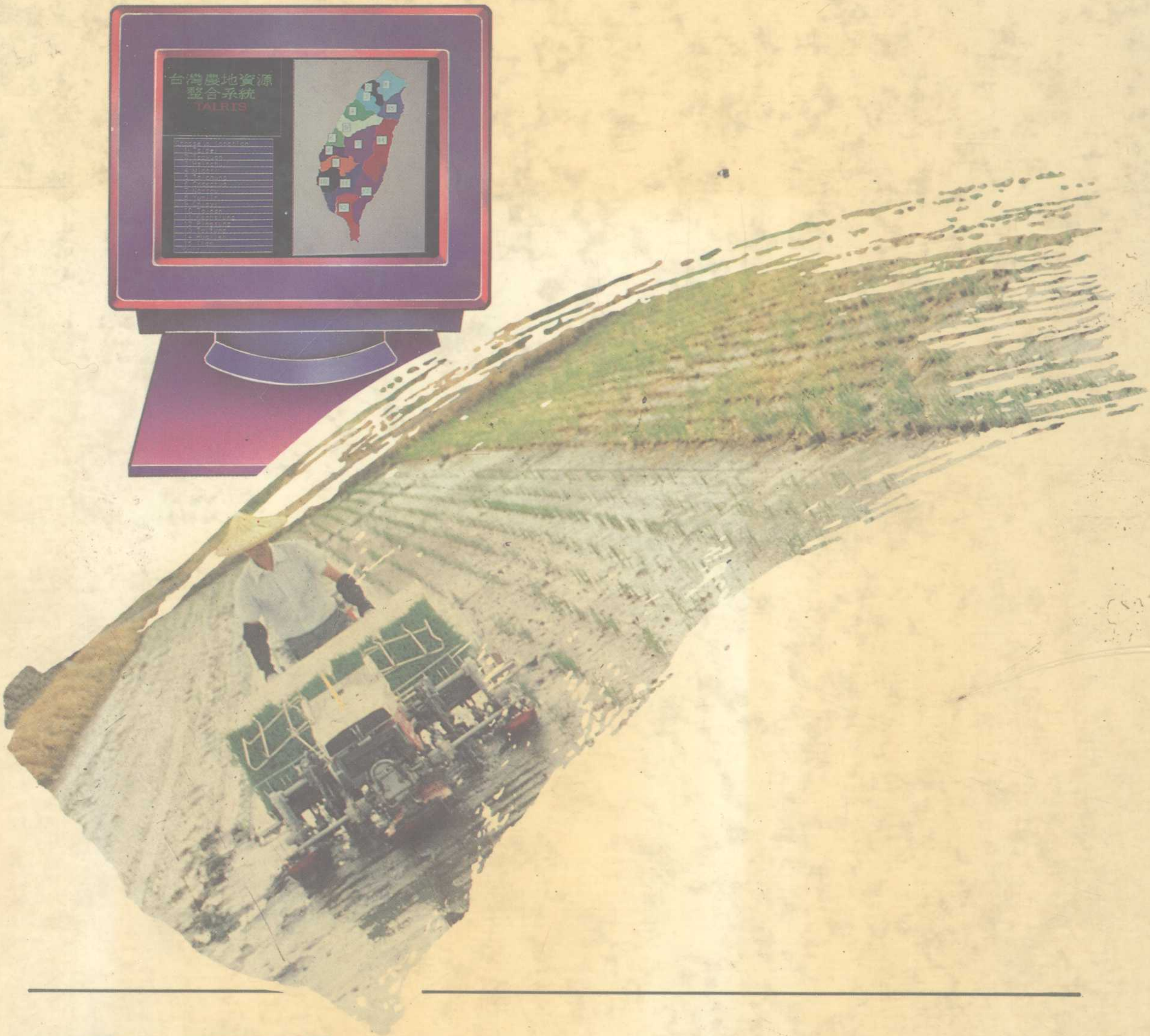
農地生產力評估技術之開發與應用



行政院農業委員會
COUNCIL OF AGRICULTURE
國立中興大學

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序言

農地生產力一向是農業從業人員關注的焦點之一，也特別是從事土壤與肥料研究、推廣者，進行土壤管理的主要工作目標。隨著台灣農業經營環境的轉變，農業發展目標進入了包含生產性、生態性及生活性等三大功能的時代。此時，農地生產力的涵義也由狹義的生產面進入廣義的以追求區域性整體農地資源整合利用的時代。在目前農業發展過程中，各種農業問題與日俱增的現象，諸如：非農業用地的擴張、農業投資報酬偏低、農場規模過小與資金不易投入、生產環境的惡化等等，不僅顯示農地資源整體性整合規劃的重要，也凸顯農地生產力之傳統性角色擴張的必要。本專集邀請了國內外等學者專家從不同角度，包括：農地資源調查，開發利用，規劃管理等方向；及利用現時本省農業界尚未普遍應用的工具，如地理資訊系統，作物模式，評估指標體系等方法，就農地生產力在資源整合規劃中的從屬及互補關係進行探討，以賦予農地生產力一個較寬廣的內涵，，並爲其涵義中的技術層面開啓新的研究與發展領域。

林正錺．蔡彰輝

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目　　錄

PEDOLOGY AS A TOOL IN LAND RESOURCE PLANNING

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Introduction:

Pedolegy is this component of the Earth Science that quantifies the factors and processes of soil formation including the quantity, extent, distribution and spatial variability of soils from microscopic to megascopic scales. It is an integrative science. Pedology provides the opportunity to systematize our knowledge base from large scales (high resolution) to small scales (low resolution). Pedogenic processes are interactively conditioned by lithology, climate and relief through geologic time. Soils are welded together in landscapes like chains; processes and impacts on higher topographic surfaces directly affect processes on adjacent lower surfaces. This is because energy flow and mass flux the dynamic driving forces of pedogenesis, move through and over the three-dimensional surface. Renewal vectors of biomass production--solar energy, rainfall and dusts -- counter constituent losses via drainage waters, lateral flow and downslope migration of erosion products. To adequately comprehend, interpret and transfer knowledge of soil resources from one area to the next, soil/geomorphic systematic landscape approach must be applied.

Pedology provides an interpretational basis for accurate prediction of food, feed, and fiber production; safe disposition of toxic and non-toxic wastes in soil and geologic systems; reclamation and management of drastically disturbed lands; preservation and conservation of soil resources against erosion, desertification and chemical degradation; elucidation of temporal soil properties including; water retention, redox,fluid and solute transport, shrink-swell, soil strength, porosity, structural stability, and chemical-biochemical intensity-capacity factors.

Through extensive knowledge of soil/landform relationships, pedologists have verified the occurrence, configuration, depth and pedogenic formation of root and water restrictive layers; documented the origin and distribution of cracking and fissuring patterns in soils and geologic material the govern by-pass flow of nutrients, chemicals, solutes and fluids; identified the scale, mode, and occurrence of systematic spatial variability fundamental to the design efficiency and sampling of soil unite; and utilized soil color patterns on a macro- and micro- scale to infer major periods of soil aeration/reduction and indirectly relative periods of excess, sufficient and deficient soil moisture contents for specified land uses.

A knowledge of the soil physical, chemical, mineralogical, and biological properties and their formation is fundamental for assessing soil behavior including nutrient cycling dynamics, water retention, plant uptake, salinity/alkalinity, wind and water erosion, crusting, tillage pans, pedogenic restrictive layers, soil strength, irrigation and drainage. The spatial and laboratory data bases that comprise the soil resource inventory data base in the United states are prerequisite of attempts in this country to utilize pedology as a tool in land resource planning and crop productivity evaluations.

Objective:

The Purposes of this paper are to: (1) the report on the satus of The National Cooperative Soil Survey (NCSS) Program in U.S. and priorities; (2) to identify ways in which geographical information systems are being utilized as tools for soil resource evaluation; and (3) present an new pilot crop productivity model under development by the NCSS in the United States.

Status of NCSS program in U.S.:

The NCSS is a state/federal partnership to inventory and interpret soil resources of the United States. It's mandate is to : (1) improve methods and content of information transfer to users; (2)develop new research and knowledge bases; (3) provide technical soil services; and (4) implement support and maintenance of soil survey activities. The public investment in this program for 1991 was nearly 90 million dollars of which about 80% is direct congressional support for the soil survey program via the USDA-SCS. The remainder is by State support through universities and other state agencies. The NCSS program comprises about 1100 federal employees, and 100 state employees aggregating about 1200 person-years annually. The accomplishments to date are as follows:

* 73% of land area in USA are mapped;
* 93% of non-federal and private land are mapped;

* 60% of the federal lands are mapped;
* 43% of the land area has published soil surveys in modern format, mostly at map scales between 1:15,840 to 1: 24,000;
* 18,000 series have been established with soil interpretation records for 32,500 phases of soil series;
* Massive laboratory verification data bases(over 50,000 pedons) have been established by state and federal laboratories; these data are currently being assembled in into a National Soil Information System (NASIS); and
* Soil Taxonomy has been revised, expanded and internationalized-- numerous training forums, workshops, and international committees have provided technical assistance to over 50 countries

Priorities of soil resource inventory programs in the USA are driven by public mandates and regulations to minimize environmental degradation and to preserve wildlife habitats. Recent programs motivated by public forums are the Farm Security Act, the Surface Mine Reclamation Act, and the Water Quality Act. These programs have the effect of: (1) shifting agricultural production to the prime farmland resources and removing marginal, severely eroded soils from production (sodbuster provision); (2) preserving wetland habitats from further drainage and degradation (swamp buster provision); (3) requiring reclamation of disturbed lands to a performance level equal to or better than pre-mined soil conditions; and (4) the development of best management practices to minimize non-point source pollution of streams, lakes and groundwaters. These goals are considered the highest priorities of the next decade. They are in concert with this countries food sufficiency; extensive land utilization practices with mechanized, high capital and energy inputs; and public mandate for safe food and sustainable agricultural systems.

Pedology as tool in land evaluation:

Land evaluation, while undergirded by pedology/landform/soil resources must realistically incorporate other discipline components including social, political, economic, governmental, demographic, population, infrastructure, transportation, etc. Most successful systems involve integration of physical and social elements utilizing integrated watershed management units as a working model. In the following discussion, I will emphasize the importance of pedology in the land evaluation dimension.

Soil Limitation Classes-- Historically approaches of land evaluation in this country have focused on identifying soil constraints to land use. Multiple use classed of interpretive hazards have been established (eg. Land Capability Units; of slight, moderate and severe classes of flooding, wetness, erosion, droughtness, chemical sorbitivity, corrosion, soil stability, etc.). In a recent survey of Brazos County, Texas, considerable attention has been focussed on map unit composition and consequent statistical verification of use limitations for soil components of map units. This is a good example of quantifying degree of hazards for land areas. Established limitations have been used at local, state, regional and even national levels as a means of land evaluation.

Soil Potentials -- At the local level, land evaluation resulting in establishing soil potentials has been utilized. The feasibility of *utilizing* soil resources by correcting limitations using remedial practices that require variable capital inputs was determined. Such evaluations inciuded an economic analysis; they required multidesciplinary teams to determine constraints, assess expenditures necessary to overcome specified limitations, and recommend best management practices to utilize the soil resource. Establishing soil potentials for soil survey areas has also been a powerful interpretive land evaluation tool. It has high value for local application but limited potential for extrapolation or generalization regionally or nationally. It likewise is quite labor intensive, loci specific and is quickly dated because of changing economic environments. Hence, the soil potential as a land evaluation tool, while still viable, is progressing more slowly in this country than initrally planned.

A New Model for Plant Growth Ratings -- A topic more closely aligned with the theme of this symposium, is called Soil Rating for Plant Growth (SPRG). This is a pilot NCSS program for developing plant growth ratings as one of the components for a land productivity rating model. This model is currently under development and not yet available for release. It will be briefly presented here and discussed in more detail later. The intent is to develop a rating scheme at national, regional or statewide levels to evaluate land productivity potentials of various plants under defferent management, economic, and local systems. The soil component, SRPG, is based on intrinsic soil properties observed, measured or inferred; most of these are used by the NCSS for mapping soils in the inventory program. To accomplish the goals of the SRPG will require integrating spatial and tabular data bases with GIS. The data bases are closely allied to cartographic map unit differentiae. These include organic matter content, bulk density, particle size, rock fragments, avalilable water retention, PH, SAR, EC, carbonate, gypsum, CEC, shrink-swell, seasonal water table, soil depth, permeability, toxic or restrictive subsoil layers, soil climate, landscape position, slope and parent material. They are also the properties commonly used to define classes in Soil Taxonomy.

Geographic Information System (GIS) a as Tool for Resource Evaluation:

The use of GIS during the nest decade will have tremendous potential for aiding land evaluation appraisals. GIS technology allows for the interaction of soil data with other land, climatic and cultural data. By examining a wider range of environmental variables than are usually considered in land management decisions, this technology will lead to a better understanding of how landscpae systems function and interact. This technology will enable decisions to be made with greater sensitivity to environmental quality, more complete exploration and land use options, and greater public participation.

The Soil Conservation Service (SCS) has established three soil geographic data bases representing different intensities of soil mapping. Common to each soil geographic (spatial) data base is the linkage to a soil interpretation (attribute) record data base, which gives the proportionate extent of the component soils and their properties for each map unit. The three soil geographic data bases include the Soil Survey Geographic Data Base (SSURGO), the Stae Soil Geographic Data Base (STATSGO), and the National Soil Geographic Data Base (NATSGO). The soil interpreation record data base encompasses more than 25 soil physical and chemical properties for the 32,500 phases of soil series recognized in the United States.

SSURGO has the most detailed level of information and is used for local level use and planning. It is used for farm and ranch conservation planning, range and timber management county and parish resource planning. Soil maps are made by field methods, using observations along soil delineation boundaries and traverses and determining map unit composition by field transects. Maps are made at scales ranging from 1:15,840 to 1: 31, 680. The mapping base is normally orthophotoquads and digitizing is by line segment(vector). SSURGO data is collected and archived in 7-1/2 minute topographic quadrangle units.

STATSGO is used primarily for multi-country, or statewide resource planning, or river basin planning and management. Soil maps are made by generalizing more detailed soil survey maps. If detailed maps are unavailable, a variety of data sources are used to develop the map. The U.S. Geological Survey's (USGS) 1: 250, 000 scale topographic quadrangle series is used as a map base and the soil data are digitized by line segment. STATSGO date are collected and archived in one degree by two degree topographic quadrangle units, and distributed as complete coverage for a state.

NATSGO is used primarily for regional, multi-state and national planning. Major land resource areas (MLRA) and land resource regions were used to form the NATSGO data base. Most of the boundaries were developed from state general soil maps. The NATSGO map has been digitized at a scale of 1:7,500,000 by line segment and is available as a single data unit for the conterminous U.S. coverage. It is used for national, regional and multi-state resource planning.

Soil Rating for plant Growth Model (SRPG):

At the national level there is a need among several agencies involved in regulatory and conservation arthorities to determine the relatve productivity between mapping units of soils. We need a uniform way to determine yields in the soil database. Currently methods vary by states and counties within the states. The emphasis previously has been to estimate crop yields and assess productivity indices of soils at the local level where climatic conditions are more uniform. In several states, during the course of soil surveys, crop yields have been measured on plots of benchmark or key soils.

Some of the considerations in developing this model were:

- Use of soil survey for land valuation and tax assessment is a major application of productivity indices;
- Digitized soil survey data useful in computing weighted productivity index by ownership parcel for use in tax assessment or economic analysis;
- Flexibility of a soil to grow economically advantageous crops is key idea (soil fitted to only one crop is of less value for management choices);
- The productivity indices should continue where Land Capability Classes stopped--identify the best intrinsic properties of a soil to grow a crop;
- Variability of yield over time is as important as absolute yield;
- Separate productivity indices are needed for different crops on the same soil

due to specific crop requirements and reactions;

* Variation in soil survey quality assurance and close-interval spatial variability will need to be considered in yield ratings;

* All map units need to be included regardless of Land Capability Class or current land use;

* Productivity index should be based on data in soil survey data file and be specific to map units;

* Basic assumption is that conservation ethic will be followed to sustain production on steeper slopes, while more level ground will be intensively cuitivated;

* Consider ease of manipulation and cost effectiveness of treating surface properties (PH, nutrients) versus subsoils that are physical or chemically intractable.

The full model includes submodels for soil rating for plant growth (SRPG), climate, conservation sustainability, individual plant growth modules, economics and local influences which lead to the final product--Land Productivity Rating. The thrust of present work deals with the SRPG component of the model. The soil factors to be used and later weighted are as follows:

Factor	
S = Surface structure and nutrients	Scaling Range
W = Water and moisture	75 ~ 100
T = Toxicity	50 ~ 100
A = Acidity	50 ~ 100
C = Soil Climate	40 ~ 100
P = Physical Profile (Depth of Profile)	20 ~ 100
L = Landscape and slope	15 ~ 100

The rating values are calculated for each map unit by: (1) rating soil property within each factor; (2) sum the property values within each factor diviced by number of factors times 100(factor mean); and obtaining the product of factor means divided by 100. This will provide the rating called SRPG. Grouping of SRPG's into limitation classes for crop and forage production will then be done:

Severe - 10 ~ 30

Moderate - 31 ~ 70

Slight - 71 ~ 100

While the SRPG is not far enough along to be specify the precise scaling of kinds of properties that will comprise factor means for each of the input variables, the present status is as follows:

A. Surface structure and nutrients (S)

- organic mater %
- bulk density
- available water capacity
- PH
- SAR
- carbonate %
- gypsum %
- CEC
- shrink-swell potential
- rock fragments

B. Water features -- most limiting layer within 75 cm of surface (W)

- seasonal high water table -- rating depends on soil moisture regimes
- permeability
- available water capacity

C. Toxicity -- depth is subsurface to 60 cm or in control section (T)

- SAR
- EC
- CEC

D. Acidity -- depth is subsurface to 75 cm

- PH

E. Soil Climate -- (C)

- soil moisture regimes
- temperature regimes and growing seasons
- moisture X temperature interaction

F. Physical Profile -- depth to root restrictive, non-water layer (P)

* bulk density of restrictve layer
* depth of layer
* degree of development of layer

G. Landscape and slope (L)

* percent slope
* parent material

Summary:

Pedology as a tool in land resource planning serves as the basis for most approximations. Soil recources are only one of the ingredients in this process but often the most critical. In such evaluations it is important to consider the following:

* Need to incorporate an error analysis for soil spatial variability into land evaluation and productivity models.
* Land evaluation and productivity models should be consistent with the level of resolution required and objectives of the model utilization.
* Need to learn from countries with intensive agriculture land use how to prepare for greater land population pressures and sustainability in the United States.

Benchmark Sites for Evaluating Soil Quality Changes of Agricultural Land In Canada

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Introduction

There have been numerous studies conducted and statements prepared pertaining to the decline in the quality of the agricultural land recources of Canada. The decline in soil quality is caused by degradation processes such as erosion, compaction, salinization and acidification. Although most of these are natural processes, the rate of deterioration has been accelerated by conventional farming practices. National network of representative benchmark sites is a way to determine quantitatively changes in soil quality and to serve as a place to determine environmental indicators for various major agricultural practices through long-term monitoring.

In 1988 Agriculture Canada's Land Resource Researech Centre (now CLBRR) started a pilot project in eastern Canada to establish benchmark sites for collecting basline data to monitor trends in soil quality. This study was adopted nationally, in 1990, by the National Soil Conservation Program (NSCP) as part of the Soil Quality Evaluation Project (SQEP) managed by CLBRR.

Hypotheses

1. By selecting monitoring sites that are representative of agro-ecosystems, it is possible to use regional soil climate information and expert systems to make general statements on soil quality trends regionally and nationally.
2. Monitoring selected soil variables of a soil landscape under a typical farm production system for 5 or more years can demonstrate changes in soil conditions.

Objectives

1. To provide a database for assessment of change in soil quality and biological productivity (yields, etc.) of representative agro-ecosystems.

2. To provide a means of testing and validating predictive models of soil degradation and productivity.
3. To provide a means of evaluating agricultural sustainability of current farming systems in major agricultural regions of Canada.
4. To provide a network of benchmark sites at which integrated multi-disciplinary research programs can be developed.

Benchmark Site Selection Criteria

Criteria were developed to guide the selection of benchmark sites, the main focal being to represent the dominant landscape within major agro-ecological regions. Since only a few agro-ecosystems in Canada can be represented, top priority was given to the first three criteria. Each site should:

1. Represent a major soil zone and/or agro-climatic region;
2. Represent a typical physiographic region (landscape) and/or broad textiural grouping of soils;
3. Represent a major farming system (or potentially major) within a region;
4. Complement provincial priorities and opportunities;
5. Provide potential for impact of a degradation process(es);
6. Cover about 5 to 10 ha. in size, or a samll watershed in some cases.
7. Be limited to cultivated agricultural land, as part of actual farming system.

Final site selection occurs in the field. Factors that affect the final decision include representativeness of the soils and topography, type of farming system in use, cooperativeness of the farm operator, and, in some cases, proximity to a climate station. The site should be of sufficient size and shape to represent all segments of the targeted landscape.

By using the above criteria, 22 sites were identified (Figure 1, Quebec's two sites are split). In Table 1 some general characteristics of the selected sites were outlined. Site manager's name and address is listed on Table 2.

Deliverables

1. Initial characterization of 22 benchmark sites which includes; selected chemical, physical, mineralogical and morphological properties of each benchmark site: detailed soil map and contour map of each site; and soil climatic data for a few selected sites.