Transactions of the Royal Society of S. Aust. (1994), **118**(2), 125-131.

EVALUATION OF EXTENSIVE ARID RANGELANDS: THE LAND CONDITION INDEX (LCI)

by ROBERT T. LANGE*, BRENDAN G. LAY† & RODGER W. TYNAN†

Summary

LANGE, R. T., LAY, B. G. & TYNAN, R. W. (1994) Evaluation of extensive arid rangelands: the land condition index (LCI). *Trans. R. Soc. S. Aust.* **118**(2), 125-131, 31 May, 1994.

Social and historical circumstances that have given rise to rigorous new rangeland management legislation in South Australia are outlined. A program specified by the legislation is explained and described which will determine the condition of the 40 million hectares of arid rangeland in South Australia relative to criteria about sustainability and prevention and rectification of degradation. An objective assessment of average rangeland condition, the Land Condition Index (LCI) is introduced and results obtained by its use are illustrated and appraised.

KEY WORDS: Arid zone, rangelands, Australia, vegetation, assessment, technique.

Introduction

The Pastoral Land Management and Conservation Act (1989) came into operation in South Australia in March, 1990, after years of public contention. It challenged the then Outback Management Branch of the South Australian Lands Department (as the responsible agency) with an immense, mandatory land assessment task within an 8-year deadline. In its combination of difficult features and its emphasis on sustainability, this task may have parallels in other arid parts of the world, where our procedures might, therefore, be applicable.

The particular combination of challenging features is a vast rangeland area (the size of Iraq or Somalia for example) poorly documented and difficult of access, to be assessed for the integrity of its vegetation and soils in detail, according to characteristics not accessible by remote sensing, using minimal time, staff and money.

We faced the further difficulty (given the limited amount of resources relative to the immense size of the task) that our assessments even of small tracts of land (a few hundred ha or so) would have to be capable of withstanding challenge and close scrutiny in a court of law.

This paper outlines (a) the historical and social context of the Act, (b) an approach (including a new index of land condition) which we have devised to help achieve what the Act requires and (c) some initial results obtained by application of the index.

* National Key Centre for Teaching and Research in Dryland Agriculture and Land Use Systems. The University of Adelaide Roseworthy Campus, Roseworthy, South Australia 5371
Current address: Box 330, Whyalla, South Australia 5600.
† Pastoral Management Branch, Resource Conservation Division, Department of Environment and Natural Resources, GPO Box 1047, Adelaide, South Australia 5001

Australian Background

Whether native inland Australian vegetation can ultimately withstand the impact of ungulate flocks and herds is yet to be determined. Since it evolved in total isolation from ungulates, it may prove unavoidably susceptible to the effects of large numbers of them. From prehistoric time until the mid-19th century, the inland arid regions of S.A. sustained only sparse Aboriginal nomadic hunter-gatherers. Due to lack of surface waters most vegetation probably experienced only very light grazing pressure, on average, by kangaroos alone. That regime changed "cataclysmically" (Adamson & Fox 1982) when Europeans colonised much of the country, tapped ground waters and introduced millions of ungulate stock and various feral animals, creating a sedentary grazing industry which now occupies 40 m ha (Fig. 1) and is mostly in the early part of its second century of operation.

The saying "Out of sight, out of mind" aptly summarises public and governmental attitudes to pastoral zone landcare throughout much of the industry's history (Lange 1983). Nearly all of South Australia's 1 m people dwell in the arable coastal regions and of these the vast majority live in and about Adelaide. Only a few hundred at any one time have had extensive pastoral zone experience. City-dwellers have only recently become better aware and more vocal about the arid zone, as tourism, wildlife protection, recreation and mining have increased.

Sheep stocking enterprises typical of the more southerly parts of the zone are protected from predatory dingoes by a special fence (the Dog Fence). Features include the subdivision of the rangeland into wire-fenced paddocks with water available for stock at fixed points, approximately fixed flock size year in, year out and a system of vehicular access tracks. This leads to the development of repeated drink-centred patterns of unequal flocktime distribution (piosphere pattern, Lange 1969, 1985; Andrew 1988) in which flocktime

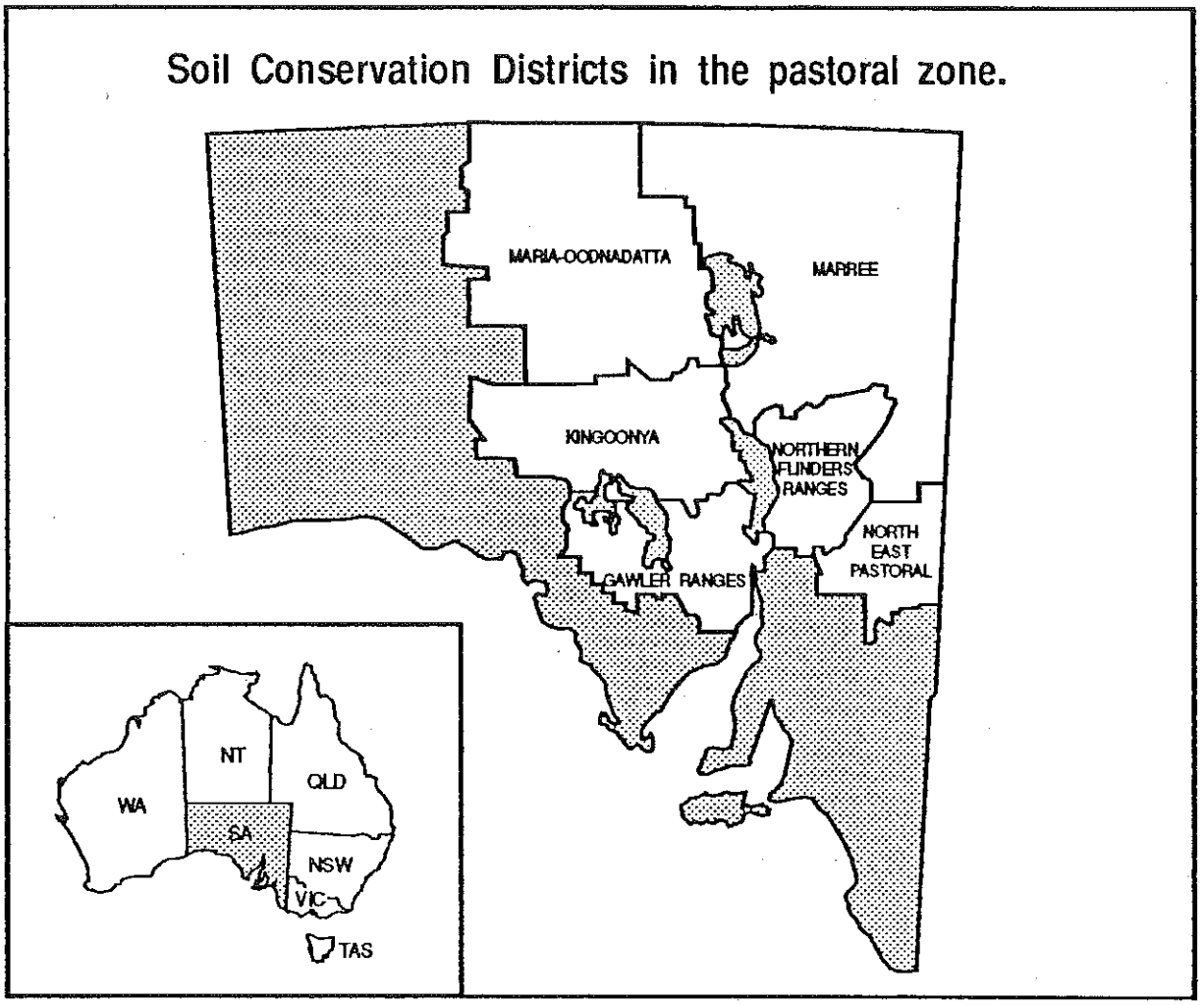

Fig. 1. The pastoral lease lands of South Australia, showing also their subdivision into Soil Conservation Districts.

concentrations can rapidly cause damage to the vegetation and soil, particularly during drought periods. The northerly extensions, exclusive to cattle, show the same patterns on a broader scale, with most pastoral properties there without internal fences.

Scientific and general literature, government inspectors' reports and the like show that from its inception onwards, this industry has caused great damage to the land, in some cases denuding the soil in just 2-3 decades (Dixon 1892; Waite 1896; Ratcliffe 1936; Pick 1944; Lay 1979). This was of public concern particularly in the 1930s when the issue of soil erosion was topical worldwide (Jacks & Whyte 1939) and has subsequently remained a problem. Half a century later in the 1980s, government administration again publicly conceded that some pastoralists were still failing to meet landcare obligations and that land degradation from overstocking and feral animal pests was extensive[1]. In an attempt to accommodate all interested parties, the Pastoral Land Management and Conservation (PLMC) Act was finally passed in 1989. This Act is profoundly different from earlier South Australian pastoral laws in its great emphasis on resource protection. It is, in fact, unequivocal landcare legislation (in some ways setting scarcely-attainable ideals of landcare perfection) but it also provides provisions for grazing industry protection and appeal. How these opposites will be reconciled in practice is yet to be shown.

Of special relevance to this paper, the new Act gave the Minister of Lands greatly increased scientific and technical responsibilities. The administration of the Act is delegated to the Pastoral Board (whose membership reflects major interests in pastoralism and conservation) but the technical tasks must be carried out by the Pastoral Management Branch. Of these tasks, this paper refers to the requirement for vegetation assessment. This immense task, which the Act requires

[1]South Australian Government, Lands Department (1981). The administration, management and tenure of South Australia's Pastoral Lands. Interdepartmental Report (Chairman: J. Vickery, Lands Department).

to be carried out within eight years and at 14-year intervals thereafter, relates to 40 m ha of the rangelands and is to specify the condition of the land according to criteria derived from the Objects of the new Act. These effectively require that the whole area be directly inspected by teams of trained assessors on the ground. As is usual where a large and complicated task must be accomplished piecemeal by different teams, objective, standardised procedures need to be adopted to ensure that the findings of any assessment are independent of the particular team employed. The development of the index and training procedures described below is an attempt at such standardisation.

The Legal Stipulations about Assessment

In South Australia's non-arable inland regions a pastoral lease is the only form of tenure than can be granted over Crown (government) land that is to be used for long-term grazing purposes; a pastoral lease cannot be granted or extended without an assessment of the condition of the land first having been made (PLMC Act, 1989, Sec. 20, 25). This is why the assessment program is urgent and crucial. The pastoral industry is awaiting the issuing of new leases, specifying new stocking limits and other conditions consequent upon these assessments.

Section 6 of the PLMC Act states that such assessment of the condition of the land must be thorough, must include an assessment of the capacity of the land to carry stock, must be conducted in accordance with recognised scientific principles and must be carried out by persons who are qualified and experienced in land assessment techniques.

The further meaning of assessment derives directly from relevant Objects of the PLMC Act (Sec. 4) which are: (a) to ensure that all pastoral land in the State is well-managed and utilised prudently so that its renewable resources are maintained and its yield sustained and (b) to provide for (1) the effective monitoring of the condition of pastoral land, (2) the prevention of degradation of the land and its indigenous plant and animal life and (3) the rehabilitation of the land in cases of damage. The Minister is expressly charged (PLMC Act, Sec. 5) with the duty of acting consistently with and in furtherance of those Objects. Assessment pursuant to the Act thus is the process of obtaining scientifically based answers to the Objects posed as questions, viz., Is this pastoral land well-managed and utilised prudently so that its renewable resources are being maintained and its yield sustained? Is degradation of the land and of its indigenous plant and animal life being prevented? Is there degradation which requires rehabilitation? Has effective monitoring of the condition of the land been provided? What is the capacity of the land to carry stock consistently with answers to the foregoing questions?

Since "degradation" is defined (PLMC Act, Sec. 3) as a decline in the quality of the natural resources of the land resulting from human activities, some of the implications arising from the Objects are immediately apparent. For instance, the conventional rangelands dogma that the desirable condition of the vegetation is that which feeds most stock is potentially denied by this legislation. The optimal condition instead is that where indigenous plant and animal life retain their prepastoral integrity while as far as possible sustaining a viable pastoral industry. Appreciation of this difference is crucial to developing the condition index outlined below and it will be further examined in the Discussion.

That the answers to these assessment questions are meant to be taken seriously is made plain in many parts of the PLMC Act including Sec. 43 for example, a Section excluded from the appeal provisions (Sec. 54, 55). Section 43 makes it clear that the Pastoral Board should require the removal of stock from an area not only if its believes that the land has been damaged but also if the Board considers that the land is likely to suffer damage.

Essential Preliminaries to Assessment

It should be noted here that the assessment program as developed consists of two parts viz., the lease-based Land Condition Index determination (the subject of this paper) and a network of paddock-based photo-monitoring sites. These latter sites, with vegetation and soils data collected, form the base line for the assessment of future trends in each paddock.

Access and Sampling

Any thorough assessment of a station or lease in accordance with recognised scientific principles (Sec. 6 of the PLMC Act) should employ many independent samples in an effort to achieve a picture which is as balanced and equitable as is practicable. In practice, sampling falls somewhere between systematic and random, as in the way the industry itself informs potential buyers about the contents of a bale of wool, for example, where the sample is from an arbitrary grab. In sampling station condition, reliance is usually placed upon the pastoralist's system of vehicle access tracks to spread samples throughout the overall area. Then, to avoid possible observer bias, samples are drawn by strict restricted-random processes from what is track-accessible. There are some obvious consequences of such sampling but they are more academic than practical and there is no evidence that they significantly affect comparisons. All well-developed pastoral land has adequate watering points and a network of access tracks linking them. Thus there is a higher than random likelihood of sampling closer to water, and a correspondingly reduced likelihood at intermediate ranges, than would result on random

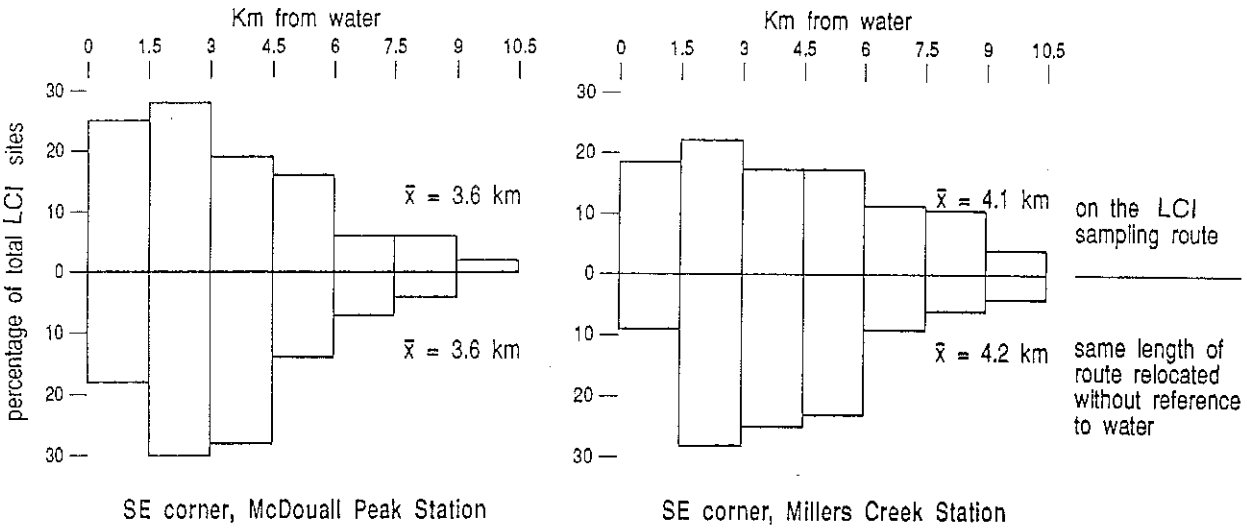

Fig. 2. Histograms showing the percentage of sampling points at various distances from water points on the access tracks (above) and when the same track-grid is offset from water-points (below).

tracks. This effect is consistent from station to station (Fig. 2) and can always be taken into account.

Recognition of Vegetation Type and Component

The next essential of the assessment procedure is that the assessment team member, at any sample point, must recognise which of the many different vegetation types is represented and, of that type, which of the various sub-types called components. In practice this ability comes from instruction manuals and field training provided by us, as experienced team members, who have a collective 60 years of botanical work experience in the region to draw upon. Learning is simplified by restricting consideration to manuals drawn up for one Soil Conservation District at a time, thus reducing the immediate diversity to be handled. The assessment teams then attack the task by completing assessments of one District before re-calibration and assessment of the next District and so on.

We write keys for the identification and separation of the vegetation types and components in each district, with sets of criteria to distinguish condition classes (see below) and we illustrate the resulting manuals with extensive colour photo-guides. All teams are then trained en bloc (in extended field calibration exercises) to achieve a uniform, consistent interpretation of all criteria.

All main diagnostic criteria refer to perennial plants, rather than to ephemerals which appear only after significant rainfall. The main reason for reference to perennials is that they embody the drought fodder reserves of the rangeland as well as being the reliable buffer against wind erosion. There are a few places, particularly in northern cattle rangelands, that lack perennial vegetation sufficient for present purposes; these will be treated in separate ways.

TABLE 1. *Vegetation type and component used in LCI.*

Type	Component
Chenopod shrublands	*Atriplex vesicaria-Maireana astrotricha* treeless plains
Woodlands with grassy understorey	*Acacia aneura- A. ramulosa*-grass sp. on deep sands.

The level at which types and components in general are distinguished is indicated by the examples giving the names of predominant species in Table 1.

Condition Classes

Arguments about non-linear "state and transition" models of rangelands dynamics notwithstanding (Westoby *et al.* 1989), experience of S.A. rangelands shows that in general any component can be placed into one or other of three condition classes viz., **Class 3**, with the original stock-palatable perennial species still present and reproducing, **Class 2**, with the original palatable perennial species being eliminated (if grasses or low shrub species) or lacking all juveniles (if large long-lived perennials) and with replacement by much less-palatable perennial species including weeds or by ephemerals and **Class 1**, with all palatable perennial species eliminated except old trees; unpalatable species heavily pruned, many weeds present or, in some cases, the integrity of plant cover totally destroyed. It has of course been demonstrated for nearly 60 years that deterioration to Class 1 goes hand in hand with the onset and rapid acceleration of soil erosion (Ratcliffe 1936; Jacks & Whyte 1939; Pick 1944; Lay 1979).

The advantage of distinguishing only three classes is that only two sets of separation-criteria are then required i.e. separating Class 3 from Class 2 and Class 2 from Class 1. Obviously, it is easier to train all

assessment teams to absolute consistency when they have to apply only two sets of separation criteria to describe the condition of some given vegetational component instead of three, four or more sets. Contrary to what at first sight might seem to be the case, this restriction to just three condition classes in no way limits the general sensitivity of inter-lease comparisons. When the condition of two leases is to be compared, the sensitivity of the index of comparison depends instead on a sufficient number of samples plus the use of weighted averages, as will be demonstrated. So, in specifying arbitrary but consistent criteria for the separation of condition classes, counts can be avoided in favour of absolute differences. Regarding the *A. vesicaria-M. astrotricha* component of the chenopod shrublands, for example, the main criterion for separating condition Class 3 from condition Class 2 is the elimination of *A. vesicaria* (a grazing-susceptible species of the original palatable perennial component). Condition Class 1 is distinguished from Class 2 by loss of *M. astrotricha*, a palatable but more grazing-resistant perennial. Taking the example of the *Acacia aneura-A. ramulosa*-grass sp. component of the woodlands with grassy understorey, condition Class 2 involves loss of all *A. aneura* regeneration, appearance of a distinct browse line on old trees, elimination of the most palatable perennial grasses (e.g. *Monachather paradoxa*) and severe pruning, at least, of palatable shrubs (e.g. *Eremophila latrobei*). Similar sets of criteria have been adopted to distinguish condition classes of all vegetational components of all types in the rangelands, supported by photographic examples of these classes.

Training

An essential for condition assessment conducted piecemeal by different teams, using this method, is a full scale combined field-training exercise. The Soil Conservation District to be assessed it traversed to intersect all vegetation types and components. At stop after stop on this traverse, samples are assessed by the party as a whole, according to the manual, until all questions have been resolved on the spot, guaranteeing uniformity of interpretation. Only then are the different teams allocated their particular shares of the district workload and the actual assessments conducted.

Predetermination of Sampling Points

Using available maps of station tracks, the assessment sampling route is pre-selected for best systematic coverage and the total length involved is calculated using an opisometer. That length is then divided into 100 equal parts within each of which a precise stopping-point is drawn at random. The results are then programmed into a computerised trip-meter (Halda Instrument Co.) mounted in the access vehicle, which then signals the stops. This guarantees restricted-random sampling of the route.

Assessment and LCI Calculation

Field teams comprising a scientific officer and a technical officer operate self-contained 4-wheel drive expeditionary vehicles equipped for remote area operations, including radio communications. Navigation is by reference to available maps and satellite imagery using a vehicle-mounted GPS unit. At each sample site (of which the trip meter sounds prior warning and displays a count down to 10 m), the reference is made to the 50 m-square plot located immediately beyond a line parallel to the direction of vehicular travel, 10 m offset from the left side of the vehicle. The sample within this plot is rated according to vegetation type, component and condition, is photographed and the data are recorded. At the conclusion of sampling, the station land condition (LCI) is calculated as in the hypothetical example in Table 2.

TABLE 2. *Example of calculation of LCI (station land condition).*

Condition Class	Percentage of samples	Multiplier		Totals
3	50	×3	=	150
2	30	×2	=	60
1	20	×1	=	20
	100			230
		LCI	=	2.30

Note that this index has limits of 1.00 (the whole station in "degraded" condition) and 3.00 (the whole station in "undegraded" condition). Actual stations have values between these limits. Note also that the index, once calculated, is not to be interpreted mechanistically but instead is used for first-order sorting of stations according to condition. Other evidence and data collected independently about each station are then taken into account. Stations can be compared directly by the LCI only where they involve similar pasture types and components in similar proportions.

The Nature of Initial Results

Assessment teams obtained first results during 1991 from the Kingoonya Soil Conservation District of South Australia using 19 stations. Fig. 3 makes a comparison between the LCI scores of lands making up the stations in this district and the maximum stocking permitted on them by the provisions of existing lease documents. As can be seen, no station attains the ideal of the Act (all samples in Class 3). Instead, stations range very widely in condition, from as low as 160 up to 270, with an average of about 200. This low average score would imply that maximum stocking allowances will have to be reduced, on average, to enable some progress with

the rehabilitative process prescribed by the PLMC Act. As can also be seen, there is no consistent relationship between the present condition of stations and the maximum stock that they are currently permitted to carry. This is in contradiction to the Objects of the legislation which imply clearly that stocking, if it is to be intense, must go hand in hand with the maintenance of a high LCI score.

From the descriptions above it can be seen that the LCI provides a comparative assessment of stations on standardised criteria derived specifically from the Objects of the Pastoral Land Management and Conservation Act, synthesising an overall picture from data provided by means of teams of which none has seen more than a few of the total stations. It thus fulfils its design purpose and can deliver defensible comparative assessments to the Pastoral Board, which has the task of finalising judgments affecting stocking.

Fig. 3 shows the crucial difference between station country as perceived according to the Objects of the Act on the one hand and as perceived through "pastoral production" eyes on the other. For example, station land occupied by salt flats with inedible samphires (Chenopodiaceae tribe Salicorneae) vegetation might score a perfect 3.00 on the LCI scale, for completely satisfying the landcare Objects of the Act, while being intrinsically useless for pastoral production whereas overgrazed and denuded lands (e.g. chenopod shrublands reduced to ephemeral grasslands) of very low LCI score might earn the pastoralist substantial profits as a result of high animal production. The aim of the Act where LCI scores are low is to arrest decline and then reverse it into a long-term trend of ascending LCI scores as a first priority. Any stocking of the lands has to be commensurate with that and be a secondary consideration.

Two major advances in ecological data-collection arise from the LCI sampling program. Since the distribution of the sampling sites is known, and is as close to an even scatter as can be achieved, the data yield estimates of the proportions of the district that are occupied by the various types and components of the rangelands vegetation as well as distribution details. Further, since the condition of the component at each site is recorded, the condition-profile of each rangelands vegetational component can be specified,

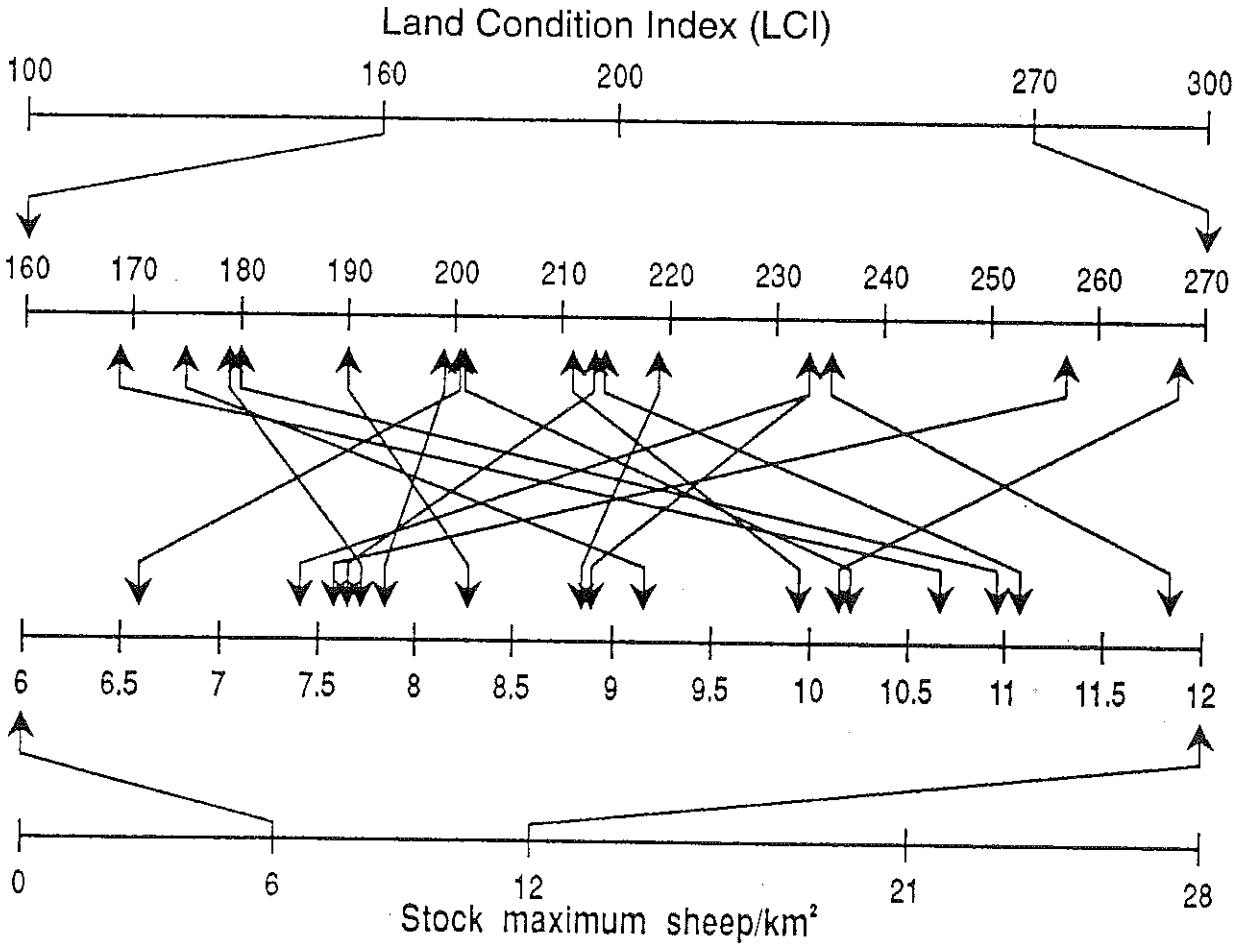

Fig. 3. The prevailing mismatching between stocking allowances amongst leases of the Kingoonya Soil District, South Australia.

revealing the relative degree to which the different types have been degraded. This is important management information. It is upon the basis of data such as these that the Pastoral Land Management and Conservation Act must operate and without which its administration cannot address its legally-stipulated imperatives.

Discussion

Well-reasoned technical prescriptions for landcare in the State's pastoral zone have been available for almost a century. Waite (1896) aimed for a balance between offtake and sustainability via a well-reasoned ecological argument involving land and flock subdivision, waterpoint multiplication, nutrition of lactating ewes, the distances sheep walk, drought strategy, deferred grazing, spelling and economics. Waite's key principles have been firmly linked with good landcare by Lay (1979) on the basis of long-term studies. The most recent managerial prescription (Stafford-Smith & Morton 1990) is little different in principle from the first (Waite 1896) so it is not deficiency of management advice that explains a century of ongoing degradation.

From initial experience with the LCI it now seems probable that most stations in South Australia will fall short of the land condition ideal of the new Act. This means that reclamatory, rehabilitatory action will predictably be required which involves recommendations for reduced stocking levels. We believe that those stations managed in closest accord with the Act (highest LCI) should retain for the present their existing stocking allowances and act as benchmarks for other stations with similar vegetation types but lower indices. These other stations should be given lower stocking limits while rehabilitation programs are initiated. One reason for not recommending stocking allowances higher than at present in any instance (even on stations with highest LCI) is due to a feature of the index itself. In order to guard against likely accusations that the assessment scoring procedures are too severe, they were structured in favour of high LCI scores rather than otherwise. For example, downgrading a saltbush (*Atriplex vesicaria*) shrubland from condition Class 3 to 2 is forestalled while just a scattering of saltbush remain, even though the ungrazed density was many thousand/ha. Thus where even the best-preserved vegetation in an area scores less than the ideal, there is no full compliance with the sustainability notion central to the Act.

In its initial considerations of the first leases assessed by this method in the Kingoonya Soil Conservation District, the Pastoral Board has been reluctant to adjust leases with low LCI scores unless these scores can be directly attributable to current management. Rather, it has indicated it would await an indication of trend from permanent photo-monitoring sites set up at the time the LCI is determined.

Of the many further points that might be made, the one warranting most emphasis here is that the LCI and associated procedures have to be taken against the backdrop of the stringencies, pressures and urgencies that attend it. Those who might regard is as hasty (compared with what has been attempted in some other Australian States) should recall the timeframe. The whole rangelands (40 m ha) must be by law assessed in eight years; this is a formidable and costly task.

Ultimately, however, landcare in the zone will depend not on the assessments but on the determination with which executive government uses the assessment information to ensure that more sustainable land management practices are adopted in our arid rangelands.

References

ADAMSON, D. & FOX, M. (1982) Change in Australian vegetation since European settlement pp.109-146 *In* Smith, J. (Ed.) "A History of Australasian Settlement" (McGraw-Hill, Sydney).

ANDREW, M. H. (1988) Grazing impact in relation to livestock watering points. *Trends in Ecol. and Evol.* **3**, 336-339.

DIXON, S. (1892) The effects of settlement and pastoral occupation in Australia upon the indigenous vegetation. *Trans. R. Soc. S. Aust.* **13**, 195-206.

JACKS, G. V. & WHYTE, R. O. (1939) "The Rape of the Earth. A World Survey of Soil Erosion". (Faber & Faber, London).

LANGE, R. T. (1969) The piosphere: sheep track and dung patterns. *J. Range. Manag.* **22**, 396-400.

_____ (1983) Arid zone landcare: Education and Politics. pp. 112-129 *In* "What Future for Australia's Arid Lands?" (Aust. Conserv. Found., Vic., Aust.).

_____ (1985) Spatial distributions of stocking intensity produced by sheep flocks grazing Australian chenopod shrublands. *Trans. R. Soc. S. Aust.* **109**, 167-174.

LAY, B. G. (1979) Shrub population dynamics under grazing – a long term study. pp. 107-129 *In* Graetz, R. & Howes, K. (Eds) "Studies of the Australian Arid Zone IV. Chenopod Shrublands." (CSIRO, Aust.).

PICK, J. H. (1944) "Australia's Dying Heart" (Melbourne University Press, Oxford University Press).

RATCLIFFE, F. N. (1936) Soil Drift in the Arid Pastoral Areas of South Australia. CSIR (Aust.) Pamphlet No. **64**.

SOUTH AUSTRALIAN GOVERNMENT (1989) Parliament. Pastoral Land Management and Conservation Act. (Govt. Printer, Adelaide).

STAFFORD-SMITH, D. M. & MORTON, S. R. (1990) A framework for the ecology of arid Australia. *J. of Arid. Env.* **18**, 255-278.

WAITE, P. (1896) Pastoral development – past and present. "Adelaide Observer", Sept. 26, 1896 (S. Aust.).

WESTOBY, M., WALKER, B. & NOY-MEIR, I. (1989) Opportunistic management for rangelands not at equilibrium. *J. Range Manag.* **42**, 266-274.