Measuring, mapping and interpreting the spatial distribution of soil salinity in the cotton growing areas of northern NSW

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INTRODUCTION

Owing to the vast natural stores of soluble salts in semi-arid and arid lands (Szabolcs, 1989), information is required to ascertain the likely consequence of agricultural development. To date this has not occurred and as a result secondary salinisation of surface soil affects approximately 500,000 of dryland and 120,000 ha of irrigated areas in Australia (Williams and Fiddler, 1983). Using traditional field sampling and laboratory analysis of soil, systematic salinity assessment of these lands to provide information to determine cause and management strategies to remediate the problem is almost impossible, except on a relatively coarse scale (Northcote and Skeene, 1972).

In recent years technological advances in design and construction of field instruments has led to a revolution in soil salinity assessment. Electromagnetic (EM) induction instruments, which measure electrical conductivity, have proven useful in ascertaining the causes and describing the spatial distribution of soil salinity on the field and catchment scales once calibrated. Today, a number of EM instruments (i.e. EM38, EM31 and EM34-3) are commercially available and are capable of providing estimates of rootzone and subsoil salinity to depths of 15 m, depending on the instrument used. Since 1991, researchers at the University of Sydney have used these instruments to measure and map the spatial distribution of subsoil salinity on Auscott Farm located in the lower Namoi valley (Triantafilis, 1996).

In the following paper some of the results of this research (US05C) are shown. In addition, some of the future work (US22C) that is planned including the construction of a vehicle that is capable of carrying several EM instruments and a GPS is briefly outlined. The need for developing such a rig is that researchers and extension personnel will be able to assess the current and potential salinity threat more efficiently, in particular in areas where little soil information exists or where incipient traces of soil salinity become apparent in the cotton growing areas. Where salinity does occur, the instruments should provide useful information that will assist in determining the cause, location and extent of the problem. With such data, suitable management strategies to remediate the problem or minimise its spread can be suggested, implemented and subsequently monitored.

AUSCOTT STUDY

Where incipient traces of soil salinity occur or where large amounts of stored soluble salts are apparent in the landscape, the nature, origin and spatial distribution needs to be assessed to determine the current and potential threat. Triantafilis and McBratney (1993) in their numerical classification of the Edgeroi data set (McGarry *et al.*, 1989), identified the presence of a saline subsoil layer located within profiles used extensively for irrigated cotton production. Some of the more saline layers were located in many fields that over the past thirty years have been used extensively for irrigated cotton production. In order to determine if irrigation has led to the creation of this saline layer a detailed investigation using EM instrumentation and geostatistical techniques was initiated.

Study area

In total, 8 fields covering 649 ha. were selected for study as shown in Figure 1. Fields 16 through 20 are essentially centered around Galathera Creek and lie adjacent to Auscott Storage. Fields 23 to 25 are associated with the larger Foster's Storage and located to the south of the creek. The fields were selected owing to the large number of saline subsoil layers identified in the general vicinity and also due to their close proximity to the two large earthen storages. Differences in the length of time these two areas have been irrigated was an additional consideration with the southern fields developed in the last 15 years as compared to 30 years for those located around Galathera Creek.

EM survey and soil sampling

Based on preliminary EM transects, EM measurements were made on a 50 m sampling interval throughout each of these fields. Where conductivity and hence salinity was felt to be larger a more intensive sampling strategy was adopted (i.e. from 25 to 12.5 m). Figure 2a), b) and c) show the location of the more than 3,000 EM38 measurement sites made in these fields. It should be noted that a larger concentration of EM measurements were made in the northern parts of fields 19 and 20 as well as a band of measurements stretching from the mid to northeast corner of field 16 to the southwest corner of field 17. These patterns of larger conductivity were similarly reflected in the EM31 and EM34-3 surveys.

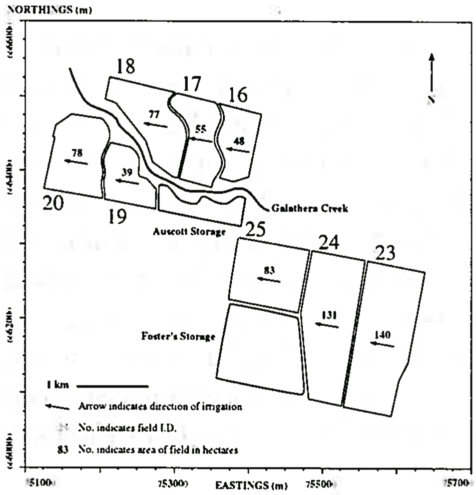

Figure 1. Auscott fields selected for detailed investigation to determine the origin, nature and spatial distribution of the saline subsoil layer.

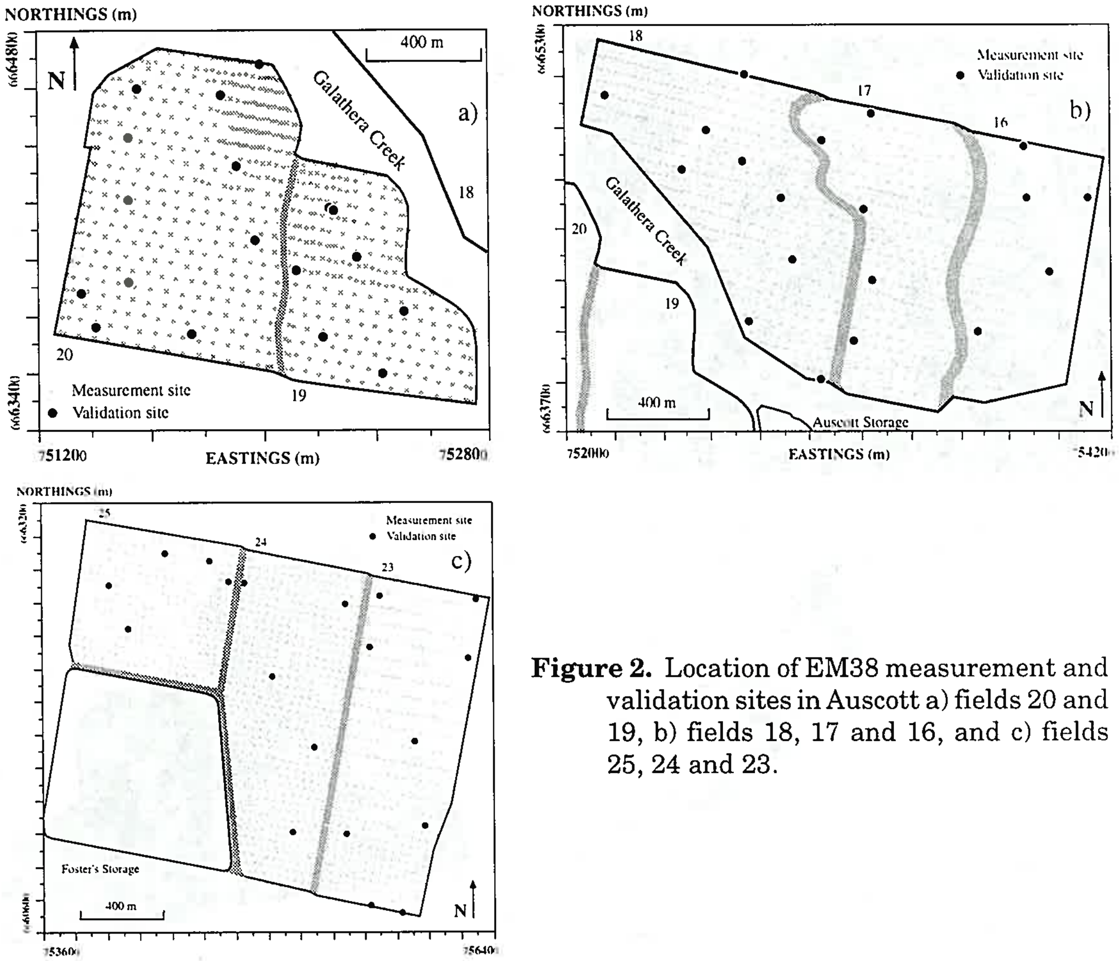

Figure 2. Location of EM38 measurement and validation sites in Auscott a) fields 20 and 19, b) fields 18, 17 and 16, and c) fields 25, 24 and 23.

Calibration

In order to relate EM measurements to soil salinity (i.e. EC_e), calibration is required. Calibration of each of the instruments involved soil sampling at a relatively small number of locations within the area for the deeper penetrating instruments (i.e. EM31 and EM34-3) but also in adjoining areas for the EM38. Soil samples were similarly collected as illustrated in Figure 2, to allow for validation of both the calibration and also geostatistical analysis of the generated EM survey data. With respect to calibration, a wide number of calibration approaches have been proposed including the use of average soil salinity within the profile (Triantafilis and McBratney, 1994). Here our interest was in determining the spatial distribution of the saline subsoil layer and any deeper subsoil salts. Therefore, estimates of salinity with depth were required.

In the literature several approaches have been suggested so as to provide for such estimates. Of these, the established-coefficients approach (Corwin and Rhoades, 1982) that was developed for the EM38 was found to be suitable for all three instruments including the EM31 and EM34-3. In addition, the logistic-coefficients approach (Laslett, 1995) was developed for the EM38. Compared with the established-coefficients approach it was found to be slightly more accurate in predicting EC_e owing to the statistically rigorous nature of the calibration procedure. Nevertheless, both methods provided good estimates

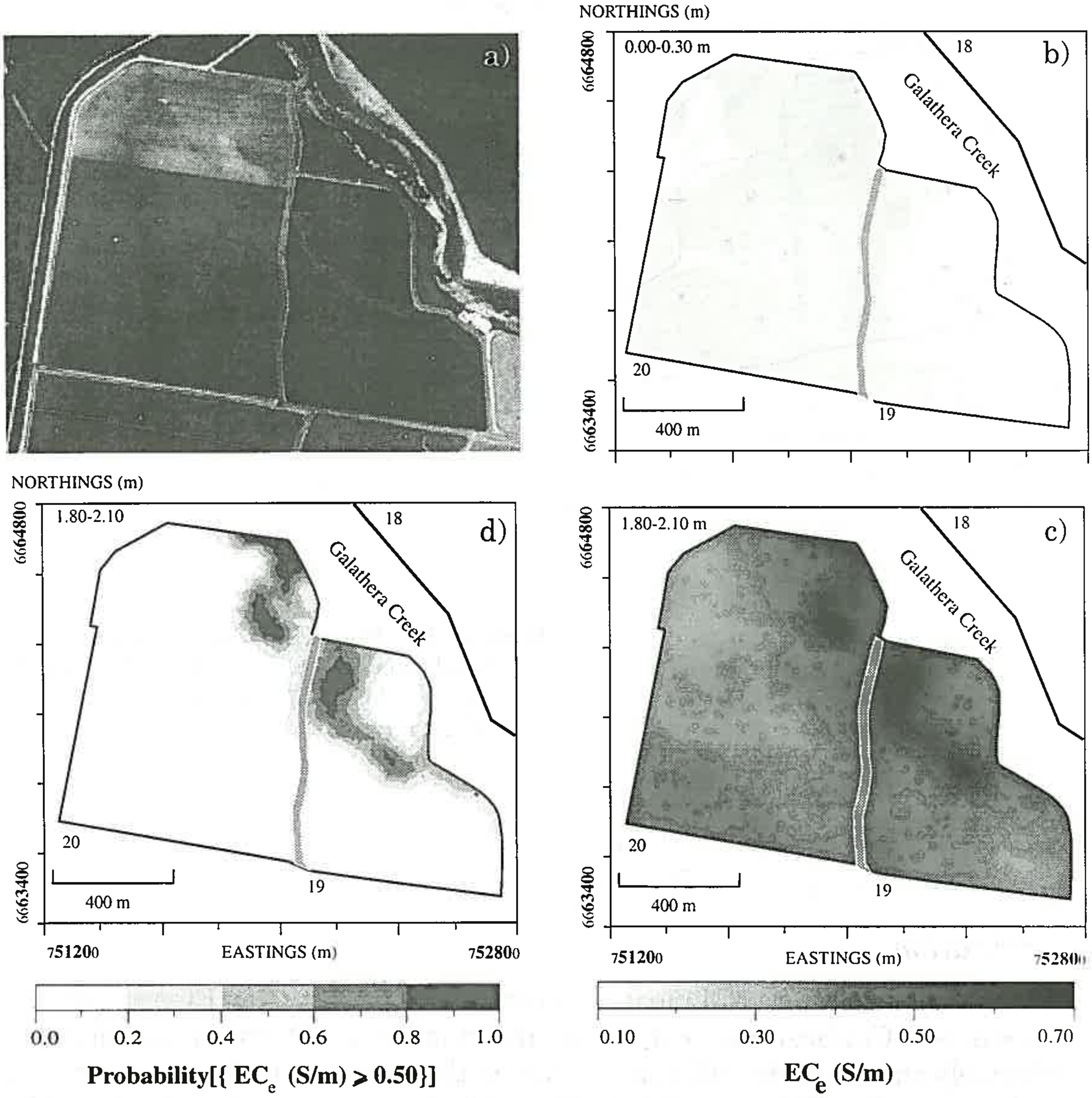

Figure 3. a) Air-photo of Auscott, Narrabri fields 19 and 20 b) spatial distribution of soil salinity at 0.0-0.3 m, c) spatial distribution of soil salinity at 1.8-2.1 m, and d) inicator kriged map of ECe ≥ 0.50 S/m.

of soil salinity or EC$_e$ within the soil profile at discrete depth increments. For the EM38 estimates can be obtained at 0.1-0.3 m to a depth of 2.1 m, whilst for the EM31 and EM34-3, equations were developed to estimate average soil salinity at 1.0 and 2.0 m intervals to depths of 7.0 and 15.0 m, respectively.

Geostatistical analysis

Once calibrated, the EM data generated was used to prepare salinity maps. These maps were generated using a number of geostatistical approaches that were tested, using the validation data set, to determine the most optimal methods of interpolation. The methods compared included: ordinary-, regression-, three-dimensional- and co-kriging. Of these regression- and co-kriging were the most accurate for the EM38 data whilst for the EM31 and EM34-3 ordinary kriging gave the most precise estimates. The results of some

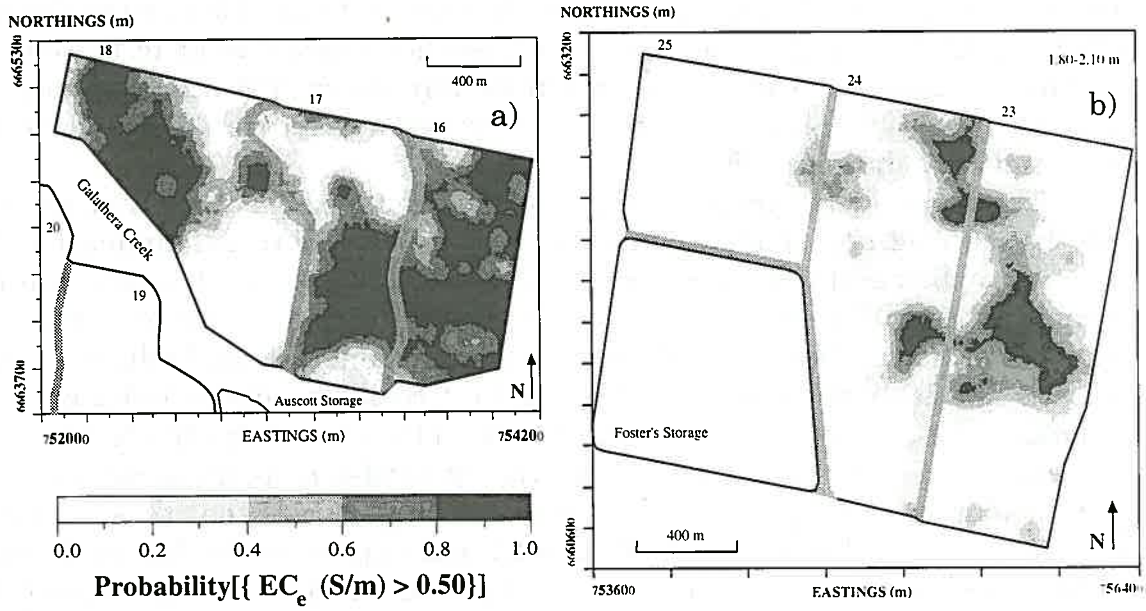

Figure 4. Indicator kriged maps of $EC_e \geq 0.50$ S/m at depths of 1.80-2.10 m a) in fields 18, 17 and 16, and b) in fields, 25, 24 and 23.

of these interpolations are shown in Figures 3b) and c) which show the spatial distribution of soil salinity within fields 19 and 20 at depths of 0.0-0.3 and 1.8-2.1. It is obvious from these two maps that salinity is greater at the deeper depth.

Interpretation

In addition, the northern parts of fields19 and 20 contain larger stores of salts in the subsoil than in the southern areas, particularly in the area where a larger number of EM measurements were made. Using indicator kriging, a geostatistical method which indicates the presence or absence of a particular attribute of interest, in this case identifying a saline subsoil layer that characteristically has an EC_e greater than or equal to 0.5 S/m, this pattern of salinity can be illustrated more clearly. Figure 3d) illustrates the result of this method of interpolation and shows the probability of locating a subsoil sample with an EC_e that is equal to or greater than 0.50 S/m. On comparing these three figures with Figure 3d), which is an aerial photo of fields 19 and 20, it is obvious that the saline band coincides with a prior stream channel of Galathera Creek. Similarly within fields 16 and 17 and fields 23 and 24, as illustrated in Figure 4a) and b) respectively, air-photo's (not shown) similarly reveal the presence of prior streams in the areas of higher salinity within these fields.

The correlation between greater subsoil salinity and location of the prior stream channel has two possible explanations. The first, is that as with saline incursions in irrigated cotton fields within the Bourke area and lower Macquarie valley, the large earthen structures here have leaked and owing to the presence of subsoil textural boundaries local water tables have formed redistributing subsoil salts within the rootzone. This is particularly the case in the areas lying adjacent to the prior stream channels. This hypothesis can be discounted, since during soil sampling to depths of up to 15 m, no evidence of any shallow or deep water tables in these fields or adjacent to the large earthen structures existed nor were their any sharp textural boundaries apparent. At two calibration sites, saline water was recovered at depths of 17.5 and 18 m, however.

The more likely explanation is that the salts identified and mapped at depths of 0.70-2.10 m, have accumulated naturally by continual inundation of the local ephemeral Galathera Creek. The Creek has its headwaters within Bobbiwaa State Forest. The soil here has been derived *in situ* from Pilliga Sandstone and has been strongly leached of many nutrients and soluble salts. This is similarly the case with the Tarlee Creek, the major tributary of Galathera Creek, which has its headwaters on the same ledge but further to the east in an area where Tertiary weathered sandstone is the predominant parent material. It appears from air-photo's (not shown) that these creeks reviously flowed through fields 23 and 24 and beyond to the Namoi River. Today, these creeks have no natural outlet and as a result the salts deposited by rainfall in the upper part of the catchment are now accumulating in this area which is acting as a natural sink.

CURRENT RESEARCH

The EM instrument calibrations and geostatistical techniques described here illustrate quite clearly the usefulness of such methods in describing the spatial distribution of saline layers in the landscape in addition to the nature and origins of these salts. To improve the speed and efficiency of data collection, the EM instruments along with a GPS and various data loggers will be mounted onto a single vehicle. The development of the vehicle, similar to that developed by the U.S. Salinity Laboratory (Rhoades, 1992) (see Figure 5), is being funded by the CRDC and Salt Action, who additionally provided funds for the purchase of digital EM instruments, including an EM38 and EM31, as well as an analogue EM34-3. Once developed (September-October 1996) the salinity module will be used on field and catchment scale investigations to determine and assess the current and potential salinity threat primarily in the cotton growing areas of northern New South Wales. In areas where incipient traces

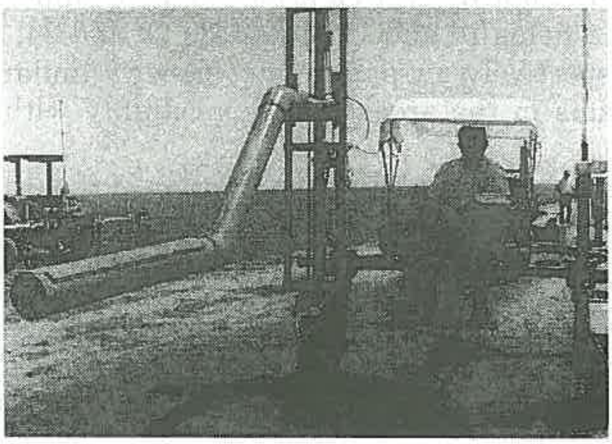

Figure 5. U.S. Salinity Laboratory Mobile Assessment Vehicle.

of salinity are apparent or where it is severe the vehicle can be used to generate data to determine the causes of soil salinisation. With such information management decisions can be suggested. In order to gauge the usefulness of management strategies the vehicle can be used in follow-up investigations for monitoring purposes.

CONCLUSIONS

The use of EM instruments and geostatistical techniques proved useful in determining the origin, nature and spatial distribution of the saline rich subsoil layer identified previously. The origin, nature and spatial distribution of the water located at depth at two of the EM34-3 calibration sites needs to be investigated further. To increase the speed and efficiency of field salinity assessment the EM instruments need to be mobilised for more rapid on-the-go measurement. In addition, soil\water balance modelling could be used to determine areas of potential salinity concern that require further investigation.

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