Saving the soil at Puckapunyal

Computer-based land management is helping preserve the environment at the Army's main armoured-vehicle training ground

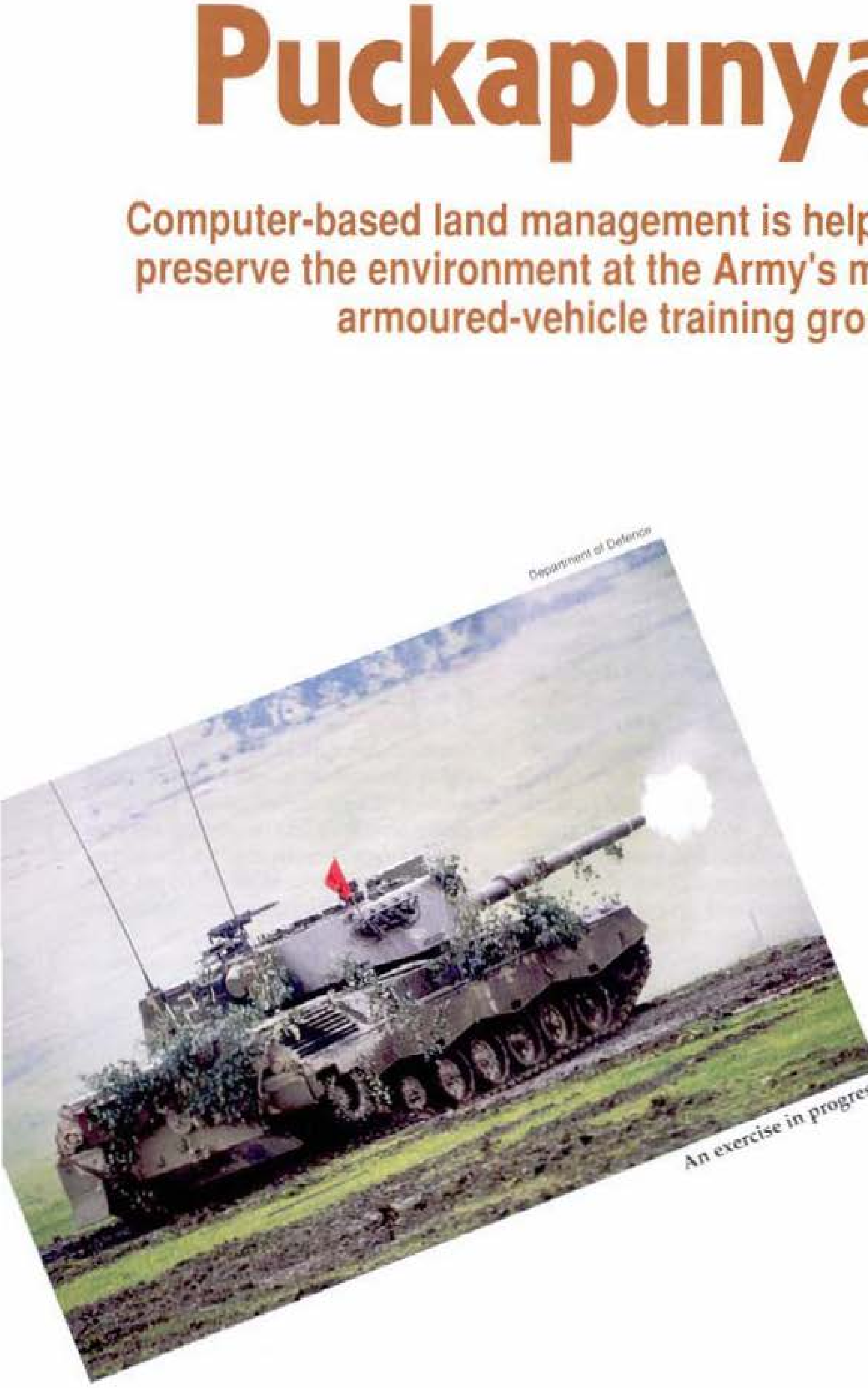
Australia's European settlers brought with them a tradition of land management based on generations' worth of local knowledge about the levels of exploitation the land could be expected to bear without degradation.

Such a system was neither perfect nor always relevant to this continent. Tradition included many practices that actually degraded the land in subtle ways, largely as a result of economic pressures or lack of scientific knowledge. In more recent times expanding populations and technological developments have greatly increased pressures on the land, but, with the realisation that land is a finite resource, management strategies predicated on sustainable returns are coming to the fore.

Efficient land management based on a scientifically based knowledge of the land and its ability to resist degradation need not be limited to agriculture. National parks, wilderness areas and reserves devoted to recreation must balance their recreational roles with the conservation of the values that attract increasing numbers of visitors.

Similarly, land subjected to pressure from activities such as military exercises must be maintained in the best possible condition for a multiplicity of purposes: for environmental conservation; to ensure as much land as possible is available for exercises over the longest possible time for the greatest number of users; and to keep management and repair costs to a minimum.

Computers are proving useful tools in land management, not only keeping



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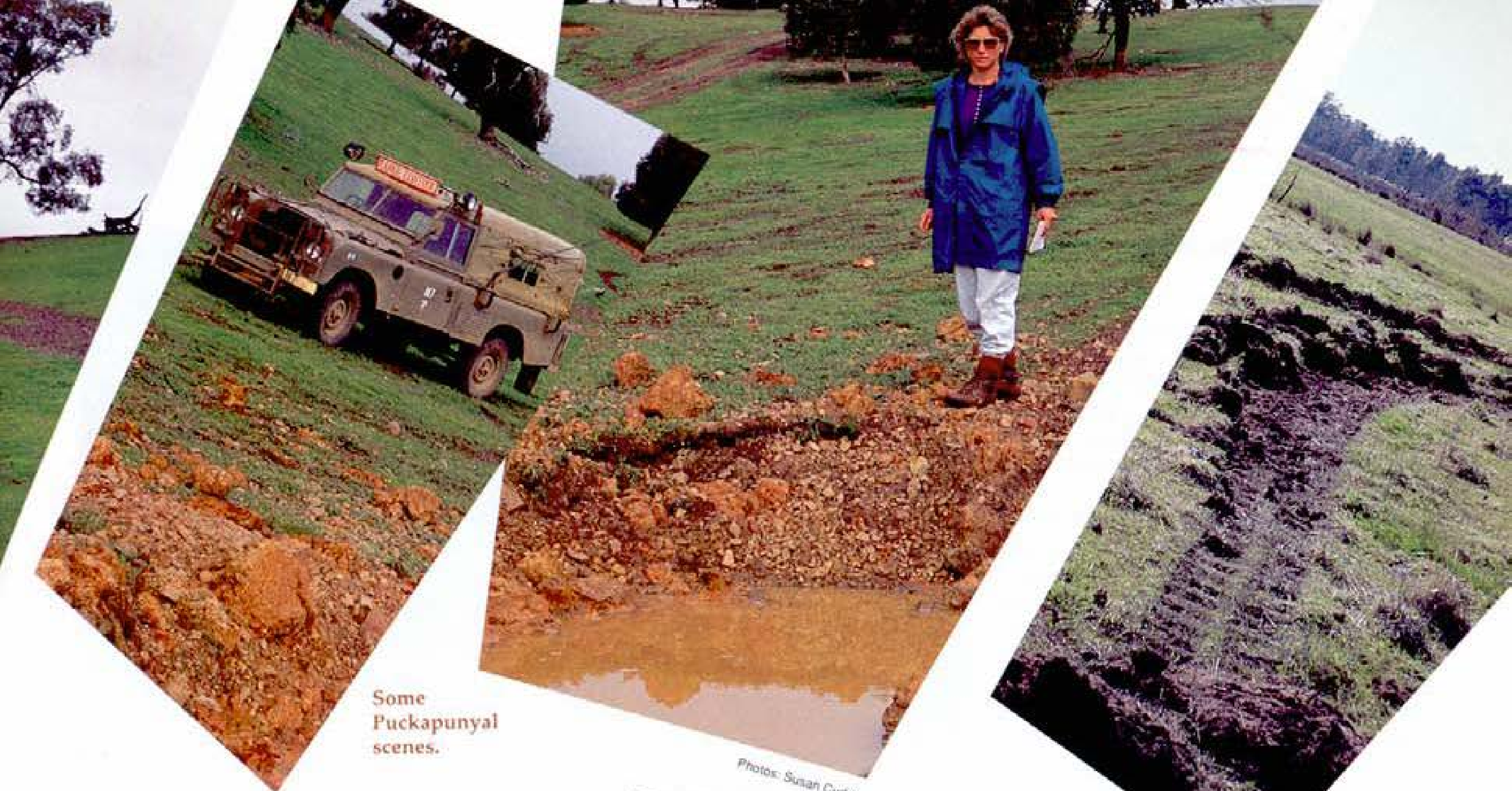
An exercise in progress.



Some Puckapunyal scenes.

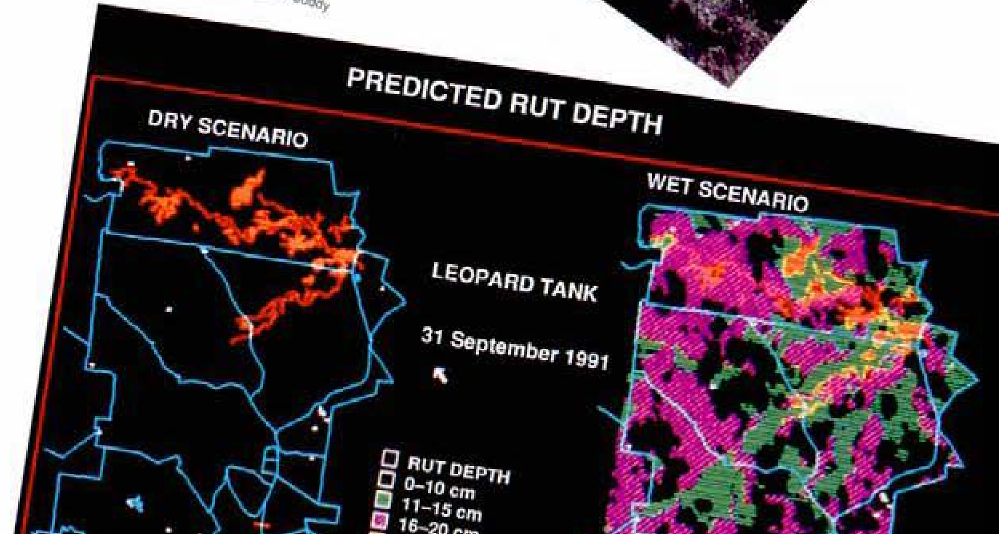
Photos: Susan Cuddy

records of natural resources and of management decisions and their effects, but also offering land managers a means of predicting the outcomes of management strategies before implementing them.

The keys to computer-based land management lie in two powerful computer techniques: geographic information systems and expert systems.

Geographic information systems are among the most successful computer technologies of the past decade, offering planners a combination of geographically indexed data-bases and mapping software that enables them to store landscape and resources information and to test the effects of different management strategies on the landscape.

They represent landscapes as sets of features that have both locational (related to the positions of landscape features) and thematic (relating to the attributes of those features) importance.



A computer comparison shows the difference rain can make in different parts of the Range to the damage a Leopard tank will cause.

Modelling with such a system mostly extends no further than the creation of a composite map of the landscape by combining layers of information (for example, overlaying a soils map with a land-use map to show how these attributes are related). Geographic information systems are thus inherently slow — because an immense number of data must be combined — and limited in their applications. They offer little freedom to solve land-use problems by exploring relations between alternative strategies and their consequences.

Many of those limitations have been overcome with the rise of expert systems, which can predict the outcomes of management decisions by mimicking the deductive and/or inductive reasoning of a human expert. They use formal logic, most commonly expressed in 'if… then' relationships, that enables users to see clearly how a result was achieved, making their results more credible than those based purely on mathematical relationships.

Expert systems grew from research into artificial intelligence in the 1960s and have since been applied to modelling aspects of medical diagnosis, geological prospecting and the prediction, design, planning, monitoring, repair and control of a variety of activities that involve logical systems… including engineering and land management.

The CSIRO Division of Water Resources has been developing them for the management of natural resources for several years, and has combined their virtues with those of geographic information systems in what it calls the ARX spatial expert system shell. This program allows an experienced resource manager to develop and store rules linking causes and effects, and offers the advantage of including the sort of spatial information that forms a part of the geographic systems in those rules so that the effects of a given management decision at one location can be tested at others.

The 'proving ground' for this new software is, appropriately, the Australian Army's main armoured-vehicle training ground — the 424-sq.-km Puckapunyal Range training base, about 100 km north of Melbourne.

When it was purchased by the Army in 1939, Puckapunyal was already severely degraded by clearing, overgrazing, mining, tree-felling and rabbit infestation, with extensive sheet, gully and tunnel erosion. By 1969, intensive use by tanks and wheeled vehicles meant one-third of the Range was impassable in winter, mainly as a result of waterlogging and the exacerbation of soil loss that began during Puckapunyal's days as farming land.

A $13 million environmental restoration program was instituted in 1971 to ensure the Range's long-term future as a training facility through repair of eroded areas, tree-planting and the establishment of deep-rooted perennial grasses, and was completed in 1985 (see *Ecos* 43).

All but a few particularly sensitive areas of the Puckapunyal Range are now available year-round for training exercises, their condition and accessibility monitored by a land-management advice system, which employs ARX and was developed by the Division's Ms Susan Cuddy, Dr Richard Davis, Mr Peter Wigham and Dr Peter Laut. The system is the product of a contract, entered into with the Army in 1988, to develop a computer system that could model the environmental effects of training exercises and provide ongoing advice on which parts of the Range were capable of handling military traffic.

It combines the virtues of expert and geographic information systems to create a three-part model of the Range, utilising information collected at regular intervals over representative sample areas. It predicts soil moisture and strength at nominated times of year or following given amounts of rain, relates soil moisture and strength to the ground pressure exerted by Army vehicles to predict the depths of wheel ruts and estimates the likelihood of environmental damage from those ruts and its repair cost. It has the advantages of flexibility in capturing local knowledge and experimental results, and of presenting that information in a way that is accessible to someone not versed in computer languages.

Armoured vehicles at Puckapunyal.

Susan Cuddy

The system is used by the Range Control Officer, who is in charge of a Range management team responsible for maintaining Puckapunyal and for the ongoing land-management program (through continued tree-planting, installing dams, smoothing and deep-ripping erosion sites and repairing creek banks). Appointed for a 3-year term, the Range Control Officer oversees the land-management program and arranges bookings up to 18 months in advance. The Range Control Officer is assisted by a Scientific Officer, who is responsible for the maintenance of the land-management advice system.

The Range is divided into 19 'management zones', which are booked by units of varying size (troops, armoured squadrons, regiments and so on). Drawing on records of rainfall and of each zone's history of degradation, use, repair and current condition, the Range Control Officer assesses the proposed exercise, unit size and time of year in terms of the topography appropriate for the activity — advancing tank units, for example, would not use ridges, but these landforms are suitable for infantry exercises — and recommends particular areas of the Range. He provides unit commanders with information on the condition of the exercise area, including the potential for damage and the probability of vehicles becoming bogged or damaging the land.

The soil moisture/soil strength component of the land-management advice system predicts the daily water balance at different layers of different soil types, using a five-point 'wetness index' that indicates the influence of location on the likely wetness of soils following a given amount of rain.

The wetness index is closely linked to topography — ridgelines, for example, typically have a low value (1), while perennial swamps have the highest (5) — and was inferred from rules. Other inputs to this component are rainfall scenarios (based on 80 years of rainfall records for Puckapunyal and/or surrounding districts) plus a landscape map that divides the Range into 2503 land-units, averaging 17 ha, and records the distribution of 14 soil types.

These land-units were mapped by Dr Laut and digitised and stored, together with geological and slope information, as a geographic information system map layer, then combined with information collected in the field to develop rules for predicting wetness index and soil types. The ARX rules allow the Range Control Officer to base decisions not only on a proposed land-unit's characteristics, but also on the basis of that land-unit's relationship to adjoining units. A typical rule would be:

IF the landscape type of the land-unit under investigation is 'floodplain',

AND the landscape type is 'seasonally inundated floodplain' for any adjacent land-unit,

THEN the wetness index of the land-unit under investigation is 5.

Although the system can store mathematical relationships, these are normally encoded in external models, rather like libraries, that are linked to it, so that a user who needs to determine a particular land-unit's moisture content can 'call' an external water balance model to obtain this information. The system employs spatial facts (for example, landform class), non-spatial facts (like time of year) and time-dependent information (such as the amount of rain recorded over a given period) to predict the outcome of management strategies.

The user may choose to map any attribute for hard copy or for display on screen when an inference is completed. The land-management advice system typically creates a map of predicted repair actions, showing where most of the repair cost will occur; an explanation module shows how results were justified by the causal chain of operations that occurred to arrive at each inference, aiding interpretation and informed decision-making.

The Range Control Officer can make decisions in the confident knowledge that accurate information about each part of the Range's condition is available at all times; and the Army can ensure that the Officer's local knowledge and experience are not lost at the end of each 3-year term, since they can be stored to enhance the system.

Expert systems are popular tools for the modelling of qualitative processes, while geographic information systems are useful in the development of natural resources strategies and for the management of those resources. Harnessing these two in tandem allows planners to create interactive models that can be applied to a host of resource-management tasks, incorporating local knowledge and providing land managers with a cost-effective, efficient way of exploring the implications of alternative management strategies. A planner could, for example, use ARX to address the sorts of problems discussed in the article on the Bungle Bungle in *Ecos* No. 67, building a model to assess how much tourist traffic the area could bear without further degradation of its fragile ecosystems.

In a military context, the Australian Army's success with ARX has been so impressive that United States Army representatives have visited Puckapunyal to inspect the system at work, with a view to collaborative research into the management of its own training facilities.

Carson Creagh

More about the topic

'How Many Tanks to the Hectare? The Story of Puckapunyal Resoration and Conservation Project.' (Soil Conservation Authority: Melbourne 1977.)

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