Tuteja et al. 2004). Developed to overcome the limitation of models such as Catsalt.. Accounts for full range of processes that control movement of water, and includes pasture, crop and tree growth modules to simulate ET. Freely available
CERES	http://nowlin.css.msu.edu/wheat_book/	Popular models such as PERFECT and SOILWAT are based on the concept of CERES with respect to soil physical properties.

ALSIS	http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.658.6226&rep=rep1&type=pdf	Atmosphere land surface integration scheme model. Freely available
AWBM	https://wiki.ewater.org.au/display/SD41/Australian+Water+Balance+Model+%28AWBM%29+-+SRG	The Australian Water Balance Model (AWBM) is a catchment water balance model that relates daily rainfall and evapotranspiration to runoff, and calculates losses from rainfall for flood hydrograph modelling. The model contains five stores; three surface stores to simulate partial areas of runoff, a base flow store and a surface runoff routing store. Freely available
Pride	https://wiki.ewater.org.au/display/SD41/PRIDE+Demand+model+-+SRG	Program for Regional Irrigation Demand Estimation (PRIDE) is a crop demand model that uses a combination of climate data, crop culture information and knowledge of traditional farming practices to estimate irrigation demands. PRIDE has traditionally been used to estimate private diverter and irrigation area demands across Victoria for use in REALM and has been incorporated into Source within the water user node. Freely available
BASINMAN	https://www.researchgate.net/publication/242512283_BASINMAN_-_A_WATER_BALANCE_MODEL_FOR_FARMS_WITH_SUBSURFACE_PIPE_DRAINAGE_AND_AN_ON-FARM_BASIN	Multilayer soil water balance model. Useful to measure the hydraulic relationship between farmed areas and on-farm basins, and useful to avoid farm waterlogging issues. Freely available
Catsalt	https://www.google.com.au/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUK	Spatial soil water balance model, freely available.

	EwiS96HBzfHXAhUGUbwKHVUhCx4QFggxMAE&url=http%3A%2F%2Fciteseerx.ist.psu.edu%2Fviewdoc%2Fdownload%3Fdoi%3D10.1.1.565.1387%26rep%3Drep1%26type%3Dpdf&usg=AOvVaw1q-sQVB-74F2nbahKx2FO6	
BIOEVOLVE	https://www.researchgate.net/publication/220274213_Review_of_soil_water_models_and_their_applications_in_Australia	Multilayer soil water balance model. Freely available
IQQM	https://toolkit.ewater.org.au/Tools/PublicationDetail.aspx?id=1000000&publicationID=1000049	IQQM is designed to provide more reliable information relating to issues such as environmental flows and water quality than was possible with the monthly simulation models which have been used for water resource management planning studies
Century Model	https://www2.nrel.colostate.edu/projects/century/MANUAL/html_manual/man96.html	The CENTURY Model Version 4.0 embodies our best understanding to date of the biogeochemistry of Carbon, Nitrogen, Phosphorus, and Sulphur. The primary purposes of the model are to provide a tool for ecosystem analysis, to test the consistency of data and to evaluate the effects of changes in management and climate on ecosystems. Evolution of the model will continue as our understanding of biogeochemical processes improves.
DairyMod, PlantMod, SGS	http://imj.com.au/dairymod/	Whole farm systems models comprising submodels Carbon, plant, Soil Water, Nitrogen, OM etc... Model structure is well described.

Response Inducing Sustainability Evaluation (RISE)	RISE – getting sustainability down to earth https://www.hafl.bfh.ch/en/research-consulting-services/agricultural-science/sustainability-and-ecosystems/sustainability-assessment/rise.html	RISE is a computer-supported method developed at HAFL, which facilitates a holistic assessment of agricultural operations. The evaluation is based on ten indicators that reflect environmental, economic and social aspects. The most important data source is a questionnaire-based interview with the farmer. The evaluated data are visualized as a sustainability polygon and serve as a basis to a feedback dialogue in which the farmer and the trained RISE consultant jointly identify potentials for improving farm sustainability performance.
Integrated risk assessment toolkit	Saravanamuthu, K. and Lehman, C. 2013. Enhancing stakeholder participation through risk discourse. Critical Perspectives on Accounting 24: 410-37.	Uses semi-qualitative risk to integrate the multiple indicators of a degraded site (or conversely, indicators to facilitate sustainability via adaptive or mitigation strategies)
WNMM model	Computer codes and software available	The processes simulated by WNMM include: water dynamics (soil evaporation, crop interception and transpiration, infiltration and redistribution, crop water uptake, and percolation below the root zone); water table fluctuation; soil temperature; C and N cycling in soil and crop (decomposition, mineralisation/immobilisation, nitrification, denitrification, NH3 volatilisation, crop uptake and residue return, input from precipitation and irrigation, and leaching below the root zone); crop growth (radiation interception, development of dry matter and leaf area index, harvest index, and stresses due to soil water and N shortages and temperature) and agricultural

		management practices (crop rotation, fertiliser application, irrigation, and cultivation).

AUTHORS

David Falepau

Keith Pembleton

Peter Dahlhaus