THE IRAP PROJECT: PREDICTIVE FARM- AND REGIONAL-SCALE TOOLS FOR ASSESSING LAND USE IMPACTS ON GROUNDWATER QUALITY

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Introduction

Nitrate in groundwater is a major environmental contaminant internationally. In New Zealand, regulatory authorities (regional councils), vested with responsibility to maintain environmental quality, have found increasing nitrate levels in groundwater and surface water, some of which exceed the acceptable drinking standard (11.3 mg/L NO_3-N) (Smith, 1993, Selvarajah et al., 1994, Ford and Taylor, 2006). It is believed that increases in nitrate are mainly related to non-point contamination from agricultural land uses (Burden, 1982). Research is therefore being undertaken to determine risks of groundwater pollution from agriculture, and to provide a rationale for targeting land-use change to minimise contamination effects on groundwater.

This paper introduces a collaborative research programme (IRAP) aimed at developing tools to understand and model the effects of agricultural land use on aquifer quality on the alluvial plains of New Zealand. The programme brings together research on farm management, agronomy and soil processes together with research on water and contaminant processes in the vadose zone and aquifer.

What is IRAP?

IRAP – Integrated Research for Aquifer Protection – is a collaborative research project with the primary aim of producing nationally applicable tools to predict the cumulative effects of changes in land use on groundwater quality at the aquifer scale and the consequent effect on surface waters. In particular, the research will focus on understanding and modelling the transport of nitrate from agricultural land uses to groundwater on the alluvial plains of New Zealand. Key questions that the resulting tools will answer are:

- How do nutrients from existing land use move through the soil to the aquifer and then through the aquifer system?
- What impact will land-use changes have on the quality of groundwater in the future?
- Will using best-practice farm management techniques be enough to maintain acceptable groundwater quality?

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The organisations collaborating in IRAP are Crop & Food Research, AgResearch, Dexcel, Landcare Research, ESR, Lincoln Ventures, Aqualinc, Environment Canterbury and Environment Waikato. The contributions by the science providers are primarily funded by the New Zealand Foundation for Research, Science and Technology.

Experimental work

IRAP includes some basic experimental research on nitrate movement in the root zone, and on vadose and aquifer properties. The results from this experimental work will be incorporated into the IRAP software outputs. Some of this experimental research is presented in these proceedings: two studies into the behaviour of the vadose zone at Lake Taupo (Stenger et al., 2006) and in Canterbury (Close et al., 2006), and the results of a study into how fertiliser and irrigation applications impact on nitrate leaching from a crop rotation (Francis et al., 2006). Also in these proceedings is a simulation study aimed at quantifying the effects of within-paddock variability on predictions of nitrate leaching (Lilburne et al., 2006).

The IRAP tools

The major output of IRAP is a set of software modules that form the building blocks of two end-user tools: FarmSim and AquiferSim. Figure 1 shows the range of environmental domains and scales that will be integrated, and the relationship between FarmSim and AquiferSim.

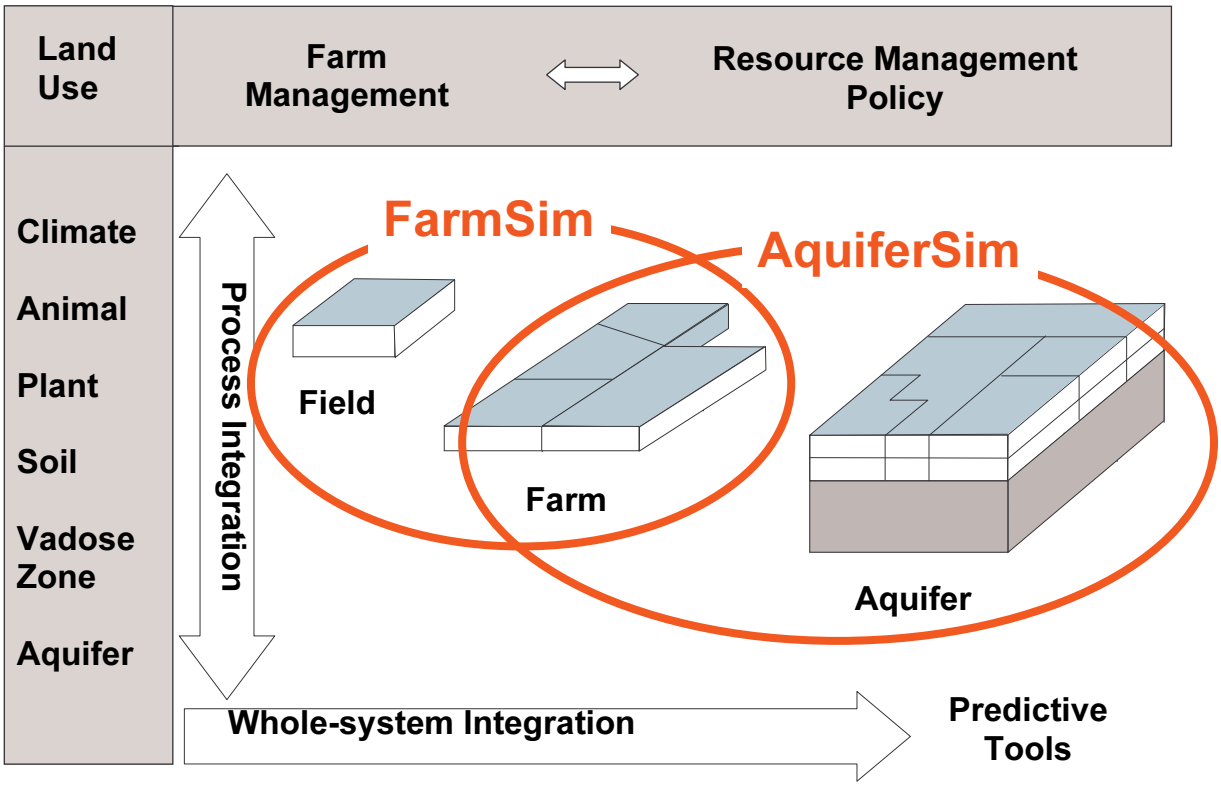

Fig. 1 Conceptual diagram of integration within IRAP.

The purpose of FarmSim is to simulate nitrogen dynamics at a farm scale for cropping and pastoral (sheep, beef and dairy) farms under differing management regimes in a manner that reflects the unique conditions of each individual paddock within the farm. FarmSim includes modules for soil-water movement, nitrogen cycling, plant growth, irrigation, fertiliser application, crop rotation, stock management, and an end-user interface (Fig. 2). Simulations

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are conducted at individual paddock (field) scale (taking into account farm constraints) and aggregated to the whole farm, providing time-series estimates of drainage fluxes and nitrate concentration leached from each farm. The design of FarmSim is described by Good & Bright (2005). One of the papers at this conference describes the arable plant module (Zyskowski et al., 2006).

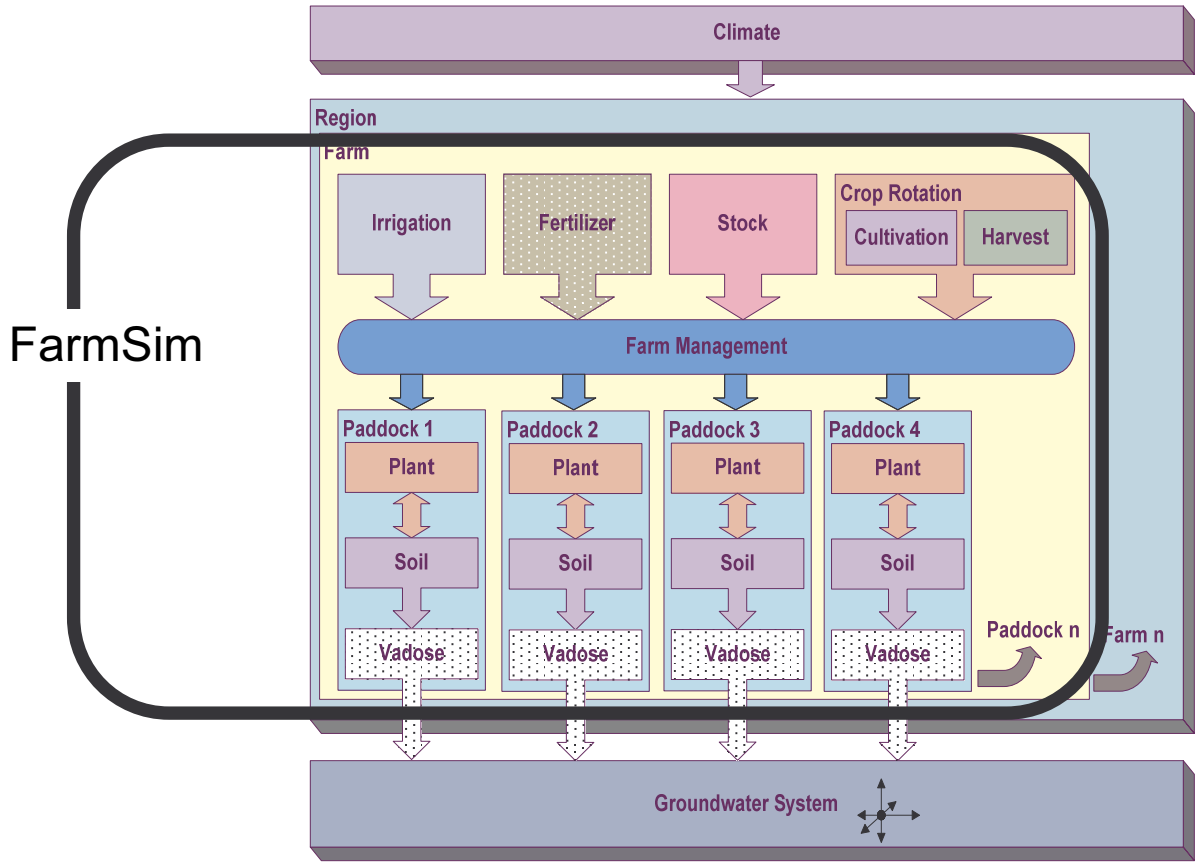

Fig. 2 FarmSim model structure and interactions.

The AquiferSim tool integrates the effects of the nitrate-contaminated drainage estimates from FarmSim, and provides information about the resulting horizontal and vertical distribution of nitrate in the aquifer. It comprises: a GIS to manage the various data layers; annual farm-scale drainage and nitrate flux data from FarmSim; an end-user interface for the user to define *what-if* catchment-scale scenarios and to view model output; and mathematical groundwater models to derive the piezometric surface, calculate the flowpath of the contaminant, and simulate transport within the aquifer. The design of AquiferSim is described by Bidwell et al. (2005). Figure 3 illustrates the conceptual design of AquiferSim, where GIS layers provide information on aquifer properties, and on nitrate concentration and drainage recharge from the base of the soil profile. The aquifer properties are derived from data from boreholes, groundwater modelling, and expert knowledge. Farm types are grouped according to farm management practices affecting nitrate leaching. The farm-type layer may be based either on current-land-use information or represents a hypothetical land-use scenario generated by the end-user.

Nitrate leaching under the various combinations of farm types, soils, and climate is simulated in FarmSim, and the results recorded in a look-up table. The GIS accesses this table to 'map'

the nitrate concentration and drainage recharge for each location for any target region. The GIS data are then input into the groundwater engine, which calculates the 2-D flowpath through the location of interest, and simulates nitrate transport along the flowpath. The output is a graph of nitrate concentration by depth along the flowpath (Fig. 3).

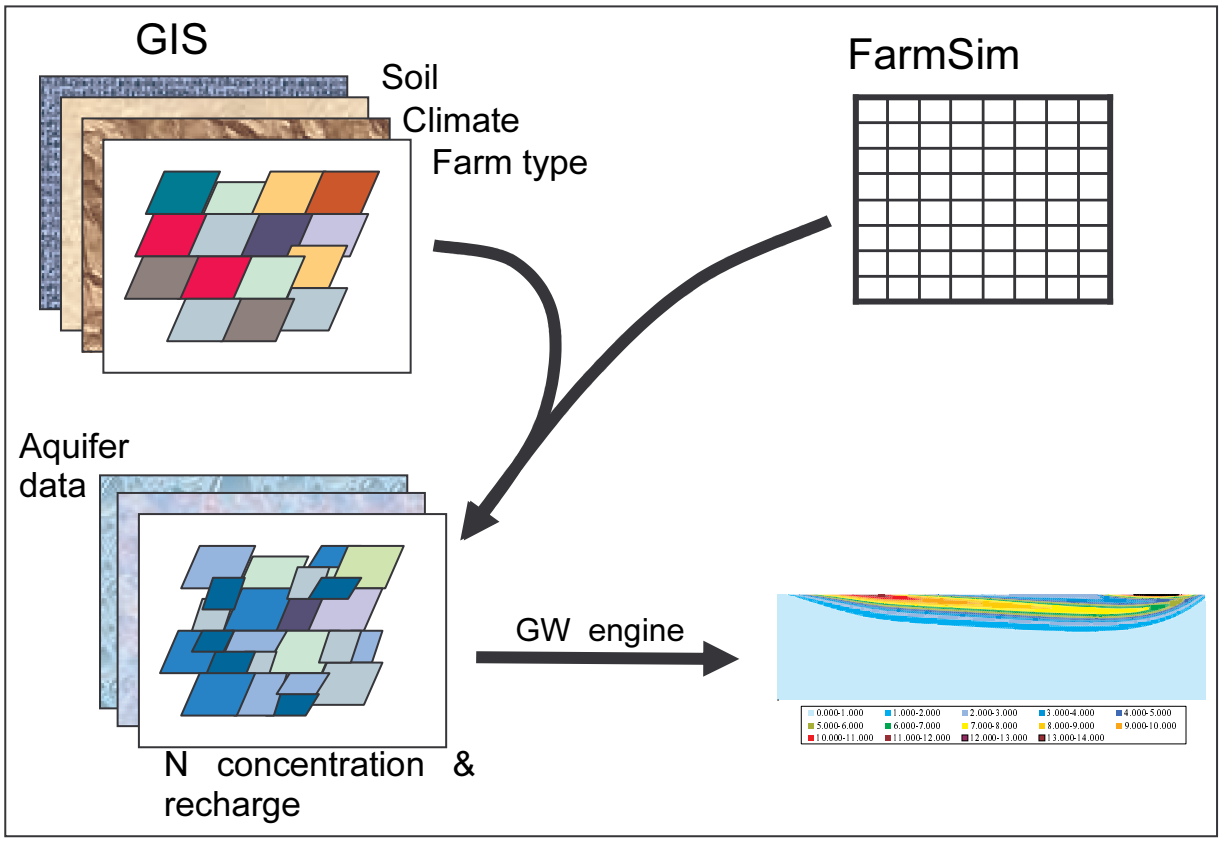

Fig. 3 Conceptual design of AquiferSim.

Work on these tools is underway. End-users of FarmSim will include land managers wanting to assess their environmental performance. End-users of AquiferSim will primarily be regional council staff including policy analysts, planners, and ground water scientists. A formal end-user advisory group of representatives of relevant industry groups and government organisations has been set up to advise the development team, as well as an informal group of regional council staff. Further information on IRAP can be obtained from www.irap.org.nz.

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