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des sols à l'érosion utilisable à l'échelle du 1 : 25 000.

La superposition de la carte du cadastre agricole à ce document au sein de la base permet de définir les zones sensibles au niveau des exploitations agricoles et de proposer des techniques agricoles appropriées à la gestion durable des sols.

FORTOON: A USEFUL TEACHING TOOL IN LAND EVALUATION FOR FOREST MANAGEMENT

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SUMMARY

Land evaluation requires assessment of the performance of clearly and thoroughly-defined land use types. Such assessment is based on the comparison of inputs and outputs and its projection into the future.

The FORTOON software for forest management provides a library of 64 land use types with their performance on a given land unit assessed in terms of many evaluation criteria. These include vegetation, soil, and socio-economic criteria and their long-term evolution.

The program has proven to be a very useful tool in undergraduate courses in land evaluation, covering some important gaps that have not been properly taken into account in the literature. It stresses the importance of a detailed stakeholder-driven definition of the land use types, and the widely different results that may be obtained when different criteria are used to assess the same land use system.

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1 INTRODUCTION

Land evaluation, as defined in the *Framework for Land Evaluation* (FAO 1976), is the assessment of the performance of specific land units under specific land uses. As a parallel process to soil survey, land evaluation has traditionally strongly focused on the definition of land units (LUs) and associated concepts (land characteristics, land qualities, land requirements). On the other hand, and with notable exceptions, it has paid less attention to the definition of land use types (LUTs), and to the evaluation criteria for matching land use with land (Olarieta 1996).

In many cases, LUTs are still defined in a very general way, *e.g.* farmland, grassland, bush, and forest, or wheat, maize, and potato. The evaluation criterion most often used is maximization of yield or gross margin, in an implicit rather than in a clearly explicit way. That is, no discussion is undertaken to compare the merits of various criteria and it is simply assumed that such maximization is a universal criterion upon which all decisions are taken.

This is the result, in the first place, of the cultural dominance of mainstream economics and its own assumption of universal monetary-profit maximizing behaviour, which has been shown to be a gross simplification of reality (Greenwood 1976, Giampietro *et al.* 1992, Lumley 1997) and to give a very limited picture of the performance of both the land use types and the land units (Behnke 1985, Olarieta 1994). It is also the result of the above-mentioned neglect in the definition of LUTs, which have become abstract concepts in actual practice because they are not derived from specific field work with land users.

Therefore, the actual objectives (*e.g.* improved standard of living, maintain a dairy farming system), and constraints (*e.g.* land, labour, machinery) of these users are not known, and evaluation criteria (*e.g.* increased milk production per cow, increased milk production per hectare, decreased work hours) relevant to these aims and objectives cannot be obtained.

The FAO Framework also requires the assessment of the sustainability of the land use system, *i.e.* the LUT/LU combination, which is related to the long-term projection of inputs and outputs in

terms, for example, of the availability of some inputs, such as energy and fertilizers (Smit *et al.* 1981), or in terms of the evolution of the amount of produce obtained as affected by land degradation (Biot 1988, Moreira 1991, Abel 1997).

It is thus relatively simple, on the basis of empirical data, to prepare exercises for students to work on the effect of land variability on, for example, yield per hectare of a certain land use type. But because few steps have been taken to really make land evaluation multidisciplinary (Olarieta 1996), it is difficult to devise exercises to highlight how, maintaining the same general purpose of the LUT, *e.g.* wood production, changes in management practices, *i.e.* changes of LUT, affect the various possible evaluation criteria. In this paper we discuss a computer program that may be useful to fill this gap.

2 AN OVERVIEW OF FORTOON

FORTOON (Kimmins *et al.* 1997) is an educational forest management software program driven by the FORECAST and FORCYTE series of management models (Kimmins 1993, Seely *et al.* 1999). The latter are hybrid models, partly process-based, partly empirically-based, which have been developed, and tested in different environments, to assess the impact of various forest management strategies on long-term site productivity, particularly in terms of nutrient availability.

FORTOON consists of three modules: a forest management game; an information module on ecology, ecosystems, forestry, soils, *etc.*; and a module to explore different forestry LUTs by forecasting their performance in terms of different criteria. It is with this last module that we have worked as a teaching tool in under-graduate courses in land evaluation.

FORTOON refers thus to only one single land unit and to 64 LUTs. Hence, it is a "closed program", and all the information about the land unit and the 64 LUTs is already in the program.

The FORTOON simulation program works with the DOS operating system, requires a 386 or better PC, and needs about 10 Mb of hard disk storage space.

2.1 The land unit

The forest site or land unit considered is located at low altitude in the south-central part of Vancouver Island, in British Columbia, Canada. It is included in the Dry Subzone of the Coastal Western Hemlock Biogeoclimatic Zone. In terms of moisture and nutrients it is qualified as a medium quality site.

In the biogeoclimatic ecosystem classifications of the various provinces of Canada, and in particular in British Columbia (Pojar *et al.* 1987), such a site includes certain combinations of soil depth, texture, coarse fragments and organic matter content, gleyed horizons and external inputs and soil water movement due to its position in the landscape. It is thus not univocally related to a single soil type, but to various combinations of the above-mentioned site characteristics. In fact, this type of categorical classification seems to provide a better relationship with the growth of various forest species than combinations of analytical variables such as, for example, actual evapotranspiration, water deficit, *etc.*(Klinka and Carter 1990).

This ecosystem has been subject to wildfires every 200-500 years. This disturbance regime has produced forests dominated by commercially valuable Douglas Fir (*Pseudotsuga menziesii* Mirb., Franco), and red alder (*Alnus rubra* Bong.). The main shrub and herbaceous species are salmonberry (*Rubus spectabilis* Nutt.) and fireweed (*Epilobium angustifolium* L.) respectively.

2.2 The land use types

FORTOON contains data on the performance of 64 management options (LUTs) calculated for a period of 240 years on the previously defined land unit. All these LUTs have a common starting point: the Douglas Fir forest has been clearcut the year before the start of the simulation, leaving on the site all the slash and logs with a diameter of less than 20 cm. Two year-old seedlings of Douglas Fir are then planted on the site at a density of 1200 per hectare. It is assumed that salmonberry and fireweed become re-established this same year.

From then on, the 64 LUTs are defined by the combinations of

management options permitted by the program in relation to six broad management areas: tree age at harvest (40 or 80 years), leave or control herb and shrub weeds, leave or control non-crop trees (red alder), thinning or no-thinning of the stand, harvest intensity (whole-tree or stem-only harvesting), and addition or not of sewage sludge.

For example, a certain LUT, hereinafter called LUT 1, involves a tree age at harvest of 40 years, cutting down herbs and shrubs in year 6, controlling red alder (leaving all biomass on the ground), thinning of Douglas Fir to 600 trees per hectare in year 12 (leaving all biomass on the ground), and to 300 in year 30 (the wood is taken away in this case), stem-only harvesting, and applying sewage sludge up to 1000 kg equivalent of nitrogen per hectare after the first thinning and again in years 20 and 30.

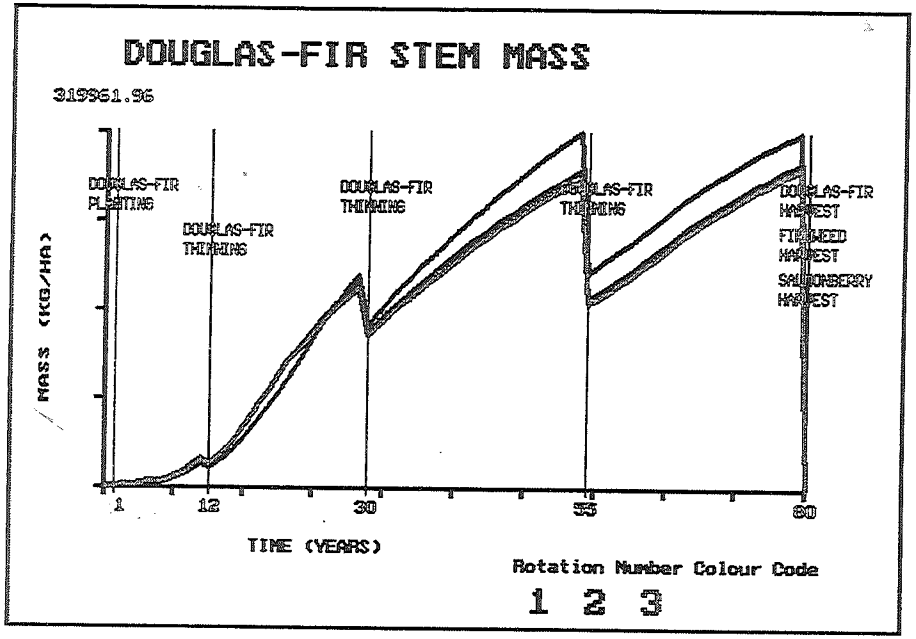
Another LUT, hereinafter called LUT 3, involves a tree age at harvest of 40 years, cutting down herbs and shrubs, not controlling red alder, thinning of Douglas Fir as in LUT 1, whole-tree harvesting, and not applying sewage sludge. And LUT 4, for example, would involve a tree age at harvest of 80 years, not controlling herbs and shrubs, controlling red alder, thinning of Douglas Fir to 600 trees per hectare in year 12 (leaving all biomass on the ground), to 400 in year 30, and to 200 in year 55 (these two would be sent to the saw mill), stem-only harvesting, and not applying sewage sludge.

2.3 The evaluation criteria

The user of the program may choose one of the 64 LUTs included in FORTOON and assess its performance in relation to a wide array of evaluation criteria. In the *Graphical Presentation* mode these criteria are: (1) Douglas Fir stem mass, (2) Douglas Fir foliage mass, (3) red alder stem mass, (4) fireweed foliage mass, (5) salmonberry foliage mass, (6) forest floor mass, (7) humus mass, and (8) an index of nutrient site quality. This mode shows, for the chosen LUT, the variation in the absolute value of these criteria from year 0 to year 240 (Figure 1).

The *Pictorial Visualization* mode shows, for each LUT, eight further criteria: (9) habitat for deer, (10) carbon storage, (11) total organic matter in the soil, (12) available nitrogen, (13) available phosphorus,

Figure 1
Graphical presentation of the results of LUT 4 defined in section 2.2. Each line represents each of the three 80 year-rotations



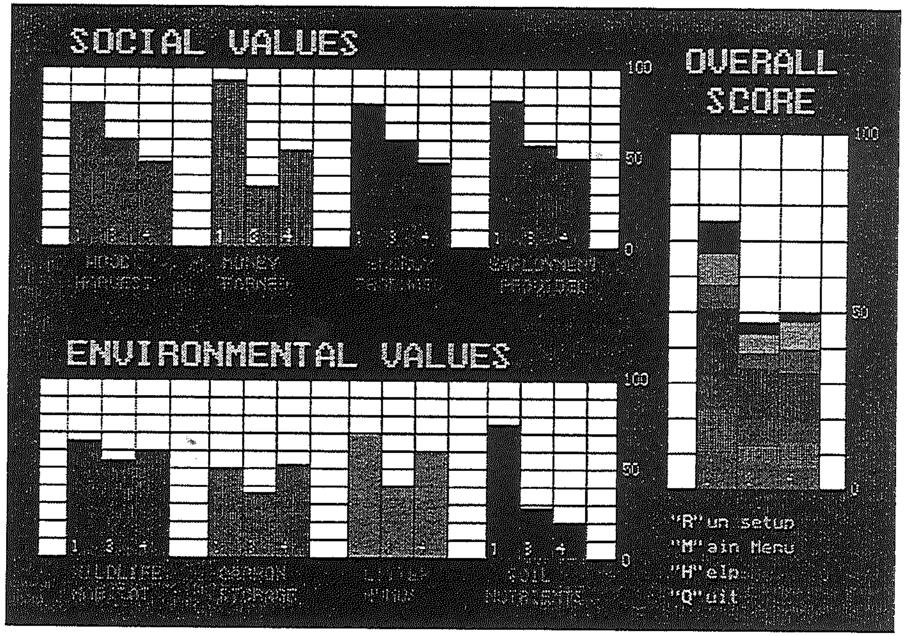
(14) available potassium, (15) wood harvested, (16) money earned, (17) energy produced (assuming part of the wood obtained is used as biofuel), and (18) employment provided. In this case, the time-variation of scores obtained by the LUT for each criterion relative to the maximum attainable with any of the 64 possible LUTs are shown.

The *Analysis of Results* mode represents the same relative scores for these last eight criteria as averages of the 240 years and, simultaneously, for up to 8 of the 64 LUTs. It also shows an overall score for each LUT, calculated as the mean of scores obtained for these eight criteria (Fig. 2).

In the *Comparison of Results* mode, another four evaluation criteria are considered: (19) total site biomass, (20) total site nitrogen, (21) total

site phosphorus, and (22) total site potassium. Again, for each of these criteria, scores relative to the maximum attainable averaged for the 240 years are shown. Qualitative cost-benefit comparisons in monetary and energy terms may also be displayed in this mode for the LUT being analyzed.

Figure 2
Analysis of results for LUT 1, LUT 3 and LUT 4 defined in section 2.2. From left to right, Social Values: wood harvest, money earned, energy produced, employment provided; Environmental Values: wildlife habitat, carbon storage, litter humus, soil nutrients. Within each criterion, bars represent, from left to right, LUT 1, LUT 3 and LUT 4



3 DISCUSSION

FORTOON is limited in the sense that it is a *closed* program that simply provides examples from land use systems in British Columbia. The choice of LUTs is restricted to those already contained in the program, and only one LU is considered. No new LUTs nor LUs may be defined and assessed. Nevertheless, FORTOON complies with the six principles of the FAO Framework for land evaluation, even though it was not designed to do so. And it is strong in those principles which have traditionally been neglected in land evaluation.

It assesses quite precisely defined LUTs, although some details are not specified, e.g. whether shrub and weeds are controlled by hand, or by mechanical or chemical means. In any case, the degree of detail is much higher than is common in the literature on land evaluation.

The choice of LUTs is restricted, though a number of 64 of those seems nevertheless quite satisfactory enough to put forward the idea that defining LUTs in a general way may lead to serious errors. It is neither taken for granted that *all forestry* LUTs result in soil conservation!

The land unit assessed is also explicitly described in varying degrees of detail. Vegetation, general climatic conditions, and some soil properties are clearly defined, but other land components, e.g. geomorphology, are not. This may be considered a minor issue when exercises with FORTOON are complemented with exercises based on traditional land evaluation literature, which usually does stress the importance of land variability and the need for thoroughly-defined land units.

Land evaluation requires the explicit presentation of all inputs (*e.g.* labour, fertilizers, climate, a soil ecosystem with a certain set of properties) and all outputs (the *welcome* harvest as much as the *unwelcome* harvest, *e.g.* kilograms of protein and carbohydrates obtained, runoff and sediments produced, a new soil ecosystem with a set of properties more or less different from the previous one). All these inputs and outputs should be presented in their own units of measure first. Further elaboration into a single metric would involve some kind of value judgment (Olarieta 1994) and a non-trivial loss of information (Vatn and Bromley 1994).

Inputs used and outputs obtained from the LUTs are also specified

in quite some detail in FORTOON, although the step from one to the other remains at a *black-box* level. The forest growth model embedded in the program is empirical and based in experience in British Columbia.

Soil scientists and other land resources specialists might feel squeamish about universal application of the model. For example, the program emphasizes the limiting effect of plant nutrients on forest growth whereas, in drier environments, sufficiency of water may be the key land quality, and different management practices will be adapted to mitigate this constraint.

The inputs, outputs, and evaluation criteria shown by the program reflect a broad view of land use. Money, soil organic matter, mineral nutrients, vegetation, wildlife, employment, energy, and wood are all taken into account. This eclectic list emphasizes the need to develop locally-relevant evaluation systems, which is one of the topics that makes land evaluation such a rich discipline.

Finally, the issue of the sustainability of the land use system is also clearly presented in FORTOON by projecting the effects of forest management 240 years into the future (Figure 1).

Three other important topics are also shown by FORTOON that have encouraged little discussion within land evaluation: how we deal with the time-variability of our evaluation criteria, how we use these criteria to define a unique suitability for a given land use system, or whether this is possible in the first place, and whether comparing two LUTs on a given LU is possible.

The *Graphical Presentation* and *Pictorial Visualization* modes of FORTOON show the time-variation of different criteria (Figure 1), while the *Analysis of Results* and *Comparison of Results* modes work with time averages (Figure 2). The question is: what shall we take into account to define the suitability? the average or whether, for example, a certain criterion is always above a minimum or under a maximum value, or the three simultaneously?

Working with averages gives a static picture of the land use system, whereas we may need to know that, for example, the minimum amount of money earned never falls below a certain level, or that wood harvested never goes over the maximum our saw mill can handle.

If we try to apply the sustainability principle of the FAO Framework and interpret it in terms of a non-declining production of services by the land use system (Hueting and Reijnders 1998), we may face a situation such as that produced by LUT 3, which gives a higher than average mean wood harvest (Figure 2), but shows a declining mass of Douglas Fir stems in the long run (Figure 1). Of course, both parameters are not exactly equivalent, but are used here just to stress the point. Is thus LUT 3 suitable or not-suitable on this LU? Surely there is no universal answer, and even in a given situation each criterion may deserve a particular answer.

We have previously argued that the full picture of the land use system can be appreciated only when all the criteria are explicitly presented in their own right. Others, *e.g.* Vatn and Bromley (1994), prefer a combined index which implies mixing all criteria into one single number or category. For example, the *Analysis of Results* mode in FORTOON gives an overall score for each LUT obtained as the average score for the eight criteria considered (Figure 2).

There is one value judgement implicit in this procedure in that all criteria are given the same weight. But, obviously, this is just one of many possibilities. Relying only on such average score we would conclude that LUT 4 is more suitable than LUT 3, but it would hide the fact that LUT 3 is more suitable than LUT 4 in terms of wood harvest, energy produced, and employment provided.

Similarly, the definition of the suitability class in the FAO Framework requires mixing into one category questions such as, for example, produce and price obtained, inputs and costs involved, labour needed, fossile fuel consumed, soil erosion produced, and nutrient depletion involved. This issue has mostly been ignored by only relying on the yield/gross margin criterion, which does not take into account all these factors, and particularly those related to soil properties. Attempts at taking these into account are based on defining the suitability class on the basis of the yield/gross margin criterion in the first place and then lowering that class if the land use system results in soil erosion (Young and Goldsmith 1977), or on defining the land use system as not suitable if a threshold level of soil loss is exceeded (Purnell 1986).

These approaches also rely on value judgements relating the produce/money obtained to the amount of soil lost. But even the yield criterion may not produce the same results as the money criterion, as can

be seen by comparing LUT 3 and LUT 4 in Figure 2. Furthermore, when using either of the two criteria, there is a value judgement implicit in deciding, for example, that a score of 80% of the maximum mean yield means an S1 suitability class whereas a score of 78% is an S2 class.

Certainly, multi-criteria evaluation procedures can help in handling various objectives and constraints (Van Keulen and Van de Ven 1988, Alfaro *et al.* 1994, Veeneklaas *et al.* 1994), but these procedures also need assigning weights and priorities. And in the absence of a universal theory of value (Meister, 1982; Bromley, 1985), it is not the land evaluator who should make such value judgments, but the individual or social group that bears the responsability for the husbandry of the land use system. Therefore, there can be no definition of the suitability of a particular LUT on a given LU unless this individual or social group explicitly defines the relative weights it assigns to the different evaluation criteria.

This is why we believe that land evaluation should only provide information (Brinkman 1977, Beek 1981, Dent and Young 1981, Smit *et al.* 1981, Purnell 1986, Van Diepen *et al.* 1991) and not become a decision-taking procedure (as some authors suggest, *e.g.* De Gruijter 1996), because decison making comes later (Young and Goldsmith 1977). It should thus avoid making any value judgements and leave the results of the evaluation process, inputs needed and outputs obtained, open to interpretation. In any case, it should certainly not become a procedure of decision making in disguise, and this means stating clear and explicitly the criteria and any value judgements that may be assumed, as well as the reasons why these are relevant to the particular land use system.

It similarly follows that no comparison can be made between the performances of two LUTs. In all probability, one LUT will score better for some criteria while the other will score better for the other criteria. In Figure 2, for example, LUT 3 scores better than LUT 4 for most of the social values, whereas LUT 4 scores better for most of the environmental values. Again, unless the decision-maker has clearly spelt out his or her preferences, and thus the need for interaction with the stakeholders from the early beginning, no conclusion can be obtained in relation to the relative suitability of the two LUTs, unless, of course, one of the LUTs is superior to the other for all the criteria considered (see, for example, LUT

1 and LUT 3 in Figure 2).

A procedure such as FORTOON would enable the interaction of the decision maker with all the relevant data at the point of decision.

4 CONCLUSIONS

We have found the FORTOON program to be a very useful teaching tool because it integrates all the principles of the FAO Framework, and focuses in particular on two important aspects of land evaluation that have traditionally been neglected: it stresses both the need to define land use types as precisely as possible, and to analyse as many evaluation criteria as possible and their projection into the future. Even though the program was developed for forestry courses, students with an agricultural background have no major problems in following it, and the issues that emerge are relevant to all situations.

It also reminds land evaluators that there may be a great deal of information about land evaluation in other disciplines (in this case forest management) - information that does not necessarily use our jargon, but which is using our concepts and actually evaluating land better in some respects than we have been doing it ourselves.

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REFERENCES

Abel N. 1997 Mis-measurement of the productivity and sustainability of African communal rangelands: a case study and some principles from Botswana. *Ecological Economics* 23, 2, 113-134

Alfaro R., J. Bouma, L.O. Fresco, D.M. Jansen, S.B. Kroonenberg, A.C.J. van Leeuwen, R.A. Schipper, R.J. Sevenhuysen, J.J. Stoorvogel &

V. Watson 1994 Sustainable land use planning in Costa Rica: a methodological case study on farm and regional level. In: : L.O. Fresco, L. Stroosnijder, J. Bouma and H. Van Keulen (eds.), *The future of the land. Mobilising and integrating knowledge for land use options*. J.Wiley, Chichester, 183-202

Beek K.J. 1981 From soil survey interpretation to land evaluation. Part 1. From the past to the present. *Soil Survey and Land Evaluation* 1, 1, 6-12

Behnke R.H. 1985 Measuring the benefits of subsistence versus commercial livestock production in Africa. *Agricultural Systems* 16, 109-135

Biot Y. 1988 *Forecasting productivity losses caused by sheet and rill erosion. A case study from the communal areas of Botswana.* Ph. D Thesis No.1. School of Development Studies, University of East Anglia, Norwich

Brinkman R. 1977 In: Discussion of: A. Young and P.F. Goldsmith, Soil survey and land evaluation in developing countries. A case study in Malawi. *Geographical Journal* 143, 432

Bromley D.W. 1985 Recursos y desarrollo económico: un enfoque institucionalista. *Agricultura y Sociedad* 35, 49-75

De Gruijter J.J. 1996 In: Discussion of: D.G. Rossiter, A theoretical framework for land evaluation. *Geoderma* 72, 194-197

Dent D. and A. Young 1981 *Soil survey and land evaluation.* Allen & Unwin, London

FAO 1976 *Un esquema para la evaluación de tierras*. Boletín de Suelos FAO 32. FAO, Rome

Giampietro M., G. Cerretelli and D. Pimentel 1992 Assessment of different agricultural production practices. *Ambio* 21, 7, 451-459

Greenwood D.J. 1976 *Unrewarding wealth. The commercialization and collapse of agriculture in a spanish basque town.* Cambridge University Press, Cambridge

Hueting R. and L. Reijnders 1998 Sustainability is an objective concept. *Ecological Economics* 27, 139-147

Kimmins J.P. 1993 *Scientific foundations for the simulation of ecosystem function and management in FORCYTE-11.* Information Report NOR-X-328. Forestry Canada, Northwest Region, Northern Forestry Centre, Edmonton

Kimmins J.P., K.A. Scoullar, L.L. Kremsater, R. Thauberger and W.C. Waldie 1997 *FORTOON forest management program, version 2.7.* Life Science Programming Ltd, Naramata, British Columbia

Klinka, K. and R.E. Carter 1990 Relationships between site index and synoptic environmental factors in inmature coastal Douglas-fir stands. *Forest Science* 36, 3, 815-830

Lumley S. 1997 The environment and the ethics of discounting: an empirical analysis. *Ecological Economics* 20,1, 71-82

Meister A.D. 1982 *The preservation and use of agricultural land: land use policies and their implementation, a survey.* Discussion Paper in Natural Resource Economics No.5. Massey University, Palmerston North, New Zealand

Moreira J.M. 1991 *Capacidad de uso y erosión de suelos. Una aproximación a la evaluación de tierras en Andalucía.* Agencia de Medio Ambiente, Junta de Andalucía, Sevilla

Olarieta J.R. 1994 Soils in land-use planning: some issues on land evaluation. Paper presented at the 34th Seminar of the European Association of Agricultural Economists, Instituto Agronómico Mediterráneo de Zaragoza

Olarieta J.R. 1996 Información de suelos para la ordenación del territorio. Una discusión metodológica. 367-368 In: *Información de suelos para elsiglo XXI. IV Congreso Nacional de la Ciencia del Suelo.* Universitat de Lleida, Lleida

Pojar J., K. Klinka and D.V. Meidinger 1987 Biogeoclimatic ecosystem classification in British Columbia. *Forest Ecology and Management*, 22, 119-154

Purnell M.F. 1986 Application of the FAO framework for land evaluation for conservation and land-use planning in sloping areas; potentials and constraints. 17-31 In: W. Siderius (ed.) *Land evaluation for land-use planning and conservation in sloping areas.* ILRI Publication 40. International Institute for Land Reclamation and Improvement, Wageningen

Seely B., J.P. Kimmins, C. Welham and K. Scoullar 1999 Defining stand-level sustainability, exploring stand-level stewardship. *Journal of Forestry* 97, 6, 4-10

Smit B. and The Land Evaluation Project Team 1981 *Procedures for the long-term evaluation of rural land.* CRD Publication No.105. University of Guelph, Guelph

Van Diepen C.A., H. van Keulen, J. Wolf and J.A.A. Berkhout 1991 Land evaluation: from intuition to quantification. *Advances in Soil Science* 15, 139-204

Van Keulen H. and G.W. Van de Ven 1988 Application of interactive multiple goal linear programming techniques for the analysis and planning of a regional agricultural development: a case study for the Mariut Region (Egypt). 36-56 In: J.M. Boussard (ed.) *Socio-economic factors in land evaluation.* Commission of the European Communities, Luxembourg

Vatn A. and D.W. Bromley 1994 Choices without prices without apologies. *Journal of Environmental Economics and Management* 26, 129-148

Veeneklass F.R., H. Van Keulen, S. Cissé, P. Gosseye and N. Van Duivenbooden 1994 Competing for limited resources: options for land use in the Fifth Region of Mali. In: L.O. Fresco, L. Stroosnijder, J. Bouma and H. Van Keulen (eds.), *The future of the land. Mobilising and integrating knowledge for land use options.* Wiley, Chichester, pp. 227-247

Young A. and P.F. Goldsmith 1977 Soil survey and land evaluation in developing countries. A case study in Malawi (with Discussion). *Geographical Journal* 143, 407-431