# Farm4Prophet: 2. Assessing environmental risk of changes to farm management

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## Abstract
Farm4Prophet is a web-based, whole-farm business management tool. It offers the capability to assess potential financial and environmental impacts of changes to farm management on mixed crop-livestock enterprises. Long term crop, pasture and livestock production are simulated using AusFarm to provide estimates of production, cashflow, financial risk and sustainability. These outputs can be used by farmers and their advisors to make decisions about the structure of their enterprise. This paper focuses on the environmental and natural resource management (NRM) impacts of changes to farm management.

## Keywords
Whole farm modelling, environmental impacts, decision support tools.

## Introduction
With continually rising production costs, plateauing yields, and exposure to financial shocks brought about by a highly variable climate, farm managers are seeking efficient access to new information to help increase their profitability and reduce their exposure to risk. Managing seasonal climate variability requires tactical management one season at a time, as well as the right strategic mix of crops, pastures and livestock to match longer term climate and market variability. Long-term consequences of management strategies on the natural environment also need to be considered. An understanding of how changes to management practices impact both financial and NRM risk will better enable farmers to select sustainable long-term management options for their businesses.

Farm4Prophet (www.farm4prophet.com.au) is a new web-based decision support tool that builds on the Yield Prophet (Hochman et al. 2009) concept of using simulation modelling to test and evaluate farm management decisions. Farm4Prophet allows users to assess financial and environmental risks associated with strategic changes to farming enterprises. This paper focuses on the NRM impacts of changes to farm management, while financial risks are discussed in Part 1 in van Rees et al. (2017).

## Model description
Farm4Prophet comprises a web-based user interface linked to a whole-farm model embodied in the AusFarm software package. AusFarm integrates the GrazPlan animal model (Freer et al. 1997) with the APSIM soil and cropping models (Holzworth et al. 2014) to simulate mixed farming systems in temperate southern Australia. In Farm4Prophet, crop, pasture and sheep production are modelled using the most recent 30 years of local climate data, farm-specific soil and enterprise (crops and livestock) information, and current financial data. Users set up a baseline simulation that matches their current situation, and can test the following scenarios to investigate potential impacts on farm financial risk, cashflow and sustainability:

- Changing enterprise mix (e.g. changing crop rotations, more or less livestock)
- Buying, selling or leasing land
- Changing starting financial position (as might follow a drought or series of profitable years)
- Changing interest rates

Additional scenarios and the capability to model a wider range of farming systems will be added as the tool is developed. The environmental assessment capability of Farm4Prophet includes modelling the potential impacts of farm management changes on the following sustainability indicators:

- Secondary salinity: Deep drainage beyond the root zone (mm/ha/year)
- Nitrate leaching: Nitrate leached beyond the root zone (kg/ha/year)
- Wind erosion potential: Ground cover (%) during February 1 to April 30
- Soil Organic Carbon status: Change in soil organic carbon (kg C/ha/year)

- Greenhouse warming potential (GWP): Global warming potential calculated from on-farm methane and nitrous oxide emissions (kg $CO_2$-equivalents/ha/year).

The impacts are presented using sustainability polygons (Hochman et al. 2017) alongside modelled values for each parameter, which provides an integrated graphic representation of multiple sustainability indicators. The polygons are designed to provide a holistic visual summary of the environmental risk of enterprise changes. Each sustainability indicator is represented by a relative value from 0 to 1, where 1 is the most desirable outcome (e.g. lowest global warming potential). For desirable attributes (soil organic carbon, ground cover) the relative sustainability value is calculated as the value of the strategic management option being considered divided by the highest value (baseline or scenario). For example: baseline ground cover for a farm is 65 %. In a scenario with changed crop-pasture rotations, it is reduced to 60 %. The sustainability value of the baseline (65/65) is 1.0, and the sustainability value of the scenario (60/65) is 0.92. For an undesirable attribute (secondary salinity, nitrate leaching, GWP) the minimum value (baseline or scenario) is divided by the value of the strategic management option. Using the same example, if nitrate leaching is reduced from 3 kg/ha/year (baseline) to 2 kg/ha/year (scenario), the relative sustainability values of the baseline (2/3) and scenario (2/2) are 0.67 and 1.0, respectively.

## Methods

*Case study farm*

Application of the NRM outputs of the Farm4Prophet tool is illustrated for a case-study farm in the southern Victorian Mallee. The baseline farming system is comprised of 3 soil types, allocated to different crop-pasture rotations (Table 1). Approximately 60 % of the land is allocated to cropping, and 40 % to the livestock enterprise.

**Table 1. Summary of soil types and crop-pasture rotations in case study farm and two modelled scenarios. B: barley, C: canola, F: fieldpea, L: lentil, M: medic, W: wheat.**

| Soil type | Max rooting depth (cm) | Area (ha) | Crop/pasture rotation | | |
|---|---|---|---|---|---|
| | | | Baseline | Scenario 1 – reduced livestock | Scenario 2 – crop only |
| Sandy clay loam 1 | 120 | 1160 | C, W, W, B, L | C, W, W, B, L | C, W, W, B, L |
| Sandy clay loam 2 | 80 | 2235 | W, W, B, M, M | W, W, L, B, F | W, W, L, B, F |
| Clay loam | 60 | 1727 | M, M, M, W, B | M, M, M, W, B | W, W, B, L |

Farm4Prophet applies general sowing rules based on the location of the farm to be modelled. Rules for the farm (southern low rainfall zone) are described in Table 2. Crops are sown within a specified sowing window based on rainfall, and are sown on the final day of the window if suitable conditions have not previously been met. A maximum amount of fertiliser N is specified by Farm4Prophet users and applied to cereals and canola up to two times during the growing season. The amount of N applied at sowing is based on available soil $NO_3$. If less than 50 ppm $NO_3$ is available, 30 kg of N is applied. If there is more than 50 ppm $NO_3$ available, only 10 kg N is applied. Topdressing occurs between zadok stages 30 and 37. If there is more than 50 mm plant available water present during this period, the remaining N is applied. For our example farm, a maximum of 40 kg of N is applied to crops on sandy clay loam soils, and 30 kg N on the clay loam soil.

**Table 2. Sowing rules applied to crops in southern low rainfall zone**

| Crop type | APSIM crop cultivar | Sowing window | Density (plants/m$^2$) | Sowing depth (mm) | Row spacing (mm) |
|---|---|---|---|---|---|
| Barley | Buloke | 15 Apr – 31 May | 150 | 30 | 250 |
| Canola | Mid | 1 Apr – 15 May | 50 | 20 | 250 |
| Fieldpea | Kaspa | 15 Apr – 30 May | 40 | 30 | 250 |
| Lentil[A] | Amethyst | 15 Apr – 30 May | 120 | 30 | 600 |
| Wheat | Derrimut | 15 Apr – 31 May | 150 | 30 | 250 |

[A] The lentil module was not available in AusFarm so chickpea was substituted.

The livestock operation is a self-replacing merino flock with approximately 2,800 breeding ewes. The ewes and lambs graze medic pastures over autumn/winter and crop stubbles over summer/autumn. The flock is supplemented with barley grain when simulated body weight and condition reaches a critical level.

*Scenario – changing enterprise mix*
Two changes to the enterprise mix are simulated: (1) reduced livestock and (2) crop-only. For the first scenario (reduced livestock), the livestock portion of the enterprise is reduced by replacing the medic pasture on sandy clay loam 2 with lentils and fieldpeas (new rotation: wheat, wheat, lentil, barley, fieldpea) (Table 1). The number of sheep was reduced automatically by Farm4Prophet to maintain the stocking rate. In the second scenario (crop-only), livestock and pastures are completely removed from the enterprise. In addition to the rotation changes made in the first scenario, the rotation for clay loam is changed to wheat, wheat, barley, lentils.

## Results

Reducing and then eliminating livestock from the enterprise was associated with higher secondary salinity, nitrate leaching and wind erosion potential. However, there was also an improvement in soil organic carbon and a reduction in global warming potential. The Farm4Prophet sustainability polygons (Figure 1) illustrate the relative changes in environmental impacts of these scenarios.

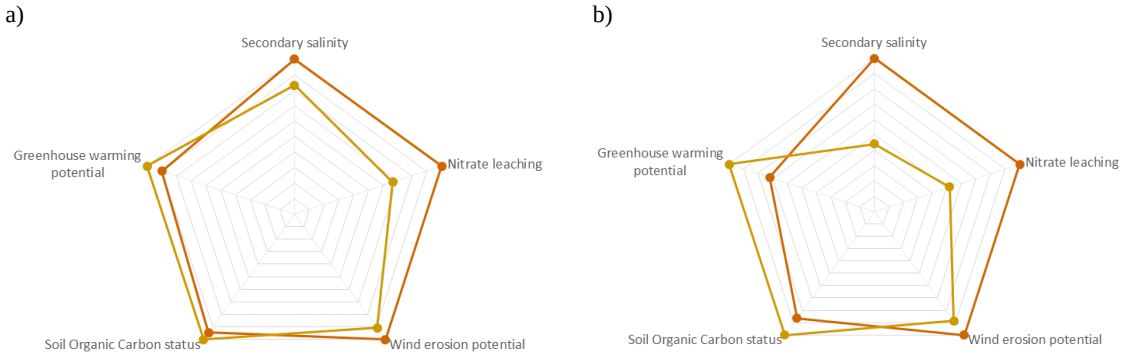


**Figure 1. Comparison of modelled environmental impacts for baseline mixed crop-livestock enterprise (orange) compared to changed management scenarios (yellow). The scenarios are (a) reduced livestock and (b) crop-only. Points closest to the outside of the graph represent the most environmentally desirable outcomes.**

Secondary salinity (deep drainage) was increased from 7.4 (baseline) to 8.9 (reduced livestock) and 16.8 (crop only) mm/ha/year. Nitrate leaching increased from 1.4 to 2.1 and 2.7 kg/ha/year for reduced livestock and crop-only scenarios, respectively. Soil organic carbon increased from 35 to 37 and 41 kg/ha/year for the reduced livestock and crop-only scenarios, while GWP was reduced from 682 to 614 and 491 kg $CO_2$-equivalents/ha/year. Ground cover was reduced from 65 % to 59 % and 57 % in the reduced livestock and crop-only scenarios.

## Discussion

The Farm4Prophet tool is a simple way for farmers to investigate potential financial and environmental risks of changes to farm management. While profit and financial risk may be the main drivers of strategic changes to farm management, NRM is important for the long-term sustainability of an enterprise. In Farm4Prophet, sustainability polygons are used to visually compare NRM outcomes and easily identify the most sustainable management scenario. Modelled values of environmental parameters are also presented, so farmers and their advisors can consider the likely impacts for their farm and the level of risk they are prepared to accept. Results can also be used to highlight NRM issues within the current enterprise setup.

In the example farm used for this paper, reducing the proportion of livestock in the enterprise resulted in some negative NRM outcomes. Nitrate leaching and secondary salinity both increased with increased cropping on the farm. However, further changes to farm management (e.g. fertiliser application, use of perennial pastures) could reduce these impacts. In the reduced livestock scenario, the farmer may consider that the increases in nitrate leaching and deep draining are offset by improvements in soil organic carbon status and GWP.

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