Identifying deep drainage risk areas in the lower Gwydir

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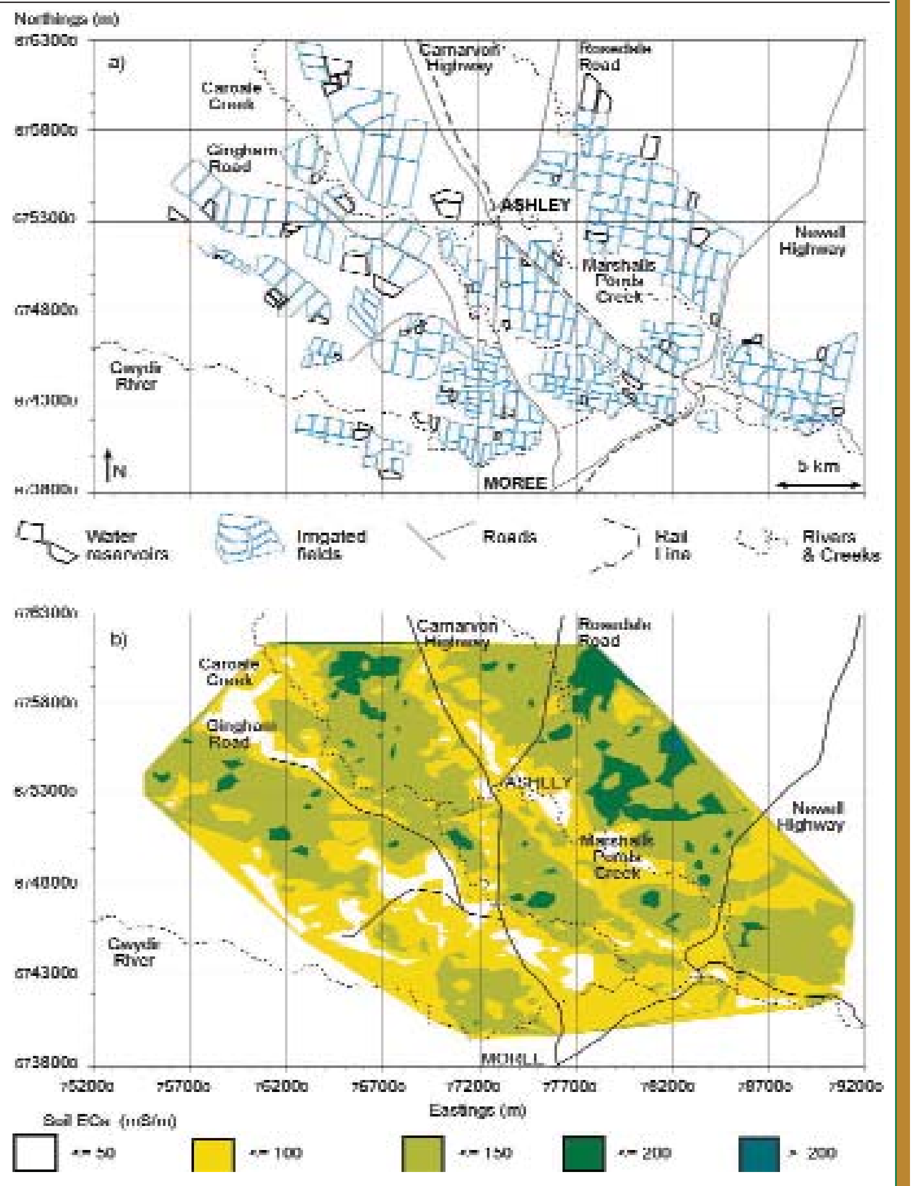
It has been suggested that one third of global food and fibre is produced by irrigation agriculture and this will rise by 50 per cent in 2040. Good management of the irrigated land is therefore an important factor in ensuring sustainable production.

But in the Murray-Darling Basin, inefficient irrigation practices have resulted in the creation of perched water tables, waterlogging, rising water tables and salt mobilisation.

A common cause of these problems is deep drainage (DD) — defined as water passing through the root zone into water tables. With the increasing pressures on water resources and expectations from the community regarding natural resource management, it is important to identify where DD occurs and show where improvements can be made in water delivery and application.

This article describes methods to estimate DD risk areas for irrigated fields, conveyance and storage structures in the irrigated-cotton growing area around Ashley in the lower Gwydir valley of northern NSW (see Figure 1a).

FIGURE 1: a) Irrigated infrastructure; and, b) Contour plot of ECa (mS/m) in the Ashley Irrigation District



ESTIMATING DEEP DRAINAGE

The Salt and Leaching Fraction (SaLF) model, developed by the Queensland Department of Natural Resources, can provide DD estimates from soil sample data (such as clay content and cation exchange capacity — CEC). But large numbers of soil samples are required for acceptable precision. And soil sampling and laboratory analysis are expensive and time consuming.

Electromagnetic (EM) induction instruments have been used extensively for the measurement of soil attributes that are related to DD. EM instruments measure bulk soil electrical conductivity (ECa), which is related to soil moisture, clay content, mineralogy and salinity.

ECa measurements can be used to estimate DD if they are calibrated against estimates of DD obtained (using the SaLF program) from soil samples.

DATA COLLECTION

An EM38 survey was carried out in the Ashley district. This instrument was used because it measures ECa within the agriculturally significant portion of the root zone (1.5 metres). A grid spacing of 500 metres was used. In all, 1510 EM38 measurements were made across an area of approximately 55,000 hectares.

To complement the EM survey, soil samples were collected at 105 sites. At each site an EM38 measurement along with a soil core were recovered and sampled for laboratory analysis at depths of:

- 0.0 to 0.3 metres;
- 0.3 to 0.6 metres;
- 0.6 to 0.9 metres; and,
- 0.9 to 1.2 metres.

As required by the SaLF program, clay content and exchangeable cation capacity were determined at each depth. Water

20 ▷

◁ 19…GWYDIR DEEP DRAINAGE

samples were also collected from the Gwydir River. The ECw value for the Gwydir River (determined to be 0.4 dS/m) and Moree's mean annual rainfall were also required by the SaLF program.

Four irrigation (I) simulations (300; 600; 1200 and 1800 mm per annum) were carried out using the SaLF program. The various scenarios were undertaken to simulate a wide range of possible DD conditions at each of the 105 soil sampling sites.

For example, 600 and 1200 mm were used to simulate the DD characteristics of soil profiles in an irrigated cotton field and beneath a head ditch or shallow supply channel. Likewise, 1800 mm of applied water was used to simulate the DD anticipated in a shallow water reservoir.

CONDUCTIVITY (ECa) MAPS

Figure 1b shows the distribution of ECa across the Ashley district. The low values of ECa (white and yellow shaded areas) are associated with red-brown earths and deep sandy soils and the various streams that pass through the district. This is particularly the case with Marshalls Ponds and Caroale Creeks.

The higher values of ECa (light and dark green shaded areas) are mostly self-mulching clay plains. Most fields developed for irrigation are located on this soil type.

Some storages have been sited in unsuitable areas.

ECa VERSUS ESTIMATED DD

The deep drainage estimates from the 105 soil sampling sites showed a good correlation with the ECa measurements. Low values of ECa (below 100 mS/m) epitomise coarse textured soil profiles where DD is high (over 50 mm per annum).

Conversely, higher ECa values represent profiles with DD below 50 mm per annum and relate to the clay plains.

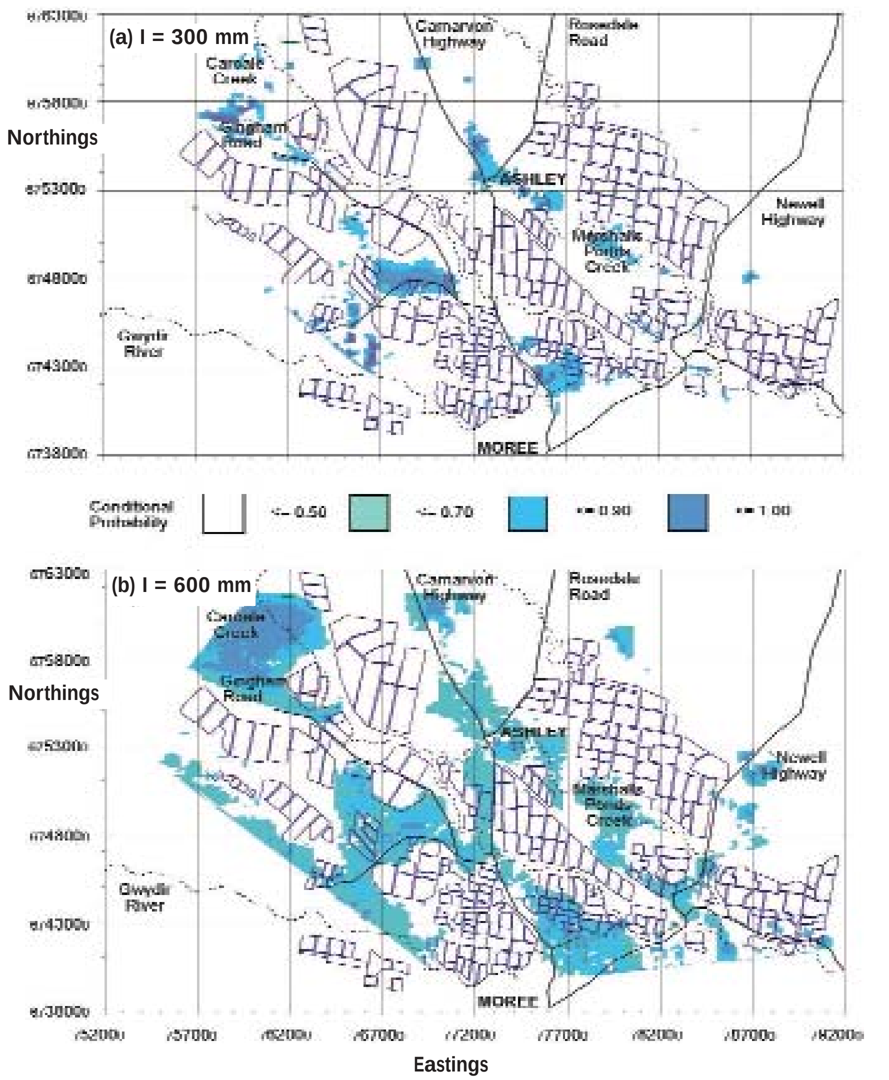
The estimates of DD are consistent with results reported in the November–December 1999 issue of *The Australian Cottongrower* — titled "Estimating deep drainage at the field level."

RISK MAPS

From the relationship between ECa and deep drainage found at the soil sampling sites, the ECa measurements were used to estimate DD at each of the 1510 EM survey points. But rather than produce maps of DD (mm per annum) a more revealing map is one which shows where DD may be significant — and a potential problem.

In the case of the two irrigated cotton simulations (I = 300 and 600 mm per annum) a value of 50 mm per annum indi-

FIGURE 2: Map of conditional probability (CP) that soil at a particular site will exceed an estimated deep drainage (DD) value of 50 mm/annum if a) 300, and b) 600 mm of irrigation water was applied



cates soil which is coarser textured and more permeable. These are the types of profiles we want to identify as areas where there is a high risk of DD.

To produce this kind of map, the 1510 estimates of DD were used to produce maps of conditional probability (CP) that DD exceeds a critical cut-off value.

The closer to 1, the higher the probability that this critical value of DD would be exceeded and therefore the more permeable the soil is likely to be.

The map in Figure 2a shows the CP of DD exceeding 50 mm per annum if 300 mm per annum of irrigation water was applied. The white area indicates where the CP is low (below 0.5) — where DD is least expected to be above 50 mm per annum. The dark blue shaded area indicates where the CP is greater than 0.9 and shows where DD is most likely to exceed 50 mm per annum.

All irrigated cotton-growing fields are located in areas of low CP. The areas where DD is most likely to exceed 50 mm per annum are associated with Marshalls Ponds Creek, Caroale Creek and the Gwydir River. The results suggest that crops requiring low water volumes or more efficient methods of irrigation (trickle or sprinkler) may be the best options in these areas.

Figure 2b shows the map of CP that DD at a particular site will exceed 50 mm per annum if irrigation of 600 mm per annum was applied. This is equivalent to six megalitres of applied water per hectare.

Again, most irrigated cotton fields are located where the CP is low (less than 0.5). And the higher risk areas (CP over 0.5) are associated with the current stream channels of Marshalls Ponds Creek, a prior stream channel located south of and in parallel with the present day Caroale Creek, and the area to the northeast of Moree associated with the Gwydir River.

In terms of areas that could be considered for future irrigated cotton development, northeast of the Carnarvon Highway seems to be the most suitable location.

LOCATION OF INFRASTRUCTURE

Figure 3a shows the CP associated with the location of infrastructure such as shallow supply channels or head ditches (1200 mm of free standing water). Interestingly, many of the irrigated fields located north of Moree coincide with areas with high risk of DD beneath supply channels and head ditches. But the fields in this part of the district are generally smaller, have shorter irrigation runs and their designs have taken the more permeable soil types into consideration.

The final simulation carried out (I = 1800 mm) indicates the most unsuitable areas to locate a main supply channel and/or shallow earthen water storage. The CP map shown in Figure 3b, indicates CP for a cut-off DD value of 100. Here, three areas stand out as being most suitable.

But it is also evident that some storages are located in areas where water loss may be high and so efficiency in water storage and delivery may need to be improved. This is particularly the case in the area north and south of the Gingham Road.

It is worth noting that of the storages located here, two are known to experience some problems with leakage. One is a dual-cell storage located in the centre of the study area. The southern cell is located predominantly in the moderate risk zone ($0.5 \leq CP < 0.7$), while the northern cell lies exclusively in the moderate to high-risk area ($0.7 \leq CP < 0.9$). The northern cell is known to experience waterlogged soil conditions around the perimeter, suggesting the simulation carried out is consistent with the farmer's experiences.

The same is the case with the second storage which is only used as a reservoir for holding water that falls on-farm during heavy rainfall events and it is no longer used as a major storage because of the leakage problems.

Management on this farm has constructed several smaller reservoirs in more suitable locations. This has abated waterlogging and led to increases in water use efficiency.

Interestingly, an adjacent reservoir is not perceived to have the same problem, even though the simulation suggested the CP was similarly high.

22 ▷

CONCLUSIONS

The use of CP maps identified those areas where irrigation inefficiencies were likely to occur in the Ashley irrigation district. The areas with the highest risk of excessive DD correspond with the coarser sediments and more permeable soil types. But some caution is required when considering the maps produced.

Firstly, and although the measurements were made soon after a heavy rainfall event, the measurements of ECa were made at the height of summer and across dryland and irrigated fields. There may be some issues associated with differences in ECa measurements obtained under variable soil moisture conditions. In addition, errors may be associated with the estimate because of the ECa sampling interval used.

INDUSTRY SIGNIFICANCE

Nevertheless, the CP maps of DD risk do provide a strategic approach that can be implemented at the district scale when considering options to improve irrigation efficiency and suitability of a given site for locating irrigated fields, supply channels and water storages.

For example, at the district scale, the loss of water from storage or conveyance structures could be reduced by carrying out more detailed investigations to identify where they could be repositioned to areas exhibiting low risks of excessive DD. The maps could also identify areas of structures where improvements could be made (such as recompaction or reinforcement of the structure with geomembranes).

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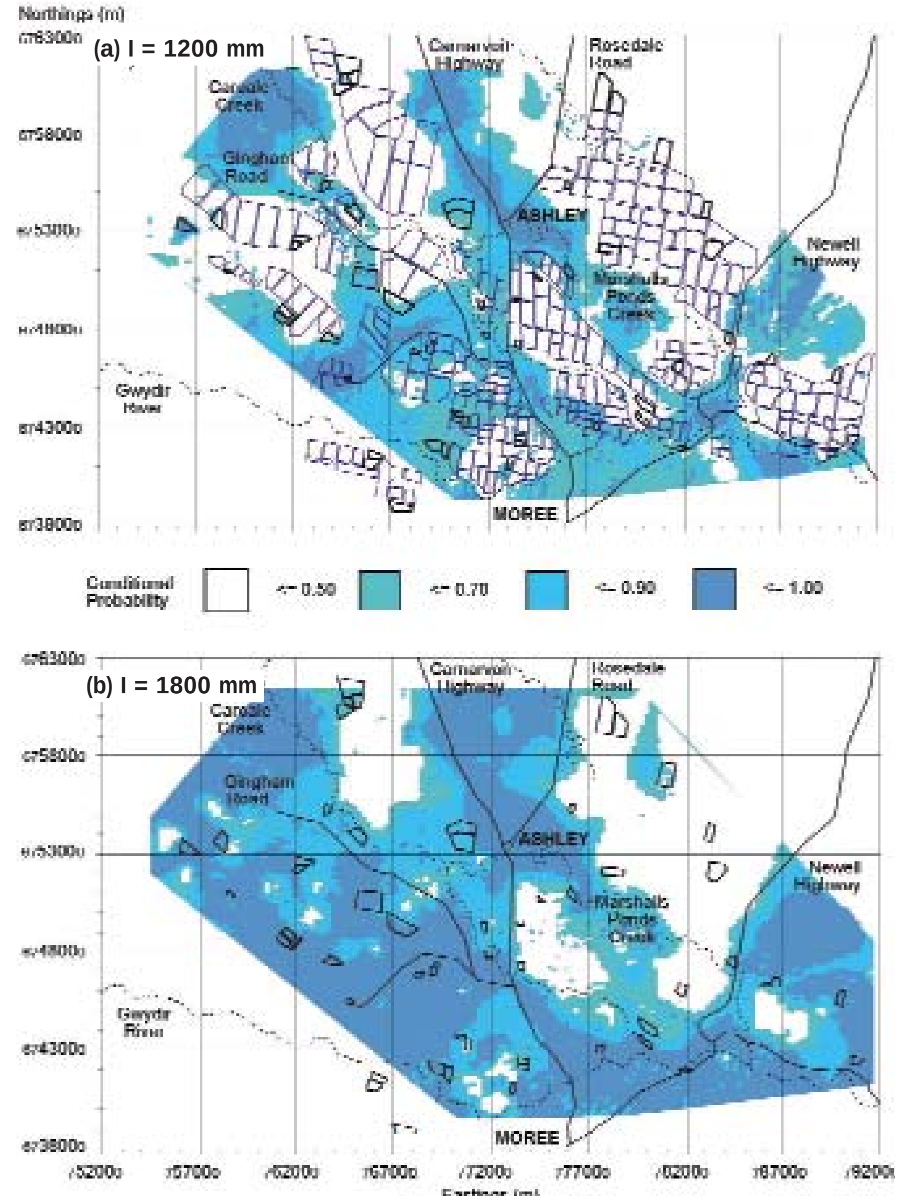
FIGURE 3: Map of conditional probability (CP) that soil at a particular site will exceed an estimated deep drainage (DD) value of:
a) 75 mm/annum if 1200 mm of irrigation water; and,
b) 100 mm if 1800 mm of irrigation water was applied*



* Average rainfall of 584 mm also assumed

Channels should be positioned in areas with low risk of excessive deep drainage.