Proceedings of the Land Use Planning Seminar

Land Development Department
Asian Development Bank

PROCEEDINGS OF

THE LAND USE PLANNING SEMINAR

10-11 January 1987

THAILAND DEVELOPMENT RESEARCH INSTITUTE

LAND USE PLANNING PROJECT

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SECTION I -- REPORT OF THE SEMINAR

PROCEEDINGS OF THE SEMINAR

The Thailand Development Research Institute (TRDI) under the sponsorship of the Department of Land Development (DLD) and the Asian Development Bank (ADB) organized a seminar on "Land Use Planning" at the Asia Pattaya Hotel, Chonburi, Thailand, January 10-11, 1987. Fifty-nine participants from various key institutions concerned with land use planning within and outside Thailand participated in the seminar. Appendix 1 contains the list of participants. The seminar's agenda is attached as Appendix 2.

The seminar was opened by Dr. Anat Arbhabhirama, President of TDRI, introducing the issues and policy options for land use planning. In addition, his address set the stage for the seminar by providing a conceptual framework and thematic perspective for the subsequent presentations and discussions. The full text of his speech is contained in Appendix 3.

All the papers that.were presented were based on a previous study conducted by ULG Consultants Limited for the Department of Land Development funded by the Asian Development Bank. The papers were presented by Dr. David Moffatt, Mr. John Shearing, Dr. Tom Chidley and Mr. Mike Pooley.

Nine technical papers, divided into three sessions, each dealing with a related aspect of land use planning, were presented during the seminar. The opening technical paper (appendix 4) dealt with the development of the present concepts of land use planning by reviewing the main types of land use planning systems in use throughout the world. The second technical paper (appendix 5) provided a broad introduction to quantitative land evaluation and introduced the concept of Economic Land Units, these being a redefinition of primary land units. The third paper (appendix 6) concerned an overview of the use of computer technology in land use planning. The fourth technical paper (appendix 7) touched on the application of crop comparative advantage measures, namely financial gross margin; economic gross margin; international value added; domestic resource cost of value added; international competitiveness; and foreign exchange, to land use planning. A model using a common spreadsheet package was presented. The fifth paper (appendix 8) discussed decision support tools in regional and national land use planning. The sixth paper (appendix 9) discussed the integration of decision support tools and optimizing methodologies in land use planning and described a four phase system: database; cost modelling, production function, constraints and requirements; linear program modelling; and post processing of the model's output. The seventh technical paper (appendix 10) gave a very general introduction of the role of Geographic Information Systems (GIS) in land use planning. The eighth technical paper (appendix 11) broadly introduced the use of knowledge based systems for land evaluation. The final presentation (appendix 12) was a brief overview of the proposed project to further develop Thailand's capability in evaluating and planning its land resources.

The fourth session was devoted to various demonstrations of some of the computer models discussed during the presentations.

The fifth and final session was an open discussion. Dr. Smarn Panichapong, DLD, presented a perceptive summary of the seminar and general discussion (appendix 13). The seminar was closed by Dr. Anat Arbhabhirama.

A synopsis of each of the sessions, with the exception of the fourth demonstration session, is presented in the following:

HIGHLIGHTS AND COMMENTS OF SESSION I

Session papers:

Land Use Planning-Development of the Concept (Appendix 4)

Introduction to Quantitative Land Evaluation (Appendix 5)

Computer Technology for Land Use Planning-Appropriateness to Thailand (Appendix 6)

The first technical paper, "Land Use Planning-Development of the Concept", traced the growth of the present concepts used in land use planning. This paper reviewed the three main land use planning schemes: Land Capability Classification of the US Department of Agriculture; the Irrigation Suitability Classification from the US Department of the Interior; and the Framework for Land Evaluation from FAO. Strengths and shortcomings in each were examined. It was pointed out that the Framework, although well accepted internationally, was nonetheless based on limitations rather than benefits. In order to progress from the evaluation of physical characteristics to the possible benefits derived from any land units, it is necessary to introduce the concept of Economic Land Units (ELU). The ELU would embody physical characteristics of the land as well as infrastructure, current land use, land tenure, and other socio-economic aspects. Possessing these data would allow the appraisal, by economic measures, of other possible land uses.

A point was raised during the discussion of this paper concerning the input of ecological constraints into the ELU concept. Although the notion of an ELU includes economic factors it is firmly based upon a Primary Land Unit (PLU) which incorporates the physical constraints so that the ELU concept was not divorced from ecological factors.

This session's second technical paper, "Introduction to Quantitative Land Evaluation", sought to further acquaint the participants with the concept of an ELU and the quantitative aspects of land evaluation. It was pointed out that basing a land evaluation system simply on the matching of a crop's physical growth requirements with areas of land was an over simplification of an extremely complicated situation. Actual benefits derived from growing a crop at a specific location involve not only a relationship between yield potential and direct inputs but also include socio-economic factors such as subsistence requirements, land tenure, customs and beliefs, infrastructure and market opportunities. The land evaluation process usually involves a two step method: the inaugural step includes a first approximation based on physical criteria to obtain a catalogue of possible alternative land uses, in the following step the most promising possible land uses are further investigated financially and economically to determine the most practible and optimal land use.

During this paper's discussion, questions regarding the collection and input of intangible data such as information on soil erosion and of a farmer's "willingness to pay for soil conservation measures" arose. The author pointed out that this type of data can be quantified, at least to some extent, by rigorous collection through field surveys and interviews. Further questions were raised concerning the problem of falling commodity prices with increased supply of farm goods and its impact on land evaluation. In order to resolve this price fluctuation problem, some form of government control of marketing and pricing would need to be implemented in order to guarantee that individual farmers would have sufficient incentive to continue with certain land use patterns that were thought to hold economic benefits for the country as a whole.

The final paper of this session "Computer Technology for Land Use Planning-Appropriateness to Thailand" provided a short overview of computer and remote sensing technology suitable for use in the land use planning process. It was pointed out that while the cost of raw computing power, the hardware, has fallen dramatically with time, the cost of the software to take advantage of it has risen. This has been paralleled by the increase in the power and resolution of image processing and remote sensing technology.

The various methodologies and technologies for spatial data capture and manipulation were summarized. Of importance to land use planners is the increasingly "user-friendly" nature of the computer tools available to him. This allows their use without the land use planner necessarily becoming a computer expert. Another aspect of computer technology relevant to land use planning is the area of artificial intelligence (AI) and expert systems. Where previously only facts were stored in a computer, it is now possible to store knowledge enabling the user to phrase his enquiries in a more natural fashion.

A tentative survey of present computer use within the Royal Thai Government (RTG) agencies concerned with land use planning was made. It indicated that while many RTG agencies have made good progress in the use of computers for land use planning it is still very much in its infancy. It was recommended that this aspect of land use planning be further developed. Future prospects are very bright in that a number of universities are involved with computer usage and should produce an adequate supply of computer scientists and computer-literate graduates needed for land use planning.

Several participants raised the issue that much of the data collected here in Thailand was being under utilized. It was pointed out that a computer based land use planning system would address this very problem and go a long way towards making the data already collected more widely and more efficiently used. One comment contrasted the way computers are presently being used in Thailand, mainly for administration, to the way they would be used for GIS work. It was put forward that the main customers of a computerized system would be the technical advisors to planners and decision makers. Some technical policy points were also raised concerning the need for a national database and the need to establish networks between the various existing and planned databases. Most of the participants were of the view that any GIS used should contain data import and export facilities. Several participants commented strongly on the need for a small pilot study prior to Thailand committing itself to any GIS on a large scale.

HIGHLIGHTS AND COMMENTS OF SESSION II

Session papers:

The Application of Crop Comparative Advantage Measures in Land Use Planning
(Appendix 7)

Case Study in Using Decision Support Systems in Land Resource Planning
(Appendix 8)

Integration of Decision Support Tools and Optimising Methods in Land and Water Resource Planning
(Appendix 9)

The opening paper of this session "The Application of Crop Comparative Advantage Measures in Land Use Planning" illustrated the methodology of assessing comparative advantage as a tool in allocating resources for agriculture. A simple model based on spreadsheet package that could be run on a standard microcomputer was used as an example. The methodology outlined provides the planner with means of scrutinizing the correlation between financial (short term, producer level) and economic (long term, national level) measures of comparable but different advantages. In light of Thailand's present foreign exchange situation, it stressed the importance which must be given to generating foreign exchange through export or import substitution. A review of several crop comparative advantage measures output from this model; financial and economic gross margin, international value added, the domestic resource cost of international value added, international competitiveness and foreign exchange dependence along with their application to various cropping systems was presented.

Example output from this model was the subject of much discussion among the participants. It was thought that this model did not incorporate sufficient price elasticity and that it would be difficult to explicitly input labor costs and to associate them with any proposed ELU. Further clarification of the model's built-in production functions was also felt to be needed before its utility could be accepted.

The next technical paper of this session "Case Study in Using Decision Support Systems in Land Resource Planning" presented an example of the use of readily available, low cost computer tools in land resource planning. The system used was based on a spreadsheet package and was readily programmed using techniques in its "macro" command language. The package also had the facility to "remember" the steps involved in constructing the model, allowing the model to be easily re-run or modified by the user. This demonstrated one of the previously made points concerning the ease of use of computers by non-expert users. A complete, detailed description of the data and the programming "macros" used in the model was presented. The model itself was based on relatively simple matrix algebra.

Comments from the participants indicated that they felt that the results from this case study were not conclusive and further tests with actual field data were necessary. Particular attention should be paid to what particular crops to promote as results from this model seemed inaccurate in the face of specific evidence from the field.

The third paper of the session "Integration of Decision Support Tools and Optimising Methods in Land and Water Resource Planning" presented a hypothetical example that was based on a real situation of the use of up-to-date decision support tools. The system presented consisted of two relatively affordable pieces of software, a spreadsheet and a linear programming package. The spreadsheet acted as a front end processor to produce the matrices used by the linear programming package. The results were in turn passed to a post-processor spreadsheet for final analysis. Cost models, resource and policy constraints were computed as "what if" analysis. The basic size of this particular tableau was 230 variables by 200 constraints, which allowed about 80% of the agricultural economy of the country in question to be modelled. The model also permitted an estimation of the costs of political decisions.

During this paper's discussion several comments stressed that this model had yet to be tested in Thailand. Doubts were expressed over its validity to local conditions. It was suggested that the model be rigorously tested before it be applied.

HIGHLIGHTS AND COMMENTS OF SESSION III

Session papers:

A Review of Geographic Information Systems, Considering Their Role in Land Use Planning For Thailand
(Appendix 10)

The Role of Intelligent Knowledge-Based Systems in Land Evaluation for Thailand
(Appendix 11)

Project Proposals
(Appendix 12)

The first paper of this final technical paper session "A Review of Geographic Information Systems, Considering Their Role in Land Use Planning For Thailand", provided a very brief review of the field of Geographic Information Systems (GIS). Some specific systems were reviewed to illustrate the major principles of GIS.

The possible components of a typical GIS might consist of:

- spatial databases (locational or geographical data),
- attribute databases (specific non-geographic data associated with a line, point or area in a GIS),
- an image processing system (remote sensing data or automated map data capture by digitizing cameras or line followers),
- text scanner (similar to image processing system but has the ability to recognize text characters on paper and transfer them to computer storage),
- economic models as outlined in the previous technical papers,
- map production system.

Many comments concerned with the technical aspects of a GIS were made. A common question raised concerned the minimum size of the hardware required to implement a useful GIS. It was thought by some participants that a mini or mainframe sized computer was necessary while others argued for microcomputers as the most cost effective GIS particularly in light of the rapidly increasing power and speed of microcomputers especially the newer 32 bit models and their relatively low maintenance costs.

Another common comment dealt with the actual data structure of the GIS database, raster (regular grid cell data structure) versus vector (data structure that encodes line and area information in the form of units expressing magnitude,direction and connectivity) The general consensus was that a vector data structure was the most technically sound as it could be rasterized (converted to raster form) at a later time and offered the best accuracy and storage requirements.

It was generally agreed among the participants that Thailand was in need of some form of GIS but that it should not rush into the acquisition of a full scale one. It was felt that the usefulness of a GIS to Thailand was largely unproven so as to make any large scale investment risky. Rather a limited pilot study of a specific and well understood land use planning problem should be undertaken to rationally appraise any potential problems and assess the cost/benefits of a GIS to Thailand. One possible problem suggested as a pilot study was the application of a GIS to the selection of potential oil palm area in southern Thailand.

The second paper of this session "The Role of Intelligent Knowledge-Based Systems in Land Evaluation for Thailand" further developed the idea of artifical intelligence (AI) applications to land use planning. The idea of automating the land evalution or classification task through the use of expert sytems was introduced. The use of natural language front ends (simple English-like commands) to a GIS database would also allow the non-computer oriented land use planner easy access to needed data. Alternatives to actually programming the expert system, such as expert system shells were recommended. A prototype land evaluation system embodying many of the principles of AI, developed for Rayong province, was discussed.

A main concern of the participants was the actual value and accuracy of expert systems for use in land use planning. It was suggested that AI techniques were generally only used in academic research but rarely to solve "real world" problems. The need for further testing and practical problem solving research was indicated.

The final paper of this session concerned the proposed project. A very brief overview of the project's main components and main benefits to Thailand was made. Some discussion revolved around the allocation of various resources within the project plan. Many comments questioned the cost of the proposed system, and whether it would become rather open-ended. It was stressed that the purpose of this seminar was to gather information and provide a forum to exchange ideas concerning the improvement of land use planning techniques in Thailand rather than to pass judgement on specific proposals.

The general feeling was again that Thailand was in need of a GIS but caution was urged. A series of small pilot projects were suggested as an effective means of evaluating GIS for its appropriateness to Thailand.

SUMMARY OF THE GENERAL DISCUSSION, SESSION V

GIS has been debated in Thailand for well over a decade now. However, nothing specific has been resolved to date. Land related data has been collected in Thailand by different agencies for a number of years. The difficulty is that such information is rarely shared and whenever shared it is generally not in a format that allowed the data to be readily used. What is required now is a strong national policy to promote a concerted effort among the user agencies in sytematically executing a workable GIS program in a cost-effective manner.

Various agencies concerned with land related information have been trying to establish their own data bases. Some agencies are carrying out feasibility studies and pilot projects, for example the Bangkok Metropolitan Authority (BMA) and the Soil Information System (SIS) within the Department of Land Development (DLD) SIS is also developing a microcomputer-based national soil use information system. New technologies are also being introduced for map production. Concurrently the Land Department is establishing a land titling document database.

In spite of these starts a number of issues remain to be answered:

1) A primary concern among the line agencies involved with land use planning is the lack of appropriate computer hardware and software. In some instances hardware has been acquired without regard to its applicability to GIS. In some other cases hardware appropriate to GIS has been acquired but the associated software was not.

2) In establishing a workable GIS a massive quantity of data needs to be collected, verified and analysed before it can be readily applied to land use planning. Data collection today is being done in a non-standard fashion. This prevents the exchange of related data between government agencies. Such data is invariably in a format that is difficult or impossible to work with by the common user.

3) In general, personnel experienced in establishing or using a GIS is lacking. Just as with most other forms of complicated technology, a GIS needs to be used and operated by a trained staff. Provisions must be made for the retraining of present staff and the hiring of new staff. Above all staff must be motivated to familiarize themselves to take advantage of this new tool.

4) The organizational aspects of a GIS have not been fully considered. There is no clear cut division of responsibilty between governmental agencies concerning land related data. Within governmental agencies there is rarely any serious

consideration of the ways in which a GIS will interact with the rest of the organization. The positive aspects of establishing and using a GIS, the challenge of a new technology and the rapid reduction of the problems in manually analysizing spatial data, have not been fully emphasized. Efforts must be made to improve inter-agency and intra-agency cooperation as this seems to be a key stumbling block.

5) In general, there are three main funding problems related to the establishment of a GIS. Firstly, budget is very limited. Secondly, the continuing funding needed to maintain or upgrade any GIS is also severely limited. Finally, existing budgets are at times not used effectively. Extreme budgetary limits placed on initial purchases or regular maintanence will most likely lead to later problems with the day-to-day usage of the GIS system.

6) The above issues can all be related directly to the lack of a clear national policy on GIS. User agencies have yet to be clearly catagorized. Their tasks have not been fully delineated nor has the scope of each of the individual applications involved. A strong policy statement on GIS is required prior to it's establishment on any large scale.

On the positive side it was reiterated time and again that the users, especially at the provincial level, were very willing to test and make use of a GIS to assist them in their land use planning. However, the consensus was that the tools available were not sufficiently tested here in Thailand. Numerous calls were made for a pilot study to systematically assess the potential problems and benefits of a GIS to Thailand.

The consensus was that a GIS would be a valuable tool for national planning purposes. A prerequisite to its successful implementation here in Thailand would be rigorous testing of the GIS and any of the associated financial or economic models. It should be developed in a systematic manner involving all of the line agencies dealing with land use planning notably, DLD, BMA, the Ministry of Interior (Department of Lands), and local administrations at the provincial level.

SECTION II -- APPENDIXES

Appendix 1

LIST OF PARTICIPANTS

I. **Local Participants** (listed alphabetically by fist name)

1. Dr. Anat Arbhabhirama
   President
   Thailand Development Research Institute (TDRI)
   Bangkok, Thailand

2. Dr. Anucha Chintakanond
   National Institute of Development Administration
   Bangkok, Thailand

3. Ms. Benchawan Srangnitra
   Office of the Civil Service Commission
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4. Mr. Boonsong Sabhasri
   Royal Forestry Department
   Bangkok, Thailand

5. Mr. Boonyok Vadhanaphuti
   Royal Irrigation Department
   Bangkok, Thailand

6. Mr. Chakrit Manotham
   Land Development Department
   Bangkok, Thailand

7. Ms. Chalinee Niamskul
   International Board for Soil Research and Management
   Bangkok, Thailand

8. Dr. Churai Tapwong
   National Economic and Social Development Board
   Bangkok, Thailand

9. Mr. Dacha Vanichvarod
   National Economic and Social Development Board
   Bangkok, Thailand

10. Dr. Darasri Srisaengthong
    National Research Council
    Bangkok, Thailand

11. Dr. Dhira Phantumvanit
    Thailand Development Research Institute
    Bangkok, Thailand

12. Mr. Mongkol Chuntrapen
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Bangkok, Thailand

13. Dr. Nipon Tangtham
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Bangkok, Thailand

14. Mr. Niwat Chatikanond
Royal Forestry Department
Bangkok, Thailand

15. Mr. Ob Preeyagrysorn
Royal Forestry Department
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16. Mr. Padege Srijan
Land Development Department
Bangkok, Thailand

17. Dr. Pairat Decharin
Governor
Chainat Province, Thailand

18. Mr. Paisan Impat
Land Development Department
Bangkok, Thailand

19. Mr. Paitoon Pootasri
Land Development Department
Bangkok, Thailand

20. Mr. Palakorn Suwanrath
Office of Policy and Planning, Ministry of Interior
Bangkok, Thailand

21. Mr. Pittayapol Nattaradol
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22. Mr. Pongsant Srijantr
Kasetsart University
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23. Ms. Poonsin Wongkoltoot
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24. Mr. Pramuan Satarath
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25. Mr. Pravit Ruyaporn
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26. Mr. Rawee Tahtniyom
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Bangkok, Thailand

27. Dr. Samarn Panichapong
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28. Mr. Sanarn Rimwanich
Land Development Department
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29. Mr. Silpasit Tivayanonda
Thai Military Bank
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30. Ms. Siriporn Sagetong
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31. Mr. Somjet Taracoop
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34. Dr. Sujin Jinahyon
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35. Mr. Sunya Souvapap
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41. Dr. Tongroj Onchan
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II. **Foreign Participants** (listed alphabetically by last name)

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49. Mr. Paul Hastings
Bangkok, Thailand

50. Mr. Quill Hermans
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51. Mr. Will Knowland
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58. Mr. Charlie H. Weir
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59. Mr. Rob Wiles
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Thailand Development Research Institute Staff

Responsible for the seminar secretariat

1. Mr. Adis Israngkura
2. Ms. Benjawan Wiriyachaisirikul
3. Ms. Chuchitt Sombunthawong
4. Ms. Noppawan Matawattananun
5. Ms. Santivipa Panichakul
6. Mr. Surachai Chaiyawattanakijja
7. Ms. Surangkana Techakupta

Appendix 2

AGENDA OF THE SEMINAR

"LAND USE PLANNING"

10 - 11 January, 1987
Asia Pattaya Hotel, Pattaya, Chonburi

January 9, 1987 (Friday)

p.m. 04.00-09.00	Registration/Check in Hotel

January 10, 1987 (Saturday)

a.m. 8.00-9.00	Registration
9.00-9.30	Opening Address Dr. Anat Arbhabhirama President, TDRI

SESSION I: **Introduction**

Chairman :	Mr. Sanarn Rimwanich Director General Land Development Department
Rapporteur :	Mr. Sopon Chomchan Land Development Department
9.30-10.00	Land Use Planning-Development of the Present Concepts Dr. D. J. Moffatt
10.00-10.15	Coffee Break
10.15-10.45	Introduction to Quantitative Land Evaluation J. D. Shearing
10.45-11.15	Computer Technology for Land Use Planning-Appropriateness to Thailand Dr. T.R.E. Chidley
11.15-12.00	Open Discussion
12.00-1.30	Lunch

SESSION II: Land Use Planning

Chairman :	Mr. Pravit Ruyaporn Secretary-General, Office of the National Environment Board
Rapporteur :	Dr. Dhira Phantumvanit Associate Director, Natural Resources & Environment Program, TDRI
m. 1.30-2.00	The Application of Crop Comparative Advantage Measures in Land Use Planning J. D. Shearing
2.00-2.30	Applying Decision Support Tools to Regional and National Land Use Planning J. D. Shearing and Dr. T.R.E. Chidley
2.30-3.00	Integration of Decision Support Tools and Optimising Methods in Land and Water Resources Planning Dr. T.R.E. Chidley and J. D. Shearing
3.00-3.15	Coffee Break

SESSION III: GIS and Proposed Project

Chairman :	Dr. Wicha Jiwalai Deputy Governor, Bangkok Metropolitan Administration
Rapporteur :	Dr. Dhira Phantumvanit
3.15-3.45	A Review of Geographic Information Systems, Considering Their Role in Land Use Planning For Thailand M. Pooley and Dr. T.R.E. Chidley
3.45-4.15	Role of Intelligent Knowledge Based Systems for Land Evaluation M. Pooley and Dr. T.R.E. Chidley
4.15-4.45	Proposed Project - Development of Information Technology - Improving Data Inputs - Support for Systems Development - Organization and Management Dr. D. J. Moffatt and Dr. T.R.E. Chidley
4.45-5.30	Open Discussion
7.00	Dinner Reception

January 11, 1987 (Sunday)

SESSION IV: Demonstrations

a.m.	8.30-11.00	Demonstrations : Computer Technology for Land Use Planni
	11.00-11.15	Coffee break

SESSION V: Summary & Conclusion

	Chairman :	Dr. Anat Arbhabhirama
	Rapporteur :	Mr. Sopon Chomchan
	11.15-11.30	Summary of Key Points from the Presentations Dr. Samarn Panichapong
	11.30-13.00	Open Discussion Dr. Anat Arbhabhirama
p.m.	13.00	Conclusion and Closing
	13.10	Lunch

OPENING ADDRESS

by

Dr. Anat Arbhabhirama

On behalf of Thailand Development Research Institute I would like to thank all participants. This seminar is an outcome of the study on Land Resource Evaluation, sponsored by the Asian Development Bank, which commenced in early 1986. This seminar intends to explore new techniques which might be adopted for land use planning in Thailand. It consists of both presentations of the conceptual framework and some demonstrations of computer models that were developed. With specialists and those concerned in the country's land development issues participating in this seminar, I am confident that we all can explore the possibility of implementing such techniques in Thailand.

In the past year TDRI conducted a study on Land Policy and has made recommendations in four areas:

1) **Land Policy for Economic Objectives**

   Regarding land use for economic purposes, the land in Thailand can be classed into two main parts: land within the forest and land outside it. Relevant policy for land outside the forest deals with: land rights, land tax, agricultural zoning, farm development strategies, soil conservation and urban land use. For land within the forest, 40% of the country's land should be reserved. Within this amount, 25% of the country's total land should be commercial forest. Other relevant policies include degazettment of already occupied national forest and the development of mangrove forests.

2) **Land Policy for Social Objectives**

   At present about 12 million people are experiencing problems about land for their livelihood. Land is being distributed to these people by a number of agencies: Agricultural Land Reform Office, Public Welfare Department, the Cooperatives Promotion Department and the Royal Forestry Department to name just a few. There is a need to minimize differences between these agencies as well as speed up implementation.

3) Land Policy for Conservation

Forest policy has set aside 15% of the country's land for conservation. Headwater areas are to be protected. Reforestration should be accelerated. A national plan for the development of park areas is also needed.

4) Land Policy for National Security

Land areas should be set aside for military purposes. Border settlements should be encouraged so as to promote national security.

Additionally land policy related to the special conditions of Thailand's hilltribes must also be dealt with.

In retrospect, there exists a lack of clear delineation of responsibility among public agencies whose tasks involved the development of land resources.

For instance, the National Economic and Social Development Board is involved in promoting development projects according to the Five Year Development Plan, the Department of Land Development conducts surveys and land evaluation, the Royal Irrigation Department focuses on land resource development with respect to irrigation, the Royal Forestry Department deals with afforestation and forest villages, the Department of Lands is responsible for land titles while the Department of Public Welfare targets land allocation for cultivation purposes. Even though these activities are being conducted by different agencies they are in fact all interdependent.

I believe that there is a need for a central agency who is responsible for integrated land use planning. Problems that continually arise because of its absence are:

1) Unsuitable land use i.e. land suitable for rice cultivation is being used for other activities or vice versa.

2) Failure to maximize the economic benefit from land resources i.e. the yield per rai in Thailand is relatively low in comparison with other countries.

3) Resources deterioration i.e. cultivation on steep slopes resulting in soil erosion, sedimentation and soil salinity in the Northeast Region.

4) Conflicts in land use both economically, socially and politically i.e. the use of the coastal zone for aquaculture vis-a-vis mangrove plantation.

There are three requirements which one might consider when applying new techniques to the country's land use planning:

1) Infrastructure development - i.e. dams, canals, roads. Land use pattern will change dramatically depending on the type of infrastructure being implemented;

2) Land suitability - should be based on soil characteristics as well as crop requirements.

3) Economic Returns - any system implemented must above all provide economic benefits beyond mere subsistinence levels.

The essence of this seminar is to address the important factors influencing land use planning and to discuss how these factors might contribute towards land use planning, how computer facilities might assist in this regard, in what area can the new techniques developed help the planners and who will be using these techniques.

Finally, on behalf of Thailand Development Research Institute, I'd like to express my appreciations to the Asian Development Bank and the Department of Land Development for the support and to all participants who have come to contribute to the success of this seminar.

LAND USE PLANNING-DEVELOPMENT OF THE CONCEPT

Dr. D.J. Moffatt

1. DEFINITION

The function of land use planning is to guide decisions on land use in such a way that the resources of the environment are put to the most beneficial use for man whilst at the same time conserving those resources for the future (FAO, 1976). The rational planning of the agricultural land use requires the close integration of a large number of factors. These include the physical resources, social and economic conditions, current land use patterns, current or attainable levels of technology and management, regional, national and international demands for agricultural produce, and a range of features which contribute to the infrastructure support of agriculture. In the long term it must take account of the competiting demands for land, water, human resources and finance, for non-agricultural activities.

2. TRADITIONAL APPROACHES

Decisions about land use in the past were made by individual farmers. The evaluation procedure was one of subjective judgment based on incomplete information but often incorporating a high degree of skill born of experience. Where judgment erred, trial and error supervened. It was by such means that the cultivation of particular crops became established long before scientific knowledge of climatic and soil conditions existed. The need for more formalized land use planning has arisen with the development of a more complex social, economic and political environment, the increasing scarcity of land and the advances in technology which increase the options for using a particular tract of land.

These factors have led to the development, particularly during the last 40 years, of systems for classifying and evaluating land. Many local, national and international systems have been devised which were appropriate to the prevailing needs and circumstances, and to the level of knowledge and analytical capability available at the time. Two systems, both developed in the United States, have formed the basis of many land classification systems throughout the world. These are described here as typifying the traditional approaches to land evaluation.

2.1 **The USDA System**

The Land Capability Classification used by the Soil Conservation Service of the United States Department of Agriculture (Kligebial and Montgomery, 1961) illustrates many of the principles of traditional land classification, and many local and national schemes have been based on adaptation of it. The following review of this is drawn from Young (1973): The USDA system is an interpretative grouping of soil mapping units primarily for agricultural purposes. Soil is in fact taken in its wider meaning of land, since slope angle, climate and frequency of flooding are taken into account. The main concept used in that of limitations, restrictions upon the type of land use or the land potential. A distinction is made between permanent and temporary limitations. Permanent limitations are those which cannot be altered, including slope angle and soil depth; temporary limitation include low soil fertility and minor drainage impedance, each of which can be modified by land management. Land is classified mainly on the basis of permanent limitations. The level of management assumed is that 'within the ability of a majority of the farmers', a mode of definition that enables the application of the scheme to be modified according to farming standards in different countries.

a) The Structure of the USDA System.

On a basis of soil mapping units, there is a three-category structure.

- A capability unit is a grouping of soil mapping units that have the same potential, limitations and management responses. All soils within a given capability unit can be used for similar crops, require similar management practices and soil conservation measures, and have a comparable productive potential; specifically, the yield range of a crop within a capability unit is not expected to exceed 25 per cent.

- A capability subclass is a grouping of capability units that have the same kinds of limitation or hazard. These kinds are indicated by letter subscripts, of which in the original system there are four: erosion hazard (e), excess water (w), soil root-zone limitations (s) and climatic limitations (c) Later modifications of the scheme commonly employ additional kinds of limitation (e.g. stoniness, low fertility, salinity).

- A capability class is a grouping of capability subclasses that have the same relative degree of limitation or hazard. Classes are indicated by Roman numerals, the limitation to the type of land use and the risks of damage to the environment increasing from Class I to Class VIII.

The following are abbreviated definitions of the the capability classes:

Class I	Soils with few limitation that restrict their use.
Class II	Soils with some limitations that reduce the choice of plants or require moderate conservation practices.
Class III	Soils with severe limitations that reduce the choice of plants or require special conservation practices, or both.
Class IV	Soils with very severe limitations that restrict the choice of plants, require very careful management, or both.
Class V	Soils with little or no erosion hazard but with other limitations impractical to remove that limit their use largely to pasture, range, woodland or wildlife food and cover. (In practice this class is mainly use for level valley-floor lands that are swampy or subject to frequent flooding.)
Class VI	Soils with very severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland or wildlife.
Class VII	Soils with very severe limitations that make them unsuited to cultivation and restrict their use largely to grazing, woodland or wildlife.
Class VIII	Soils and landforms with limitation that preclude their use for commercial plant production and restrict it to recreation, wildlife, water supply or aesthetic purposes.

b) Relationship within the USDA System.

The main features of this system are: its three-category structure; that it is based on negative limitation rather than positive potential; and that the class to which land is allocated is strongly influenced by considerations of soil conservation. At the class level it results in a single ordering of relative value, with a major distinction between cultivable and non-cultivable land between classes IV and V. It implicitly assumes a decreasing order of value from arable use through to grazing and forestry to recreation, wildlife is only valid where these relative priorities hold good.

Features of location, such as the distance to markets, are explicitly left out of consideration. No account is taken of the scarcity value of a particular type of land in a given location, a factor which in certain circumstances can greatly modify land values. For example, the headwater catchment area of a river in a region of savanna climate serves to maintain rural water supplies for large area downstream; a cliff suited to rock-climbing located near a large city in a lowland area acquires a recreational value out of all proportion to its inherent characteristics. The meaning of subclass letters changes according to the class to which they are attached. Thus the 'e' in Subclass IIIe indicates a more severe erosion hazard than that in IIe. With the exception of soil depth, the original system does not give precise limits for subclass and class allocation. This lack of precise criteria for the environmental parameters permitted in each class could lead to subjectivity and looseness of definition. However, there is an objection is principle to the use of rigid limiting values, in that the effect of an individual environmental factor varies according to its interaction with others. Thus erosion hazard is not a function of slope angle alone, but of the combined effects of slope angle and length, soil permeability and structural aggregation, and frequency and intensity of rainfall. Even more complex are the effects of soil texture, which involve root growth, moisture retention, and rate of leaching losses. It is impossible to say that in all environments clays are more valuable than sandy soils or vice versa. The lack of precise criteria imparts flexibility to the USDA system, enabling it to be adapted to local conditions, where particular properties are of special significance in rating land value; an example is the importance of soil-moisture retention in the climatic zone between the savanna and semi-arid environments.

It is not clear how the climatic limitation is to be interpreted in the USDA system, nor does it deal satisfactorily with wetlands. Wetness is classed on the basis of 'continuing limitation after drainage', measures considered practical at the present day. It is necessary to specify whether classification is on the basis of such drainage works as can be undertaken by the individual farmer, or whether a regional drainage scheme is under consideration. A special difficulty that arises in the humid tropics is that potential paddy cultivation has totally different requirements from other forms of annual cropping.

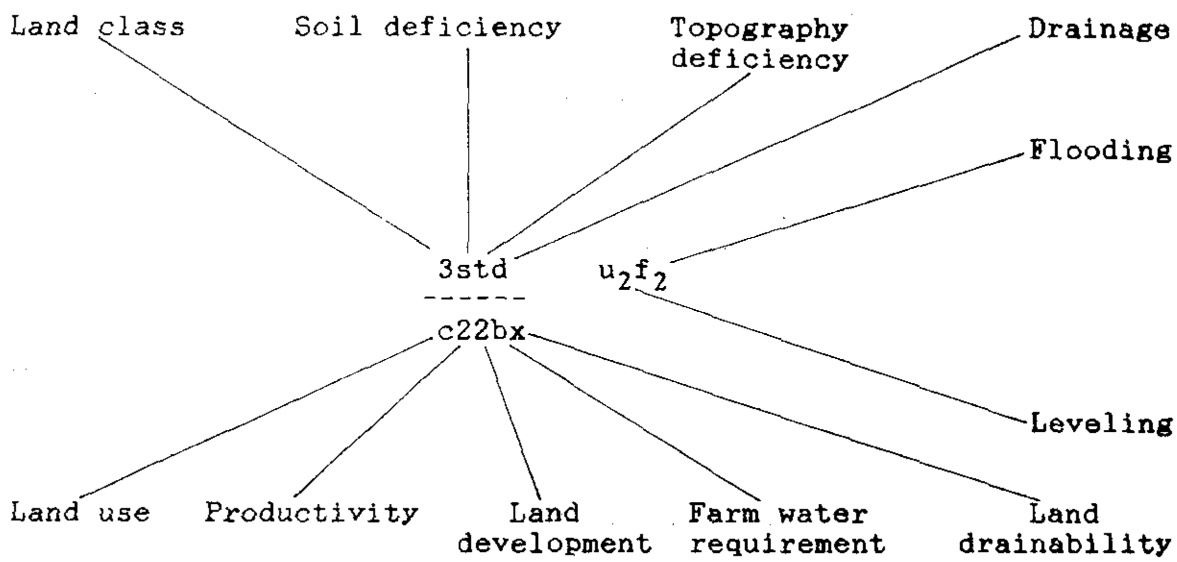
An important feature on which the system is not explicit is the extent to which economic considerations are taken into account. There is certainly some economic element, implied in the reference to 'practicable' measures for the removal of temporary limitation, and specifically noted in a reference to the need for a favourable input/output ratio to the farmer. Precise farm costing, however, is not attempted.

2.2 **The USBR System**

The system of the U.S. Bureau of Reclamation (U.S. Department of Interior, 1953) is specifically for the classification of potentially irrigable land. It is again based on the limitation of the land rather than its positive qualities, but it contains precise local specification for the permitted range of values within each land class. Costs of management and amelioration measures are taken into account. Land Classes 1-3 have progressively less repayment capacity for development under irrigation; Class 4 is special-purpose land; Class 5 is non-arable at present but could become arable if some major works were undertaken, and Class 6 is non-arable.

In a given project area, specific limits of soil properties and other parameters are set up to segregate the the different classes. In the western part of the United States, soils suitable for use with sustained irrigation have permeable profiles with hydraulic conductivities ranging from about 0.05 to 5.00 inches per hour, textural classes ranging from loamy sands to friable clays, cation exchange capacity greater than 3 milliequivalents per 100 grams of soil, depths to root-restricting layers ranging from 12 to 60 inches or more, water-holding capacities varying from 0.75 to 3.00 inches per foot of soil depth, salinity levels at equilibrium with the irrigation water of 8 millimhos per centimeter or less, and equilibrium exchangeable sodium percentage not exceeding 15 per cent (Maletic and Hutchings, 1967). Flexibility in the class limits, of course, is required from project area to project area; some soils in the tropics have cation exchange capacities less than 3 milliequivalents per 100 grams of soil, but yet produce well under irrigation with properly selected and applied management systems.

At the detailed scale of study appropriate to the selection of land for irrigation purposes the individual mapping units are characterized in considerable detail with compound symbols. A numeral -1,2,3,4, or 6 - designation is used for the appraisals that relate to the appropriate land class level. An estimation of farm water requirements is made using the letters A,B, and C to indicate good, restricted, and poor drainability conditions in the 5-10-foot zone. Additional informative appraisals are made using g for slope, u for undulations, f for flooding, k for shallow depth to sand, gravel, cobbles, and so on. An example of the compound mapping unit symbol is given on the following page.



3. APPLICATION OF THE TRADITIONAL APPROACHES IN THAILAND

The two systems outlined above have both been applied to land classification in Thailand.

3.1 The Soil Interpretation Handbook for Thailand

This basis of land classification was prepared by the Land Classification Division (1973) working in conjunction with the FAO Project For Strengthening Soil Survey and Land Classification It is based on the USDA system with one major modification which is to recognize separate classifications for different broad categories of land use. The categories are: upland crops; paddy (wetland rice); and rubber.

a) <u>Classification for Upland Crops.</u>

The land capability classification system groups soils into eight broad classes, with the risks of soil damage or the limitations in use becoming greater from class U-I to class U-VIII. The capital letter "U" shows that the classification is for upland crops. Soils placed in class U-I have only minor limitations for growing upland crops during most of the year; relatively little effort is required to produce satisfactory yields of a wide range of crops. In classes U-II and U-III there are increasing limitations for use as cropland; greater effort and care in management are required to produce satisfactory yields, and the choice of crops may be narrow. These problems are still more severe in soils in class U-IV, which, though capable of producing a few crops, are more nearly marginal in use as cropland.

Soils in classes U-V through U-VII are not generally suited for the cultivation of upland crops, but they may be suited for other uses, such as grassland, woodland, tree crops and rice. Soils in class U-VIII do not produce economic returns in agriculture or forestry, but may require planting or treatment for watershed protection and downstream benefits.

b) <u>Classification for paddy (wetland rice).</u>

Because of its great importance as a crop, and because its requirements are entirely different from those of other common crops, rice is given special treatment in classifying land. Soil suitability for rice is classified separately from land capability for upland crops. A complete system of suitability groups and subgroups shows the relative suitability for rice in the same way that capability classes and subclasses for upland crops show general suitability for common upland crops.

The soil suitability groups for paddy have been developed by the Land Classification Division of the Land Development Department. In this system soils are placed in five broad groups numbered P-I to P-V, with the letter P used to show paddy. These have been called land capability classes for paddy in the past, but as they refer only to specific suitability for a single crop it seems better to distinguish them from capability classes, which apply generally to suitability for common cultivated crops.

Determining suitability of soils for paddy is complicated by the need for controlled flooding. The water (apart from irrigated areas) comes from direct rainfall, natural flooding by rise of water in streams, diversion from stream channels, and in places by runoff and seepage from adjacent higher areas. In addition to the amount, distribution and dependability of the water supply, its salinity and other chemical qualities and the silt load are of importance in growth of the rice.

Availability of water on a specific area may be the most important factor in its suitability for paddy. Soil and water supply must be considered together in determining suitability of an area. Soil mapping units are placed in groups showing suitability according to soil qualities and the conditions in which most of the soil occurs. If water supply is changed by large irrigation projects or by diverting water from streams the soil in the area will be regrouped in the appropriate group to show the new suitability.

Soils in groups I through IV receive enough water and have characteristics that enable them to hold water on the surface for periods long enough to mature one crop of rice in most years. Soils in group V are not suited for rice grown under submerged conditions, but may be well suited for other uses.

c) Classification for rubber.

Some soils that are too steep for cultivated crops may be planted to rubber, fruits or other tree crops, with little disturbance or damage to the soil. In such cases soils will be classified as U-IV to U-VIII for upland crops but this does not imply that they are unsuited to rubber or other tree crops. A special suitability grouping has therefore been recognized for rubber cultivation with increasing limitation from R-I to R-III; land in group R-IV is not considered suitable for rubber cultivation.

d) Other Specific Classifications.

The Soil Interpretation Handbook describes a number of other specific classifications for pasture and forage maps, woodland, engineering uses, and town and country planning.

3.2 Land Classification Survey for the Lam Nam Oon Project

The United States Bureau of Reclamation prepared specific instructions for the conduct of feasibility grade land classification surveys for the Lam Nam Oon Project (USBR, 1967). This was essentially based on the standard USBR system but with the important modification of recognizing two special classes of suitability for wetland rice. The classification comprises two basic diversified crop classes, two basic wetland rice classes and two non-arable classes. The major basis for differentiating physically, chemically, and economically diversified croplands from wetland ricelands is the ability to attain optimum soil submergence, susceptibility to soil puddling, and control of water tables. Therefore, the differentiating characteristics of wetland rice classes are to be primarily predicated on water control as related to soil characteristics and conditions which will control the moisture regime for wetland rice production. Diversified cropland classes are to be predicated on conditions of adequate drainage and differentiating soil characteristics that have a strong influence on the yield and cost of producing diversified crops. The two classes for both wetland ricelands and diversified croplands represent lands with progressively lesser net farm income.

The Classes recognized are:

Class 1 diversified crops - Arable : lands that are highly suited to irrigation farming.

Class 2 diversified crops - Arable : lands that have moderate to fair suitability for irrigation farming.

Class 1R wetland rice - Arable : lands that are highly suitable for paddy rice production under irrigation.

Class 2R wetland rice - Arable : land of moderate to fair suitability for paddy rice production under irrigation.

Class 5 - nonarable : Land currently not suited to irrigated farming but warranting further study.

Class 6 - nonarable : land not suited to irrigated farming.

4. THE FAO FRAMEWORK FOR LAND EVALUATION (1976)

A universal framework for the evaluation of land was developed by FAO after wide international consultation. The framework does not set specific standards of land capability since these must vary with individual situations, but provides a set of general principles and concepts which can be applied throughout the world.

The basic principles of the framework are that:

- Suitability is assessed with respect to specific kinds of land use.
- Evaluation requires a comparison of benefits obtained and inputs needed.
- Evaluation is relevant to the physical, economic and social context of the area.
- Suitability refers to use on a sustained basis.
- Evaluation involves comparison of more than one kind of use.

There are two fundamental concepts in the system, namely the Land Unit and the Land Utilization Type.

- **Land Units** comprise the overall physical environment including climate, relief, soils, hydrology and vegetation.
- **Land Utilization Types** are possible uses of the land defined in as great a degree of detail as the level of study permits; these would include agricultural and non-agricultural uses.

The system of classification is a hierarchical one; four categories of increasing generalization are recognized:

- Land Suitability Orders; reflecting kinds of suitability.
- Land Suitability Classes; reflecting degrees of suitability within Orders.
- Land Suitability Subclasses; reflecting kinds of limitation, or main kinds of improvement measures required, with classes.
- Land Suitability Units; reflecting minor differences in required management within Subclasses.

Land Suitability Orders indicate whether land is assessed as suitable or not suitable for the use under consideration. There are two orders represented by the symbols S and N respectively.

Order S Suitable:	Land on which sustained use of the kind under consideration is expected to yield benefits which justify the inputs, without unacceptable risk of damage to the land resources.
Order N Not Suitable:	Land which has qualities that appear to preclude sustained use of the kind under consideration.

Land may be classed as Not Suitable for a given use for a number of reasons. It may be that the proposed use is technically impracticable, such as the irrigation of rocky steep land, or that it would cause severe environmental degradation, such as the cultivation of steep slopes. Frequently, however, the reason is economic: that the value of the expected benefits does not justify the expected costs of the inputs that would be required.

Land Suitability Classes reflect degrees of suitability. The classes are numbered consecutively, by arabic numberals, in sequence of decreasing degrees of suitability within the Order. Within the Order Suitable the number of classes is not specified. There might, for example, be only two, S1 and S2. The number of classes recognized should be kept to the minimum necessary to meet interpretative aims; five should probably be the most ever used.

If three Classes are recognized within the Order Suitable, the following names and definitions may be appropriate in a qualitative classification:

Class S1 Highly Suitable:	Land having no significant limitations to sustained application of a given use, or only minor limitation that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
Class S2 Moderately Suitable:	Land having limitation which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably interior to that expected on Class S1 land.
Class S3 Marginally Suitable:	Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
Within the Order Not Suitable:	there are normally two classes:
Class N1 Currently Not Suitable:	Land having limitations which may be surmountable in tine but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.

Class N2 Permanently Not Suitable: Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner.

The boundary of Class N2, Permanently Not Suitable, is normally physical and permanent. In contrast, the boundary between the two orders, Suitable and Not Suitable is likely to be variable over time through changes in the economic and social context.

Land Suitability Subclasses reflect kinds of limitations, e.g. moisture deficiency, erosion hazard. Subclasses are indicated by lower-case letters with mnemonic significance, e.g. S2m, S2e, S3me; there are no subclasses in Class S1.

The number of Subclasses recognized and the limitations chosen to distinguish them will differ in classifications for different purposes. There are two guidelines given in the "Framework":

- The number of subclasses should be kept to a minimum that will satisfactorily distinguish lands within a class likely to differ significantly in their management requirements or potential for improvement due to differing limitations.

- As few limitation as possible should be used in the symbol for any subclass. One, rarely two, letters should normally suffice. The dominant symbol (i.e. that which determines the class) should be used alone if possible. If two limitations are equally severe, both may be given.

Land within the Order Not Suitable may be divided into suitability subclasses according to kinds of limitation, e.g. N1m, N1me, although this is not essential. As this land will not be placed under management for the use concerned it should not be subdivided into suitability units.

Land suitability units are subdivisions of a subclass. All the units within a subclass have the same degree of suitability at the class level and similar kinds of limitations at the subclass level. The units differ from each other in their production characteristics or in minor aspects of their management requirements (often definable as differences in detail of their limitations). Their recognition permits detailed interpretation at the farm planning level. Suitability units are distinguished by arabic numbers following a hyphen, e.g. S2e-1, S2e-2. There is no limit to the number of units recognized within a subclass.

The structure of the suitability classification is given below.

STRUCTURE OF THE SUITABILITY CLASSIFICATION

	CATEGORY		
ORDER	CLASS	SUBCLASS	UNIT
S Suitable	S1 S2 S3 etc.	S2m S2e S2me etc.	S2e-1 S2e-2 etc.
<u>Phase</u>: Sc Conditionally Suitable	Sc2	Sc2m	
N Not Suitable	N1 N2	N1m N1e etc.	

5. APPLICATION OF THE "FRAMEWORK" TO THE WESTERN REGION OF THAILAND

The workings of the framework may be illustrated by reference to the land use planning component of a major regional planning study for the 'Western Region of Thailand' (Halcrow-ULG, 1980) For the purposes of this exercise it was considered necessary to draw a clear distinction between a first stage land evaluation based on the major physical characteristics of the land and the more comprehensive evaluation which is implied, though frequently not applied, in the "framework". For this reason the Western Region evaluation is considered to be a "Capability Classification", i.e. one based on the physical capability of the land to support different cropping systems, rather than a "suitability classification" i.e. one in which the suitability of the different cropping systems is based on some kind of economic criteria. (The broader concepts of economic land evaluation are introduced below and elaborated on in the next paper.)

For the land capability evaluation the four essentially permanent factors of climate, topography, soil and irrigation command were used to define the land units. Of the permanent land characteristics given only "irrigation command" may require some clarification. Sensu stricto irrigation command is not a permanent characteristic of the land - land currently irrigated may go out of irrigation if it was decided to direct the water elsewhere, while new sources of irrigation water from further storage schemes or the utilization of ground water may lead to new areas coming into irrigation command. However, as end-state plans were not the primary objective of the study it was decided that land within command of irrigation water a scheme to which there was a firm commitment to implementation. Clearly, this is a step in the system which can readily be altered should conditions change.

The land utilization types considered in the land capability evaluation were confined to the major cropping systems within the region and a small number of individual crops with specific requirements and whose development was considered to be of particular significance in the region. These are listed below.

a) Irrigated Agriculture.

- double cropped rice
- double cropped general upland crops
- single paddy rice/single upland crop
- sugar cane
- cotton
- pineapple
- tree crops (essentially fruit trees including coconuts)

b) Non-Irrigated Agriculture.

- rainfed paddy rice
- general upland crops
- sugar cane
- cotton
- groundnuts
- pineapple
- coconuts

c) Non-Agricultural Utilization.

- fish farms/salt pans
- plantation forest
- production forest
- protection forest

A matrix was prepared evaluating the capability of the 31 land units for the 18 land utilization types. Three orders of capability were recognized; the first two orders refer strictly to capability in the current situation, while the third is a conditional situation depending on the execution of works beyond the scope of normal cultivation techniques.

C Capable - land currently capable of being used for given land utilization type.

N Not Capable - land currently not capable of being used for given land utilization type; corrective works may or may not alter this situation.

PC Potentially Capable - land capable of being use for the given land utilization type following the execution of corrective works.

Four classes of capability are given:

C1 Very Highly Capable - for the given land utilization type the land has no limitation to attaining maximum potential production; no special works, cultivation practices or fertilizer inputs are required beyond standard husbandry techniques.

C2 Highly Capable - for the given land utilization type the land has minor limitations to attaining maximum potential production; these limitation may or may not be overcome by corrective works, special cultivation practices or higher fertilizer inputs.

C3 Moderately Capable - for the given land utilization type the land has moderate limitations to attaining maximum potential production; this may take the form of one relatively severe limitation or a combination of several minor limitations; these may or may not be overcome to some degree by corrective works, special cultivation practices, high fertilizer inputs or a combination of these.

C4 Marginally Capable - for the given land utilization type the land has severe limitations to attaining maximum potential production; this may take the form of one severe limitation or a combination of several lesser limitation; these limitations may or may not be overcome to some degree by corrective works, special cultivation practices, high fertilizer inputs or a combination of these.

The kinds and degrees of limitations were those given in the Soil Interpretation Handbook for Thailand. In considering paddy rice the four classes can be essentially equated with Groups P-I to P-IV. For other crops the criteria are essentially as for Groups U-I to U-IV, with Groups U-V to U-VIII normally taken to be "not capable"

The potential for changing the current capability is separated into two levels:

P1 High Potential - the corrective works required are of a relatively minor nature and relatively easy to implement.

P2 Low Potential - the corrective works required are of a relatively major nature and relatively difficult to implement.

This was a very broad separation with a wide range of works covered in each level, but was used simply as a broad indicator.

In a number of cases it was not applicable to evaluate certain land units for some land utilization types e.g. the evaluation of land within an ongoing irrigation scheme for non-irrigated agriculture. In this case the appropriate evaluation was designated NA - not applicable.

6. FUTURE DEVELOPMENTS IN LAND USE PLANNING IN THAILAND

The development of the concepts of land use planning has been described as moving from a general determination of whether the physical characteristics of the land are capable of sustaining agriculture to an appreciation of the need to determine suitability for specified kinds of land use as dictated by the relative costs and benefits. This development has been shown to have been applied to land use planning in Thailand.

Two converging situation have led to the need to re-appraise land sue planning and to set out a long term programme for this. In an increasingly complex economic environment it is no longer feasible simply to maximize production. This must be achieved in the most efficient and cost effective way and be closely attuned to both internal and international market forces. At the same time computer technology has advanced to the point where the complex data sets needed to meet these demands can be handled within systems which are available at an affordable cost. Effective land resource planning needs to meet three basic criteria. It needs to be a dynamic process; the environment within which the farmer and the national economy are operating is in a state of continuous change in respect of:

- technology, e.g. cultivar performance/adaptability, fertilizer regimes, land management practices, farming systems;

- management factors, e.g. farmer education, type of holding, access to credit;

- market forces, e.g. local, national and international input costs and output prices, marketing systems, supporting infrastructure.

Any system of planning, therefore, must be capable of taking account of changing circumstances.

The second basic criterion is that land resources evaluation should produce its results in terms which are meaningful to and understood be the users of the evaluations. As the ultimate measure of the appropriateness of any land use is the benefit which derives from it, the evaluation must be cast in quantifiable benefit terms which implies some form of economic or financial measure.

Finally, the system must be flexible in terms of its application to the different planning levels. While the level of input detail and the specific form of output will differ according to the planning level - national, regional, programme, project or farm - the principles and techniques remain the same. Moreover, it is important that planning is integrated through these different levels by applying a common data base and criteria.

Comprehensive resource evaluation and planning proceeds through a number or clearly defined stages each of which must be addressed in the development of the long-term programme. These stages are described below.

The first step in the planning process is to define and delineate areas of land with specific physical attributes. These are generally referred to as 'land units' but in order to distinguish them from the more complex units described below they are referred to here as primary land units' (PLU).

The PLU is essentially defined in terms of:

- the prevailing climate;
- topography (altitude and slope characteristics);
- soils (with specific regard to those features of the soil soil which most directly affect plant growth).

The land unit concept may be applied at any level of detail. Poorly drained, fine textured soils in a relatively flat basin with a wet tropical climate would constitute a PLU at a general reconnaissance level of planning. At the more detailed scale the primary land unit may be, for example, a well drained, sandy loam soil of low fertility, between 1.0 and 1.5 m deep, occupying the mid-slope position of a long convex slope of between 10 and 15 degrees, in an area with an annual rainfall of 1200 - 1500 mm and not more than 70 continuous days in which evaporation exceeds rainfall

An important aspect of the primary land unit is that it is essentially permanent. Major land levelling operations or drainage schemes may lead to a change in characteristics of the PLU but in the absence of such major works the attributes of the unit remain constant.

Any crop cultivar will have genetically determined growth requirements, that if completely satisfied, would enable that crop to achieve its full yield potential. These need to be determined in order to assess both the requirements of, and effects of constraints on, crops in different land units. The attributes of the crop are prepared as a 'crop inventory' or 'crop adaptability inventory' covering the following factors:

- photosynthetic pathway type;
- radiation intensity requirement for maximum photosynthesis
- maximum net rate of CO_2 exchange at light saturation;
- life span (annual/perennial);
- part of plant producing economic component
- stage of growth at which economic component is produced;
- optimum temperature range, and specific temperature constraint;
- maximum crop growth rate;
- water use efficiency;
- growing period (days from germination/start of growth to maturity of economically desirable crop part);
- photoperiodic sensitivity;

Once the primary land units have been defined in terms of physical environmental characteristics and have been delineated, and the crop or crop system's requirements of its environment have been determined, a suitability matching of crop to land may be made.

It is necessary for the suitability analysis to take account of management levels. A minor constraint - for example a slight propensity to erosion - which may limit the long term production under a low level of management may have no deleterious effect on yields where good management is being applied. On the other hand a condition such as low bearing capacity which would render land poorly suited to a highly mechanized level of management may have little effect on a system based on hand - held tools.

It is recognized that the matching of a crop's growth requirements with areas of land defined in physical environmental terms is a gross simplification of a more complex situation. The actual benefits deriving from growing a specific crop in a particular place are not controlled only be the yield potential in relation to direct inputs. It is, therefore, necessary to introduce the concept of the Economic Land Unit (ELU). It should be noted that the FAO is currently working on the development of quantitative evaluation systems as the logical extension of its earlier "Framework for Land Evaluation" (FAO, 1976). These developments should be taken into account in the proposed programme.

In order to redefine the boundaries of these primary land units in terms of their socio-economic suitability for alternative land uses it is necessary to first consider the following factors:

6.1 Subsistence Requirements

Many farmers are forced to adopt low technology subsistence production. This means that they tend to grow a range of crops necessary to satisfy their household needs even when their land is not ideally suited to the production of these crops. it is likely that irrespective of land quality such farmers will produce those commodities directly required by the homestead which would include other subsistence requirements such as fuel - wood or grazing areas. The ELU would need to take account of the area of land which in certain circumstances will be allotted irrespective of suitability, to these needs. At higher management levels increased fertilizer use may enable farmers to reduce the area needed to grow their own subsistence requirements.

6.2 Markets

Before alternative land utilization types are proposed it is important that the potential market for the commodity is reviewed to avoid wasteful over-production. This should involve consideration of the local, regional, national and international markets as appropriate. Proximity to market outlets is often a key determinant of suitability. Two areas may have identical environmental characteristics, but that which lies closer to a major consumer area for its produce is inherently better suited to its production.

6.3 Infrastructure

Existing infrastructure should be taken into account under the land quality classification particularly potential accessibility. In general Thailand has a highly developed infrastructure but transport costs for input supply and product shipment will affect land suitability. For crops requiring processing it may be important to carefully consider the proximity of agro-processing facilities particularly if the crop is perishable. This problem could be quantified in the land evaluation process by establishing upper limits for crop transportation to safeguard quality. With RGT's emphasis on improved quality of export commodities this factor need particular consideration.

6.4 Population and Labour Supply

Population and labour supply are major criteria in decisions relating to land use. It is important to consider local demand for production and also whether adequate labour will be available to match the requirements of the proposed alternative land use. In areas of high unemployment such consideration might favour the adoption of labour intensive activities.

6.5 Land Tenure

The form of land tenure will have a direct bearing on a farmer's acceptance of alternative land utilization types. For example, a farmer is unlikely to be willing to plant long term plantation crop if there is no legal title to the land. Similarly commercial rights to land can present a major constraint to the optimal use of the land.

6.6 Customs and Beliefs

Particular areas might well have customs or beliefs which effectively bar certain alternative land uses. These should be taken into account when redefining land unit boundaries in socio-economic terms.

Depending on the specific purpose of the planning exercise these, and other factors - such as current land use, potential for irrigation or drainage, existing farmer skills and access to advice may need to be taken into account.

The technology of the Geographic Information System permits all relevant factors to be combined according to the extent of their importance so that parcels of land are defined and delineated on the basis of different land uses. This technology is discussed in a subsequent paper.

REFERENCES

FAO 1976. A Framework for Land Evaluation.FAO Soils Bulletin No. 32. 72 pp.

Halcrow-ULG. 1980. Final Report: Western Region Planning Study for National Economic and Social Development Board under Assignment by Overseas Development Administration. Bangkok, Thailand.

Kligebial, A. A. and Montgomery, P. H. Land-Capability Classification. Agricultural Handbook 210, Soil Conservation Service. U.S. Govt. Printing Office, Washington D.C. 21 pp.

Land Classification Division. 1973. Soil Interpretation Handbook for Thailand. Land Development Department, Bangkok, Thailand

Maletic, J. T. and Hutchings, T.B. 1967. Selection and Classification of Irrigable Land. In R. M. Hagan, Choal (eds), Irrigation of Agriculture Lands. American Society of Agronomy, Madison, Wisconsin pp 125-273

U.S. Department of Interior, 1953. Bureau of Reclaimation Manual, Vol. V, Irrigated Land Use Part 2, Land Classification. Washington D.C. 132 pp

USBR. 1967. Instructions for the Conduct of Feasibility Grade Land Classification Surveys of the Lam Nam Oon Project-Thailand, October, 1967

Young, A. 1973. Rural Land Evaluation. In: J. A. Dawson and J. C. Doornkamp, (eds.). Evaluating the Human Environment. Arnold, London pp. 5-33

Table 1a Land Capability Matrix for Western Region Thailand

(Non Irrigated Agriculture)

Land Unit \ Land Utilisation Type	NON-IRRIGATED AGRICULTURE						
	PADDY RICE	GENERAL UPLAND CROPS	SUGAR CANE	COTTON	GROUNDNUTS	PINEAPPLES	COCONUTS
1	NA	NA	NA	NA	NA	NA	NA
2	NA	NA	NA	NA	NA	NA	NA
3	NA	NA	NA	NA	NA	NA	NA
4	NA	NA	NA	NA	NA	NA	NA
5	NA	NA	NA	NA	NA	NA	NA
6	NA	NA	NA	NA	NA	NA	NA
7	NA	NA	NA	NA	NA	NA	NA
8	NA	NA	NA	NA	NA	NA	NA
9 [1]	NA	NA	NA	NA	NA	NA	NA
10	NA	NA	NA	NA	NA	NA	NA
11	NA	NA	NA	NA	NA	NA	NA
12	N	C4	N	N	C3	C2	C2
13 [2]	C3	C2 / P1C1	C3 / P1C2	C2 / P1C1	C2 / P1C1	C2	C4
14 [3]	N	N-C2 / P1-P2 N-C1	N-C2 / P1-P2 N-C1	N-C2 / P1-P2 N-C1	N-C1	N-C2 / P1-P2 N-C1	N-C4
15	N	N	N	N	N	N	N
16 [2]	N	C4 / P1 C3	N	N	C3 / P1 C2	C2	N

Source: Halcrow-ULG, 1980

Table 1b Land Capability Matrix for Western Region Thailand
(Irrigated Agriculture)

LAND UNIT \ LAND UTILISATION TYPE	IRRIGATED AGRICULTURE						
	DOUBLE CROPPED PADDY RICE	DOUBLE CROPPED UPLAND CROPS	SINGLE PADDY RICE SINGLE UPLAND CROP	SUGAR CANE	COTTON	PINEAPPLE	TREE CROPS
1	C2 P2 C1	N P2 C4	N P2 C3	N P2 C3	N	N	N P2 C1
2	NA	NA	NA	NA	NA	NA	C1
3	NA	NA	NA	NA	NA	NA	C2 P2 C1
4	NA	NA	NA	NA	NA	NA	NA
5	N P2 C2	N	N	N	N	N	N
6	C3 P2 C2	N P2 C4	N P2 C3	N P2 C2	N	N	N P2 C2
7	C2 P1 C1	N P2 C4	N P2 C3	N P2 C2	N	N	N P2 C1
8	C2 P2 C1	N P2 C4	N P2 C3	N P2 C3	N	N	N P2 C1
9 [1]	C4/C2 -/P1 C1	C2/C4 P1C1/P1C3	C3/C3 P1C2/P1C2	C2 P1 C1	C2/C3 P1C1/P1C2	C2/N	C1/C4 -/P2 C1
10	C3	C1	C2	C1	C1	C2	C1
11	C3 P1 C1	N	N	N	N	N	N P1 C2
12	N	N	N	N	N	N	N
13 [2]	N (P2C3)	N (P2C1)	N (P2C2)	N (P2C1)	N (P2C1)	N (P2C1)	N (P2C1)
14 [3]	N	N	N	N	N	N	N
15	N	N	N	N	N	N	N
16 [2]	N (P2C4)	N (P2C3)	N (P2C4)	N	N (P2C3)	N (P2C1)	N (P2C2)

Source: Halcrow - ULG, 1980

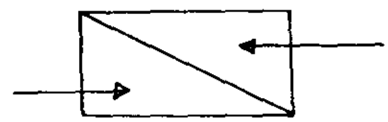
Table 1c Land Capability Matrix for Western Region Thailand
(Non-Agricultural Utilisation)

LAND UTILISATION TYPE / LAND UNIT	NON-AGRICULTURAL UTILISATION			
	FISH FARMS / SALT PANS	PLANTATION FOREST	PRODUCTION FOREST	PROTECTION FOREST
1	N	NA	NA	NA
2	N	NA	NA	NA
3	NA	NA	NA	NA
4	C1	NA	NA	NA
5	N / P1 C1	N / P1 C3	C4	NA
6	N	NA	NA	NA
7	N	NA	NA	NA
8	N	NA	NA	NA
9 [1]	N	NA	NA	NA
10	N	NA	NA	NA
11	N	NA	NA	NA
12	N	C2	NA	NA
13 [2]	N	NA	NA	NA
14 [3]	N	C1	NA	NA
15	N	N	N-C1	C1
16 [2]	N	C1	NA	NA

Source: Halcrow-ULG,1980

KEY

INDICATES POTENTIAL CAPABILITY



INDICATES CURRENT CAPABILITY

C1	VERY HIGHLY CAPABLE	N	NOT CAPABLE
C2	HIGHLY CAPABLE	P1	HIGH POTENTIAL
C3	MODERATELY CAPABLE	P2	LOW POTENTIAL
C4	MARGINALLY CAPABLE	NA	NOT APPLICABLE

INTRODUCTION TO QUANTITATIVE LAND EVALUATION

J. D. Shearing

1. INTRODUCTION

The matching of a crop's growth requirements with areas of land defined in purely physical terms is considered to be a gross simplification of a more complex situation. It is well recognized that the actual benefits derived from growing a crop in a specific location is not only controlled by the yield potential in relation to direct inputs, but also by socio-economic factors such as subsistence requirements, land tenure, customs and beliefs, infrastructure and market opportunities. For this reason it is necessary to redefine the boundaries of the primary land units to produce Economic Land Units (ELU) which take account of socio-economic suitability for alternative land use. This process leads to the ability to undertake Quantitative Land Evaluation within each of these ELUs.

Land evaluation in quantitative terms is generally accomplished using a two stage approach. During the initial stage a first approximation is made on the basis of physical criteria to arrive at a list of possible alternative land utilization (LUT) types. During the subsequent stage the most promising alternative land uses are subjected to detailed financial and economic analyses to determine feasible and optimal land use for a given parcel of land. At this stage the ELUs may be redefined to arrive at a minimum number of discrete planning units considered necessary for a particular area.

This paper provides a brief outline of the broader concept of Quantitative Land Evaluation as well as possible approaches which can be adopted by the land use planner. A clear distinction is drawn at the beginning of the paper between financial and economic analysis.

2. DEFINITION OF FINANCIAL AND ECONOMIC ANALYSES

Before considering a possible methodology to be applied when applying quantitative measures of land evaluation it is pertinent to first draw a clear distinction between the terms financial and economic analysis.

2.1 **Financial Analysis**

Financial analysis is concerned solely with measuring the profit or loss to the farmer or enterprise from alternative land use. As such, input prices and output values are expressed in terms of local market prices paid or received by the farmer. Financial analysis should attempt to ensure that the producer receives an acceptable income level. Financial profitability is generally measured as gross margin per unit area, net farm income, net present value (NPV) or financial internal rate of return (FIRR). These measures are discussed in more detail later in this paper.

2.2 **Economic Analysis**

Economic analysis is concerned with measuring the economic benefits to a country. In order to achieve this objective economic it is necessary to value the various factors of production in terms of their opportunity cost to the economy. For traded goods this involves the valuation of production inputs and outputs at their point of consumption or production in relation to world market prices. For non-traded commodities, valuation is either based on long run average financial prices, domestic resource cost or on the opportunity cost of alternative use. As such, economic analysis involves the removal of all internal transfer payments such as taxes, subsidies and 'excess profit' so as to arrive at a truer reflection of the costs of production. Economic measures are normally expressed in terms of economic gross margins per unit area, cost/benefit ratios, net present value, economic internal rates of return (EIRR) or one of a series of other measures concerned with economic comparative advantage. These are discussed later in this paper or in subsequent papers.

3. A QUANTITATIVE APPROACH TO LAND EVALUATION

3.1 **General**

Natural resource data, provides the basis for land evaluation. Such biophysical information allows the suitability of land for alternative uses to be determined in either qualitative terms such as low, moderate or high suitability or alternatively, in broad quantitative terms such as crop yields, species diversity or recreational capacity Financial and economic analyses provide an additional quantitative dimension which allow the likely returns from a given land use to be measured and the desirability of alternative land use considered.

The application of financial and economic analyses is most appropriate when there is general social agreement on values and policy goals, and where there are likely to be few unintended cost impacts (externalities) such as soil erosion, increased water salinity, species loss or landscape loss. In cases where enternalities are likely to have an important impact, a combined economic/ecological from of analysis is necessary to allow the conservation and development aspects to be considered in parallel. The term 'sustainable development' is already widely used in this context although the methodology for effectively valuing externalities is still in its infancy.

3.2 Principal Phases

Quantitative land evaluation can be conveniently divided into two distinct phases as follows (see Figure 1):

- **Phase 1**

  This requires an assessment of the physical input/output relationships associated with farming systems on different land units. Such an assessment should record the level of management employed and the quantities of all factors of production, including the division of labour between the farm family and hired help. Although it is possible to contrast different land units on the basis of physical quantities (e.g. tones of product per kg of fertilizer) this has limited application because it is impossible to bring all factors of production onto a common basis without applying a price. It is worth noting that the definition of the input/output relationship has long time validity. As such it forms the basis for valuation in either financial or economic terms over a reasonable time span and faciltates updating if significant movements in prices are noted.

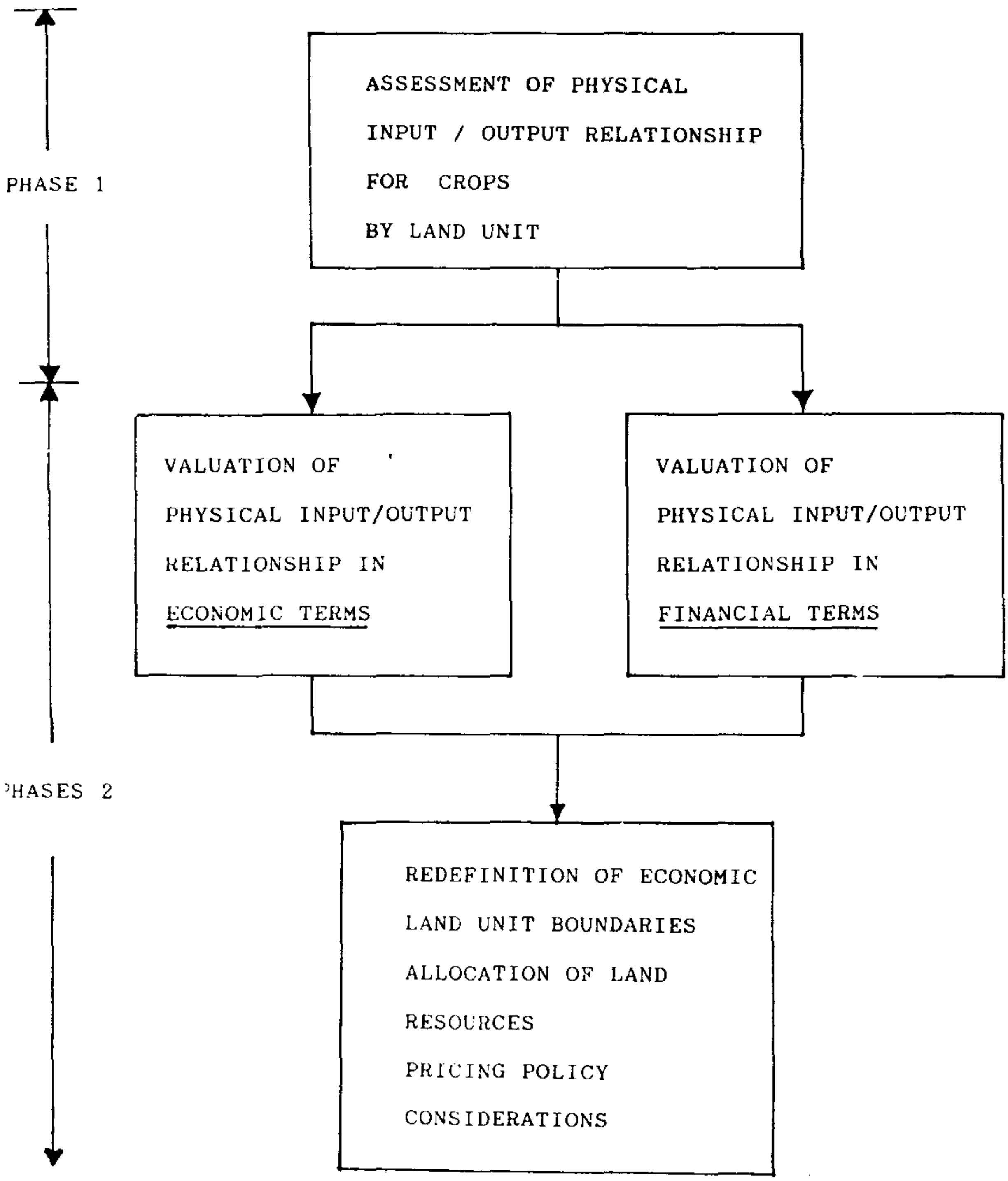
- **Phase 2**

  The second phase involves the valuation of the physical input/output relationship in either financial or economic terms. As such it allows the likely returns to the farmer to be contrasted with benefits to the economy and provides a system for redefining the boundaries based on physical land classification, in terms of either financial or economic criteria. Because of the short time validity of prices, frequent updating is necessary.

3.3 Outline Methodology

The level of investment associated with promising land-use alternatives will largely dictate the level of quantitative analysis to be undertaken If alternative land-use involves switching from one annual crop to another a gross margin or net farm income approach will generally suffice. In cases where investment is required in terms of infrastructure such as irrigation facilities or agro-industrial development, this can be taken into account by incorporating a charge for irrigation or

Figure 1 Principal Phases involved in Quantitative Land Evaluation



processing in the variable costs. Where alternative land use involves comparison of plantation crops with annual crops, discounted cash flow techniques must used to bring future net cash flows from perennial crop production to present values for comparison on a common basis. The two basic techniques for quantitative analysis are reviewed below.

a) Gross Margin Analysis

The gross margin is calculated by subtracting the variable (or direct) costs of production from the gross value of output.

Gross Margin = Output value per unit area - Variable costs per unit area.

By applying either financial or economic values to the physical quantities associated with the production process, it is possible to contrast financial and economic gross margins for a crop, cropping system or farming system on a per unit area basis. Such an approach would indicate the degree of harmony between the marginal financial returns to the producer and the potential marginal economic benefits to the country. If it was considered necessary to estimate the likely profit accruing to the farmer this could be calculated by subtracting the incremental fixed costs per unit area from the gross margin.

Because there are generally no abrupt changes in either the physical characteristics of a soil or plant growth when moving from one land unit to another, the application of gross margin analysis can offer a suitable method for determining the boundary between land of marginal suitability (S3) and land currently unsuitable for the production of a particular crop (N). Such boundaries would normally be defined in terms of a minimum financial gross margin per unit are that reflected a threshold income level to the producer. This approach is illustrated below:

Land Suitability Class		Gross Margin per hectare (1986 prices) US$
S1	Highly Suitable	Over 275
S2	Moderately Suitable	150-275
S3	Marginally Suitable	75-150
N1	Currently Not Suitable	Less than 75
N2	Permanently Not Suitable	-

Such an approach would be useful if it was necessary to establish a minimum farm size for a settlement scheme required to match a predetermined household income target. In this case it would be necessary to estimate a gross margin for the farm on the basis of the proposed farming system, and then subtract estimated fixed or indirect costs to arrive at the net income level available to the household.

The principal steps to be followed when carrying out gross margin and net farm income analysis, in relation to land evaluation, are summarized below:

- select the more promising land utilization types (LUT) with in a defined crop suitability range (preferably S1 and S2 which would limit each LUT to either highly or moderately suitable);

- estimate the physical input/output relationship for each crop or farming system by land unit and technology level (this should either be accomplished by field survey within each Land Unit or through the application of production functions based on field survey and experimental results);

- collect price information for both material and non-material inputs; sources of such data would be by primary survey or from secondary sources;

- estimate average farm fixed (or indirect) costs by land unit;

- calculate gross margins and estimate net farm income for the average farm by Land Unit.

The above procedure would allow crops cropping systems or farming system including livestock to be contrasted in financial and economic terms for each land unit. This would indicate optimal enterprise combinations. Generally such information is presented in tabular format as shown in Table 1.

b) Discounted Cash Flow Analysis

It is necessary to undertake discounted cash flow analysis (DCF) where alternative land use involves substantial capital investment. The techniques enable future costs and benefits to be expressed in terms of net present value for comparison with alternative land use, including those offering returns within a one year time frame.

The DCF technique involves the establishment of various pricing assumptions and also estimation of future cost and benefit streams (in constant prices) over the discounting period, often extending up to 30 years. DCF can be used to guage the financial profitability of an enterprise by expressing prices in terms of market prices or, alternatively, to measure likely economic benefits by using economic pricing assumptions. Which ever of these approaches is adopted the results of the analysis can be expressed in one of the following terms:

Table 1 Example of Gross Income and Net Margin Per Hectare, by Land Utilization Type, at S1 and S2 Productivity Levels, 1975 Prices, Philippines

	Land Utilization Type	Annual cropping intensity	Land Suitability Class S1 Yield kg/ha	S1 Gross income ₱/ha	S1 Annual gross income ₱/ha	S1 Net margin ₱/ha	S1 Annual net margin ₱/ha	S2 Yield kg/ha	S2 Gross income ₱/ha	S2 Annual gross income ₱/ha	S2 Net margin ₱/ha	S2 Annual net margin ₱/ha
2	Rainfed wetland rice plus Rainfed wetland rice	1.5	3 000 1 500	2 640 1 320	3 960	1 381 690	2 071	2 200 1 100	1 936 968	2 904	800 400	1 200
3	Rainfed wetland rice plus Corn (maize)	2.0	3 000 1 700	2 640 1 224	3 864	1 381 470	1 851	2 200 1 160	1 936 828	2 764	799 193	992
10	Coconut plus Abaca (hemp)	0.85 1.0	1 600 1 150	2 218	2 218	611	611	1 120 780	1 535	1 535	174	174
11	Coconut	1.0	2 500	-	875	-	125	1 730	-	575	-11	-11
12	Rubber	1.0	2 170	-	2 584	-	1 180	1 628	-	1 731	-	648

All perennial crops output at full production. Net margin is present value of average income less establishment and production costs over life of plantation.

Source: Guidelines: Land Evaluation for Rainfed Agriculture FAO Soils Bulletin 52, Rome 1983.

- Net Present Value This represents the present value of benefits less the present value of costs both having been discounted at the chosen opportunity cost of capital;

- Benefit/Cost Ratio This is calculated by dividing the present value of benefits by the present value of costs after discounting at the chosen opportunity cost of capital;

- Internal Rate of Return This represents the discount rate at which the discounted present value of benefits is equal to the discounted present value of costs.

DCF analysis normally commences with the calculation of gross margins as discussed above. These are then multiplied up by projected crop areas over the project period to arrive at a total benefit stream for the project, calculated on a gross margin basis (i.e. gross output less variable costs of production). Other capital and recurrent costs are subsequently estimated over the project period and the resulting cash flow discounted to arrive at the DCF measures discussed above.

An illustrative example, which shows the sue of DCF analysis in evaluating the effects of improving imperfectly drained land by drainage, is shown in Table 2.

Reference to Parts A and B of Table 2 illustrates the application of the DCF technique to the problem. The results presented at Part C of the table indicate that in the case of tobacco cultivation land improvement work is well justified, showing an attractive net present value and benefit cost ratio.

Any programme for quantitative land evaluation should utilize both the gross margin and discounted cash flow techniques as appropriate to the land utilization types under consideration.

4. CONCLUSION

The application of financial and economic analyses provides an additional quantitative dimension which allows the likely returns from a given land use to be more accurately measured and the desirability of alternative land use to be reviewed. In all cases, emphasis should be placed on 'sustainable development' which necessitates adequate consideration of the conservation aspects of land use. Where externalities such as soil erosion and landscape loss are likely to have an important impact, an attempt should be made to value these in economic terms. Two possible approaches might centre on the 'willingness to pay for conservation' or the 'willingness to be compensated for loss of conservation benefits' Providing quantitative approaches to

Table 2 Example of Discounted Cash Flow Analysis for Improving Imperfectly Drained Land By Drainage

A. DATA

Land unit	Fertile soil, imperfectly drained	
Land improvements	Drainage	
Economic assumptions	Discount rate 5%, project life 20 years	
Cost of land improvements (drainage):		
Capital	£/ha	500
Recurrent	£/ha	50
Annual value of benefits:		
Tobacco	£/ha	198
Maize (compared with non-use)	£/ha	156
Maize (without drainage benefits)	£/ha	120
5-hectare farm: 2 ha maize, 1 ha tobacco, 1 ha fallow, 1 ha woodlot	£/farm	398
	£/ha	80

B. DETAILS OF CALCULATION FOR CASE OF TOBACCO

i. Using tables of annual discount factors

Year	Costs £	Benefits £	Discount factor	Present value Costs £	Present value Benefits £	Present value Benefit-cost £
0	500	0	1.000	500	0	-500
1	50	198	0.957	48	189	140
2	50	198	0.907	45	180	135
3	50	198	0.864	43	171	128
:	:	:				
20	50	198	0.377	19	75	56
20	-	-	-	1 123	2 467	1 344

ii. Using tables of cumulative present value

	£
Present value of recurrent costs, years 1-20 = £50 = 12.46 =	623
Capital costs	500
Present value of costs	1 123
Present value of benefits, years 1-20 = £198 x 12.16 =	2 467

C. **RESULTS**

		Tobacco	Maize (compared with non-use)	Maize (without drainage)	5-hectare farm (without drainage)
Net value of benefits	£/ha	2467	1944	1296	992
Net value of costs	£/ha	1123	1123	1123	898
Net present value	£/ha	1344	821	123	94
Benefit/cost ratio	ratio	2.20	1.71	1.11	1.10
Internal rate of return		30	21	9	8

Source: Guidelines: Land Evaluation for Rainfed Agriculture
FAO Soils Bulletin 52, Rome 1983.

land evaluation allow development and conservation to be considered in parallel, the outline methodology briefly reviewed above offers an approach to more clearly define the boundaries of the Economic Land Units.

COMPUTER TECHNOLOGY FOR LAND USE PLANNING APPROPRIATENESS IN THAILAND

Dr. T. R. E. Chidley

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1. INTRODUCTION

The unit cost of raw computer power has fallen dramatically over the last 20 years, and will continue to fall into the foreseeable future. However the cost of the computer software to harness that raw power rises in relative terms. It is now common for software costs to exceed hardware costs in many installations. When considering investment in computer technology one can safely assume that what is too expensive today will become affordable within the time required to mobilise financial and staff resources to utilize the technology.

Land Use Planning requires the use of large databases of spatially related data as well as conventional tables of data. Historically the planner has represented spatially related data in map form. Maps containing different information are overlayed to form new maps showing important combinations of attributes. These combinations are interpreted by the planner and show situations ripe for development or identify ways of meeting policy requirements in a feasible way. It depends very much on the skill, knowledge and intelligence of the planner in selecting the combinations of spatial attributes that are beneficial. It is also a time consuming task. The computer can help in manipulating the large spatial data sets and with the intelligent retrieval of information.

To mobilize the power of the computer requires trained staff, equipment and software. Because a large part of the cost of software is in labour - albeit skilled labour - there are opportunities for Thailand to exploit a situation where labour costs are relatively low compared to other countries. However, the labour force engaged in this activity must be well trained and guided by experienced staff. One can see the tremendous interest in Thailand in the use of computer technology and Government Policy encourages and fosters this interest. A project as outlined later in this Workshop demonstrates how progress can be made in the introduction of computer technology to Land Resource Planning.

2. OVERVIEW OF THE TECHNOLOGY

The development of micro electronics has made considerable impact on the way in which land resource evaluation and planning is carried out. It is now routinely used in the processing and presentation of information. Current developments in data capture and knowledge representation aim to increase the reliability of information stored and to provide Decision Support Systems for planners that can be used without them having to become computer experts.

The land use planner is concerned with the storage, retrieval and processing of large sets of related data. A significant volume of these data are related spatially rather than logically. He needs therefore a database management system that can not only handle data that is logically related but can also handle digital map data. Such a system is provided by a Geographical Information System (GIS), which can process related tables of data and digital maps.

Before any data can be used it must be entered into the computer and verified. Tabular data is entered via a keyboard or optical character reader. Map data is entered via a digitizer which may be manually or automatically driven. In entering tabular data it is a good principle to have it entered as close to the source as possible. Hand held data loggers used in the field can achieve this. In the case of map and image data some information can be collected directly by remote sensing.

Hand in hand with the development of computer technology for processing of spatially related data has gone the development of Image Processing and Remote Sensing Techniques. These enable copies of existing maps and photos to be digitised instantaneously and can provide up to date maps of land cover and land use very cost effectively. The information so gathered can be incorporated directly into the database management and Geographic Information systems used by the planner. Modern sensors and platforms for these sensors can provide from space a ground resolution of as little as 10 metres (SPOT) in the panchromatic band; and 20 - 30 metres (SPOT - TM) with up to seven separate bandwidths or windows through which to view. The former provides an effective photomap equivalent to 1:50,000 aerial photography. The latter enables a multitude of separate land use classes to be identified with both visual and digital analysis techniques.

Numerous other satellites are planned to be launched over the next two decades by European nations, the USA and Japan. These will maintain and enhance existing systems. There is the guarantee that the source will be there for many years. The new systems will provide greater resolution and greater discrimination than those available at present.

In terms of digitising maps and aerial photographs, scanners may 'grab' a frame of 512 x 512 pixels. A pixel is a picture element and can be thought of as a dot of given colour or greyness. A 60 x 60 cm. 1:50,000 map sheet could be represented by 0.5 mm. pixels with a 512 x 512 frame grabber or 0.125 mm. pixels with a 2000 x 2000 charged couple device(CCD) scanner. The latter picture would be indistinguishable with the naked eye from the original. The volume of information gathered by such techniques is enormous but data compression and digital video technology makes it possible.

There are other great advances being made in the use of computer based information systems at this time. They are concerned with making computers easier to use and more intelligent. Computers are being used to store knowledge as well as mere facts or data. If computers have more knowledge they are more understanding of the requirements of the user. The user is enabled to phrase his queries in a more natural language than the language of computer programming.

This is the area of Artificial Intelligence (AI) and Expert Systems (ES). Many believe that the Information Technology (IT) revolution which manifests itself in bringing intelligence to computers will rival the industrial revolution of the previous century. An expert system is an attempt to encapsulate in a computer the knowledge of one or more human experts, together with some of the reasoning powers of those experts. This makes that expertise more widely available. It is therefore an excellent vehicle for technology transfer. Commonly the system may provide intelligent access to and interpretation of facts stored in a database. In the context of land use we may ask questions of the form:

- at coordinates x and y on the map on the screen, what can I grow there?

An unintelligent system could not even understand the question; a slightly more intelligent one will give you facts about the point x,y; a better one still may even give you advice - which you could question; the best might respond with a question - why are you asking this question - and start from there.

Another type of question the planner might ask is :

- The country needs to expand its production of maize; for maximum economic and technical efficiency where would be the best places to encourage maize production; would it mean encouraging changes in another area to the production of crops displaced by the maize; if so, where should the production of those crops be encouraged ... and so on ?

In order to solve this particular problem a national database is needed together with the means to identify land, climate, socio-economic and infrastructure resources that give rise to efficient conditions for maize production. One also needs the knowledge of how to identify these conditions - an expert or an expert system who can intelligently retrieve the necessary facts from the database and interpret them appropriately. It is perfectly possible for systems that are able to respond to the types of question stated above to be built in Thailand using appropriate computer hardware and software, as will be demonstrated during the workshop.

On the way to achieving these ultimate ends several intermediate steps will have to be taken, indeed DLD has already made a start. These include the development of computer based methods using simple and complex GIS systems for :

- soil classification;
- aggregating soil series to form homogeneous units;
- determining procedurs for establishing agro-climatic zones;
- determining input-output relationshps by Land Unit;
- and, developing and testing crop simulation models.

From data already collected in Thailand, and where appropriate from data collected from abroad, and from data collected as a part of an intensive knowledge gathering programme, knowledge of the relationships between data must be acquired. These relationships will be mathematical and logical, representing the laws of physics and pragmatic experience.

Knowledge may be represented in computer format as:

- mathematical models based on the laws of physics;
- mathematical models based upon statistical relationships;
- mathematical models based upon concepts which may include a mixture of physical and statistical models, empirical and conceptual models;
- logic based models;
- heuristic models.

The latter two formats deserve further description. A soil classification system is and example of a mixed heuristic and logic based system. A soil is assigned to a class on the basis of a number of attributes of the soil and the experience of the classifier. A completely heuristic system is a way of representing relationships between inputs and outputs or causes and effects when complete information is unavailable. It is a working hypothesis which serves the function for much of the time. Humans frequently make decisions in a heuristic fashion. An essential element of such a system is that it is able to feed back the results of decisions to improve future decisions. The system must be able to learn from its mistakes and successes.

Many tools are available to develop the necessary models for use in land resource evaluation and planning, and many models exist. The main tools are:

- comprehensive multi-variate statistical packages;
- expert system shells;
- spread sheet packages;
- graphics packages;
- optimal resource allocation packages.

During the course of the workshop these will have been explained and demonstrated. A component which should be noted is the way in which different tools are linked. This is done on the same or similar computers, this empahasises the need for compatibility and communications, for all of the necessary information cannot be assumed to be in the same place or on the same computer, as is the case in the demonstrations.

3. PRESENT USE OF COMPUTERS

A number of government organizations concerned with land use are using computer technology. These include :

- Department of Land Development;
- Office of Agricultural Economics;
- Asian Institute of Technology Regional Computer Centre;
- National Statistical Office;
- Meteorological Department;
- Royal Irrigation Department;
- National Remote Sensing Centre;
- Department of Lands;
- Universities;
- Royal Forestry Department.

DLD has just started to make use computers in its work. A multi-user/multi-tasking micro computer has been installed for use by the Soil Survey and Land Classification division. It is charged with developing a number of soils databases, crop suitability evaluation programs, climate databases and to develop digital mapping and cartography functions.

The National Statistical Office vies with the Royal Irrigation Department and the Department of Agricultural Economics in their provisions for computer capacity. The NSO runs a medium sized mainframe computer with communications links to several government departments. Its function is to provide a national statistical service including population census and an economic database. The RID have just centralized their capacity and are providing management information systems and operation systems to RID. They also hold a number of climate and hydrology data bases. They plan to expand their existing capacity for Computer Aided Design.

The Meteorological Department maintain a number of computer systems to store and retrieve basic historical information, provide message switching and to receive and process satellite data. They are due for a number of enhancements, and a three phase plan has been drawn up which would be complementary to that proposed for DLD.

A number of universities are heavily involved in developing computer usage and the signs are that the supply of computer science graduates and computer literate graduates in the many disciplines used in land resources planning will be adequate for the future. The universities may also become involved in the development of the technology for Thailand. In addition to this basic level of activity many academic institutions are involved in holding valuable databases on agricultural and social statistics and possess communications links with national and international databases.

The Thailand Remote Sensing centre has the capacity to receive a wide range of satellite data and is proposing to increase this capacity. It can also undertake the preparation of hard copy and digital processing products.

4. APPROPRIATENESS AND TIMING

During recent studies made for the ADB/DLD Land Use Planning Project it became clear to the writer that Information Technology (IT) is taking off in Thailand in all sectors of the economy. Government policies have done their bit by reducing duties on imported IT products. The Universities are developing IT courses and are aiming to produce graduates with exposure to computers during their courses. The private sector is expanding quickly, with the number and size of firms selling hardware, software and computer expertise growing rapidly. As described in this paper many government departments too are expanding their IT capacity. Having already started out on the road to using IT in their work, the proposed Project provides funding for hardware, software and computer expertise thus enabling DLD and a number of related organizations to naturally expand their Information Technology capacities.

The timing of the Project and the scheduling over a five year period will enable DLD and the related organizations to strengthen their capacity to use computers in their work. The pace of expansion permitted by this investment is considered appropriate to the capacity of the organizations to build manpower resources and skills from the existing bases. There will be the opportunity to rationalize some tasks as other government organizations see the benefits of having a common database for selected data. Communication links to facilitate this are provided.

'Knowledge is Power' and if Thailand is going to be able to deliver the knowledge that will give the power to the agricultural economy, then those concerned with collection, collation and distribution of both basic data and knowledge of available resources, expertise and the socio-economic climate must be equipped with the appropriate tools to do the job. The ability to use the new tools must be acquired by learning new skills and gaining experience. It is self evident that there are no short cuts to gaining real experience in a fast moving field, other than to become involved in the growth and the movement. At the same time one can learn from other people's experience by having such people to give their advice and experience. There will be difficulties and hiccups in the progress, but it is as essential to become involved in the revolution of the late 20th Century - Information Technology - as Thailand has become in the green revolution of a decade or so ago.

There is considerable awareness of computer technology in Thailand - at all levels of society. Secretaries are aware of word processing and are keen to learn how to use the new methods. Even the humble man or woman in the street is aware, and may wistfully comment on how much better off he/she would be if they knew something about computers. These social factors and the need not to fall behind make it appropriate for Thailand and in this context the agricultural sector, to develop its IT capacity.

The agricultural sector of the Thai economy is large and will continue to be so in the future. it is therefore important for this sector to be managed efficiently. To do this requires knowledge - from the farmer up to the highest policy making levels in government. By not being aware of facts government decisions can unwittingly destroy parts of the agricultural economy. It is necessary that those taking decisions that affect the agricultural economy are aware of the facts and are advised on the consequences of their decisions. The proposed information system will enable those concerned with the provision of facts and knowledge of land resources utilization and potential to respond quickly and accurately to requests for information to use in decision making. It is modern IT products and expertise on how to use them that enables such a response to be made.

THE APPLICATION OF CROP COMPARATIVE ADVANTAGE MEASURES IN LAND USE PLANNING

J. D. Shearing

1. INTRODUCTION

There is a need to consider comparative advantage when allocating scarce resources within the agricultural sector to ensure optimal land allocation. These calculations should be made using both local market and economic prices to allow crops and cropping systems to be compared in terms of their potential returns to the producer and net benefits to the economy. Ideally, those crops or cropping systems offering the highest potential net economic benefits should also offer attractive returns to farmers to encourage production.

The methodology outlined in this paper allows the planner to examine the degree of correlation between financial and economic measures of comparative advantage. In cases where the ranking exercise illustrates wide divergences between chosen measures, the methodology provides the basic data required for formulation of policies directed at appropriate price intervention.

Thailand's present shortages of foreign exchange makes it increasingly important for the land use planner to pay due regard to the relationship between imported inputs and potential foreign exchange generation from either crop export or import substitution.

This paper describes a simple illustrative Crop Comparative Advantage Model which has been prepared using Lotus 123 for use on a micro-computer. The model allows the land use planner to derive six measures of comparative advantage for up to 20 annual crops grown in 30 land units using 'macro' programming commands. The model permits the entry of crop physical input/output data and financial prices on a land unit basis and economic prices into a single matrix on the assumption that they are equally relevant to all land units under consideration. Measures of crop comparative advantage briefly reviewed in the paper are:

- Financial Gross Margin;
- Economic Gross Margin;
- International Value Added;
- Domestic Resource Cost of International Value Added;
- International Competitiveness;
- Foreign Exchange Dependence.

The paper also discusses the application of these measures to alternative cropping systems and the comparison between annual and perennial crops.

The model can be used at various planning levels depending on the input data available. Data from the model can also be used to rank alternative crops or cropping systems in terms of their financial and economic comparative advantage by land unit. As such the model is able to highlight crops and cropping systems offering the greatest economic benefits to the economy. A flow chart for the model is illustrated in Figure 1.

2. DEFINITION OF FINANCIAL AND ECONOMIC ANALYSIS

Before considering the financial and economic measures of comparative advantage derived by the model it is important to first draw a clear distinction between analysis conducted in financial and economic terms.

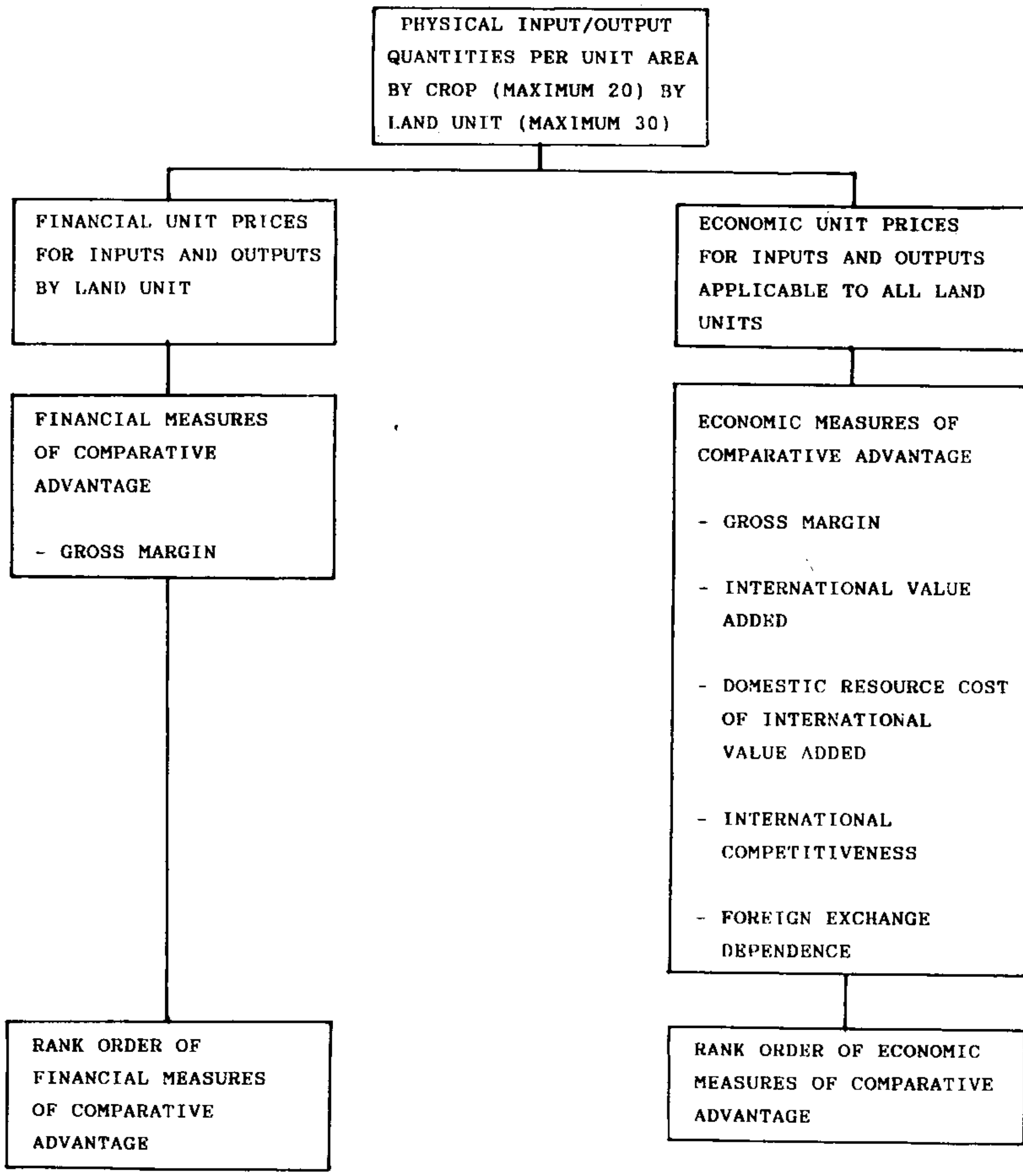
2.1 Financial Analysis

Financial analysis is concerned solely with measuring the profit or loss to the producer from alternative land use. As such, input prices and output values are expressed in terms of local market prices paid or received by the farmer. Financial profitability for the purpose of crop comparative advantage is generally measured in terms of "gross margin per unit are" This can either be estimated on a single crop basis or in terms of a cropping system if this is more appropriate.

2.2 Economic Analysis

Economic analysis is concerned with measuring the benefits to the economy of a country. In order to achieve this objective it is necessary to value the various factors of production in terms of their opportunity cost. For traded goods this involves the valuation of production inputs and outputs at their point of consumption or production in relation to world market prices. For non-traded commodities, valuation is either based on long run average financial prices, domestic resource cost or on the opportunity cost of alternative use. As such

Figure 1 FLOW CHART FOR CROP COMPARATIVE ADVANTAGE MODEL



economic analysis necessitates the removal of all internal transfer payments such as taxes, subsidies and "excess profit" in an attempt to arrive at a truer reflection of the costs of production to the economy.

3. FINANCIAL MEASURES OF COMPARATIVE ADVANTAGE

The most commonly used measure of financial profitability to the farmer is termed "financial gross margin". This is derived by subtracting input costs from the output value expressed in terms of local market prices.

Although this measure of comparative advantage is likely to be initially estimated on a single enterprise basis it is important to derive a farming system value per annum for comparison with alternative systems of land utilisation. Alternative land uses might include long-duration tree crops such as rubber, cashewnut or fruit trees. In such cases it would be necessary to derive an average annual net present value so that comparisons could be made on an annual basis. This would necessitate the preparation of a net cash flow for the duration of the crop so that the establishment cost, annual recurrent costs and projects revenues could be taken into account. To allow valuation of the model in economic terms, the base data should be expressed in physical terms (e.g. kgs of fertilizer per hectare etc). The resulting net cash flow should be discounted using the chosen opportunity cost of capital to produce a net present value per hectare which would then be divided by the discounting period to provide an average annual figure.

4. ECONOMIC MEASURES OF COMPARATIVE ADVANTAGE

The model allows five principal measures of economic comparative advantage to be estimated, namely:

4.1 Economic Gross Margin

This measure represents the difference between the economic output value and the economic input cost. As such it provides a direct measure of the economic benefit from producing a crop. As it includes both foreign and domestic resource costs the measure does not consider the foreign exchange requirements of the production system. Hence, a positive economic margin merely indicates that the economy receives a positive benefit from production.

4.2 International Value Added

This coefficient measures the net foreign exchange earnings or savings generated through the production and marketing of a particular commodity. It is calculated by subtracting the foreign exchange requirements of production from the foreign exchange generated from export or import substitution. Where foreign exchange is a severe constraint on development, it is an important measure to maximize.

4.3 Domestic Resource Cost of International Value Added

In the case of an export commodity this coefficient measures the domestic non-traded resources necessary to earn one unit of foreign exchange. For a commodity which is normally imported (i.e. import substitution) the coefficient measures the amount of domestic resources required to save one unit of foreign exchange. If the rate is less than the official exchange rate the measure indicates economic comparative advantage.

4.4 International Competitiveness

This compares the domestic resource cost of international value added with the official exchange rate. A value greater than unity indicates an economic comparative advantage.

4.5 Foreign Exchange Dependence

This coefficient measures the amount of foreign exchange that must be spent on traded inputs to generate one unit of gross foreign exchange earnings or savings. Because the values are unitless, the measure should be considered alongside other performance measures. The lower the coefficient the greater the product's positive contribution to the balance of payments. It also indicates the extent to which production would be sensitive to disruptions in the importation of production inputs.

5. DATA INPUT REQUIREMENTS OF MODEL

The data input requirement of the model fall into three categories as reviewed below.

5.1 Physical Input/Output Quantities

Provision is made in the model for the land use planner to review the comparative advantage of up to 20 crops by 30 land units. If the number of crops or land units exceeded this level it would be necessary to make further runs of the model.

The model requires the planner to enter the physical input/output quantities per unit area for selected crops. The principal inputs would include seed, fertilizer by type, pesticides by type, cultivations by type and labour days. Outputs would be limited to the main products and any coproducts such as straw, hulls etc which may have considerable local value as feedstuffs, fuel or as thatching materials.

Physical input/output quantities for selected crops would be collected by field survey on a land unit basis and from secondary data sources.

5.2 Financial Unit Costs

Financial unit costs refer to those prices prevailing in the market place. For the purposes of the model they would be the prices paid by the farmer for production inputs or received for production outputs. Care should be taken to express such prices at a common point such as the farm-gate to avoid possible distortions. If prices refer to those prevailing in the local town, these should be adjusted to reflect likely transport costs between that point and the farm gate. As the financial price of many products is likely to vary during the production season according to supply and demand, it is advisable to use a weighted average price for the year in question. If sufficient secondary data is available this weighting exercise should take into account weekly prices by grade and the quantities of product delivered to the market place.

It is likely that financial unit prices would be assembled partly from field surveys conducted on land unit basis and also from appropriate secondary data sources. As there are likely to be variations in local prices depending on the distance from the market place, the model makes provision for the entry of prices on an individual land unit basis.

5.3 Economic Unit Costs

Economic unit costs reflect the estimated value of the production inputs and outputs to the economy rather than to the individual producer. As such, they are only likely to mirror local market prices in cases where there is no internal price intervention by way of taxes and subsidies. Under the present relatively free market conditions prevailing in Thailand, it is therefore possible that there will be reasonable correlation between financial and derived economic prices, particularly in the case of traded commodities.

As explained at Section 2.2. the derivation of economic prices falls under the broad headings of traded goods and non-traded goods. These are reviewed in more detail below:

a) Traded Goods

When Valuing internationally traded commodities such as rice, cassava, sugar, petroleum and fertilizers in economic prices it is important t^ first decide whether the country in question is a net exporter or net importer of the respective commodity. This decision should not only take account of the present situation but also likely changes in the medium and longer term, as commodities which replace imports (i.e. import substitutes) have a greater economic value then potential exports. The simple illustrative example presented in Table 1

Table 1 Comparison of Derivation of Economic Prices for Imported and Exported Commodities

IMPORTED COMMODITY

		US$ per Tonne	
FOB[1/]	point of sale		150
Plus	Transport/loading costs from point of sale to port of entry	15	
CIF[2/]	at point of entry		165
Plus	Port/handling charges	5	
	Internal transport costs and marketing costs to relevant market	35	
		40	205
Less	Transport and marketing costs to relevant market	10	
	Local storage	10	
		20	
Potential Economic Value at the Farm-gate assuming the commodity is imported (or an import substitute)			185

EXPORTED COMMODITY

		US$ per Tonne	
CIF[2/]	point of sale		150
Less	Transport/loading costs from point of export to point of sale	15	
FOB[1/]	at point of export		135
Less	Port/handling charges	5	
	Internal transport costs	10	
	Marketing costs	25	
	Local storage	10	
		50	
Potential Economic Value at the Farm-gate assuming the commodity is exported			85

1/ FOB = Free on board

2/ CIF = Carriage, insurance and freight clearly shows why this is the case.

The construction of the crop comparative model assumes that the economic value of production inputs and outputs will be equally relevant to all land units under consideration. This is considered to be a reasonable assumption when planning up to regional level.

b) Non-Traded Goods

Crops which are not traded internationally should be valued on the basis of their average financial price as discussed at Section 5.2 above. If a time series series exceeding one year is used, suitable adjustments for inflation should be made so that all prices are expressed on the same price base.

In the case of production inputs such as labour, it is necessary to make a judgment on the real value or opportunity cost to the economy. Frequently the minimum financial wage rate for unskilled labour is set by government at a level which allows the essential foodstuffs to be purchased by the average family. As such, the financial wage bears little relationship to the economic costs of unskilled labour as supply generally exceeds demand except at peak periods. With skilled labour the converse is frequently true - generally there is a chronic shortage of skilled manpower yet official salary scales hold wages at an artificially low level. Hence the economic value of unskilled labour is likely to be below the market wage and that for skilled labour above.

c) Costs with Traded and Non-Traded Components

In cases where financial costs have both traded and non-traded components it is necessary to disaggregate the composite cost into its respective components and revalue in economic terms. An example of such a cost would be land preparation using machinery. In such a case it would first be necessary to isolate the capital and operating costs and then to remove internal transfer payments such as taxes and duties on capital expenditure before revaluing the remaining traded and non-traded components. This exercise is generally restricted to one level of disaggregation.

6. APPLICATION OF CROP COMPARATIVE MEASURES

6.1 General

Sample printouts from the crop comparative advantage model are presented in Table 2 and 3 for financial and economic gross margins respectively. Reference to these figures will illustrate that a rank number has been attributed to the crop values within each land unit to reflect their order of magnitude. This ranking exercise assigns number 1 to the crop showing the

Table 2 Financial Gross Margin - Measure of Crop Comparative Advantage Showing Rank Order by Land Unit

(Baht per rai)

Crop	1	Rank	2	Rank	3	Rank	4	Rank	5	Rank	6	Rank	7	Rank	8	Rank	9	Rank
Rice (Transplanted/Rainfed)					208.57	4	9.43	3	55.38	1	246.33	5	863.47	1	297.44	2	182.10	3
Rice (Broadcast/Rainfed)	310.29	1									-31.95	7						
Rice (Dry seeded/Rainfed)																		
Glutinous rice(Transplanted/Irrigated)																		
Glutinous rice(Transplanted/Rainfed)					210.93	3			-213.09	2							-119.26	7
Glutinous rice(Dry seeded/Rainfed)																		
Maize (Animal feed)							28.94	2			384.09	2			-81.74	3	141.86	4
Cassava					268.67	2	208.63	1			273.03	4					361.53	2
Kenaf					1523.01	1											806.43	1
Sorghum											310.28	3					-86.17	6
Cotton											-8.02	6						
Mungbean			287.44	1											398.61	1		
Groundnuts																		
Chilli											707.95	1					21.30	5
Watermelon																		
Local rice(Transplanted/Irrigated)																		

Crop	10	Rank	11	Rank	12	Rank	13	Rank	14	Rank	15	Rank	16	Rank	17	Rank	18	Rank
Rice (Transplanted/Rainfed)			130.04	1	302.88	4	175.23	4	240.82	1	-12.64	2					-220.66	4
Rice (Broadcast/Rainfed)							-204.61	6										
Rice (Dry seeded/Rainfed)									-91.34	6							-317.56	5
Glutinous rice(Transplanted/Irrigated)																		
Glutinous rice(Transplanted/Rainfed)			-27.64	2					-75.14	4	10.45	1						
Glutinous rice(Dry seeded/Rainfed)									-703.20	5								
Maize (Animal feed)	511.47	2			478.08	2	213.51	2	-44.82	3					34.74	3	609.38	2
Cassava	763.47	1	-710.50	3	-114.01	5	185.98	3	132.87	2			256.86	1	-73.46	4	541.55	3
Kenaf					680.23	1	558.56	1										
Sorghum					448.52	3	114.21	5					41.98	2				
Cotton															1939.25	1		
Mungbean																		
Groundnuts															460.87	2	726.27	1
Chilli																		
Watermelon																		
Local rice(Transplanted/Irrigated)																		

Crop	19	Rank	20	Rank	21	Rank	22	Rank	23	Rank	24	Rank	25	Rank
Rice (Transplanted/Rainfed)							434.06	1						
Rice (Broadcast/Rainfed)														
Rice (Dry seeded/Rainfed)														
Glutinous rice(Transplanted/Irrigated)					542.15	1							-15.67	3
Glutinous rice(Transplanted/Rainfed)							164.74	2						
Glutinous rice(Dry seeded/Rainfed)														
Maize (Animal feed)	485.56	1	235.28	4	-84.30	3	-83.45	3	403.09	4				
Cassava	-319.84	2	463.90	2					785.44	2			481.01	2
Kenaf													858.92	1
Sorghum			81.78	5										
Cotton			1671.92	1					4237.79	1				
Mungbean									460.54	3				
Groundnuts														
Chilli														
Watermelon			371.31	3										
Local rice(Transplanted/Irrigated)					520.20	2								

Source: DLD data and Consultants' Estimates

Table 3 Economic Gross Margin - Measure of Crop Comparative Advantage Showing Rank Order by Land Unit

(Baht per rai)

Crop	1	Rank	2	Rank	3	Rank	4	Rank	5	Rank	6	Rank	7	Rank	8	Rank	9	Rank
Rice (Transplanted/Rainfed)					1455.40	2	813.63	1	901.82	2	1096.85	3	3004.77	1	1608.56	1	984.66	1
Rice (Broadcast/Rainfed)	1588.26	1									423.41	7						
Rice (Dry seeded/Rainfed)																		
Glutinous rice(Transplanted/Irrigated)																		
Glutinous rice(Transplanted/Rainfed)					1629.17	1			912.63	1							627.91	5
Glutinous rice(Dry seeded/Rainfed)																		
Maize (Animal feed)							314	2			1118.79	2			512.11	2	844.41	3
Cassava					504.45	4	11.80	3			777.70	6					571.72	6
Kenaf					1149.03	3											774.74	4
Sorghum											797.58	5					55.02	7
Cotton											1086.90	4						
Mungbean			306.87	1											325.38	3		
Groundnuts																		
Chilli											1578.89	1					942.39	2
Watermelon																		
Local rice(Transplanted/Irrigated)																		

Crop	10	Rank	11	Rank	12	Rank	13	Rank	14	Rank	15	Rank	16	Rank	17	Rank	18	Rank
Rice (Transplanted/Rainfed)			1842.95	1	1437.65	1	945.22	1	1064.53	1	857.53	2					449.22	4
Rice (Broadcast/Rainfed)							239.93	6										
Rice (Dry seeded/Rainfed)									691.75	3							102.03	5
Glutinous rice(Transplanted/Irrigated)																		
Glutinous rice(Transplanted/Rainfed)			779.51	2					754.51	2	859.52	1						
Glutinous rice(Dry seeded/Rainfed)									-75.96	6								
Maize (Animal feed)	1381.46	1			1351.55	2	624.79	2	399.19	4					740.69	2	1183.02	1
Cassava	765.11	2	256.42	3	316.34	5	292.58	5	332	5			338.14	1	190.88	4	736.78	2
Kenaf					545.88	4	452.27	3										
Sorghum					1052.98	3	395.70	4					249.74	2				
Cotton															3548.24	1		
Mungbean																		
Groundnuts															357.62	3	715.78	3
Chilli																		
Watermelon																		
Local rice(Transplanted/Irrigated)																		

Crop	19	Rank	20	Rank	21	Rank	22	Rank	23	Rank	24	Rank	25	Rank
Rice (Transplanted/Rainfed)							1943.87	2						
Rice (Broadcast/Rainfed)														
Rice (Dry seeded/Rainfed)														
Glutinous rice(Transplanted/Irrigated)					1918.74	2							1036.39	1
Glutinous rice(Transplanted/Rainfed)							2515.97	1						
Glutinous rice(Dry seeded/Rainfed)														
Maize (Animal feed)	1225.40	1	868.77	2	1605.27	3	269.03	3	1022.88	1				
Cassava	487.01	2	766.13	3					482.63	3			589.61	3
Kenaf													768.95	2
Sorghum			398.97	5										
Cotton			2450.89	1					5260.74	2				
Mungbean									453.27	4				
Groundnuts														
Chilli														
Watermelon			737.54	4										
Local rice(Transplanted/Irrigated)					2952.73	1								

Source: DLD data and Consultants' Estimates highest value. The model performs the same ranking exercise for the other comparative advantage measure not shown in the sample printouts. This allows the various measures of financial and economic comparative advantage to be contrasted.

6.2 Crop Rank Order

a) Financial Comparative Advantage

The model estimates one financial measure of crop comparative advantage, namely financial gross margin. This represents the market value of the main product plus any co-product, less the direct costs of production valued in market prices. As such the financial gross margin is a direct measure of the potential marginal return to the farmer or producer, although in the case of smallholders, adequate supplies of basic foodstuffs for the household (subsistence requirements) may be considered of greater importance than likely cash return. From this point of view, financial gross margin may not be the primary motivating factor of the small subsistence producer. This is an important factor to remember when ranking alternative crops or cropping systems in financial terms.

b) Economic Comparative Advantage

In view of the present shortages of foreign exchange it is essential that the land use planning process pays due regard to the relationship between imported inputs and the potential foreign exchange generation available from either crop exportation or import substitution. There is considerable scope in Thailand for improving cropping intensity principally though irrigation and flood control. However, before this is done careful consideration should be given to the following questions:

- what is the cost of importing the basic foodstuff shortfall?
- what is the cost of producing the basic foodstuff shortfalls domestically, either from improved cropping intensity or improved yields, principally through better water control, improved fertilizer supply, new varieties or crop substitution?

The nature of the crop comparative advantage model and the economic measures of crop comparative advantage derived from its use, allow these questions to be addressed. If, for example, foreign exchange was shown to be the major constraint on development then crops or cropping systems having a low foreign exchange dependence might be selected even though they produced lower net economic benefits.

6.3 Cropping System Rank Order

One of the principal questions to be addressed by the land use planner is the merit of planting a perennial crop on land equally suitable for either annual or perennial crop production. In order to answer this question it is necessary to bring both annual crop production and perennial crop production onto a similar basis so that realistic comparisons can be made. The most straightforward approach to this problem is to contrast the potential annual returns from alternative cropping systems with the average annual net present value obtainable from perennial crop production. Such an approach takes account of the establishment period for tree crops and also the production profile over the remaining life of the crop. It is possible to make such comparisons either in financial or economic terms depending on the circumstances.

7. CONCLUSION

The simple illustrative crop comparative advantage model outlined in this technical paper provides a useful tool for the land use planner when attempting to allocate scarce resources within the agricultural sector. Its construction allows iterative calculations to be made quickly to test the effects on comparative advantage from changes in basic parameters such as traded value and changes in the physical input/output relationship following improvements in varieties or varying fertilizer use. The model also allows the effects of enhanced irrigated production to be tested through the incorporation of an annual charge selecting the capital and recurrent costs of supply irrigation water on the input side of the production equation.

It is worth noting that the construction of the model using Lotus 123 allows modifications and imprpvements to be made with limited difficulty. Also the ability to run the model on any IBM-compatible micro computer with 640 KB random access memory allows the model to be run in any location having standard mains voltage.

CASE STUDY IN USING DECISION SUPPORT SYSTEMS IN LAND RESOURCE PLANNING

J. D. Shearing and Dr. T. R. E. Chidley

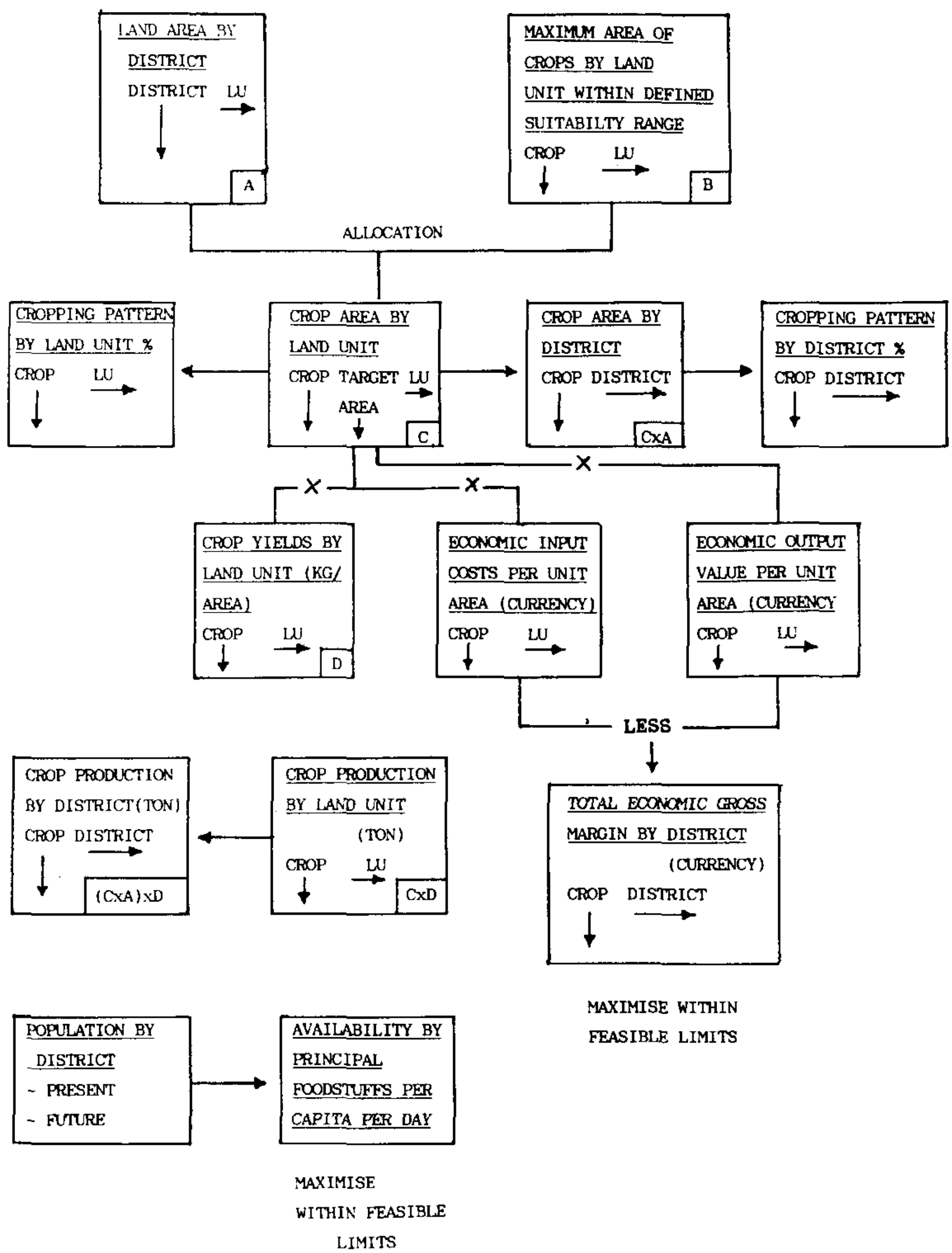
1. INTRODUCTION

The problem of land use planning is to decide how to allocate available land to alternative activities. Planners frequently have goals which involve the achievement of policy set or the optimization of selected economic measures. The work described in this paper is concerned with planning the use of land for agriculture. At the level of planning addressed in this paper no consideration is given to how to implement the plan. The model is concerned with helping the planner to determine whether a plan is feasible and what resources will be needed for its implementation. Also likely effects of changes of internal and external factors on the plan, such as policy movements or price rises. The planner may also wish to see that changes would be needed to move from the present situation to a planned state and whether this looks feasible. Single decision support tools such as the one described in this paper can greatly assist the planner in his work.

The application of a relatively simple decision support system - the Lotus 123 spreadsheet - is described. It can be used to prepare quite large and detailed plans and is easily learned and understood. The data base and the estimating rules are readily checked and edited without the need for the user to be an expert in computer programming. The effects of alternative assumptions are obtained interactively using low cost equipment.

The decision support system can be taught to remember a number of repetitive operations, saving the planner's time when tackling similar problems. One major task is setting up the model framework, another is entering the basic data, a third is performing the calculations and a fourth is presenting the results. Since each of these tasks are essentially similar for each of a number of areas or Provinces a set of rules for these tasks has been defined. The rules automatically set up a shell. The user is left to modify the shell to suit specific needs. In this way reality can be introduced into the planning process by taking into account local variations. A simple flow chart for the allocation model is presented in Figure 1.

Figure 1 FLOW CHART FOR ALLOCATION MODEL



OTHER OUTPUTS : PRODUCTION INPUTS BY DISTRICT
(SEED,FERTILISERS,LABOUR,DRAFT,POWER)

2. THE DATABASE

The basic data used in the model comprises tables or matrices of available land by land unit (LU) and district; agricultural inputs and outputs by activity and LU; costs of inputs and prices of outputs by local and foreign exchange components; and, the suitability of each activity on each LU. A land development unit is or set of parcels of land that may be described in terms of some common attributes which affect its suitability for agricultural use. The attributes typically may include soil type and land slope. These parcels of land are tabulated by administrative district within a province or even a whole country. This enables the planner to make some spatial allocation of the resources that may take into account district requirements.

An agricultural activity may be the production of a single crop in a single season, a tree crop, animal products or a complete cropping system with mixed crops over many seasons or years. The basic production inputs and outputs are measured over a twelve month period.

3. THE ALLOCATION PROCEDURE

Effective allocation requires substantial quantities of detailed information by LU. Without such data the usefulness of the model is severely restricted. The planner enters the raw data into the database component of the model. A target is set for each activity within the planning area, which could be a district, province, country or region. The total land area within each subdivision of the planning area is computed by post multiplying the available land matrix by the unit vector. Next the area of each land unit is computed by pre-multiplying the available land matrix by the unit vector.

The planner selects a level of suitability which is regarded as a minimum for each activity and forms a matrix showing the maximum area by LU that could be used for each activity. This is done by inspecting the suitability matrix for each activity and each LU and bringing across the area of that LU into the corresponding cell of the maximum area matrix. The sum of each row in this matrix is formed by post multiplying it by the unit vector, or summing the row entries.

A provisional allocation of land area by LU is then made for each activity on the basis of scaling each entry in the maximum area matrix by the ratio of target area of each activity by maximum available area for that activity at the chosen level of suitability. The sums of the columns of this matrix are checked to ensure that the total area of land allocated does not exceed that available for the LU. If it does then the planner must choose to reduce one or more target levels. This step can be repeated until a feasible allocation is made.

The area of land allocated to each activity in each LU is now allocated to districts on the basis of the proportional area of each LU in each district. The area allocated to each activity in each district is then obtained. Similar operations are used to estimate total production of each activity by LU and total needs of inputs. Inputs and outputs are distributed to districts and the costs and values are determined using local prices. These operations are described in matrix form in Appendix 2.

4. THE MODEL

This section describes the implementation of the model on LOTUS 123. Much use is made of programmable macros in setting up the framework for a new model and operating an existing model. The key starting data are the sizes of the arrays or matrix used. These include the number of different kinds of input, the number of LDU's, the number of activities and the number of districts within the planning area.

In terms of implementation a number of work areas, and unit vectors and matrices are set up to cover all eventualities. These are superimposed on one another within the scope of the largest possible matrix or vector. The set up procedure creates all of the space needed for the basic and derived data arrays and copies formulae into them where needed. Names of crops, inputs, districts and LDU's are entered once and are transcribed by the setup programme. The rest of the operations, after entering the data, which may be copied from separate data bases elsewhere, are carried out by invoking a series of macros which enable the user to stop at any stage and reiterate or make arbitrary changes.

With the basic model now formulated additional refinements can be added. These include the introduction of an element of nonlinearity and sub-optimization. For example the yield data which would normally be abstracted from a database would be modified to make it a function of the input data. This function would have to be multi-faceted in order to take into account different management of the basic inputs. The information for such an approach is not yet available in Thailand though work is current in this area.

It would also be feasible to set the problem to run with an element of automatic searching to meet target output requirements. This is done by two methods. The first is to make the target both an input and an output to the model. the spreadsheet will then note that there are circular references in the programme and automatically recompute the whole sheet until the circular references are resolved. The second method is to control the repetitive calculations by discrete criteria involving the systematic adjustment of some of the variables until the targets are met.

5. CONCLUSION

The paper demonstrates the use of a simple modern decision support tools in land use planning. The approach is easily learned. The person carrying out the procedure sets out what they want to do on a series of sheets of paper which have been divided into an array of cells, rows and columns. The raw data for the problem is copied into the cells from basic data. The procedure for allocating land to activities is then decided upon. this procedure is implemented on the paper forms. The various output forms are completed to show the results of the allocation in the form of consequent allocations, inputs and outputs. The procedure is thus fully understood by the planner.

The spreadsheet is then invoked and the arrays of data used on the paper plan are copied onto the spreadsheet. The operations required to compute the allocation and consequent input and output tables are carried out using the spreadsheet, including the setting up of row and column headers. In determining the operations, use is made of matrix arithmetic where possible. the reason for this is that it saves enormous volumes of computer storage and facilitates the later use of macros. The planner is now familiar with the spreadsheet model and its setting up and operation.

The next step is get the spreadsheet to 'learn' the steps carried out by the planner in setting up the model on the spreadsheet. This is done by simply writing down the exact steps used to set up the spreadsheet in the first place. At the appropriate point, however, the planner substitutes the dimensions of the problem instead of the counted key presses. The dimensions are stored in cells which are filled in at the beginning. Each array used is given a name, including the dummy work area arrays which are needed for the matrix arithmetic. The planner with no experience of computer programming is thus able to build a general purpose planning model. The planner can also test its validity on a small data set and be confident in its application to larger sets.

The benefits include bringing an awareness to the non-computer aware planner of the benefits of an integrated computer database. The planner soon gets tired of reentering data once the advantages of storage and retrieved using the computer have been learnt. Also the planner needs very little advice from the computer professional which saves on costs and gives great satisfaction.

Experience has shown that a basic micro computer with 640 Kilo bytes of storage can handle a problem with 20-25 land development units in 20-30 districts and about 20 crops and 10 inputs. It takes a few minutes to run each case enabling many cases to be tried. With an enhanced computer, (additional 1000 dollars) a problem 10 to 15 times as large can be processed. This brings the problem of the class of a national planning exercise onto the planner's desk.

Appendix 8.1

THE DATA DESCRIPTION

Each data set is described as an array whose maximum dimensions are given. The dimensions are as follows:

Number of activities or crops	I
Number of inputs	J
Number of Land Development Units	L
Number of Districts	D

Matrix	Description
INPUT (I,J)	inputs J required to produce crop I in units of resource per hectare per year.
AVAIL (D,L)	available land of type L in district D, hectare.
SUIT (I,L)	suitability of LDU L for crop/activity I.
MAXAVAIL (I,L)	maximum availability of land of type L in selected suitability range for crop I, hectare.
ALLOC (I,L)	the trial allocation of LDU L to crop I to meet target areas, hectare.
TARGET (I)	the target area in the planning region to be allocated to activity I, hectare.
TOTDIST (D)	the total land area available in district D, hectare.
TOTLDU (L)	the total area of land of type L, hectare.
TOTALLOC (L)	the actual area of land allocated to all activities in LDU L, hectare.
RATIO (I)	the ratio of target area for a given activity to total potential area available.
TOTAVAIL (L)	the total area potentially available for a given activity, hectare.
PROP (D,L)	the proportion of the total area of each LDU L within each district D.

A (D,I)	the area of land in each district D allocated to each activity I, hectare.
YIELD (I,L)	the yield of each activity I on each LDU L.
TINPUT (J,L)	the total of input J required for all activities on LDU L, units of need.
TDINPUT (J,D)	the total input of J required for all activities in district D, units of use.
COST (J,D)	the unit cost of each input J in district D, cost/unit.
PRICE (I,D)	the price fetched foe one unit of activity I in district D, cost/unit.
CCOST (I,L)	the cost of engaging in activity I on LDU L at the allocated level.
DCOST (J,D)	the cost of all inputs of type J in district D.
TYIELD (I,L)	the total yield of activity I on LDU L under the allocation.
MAXSUIT (I)	maximum tolerable suitability for activity, I.
DYIELD (I,D)	yield of each activity I in district D.
TDYIELD (I)	total yield of each activity.

Appendix 8.2

OPERATION

This appendix describes the operation to be carried out once the data has been set up. Matrix algebraic notation is used where possible. The matrix in Appendix 1 is used together with some unit matrix.

HN - horizontal unit matrix of length W
VN - vertical unit matrix of length N

Superscript T denotes the transpose of the matrix is used.

Step 1: Compute total land area in each LDU.

HD * AVAIL = TOTLDU

Step 2: Compute total land area in each district.

AVAIL * VL = TOTDIST

Step 3: Compute area available under given suitability,

MAXAVAIL

Step 4: Compute ratio of target to total availability of land,

RATIO

Step 5: Compute allocation, ALLOC

Step 6: Compute total area potentially available to all activities in LDU, L

MAXAVAIL * VL = TOTALLOC

Step 7: Compute the actual area of land allocated to all activities in LDU, L

HI * ALLOC = TOTALLOC

Step 8: Compute proportion of each LDU in each district allocated, PROP

Step 9: Compute the area of each district allocated to each activity

PROP * ALLOCT = A

Step 10: Compute total input of J required on LDU, L for all activities.

INPUTT * ALLOC = TINPUT

Step 11: Compute total input of J required for all activities in district D.

TINPUT * PROPT = TDINPUT

Step 12: Compute the cost of all inputs of type J in district D.

TDINPUT * COSTT = DCOST

Step 14: Compute total yield of activity I in LDU, L.

Step 15: Compute the yield of each activity I in district D.

TYIELD * PROPT = DYIELD

Step 16: Compute the total yield of each activity I

DYIELD * VD = TOTYIELD

APPENDIX 8.3

MACROS

\E To enter the size of the problem, called first.

\N To set the names of crops, inputs LDU's and districts, called second. After calling enter the names in the labelled rows.

\S To set up work spaces and arrays of data, copies names of items into place for easier reading, called third. At this stage data is entered into the data input areas by direct typing or transfer from other databases, e.g. current prices and costs of inputs.

\R To run the model after data input has been completed, called fourth. It may be called many times with edited data.

SETUP MACRO \S

```
CELL                         MACRO CONTENTS

A1  :  '{windowsoff}{goto}a50~/df{bs}.{right mm}~1~0~max~/rnchi~
       {bs}.{right imm}~{right max}{down}/df{bs}.{down mm}~1~0~max

A2  :  '{left max}{up}/rnchd~{bs}.{right dmm}~/rnchl~{bs}.
       {right lmm}~/rnchj~{bs}.{right jmm}~

A3  :  '{right max}{down}/rncvi~{bs}.{down imm}~/rncvd~{bs}.
       {down dmm}~/rncvl~{bs}.{down lmm}~/rncvj~{bs}.{down jmm}~

A4  :  '{left max}{down max}/rncwkdl~{bs}.{right lmm}{down dmm}~

A5  :  '/rncwkld~{bs}.{right dmm}{down lmm}~

A6  :  '/rncwkil~{bs}.{right lmm}{down imm}~

A7  :  '/rncwkli~{bs}.{right imm}{down jmm}~

A8  :  '/rncwkji~{bs}.{right imm}{down jmm}~

A9  :  '/rncwkji~{bs}.{right imm}{down jmm}~

A10 :  '/rncwkdi~{bs}.{right imm}{down dmm}~
```

```
A11 :  '/rncwkid~{bs}.{right dmm}{down imm}~

A12 :  '/rncwkjl~{bs}.{right lmm}{down jmm}~

A13 :  '/rncwklj~{bs}.{right jmm}{down lmm}~

A14 :  '/rncwkjd~{bs}.{right dmm}{down jmm}~

A15 :  '/rncwkdj~{bs}.{right jmm}{down dmm}~

A16 :  '{down max}{right}input~{down}{left}crop~{right}/
        /cresource~~{left}{down}/rtcropname~~{right}/rncinput~
        {bs}.{down imm}{right jmm}~{left}

A17 :  '{right j}{right}{up}maxsuit~{down}/rncmaxsuit~{bs}.
        {down imm}~{right}{up}target~{down}/rnctarget~{bs}.
        {down imm}~{left 3}{left jmm}

A18 :  '{down i}{right}yield~{down}{left}crop~{right}/cldu~~
        {left}{down}//rtcropname~~{right}/rncyield~{bs}.
        {down imm}{right lmm}~{left}

A19 :  '{down i}{right}avail~{down}{left}crop~{right}/cldu~~
        ~~{left}{down}/rtdistrict~~{right}/rncavail~{bs}.
        {down dmm}~{right lmm}{left}

A20 :  '{right}{right l}{up}totdist~{down}/rnctotdist~{bs}.
        {down dmm}~{left l}{left}

A21 :  '{down d}{right}totldu{down}{left}totldu~{right}/cldu~~
        {left}{down}total~{right}/rnctotldu~{bs}.{right lmm}~
        {left}

A22 :  '{down l}{right}suit~{down}{left}crop~{right}/cldu~~
        {left}{down}/rtcropname~~{right}/rncsuit~{bs}.
        {down imm}{right lmm}~{left}

A23 :  '{down i}{right}maxavail~{down}{left}crop~{right}/cldu~~
        {left}{down}/rtcropname~~{right/rncsuit~{bs}.
        {down imm}{right lmm}~{left}

A24 :  '{right}{right l}{up}totavail~{down}/rnctotavail~{bs}.
        {down imm}~{left l}{left}

A25 :  '{down i}{right}alloc~{down}{left}crop~{right}/cldu~~
        {left}{down}/rtcropname~~{right}/rncalloc~{bs}.
        {down imm}{right lmm}~{left}

A26 :  '{right}{right l}{up}ratio~{down}/rncratio~{bs}.
        {down imm}~{left l}{left}

A27 :  '{down i}{right}totalloc~{down}{left}crop~{right}/cldu~~
        {left}{down}total~{right}/rnctotalloc~{bs}.{right jmm}
        ~{left}
```

```
A28 :  '{down}totldu~{right}/ctotldu~~{left}

A29 :  '{down 1}{right}prop~{down}{left}district~{right}/cldu~~
        {left}{down}/rtdistrict~~{right}/rncprop~{bs}.{right jmm}
        ~{left}

A30 :  '{down d}{right}a~{down}{left}district~{right}/ccropname
        ~~{left}{down}/rtdistrict~~{right}/rnca~{bs}.{down dmm}
        {right imm}~{left}

A31 :  '{down d}{right}tinput~{down}{left}input~{right}/cldu~
        {left}{down}/rtresource~~{right}/rnctinput~{bs}.
        {down jmm}{right lmm}~{left}

A32 :  '{down j}{right}tdinput~{down}{left}input~{right}
        /cdistrict~~{left}{down}/rtresource~~{right}
        /rnctdinput~{bs}.{down jmm}{right dmm}~{left}

A33 :  '{down j}{right}cost~{down}{left}input~{right}/cdistrict
        ~~{left}{down}/rtresource~~{right}/rnccost~{bs}.
        {down jmm}{right dmm}~{left}

A34 :  '{down j}{right}dcost{down}{left}input~{right}/cdistrict
        ~~{left}{down}/rtresource~~{right}/rncdcost~{bs}
        {down imm}{right dmm}~{left}

A35 :  '{down j}{right}price{down}{left}input~{right}/cdistrict
        ~~{left}{down}/rtcropname~~{right}/rncprice~{bs}.
        {down imm}{right dmm}~{left}

A36 :  '{down i}{right}tyield~{down}{left}crop~{right}/cldu~~
        {left}{down}/rtcropname~~{right}/rnctyield~{bs}.
        {down imm}{right lmm}~{left}

A37 :  '{down i}{right}dyield~{down}{left}crop~{right}
        /cdistrict~~{left}{down}/rtcropname~~{right}
        /rncdyield~{bs}.{down imm}{right dmm}~{left}

A38 :  '{right}{right d}{up}totyield~{down}/rnctotyield~{bs}
        .{down imm}~{left d}{left}

A39 :  '{windowson}
```

RUN MACRO \R

CELL MACRO CONTENTS

```
M1  :  '/dmmhd~avail~totldu~/dmmavail~vl~totdist~{goto}totavail~
        {right}/cmaxsuit~~{goto}maxavail~

M2  :  '@if(@index(suit,0,0)<{right}{right l}{abs 3},@index
        (avail,0,0),0)~/c~maxavail~/dmmmaxavail~vl~totavail~
```

```
M3  :  '{goto}ratio~@if(@index(totavail,0,0)=0,0,@index
        (target,0,0)/@index(totavail,0,0))~/c~.{down imm}~

M4  :  '{left 1}@index(maxavail,0,0)*@index($ratio,0,0)~
        /c~alloc~/rvalloc~alloc~/dmmhi~alloc~totalloc~
M5  :  '{goto}prop~@index(avail,0,0)/@index($totldu,0,0)~/c~prop~

M6  :  '/rvprop~prop~

M7  :  '/rtalloc~wkli~/dmmprop~wkli~a~

M8  :  '/rtinput~wkli~/dmmwkji~alloc~tinput~

M9  :  '/rtprop~wkld~/dmmtinput~wkld~tdinput~

M10 :  '/rtcost~wkdj~/dmmtdinput~wkdj~dcost~

M11 :  '{goto}tyield~@index(alloc,0,0)*@index(yield,0,0)~
        /c~tyield~/rvtyield~tyield~

M12 :  '/rtprop~wkl~/dmmtyield~wkld~dyield~

M13 :  '/dmmdyield~vd~totyield~{indicate}{panelon}{windowson}
        {beep}
```

NAME MACRO \N

CELL MACRO CONTENTS

```
V9  :  '{goto}i1~no of crops (I)~{goto}k1~{?}~{beep 1}

V10 :  '{goto}i2~no of districts (D)~{goto}k2~{?}~{beep 2}

V11 :  '{goto}i3~no of ldu's (L)~{goto}k3~{?}~{beep 3}

V12 :  '{goto}i4~no of inputs (J)~{goto}k4~{?}~{beep 4}
```

APPENDIX 8.4

SAMPLE OUTPUT

```
names of rows and columns

cropneme        crop 1    crop 2    crop 3
district name   dist 1    dist 2    dist 3    dist 4
ldu name        ldu 1     ldu 2     ldu 3     ldu 4     ldu 5
resource        water     npk

       1         1         1         1         1 unit row vectors
                                                          1
                                                          1
                                                  unit    1
                                                column    1
                                                vectors   1

    0.25     0.25      0.25      0.25
    0.25     0.25      0.25      0.25
    0.25    work areas for       0.25
    0.25    transposed arrays    0.25
    0.25     0.25      0.25      0.25
            input
crop        water    npk      maxsuit  target
crop 1          1        1          2        5
crop 2          1        1          2        5
crop 3          1        1          2        5
            yield
crop        ldu      ldu 2    ldu 3    ldu 4    ldu 5
crop 1          1        1        1        1        1
crop 2          1        1        1        1        1
crop 3          1        1        1        1        1
            avail
district    ldu 1    ldu 2    ldu 3    ldu 4    ldu 5   totdist
dist 1         10       10       10       10       10        50
dist 2         10       10       10       10       10        50
dist 3         10       10       10       10       10        50
dist 4         10       10       10       10       10        50
            totldu
totldu      ldu 1    ldu 2    ldu 3    ldu 4    ldu 5
total          40       40       40       40       40
            suit
crop        ldu 1    ldu 2    ldu 3    ldu 4    ldu 5
crop 1          1        2        3        4        5
crop 2          1        2        3        4        5
crop 3          1        2        3        4        5
            maxavail
```

crop	ldu 1	ldu 2	ldu 3	ldu 4	ldu 5	totavail	
crop 1	10	0	0	0	0	10	2
crop 2	10	0	0	0	0	10	2
crop 3	10	0	0	0	0	10	2

alloc

crop	ldu 1	ldu 2	ldu 3	ldu 4	ldu 5	ratio
crop 1	5	0	0	0	0	0.5
crop 2	5	0	0	0	0	0.5
crop 3	5	0	0	0	0	0.5

totalloc

crop	ldu 1	ldu 2	ldu 3	ldu 4	ldu 5
total	15	0	0	0	0

totoldu

prop

district	ldu 1	ldu 2	ldu 3	ldu 4	ldu 5
dist 1	0.25	0.25	0.25	0.25	0.25
dist 2	0.25	0.25	0.25	0.25	0.25
dist 3	0.25	0.25	0.25	0.25	0.25
dist 4	0.25	0.25	0.25	0.25	0.25

a

district	crop 1	crop 2	crop 3
dist 1	1.25	1.25	1.25
dist 2	1.25	1.25	1.25
dist 3	1.25	1.25	1.25
dist 4	1.25	1.25	1.25

tinput

input	ldu 1	ldu 2	ldu 3	ldu 4	ldu 5
water	15	0	0	0	0
npk	15	0	0	0	0

tdinput

input	dist 1	dist 2	dist 3	dist 4
water	3.75	3.75	3.75	3.75
npk	3.75	3.75	3.75	3.75

cost

input	dist 1	dist 2	dist 3	dist 4
water	1	1	1	1
npk	1	1	1	1

dcost

input	dist 1	dist 2	dist 3	dist 4
water	15	15		
npk	15	15		

price

input	dist 1	dist 2	dist 3	dist 4
crop 1	1	1	1	1
crop 2	1	1	1	1
crop 3	1	1	1	1

tyield

crop	ldu 1	ldu 2	ldu 3	ldu 4	ldu 5
crop 1	5	0	0	0	0
crop 2	5	0	0	0	0
crop 3	5	0	0	0	0

dyield

crop	dist 1	dist 2	dist 3	dist 4	totyield
crop 1	1.25	1.25	1.25	1.25	5
crop 2	1.25	1.25	1.25	1.25	5
crop 3	1.25	1.25	1.25	1.25	5

INTEGRATION OF DECISION SUPPORT TOOLS AND OPTIMISING METHODS IN LAND AND WATER RESOURCE PLANNING

Dr. T. R. E. Chidley and J. D. Shearing

1. INTRODUCTION

The problem described here is based upon a real situation. The aims of the study were to determine the best investments and the best levels of investments in water diversion works and irrigation infrastructures taking into account a variety of cropping patterns and lands with different capabilities. The model also allocates land to different uses within the constraints suppplied.

However the main purpose of this paper is to show how one can integrate decision support tools with a Linear program in the context of land use planning. It shows that quite large optimization problems can be solved on modest technical equipment by non computer specialists. The spread sheet was linked to a linear programming code to produce an integrated decision support environment for the problem. The linear programming tableau (or matrix) was generated by the Lotus 123 spreadsheet. The cost models, resource and policy constraints were all computed below the main tableau using information entered live as a 'what if' scenario. The Scicon Micro LP code was then used to solve the matrix generated by Lotus. The output from the LP was then post-processed by another Lotus spreadsheet programmed to load information automatically from the matrix generator sheet, thus ensuring that the appropriate information was used in the post processing. The post processing was designed to provide the user with an appreciation of the optimal policy subject to the 'what if' questions he had put originally.

The environment of the problem is the lower reaches of a river system with two main channels going through the middle of the planning area. Figure 5 shows a schematic layout of one of the proposals investigated. The constraints, cost models and comments on the use of the integrated system are set out below. The concept of the model was first put in 1977 in the context of a national soils and land capability database.

2. THE PROBLEM

A number of individual cropping rotations were developed for both rainfed and irrigated production. Provisional allocations of these rotations were made to each district to give three comprehensive cropping patterns. Each comprehensive cropping pattern will be referred to as an activity.

The problem resolves itself into deciding for each command area (CA) the proportion of the total area to allocate to each activity. A CA is an area commanded or developable from a given reach of river. In the macro scale of this allocation it is assumed that it will be feasible with respect to the variety of land types in each CA. Additional upper bound constraints for selected crops within each activity were used to constrain amounts allocated to activities to ensure feasibility. Provision is made in the optimizing procedure for deciding on the size of major canals and groundwater pumping capacities.

In making an allocation to each CA for each activity and setting maximum canal and abstraction capacities, resource constraints and other requirements have to be complied with. A monthly basis in the design yeer was used, though only those months thought to offer real resource constraints were introduced into the problem, all other possible monthly constraints are redundant.

Initially the aim of the optimization was to minimize the cost of providing food to the population. Since a provision was made for importation of some key foods this would not necessarily lead to outrageous costs, all be it the least cost.

Five separate problems were formulated and investigated. The inputs from neighbouring countries were represented as limiting amounts of water available in each of the critical months. These were set as ranges in the optimization problem to examine the effect of variations in these values. In cases when they proved to be constraining development shadow prices for this water were produced. The optimization only addressd the central command area of the country. National requirements were reduced by what is produced and/or consumed outside these areas.

3. THE DATA BASE

Much of the database for the problem is held on the matrix generator spreadsheet. However the cropping patterns on the individual land development or command area units have been built up from basic input data for each crop. These inputs show monthly resource requirements per hectare for each physical crop, as in Figure 1. There is one table for each resource in each district. Note that a crop planted at a different time is regarded as a different crop even if it is the same cultivar. This is called CN

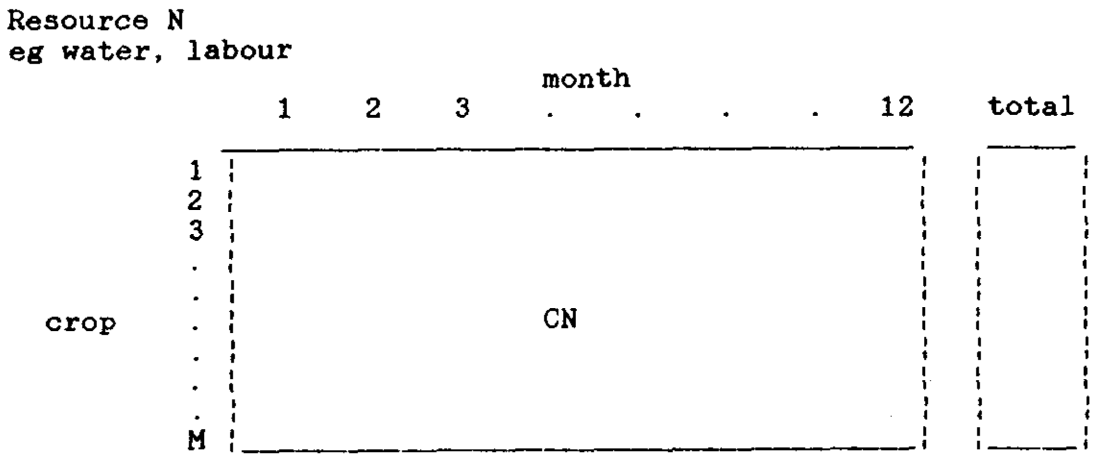


Figure 1 Monthly Crop Requirements

Figure 2 shows how a number of cropping rotations are built up. The proportion of the unit area allocated to the crops in the rotation are noted, each row should sum to one. This is called RT.

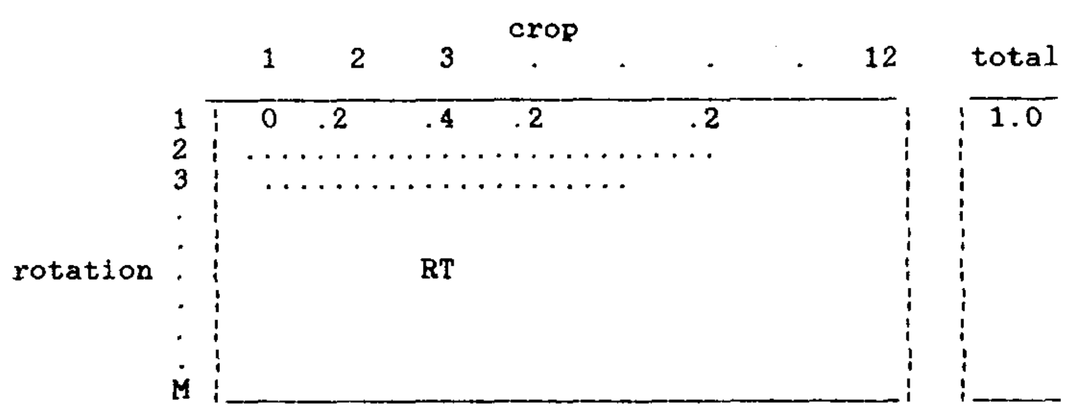


Figure 2 Crop Rotations

If the matrix RT is multiplied by CN the resultant matrix will show the total amount of resource N (eg water labour etc.) required by the rotation in each month for each hectare. These data are available for each district or land type. These unit resource requirements for the activity represented by the rotation are copied across to the matrix generator for the critical months. At the post processing stage total annual requirements can be computed from the data above with the allocations provided by the LP. The LP indicates how much area in each district or CA should be put to each crop rotation or pattern.

A similar operation is carried out to determine the yields of each physical crop in each rotation. In this case a matrix of yields for each crop is multiplied element by element with the matrix RT to obtain the yield of each crop in proportion to the area under each crop.

4. COST MODELLING

The cost model will comprise the sum of the provisions for:-

a) Diverted water;
b) Ground water;
c) Local diverted water;
d) Labour;
e) Power;
f) Fertilizer;
g) Pesticides;
h) Working capital;
i) Seed;

Items (d) to (i) will be aggregated into a cost per unit area for each district. This will require that the three activities be costed for each rotation and allocation. The cost of these items will be the annual cost of engaging in the activity on one hectare in the proportions and rotation specified. This coefficient will be denoted CXXj.

Item (c) will be costed at a lump sum representing the annual capitalized operation and maintenance costs for using that class of water.

Item (b) is in two parts, the capitalized provision for a maximum pumping capacity MAXG and the O&M costs related to actual abstraction in the three key months. Note that as of the date of this report only the costs of lifting the consumptive use are provided. Additional pumping capacity is needed to provide for recycling. The costs of this latter are assumed to be borne by the agricultural inputs and will include local redistribution of surface water supplied.

Item (a) is in two main parts, annual capitalised costs, and operation and maintenance (O&M) costs. The O&M costs are assumed to be proportional to the actual area put under irrigation. They include fuel for pumps, physical maintenance, labour etc. The annual capitalized costs are comprised of; cost of diversion, if any; cost of main canal; cost of subsidiary canals; cost of equipment and pumps; and land levelling. Some of these costs will be proportional to the area put under irrigation and some will be attributed to the cost of the diversion and main canal.

Each of the two diversions will be a relatively fixed cost independent of capacity. The major canals will be costed according to size. The size will be made big enough to carry the largest monthly demand. This is true of all commanding canals, but more true of the main transfer channel.

The cost model for each major structure will comprise a linear function with an intercept and a slope term. The slope term will fix the size of the strucure be it a set of headworks or storage on the diversions. The intercept costs are shared over the potential area benefitting from the works. The concept is illustrated below in Figure 3.

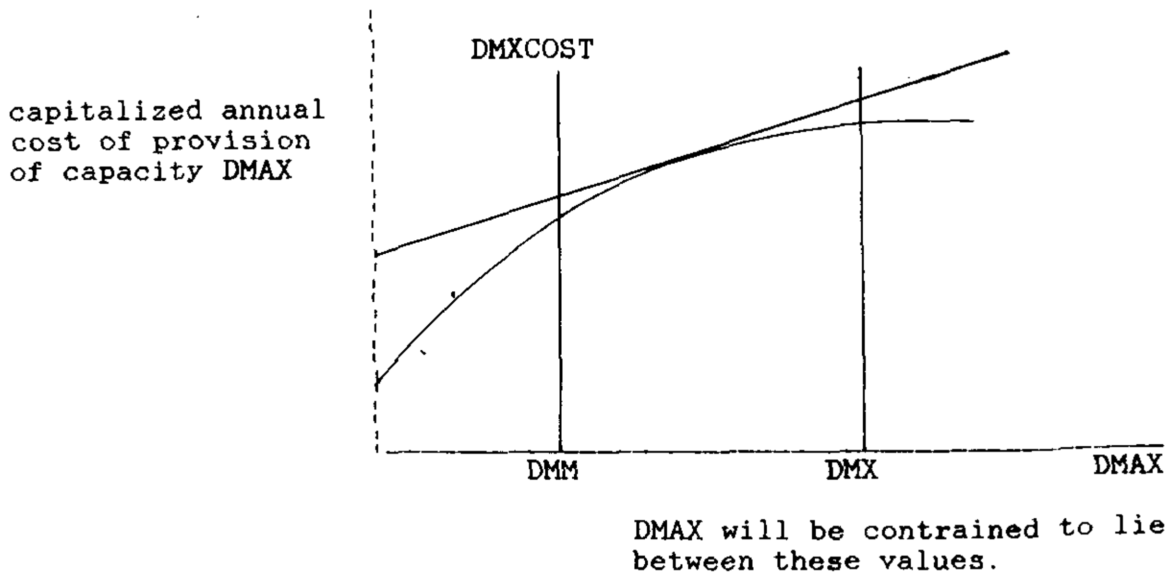
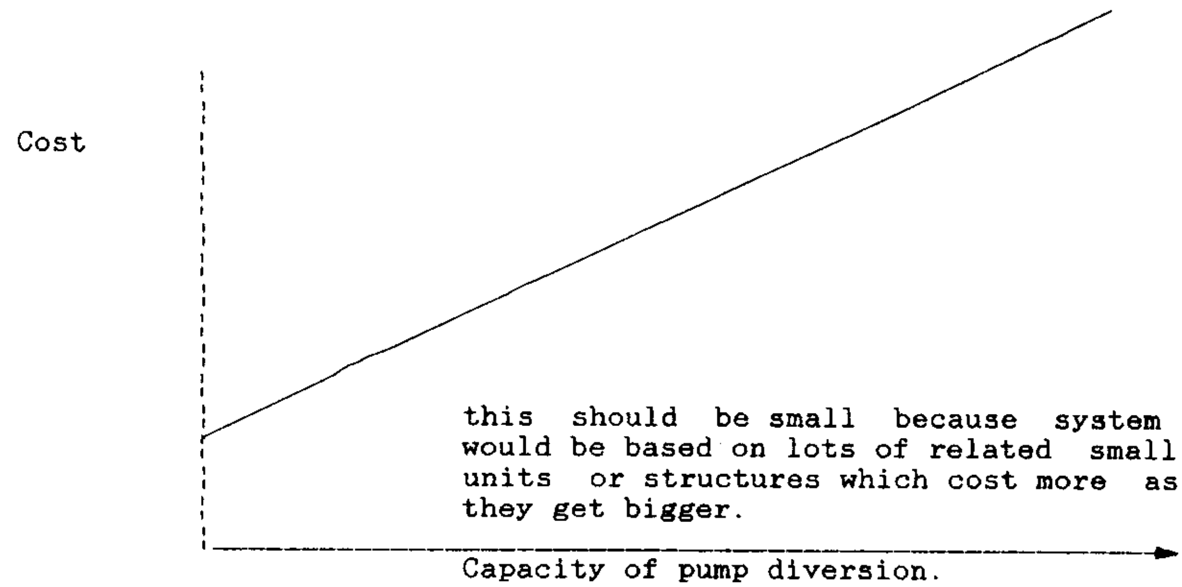


Figure 3 Linearizing of Cost Model

This cost will include provision for the canal and principal distribution structures associated with an option.

It is assumed that the annualized capital costs of installing an irrigation system will be made up from the cost of a diversion, if used; the cost of appurtenances and levelling; and, the cost of the canal with the maximum capacity needed. Since it will be assumed that a very large proportion of the command area will be irrigated if a diversion is built then if the cost of the diversion is divided by the total area commanded the cost per unit area of provision of a diversion is obtained. Similarly the cost of appurtenances and levelling is directly proportional, on the scale envisaged, to area developed. The cost model for the main canal is assumed to be linear over the range of interest. The constant part of the curve will be divided by the expected area to be commanded by the canal, the variable part will be a function of canal capacity DMAX.



Cost includes all structures from intakes to the main canal distributaries as for surface water diversions plus costs of machinery.

Figure 4 Cost Model for Major Surface Abstractions

Additional operating costs are incurred to bring the water into the system from the river. These are principally energy costs - since O & M is covered by a capital percentage factor.

The overall cost equation becomes :-

```
TOTCOST  =   E CCXX DMAXXX      (provision for max canal size)
             XX
         +   E  E (DCXXj + MCXXj) AXXj
             XX j
             annual capital      O M costs/unit area
             cost/unit area
         +   E  E CXXj  AXXj          all other costs of productio
             XX j

         +   E  E E  GCXX  GXXjk     cost of operating pumps/wells
             XX j k

             unit cost of operating
             to produce one unit of water.

         +    E MAXGXX. GX           cost of providing the
              XX                       pumps/wells
                                    unit  cost of  provision
                                    of capacity.

         +   E  E E LcXXjk. CLcj     cost of using locally
             XX j k                       available water
```

Total cost of capital (annual value) for area XX is

DCXXj
[(diversion ± Appurtenances, Levelling ± Intercept)] actual area.
expected area

+ CCXX. DMAXXX
slope of canal cost curve.

4.1 Cost of Groundwater

It is assumed that groundwater costs are related to the number of wells provided and the cost of lifting water. Thereafter the water goes into the system provided under annual capital costs per unit area. If there are a large number of wells of uniform capacity and lift then the cost model for groundwater is linear and represents cost of capital plus Operation and Maintenance costs.

The capital cost will be for the maximum number of wells needed and the operating costs will be related to hours worked. Total costs of groundwater in a scheme will be therefore:-

$$\mathrm{E}_{XX}\ \mathrm{E}_{k}\ GCXX\ \ GXXk\ + MAXGXX * GX$$

where $GXXk\ - MAXGXX \leq 0 \qquad XX = 1,7,\ k=1,5$

and

$$\mathrm{E}_{XX}\ \mathrm{E}_{k}\ GXXk \leq GTOTXX \qquad XX = 1,7$$

The link canal 'intercept' costs are shared over all benefitting areas by dividing the intercept cost by the total area commanded and attributing that result to the unit costs of development of each area benefitting. Provided all areas are brought into irrigated production by the model there will be enough money to build the link canal. The link canal intercept costs are built into formulae in the appropriate cell. The outcome should not be very sensitive to area developed because these costs are such a small proportion of currently estimated total costs. Additional costs are attributed to area B2 for developing headworks and some pumping lift.

The fixed costs of each diversion are attributed to each area benefitting from the diversion in proportion of each area benefitting to the total area benefitting in the same way as intercept costs. Other more arbitrary assignments could be used.

The variable costs are treated separately and are attached to the decisions on the maximum size of canal, storage structure or groundwater abstraction capacity. A guestimate was made of the relationship between storage of water in the diversion and the cost of the diversion.

Operational costs are set as a proportion of capital invested per unit area plus basic every costs for lifting water at rivers or from groundwater to put it into circulation. Having got the water into circulation additional pumping costs will be required on a routine basis. These costs are included in the cost model as separate entries.

5. CONSTRAINTS

5.1 Land

The land allocated to each activity(j) (j=1 to 3) in each CAXX XX=B1,B2,B3,B4,B5,B6,B7 is denoted AXXj. The sum of lands allocated must be less than the total available AVARi.

$$\sum_{j=1}^{3} AXXj \leq AVARj \text{ for all } AXX$$

Additional constraints are needed to cope with situations where land is affected by saline intrusion. A further constraint is that the irrigated area must not exceed the potential irrigable area.

$$AXX1 + AXX2 \leq IRRPRXX * AVARj$$

The constraints dealing with land are in general:

$$AB11 + AB12 \leq IRRPR1 * AVAR1$$

where B1 varies over B2, B3, B4, B5, B6, B7, IRRPR, is the proportion of the total land area AVAR1 that can be irrigated in CA1, which is B1.

The constraints dealing with the availability of land are:

$$AB11 + AB12 + AB13 \leq AVAR1$$

which means that the sum of land allocated to high water demanding crop patterns (AB11), low water demanding crop patterns (AB12) and rainfed patterns (AB13) is less than the total available land. This is repeated for B2, B3, B4, B5, B6 and B7.

5.2 **Water**

There are two sets of water constraints, one set deals with the allocation of water to the land and the other with the continuity at junctions in the system. Water can be allocated to land from surface water diversions DXXk; groundwater abstraction, GXXk; and local surface water LcXXk. A return flow from an area DXXkF is permitted to ensure that a feasible solution is obtained, and local priority demands are expressed as LDXXk. The subscript XX denotes CA and k the month concerned. The total demand for supplemental irrigation water in the critical months must be met. If UXXjk is the unit demand for water for activity j in CA XX in month k, then:

$$\underset{j}{E}\; UXXjk.\ AXXj + DXXkF + LDXXk < DXXk + GXXk + LcXXk \qquad XX = 1\text{-}7,\quad k = 1\text{-}5$$

or

$$E\; UXXjk.\ AXXj + DXXkF + LDXXk - DXXk - GXXk = LcXXk \qquad XX = 1\text{-}7$$

Additionally the values of D and G are limited by upper bound and /or lower bound constraints.

The diversion capacity is set at DMAXXX. The groundwater abstraction capacity is set at MAXGXX. DMMXX and DMXXX are the lower and upper bounds for DMAXXX.

$$DXXk - DMAXXX \leq 0 \qquad XX = 1,7, \ k=1,5$$
$$GXXk - MAXGXX \leq 0 \qquad XX = 1,7, \ k=1,5$$

$$DMMXX \leq DMAXXX \leq DMXXX$$

or

$$DMAXXX \leq DMXXX$$
$$DMAXXX \geq DMMXX$$

DMAXXX and MAXGXX are to be determined by the linear programme solution.

An additional constraint on G is that the total abstraction in the critical 5 months must not exceed the total availability (GTOT) of groundwater in that CA. ie.

$$\sum_{k=1}^{5} GXXk < GTOTk$$

For the zone affected by salinity this is altered to:

$$\sum_{k=1}^{5} GB5k - AVAR5.GTOT5/\text{Area of salinity zone} < 0$$

This ensures that groundwater is only used in this zone in proportion to the area AVAR5 not affected by salinity.

5.3 Junction Equations

With reference to Figure 5 the junction constraints are as follows:

F denotes a flow in a channel that is not controlled by the LP

D denotes a diversion which is a decision variable

R denotes a return flow which is regarded as a function of total irrigation water applied.

S denotes a change in storage

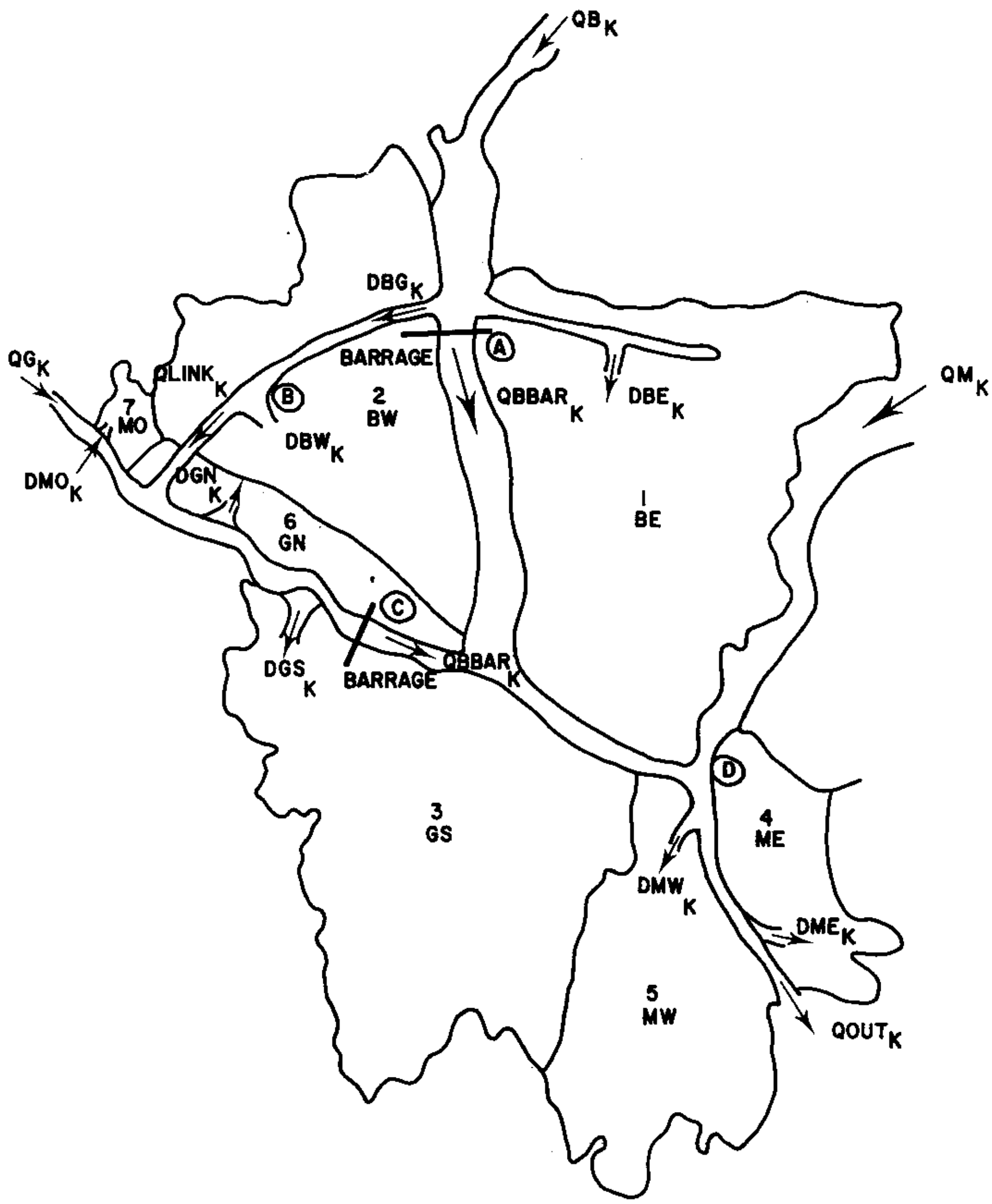


Figure 5 Schematic Layout

for each k=1,5

Junction *Constraint*

A: DB1K + DLINKK + QBBARK +SBK+1 - SBK = FBK

B: -DB2K + DLINKK - FLINKK = 0

C: DB7K + DB6K + DB3K + FGBARK + SGK - SGK-1 = FGK

D: DB5K + DB4K + FOUTK - FBBARK -DB1KF

-DB2KF -DB6KF -DB7KF = FMK

The following additional constraints are put on SBk and SGk to ensure that the maximum value is selected from the 5 possible monthly values and that any given monthly value does not exceed the maximum. It is assumed that the diversion is full at the start of month one.

$$SBK - SBMAX \le 0$$

$$SGK - SMAXG \le 0$$

5.4 **Labour and Power**

It could be that labour and power are critical constraints. In this case the labour and power requirements for each activity *in each month* need to be estimated. From a consideration of the total labour and power available in each CA those months and CA's where these resources may be constraining can be identified. The typical power and labour constraint is

$$E_{j} \; PXXjk \; AXXj \le TOTPXXk \qquad XX = 1,7$$

$$E_{j} \; LXXjk \; AXXj \le TLABXXk \qquad k = 1,5$$

for each XX and k that may be considered

To simplify the problem the seasonal variation in demand for labour and power will be ignored and only annual amounts used, giving. This illustrates another important modelling point, keep the model as simple as possible but leave enough detail to investigate the sensitivity of a feature. If found to be sensitive to that issue then elaborate.

$$E \; PXXj \; AXXj \le TOTPXX \text{ for each XX.} \quad XX = 1,7$$

In this case TOTPi is obtained by estimating the proportion of the year that labour and power is used and then multiplying by the number of labourers and bullocks.

5.5 **Salinity Intrusion**

The amount of land available for irrigation in one zone is affected by saline intrusion as the upstream flows are consumed. The total area of land AVAR is a function of the flow in the channel downstream of the finals diversions. This was modelled by assigning two flows, an upper and a lower limit over which the irrigable area of the zone was reduced in a linear fashion with respect to the outflow at that point. Additional upper and lower bound constraints on discharge are introduced so that the worst case month is selected for this computation.

The key data to be provided are

- maximum irrigable area of salinity affected zone
- maximum range of linear reduction of irrigable area.
- minimum irrigable area of salinity affected zone
- minimum range of linear reduction of irrigable area.

5.6 **Production Requirements**

Each activity produces an annual yield of a basket of crops, Yijm, where m is a particular crop. A number of production constraints can be written for the country as a whole or for each CA. Because the cropping patterns have been written to ensure an adequate mix of crops one only needs one or two crops for each basket to be included together with key requirements for total food grains, either by CA or Nationally.

The typical production requirement for National provision of food grains for example is:-

$$\sum_{XX} \sum_{j} \sum_{m} YXX_{jm} \; AXX_{j} + I_{m} \geq REQ_{m}$$

where m is selected for the given crop. At CA level the summation is only over j and m. Im are imports of crop m.

6. COMMENTS

The various components of the models have been run on a range of micro-computers. The performance varies widely. The basic IBM AT range of computers with no floating point arithmetic unit reduces the total time of loading, modifying and saving the tableau; running the LP; and, post processing the output from about 2 hours using an IBM XT to 30 minutes. Having the floating point arithmetic unit save a further 10 minutes. The principal time savings are due to the faster and more powerful micro processor on the AT compared to the XT.

The basic size of the LP tableau was 230 variables by 200 constraints.

The simplified appoach enbled about 80% of the agricultural economy of the country in question to be modelled. Major investments were studied in the context of land use allocation. A number of insights into the way in which the system would operate were obtained, these were by no means obvious at the start. The approach also illustrates another feature of optimal economic modelling which is the benefit of building a small model first and expanding it as confidence in it and understanding grows. The system is percieved as a decision support tool to enable planners to ask 'what if' questions, and in this case know that the answers will be both feasible, and within the constructs of the model, optimal.

A REVIEW OF GEOGRAPHIC INFORMATION SYSTEMS, CONSIDERING THEIR ROLE IN LAND USE PLANNING FOR THAILAND

M. Pooley and Dr. T. R. E. Chidley

1. INTRODUCTION

Land use planning has traditionally relied upon the production of one or more maps of the region under study to convey the results of a land evaluation survey. It is usual to produce a map of current land use and then a series of maps showing the suitability of land for particular crops, often distinguishing between suitability at different management, or technology levels. The maps are normally accompanied by a weighty report, probably in two or three volumes. Currently in Thailand, much effort is applied to the production of such maps and reports, at the Reconnaissance level, for provincial planning. Experience elsewhere has shown that such careful work may well be under-utilised, either through lack of awareness, or an inability to readily manipulate the results, for application to a specific problem. Often the personnel making use of the survey are not land use planners and may not appreciate the degree of detail summarised in a land use rating, or they require more quantitative estimates of suitability.

A computer automated Geographic Information System (GIS) is an answer to some of these problems. GIS is a unique form of information system, in that data are indexed by using a geographic locator, which permits storage and retrieval of all data by spatial location.

GIS which have progressed roughly at the rate of advancement in computer technology, seek to capitalize on the synergism inherent in being able to automatically compare a variety of socioeconmic, environmental and land use data sets for the same point on the ground (Bryant & Zobrist, 1976). A GIS may simply be a manual system, or computer automated, as is now more usually the case. Input data to such a system can be point, line, or spatial(i.e. coded data expressed by areal measurements), or facts and observations. Output consists of text, or tabular and graphic information.

There are a number of important advantages in using a Geo-referenced information system for land evaluation purposes:

a) Archive data can be stored in a form which encourages utilisation.

b) Spatial data from maps and images can be encoded and stored in a form facilitating manipulation of the data.

c) Raw data can be integrated with other data by mathematical operations, for a particular purpose, using specific programs which form a part of the system, or other programs that can be easily interfaced.

d) Graphic displays can be shown of either the raw data, or of the results from mathematical operations and data combination. This is usually output as a thematic map.

This paper is presented as a review of some of the ways in which GIS concepts have been applied in other countries, followed by some suggestions as to the kind of approach which could be adopted by the Department of Land Development (DLD) in Thailand.

2. REVIEW

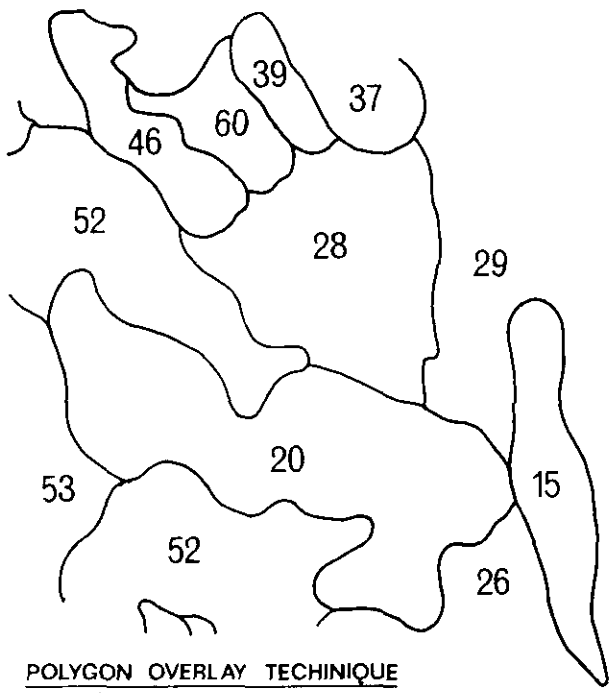
Soil research has long been recognised as of central importance to the improvement of agricultural productivity, in any country. Such research depends upon extensive soil surveying, involving the recording of very many characteristics for each soil profile pit, or auger core. Storage of the multitudinous records that result from this activity, in a useful form, has always been a problem. Usually this has been accomplished by classification of the soil as a certain type which is then recorded on a soil map. Inevitably this leads to a loss of site specific information on soil characteristics (Webster, 1977). Webster cites this problem as one of the reasons for adopting a soils information system.

The Soil Survey of England and Wales has recognised the utility of an automatic soil and land classification for some time (Rudeforth, 1975), although it has only recently managed to partially complete the task. The Soil Survey now has an operational soils information system, the workings of which are shrouded in much secrecy, however it would seem to be similar to that of the Netherlands Soil Survey Institute (Bie & Schelling, 1977).

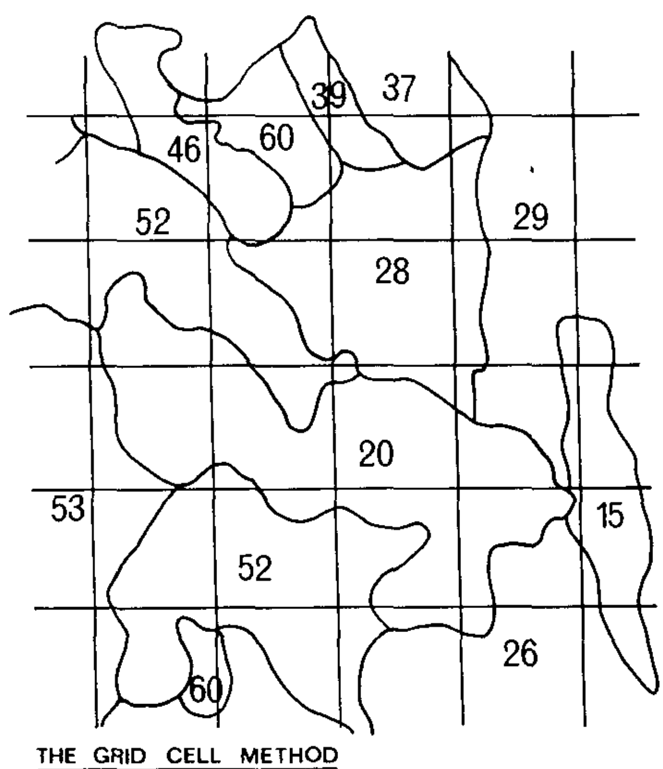
The Netherlands system is a computer-based information system using earth science information from the Soil Survey Institute and the Geological Survey. It was particularly aimed at capturing archive information with the minimum of transliteration. To this end much use was made of optical character readers to input data directly to the system. At the heart of the system is the G-EXEC file organisation system, developed by the National Environmental Research Council of the United Kingdom. G-EXEC includes a large number of application programs such as statistical packages. Another important feature of this system is that additional applications packages, such as the SYMAP mapping software (Sheehan, 1979), can be readily interfaced for input or output of information. Bie & Schelling point out that more powerful data handling allows new methodological research to progress. Also international soil data transfer is currently limited, due to lack of standardisation in classification and analytical methods. This has been recognised in the establishment of the IBSRAM program within the headquarters at the DLD in Bangkok.

Recently agriculturalists have become aware of the possibilities for gleaning useful information from remotely sensed images. This will need to be considered as an essential input to any future GIS. With improved resolution of satellite imagery, down to 10 metres for imagery from the newly launched SPOT satellite, and with more frequent imaging, useful applications in crop management and yield prediction are feasible (Jackson, 1984).

The Lauragais project (Jeansoulin, 1983) to evaluate SPOT simulation data used an informtion system approach, where manipulation of information form a database in geometric form was crucial to the analysis for agricultural and yield assessment. The potential for integration of remotely sensed data and other data, for agricultural applications, has been recognised and applied for some time in the USA, exemplified in the LACIE project (Powers et al., 1979) for global crop forecasting, and the operational systems that are already providing forecasting information, such as CROPCAST (Merritt et al., 1981) and the CRIES project (Schultink & Lodwick, 1981). One problem has been the integration of different data units, and the first GIS tended to be of the polygon overlay or grid cell format but not both (see Figure 1), with satellite imagery geocoding is in a raster format (Bryant & Zobrist, 1976). A polygon overlay technigue represents geocoded information as irregular geographic areas simulating the known spatial distribution of the statistics. A grid cell technique imposes a digital grid over the spatial data, whereby geo-located data is retrieved through the cross tabulation of variables, encoded within a particular cell. A raster scan is equivalent to an ultra-fine mesh, grid cell data set. The system Bryant & Zobrist put forward, for integrating existing GIS data with thematic maps and satellite imagery, is based on the premise that geo-coded data can be referenced to the fine grid raster scan. The Image Based Information System (IBIS) they developed makes use of digital image processing techniques. Such an approach probably indicates the route to an inexpensive GIS of the future, well suited to agricultural applications.



POLYGON OVERLAY TECHINIQUE
Geocoding simulates the spatial distribution of the attributes concerned



THE GRID CELL METHOD
Imposing a digital grid over the data

FIGURE 1 Showing the Polygon Overlay & Grid Cell Format
A Raster Scan is equivalent to an ultra fine mesh, grid cell data set.

Bryant and Zorist also specify four basic criteria which GIS should satisfy if they are to be useful.

a) They should provide specific point locations, as well as area locations of data.

b) They should provide for variable aggregating (sub-setting) of the data.

c) They should provide a method for representing spatial arrangements.

d) They should be able to interface with mathematical and statistical programs which can be called as needed to aid in the analysis of spatially orientated data.

The last of these points is of particular importance in view of the recent developments in artificial intelligence techniques, particularly expert system technology. Interfacing of mathematical programs has to be easily accomplished, for the GIS to be utilised fully by resource planners and other users, and the need for a simple design, requiring no previous programming experience, has been noted by several authors (Campbell & Goldberg, 1979 ; Sinton, 1979). Frank (1981) presents one novel and simple solution to the problem with the use of an electronic coordinate digitiser as the primary communication mechanism in a GIS system. With this approach, one compartment of the digitiser tablet is reserved for mounting a base map of the area, stored in a data base, while the other compartment contains an instruction menu.

However, expert systems might fulfil this role of a "user friendly front end" in a more flexible and convenient manner. Expert systems have other important attributes, namely the ability to combine fuzzy logic and uncertain information with that which might be accessed from the GIS, and subsequently, either incorporating results back into the GIS, or sending the output elsewhere.

Peuquet (1983) cites two major problems with interactive GIS. One is data storage difficulties and slow response times and the second is that they tend to be applicable to only a narrowly defined set of problems. The underlying cause of these problems is that GIS are characterised by: a tendency to become extremely large; fuzzy geographic boundaries tend to give incomplete, imprecise and error-prone data sets; and the number of possible spatial interrelationships is very large. Peuquet believes that the combination of artificial intelligence (AI) techniques with data base management systems and computer vision, shows great potential for dealing with these problems.

Knowledge-based expert systems for agricultural applications already exist. APRIKS developed on a pilot basis is a good demonstration of this (Ton & Cheng, 1983). The system permits the user to interact with the computer in conversational mode to obtain advice on pest control; plant disease treatment and several other topics. However the APRIKS system uses an in built hierarchical index table for data storage, rather than interfacing to a database management system, which could then be a GIS.

Already then, many applications for geographic information systems have been identified and a market perceived. Computer technology is advancing apace, particularly in ways which overcome the storage problem. The interfacing of the various technologies concerned has not been commonly achieved by a single system, but this does not now seem to pose an insurmountable problem, much depends simply on standardisation of software. However what is generally recognised is that the perceived applications must be proved and implemented. In this, the applications programs and particularly expert systems will be important.

3. THE RELEVANCE OF GIS TO LAND USE PLANNING IN THAILAND

In Thailand there is a substantial amount of data available on the agricultural sector, but much is ignored because it is not readily incorporated in the survey procedure, resources may thus be wasted in duplicating data. A land evaluation computer system linked to a computer database would immediately identify which data were needed and a survey could be designed to collect only that information, optimising the use of scarce DLD resources.

The incorporation of applications packages within a GIS facilitate the provision of precise information on land use, in response to queries from other departments, non-government organisations and farmers. A suitability classification system would be central to the GIS, but other applications packages might include: A Land Unit Classification Model; A Crop Comparative Advantage Model; Optimal Crop Allocation; Farming System Recommendation; Image Processing System; and a model to adjust recommendations in keeping with National Plan Targets. Undoubtedly further applications could be identified.

The advantage of the GIS concept is that all the above mentioned models would utilise a common database and linkages between applications systems would ensure integration, with common objectives. It is envisaged that most of the application systems would be expert systems, custom designed to fulfil the desired functions. The use of expert systems, means that the end-user of the system need not be expert in a particular discipline to understand how to obtain the informatiion he wants. The user will also be able to demand justification of any recommendations and the system will then outline it's reasons for arriving at a particular decision. This allows the interested party to satisfy themselves that the judgement has been made on a sound basis. This facility is often lacking in other computer systems where 'blind faith' in the power of the micro chip is assumed.

The use of a GIS means that in response to a request for particular information, an application system can be used to quickly provide a customised output showing only the relevant details in text, tabular or graphic form as appropriate. Indeed a request could be met to extract the required information and send it to a file on a floppy disc for further processing on the clients own system. This is particularly useful within departments, when it is considered desirable for provincial stations to partake in parallel development of a particular model on the station micro computer, or if they wish to pursue their own direction of research. All data and results from provincial stations would then be sent by floppy disk for collation on the central GIS in Bangkok.

4. POSSIBLE COMPONENTS OF THE PROPOSED GIS (see Figure 2)

4.1 The Database

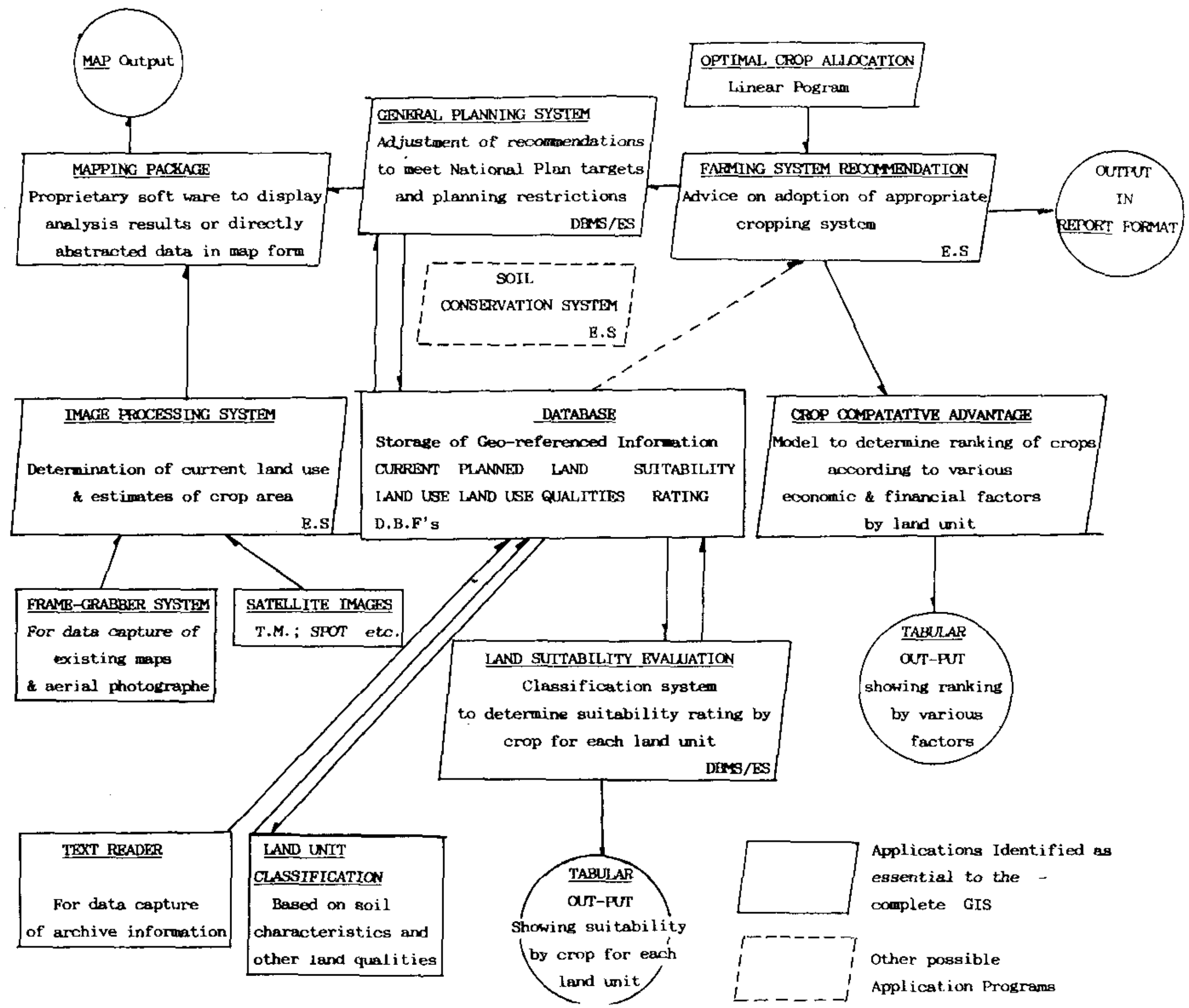
At the heart of any GIS are the database files for storage of wide ranging data, spatially referenced with map coordinates for each record, or cross referencing to geo-referenced records. The database should be a central information store to be accessed and updated by all users for all applications within the integrated planning system.

Database files would be established for each type of data set, including: Current land use; Land qualities; Suitability rating; Planned land use; Soil records and any other relevant data sets. Where databases already exist, as in the case of soils information within DLD, then these should be accessed through communications software rather than duplicating data. Databases would be cross indexed to one another, often by the land unit type for that area. For instance, in the current land use database file, for a particular area, say a grid cell, the present cropping practice would be recorded and also the land unit type for that cell. In the land qualities database file, for each land unit type, values for all relevant qualities are recorded. Thus land qualities can be linked to current land use.

4.2 Image Processing System

This system would be used for digital image processing of satellite data or other imagery. The principal function of the system would be to provide up to date information on current land use. It could also be used to manipulate and reform spatial data input from the frame-grabber system, before that data is stored in image and database files. Most GIS systems reference image files to a grid for extraction of information to database files and this is likely to be the preferred option, although other techniques do exist.

Figure 2 Showing Proposed Structure of a Geographic Information System for Land Use Planning in Thailand



The image processing system will be based on a proprietary system, as there are a wide selection of good systems on the market now at competitive prices. However it is envisaged that such a system would be enhanced by an expert system designed to handle the principal processing functions required. This may be essential for some of the more 'intelligent' manipulations of digitised imagery, when expert knowledge may need to be applied. Even with the latest high resolution satellite images, expertise and skilled judgement are required for crop identification.

The frame-grabber system may be a part of the image processing system or be a separate 'stand-alone' system. A high resolution colour monitor; a video camera; frame store and processor unit (micro-computer in this case) are required.

The video camera is directed at the map, photograph or other image to be digitised. The software is then used to 'snap' or record a (picture) frame of the image which can be stored digitally in the computer. The image can then be restored to the monitor screen for processing or plotted out. Thus the frame-grabber enables current maps to be 'captured' for immediate use within the GIS system. As with the text reader, such a system offers very considerable savings in time and expense by utilising archive data such as soil maps and if appropriate, aerial photographs.

The stored images can be processed under the image processing system to remove extraneous information. For instance, contour lines may not always be required and may confuse boundary lines. Other subtle details can be enhanced and details from other images, be they maps or satellite data, can be superimposed until the desired image is created and this can then be stored to the image file.

4.3 The Text Reader

The text reader is essential to the GIS since this hardware allows all written material relevant to the GIS system to be digitised without typing in the information. Thus archive information such as previous land use study reports and soil records can be utilised almost immediately under the new GIS system. Where much research is already available, as in Thailand, a text reader represents a substantial saving in time and expense and improves the quality of the advice available.

4.4 Land Suitability Evaluation System

The FAO framework for land evaluation has been adopted by the DLD in Thailand and that suitability classification will be used to provide a suitability rating by crop for each land unit.

A combination of a database management system and expert system will probably be used to automate this particular application. The FAO suitability procedure is well suited to manipulation using a database programming language.

4.5 Crop Comparative Advantage Model

Physical suitability of a crop for a given land unit cannot be used alone to advise as to the recommended land use, socio-economic factors must also be considered. The crop comparative advantage model is designed to consider economic and financial factors for each crop by land unit and rank the crops in terms of suitability for each indicator and each land unit considered.

4.6 Farming Systems Recommendations

Evaluating suitability of the land for each crop in turn is accepted as essential, but the results must be integrated into relevant advice for the farmer. Mono-cropping is only occasionally to be recommended even for large commercial farmers. Stable and wise farming systems must be identified and advice considered in relation to those systems. The farming systems work of the Department of Agricultural Extension should be useful in setting up a suitable advisory expert system, which would make use of the information from the crop allocation model and any other relevant systems developed.

4.7 Optimal Crop Allocation

Linear programming offers some advantages in deciding the optimum mix of crops to satisfy a particular objective e.g. maximising profit or minimising cost. The results should be used as a guideline for use with the farming systems model to arrive at a sensible and useful recommendation.

4.8 Soil Conservation System (possible)

Internationally research is already underway to design computer models and expert systems to automate some of the important measures used in soil conservation planning. Work in Australia has already led to a preliminary system for deriving a measure of erodibility, from soil and topographical information supplied by the user as prompted by the program.

Such programs might usefully be incorporated in a land evaluation GIS. Expert systems could be 'custom-designed' for the Thailand situation.

4.9 General Planning System

Recommendations as to cropping systems for particular locations must take account of any planning restrictions imposed on the land or proposed development. For instance, under the Proposed Eastern Seaboard Development some land will be possessed for industry. A mechanism is needed to ensure such plans are taken into account in the land use planning recommendation. The General Planning System would be designed to make such adjustments as necessary to the farming system or crop recommendation.

It would also be desirable to include some check on the effect of any recommendation on provincial cropping targets as set under the National Plan. Adjustments could be made to try and stay within proposed targets.

4.10 **Mapping Package**

The most important output of the land use planning GIS would probably be the various special purpose maps and a high quality final product is important. Mapping software packages are available to achieve this and there is a wide selection to choose from.

5. AN EXAMPLE

An example of the advantage to be gained by using a combination of data sets to describe an area of land occurs in the context of crop identification by satellite imagery.

In identifying crops from satellite imagery several attributes of the image data must be examined using digital image processing techniques, but most commonly the classification will depend on reflectance values and perhaps some textural measure. Such measures are often very similar between crops of similar physical form, besides which, resolution of the imagery can limit accuracy. For instance it might be very difficult differentiating between La-mud and Rambutan from satellite imagery, but if for that same area the soils information is accessed from the GIS, the identification might be confirmed. If the soil was a loamy sand or sand then it would be highly likely the crop was La-mud, if a clayey soil then it would probably be Rambutan. Sometimes many attributes may need to be checked for a particular area to correctly identify the crop or diagnose a problem. This would be done in a few seconds by a GIS, but is probably impractical by any other means. To accomplish such a diagnosis does still of course require intelligence in searching for and analysing the necessary data. This would again be an ideal application for an expert system. Such techniques then form the basis for a system of yield prediction for different crops, if a department wished to develop such a system.

In establishing a GIS it is very important to a decide on the data processing methods at the earliest possible stage, to avoid wasted effort in data collection. An inevitable dividend of any automated system for assessing land suitability using a common database is that gaps in data would be immediately obvious and each division could be encouraged to remedy such imformation vacuums. Equally duplication would be minimised, as if the database already contained information a division wanted to collect, justification of collection of more of the same would have to be very convincing. This in itself is a useful role for a GIS.

For tasks centering on the collection, collation, and manipulation of data as is the case for DLD, automation of information processing is an essential step in improving the precision and accuracy of advice.

REFERENCES

BIE, S.W. & J. Schelling 1977. An integrated information system for soil survey in Factual data Banks in Agriculture. Wageningen, Netherland : PUDOC pp 45-53

BRYANT, N.A. & A.L. Zobrist 1976. Integration of socioeconomec data and remotely sensed imagery for land use applications Proc. 2 nd Annual PECORA Aymp. ASP & USGS, Oct. 25-29, 1976 pp 120-130

CAMPBELL W.J. & M.Goldberg 1981. A 'user friendly' geographic information system in a color interactive digital image processing system environment. Proc. VII ann. PECORA Symp. ASP & USGS Sioux Falls, South Dakota, Oct. 18-21, 1981 pp 402-413

FISHER, H.T. 1979. Thematic cartography. Thematic Map Design Harvard University Camb.,.Mass. : Harvard University pp 8-38

FRANK, T.D. 1981 Comprehensive geo-data base control with an electronic coordinate digitizer. Proc. 7th Int. Sym. on Machine Processing of Remotely Sensed Data, 6-23rd June 1981, Purdue University. pp 497-504

JACKSON, R.D. 1984. Remote sensing of vegatation characteristecs for farm management. Proc.of the Society of Photo Optical Instrumentation Eng. 475 pp 81-96

JEANSOULIN, R., E. Cals, & J.C. Darcas 1983. Multitemporal segmentation and analysis in remote sensing. Proc. of the Geneva Meeting of the International Society for Optical Eng. 475 pp 13-20

MERRITT, E.S., J.M. Mennly, L. Heitkemper & D. Hlavka 1981. CROPCAStm : A special purpose geographically referenced information system for crop inventory applecations. Proc. of th 7th Int. Symp. on Machine Processing of Remotely Sensed Data 6-23rd June 1981, Purdue University. pp 478-490

PEUQUET,D.J. 1983 The application of artificial intelligence techniques to very large geographic data bases Proc. of the 6th Int. Symp. on Automated Cartography, Ottowa, 1983 AUTOCAR 6 pp 419-420

POWERS, J.E. et al. 1979. Advances in the development of remote sensing technology for agricultural applications. Preprint for Applications Session Symp., 13th Int. Astronautical Federation congress, Munich, Germany, 16-23rd Sept. 1979. Earth Observations Division , NASA : Houston, Texas

RUDEFORTH, C.C 1975. Storing and procssing data for soil and land use capability surveys. J. Soil Sci. 26 No.2 pp 155-168

SCHULTINK, G.R. and W. Lodwick. 1981. Application of remote sensing and geographic information system techniquis to evaluate agricultural production potential in developing conutries. Proc. of the 7th Int. Symp. on Machine Processing of Remotely Sensed Data 6-23rd June, 1981 Purdue University. pp 466-477

SHEEHAN, D. 1979 A discussion of the SYMAP program Maping Software and Cartographic Data Bases Harvard University. Cambridge, Mass. : Harvard University pp 167-179

SINTON, D. 1979. An introduction to I.M.G.R.I.D., an information manipulation system for grid cell structures. _Mapping Software and Cartographic Data Bases Harvard University_. Cambridge, Mass. : Harvard University pp 180-194

TOU, J.T. and J.M. Cheng 1983. Design of a knowledge-based expert system for application in agriculture. _IEEE Proc., Trends and App. Automatic Intelligent Behaviour, Gaithersburg MO USA 25-26 May 1983_. pp 181-189

WEBSTER, R. 1977. An automated information system for soil. _Factual Data Banks in Agriculture Wageningen_, Netherlands : PUDOC. pp 54-56

THE ROLE OF INTELLIGENT KNOWLEDGE-BASED SYSTEMS IN LAND EVALUATION FOR THAILAND

M. Pooley and Dr. T. R. E. Chidley

1. INTRODUCTION

Intelligent computer programs are those which appear to be able to simulate human reasoning. An important characteristic of knowledge-based systems is that control of processing information is determined by logical decisions rather than simply following the fixed order in which commands have been written.

Land evaluation is the term used to describe the process of collating and interpreting basic inventories of soil, vegetation, climate, and other aspects of land, in order to identify and compare land use alternatives. The Thailand Department of Land Development (DLD) is already considering such evaluation nationally at the crop specific level. The approach being followed is that recommended in the FAO Framework For Land Evaluation (FAO, 1976) and later described in more detail in FAO Soils Bulletin No 52 (FAO,1983). Since the problem is now well ordered, but commonly involves a very large amount of data, it would seem to lend itself to automation by computer. Indeed the FAO have been working on programs to automate the evaluation task for some time (Wood & Dent, 1983).

The objective of this paper is to provide an introduction to knowledge-based computer systems, to those unfamiliar with such technology and then to show how this is relevant to land use planning in Thailand.

Different programming methodologies will be considered, illustrating the advantages and disadvantages of each approach.

Finally some suggestions as to the most relevant approach for the evaluation tasks of the DLD will be suggested.

2. AUTOMATION OF THE LAND EVALUATION TASK

To successfully automate a classification task, a system must meet certain criteria (primary requirements):

a) It is essential that there is some mechanism for pattern matching so that the user input can be compared with stored information, to establish which conditions are true. The presence of certain positive conditions will then infer a particular answer or indicate the need for a further line of questioning. The direction taken depends upon the knowledge base of rules.

b) The need for a classification indicates that further information is expected, therefore a second criteria is that, the facts and rules should be handled separately allowing the system to be updated easily. Since classifications are not static it is also important to be able to readily change the rules.

c) It is also vital that any computerized classification system simplifies the process. Classification manually is tedious and depending on the experience of the individual may not always be either consistent or accurate. However if querying of the computer system requires specially prepared data files or information to be presented in a particularly exacting format then accuracy and consistency in classification are unlikely to be improved.

These primary requirements could be met by programming in a choice of many different languages. Pattern matching is not generally very difficult to achieve whatever the language chosen. It is clear that database command languages are well suited to meeting the second requirement, of separating facts and rules. Database command languages form an integral part of some relational database management systems, which are simply an automated filing system, with provision for comparison between any record and another in any file. Such systems allow manipulation of whole databases of information in much the same way that a language, such as BASIC processes each variable.

Satisfying the third requirement in many conventional languages such as BASIC or FORTRAN is quite feasible but very time consuming for the programmer, and consequently expensive. Thus elaborate systems to make life simple for the user are not as practical to implement. Systems with much help available and pleasing displays can be readily programmed in database management systems (DBMS).

The three criteria mentioned above are certainly required for adequate automation of a classification such as the FAO land evaluation scheme. Any system built to meet these requirements could probably be deemed a knowledge-based system. There are however other knowledge-based systems designed to meet more exacting requirments which may or may not be judged necessary in the automation of the land evaluation scheme. Such systems in addition to the foregoing criteria can also:

a) Provide explanation as to why a particular question is being asked.

b) Avoid asking unecessary questions.

c) Have some means of expressing the degree of certainty in their answer.

These facilities are not essential to the automation of the land evaluation process, but are undoubtedly desirable. If they can be achieved without detriment to the functioning of the primary requirements, then they should certainly be included in any system. The programs that provide these extra facilities are known as expert systems and most examples are available in the form of shells, whereby the mechanisms mentioned as requirements are supplied in a complete package, for implementation in the chosen subject domain. Some good reviews of expert systems and the theory involved are presented by Michie (1979), comparing some of the varied program structures. The advantages and disadvantages of expert systems in general will be considered first and then expert system shells will be examined in detail.

3. EXPERT SYSTEMS

A formal definition of expert systems as approved by the British Computer Society's committee of the specialist group on expert systems is :

"An expert system is regarded as the embodiment within a computer of a knowledge-based component from an expert skill in such a form that the system can offer INTELLIGENT ADVICE or take an INTELLIGENT DECISION about a processing function. A desirable additional characteristic, which many would consider fundamental, is the capability of the system, on demand, to JUSTIFY IT'S OWN LINE OF REASONING in a manner directly intelligible to the enquirer. The style adopted to attain these characteristics is RULE-BASED PROGRAMMING."

Expert systems adopt a declarative program style, in other words, if all the relevant aspects of a problem are declared by the user, the program will then find a solution without being instructed as to how to use the information, as in conventional "procedural" style. The logic embodied in the knowledge base of rules, constructed by the subject expert, determines the path taken by the program. Some computer languages have an in-built declarative control structure, such as PROLOG (programming in logic) which is why some people would suggest such a language should be used in expert systems. However this is not an essential requirement, declarative expert systems can be written in conventional procedural languages, such as FORTRAN or BASIC.

The efficiency which expert systems exhibit in avoiding repetition of questions and shortening the search path, by only asking pertinent questions is one of their major advantages. If a system is not based on logic with a declarative control structure there is a danger that questions will be repeated, even if some kind of hierarchical structure has been achieved in a procedural language, by judicious use of "IF THEN" type statements. This is annoying to the user and he is likely to quickly condemn the system as yet another 'dumb machine routine' and have little faith in the answers. So in many circumstances this attribute of expert systems is indeed very important. In the automation of the land evaluation procedure it is less important, because every question must be asked anyway. Factors are supposed to be independent so any previous reply is unlikely to give any indication as to the answer for a current question, and any factor can decide the overall suitability by scoring the lowest rating. In this respect the FAO classification is somewhat unusual in that there is no narrowing down of possibilities.

The other facilities offered by expert systems of explanation and certainty measures, would probably both be useful additions to the classification procedure. Users of the FAO evaluation guidelines as interpreted for the Thailand situation are often perplexed as to how exactly a particular site should be rated for certain factors. For instance, in assigning something like soil texture categories there may be some doubt as to which standard texture classes should be grouped together. In such a situation advice as to how a question is to be interpreted is extremely useful. This would be available at any point in the system and additionally, explanation as to why a decision has been made can be provided. The latter shows which rules have been used to arrive at a particular outcome. Showing how the information is to be used often clarifies how the question should be answered. It also satisfies the user as to whether or not the correct logic has been applied.

Certainty measures express the degree of confidence the user can have in the final decision, reflecting either uncertainty as to facts or the logic of the system being considered. In the case of land evaluation uncertainty as to the logic derives from doubt about the influence of some factors. Uncertainty as to facts reflects the level of confidence in data collected on a particular land unit. Often sampling of land units, to collect data on attributes for evaluation is not as comprehensive as would be desired. Certainty factors for each attribute would indicate the level of precision for the data used. Such a facility could be very useful in identifying regions where either the system is incompletely understood, or the data available is not yet sufficient for very reliable classification. At present, in Thailand information on detailed crop requirements is often based on work in other countries or on a very few research results. The strength of belief to be placed in these requirements could be expressed using certainty factors.

Expert systems to accomplish a particular task can be programmed directly in a chosen language, but they are more usually met in the guise of expert system shells. These shells can be likened to an original expert system designed for a special purpose, with the information specific to that purpose subsequently removed. The structure and mechanisms can then in theory be applied to any appropriate task someone else has in mind. Instead of having to program directly in a language, the non-programmer can then use such a shell to logically design his system. The facilities offered vary between shells as does the "inference engine". Inference engine is the term used to describe how rules are used to infer conclusions from input data. Some shells can handle uncertainty others cannot, and the provision of explanation is also variable. Most systems require the user to devote some time to learning how to use them but working expert systems can be built very swiftly by subject (domain) experts themselves without recourse to computer specialists.

It is clear that expert systems generally offer all the facilities listed as requirements for automation of land classification, but it is important to be aware of some of the limitations currently restricting their application.

So far none of the shells that have been tried offer the option of allowing the user to supply information in bulk by setting up a data file, each enquiry must be made one by one. This can again introduce boredom and mistakes are more likely to be made. One shell currently under evaluation does offer a solution through linking to programs written in FORTRAN. For applications within an information system it is essential expert systems can be easily interfaced with other programs.

A problem common to all shells so far appraised is that there are size limitations, even on mainframe versions. In attempting to use shells in automating land evaluation, difficulty has been experienced in handling all the factors involved. Limitations to the amount of help, text and explanation that can be provided are also restrictive when setting up a system.

Another problem seemingly common to most shells is that one of the primary requirements of a knowledge-based system is seldom adequately met. That is, the clear separation of facts and rules so that new information can easily be added or alternatively the rules changed. To some extent the consequences of this deficiency are obviated in shells, by the ease with which a complete new system can be set up. However, that would require an expert's time again and in a situation where new information is continually accruing, it is not a very satisfactory solution. For the land evaluation task it is important that DLD crop experts should be able to revise the knowledge base of rules on crop requirements, simply by adding new data or changing that already present. The expert does not want to restructure the system each time he updates it. The user should be able to add more facts on a particular attribute to a database by a simple question and answer routine with the program. New facts might be information on a new land unit not previously considered, or revision of previous information on land qualities. Most shells seem to suffer from this problem because they are actually written in conventional procedural languages such as FORTRAN or PASCAL, rather than declarative languages such as LISP and PROLOG. This is the other option when considering expert systems, to program directly in an artificial intelligence (AI) language with a one off system to suit a particular purpose. An AI language is specifically designed for work on problems requiring simulation of human reasoning.

4. AI Languages

Advantages gained by following the strategy of using an AI language would be:

a) In-built pattern matching capabilities associated with list-processing.

b) Information for the land evaluation procedure could be set up in a database and processed as a series of records rather than each record being processed singly. Linking to other programs is also usually easier.

c) Size limitations will be imposed by the host operating system rather than the language. Although it should be noted that AI languages are not generally very efficient in terms of use of memory. Requiring more memory to run a given program than most languages.

As with other languages no special provision is made in AI languages to handle uncertainty in decision making. However if a reliable method for including this can be incorporated in the inference mechanism, then this should not be very difficult to program in any of the languages discussed. If Bayesian logic is employed, a popular method to describe the probability of an event occurring given the probability of related conditions, then programming should be facilitated in a language such as PROLOG, (programming in logic). PROLOG has a built in control structure which is backward chaining, it should thus be straightforward to pass on probabilities through a line of reasoning, appending the final probability to the answer given to the user.

A disadvantage of the use of PROLOG as compared to shells is that considerable programming effort is required, at least in setting up the system. For the task of automating the land evaluation process this need not be a major disadvantage, since it is unlikely that the inference mechanism will need to be changed. The principle of matching crop requirements with land qualities is well established. The requirement is for the database of facts, either about crops or land units, to be easy to update as more accurate information becomes available or new crops are considered. This could be achieved without any programming knowledge. 'Front-ends'(data entry screens programmed to be easily understood) for such tasks could be set up when the original system is designed.

So far we have considered : the use of knowledge based systems written in any language or package desired, just to provide the primary requirements identified for automation of land use evaluation; Expert system shells; and AI languages. There is another type of expert system which can be relevant to automation of information processing procedures. This is the 'family' of inductive expert systems, again usually implemented as shells.

5. Inductive Expert Systems

Inductive expert systems are systems in which the rules to be used are actually derived by the system itself using logical induction applied to a set of example instances. Work by Michalski and Chilausky (1980) on soybean pathology diagnoses demonstrated the advantages of this approach. They found to their surprise that having experts score examples for an induction system on soybean disease diagnosis was more reliable than asking the experts directly for rules to apply. In some situations this can provide a very efficient means of deciding how to structure the rules to form the knowledge base.

The circumstances under which this holds true need clarification. The most obvious application is where the problem is incompletely understood, but a large amount of empirical data is available i.e. given certain circumstances the answer can be predicted, but it's difficult to explain why. This could be the case where acknowledged experts on a subject are available. Having gained much of their knowledge by experience they may find difficulty in supporting their judgements with established facts. It might be possible to persuade experts to try and formalise their knowledge into some basic rules, which could then be programmed in a rule-based expert system, but this may not be easily achieved as experts often have difficulty in formulating such 'rules of thumb'. In an inductive system, example combinations of attributes are supplied to the expert for his evaluation. These are then 'fed' to the computer system to be sorted logically into rules. One expert system shell that does this is Expert-Ease, developed from work by Quinlan (1979). This shell builds a hierarchical decision tree from the examples provided to it in a training set. It is then tested on further data, from the same or another expert. Any examples which are not answered correctly are then added to the training set. This is an iterative procedure until the expert system always predicts the correct answer.

These circumstances do not usually apply to the process of deciding suitability of land for a particular crop as recommended under the FAO guidelines. The procedure to be followed of matching requirements and qualities is not in doubt and the information on crop requirements, although not always available in the desired detail, can usually be decided from crop research data with reasonable accuracy. It may be that for some of the less studied crops, some rules for assessing suitability could be derived by induction, but where research data is available it should be used.

However the land evaluation framework was not meant to restrict evaluation to determination of a suitability rating. Increasingly people want to convert the suitability rating to some kind of economic measure of the advantage in growing a particular crop, so that the crop alternatives can be ranked by the chosen criteria. This is necessary in order to give a definite recommendation. The other government departments, non-governmental organizations or in some cases the farmer are less interested in knowing all the suitability ratings for each crop, particularly since many may be identical, they want to know which crop or cropping system should be recommended.

The approach of setting up an economic model to establish a ranking by land unit for the realistic spectrum of crops has been attempted and the programming involved is relatively simple. Unfortunately though there is a notable lack of economic data to run such models and the situation will not be instantly remedied. Until such time as the detailed information by crop and land unit is available inductive expert systems may provide reasonable means of achieving the aim of making a more definitive recommendation.

Many experts within DLD probably have no doubt as to what choice of crop in a given province and situation, but the rigidity of the procedure for suitability evaluation currently adopted, allows little chance for them to exercise their expertise. Experience of a wide range of local experts could be captured in a single expert system to decide the most suitable crop. The procedure would be to train a system with examples answered by different experts. This would be repeated with new examples supplied until the system gave the correct judgment for every enquiry.

6. PROTOTYPE KNOWLEDGE-BASED SYSTEMS FOR RAYONG PROVINCE

Some work on automation of land evaluation has been done in cooperation with the Department of Land Development. This has concentrated on development of a small prototype system for Rayong province. The system has been developed on an IBM compatible micro computer. This was set up, with the wider objective of designing a GIS system although at this stage mapping requirements have not been considered.

For the process of land evaluation to obtain a suitability rating, for a crop on a particular land unit, emphasis has been placed on meeting the primary criteria discussed already. This has been achieved using the dBASE III database management system. All three primary criteria are adequately met although at present there is no 'on line' help facility, which would be desirable. Display screens can also be repetitive. Requirements can be updated or changed through easy to use data entry screens, as can new information on land units. Addition of new attributes after the system has been established is more difficult but could probably be achieved without much further programming effort.

Economic evaluation has also been considered and a system to calculate the average present value of growing a crop on a given land unit is in operation. It has been very difficult to find any data for the program but in that respect it serves a useful role in showing which information is lacking. A present value approach was used because it offers a means of comparing tree crops with annual crops. This is a necessity in Rayong province as it is a choice the farmer must make.

Having obtained a land use rating in the dBASE system it is possible to choose an option to check on the present value of growing that crop on the particular land unit. After 'chaining out' (going to and returning from another system) to the Lotus system for the calculation, the user is returned to the options menu. This is an example of how a knowledge-based system can be linked to other programs which perform straightforward mathematical operations.

A small inductive system has also been attempted, to predict which crops should be grown in the absence of detailed economic information. The system presently relies on only a small training set of about forty examples taken directly from farmer responses to a questionnaire. Results are encouraging, suggesting this could be a reasonable approach. In this case the farmer was treated as the expert, but the same exercise will hopefully be attempted with local crop experts from the DLD to try and achieve accurate recommendations as to which crop or selection of crops should be grown. The expert system provides a reliability measure for each of it's answers and where several crops are considered feasible such a measure could help in choosing the appropriate farming system.

The need for a further system to classify land units has been identified. This would be designed to help in setting land units by grouping of similar conditions for each variable to be considered. Once set for a particular province the user could quickly check for a given location what the land unit should be. This would ideally be set in the context of a GIS since the information required would then be available quickly on a geo-referenced basis. The decision system itself will probably make use of an expert system shell of the inductive type. It would be trained using example combinations of the attributes judged appropriate for a particular province.

7. RELEVANCE OF IKBS TECHNIQUES FOR LAND EVALUATION IN THAILAND

In automating the land evaluation task using the procedures recommended in the FAO guidelines, the principle concern is that a suitable pattern matching technique can be achieved, that will be independent of the stored information. This allows requirements and factual information on land units to be easily altered. Also any interested staff should be able to sit down and interrogate the system.

These requirements can be met by database management systems. Since such a program will form the core of any GIS system established, it is sensible to make use of the programming language provided, to give the basic structure for the land evaluation system.

The extra facilities provided by the expert system shells, of explanation and quantification of uncertainty, could be indispensible in improving the ease with which the system can be used and the programming of certain applications, where there is doubt as to the precision of data.

Inductive expert systems are likely to be useful where the knowledge available is 'fuzzy', but too valuable to dismiss, particularly where detailed information is simply not available.

Emphasis should not be placed on using A.I. languages directly because of the weighty investment in programming time likely to be required, but for some very specific tasks their flexibility would be a great advantage.

The most reliable approach for automating land evaluation procedures is likely to be a combination of database management systems, other specialized software and expert system shells.

REFERENCES

FAO 1976 A Framework for Land Evaluation. Soils Bulletin No.32. Rome : FAO.

FAO 1983 Guidelines : Land Evaluation For Rainfed Agriculture. Soils Bulletin No. 52. Rome : FAO.

Michalski, R. S. & Chilausky, R. L. 1980 Knowledge acquisition by encoding expert rules versus computer induction from examples : a case study involving soybean pathology. Int.J.Man-Machine Studies 12, 63-87

Michie, D.(Ed.) 1979 Expert Systems in the micro-electronic age Edinburgh:Edinburgh University Press.

Quinlan, J.R. 1979 Discovering rules by induction from large collections of examples. in Expert Systems in the micro-electronic age ed. Michie, D. Edinburgh:Edinburgh University Press

Wood, S. R. & Dent, F. J. 1983 A Land Evaluation Computer System Methodology. Bogor, Indonesia : Min. of Ag. Ind. / FAO.

PROJECT PROPOSALS

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1. PROJECT OVERVIEW

1.1 Rationale

a) The National Context

The programme comprises three main facets: strengthening, and improving access to, the data base; developing the systems required for the analysis and interpretation of the data; and ensuring that the end users are able to utilize properly the output of the evaluation and planning system. The proposed project supports that programme.

Thailand faces a critical period in the effective utilization of its renewable natural resources. The country's proven ability to produce exportable surpluses of food and other primary commodities is no longer sufficient in an international environment of increasing competition and reducing margins. It has become essential that production is achieved in the most cost effective way, and that it is matched in terms of quantity, quality and timely availability to the requirements of a market in which Thailand must compete with some of the world's major producers.

This situation places a high level of demand on those whose job it is to plan the use of land whether at the macro - level of national or regional planning, or at the level of specific programme, project or farm planning. Such planners can only cope with this demand if they have access to an appropriate Decision Support System. The programme outlined above, which this project would support would effectively provide such a system. In common with many other parts of the world, Thailand has shown a strong interest in the development of Geographic Information Systems as the means for managing the comprehensive data sets required in land resource planning. This can be seen as part of the country's growing involvement in the whole field of Information Technology as witnessed by its developing micro - electronics industry and expanding pool of software experience.

The timing of the project would accord well both with the development of Thailand's own Information Technology base and with the introduction of the fifth generation of computers. The investment period of the project will cover the development from the existing Data Base Management Systems (DBMS) to Intelligent Knowledge Based Systems (IKBS). The early implementation of the project will ensure that the expertise that is built up is pertinent to the application of these new systems. The development of IKBS will overcome what has hitherto been one of the major problems in the introduction of high technology systems; namely that with the termination of the technical assistance inputs which have often been used to establish the systems, and frequently the movement of trained staff away from government service or to senior administrative positions, the knowledge required to utilize the systems is lost. Through the application of IKBS this should not happen as the knowledge which has been acquired becomes an inherent part of the system.

The programme and this supporting project fully accords with one of the primary objectives of the Sixth Development Plan, namely the effective utilization of Thailand's land resources. The plan emphasizes the need for better planning of land use and specifically identifies a Centre of Land Resource Information as a prerequisite to such planning.

b) Need for Strengthening the Existing System

In common with most other countries, Thailand has developed its capability in land use planning from the interpretation of the physical environment, particularly soils, in terms of what crops would best grow there. In its studies and surveys of soils, the Soil Survey Division of the Department of Land Development (DLD) has been accorded broad international recognition for the quality of its work. The kind of information traditionally supplied to end users was adequate in an economic environment in which there was relatively ready demand, internally and outside of Thailand, for primary agricultural products.

This situation has changed, and with it must change the type of decision support system which the country's land use planning agency provides to its users. Recommendations on land use must be based on identifying the most efficient - not just a suitable - way of using land, taking into account constantly changing input-output ratios and market situations. Advice must be in terms which are meaningful to the users of this advice, and this normally implies a quantification of benefits in economic or financial terms. This advice must be provided rapidly if it is to be used effectively.

To meet this demand requires strengthening the agency allocated responsibility for land use planning. Planning needs to be based on a much wider array of information, much of which is time variant and requires constant updating. The quality and ease of access to data need to be improved. The complexity of handling this broader data base can only possibly be undertaken if the benefits of modern information technology are applied to the process.

c) The Beneficiaries

The ultimate beneficiaries of better land use planning are Thailand's farmers. The provision of the kind of decision support system which the project would provide to policy makers would help to ensure that policies and programmes accorded with local and international commodity demands. At the same time those responsible for advising farmers on the use of their land would have access to the information that ensured the advice was as soundly based as possible. A successful farming system will in turn help to ensure the long-term economic well being of the country.

1.2 Objectives and Scope

The proposed project would provide support in the initial stages of a long term programme for more effective land use planning. While this must inevitably include the provision of the hardware and software which the new planning systems will utilize, the primary objective of the project is to strengthen existing institutional capability in the collection, collation, management and evaluation of land resource data. To meet this objective in a high technology field, the project would provide training and technical assistance to a wide range of government personnel involved in providing, analysing and utilizing the required data and information. Maximum use would be made of the growing private sector expertise in Thailand in the field of Information Technology.

Thailand's data base in many of the aspects required for comprehensive land resource evaluation and planning is well developed; only a few deficiencies have been noted which would be rectified by the project. More important is the need to make the data accessible in a unified format and to develop the systems for handling the data. The project would achieve this by establishing a centralized information system with access to relevant data sources and the facilities to convert data to digital format so that it can be incorporated in the Geographical Information System (GIS).

In common with most other countries, land use planning in Thailand has developed from the basis of determining the physical capability of land to support specific crops or cropping systems. While economic factors are often implied within such evaluations they are rarely quantified. The need for Thailand to have available a land use planning system which quantifies the benefits of alternative land uses in economic or financial terms has been emphasized. The development of such systems is an integral part of the programme, and the project proposed here would support this aspect by providing the hardware, developing the software and building up the expertise required. During the course of this study some preliminary software development in the form of illustrative models has been undertaken. These could quickly be refined for early practical application while the process of data strengthening and programme refinement is progressed.

The long term programme recognizes the fundamental importance of ensuring that proper use is made of the output from the planning system, and it has been emphasised that this output is essentially a Decision Support System for a range of users. These users include those concerned with macro-planning at national, regional or changwat level, project planners such as those concerned with irrigation, settlement of shifting cultivators, or reafforestation projects, and micro-planners advising on individual or collective farm plans. The project would support this aspect of the programme by providing appropriate computer linkages and the mechanisms for training users in applying the Decision Support System in their own planning procedures.

The project will have important inter-relationships with a number of other ongoing or proposed projects. The most important of these are:

- The Cadastral Land Information System. This is to be established under the Department of Lands'programme for national cadastral mapping. It will be a parcel-based system in which the primary definition of the parcels will be by owner and form of title. Although at a much more detailed level than is required for most land use planning, summaries of this information will be an important input to the Geographic Information System to be developed under the land resources project. At the same time the Department of Lands will be provided through this GIS with physical environment-based units which it can overlay on its cadastral data which would be of particular significance in valuation analyses.

- The Rural Land Use Study. In an ongoing project preparation a programme for extending forest reclassification is being developed. The land use planning capability which the land resources project would provide, would help to support this programme. This study is also addressing the need for a land policy and management centre. It is envisaged that this will incorporate a computerised management system, and the output from the land resources project would be an important data link to this.

  The Land Policy Study. This study will cover all aspects of land and will make recommendation to government on policy guidelines and the role of supportive information systems. The output from the proposed project would be an essential input in the field of agriculture and forestry to the overall system.

The project scope encompasses a major training programme. This will be achieved through on - the - job and course - based training. The Technical Assistance will include a major input from local computer system consultants and software houses. As well as affording training to government staff the local consultants will further progress their own expertise by working on new systems closely with specialist from overseas. Maximum use will also be made of the good local training facilities where are available.

2. THE PROJECT COMPONENTS

Although it is important for the project to be seen and managed as a single entity, it is convenient to describe it in terms of a number of components. Only by the implementation of all these in a co-ordinated way will the overall objectives of the project be achieved. A total of 16 components (including the project management office) are described below. Responsibility for the implementation of these lies mainly within the Department of Land Development but three components will be implemented by other agencies - the Office of Agricultural Economics, the Meteorology Department and the Department of Lands. One component requires a collaborative arrangement between DLD and the Meteorological Department and another will involve the Thailand Remote Sensing Centre as the agency responsible for the provision of rectified satellite imagery. Figure 1 shows the allocation of responsibility for the 16 project components.

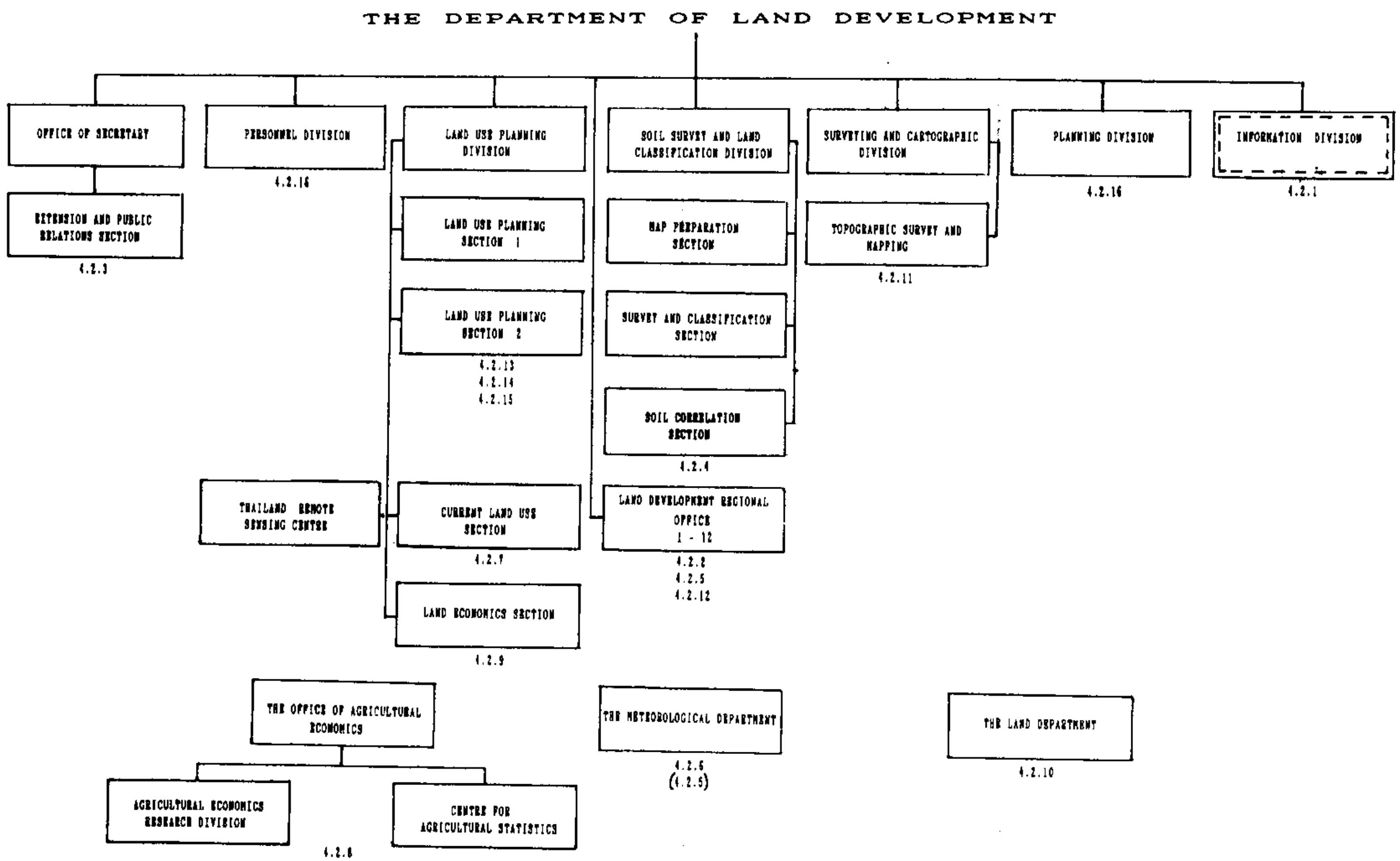
As presented the whole project is phased over a five year period, but consideration may be given to an alternative phasing according to relative priorities. On such a basis what is essentially a refinement of data flows from the Meteorological Department, which are currently of a reasonable standard, could be brought in at a later stage once other more urgent aspects have been developed. The improvement in access to cadastral data may also merit some delay while ongoing developments within the Department of Lands are progressed further. This would imply an alternative phasing in which components 2.6 and 2.10 started possibly in project year three.

2.1 Establishment of a Centre for Land Resource Information

a) Rationale and Objectives

The draft of the sixth National Plan recognizes the need for improving the accessibility of information on land resources. It identifies DLD as the agency responsible for implementing this function. The establishment of an Information Division within DLD has been proposed whose function will be to meet the responsibilities of improving the accessibility of land resource information.

Figure 1   Project Component Responsibilities



It will do this by holding a central database of all of the data required to evaluate land resources, by providing computer compatible connections between suppliers and users of information, and by strengthening DLD bibliographic, conference, and exhibition capacity. This component will assist with carrying out these functions by the provision of buildings, computer and communications equipment and software, training, and technical assistance.

It is timely to invest in the provision of Information Technology (IT) resources so that DLD and its information user community can grow along with IT. Particular features of the IT revolution which are included in the provisions of this component are the ability to represent knowledge and provide intelligent access to data. By insisting on the incorporation into the computer knowledge base of the expertise provided by technical assistance, a full transfer of technology can be effected. The same techniques can be learned and applied by DLD to make its headquarters expertise available to regions, provinces, and ultimately farmers.

b) Implementing Agency and Linkages

The implementing agency will be the proposed new Information Division of DLD. Provision is made for linking the new division with up to 16 government agencies and other sources of information, nationally and internationally, and for linking it to several key sections within DLD. The main linkages will be with the Royal Irrigation Department (RID), Office Agricultrual Economics (OAE), National Statistics Office (NSO), Meteorological Department (MD) and the National Economic and Social Development Board (NESDB).

c) Method of Approach

A computer system will be provided in DLD to expand the existing system in the Soil Survey and Classification Division. The expansion is timed to occur when the capacity of the present system is expected to be exhausted. In the meantime, provision is made for improved database and GIS software for the current system. To further facilitate the introduction of Information Technology into DLD an early purchase of micro-computers is recommended. These will serve later as intelligent terminals on the DLD internal network.

In addition to soil, land and economic data collected by DLD, copies will be held of key historic climatic, hydrological, agronomic and socio-economic data collected by other government agencies. Access to these data and knowledge in the form of expert systems and models will be provided over the internal and external data networks.

Statistical and tabular data will be stored under the control of an integrated DBMS which users can run on their own micro-computer terminals. Spatial data will be stored in a full scale GIS, though simplified GIS data will be made available to the standard micro-computers in the basic network.

2.2 Establishment of a Regional Network

a) Rationale and Objectives

As modern technology and techniques are introduced at DLD head office and for the collection of data in the field, it is important to develop the regional capacity to absorb and utilize the new methods. Support will need to be given to DLD staff in the field who are involved with the data collection programmes recommended by other Project Components. The Regional Offices are important nodes in the information network connecting land users (farmers) and knowledge gatherers in the field with headquarters staff of DLD. The regional centres have just been formed and require strengthening, not least in their capacity to utilize and benefit from modern information technology.

b) Implementing Agency and Linkages

The implementing agency for this component will be DLD. Existing linkages between users of land, the stations, the regional centres and DLD in Bangkok will be strengthened by the component as technology is transferred over the network.

c) Method of Approach

Modest amounts of computing equipment and vehicles will be provided to regional centres over a four year implementation programme. Technical assistance will be provided to assist with developing information systems for use in the regions and a local training component will ensure that equipment and systems are used effectively. Some extra staff will be required in the regions. They will be supported by the Information Division.

2.3 Strengthening of the Extension and Public Relations Section of the Department of Land Development.

a) Rationale and Objectives

Effective land use planning and conversation are fundamental to the preservation of Thailand's natural resources. Although the Department of Agricultural Extension provides technical guidance and advice in relation to crops and farming systems, this does not adequately cover land-use planning and soil conservation which are fundamental to future agricultural production. It is therefore proposed that the existing Agricultural Extension and Public Relations Section within DLD should be strengthened to enable it to prepare audio-visual and printed materials for issue to other departments such as DOAE and for DLD's own exhibitions/demonstrations throughout Thailand aimed at hightening user awareness. This objective would be accomplished through the provision of equipment, (including four mobile information centres) technical assistance and extensive in-service training.

b) Implementing Agency and Linkages

The implementing agency will be the Agricultural Extension and Public Relations Section of DLD which will execute the project component during the first year of the project to ensure that the first batch of appropriate material was available to users early in the project.

c) Method of Approach

Additional audio-visual, graphics/printing equipment and four fully equipped 'mobile information centres' plus equipment for the new exhibition and conference halls proposed for DLD would be provided under the project. The 'mobile information centres' would be responsible for organising demonstrations/exhibitions on a national basis within the North, North-East, Central and Southern Regions respectively. The provision of equipment would be accompanied by a 12 month technical assistance input to assist in the preparation of appropriate training materials for dissemination to users. There would also be extensive in service training. Incremental staff requirements will be limited to the five-man teams required for each of the four mobile information centres'.

2.4 Strengthening Soil Data Collection and Management

a) Rationale and Objectives

Information on soil conditions is a fundamental requirement of any land use planning process. Good coverage of Thailand is provided by the 1:100,000 scale changwat soil map series which provides an adequate basis for planning at the lower levels of detail. Although field work has been completed throughout the country a number of maps have not yet been finalised and it is essential that these are made available as soon as possible.

A programme of soil mapping is in progress at a scale compatible with the needs of more detailed land use planning and the design of conservation works. Field work in this is slow and there are serious delays between completion of this and publication of maps and reports.

Thailand has a skilled soil survey force; these existing traditional skills need to be supplemented by the introduction of the modern technology of soil survey. This will ensure that the required soil data for land use planning is made available.

b) Implementing Agency and Linkages

The implementing agency will be the Soil Survey and Classification Division of DLD. The component will be strongly linked to the Regional Offices where the micro-computer-based verification of field data will be done, and to the new Information Division which will provide the facilities for the storage and analysis of data.

c) Method of Approach

Systems for the collection of data in the field using hand-held data loggers will be introduced. During the early systems development phase, use will be made of existing data from the unpublished changwat series field work in order to accelerate the completion of that programme.

Data logged in the field will be verified at Regional Offices before being transferred to the central computer system. Rapid analysis of data will then be possible to facilitate the early production of maps and reports. The programme would be supported by the provision of new aerial photography and additional plotting capacity. Institutional strengthening would be provided through training and technical assistance.

2.5 Acquisition of Specialist Climatic Data

a) Rationale and Objectives

A comprehensive meteorological factor recording network exists in Thailand, with records extending in some cases over more than 30 years. These records provide the basic climatic data needed by the land resource planner, but there are three sectors in which improvements are required:

- Data on radiation, particularly photosynthetically active radiation, is sparse;
- highly relevant agrometeorological data is delayed in its transmission to the Meteorological Department in Bangkok because the stations concerned are not linked to the country wide synoptic station data transmission by radio system; and - climatic data point-specific to Land Development Stations will be required in support of the proposed crop suitability modelling data collection and validation.

b) Implementing Agency and Linkages

The Meteorological Department's, Instrumentation Division will be the implementing agency for the acquisition, installation and commissioning of twelve solarimeters at agrometeorological stations chosen to complement the few existing radiation recording stations. The same department would also be the implementing agency (but through its Telecommunications Division) for the installation of single side band radio facilities at 27 of the 28 agrometeorological stations.

Twenty automatic, and mobile, climate recording stations would be installed at Land Development Stations conducting crop suitability trials to provide modelling data or for model validation. These would be the responsibility of the Department of Land Development, through the Land Development Regional offices.

Linkages between DLD and the Meteorological Department will be necessary to ensure a rapid and efficient interchange of climatic data.

c) Method of Approach

The purchase, installation and commissioning of the solarimeters and climate stations would occur during the early part of the proposed technical assistance inputs and would be completed by the middle of project year 2. Data supply linkages between the Meteorological Department and the proposed centre for resource information within DLD would be developed, utilizing updated computer facilities at the former and the proposed new equipment at the latter.

Concurrent with the installation of solarimeters at agrometeorology stations and mobile climate recording units at Land Development stations, agronomists from the Land Development Regional offices would undergo a one month familiarisation course within the Meteorology Department to acquaint them with weather recording equipment, and its operation, and to impart a basic understanding of interpretation techniques. Systems would be devised to create data transfer routines so that all meteorological data was available both to the Meteorological Department and to the DLD land resource planners, regardless of its source. This would entail not only linkages between the Met. Dept. and DLD, but outward to include e.g. RID and the Royal Forestry Deprtment (RFD).

2.6 Meteorological Department Systems Development

a) Rationale and Objectives

The objective is to improve the computer capacity and scope within the Meteorological Department, in order to handle an increased data flow in a more efficient manner and to satisfy the often conflicting requirements of the World Meteorological Organization and local users. The Meteorological Department also needs to gain access to climatic data generated by other agencies.

The climatic information recorded in the field needs to be processed to maximize its value. The present computer system in the Meteorological Department is overloaded and expensive to maintain. The Department needs to make better use of the available data in giving information to land users, thus maximizing the return on the investment in data collection. Component 2.5 provides for the collection of point-specific climate data at Land Development Stations.

b) Implementing Agency and Linkages

The implementing agency for this component will be the Meteorological Department. It will provide historical agroclimatic data to the proposed Information Division, and maintain a regular up-dating service. Linkages would be established to collect routine climatic data, e.g. rainfall, recorded by other agencies such as the Royal Irrigation, and Royal Forestry Departments.

c) Method of Approach

A four phase approach is recommended. The first phase will be to replace and enhance the existing capacity to enter validate, store and retrieve data. This phase in essential in being able to provide the proposed Centre for Land Resource Information with the necessary climate data base. The second phase is to strengthen the Meteorological Department's capacity to process climatic data. This will include the forecasting function, and providing information more effectively to users of climatic data. A capacity to process meteosat data would be provided at this stage. The third phase is to provide a facility at Don Muang airport. The fourth phase will provide for a data network, connecting the various systems that would then be in place in the Meteorological Department.

Additional staff will be required over the four year implementation period. Computing equipment, software, technical assistance and training would be provided by the Component.

2.7 Current Land Use Mapping

a) Rationale and Objectives

Any advice that may be given, based on physical and economic criteria, relating to changing land use must recognize that the implementation of the plan starts from the current situation. The plan must be practicable in that recommended changes can move at a pace consistent with the capacity for change.

Furthermore, it is futile to make plans for change and attempt to influence land use patterns without being able to monitor effectiveness. Therefore it is important to have a current land use map at a level of detail consistent with the planning process.

b) Implementing Agency and Linkages

The implementing agency will be the Land Use Section of the DLD. Direct linkages will exist between DLD and the Thailand Remote Sensing Center (TRSC), who will acquire satellite imagery on behalf of DLD. The imagery would then be available to other users in Thailand through the TRSC. The processed Land Use outputs would be available to government departments in GIS format through the DLD Information Division network.

The acquired imagery would form an important national source of spatial data for Thailand.

c) Method of Approach

DLD would finance the purchase by TRSC of fully geometrically corrected high precision digital satellite images for the whole of Thailand on the basis of two national coverages over a five year period. An alternative would be for TRSC to undertake to carry out the geometric correction using the same funds.

The Remote Sensing Section of DLD would be equipped with sufficient image processing and computer capacity to prepare land use maps for the whole of Thailand at 1:100,000 scale about every two years. Provision would be made for staff and staff training, both in collecting 'ground truth' as a basis for the classification, and in visual and digital processing of the satellite scenes.

The phasing would ensure the early acquisition of visual images and equipment upon which to build up skills. The full capacity would not be implemented until the fourth year of the project.

Some incremental staff will be required.

2.8 Strengthening External Socio-Economic Data Sources

a) Rationale and Objectives

In addition to primary quantitative data collected by DLD, the land resource evaluation and planning process also requires ready access to secondary socio-economic data prepared by the OAE and NSO. Such data covers input prices, output values, population statistics, farm size etc and would be invaluable both during primary data collection and subsequent updating of survey results. The proposed project recognises the importance of these two data sources and recommends investment to improve information flows. In the case of OAE this will be accomplished through the provision of micro-computer facilities, on-line computer access and technical assistance. For NSO funds will be provided to install an additional terminal with on-line access to the DLD data bank.

b) Implementing Agencies and Linkages

The implementing agencies will be OAE and NSO, both of whom will be provided with computer linkages to DLD. It is proposed that this project component will be implemented during Project Years 1 and 2 to ensure that the proposed systems and procedures are thoroughly tested in time for the commissioning of the new DBMS in DLD. During the process of land-use planning OAE, NSO and DLD will be required to work in close harmony.

c) Method of Approach

(i) Office of Agricultural Economics

The method of approach will require the provision of four 20 mb micro-computers with accessories, two field vehicles to facilitate field checks on data, limited office equipment, local computer training and technical assistance for two years in the areas of survey methodology, data base management and computer modelling. No incremental staff will be required.

(ii) National Statistical Office

Equipment will comprise a micro computer with hard disk storage, appropriate software and an interface with the existing NSO computer and the proposed system at DLD.

2.9 Collection of Land Unit Specific Data by the Department of Land Development

a) Rationale and Objectives

The provision of accurate primary quantitative data on a land unit basis is an essential component in the land use planning process. Although DLD has commenced the collection of land unit specific socio-economic data on a changwat basis, the present procedures need refinement and methods identified for improving the reliability of collected data. It is therefore proposed that the project should provide support to enhance the capability of the Economics Section of the DLD Land Use Planning Division in the collection and analysis of primary quantitative data. It is envisaged that this support would:

- provide the basis of a more accurate data collection system with built in checks;
- allow surveys to be completed more quickly so enabling more frequent coverage of the country;
- provide a computer based system for rapid analysis of survey questionnaires;
- provide digitised survey data for storage on a centralised DBMS so facilitating ready access and updating when required;

- provide greater job satisfaction for survey enumerators who would be equipped with the latest field data loggers and be offered permanent employment and appropriate training.

b) Implementing Agency and Linkages

The implementing agency will be the Economics Section of the DLD Land Use Planning Diviion. It is envisaged that the project component will be implemented during Project Years 1-3 to allow the design, and thorough testing of new procedures and systems early in the project so allowing adequate time for integration of the activities with the computer DBMS during the latter part of the project. No incremental staff requirements are foreseen.

c) Method of Approach

Under the project the Economics Section of DLD would be equipped with vehicles, data loggers, micro computers, limited office equipment and be provided with both local and overseas training. Overseas training would allow up to four suitable candidates to study to Masters degree level in Information Technology. There would also be an opportunity for one of these candidates to continue studies to PhD level. Local training would include a 15 day course for all field ennumerators and 10 days training for all officers within the section. Technical assistance would be provided for a two year period to assist the Economics Section in drawing up new systems and procedures for the colection, analysis and interpretation of primary resource data.

2.10 Improving Access to Cadastral Data

a) Rationale and Objectives

As much as it is important to know current land use in preparing practicable land use plans it is also important to know the conditions of land tenure, size of holding and so on since these may dictate what is possible in effecting a change in land use. This is true for the changwat planner and more so for the project planner. Being able to access up to date cadastral data is therefore of great importance.

Because of the large size of the cadastral mapping data base, conventional methods of updating and accessing such information are relatively slow. It has been estimated that it would take at least 20 years to implement a conventional Land Information System for Cadastral Maps. Any system of shortening this time would be of immense value to the country.

b) Implementing Agency and Linkages

The implementing agency for this component would be the Department of Lands Cadastral information would be prepared for distribution to DLD, RID, Agricultural Land Reform Office (ALRO) and other agencies requiring up to date cadastral information in a form easily handled by computer.

c) Method of Approach

This component is divided into two main sections. The first will assist the Department of Lands with the preparation of 1:100,000 maps showing generalized details of cadastral data for use above the changwat planning level. The second section will provide an interim solution to the detailed cadastral mapping problem.

This interim solution is based upon digital image processing technology. The images of the maps and photo maps currently in use by the Department of Lands will be captured on laser disk storage devices. The details of land holdings can be digitally lifted from these maps and photo maps and overlaid on the originals. The system will permit the editing of the overlay data. It will enable reasonably up-to-date copies of cadastral mapping to be made available on laser disk to all authorized users.

The project provides the Information Technology hardware, software, training and technical assistance to develop and implement this solution, which is the only currently available process for digitizing the large volume of maps used in cadastral survey. By the end of the five year project it is envisaged that maps can be updated by field surveyors using this technique.

Some incremental staff will be needed.

2.11 Improving Topographic Survey Systems

a) Rationale and Objectives

The proposed DLD Information Division will become a national centre of excellence in Geographic Information Systems. The remote sensing capacity of the Land Use Section will grow in parallel to the GIS capacity and be linked with its growth. Digital Mapping is an important facet of Geographic Information Systems and therefore it is necessary to develop the capacity of DLD's Survey and Cartographic Section in digital mapping. The Information Division will hold and maintain the database. It will be the primary responsibility of the Survey and Cartographic Section to provide topographic information to the Information Division in digital form. One aim of the overall Project is to improve the speed of response to requests for land use planning information. To this end the speed at which cartography can be carried out needs to be increased.

The Survey and Cartographic Division already has some equipment for, and experience with Digital Mapping functions and a rudimentary GIS is installed. A good base from which to develop the capacity for digital mapping and cartography already therefore exists.

b) Implementing Agency and Linkages

The Survey and Cartographic Division of DLD will be the implementing agency for this component. Close linkages to the GIS at the proposed DLD Information Division will exist over a Local Area Network in DLD.

c) Method of Approach

The capacity of DLD's Survey and Cartographic Division for digital mapping and cartography will be substantially strengthened by the provision of computing equipment, software, training and technical assistance. This will be consistent with the need to provide Digital Map data to the Information Division and to process cartographic outputs.

Digital Image processing methods, coupled with conventional digitizing store-plotting methods will be introduced. The proposed new equipment should exhibit some compatibility with existing equipment and the equipment to be provided to the Information Division.

Some incremental staff will be needed.

2.12 Determination of Crop and Crop Systems Requirements

a) Rationale and Objectives

Soil and climatic knowledge bases may be developed readily, because of the large volume of information already available in Thailand. Crop knowledge bases are more complex. The three bases require similar levels of knowledge and then comparison, in the process of crop suitability modelling. Crop requirements may be listed in a preliminary process by utilizing data generally available. These data sets then require validation under crop production conditions found in Thailand.

The crop requirement programmes will have two main elements; the compilation of the crop knowledge base, and the validation (and hence updating and improvement) of the crop suitability model. These will be achieved by conducting detailed field work at Land Development Stations.

b) Implementing Agency and Linkages

The project would be implemented through the Regional Offices of DLD, utilizing existing field research expertise within the Soil and Water Conservation Division.

The key staff in this component would be the agronomist positions at each of the twelve DLD Regional Offices. Together with the proposed technical assistant, they would be required to establish close in-house linkages with the agro-zonation sector of the project and with crop physiology and agronomy experts in the Universities and Ministry of Agriculture and Cooperatives' Research Institutes. Close integration would be necessary with the work of the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) which is developing a crop modelling concept.

c) Method of Approach

The twelve regional agronomists would each undergo training by a crop suitability modelling/plant physiologist during the first year of the project, followed in Project Year 2 by a three month overseas course in the creation of soil, climate and crop requirement knowledge bases.

During the second half of Project Year 1, it is suggested that the agronomists undergo a six month course on plant physiology, in Thailand, under the supervision of the technical assistant, utilizing relevant University and Research Institution facilities. They would subsequently (latter half year 2 to end of year 4) be responsible for on-the-job training of Land Development Station Staff in the conduct of data creation and validation trial work. The technical assistant would have a full three year input with the objective of creating a fully operational crop suitability system by the beginning of year 4. This relatively long time scale is governed by the need to have at least three full crop seasons of experience.

Specialist equipment to conduct the detailed field work would be acquired and put into operation in the first half of the first year of the project, forming an integral part of the agronomists' early training and familiarisation.

2.13 Agro-zonation and Point Synthesis

a) Rationale and Objectives

The creation of an agro-zone requires the identification and validation of crop requirements (see 2.12), of climatic, edaphic, agro-economic and socio-economic factors, to indicate which crop or mixture of crops could best be grown on a specified land area. Soil data for such an area is available readily or can be obtained easily. Crop requirements can be estimated with reasonable accuracy and measured in validation trials. Unless the zone or validation site coincides with a climate recording station however the agro-zoning process requires the creation of point synthesised climatic time series data.

b) Implementing Agency and Linkages

The proposed Technical Directorate (Service 1) of DLD, embracing the existing Soil and Water Conservation Division presently responsible for research work, would be the implementing agency. It would develop the expertise to carry out agro-zonation and point synthesis, during the first three years of the project. Important linkages would be required with the Meteorological Department in further developing probability analysis procedures applied to climatic data, and Faculties of Science at the Universities in developing crop requirement knowledge (see 2.12). There would need to be close integration with the work being conducted from Bangkok, by the FAO's "Investigation of Lands of Declining and Stagnating Productivity Project" which utilizes agro-zoning concepts.

c) Method of Approach

Two suitably qualified members of the existing Soil and Water Conservation Division of DLD would be selected to take responsibility for developing agro-zoning and point synthesis techniques, under the supervision and guidance of a technical assistant with extensive experience of the two aspects. The two agronomists, with the technical assistant, would develop the relevant techniques during the first year of the project, coincident with activity in component 2.12, and then undergo a detailed six month agro-zoning course overseas. The whole system should thus be operational in the second half of year 2 of the project, by which time the other contributory components (2.5, 2.6 and 2.11) would be in place.

2.14 Developing Computer-Based Land Evaluation Techniques

a) Rationale and Objectives

Land use planning involves the integration of many elements of data and knowledge. Manual systems of overlaying map themes and assigning the wide range of characteristics required to define and delineate land units are very restrictive. Geographic Information Systems interfaced with Management Information Systems afford the means of determining, delineating and characterising land units, and matching these with crop and crop system requirements.

Substantial skills in land resource evaluation already exist, and Thailand was in the forefront of the application of recently developed principles for land evaluation (FAO, 1976). These skills must now be extended to enable the land use planners to adopt the new technology which is available.

By strengthening the existing skills through the adoption of computer-based evaluation techniques those responsible for planning programmes, implementing projects or advising farmers will be provided with the effective decision support systems which they require.

b) Implementing Agency and Linkages

The Land Use Planning Division of DLD will be the implementing agency, with the component specifically focused on the Planning Sections. It will be strongly linked to the Information Division as the central provider of data and as the source of the computer power and software development which this component requires.

c) Method of Approach

Geographic Information Systems will be developed or adapted, based on the specific needs of the land use planners. These will require a collaborative systems development between them and the programmers. In the early stages micro-computers will be utilized on which basic skills will be acquired. Subsequently most work will be carried out through the central computer system. Institutional strengthening of the Land Use Planning Division will be achieved through the provision of training and technical assistance.

2.15 Introduction of Quantitative Evaluation Systems

a) Rationale and Objectives

The present shortages of foreign exchange make it essential that future land use planning pays particular attention to the relationship between imported inputs and potential foreign exchange gains through crop export or from import substitution, as well as the financial profitability to the producer. It is only when these two measures are in reasonable harmony that both the interests of the farmer and those of the national planner can be achieved. Quantitative land resource evaluation systems offer the only meaningful way of considering the optimal allocation of scarce resources within the agricultural sector required in this process.

The principal objective of this component would be to enhance the skills of the two Planning Sections within the DLD Land Use Planning Division in the use of computer based quantitative land resource evaluation techniques.

b) Implementing Agency and Linkages

The implementing agency would be the Land Use Planning Division within DLD. It is envisaged that the project component would be implemented during Project Years 1-3. This would allow the development of suitable computer based models for quantitative analysis and their thorough testing/integration with other systems proposed for DLD. Close cooperation between the Economic Section and the Planning Sections within the Land Use Planning Divisions would be necessary to ensure effective implementation of the component. No incremental staff requirements are foreseen.

c) Method of Approach

The objectives of this project component would be achieved through the provision of micro-computers; two Technical

Assistance personnel; selected overseas training and local/in-service training. Computer equipment and software required for running the larger land resource evaluation and crop simulation models would be provided under Component 2.1 of the project.

Technical assistance would be provided in the areas of natural resource economics (24 months) and computer systems (12 months). Overseas training would allow up to four of DLD's staff to study Information Technology to MSC level with an opportunity for one candidate to continue study to PhD level. Local training would involve computer training for 20 staff at the Asian Institute of Technology (AIT).

2.16 Support for Project Management and Organisational Adjustment

a) Rationale and Objectives

The proposed project comprises a large number of individual components. Most of these will be executed within the Department of Land Development but will involve 12 different Sections and all of the Regional Offices. In addition, three agencies outside of DLD will be directly involved in the project.

Although for clarity of presentation the project has been subdivided into the separate components described above, it is important to recognize that these constitute a single project. The failure of any one component would seriously jeopardize the project as a whole and the long term programme which it is designed to support.

A very high degree of coordination is therefore required and this could only be achieved by the establishment of a strong project management office.

The programme for improving land resource evaluation and planning entails the introduction to the Department of Land Development of substantial new technology. To utilize this effectively requires the strengthening of its internal communications and liaison with a large number of outside agencies which supply data or use the output from DLD as an important decision support system.

Support in organization and management, and in communications are needed to ensure that DLD's further development is achieved in the most effective way possible.

b) Implementing Agency and Linkages

The project management office would be a discrete and self-contained unit. It could report directly to DLD's Director General or alternatively could operate through the Planning Division. It would need to have strong linkages with all the sections of DLD involved in the project, with the main external executing agencies, and with the large number of other agencies which will interface with the project as suppliers or users of information. The general support in organisation and management, and in communications would apply throughout the Department but would be channeled through the Personnel Division.

c) Method of Approach

A small project management office would be established which would be responsible for co-ordinating all project activities, maintaining project records and accounts, and organizing routine reporting to government and the funding agency. Training and technical assistance would be provided to develop the systems and skills required to manage a large multi-disciplinary project, and to effect improved management and communications.

3. PROJECT BENEFITS AND JUSTIFICATION

3.1 Benefits and Beneficiaries

The benefits of the project are those which derive from the more efficient use of Thailand's land resources. The beneficiaries will be the country's more than 5 million farm households and through them the economy as a whole, while there will be important spin-off benefit to Thailand's growing private sector in the field of information technology.

a) Policy and Programme Formulation

Those responsible for determining policies with regard to land use and for formulating national, regional or changwat land development programmes need information. This information needs to be accurate, up-to-date, and organised in a way which minimises the time that busy government planners must spend in interpreting the information in order to make decisions. At all planning levels in Thailand there is an acute awareness of the need for effective decision support systems which has led to the emphasis placed in the Sixth National Plan on developing information bases.

The proposed project would improve the effectiveness of land resource planning at all levels through the introduction of comprehensive and flexible computer based systems. These systems would be designed for use at any planning scale depending on the level of input data. The introduction of such planning systems and procedures would allow planners to:

- reliably locate areas most suited to a particular development using physical, financial and economic criteria;

- provide a system for ranking alternative development scenarios on the basis of financial and economic comparative advantage so allowing planners to consider methods of harmonising potential returns to the producer with benefits to the economy;

In a preliminary analysis of current or possible future use of land in Nakhon Ratchasima using the illustrative crop allocation model (discussed at Section 3.2.5, above) it was demonstrated that potential benefits of up to 10% would be achievable purely from improved physical matching of crops with the environment.

b) Project Planning

Many projects are studied and implemented every year. Considerable time and resources are devoted to project planning, often involving the utilisation of foreign exchange where outside expertise is brought in to assist. Even with this massive application of resources the projects formulated may not identify the optimal developments because information in the required form is not readily available and neither are the systems for handling the data. The project would benefit this planning by:

- reducing cost of studies, and
- improving project formulation.

The major areas in which this would apply are:

- Irrigation schemes, particularly in the increasingly important medium and small scale schemes which individually cannot merit major studies but where the need for accurate planning is just as critical as in large schemes;

- Land reform schemes including improved ability to match holding size to target income levels;

- Upland agricultural developments, with the particular care which must be taken in preserving ecological balance;

- Forest reclassification programme, which should not only identify the correct designation of the land but for that deemed suitable for agriculture should determine the best land uses;

- Reafforestation projects;

- Commodity expansion plans such as the ongoing oil palm development programme.

c) Advice to Farmers

Hitherto, extension advice has tended to concentrate on ways of increasing production without full regard for whether this is fully compatible with the inherent qualities of the land

and the prevailing market forces. Individual farmers would derive enormous benefit from receiving advice which allows them to utilise their scarce resources of land, finance and labour is the most effective way. This advice is largely channeled through the extension service which needs to be serviced with better information if it is to give farmers the best advice. The project would make the required information for farm planning available to the farmer through the extension service.

d) Conservation of Resources

Land use must be planned in such a way that it not only gives the best possible immediate and medium - term benefits, but ensures the sustained productivity of land in the long - term. The project would not ony provide the information base to help determine the best long - term use but would have an in - built monitoring system for determining the effects of changing land use through the regular, satellite - based, analysis and by continual updating of land unit - based socio-economic studies.

e) Institutional Strengthening

The whole basis of the project is the provision of institutional strengthening to be able to apply new technology to the vital field of land resource evaluation and planning. The institutional strengthening is itself a major benefit of the project. This applies not only to the direct benefits to planning but more widely in building up within the government agencies concerned a familiarity and confidence with computer systems generally without which no government agency will be able to meet the new challenges of the remainder of this and into the next century.

f) Private Sector Information Technology Expertise

There is already a growing involvement in Thailand in the micro-electronics industry and in the expertise of information technology. The project will introduce to and develop in Thailand new systems of data management which will have applicability in a wide range of activities within and outside of Thailand. Local computer consultants and software houses have a major role to play in the project and while their contribution will be an essential one they will simultaneously be developing their own expertise by having access to new systems and working closely with foreign consultants.

It is inevitable that some of the government staff trained in computer technology will move into the private sector. This should be regarded as a project benefit in that it is an important part of building up the national capability. This capability will not only directly benefit the country but will provide an export potential in software system and expertise as part of Thailand's increasing role in the service sector.

3.2 Justification

As virtually all of the land suitable for agriculture has already been developed, it is imperative that future increases in agricultural productivity originate from increased productivity per unit area. This should be achieved through better matching of farming systems to the physical and socio-economic environment, accompanied by greater use of production inputs and improved seed in a cost effective manner.

The RGT fully recognises the importance of effective land use planning in preserving Thailand's natural resources and has made a budget allocation for the establishment of an effective land use planning system under its Sixth National Economic and Social Development Plan BE 2530-2534 (1987-1991). This project preparation report outlines a suitable approach to effective land resource evaluation and planning and identifies the investment and incremental recurrent costs considered necessary to achieve this objective. Particular emphasis has been placed on quantitative analysis as this is regarded as the only meaningful way of reviewing the likely financial and economic implications of alternative land-use scenarios.

The agricultural sector presently provides 20% of GDP and accounts for 64% of Thailand's export earnings. Recent pressures on the international commodity market, in which Thailand operates, have heightened the need to produce those crops offering economic comparative advantage if the country's foreign exchange position is to be safeguarded. The proposed project would help in providing the necessary methodology, skills and equipment required to ensure the optimal allocation of scarce resources within the economy. In particular the project would:

- provide accurate and timely basic resource data and establish appropriate systems for its interpretation;

- integrate quantitative land evaluation procedures into the land-use planning process including the introduction of computerised data collection and analysis procedures for primary socio-economic surveys;

- establish a resource information centre using the most recent computer technology and the necessary network to link providers of natural resource and socio-economic data with the users;

- provide a rapid response decision support system to policy makers, project planners/implementors and to the advisory services operating at the primary producer interface.

It is worth emphasizing that no new agencies would be required to implement the sixteen components proposed under the project.

3.3 Economic Justification

Although it is feasible to measure the cost savings associated with improved mapping facilities on a project by project basis, the potential national benefits from improved resource allocation are much more difficult to assess. The most appropriate method for justifying the project was therefore considered to be the assessment of the incremental value of production necessary to achieve a given rate of return in relation to present levels of production and the projected growth in the renewable resource sector. This analysis, which was conducted over a 30 year period using discounted cash flow techniques, revealed that annual peak production would only have to increase by the equivalent of US$ 13.26 million by Project Year 9 to yield an attractive 20% rate of return. In relation to the GDP from the agricultural sector in 1984 this represents only a 0.18% increase which is minimal, particularly when one considers that annual growth rates are still in the order of 2% despite pressures on the international commodity markets. The results of the analysis at other discount rates are summarised below:

Annual Increases in the Value of Agricultural Production

Required to Justify the Project

Rate of Return %	10	12	14	16	18	20
Annual Incremental Value of peak Production 1/ (US$ million)	6.89	7.88	9.02	10.27	11.63	13.26

It is worth emphasising that an analysis of land unit specific resource data collected by DLD for Nakhon Ratchasima, using the illustrative crop allocation model discussed at Section 3.2.5 above, indicates that potential benefits of up to 10% would be achievable purely from improved physical matching of crops with the environment. On this basis the incremental production required to justify the project can be considered as minimal.

1/ Projected Build up in Incremental Production

Project Year	1	2	3	4	5	6	7	8	9-30
% of peak incremental production	-	-	3	10	20	45	70	90	100-100

SUMMARY

At the request of the Royal Government of Thailand (RGT), the Asian Development Bank (ADB) undertook to provide Technical Assistance for a study of the current status of land resource evaluation and planning in Thailand, and of ways in which the process may be improved in the future. The Land Use Planning Division of the Department of Land Development (DLD) was appointed as the executing agency for the study which commenced in January 1986. An interim progress report was reviewed two months from study inception and a Draft Final Report was presented after three and a half months. Following the tripartite meetings to discuss this, the Final Report is presented which takes accurate of the views and comments of the tripartite forum.

Agriculture and forestry constitute a vital sector of Thailand's economy; together they account for 20% of the country's Gross Domestic Product and generate export earnings of Baht 112 billion - 64% of total national exports. Thailand, however, faces a critical period in the effective utilisation of its renewable natural resources. The country's proven ability to produce exportable surpluses of food and other primary commodities is no longer sufficient in an international environment of increasing competition and reducing margins. It has become essential that production is achieved in the most cost effective way, and that it is matched in terms of quantity, quality and timely availability to the requirements of a market in which Thailand must compete with some of the world's other major producers.

This places a very high level of demand on those whose responsibility it is to manage the country's land resources whether in policy planning, programme formulation, project implementation or providing advice to the estimated 5 million farmers. Full account has been taken of this situation in the drafting of the Sixth National Economic and Social Development Plan due to come into effect in October of this year. In highlighting the continued development of Thailand's renewable natural resources the plan specifically identifies the need for improving the coordination and management of information in order to provide a more effective land use planning system.

By virtue of the Land Development Act of 2526 (1983) DLD, through the Land Development Board, is accorded the responsibility for land use planning. In order to meet this responsibility a specialised Land Use Planning Division was established in 1984, and this forms the natural focal point for progressing the Sixth Plan's requirement to improve the land use planning system.

As part of the study a programme has been formulated for progressing land resource evaluation and planning in Thailand. The programme is based on the recognition of two converging

situations - the increasingly complex demands of land use planning, and the recent technological developments which make it feasible to handle large volumes of statistical and spatial information in integrated computer systems. An approach has therefore been developed which will provide the type of Decision Support System needed in the management of the country's land resources by adopting the technology which is now available at an affordable cost.

As a basic programme concept it is recognised that land use planning must be:

- dynamic, capable of responding to changing circumstances;

- flexible, adaptable to use at different planning levels; and

- benefit based, producing evaluations in economic or financial terms.

Such an approach requires that those responsible for land evaluation have access to a comprehensive and up-to-date data base. Many aspects of this are well covered in Thailand, but the programme would need to rectify some critical deficiencies. More important, it must improve access to the existing data and ensure that these are held in compatible formats. A major part of the programme will be the development of quantitative evaluation systems. Some illustrative models have been developed during the course of the study for the determination of key economic and financial indicators; these would be refined and developed for application at an early stage of the programme. Integrated computer systems would be established for holding, managing and analysing the large volumes of data required. Direct access to all data sources would be established to provide a central information system. A critical aspect of the programme would be improving communication with users. This will be effected by computer linkages, but equally importantly by developing user awareness of the decision support system which would be available to them. Users must be able to articulate their requirements of the system and DLD must be able to respond to requests in a timely fashion and in the terms needed by the users. The programme envisages the formation of a specialised Information Division responsible for maintaining a centralised computer system.

In support of this programme proposals have been put forward for a project, the overall objective of which would be to provide the institutional strengthening required to meet the demands of comprehensive land use planning. The country's existing land use planning is based on traditional, essentially qualitative, land suitability determinations. The proposed programme will develop these systems to meet the demands of the current economic environment. In order to do this DLD, the Department vested with national responsibility for Land Use Planning, will be equipped with the technology and trained in the use of this, to provide a dynamic, quantitative decision support system to users at all levels of the planning process. This will be achived through a project comprising 16 individual components. Although a component approach has been adopted it is important that the project be seen and managed as a single integrated operation. The project would provide support in the key areas of:

- rectification of existing data deficiencies,

- establishing access to all data sources and user agencies,

- development of systems, and

- project organisation and management, and communications

DLD would be the major implementing agency though responsibility for some specific components would be vested with the Office of Agricultural Economics, The Meteorology Department and the Department of Lands. The project would be implemented over a five year period. Early implementation would accord well with Thailand's rapid recent advances in Information Technology as witnessed by its developing electronics industry and software expertise. It would also coincide with the introduction of the fifth generation of computers which provide Intelligent Knowledge Based Systems (IKBS).

The project's beneficiaries will be the country's farming community and through this the whole national economy. The benefits will be realised by facilitating the more efficient use of land to produce commodities, matched in quantity and quality to the markets, in the areas where they are most efficiently produced. This will be achieved by the improvements which the project will make possible in:

- Policy and programme formulation;

- Project planning, particularly for;

    - irrigation development,
    - land reform and settlement schemes,
    - upland agriculture and conservation schemes,
    - re-afforestation,
    - commodity expansion;

- Advice to farmers.

The project will ensure not only immediate returns to the farmer and to the economy but will have long term benefits in conserving resources by providing a system of monitoring the effects of changing land use. The institutional strengthening will be a direct benefit in its impact on planning, and also have the wider implications of building up expertise within the government sector in the field of information and computer technology. A further important subsidiary benefit is likely to be the development of systems and expertise within the private sector both of which will have high export potential.

Appendix 13

SUMMARY

Seminar on "Land Use Planning"

by

Dr. Samarn Panichapong

The importance of land resources to national development has een well recognized by policy-makers. National conferences and cademic seminars on land resources in recent years reflect the ffort that the country has devoted to developing its land esources.

Problems which national policy-makers have all along been ldressing relate to the ways in which a large land area can be fficiently managed--how to maximize benefits without affecting ne environment, as well as how to make this development ıstainable for future generations. A measure which is believed) help solve these problems is land use planning. Before any and use planning can offer a maximum and sustainable return, owever, a land evaluation is a prerequisite.

The papers presented stress the following points :-

1. Concept and methods of land evaluations and land use planning.
2. The data required to make rational land use policy.
3. An efficient data collection technique.
4. Problems with the methodology, lack of raw materials and supply, areas of urgent need for land evaluation, and present land use planning.
5. Ways in which land use planning can be improved through application of modern techniques.

In this connection ULG Consultants Limited has undertaken a udy to look at the pros and cons of the various possible otions which can be employed and has proposed techniques which e currently adopted in many countries and can be modified to erve the objectives of land use planning in Thailand.

Throughout the seminar various problems confronting land use .anning in Thailand have been identified: the lack of ooperation between various government agencies, the lack of odern technology appropriate to land use planning, the large nount of data required and budgetary limits. Perhaps the most critical problem with the promotion of a GIS for land use planning in Thailand lies in the absence of a strong national policy.

The techniques contained in the proposal put forward by ULG Consultants Limited for use in Thailand require two major types of investment:

1) Human resource development to handle the proposed techniques.
2) Modern equipment such as computer hardware and software to assist in the implementation of these techniques.

Concerns regarding the budget for the proposed project were raised as many of the agencies that would be involved have limited budget allocations. Many of the participants have questioned the validity and appropriateness of some of the techniques presented during the seminar. Although modern technological tools do exist now for land use planning, many are as yet unproven in Thailand and would therefore need to be first tested here. Many points of a technical nature concerning the proposed GIS, for example its data structure, were also raised and need to be resolved. Numerous calls for field studies have been made. These are the issues that are open to more deliberations now.