PCARRD BOOK SERIES NO. 34/1985

SOIL TAXONOMY:

TOOL FOR AGROTECHNOLOGY TRANSFER

PROCEEDINGS OF THE SEVENTH INTERNATIONAL
FORUM ON SOIL TAXONOMY AND AGROTECHNOLOGY TRANSFER

12-23 MARCH 1984, PHILIPPINE COUNCIL FOR AGRICULTURE
AND RESOURCES RESEARCH AND DEVELOPMENT
LOS BAÑOS, LAGUNA, PHILIPPINES

SOIL MANAGEMENT SUPPORT SERVICES
SOIL CONSERVATION SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE
AND THE
PHILIPPINE COUNCIL FOR AGRICULTURE
AND RESOURCES RESEARCH AND DEVELOPMENT
OF THE
NATIONAL SCIENCE AND TECHNOLOGY AUTHORITY
1985

All reported opinions, conclusions and recommendations are those of the authors, and not of the Philippine Council for Agriculture and Resources Research and Development, Bureau of Soils, United States Agency for International Development, or Soil Management Support Services.

1st printing, 1985

Bibliographic Reference:

Author. Title of Article. A. Maglinao, M. Recel, T. Metra, P. Lastimosa (eds), Soil Taxonomy: Tool for Agrotechnology transfer. Proc; Seventh internat. forum on soil taxon. and agrotech. transfer. SMSS and PCARRD, Los Baños, Laguna, Philippines, 1985. PCARRD Book Series No. 34 pp. 279.

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OFFICE OF THE EXECUTIVE DIRECTOR

To Our Valued Reader:

This book, **Soil Taxonomy: Tool for Agrotechnology Transfer,** details the proceedings of the Seventh International Forum on Soil Taxonomy and Agrotechnology Transfer conducted in the Philippines early last year. It was convened, among others, for the purpose of developing a critical mass of qualified personnel to support the program on soil classification and agrotechnology transfer.

This program was hinged on the proven concept that the transfer of agrotechnology from one location to another can be facilitated on the basis of soil classification. The Benchmark Soils Project has satisfactorily shown the validity of this scheme through the international collaboration of several tropical countries, the Philippines being one of them. The application of this principle can greatly reduce repetitive experimentations which may duplicate efforts and logistic support that developing countries can hardly afford.

The inventory, characterization, and the classification of our soils are the basic needs of this approach. The existence of an internationally used reference system, soil taxonomy, provides the much needed tool to facilitate the translation of concept into applicable technologies.

May this volume provide a useful reference material for those who, in one way or another, may be involved in this promising scheme.

Very truly yours,

RAMON V. VALMAYOR
Executive Director

.....

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Soil Management Support Services
Soil Conservation Service
United States Department of Agriculture
Washington, D.C., USA

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3. Dr. Modesto Recel — Chief, Research Division, BS
4. Dr. Beatriz del Rosario — Asst. Director, Farm Resources and Systems Research Department, PCARRD
5. Mr. Arturo Dayot — Chief, Soil Survey Division, BS
6. Dr. Hari Eswaran — Progam Coordinator, SMSS

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Acknowledgment

The organizers of the Forum wish to express their appreciation to Dr. C.S. Holzhey and Staff of National Soil Survey Laboratory of the Soil Conservation Service, U.S. Department of Agriculture at Lincoln, Nebraska, for the sampling and analysis of the soils studied by the participants during the Field Tour.

The support of the U.S. Agency for International Development, Manila, particularly Dr. Edward Rice is gratefully acknowledged.

The cooperation of Dr. M. S. Swaminathan, Director General of the International Rice Research Institute by allowing the services and assistance of Dr. Martin Raymundo is very much appreciated.

Acronyms and Abbreviations

AMSL	—	above mean sea level
ALMED	—	Agricultural Land Management and Evaluation Division
asl	—	above sea level
BS	—	Bureau of Soils, base saturation
BSP	—	Benchmark Soils Project
BPI	—	Bureau of Plant Industry
Bu	—	bushel
CEC	—	cation exchange capacity
CIAT	—	Centro International de Agricultura Tropical
cm	—	centimeter
cm^3	—	cubic centimeter
CMU	—	Central Mindanao University
CRDI	—	Cotton Research and Development Institute
CSR	—	Center for Soils Research
CTAHR	—	College of Tropical Agriculture and Human Resources
DANR	—	Department of Agriculture and Natural Resources
DGRST	—	General Delegation for Scientific and Technical Research
ECDAM	—	Exchange Complex Dominated by Amorphous Material
ECEC	—	effective cation exchange capacity
E.O.	—	Executive Order
FAO	—	Food and Agriculture Organization
ft^3	—	cubic foot

HAC	—	high activity clay
ha	—	hectare
IBSNAT	—	International Benchmark Sites Network for Agrotechnology Transfer
ICOMAND	—	International Committee on Andisols
ICOMLAC	—	International Committee on Soils with Low Activity Clay
ICOMOX	—	International Committee on Oxisols
IRA	—	Institute de la Recherche Agronomique
LAC	—	Low Activity Clay
NSH	—	National Soil Handbook
PCARRD	—	Philippine Council for Agriculture and Resources Research and Development
SEARCA	—	Southeast Asian Regional Center for Graduate Study and Research in Agriculture
SMSS	—	Soil Management Support Services
t	—	ton
UPLB	—	University of the Philippines at Los Baños
USAID	—	United States Agency for International Development
USDA	—	United States Department of Agriculture
UCAP	—	United Coconut Association of the Philippines
UNDP	—	United Nations Development Program
ViSCA	—	Visayas State College of Agriculture

Preface

The fact that agrotechnology can be transferred from one geographic area to another has long been generally accepted. The Benchmark Soils Project (BSP) has proven that the transfer of agrotechnology is valid within soils that are members of the same family. The Philippines is fortunate to be one of the collaborators of BSP. The task that lies ahead now is to implement an aggressive program on soil resources inventory and classification using Soil Taxonomy. This, however, requires the trained manpower of which the country is very much deficient.

The Seventh International Forum on Soil Taxonomy and Agrotechnology Transfer is primarily designed to provide an adequate number of technically trained Soil Technologists in the Philippines as support to the program and to reinforce agricultural colleges and universities by providing training to selected members of the faculty who in turn shall train future workers in the system. This objective fits very well with the goal of the Philippine Council for Agriculture and Resources Research and Development (PCARRD) to continuously develop manpower capability in support of research and development efforts.

This forum would not have been a success without the support of the Bureau of Soils (BS), the Soil Management Support Services (SMSS), the Colleges and Universities and PCARRD which collaboratively put together their resources to achieve a common goal. This proceedings is one concrete document which symbolizes such unified effort. PCARRD hopes that this will have a multiplying effect until we are able to develop a critical mass of qualified personnel to support the program on soil classification and agrotechnology transfer.

RAMON V. VALMAYOR
Executive Director
PCARRD

Foreword

Developing and maintaining soil resource inventories is an ongoing task of the Bureau of Soils, and the quality of these inventories depends largely on the background and experience of the staff. In addition, users of soil survey information must have an appreciation of the data so that the soil resource inventories are utilized for planning and research purposes.

The VIIth International Forum as well as those preceding it, has been designed to strengthen the personnel in research institutions in the Philippines particularly in making soil surveys and in interpreting soil information thus gathered. The previous forums were held in Fiji, Morocco, Cameroon, Thailand, Papua New Guinea, and in Costa Rica. The number of participants at each forum ranged from about thirty to more than seventy. With the exception of the second forum which was in French the rest were conducted in English.

Participants at each of the forums included the staff of soil survey organizations, agricultural research institutions, university personnel, and also from agro-based industries. The resource personnel invited to give lectures were experts in their field. The forums were generally two weeks in duration with about eight days of indoor discussions and six days of field trips.

The Philippines forum was attended by 31 participants from 15 institutions. The contact and exchange of information between participants during the sessions is as valuable as the instructions they receive and the discussions generated in the field.

This volume is one of the products of the forum. It contains selected papers of the meetings and the profiles studied in the field. In addition to this, the participants themselves have developed a report on the soils studied in the field. This report is on file with the Philippine Council for Agriculture and Resources Research and Development (PCARRD), the Bureau of Soils (BS), and the Soil Management Support Services (SMSS) and may be consulted as desired.

HARIESWARAN
Program Coordinator
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Opening Remarks

ALFONSO N. EUSEBIO

Participants, resource persons, guests, ladies and gentlemen:

First of all, I would like to welcome the participants, resource persons and guests to this forum — The Seventh International Forum on Soil Taxonomy and Agrotechnology Transfer. It is really nice of the Soil Management Support Services (SMSS) to coordinate the conduct of this forum with us, and of course, we appreciate the active participation of the Bureau of Soils (BS) in the preparations.

Before we start this step in the development of soil taxonomy and agrotechnology transfer in the country, I would like to bring you back to some of the relevant events leading to this important occasion. Five years ago, a group of soil experts from the University of the Philippines at Los Baños (UPLB), Bureau of Soils, Benchmark Soils Project and Philippine Council for Agriculture and Resources Research and Development (PCARRD) came together and formulated the National Soil Classification Program for Agrotechnology Transfer.

In 1980, Dr. Richard Arnold of the Soil Conservation Service of the United States Department of Agriculture (USDA) shared his expertise in refining the formulated program. Foremost among his recommendations was to develop first a critical mass of qualified personnel to support the program on soil classification and agrotechnology transfer. It could be pointed out then that very few colleges and universities in the Philippines had a trained pedologist on their staff. Furthermore, research and training along this area is relatively weak and inadequate.

The transfer of agrotechnology from one location to another can be facilitated on the basis of soil classification. The Benchmark Soils Project has satisfactorily shown the validity of this concept through the international collaboration of several tropical countries, the Philippines being one of them. The application of this principle can greatly reduce repetitive experimentations which may just be duplication of efforts and logistic support that developing countries can hardly afford.

The inventory, characterization, and the classification of our soils are the basic needs of this approach. The existence of an internationally used reference system, Soil Taxonomy, provides the much needed tool to facilitate the translation of concept into applicable technologies.

The United States Agency for International Development (USAID) through the SMSS Program has over the past six years endeavoured to provide a vehicle to familiarize soil and agronomy workers in developing countries with Soil Taxonomy and its application to agrotechnology transfer. The Philippines is fortunate to be involved in this program, and this forum is an evidence of the country's interest in such an undertak-

ing. We have also started the implementation of a soil classification and agrotechnology transfer program through the Agricultural Support Services Project II supported by the World Bank.

The development of research capability is one objective of the national research system. Considering the interest that our people have shown and the support that the agencies, like the BS, and the SMSS, and the colleges and universities have put into manpower development in this field, I believe that it would be very helpful to make this forum a regular activity, with the BS taking the lead.

Again, we welcome you all to this forum and wish you a fruitful workshop.

Thank you.

Opening Ceremonies Address

HARI ESWARAN

Dr. Alfonso N. Eusebio, Deputy Executive Director for Research, PCARRD; Dr. Nicanor C. Fernandez, Associate Dean College of Agriculture, UPLB; Dir. Godofredo N. Alcasid Jr., Director, Bureau of Soils; Mr. Chairman; ladies and gentlemen:

This morning as we were driving from the hotel to PCARRD, I saw an announcement at the church in front of the Cosmos Restaurant announcing a conference on Reconciliation and Dialogue. I have an idea of what they will be discussing, and the thought occurred to me that this is also the subject in this forum. This forum is on Soil Taxonomy and agrotechnology transfer and I will try to explain the meaning and the need for the two components.

Prior to that, I would like to say a few words about the history of this series of training courses. The Soil Management Support Services (SMSS) is a program of international technical assistance in soil survey and classification of the U.S. Agency for International Development (USAID) implemented by the Soil Conservation Service of USDA. We have an advisory committee and Dir. Alcasid is a member of that committee. We have a range of activities about which I will talk on the last day, and one of these is the training courses. This is the seventh series we have had: the first one was in Fiji, followed by the forums in Morocco, Cameroon, Thailand, Papua New Guinea, and Costa Rica. The theme of all these forums is the same "Reconciliation and Dialogue".

In many developing countries the usual constraints are time, money, and qualified personnel. In the Philippines, the supply of scientific personnel is perhaps not a problem, but money is. Agricultural research is expensive but to feed the people and maintain a standard of living, we have to have a high level of research to backstop production activities. One partial solution is agrotechnology transfer by which we mean the transfer of technology from its site of origin where it has been proven successful to another place where it is likely to succeed. To some extent, this partially circumvents expensive research inputs and requires only some adaptive research to fit the technology to local conditions.

A successful transfer depends on several factors and an important one is dialogue. We must all speak the same language, so that we understand each other. This also applies to soil science. Until recently we did not have an international soil classification system. In 1975, Soil Taxonomy was published in the U.S. after 25 years of discussions and testing involving more than 1,000 man-years of work. This system is now used by more than 40 countries as the national system and by

about another 30 countries as an adjunct system. We now have a uniform technical language which is not bound by race, color, or creed.

In the two weeks ahead of us we will review this classification system and attempt to show how it can be used. The Benchmark Soil Project (BSP) of the Universities of Hawaii and Puerto Rico was designed to test the hypothesis that agrotechnology can be transferred based on the soil family category of Soil Taxonomy. PCARRD was an active collaborator and the success of the project was due to the active and dedicated work of the PCARRD staff, particularly of the project leader, Dr. Martin Raymundo. BSP is now over, but is followed up by a more ambitious project called the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT). IBSNAT is developing methodologies through the use of computer simulation models and by matching soil conditions to crop requirements, for the horizontal transfer of agrotechnology. IBSNAT will be linking experimental stations all over the world to generate the necessary data and also to enhance the dialogue between scientists.

Two weeks is a short time and we have a lot of subject matter to cover. We hope to achieve our objective by frank discussions in an informal atmosphere. The success of this forum depends on the initiative of the participants. Your active participation is necessary for you to benefit most.

PCARRD has brought together an excellent array of guest lecturers-specialists in soils and land use, climatologists and geologists, agronomist and fertility specialists, and also people involved in agrotechnology transfer. The Bureau of Soils (BS) has also put in a lot of effort to prepare the field tour. On behalf of SMSS, we like to thank PCARRD and the BS for taking the initiative to organize this forum and for all the efforts that have been put in. The forum promises to be an excellent one, but as I said earlier, its success depends on you, participants.

Thank you Mr. Chairman.

Opening Ceremonies Address

GODOFREDO N. ALCASID JR.

First of all, I would like to express my heartfelt thanks to the SMSS, most particularly to Dr. Hari Eswaran, for reacting to and supporting almost instantly our request for this training forum here in the Philippines. Also, I would like to express my thanks to PCARRD for finalizing the arrangements and hosting this forum.

You will recall that five years ago after the Soil Taxonomy training program sponsored by the Benchmark Soils Project (Hawaii) and PCARRD and upon the recommendation of Dr. Richard Arnold of SCS, USDA, the Bureau of Soils requested for the training of additional soil taxonomists. Two years ago, Dr. Ramon Valmayor, PCARRD Executive Director, gave importance to this request and endorsed it to SMSS. In no time, Dr. Eswaran was here last year and finalized the negotiations.

Today, you as participants are here for an exposure to Soil Taxonomy. From the Bureau of Soils, Ministry of Agriculture are participants who will, for the first time in their lives get exposed to tongue-twisting words. You are technical men and women representing varied sections of soil technology and science. Soil Fertility, Soil Survey, Soil Conservation, Laboratory Analysis, Land Use Planning and Agronomy are represented here. This was intentionally done because we want each one to talk to each other in a common language. There are many things we want to talk about, all related to the needs of agricultural development. Likewise, people from other countries have experiences on each of their soils which they can share.

With Soil Taxonomy as the language then we can have that dialogue. We trust that after two weeks we can all talk sensibly. You will learn about soil horizons, diagnostic features, discontinuities and of course classification. Please remember that just as horizons alone do not make a soil, a soil alone does not constitute agriculture. The soil is of course the most important component of agriculture and for that reason we must know how to conserve it and sustain its productivity for generations to come. This sacred responsibility rests with you and perhaps is another meaning of agrotechnology transfer, which is how we can avoid the mistakes made elsewhere.

Good Luck and may you learn more. I am sure you will enjoy learning because we have such lively resource persons as Dr. Eswaran, Dr. Yeck, and Dr. Cagauan, together with our colleagues from PCARRD, UPLB, and BS.

Thank you and good day.

Participants, lecturers and guests to the Seventh International Forum on Soil Taxonomy and Agrotechnology Transfer. *First row* (left to right): J. Habana, N. Marasigan Jr., V. Asis, L. Oduro, A. Bautista, M. Viniuan, N. Mergilla, L. Tomas, F. Perez, E. Rivera, E. Orpia Jr., R. Ilao, B. Gonzales, R. Lara. *Second row* (left to right): E. Alvarez, A. Marquezes, J. Nana, H. Antonio, N. Arambulo, C. Gantioqui, C. Bacatio, N. Marasigan, G. Huelidas, C. [illegible], J. Labotigan, S. Pascual Jr., *Standing* (left to right): E. Pannichatan Jr., W. Cosico, E. Hombrebueno, R. Badayos, R. Yock, L. Ostoman, M. Recol, B. Cagauan Jr., G. Alcasid Jr., H. Escalante, A. Eusebio, N. Fernandez, A. Baloloy, C. Alcalde, A. Maglinao, H. [illegible], J. Balaoing, T. Reyes, Jr.

Participants absorbed in the lecture of Dr. Eswaran on the "Principles and Logic of Soil Taxonomy"

Participants and guests of the Forum listening with interest to the Introduction of the Soil Taxonomy lecture

SOIL TAXONOMY

Diagnostic Horizon

RODRIGO B. BADAYOS

Diagnostic horizon is defined as the combinations of specific soil characteristics that are indicative of certain classes of soils. Those which occur at the soil surface are called epipedons; those below the surface are called diagnostic subsurface horizons.

Unlike genetic horizons which express qualitative judgment about the kind of changes that are believed to have taken place, diagnostic horizons are quantitatively defined features used to differentiate between taxa. The diagnostic horizons may encompass several genetic horizons, and changes implied by genetic horizon designations may not be large enough to justify recognizing different diagnostic criteria.

A brief outline of the characteristics of the different diagnostic horizons are described below:

DIAGNOSTIC HORIZON USED IN CLASSIFYING SOILS

I. Epipedons

Concept of the epipedon

1. Have forms at the surface
2. Must show one of the following
   a. Darkening with organic matter
   b. Eluviation
   c. Loss of rock structures
3. Does not coincide with A Horizon
4. Properties determined on soil mixed to 18 cm

Kinds of epipedons

1. Mollic
   a. Attributes of mollic epipedons
      - good structure
      - deep, dark, humus-rich, fertile
      - genesis from grassland
      - Ca-rich environment
      - dominance of bivalent cations
      - not continually dry
   b. Properties of mollic epipedons
      - color
      - organic matter
      - structure
      - base saturation
      - thickness
   c. Color of mollic epipedons
      - darker than 1C

- value, moist darker than 3.5
- value, dry less than 5.5

d. Organic matter of mollic epipedons
- greater than 0.6% organic carbon
- greater than 1.0% organic matter

e. Structure of mollic epipedons
- better than massive and hard
- better than very coarse prismatic
- typically friable, granular or sub-angular blocky

f. Base saturation of mollic epipedons — 50% or more by NH_4OAc method

g. Thickness of mollic epipedons
- soils shallow (less than 18 cm to rock or hardpan) — minimum 10 cm
- soils 18 — 75 cm to rock or hardpan
  - — minimum 18 cm
  - — at least 1/3 of soil depth
- deep soils, sandy soils, alluvial soils
  - — minimum 25 cm
- all soils — often includes B1, B2

2. Umbric epipedons
   a. Morphological criteria — same as mollic
   b. Chemical criteria
      - organic carbon — same as mollic
      - base saturation — less than 50% by NH_4OAc
3. Anthropic epipedons
   a. Morphological criteria — same as mollic
   b. Chemical criteria
      - organic carbon — same as mollic
      - base saturation — no requirement (most have base saturation of 50% or more)
      - citric acid soluble P_2O_5 must be greater than 250 ppm
4. Ochric epipedons
   a. Not mollic or umbric because
      - too light colored
      - too little organic matter
      - too thin
5. Plaggen epipedons
   a. Man-made surface horizon of 50 cm or more thick produced by long continued manuring
   b. Morphological criteria
      - contains artifacts (bits of brick and pottery) throughout its depth
      - shows spade marks
   c. Variable chemical properties
6. Histic epipedons
   a. Have thin horizon of peat or muck

b. Saturated with water for 30 consecutive days or more or has been artificially drained.
c. May contain mineral matter or may be mixed by plowing and
   - has 18% or more organic carbon if 60% or more of the mineral matter is clay
   - has 12% or more organic carbon if mineral fractions has no clay
   - has an intermediate proportional content of organic carbon if part but less than 60% of the mineral fraction is clay

II. Subsurface Diagnostic Horizon

Argillic

1. Attributes of argillic horizons
   a. illuvial accumulation of layer-lattice clays
   b. fine clays moved preferentially
   c. clay dilution lowers quartz, zircon
   d. requires wetting-drying moisture regime
   e. does not form with salts, carbonates
   f. requires time
   g. requires stable surface
2. Argillic horizons — medium textures (15-40% clay)
   a. amount of change — 1.2 times, i.e. the moved materials is 1.2 times greater
   b. evidence of translocation — oriented clay
   c. thickness — 1/10 sum of overlying horizons
   d. eluvial — illuvial transition — less than 30 cm
   e. fine clay/total clay — more by 1/3
3. Argillic horizons — clayey textures (greater than 40% clay)
   a. amount of change — greater than 8%
   b. moderate or strong blocky or prismatic
   c. some clay skins in lower B
   d. fine clay/total clay — more by 1/3
   e. uncoated silt in horizons above
4. Argillic horizons — sandy textures (less than 15% clay)
   a. soils with banded B horizons
   b. bands greater than 1 cm thick
   c. amount of change — greater than or equal to 3%
   d. thickness — sum of bands greater than 15 cm
   e. evidence of translocation — bridging

Natric

1. Sodium affected argillic horizon
2. Effects of sodium
   a. dispersion of clay
   b. high pH
3. How much sodium
   a. greater than 15% of CEC
   b. SAR greater than or equal to 13

4. Sodium adsorption ratio (SAR)

$$SAR = \frac{[Na]}{\sqrt{\frac{[Ca] + [Mg]}{2}}}$$

Spodic

1. Definition
   a. illuvial accumulation of active amorphous OM-Fe-Al complexes
   b. includes Bh and Bir
   c. usually underlies an A2
2. Attributes of spodic horizons
   a. coarse textures
   b. dark and/or bright colors
   c. weak structure
   d. high CEC (e.g., 44)
   e. high content of extractable Fe
   f. may be cemented — Ortstein
3. Environment of spodic horizons
   a. cool, moist
   b. mixed vegetation
   c. mobile chelates translocated
   d. complexes precipitate at high R_2O_3 levels

Albic

1. Light colored silty or loamy horizons
2. A2 or A'2 of Alfisols, Ultisols, Spodosols
3. Underlain by argillic, spodic, or fragipan
4. Formed by eluvial loss of clay, Fe coatings
5. Color due to primary sand and silt grains
6. Color value: greater than 4 moist, greater than 5 dry

Cambic

1. Definition
   a. produced by incipient soil development
   b. formed by alteration in place
   c. weathering occurs, primary minerals remain
   d. recognized only in soils finer than loamy very fine sand
   e. lie immediately beneath an epipedon
   f. not cemented or brittle
2. Cambic alterations
   a. physical changes
      - obliteration of rock structure
      - formation of soil structure
   b. chemical changes
      - carbonate removal
      - Fe transformation, translocation
        — oxidized soils
        — gleyed soils

3. Petrographic examination
   a. weatherable minerals constitute less than 3% of fraction between 20 and 200 micron but mica (muscovite) may constitute as much as 6%.
4. Particle size distribution
   a. estimated by 15-bar water retention
5. Cation Exchange Capacity
   a. less than 16 meq/100 g in 1 N NH_4OAc
   b. less than 10 meq/100 g in 1 N NH_4Cl
6. Clay mineralogy
   a. 1:1 lattice clay
   b. oxides of iron and aluminum
   c. some Al-interlayered chlorite

Calcic

1. Definition
   a. illuvial accumulation of carbonates
   b. enriched zone must
      - be greater than or equal to 15 cm thick
      - have greater than or equal to 15% $CaCO_3$ equivalent
   c. Ca horizon may not be calcic
2. Evidence of $CO_3^=$ accumulation
   a. $CO_3^=$ decrease below maximum — maximum 5% more than C
   b. identifiable secondary carbonates
      - pendants, concretions, powder
      - greater than or equal to 5% by volume
3. Genesis of calcic horizon
   a. translocation of inherited $CO_3^=$
   b. recharge with aeolian $CO_3^=$
   c. capillary rise and evaporation

Petrocalcic

1. Continuously cemented calcic horizon
2. Barrier to roots and space
3. May have laminar cap
4. Indicates very old soils, stable surfaces

Duripan

1. Duripan characteristics
   a. brittle pan cemented by silica
   b. carbonates likely, not essential
   c. opal coatings on pores, peds, cap
   d. dissolves only in alkali
   e. horizontal
2. Duripan genesis
   a. climate
      - mediterranean or arid
      - Si translocated, not lost

3. Environments of cambic formation
   a. aquic moisture regime
   b. noncalcareous soils, humid regions
   c. calcareous soils, humid regions
   d. arid regions
4. Aquic cambic horizons
   a. reducing environment — fluctuating groundwater
   b. Fe coating removed, lost or translocated
   c. low chroma (less than or equal to 2) matrix
   d. mottles may or may not be present
   e. regular decrease in O.M.
5. Color B cambic horizons
   a. Fe released by weathering
   b. hydrated Fe coats sand, silt grains
   c. color intensifies in hue and chroma
   d. often forms weak — moderate block structure
   e. few thin clay skins, not argillic
6. Humid, calcareous cambic horizons
   a. leaching removes carbonates
      - solution pits on minerals
      - $CO_3^{=}$ increases with depth
   b. faunal mixing redistributes $CO_3^{=}$
   c. granular structure common
7. Arid cambic horizons
   a. evidence of $CO_3^{=}$ translocation
   b. some intensification of color
   c. soil structure evident

Oxic

1. Attributes of Oxic horizons
   a. mineral subsurface horizon in advanced stage of weathering
   b. greater than or equal to 30 cm thick
   c. consists of mixture of hydrated oxides of iron or aluminum or both, with variable amount of 1:1 lattice clay and accessory highly insoluble minerals such as quartz sand
   d. few or no primary minerals in the fine fraction that can weather to release bases, iron or aluminum
   e. very low CEC
   f. few or no clay skins
   g. form on stable landscape (mid Pleistocene or older than late or post Pleistocene)
   h. mostly found in tropical and subtropical climates
2. Identification in the field
   a. massive in fresh pits, but many have very weak, very coarse prismatic structure that is visible on old cuts
   b. pores visible to the eye or under hand lens, diffused boundary between epipedon and oxic horizon

b. parent material
   - low in calcium
   - high in volcanic glass

Fragipans

1. Characteristics of fragipan
   a. dense (1.8 — 2.2), uncemented
   b. hard dry, brittle moist
   c. silty or loamy
   d. low O.M., low $CO_3^=$
   e. usually acid
   f. polygons of coarse prisms
      - prism size depends on clay
      - silt streaks, iron bands
      - may have some clay skins
   g. lie beneath eluvial horizon
2. Pedologic origin of fragipans
   a. parallel to soil surface
   b. consistent depth
   c. range of parent materials
   d. associated horizons
   e. forest vegetation

III. Other Diagnostic Horizons

Agric horizons

This horizon is formed directly under the plow layer and has clay and humus accumulated as thick, dark lamellae to the extent that they occupy at least 15% of the soil volume.

Gypsic horizon

This is a horizon of calcium sulfate enrichment. It contains at least 5% more calcium sulfate than underlying material.

Plinthite

This is a humus-poor, sesquioxide-rich horizon, which hardens irreversibly to ironstone hardpans or aggregates with repeated wetting and drying. The red, indurating portions of the layer are usually mottled with yellowish or white bodies.

Salic horizon

This is a horizon containing secondary soluble salt enrichment (over 2 to 3% depending on thickness).

Lithic contact

This is a boundary between soil and continuous coherent underlying material that has a hardness greater than 3 in the Mohs scale.

Paralithic contact

This is a boundary between soil and underlying coherent material with a hardness of less than 3 by Mohs scale.

Arenic horizon

This is a loamy fine sand or coarser horizon more than 50 cm thick over an argillic horizon

Grossarenic horizon

This is a loamy fine sand or coarser horizon thicker than 100 cm over an argillic horizon.

Fibric horizon (formerly peat)

In an unrubbed condition, fibers compose over 2/3 of the mass, and the material yields almost clear solutions when extracted with sodium pyrophosphate.

Hemic horizon (formerly mucky peat or peaty muck)

In an unrubbed condition, 1/3 to 2/3 of the total mass is composed of fibers (intermediate in decomposition between fibric and sapric horizons).

Sapric horizon (formerly muck)

In an unrubbed condition, less than 1/3 of the mass is composed of identifiable fibers; and it produces sodium pyrophosphate extracts with colors lower in value and higher in chroma than 10YR 7/3.

Soil Moisture and Temperature Regimes

RONALD D. YECK

The material to be discussed here about soil temperature and moisture regimes is based partly on discussions by Dr. Guy Smith in response to questions assembled by and asked by Dr. Leamy on the rationale for *Soil Taxonomy*. These discussions, which took place from 1977 to 1980, were first published in *New Zealand Soil News* and later in the United States in *Soil Survey Horizons*. *Soil Taxonomy* itself provided most of the remaining source material. The objective of this presentation is to discuss the general rationale related to the use of moisture and temperature regimes and how they were placed into the framework of *Soil Taxonomy*.

The question has been asked why climatic parameters, moisture, and temperature, were used in *Soil Taxonomy* when these are considered by some soil scientists as factors external to the soil. Dr. Smith granted that moisture regime relates to climate imperfectly, pointing out that on a given farm, some soils are wetter than others. He emphasized, however, that soil moisture regimes strongly influence soil development and, thus, their properties. He pointed out what we commonly observe — that both moisture and temperature generally determine the vegetation to be found in a given locale. In addition, he noted the importance of temperature on the rate of chemical processes and, thus, on the rate of weathering of minerals in soils.

We recall from basic chemistry than an increase of 10°C doubles the reaction rate of substances in solution. By this chemical relationship, temperature and moisture are both directly implicated in soil weathering. Jenny recognized these ideas and listed climate as one of the factors of soil formation. In this regard, Dr. Smith listed a basic assumption used in *Soil Taxonomy*. The assumption is that properties which result from genesis (such as clay skins) or are factors in genesis (such as climate factors) which are causes of other properties are the factors that should be used in the definitions. As we will see later, these properties are regarded important enough to be considered at very high taxonomic levels.

Moisture and temperature are, to a large degree, inter-dependent in their influence on soil science and on nature generally. We will eventually discuss their interactive influence somewhat more specifically; but before we do that, let's consider how they are used individually as criteria in *Soil Taxonomy*.

Soil moisture regimes are based on the amount of time and the times of the year that a portion of the soil, defined as the moisture con-

trol section, is moist. The moisture control section is an arbitrary index depth used to compare soil moisture regimes. In a given soil, the moisture control section is defined as the depth between the lower boundary of wetting by 2.5 cm in water in 24 hours on dry soil and the lower boundary of wetting by 7.5 cm of water in 48 hours, also on dry soil. This generally equates to depths between 10 and 30 cm for fine-textured soils (fine-loamy, coarse-silty, fine-silty, or clayey), between 20 and 60 cm for coarse-loamy soils, and between 30 and 90 cm for sandy soils. These depths can also be estimated somewhat more closely from water retention and porosity data.

The specific criteria for the moisture regimes defined in *Soil Taxonomy* list the number of days and the times of the year when soils of a given moisture regime are moist or dry. Only the general concepts are listed here:

1. Aquic — In most years, the soil is saturated with oxygen depleted water during part of the growing season; peraquic if this is a continuous condition (such as tidal marshes).
2. Aridic (also Torric) — Moisture control section is dry most of the growing season.
3. Udic — No part of the moisture control section may be dry for more than three months, cumulative. This is the most favorable for plant growth. It is perudic if this is a continuous condition.
4. Ustic — Moisture control section is dry in some parts for more than 90 days, cumulative. This is intermediate between Udic and Aridic.
5. Xeric — This is common to Mediterranean climates that have moist cool winters and warm dry summers. A limited amount of moisture is present but does not occur at optimum periods for plant growth.

Let's look now at the soil orders and suborders, and observe where the moisture regimes are used.

ALFISOLS	*OXISOLS*	*INCEPTISOLS*
Aqualfs	**Aqu**ox	**Aqu**ept
Boralfs	**Tor**rox	Andept
Ustalfs	Humox	Plaggept
Xeralfs	**Ust**ox	**Tro**pept
Udalfs		Ochrept
		Umbrept
ARIDISOLS	*SPODOSOLS*	*ENTISOLS*
Argids	**Aqu**ods	**Aqu**ent
Orthids	Ferrods	Arent
	Humods	Psamment
		Fluvent
		Orthent
MOLLISOLS	*ULTISOLS*	*VERTISOLS*
Aquolls	**Aqu**ults	**Xer**erts
Rendolls	Humults	**Tor**rerts
Xerolls	**Ud**ults	**Ud**erts
Borolls	**Ust**ults	**Ust**erts
Ustolls	**Xer**ults	
Udolls		

Because of the large influence of a reducing moisture regime on a soil, in orders where they occur, the aquic suborder is listed first in the key. Looking at other orders, one of them, Aridisols, is defined primarily by moisture regime. Moisture regimes other than aquic play a major role in the definitions or suborders of six additional orders. Histosol suborders are primarily based on degree of decomposition and are, as a whole, formed under moist conditions; so, again moisture is involved.

Since Entisols and Inceptisols are less highly developed, except for Aquepts and Aquents, suborders are based on properties that cause them to be less developed. Moisture regimes, however, are used at the great group level. For example, **Ust**ochrepts, **Xer**ochrepts, **Ust**orthents, **Torri**orthents, etc.

We have described the central role that soil moisture plays in the framework of *Soil Taxonomy*. Now let's look at the role and definitions of soil temperature regimes.

Perhaps temperature more directly affects the biology and chemistry of the soil than moisture because, given adequate moisture, temperature delimits length of growing seasons, rates of soil weathering, and microbial activity. A caution was expressed by Dr. Charles Kellogg (1941). He wrote that climate within the soil is unlike that above the soil; and that, loosely speaking as the climate "enters the soil", it is modified by soil conditions. Dr. Kellogg pointed out that soil temperatures, although different from air temperatures are, however, usually predictable within practical limits from air temperature data.

The authors of *Soil Taxonomy* verify the degree of modification from air to soil temperature in some detail by graphic and tabular data. They discuss daily and seasonal fluctuations, the functions of soil depth, soil moisture, soil cover, slope, and variations due to latitude. From this knowledge, they point out relationships that, we find, are used in the rationale of soil temperature regime definitions. Air temperatures are useful for estimating soil temperatures if they cannot be measured directly.

Since the soil temperature gradiant is essentially linear in the upper meter, and temperatures at 50 cm fluctuate little relative to diurnal air temperature fluctuations, 50 cm was chosen as the soil depth on which soil temperature regimes would be based. Temperature regimes are based on mean annual temperatures and differences between winter and summer mean temperatures. Two generally parallel groups are defined: those of the temperate regions where summer and winter temperatures usually differ more than 5°C, and those that have little (< 5°) seasonal fluctuation, mostly in the intertropical zone (denoted by the prefix "iso"). The generalized definitions are:

1. Pergelic — continuously frozen
2. Frigid/Isofrigid — mean annual temperature < 8°C
3. Cryic — temperature essentially isofrigid but varies with "O" horizon cover and moisture
4. Mesic/Isomesic — mean annual temperature equal to or more than

8°C but less than 15.

5. Thermic/Isothermic — mean annual temperature of 15°C or more but less than 22.
6. Hyperthermic/Isohyperthermic — mean annual temperature of 22°C or higher.

Examples of temperature variations in locations at different distance from the equator are shown in Table 1. The similar mean annual temperature in the central United States and Ecuador but with different summer and winter temperature patterns emphasizes the utility of iso temperature regimes.

The concept of iso temperature regimes was drawn from the experience that limitations on plant growth are quite different in the intertropical regions from those of the temperate zones. Dr. Smith explained that cessation of plant growth in temperate regions is determined by temperature; whereas, in intertropical regions, it is determined by moisture. Soils in areas in which plant growth is controlled by temperature receive large organic matter "flushes" at about the same time of the year.

In the intertropical areas with udic moisture regimes, on the other hand, organic matter is added evenly throughout the year. Dr. Smith felt that there were different genetic effects of a large amount of organic matter coming over a short period and the same amount coming over a full year. Since there may also be cessation of plant growth in ustic moisture regimes in the tropics (moisture control of plant growth) with similar resulting organic matter "flushes", the Tropic great groups are primarily restricted to udic moisture regimes, although there are a few exceptions.

The selection of the temperature criteria was based on isotherms in the United States that coincided with growth of certain commercial crops. The 8°C temperature isotherm generally separates winter and spring wheat growing areas and also areas between where corn (maize)

Table 1. Temperature variations in locations at different distance from the equator

City and State	Lat.	Mean Annual	Mean Jan.	Mean July	Temperature Regime
		------Degrees C------			
Omaha, Nebraska	41°18'N	10	—4.6	25.6	Mesic
Key West, Florida	24°31'N	24	21.0	28.4	Hyperthermic
Manila, Philippines	10°35'N	30	25.1	27.3	Isohyperthermic
Cotopaxi, Ecuador	01°00'S	10	9.8	10.3	Isomesic

can be grown for grain and where it can be grown for silage only. Cryic soils were separated with the thought that they were too cold to be cultivated. The 15°C limit was chosen because that isotherm is the northernmost limit of where cotton is grown. The 22°C isotherm is the northern extent of the citrus and winter vegetable belt. For convenience, the same mean annual temperature limits were used for the isotemperature regimes.

When *Soil Taxonomy* was published, the limits also seemed reasonable for the intertropical region. Since more experience has been gained, it appears that 10°C might be a better break between isofrigid and isomesic It also appears that hyperthermic and isohyperthermic regimes could be combined. Another suggestion is to separate a higher temperature regime (megathermic) at 28°C. The placement of temperature regimes within the suborder and great group framework of *Soil Taxonomy* can be understood by observing where formative names denoting temperature regimes occur on pages 86 and 87 tables of *Soil Taxonomy*. Table 2 summarizes those sub-orders and great groups.

Primarily, Cryic and Tropo elements occur as part of great group names. Trop is also used as a suborder element with Inceptisols (Tropepts). When temperature regimes are not named or implied in suborders or great groups, they are names as part of the family designation. The soil temperature regimes, for example, are not named in families of Cryic great groups. They are, however, named in families of Trop great groups because although Trop designates uniform temperatures throughout the year, it does not designate the mean annual temperature grouping (i.e., Isomesic, Isothermic, etc.). As with moisture regimes, temperature regimes are comprised of a prominent role in the framework of *Soil Taxonomy*.

As mentioned earlier, it is appropriate to discuss soil moisture and temperature regimes together since moisture and temperature act interdependently on their effects on plant growth and soil genesis.

A number of relationships exemplify this interrelationship. The most highly weathered soils (Oxisols, Ultisols) occur where temperatures are high (thermic or hotter) and moisture regimes are Udic (and sometimes Ustic). Favorable thermic temperatures are for high chemical and biological activity and Udic moisture regimes provide ample moisture for chemical and biological activity but not excessive amounts that would impede biological activity.

At the other temperature extreme, Pergelic (continuously frozen), essentially no soil weathering occurs because the biological activity is low and moisture is frozen. Since water cannot move, the transport mechanism that contributes to soil development is nonexistent.

High temperatures (thermic and warmer) can have no beneficial plant growth influence when moisture is limited (aridic). With minimal plant growth, other biological activity is highly impeded and additionally little chemical activity occurs, again with little soil development as

Table 2. Suborders and great groups with formative names denoting temperature regimes.

ALFISOLS	*INCEPTISOLS*
Tropaqualfs	Cryandepts
Boralfs	Cryaquepts
Cryoboralfs	Tropaquepts
Tropudalfs	Cryochrepts
	Tropepts
	Cryumbrepts
ENTISOLS	*MOLLISOLS*
Cryaquents	Cryaquolls
Tropaquents	Borolls
Cryofluvents	Cryoborolls
Cryorthents	
Troporthents	*SPODOSOLS*
Cryopsamments	
Tropopsamments	Cryaquods
	Tropaquods
	Cryohumods
	Tropohumods
	Cryorthods
	Troporthods
HISTOSOLS	*ULTISOLS*
Borofibrists	Tropaquults
Cryofibrists	Tropohumults
Tropofibrists	Tropudults
Borofolists	
Cryofolists	
Tropofolists	
Borohemists	
Cryohemists	
Tropohemists	
Borosaprists	
Cryosaprists	
Troposaprists	

the result. Excessive moisture (aquic moisture regimes) also restricts biological activity. The result is commonly a larger accumulation of organic carbon. An extreme expression of this condition may result in the formation of organic soils.

As discussed earlier, patterns of moistures or temperature are also important. We mentioned that in the intertropical regions where temperatures are warm enough, plants can grow all year if there is adequate moisture; but when moisture is limited during parts of the year (Ustic), plants grow only when there is adequate moisture (unless there is irrigation). Temperature extremes, likewise, limit plant growth to warm times of the year even though moisture is available for plant

growth. We also observed the effects of moisture and temperature extremes by evidence of cracking and alternate swelling in soils. The evidence occurs as slickensides.

To summarize, we have discussed the rationale and criteria for soil moisture and soil temperature regimes. We also discussed the central role of soil moisture and temperature properties within the framework of *Soil Taxonomy*. We have also seen that functions of moisture and temperature are interdependent in soil formation and plant growth as they are throughout nature.

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Histosols and Spodosols

RONALD D. YECK

It is appropriate that we discuss the Spodosol and Histosol orders in the same session because of the commonality between them. The organic soil fraction is either dominant or plays a significant role in the development and expression of properties in both orders.

Histosol

Figures 1 and 2 show the distribution of organic soils (peat) in the world and in the United States, respectively. The peat areas are most common and extensive between latitudes 50° and 70°, both north and south, because of the temperature-moisture interrelationships that favor organic matter accumulation at those latitudes. Finland has almost a third of its land area covered by peat while Sweden, Ireland, Canada, Hungary, Scotland, and Norway all have more than 10% of their areas covered by peat. Not all of these areas would qualify as Histosols, however.

Everett (1983) notes what we discussed briefly when talking about soil moisture and temperature regimes: organic matter accumulates under reducing or anaerobic conditions that are decidedly unfavorable for the biodegradation of organic matter. This implies adequate to excessive moisture, frequently combined with low temperatures. Precipitation usually exceeds evapotranspiration where Histosols form. Maritime climates, however, also favor the formation of Histosols, demonstrated by the occurrence of Histosols along the east coasts of North America and Asia.

In addition to the organic soils formed under saturated conditions, another type is freely drained and occurs as a relatively thin accumulation of organic plant litter on rocks (blanket bogs). The order Histosols accommodates both types, but the saturated ones are more extensive and economically important. For the freely drained organic soils (Folists) to qualify as Histosols, they must contain 20% carbon.

For the saturated Histosols suborders, the minimum organic carbon requirement is partially related to clay content. Because clay and organic carbon are the main chemically active soil components, the requirements for Histosols are intended to insure that organic matter is chemically dominant. As clay content increases from 0 to 60 percent, organic carbon content must increase from 12 to 18 percent. With no clay, organic carbon must be at least 12%; and if clay is 60% or more, organic carbon must exceed 18%. The proportional requirements are shown graphically on page 71 of the blue *Principles and Procedures Course Guide.* There is a lower organic carbon requirement (8-12%) for plowed histic epipedons. Normally, data sheets express mineral con-

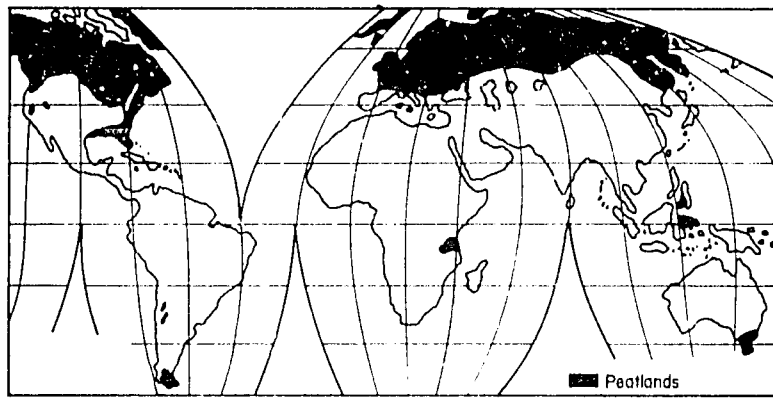

Fig. 1. Distribution of organic soil in the world

tent (determined by dry combustion at 400°C) and organic carbon content (determined by wet combustion). The wet combustion method (Walkley-Black) is reliable up to about 10% organic carbon. The mineral content values are, therefore, preferred to determine whether or not a sample is organic material by the above definitions. The dry combustion method is less reliable when samples contain amorphous material or gypsum.

Among the Histosols that are usually saturated, the degree of decomposition, because of its impact on the soil's physical conditions, is used as suborder criteria. The degree of decomposition relates somewhat to the type of plant but perhaps more to water table fluctuation. The more highly decomposed Histosols are normally ones with a fluctuating water table that allows for more oxidation within the soil than where water is more static. The degree of decomposition is opera-

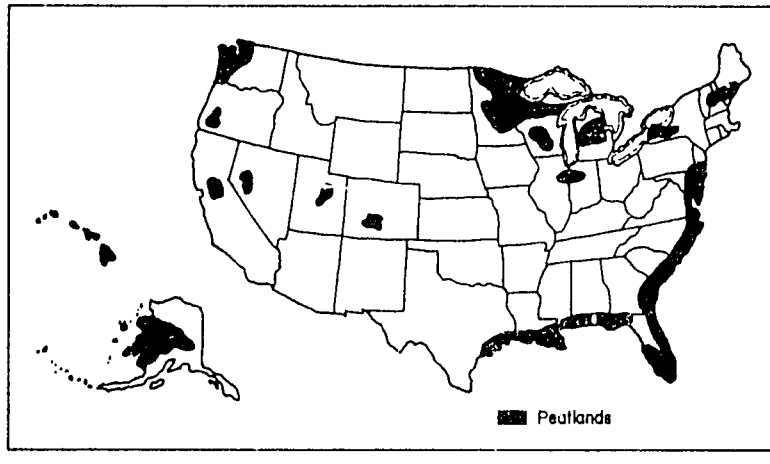

Fig. 2. Distribution of organic soil in the United States

tionally defined by both physical and chemical criteria. The suborder criteria are shown on pages 71 and 72 of the *Principles and Procedures for Using Soil Survey Laboratory Data Course Guide*. The definitions are as follows:

Fibric. > 75% rubbed fiber, or ≥ 40% rubbed fiber and light pyrophosphate color (specified on chart showing Munsell page). Most fibric materials are sphagnum mosses.

Sapric. < 17% rubbed fiber and dark pyrophosphate colors (specified on chart showing Munsell page) and are the most decomposed organic soils. Nearly all cultivated organic soils have sapric surfaces. Shallow (terric) organics tend to be sapric.

Hemic. Fail to meet the requirements for sapric or fibric. Hemic soils are commonly straw yellow. Some appear highly fibrous, but fibers disintegrate when rubbed.

The fiber content criterion directly measures the degree of decomposition. The color criterion is an application of the knowledge that as organic materials decompose, more humic acids are formed. The darker colored humic acid in the pyrophosphate extract thus relates to the degree of decomposition.

Great group criteria of Histosols are generally based on temperature regimes. One exception is that of Sulfihemists. All Histosols containing sulfidic materials are classified as hemists, regardless of the degree of decomposition. It was felt that these soils should be grouped together because of the large impact of the sulfur.

Thickness requirements for Histosols are also related to degree of decomposition. The theory is related to the relative subsidence upon drainage; i.e., if the bulk density goes from 0.1g/cm^3 to 0.2g/cm^3 , the volume would be halved.

Histosols are important timber and vegetable crop production soils, so a few points about them compared to minerals soils would seem useful to us. The following is a comparison of the surface horizon exchangeable calcium of two Minnesota soils from the Northern United States.

Property	Typic Borohemist (Oa)	Aquic Haploboroll (Ap)
Ca (meq/100g)	145	5.4
Bulk Density (g/cm^3)	.04	1.48
Ca (meq/cm^3)	5.80	8.0

These data emphasize that, although nutrients expressed as a weight percentage in organic soils are large values, they are sharply decreased if expressed as a volume percentage. Since plant roots ramify a soil volume rather than a soil weight, a volume expression provides a more meaningful method of comparing data between organic and mineral soils than does a weight expression.

Cation exchange capacity also is high as a weight percentage in Histosols. These soils have a large pH-depedent charge, so the effective CEC (sum of cations plus KCl aluminum) is the most useful CEC expression. Fairly typical Histosol data are showin in Table 1, data from a Minnesota Borosaprist. Nutrient status of Histosols is quite variable and depends, to a large extent, on the dissolved nutrients in the water feeding the organic scils. This, in turn, affects the type of plants that grow on a given Histosol. Phosphorus is commonly immobilized by the organic materials.

Histosols require careful management when drained and cultivated to control the loss of soil material by oxidation and wind erosion. Water tables are usually carefully controlled to optimize crop production and minimize soil loss.

We have discussed the properties of Histosols and their placement in *Soil Taxonomy* as well as some of the criteria for placement. Additional discussion and more specific criteria are discussed on pages 71-77 of the *Principles and Procedures for Using Soil Survey Laboratory Data Course Guide*. This material includes several diagrams which are useful in deciding whether or not a soil is a Histosol and also its degree of decomposition.

Spodosols

Spodosols are of historic origin. The term podzol refers to the ashy, leached upper horizon first described in Russia. The illuvial implication was widely applied, but somewhat altered when translated to German and English. They associated underlying dark or reddish horizons with the bleached horizon.

The concept of the spodic horizon, the diagnostic horizon for spodosols in *Soil Taxonomy*, was again shifted making the illuvial black or reddish horizons the defining horizons with no criteria tied to the bleached eluvial horizon. The reasons for excluding the eluvial horizon from the defining criteria were that it is easily destroyed naturally by the falling of trees and cultivation by man. It is partially for these same reasons that, in most cases, the defining properties are required to be recognizable below a specified depth, usually a depth below which cultivation is common.

The concept of the spodic horizon morphologically is a horizon that appears, in the idealized case, as a chromatographic column with a dark rim of illuviated organic matter over a dark red horizon that usually becomes less red with depth. A portion, or most of these horizons, may be cemented, in which case, they are termed ortstein (ironstone). Sometimes the appearance is less dramatic, but the general concepts hold.

The related physico-chemical concept is one in which there is an accumulation of illuviated organic matter and amorphous aluminum, sometimes accompanied by amorphous iron. The organic carbon and

sesquioxides are thought to combine through chelation to form metallic complexes which contribute primarily to the nature of the spodic horizon.

This type of process is most active in an acid leaching regime. Such a regime is favored by cool, temperate climates where organic carbon can accumulate coupled with sandy to loamy materials in which leaching is not severely impeded.

The distribution of Spodosols formed in cold, humid areas partially shadows that of Histosols. Additional, the soils previously termed "ground water podzols" may occur in any climatic region. They are usually classified as Aquods (sometimes Humods) and have a fluctuating water table. The fluctuating water table of the Aquods produces an illuvial organic horizon, but usually without the metallic ions common to spodic horizons that form under cool, humid uplands. These two types of spodic horizons form by distinctly different processes, but the resulting spodic horizons have some chemically similar properties. Taxonomically, the arguments for keeping them in the same order are stronger than those for separating them.

Soil Taxonomy provides both field and laboratory criteria for the identification of spodic horizons. The field criteria include continuous ortstein more than 2.5 cm thick (to distinguish it from a placic horizon) or sand grains with cracked coatings or pellets of coarse silt size or larger. The cracked coatings and pellet criteria are conceptually acceptable, but pragmatically weak, because these features are often subtle; and consistent indentification among trained scientists is difficult. There is very little problem with the ortstein criteria.

Laboratory criteria were fitted to field morphologic concepts. The laboratory criteria are designed to identify the presence of illuviated iron and aluminum (Na-pyrophosphate extraction) with a dominance of these material over layer-lattice clay. This is accomplished by requiring the ratio of pyrophosphate extractable iron plus aluminum to clay that exceeds 0.2 (in practice 0.15, because it rounds to 0.2). In the Aquods where little iron is present, pyrophosphate extractable carbon is used instead of iron.

Many of the features of spodic horizon are similar to those where allophane is present (Andepts). A criterion intended to separate those soils from Spodosols was to require the organically-bound iron plus aluminum (of spodic horizons) to be twice as abundant as the free iron plus aluminum. The resultant criteria is expressed as —

$$(Fe_p + Al_p)/(Fe_{c\text{-}d} + Al_{c\text{-}d}) \geqslant 0.5$$

where p subscripts denote pyrophosphate extraction and c-d subscripts denote dithionite-citrate extraction.

Finally, an accumulation index is applied to measure the capacity factor or the pedon overall index quantity of active amorphous materials. Generally, these chemical criteria have worked, although a

number of proposals have been made for alternative criteria. Since of the field criteria, only the ortstein criterion is easily applied, additional criteria that would help identify spodic horizons in the field are needed.

We have discussed the environmental factors conducive to spodic horizon development, the unique properties of spodic horizons, and the taxonomic criteria used to identify those properties. Now let's look at the properties of Spodosols used to separate the suborders in *Soil Taxonomy*. From Table 7, page 87 of *Soil Taxonomy*, we sense the objective of the authors. As in other orders, soils with aquic moisture regimes (Aquods) are distinguished first because of the large number of properties associated with reducing moisture regimes. Otherwise, Spodosols are separated by the dominance of one of its active components, amorphous metals (here, iron), or illuviated organic carbon. Thus, suborders include ferrods, humods, and where neither dominates, orthods. The presence of iron is further recognized as Sideraquods and Plac great groups in other sub-orders. Temperature is also a great group criterion (Cry and Tropo great groups). Spodic horizons, as mentioned earlier, are required to be recognizable below normal cultivation depths (12.5 cm), but this requirement is waived for Cryic great groups because the thought was that few, if any, of those soils would be tilled. The depth requirement is also waived for or modified for shallow Spodosols.

Let's use two typical examples, using data to illustrate the cardinal properties of Spodosols. First, Table 2 shows selected data from a Colton pedon, a sandy-skeletal, mixed frigid Typic Haplorthod from Vermont. Vegetation is white and yellow Birch, Hemlock, Spruce, and Beech. It is typically sandy. The extractable bases are very low; but due to the high pH-dependent charge, the CEC (both by sum of cations and NH_4OAc methods) is high. The CEC of the spodic horizons, by sum of cations (pH 8.2) is much higher than the ammonium acetate CEC (pH 7.0). The pH-dependent charge is a reflection of the high amorphous component. Pyrophosphate extractable iron and aluminum are maximums in the spodic horizon. The pH in water is also generally low.

Let's also look at data from a Ban Thon pedon, (Table 3) a sandy, siliceous, isohyperthermic, ortstein Typic Tropohumod from 232 km east of Bangkok, Thailand. The land is cleared for planting of coconuts. This pedon has an even higher sand content and about an equally poor base status, perhaps lower, than the Colton (Table 2). The spodic horizons again show high pH dependent charge. In this case, essentially no pyrophosphate extractable iron and aluminum are present; but there is a large pyrophosphate extractable carbon component. Since iron is low, pyrophosphate extractable carbon is used in the spodic horizon criteria.

Spodosols, such as the ones from Vermont, are commonly used for commercial timber production. The more sandy Spodosols, such as the ones from Thailand, are commonly less productive because of their very low base status, but with good management are used for high

Table 1.

Catubo
Classification: Terric Borosaprist
loamy, mixed, euic
S72HE-60-1
County: Pole
General Methods: 1A, 1B1B, 2A1, 2B
Sample nos: 72L624-72L628

Depth	Horizon	Particle Size Analysis, LT 2MM, 3A1, 3A1B, 3A1B: Sand 2-.05	Silt .05-.002	Clay LT .002	Fine Clay LT .0002	VCOS	COS	MFNS	FNFS	VFNS	COSI	FNSI	VFSI	Fam Text Sand	Intr IT .2-.02	Fine clay to clay Lt	Non-CO_3 clay Lt	Ratio 8D1 15-Bar to clay
cm		PCT LT < 2MM														PCT	PCT	
0-22	OAF																	
22-50	OE																	
50-104	OA2																	
104-120	2A1E																	
120-135	2CG																	

Depth	Particle Size Analysis, 3A, 3B, 3A1, 3A2: Vol. GT 2	Vol. GT 75	Weight 75-20	Weight 20-5	Weight 5-2	Weight LT .074	Weight 20-2 PCT	(Bulk Density) 1/3-Bar	Oven Dry	COLE	Water Content 1/10 Bar PCT	1/3 Bar PCT	15 Bar PCT	WRD	Carbonate LT 2 PCT	LT .002	PN 1.1 H_2O	PN 1.2 $CaCl_2$
0-22																		
22-50												95						
50-104												89						
104-120												28						
120-135												2						

Depth	(Organic Matter) 6A1A Orgn C	6B1A Nitg	C:N	Iron 6C2B Ext Fe	Pors Tot	Extractable Bases 6N2E Ca	6O2D Mg	6P2E Na	6Q2B K	Sum Extr	Acty 6H1A Bacl TEA	Al 6G1E KCl Ext	(Cat Exch 5A3A Extr Acty	5A6A NH_4OAc	Ratio 8D1 NH_4OAc to Clay	Ratio Ca to Mg	Ca 5F1 Extr NH_4OAc	(Base Sat) 5C3 Extr Acty	5C1 NH_4OAc
cm	PCT	PCT		PCT	PCT	MEQ/100 G											PCT	PCT	PCT
0-22						106	34.1	6	2	141.0	41.9		183	124.0		3.1	85	77	114
22-50	59.0					112	33.8	8	2	147.0	50.2		197	137.0		3.3	82	75	107
50-104	55.2					33.1	12.7	3	2	46.3				44.7		2.6			
104-120	11.8					8.0	1.1	1	1	9.3				3.8		7.3			
120-135	2																		

Depth	(Saturated Paste) 8E1 Rest OHM	8C1B pH	8A H_2O	Na 5D2 ESP	Na 5E SAR	Salt 8D5 Total Solu	Gyp 6F1A	Saturation Extract 8A1: 8A1A EC	6N1E Ca	6O1B Mg	6P1B Na	6Q1B K	6H1A CO_3	6J1A HCO_3	6K1A Cl	6L1A SO_4	6M1A NO_3	Attenberg 4F1 Lqid Limit	4F2 Plst Index
cm	OHM cm		PCT	PCT		PPM	PCT	MMHOS Cm	MEQ/LITER										
0-22																			
22-50	1900	6.1	774			4100		83	5.3	3.9	2	1R	0	2	0	4.4	3.9		
50-104	1400	5.6	793			5900		1.16	7.8	5.5	4	1	0	7	0	9.4	3.6		
104-120	650	6.8	149			4000		3.73	31.5	25.8	9	3	0	1.1	0	54.1	1.8		
120-135	1800	7.8	24	3		420		2.56	28.0	9.8	9	2	6	1.1	0	17.7	1.0		

Depth	(State of Decomposition) 8F Mint Cont	8G (Fiber Unrb	Vol Rub	Pyrophos Solubility	pH 8C1G 01M $CaCl_2$	Histosol characterization: Bulk Density 4A3A Fild Stat	4A7I 1/3 Bar Rewt	COLE 4D1 Re-wet	Subs Residue	Water Content 4B4 Fild Stat	4B1C 1/3 Bar Rewt	4B2 15 Bar	4C1 WRD
cm	PCT	PCT	PCT			G/CC	G/CC		PCT	PCT	PCT	PCT	CM/CM
0-22													
22-50	25	44	7	7.5 Yr 5/4	6.0	26				78	254	95	
50-104	11	57	22	10 Yr 7/3	5.8	19				94	356	102	
104-120	47	35	7	10 Yr 6/3	6.5	19				91	363	102	
120-135											81	23	
											14	3	

Table 2. Data from a Ban Thon pedon

Ban Thon
Classification: Sandy, Siliceous, Isophyperthermic, orstein Typic Tropohumod
S 82FN-875 — 001 Date 03/01/84
Thailand
General Methods 1B1A, 2A1, 2B

Sample No.	Hzn No.	Depth (Cm)	Horizon	Clay Lt .002	Total Silt .002 -05	Sand .05 -2	Orgn C 6A1C	Total N 6B1B	(Ratio/Clay) CEC 8D1	15 Bar 8D1
				PCT of <2MM						
821859	1S	0- 17	AP	1.6	2.0	96.4	1.08	0.030	1.81	1.31
821860	2S	17- 37	E1	2.2	0.2	97.6	0.20	0.004	0.14	0.41
821861	3S	37- 80	E2	0.8	0.9	98.3	0.12	—	0.25	1.00
821862	4S	80- 90	BH1	6.2	5.3	88.5	4.32	0.101	4.02	1.45
821863	5S	90-130	BHS	0.8	1.2	98.0	0.43	0.009	1.63	1.50
821864	6S	130-147	BH2	2.9	0.7	96.4	1.59	0.034	2.97	1.07

Sample No.	Hzn No.	NH_4OAc Extractable Bases Ca 5B5A 6N2E	Mg 5B5A 602D	Na 5B5A 6P2B	K 5B5A 6Q2B	Sum Bases	Acidity 6H5A	Extr Al 6G9A	CEC Sum Cats 5A3A	CEC NH_4 OAc 5A8B	CEC Bases + Al 5A3B
		MEQ/100 G									
821859	1	0.4	0.1	TR	—	0.5	5.8	0.5	6.3	2.9	1.0
821860	2	—	TR	—	—	TR	0.7	0.1	0.7	0.3	0.1
821861	3	—	—	TR	—	TR	1.1	—	1.1	0.2	
821862	4	0.2	—	TR	—	0.2	48.0	6.0	48.2	24.9	6.2
821863	5	TR	—	TR	—	TR	3.6	0.7	3.6	1.3	0.7
821864	6	TR	—	TR	—	TR	19.2	2.2	19.2	8.6	2.2

Sample No.	Hzn No.	Spodic Horizon Criteria: Na Pyrophosphate Extractable C 6A4A	Fe 6C5A	Al 6G5A	Fe + Al DI-CI Fe + Al	Fe + Al / PCT Clay	Al + C / PCT Clay	Index of Accum	pH $CaCl_2$ -01M 8C1F 1:2	pH H_2O 8C1F 1:1
		PCT of <2MM			Divided by					
821859	1	0.4	—	—			0.2		3.5	4.2
821860	2	0.1	—	—			—		3.9	4.7
821861	3	TR	—	—			—		4.4	5.0
821862	4	4.0	—	0.6	0.6		0.7	451	4.0	4.4
821863	5	0.3	—	—	—		0.4		4.0	4.5
821864	6	1.5	—	0.1	0.3		0.6		4.1	4.4

Table 3. Data from a Colton pedon

Colton
Sampled as: Sandy-skeletal, mixed, frigid Typic Haplorthod
S 78VT-025-003
Spodosol Study Windham County
General Methods 1B1A, 2A1, 2B

Date 03/01/84

Sample No.	Hzn No.	Depth (Cm)	Horizon	Total Clay Lt .002	Total Silt .002 -.05	Total Sand .05 -2	Orgn C 6B1B	Total N 6B3A	(Ratio/Clay) CEC 8D1	(Ratio/Clay) 15 Bar 8D1
				PCT of < 2MM			( )			
781797	1S	3- 10	A2	5.0	19.3	75.7	1.31	0.050	1.76	0.86
781798	2S	10- 17	B21H	6.5	27.2	66.3	4.77	0.181	4.92	2.31
781799	3S	17- 27	B22Hi	4.3	21.5	74.2	4.48	0.131	6.91	3.12
781800	4S	27- 44	B23IR	3.9	19.7	76.4	2.12	0.067	3.90	1.74
781801	5S	44- 80	B3	3.3	9.0	87.7	0.56		1.94	0.64
781802	6S	80-116	2C1	2.8	6.2	91.0	0.38		1.25	0.54
781803	7S	116-150	2C2	3.6	1.6	94.8	0.19		0.61	0.25

Sample No.	Hzn No.	NH_4OAc Extractable Bases: Ca 5B4A 6N2E	Mg 5B4A 602D	Na 5B4A 6P2B	K 5B4A 6Q2B	Sum Bases	Acidity 6H2B	Extr Al 6G1E	CEC: Sum Cats 5A3A	CEC: NH_4 OAc 5A8A	CEC: Bases + Al 5A3B
		MEQ/100 G									
781797	1	0.1	TR	—	—	0.1	9.8	3.4	9.9	8.8	3.5
781798	2	0.1	0.1	—	TR	0.2	45.3	7.5	45.5	32.0	7.7
781799	3	TR	—	—	—	TR	40.8	4.2	40.8	29.7	4.2
781800	4	—	—	—	—	—	23.2	1.8	23.2	15.2	1.8
781801	5	TR	—	—	—	TR	7.5	0.7	7.5	4.6	0.7
781802	6	TR	—	—	—	TR	4.7	0.4	4.7	3.5	0.4
781803	7	TR	—	—	—	TR	1.6	0.3	1.6	2.2	0.3

Sample No.	Hzn No.	Spodic Horizon Criteria: Na Pyrophosphate Extractable: C 6A4A	Fe 6C5A	Al 6G5A	Fe + Al / DI-GI Fe + Al	Fe + Al / Al + C Divided by PCT Clay	Al + C / PCT Clay	Index of Accum	pH: $CaCl_2$ .01M 8C1E 1:2	pH: H_2O 8C1A 1:1
		PCT of < 2MM								
781797	1		0.2	0.1	0.8	0.1		52	3.2	3.6
781798	2	3.6	2.5	0.7	0.7	0.5	0.7	296	3.6	4.0
781799	3	3.4	0.7	1.1	0.6	0.4	1.0	386	4.2	4.5
781800	4	1.5	0.2	0.6	0.5	0.2	0.5	361	4.5	4.7
781801	5		0.1	0.3	0.7	0.1		211	4.6	4.8
781802	6		0.1	0.2	1.0	0.1		119	4.7	4.8
781803	7								4.8	5.0

value cash crops. Similar soils are often Aquods that are difficult to farm because of the wetness unless they are drained.

We have discussed the morphologic and chemical properties of spodic horizons and Spodosols and the climatic conditions conducive to their formation. Also, we talked about criteria for spodic horizons and the placement of Spodosols in the framework of *Soil Taxonomy*. In addition to the discussion of spodic horizons and Spodosols in *Soil Taxonomy*, there is additional discussion on pages 87-92 of the blue *Principles and Procedures for Using Soil Survey Laboratory Data Course Guide*.

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Andisols

MODESTO R. RECEL

The volcanic ash soils are placed in Soil Taxonomy as a suborder of the Inceptisols. They are the Andepts.

The definition of the Andepts, however, could not accommodate all the soils developed from volcanic ash. The reason is that, at the time that Soil Taxonomy was being developed, not much information about volcanic ash soils was available. Hence, the International Committee on Andisols (ICOMAND) was organized to develop the classification of these soils. Since the Andepts are extensive, ICOMAND propose to elevate the classification at the order level as Andisol.

Some of the limitations of the definition of the suborder Andepts that were identified by ICOMAND members are the following:

1. It excludes some volcanic ash soils, because the requirements apply only to soils having bulk density of less than 0.85 g/cm^3 and an exchange complex dominated by amorphous materials throughout the upper 35 cm or to soils having more than 60% vitreous ash, etc.
2. Base saturation by NH_4OAc is used as a differentia in the classification key. The values may not represent the actual base status of the soils because the clays are mostly amorphous and the CEC is largely pH-dependent.
3. Thixotropy as a differentia is very subjective because it is partly a function of the water content and partly a function of the stress applied. Thus, characterization cannot be made uniformly.
4. Soil moisture regime is used as a differentia for all other soils but not for Andepts. The interpretation for a given family, therefore, cannot be made without the use of a climatic phase.
5. The darkness of the epipedon is weighted heavily in the subgroup definition, but there seems to be little or no relation between color and carbon content, degree of weathering or any other property in the warm intertropical areas. Many volcaniclastic materials are black when deposited and become lighter in color with weathering.
6. There is inadequate emphasis on the unique moisture retention property of the Andepts. The irreversible effect of drying is used only to define the Hydrandepts and soils, such as the Hydric Dystrandepts.

Based on the above limitations, a proposal to reclassify the Andepts and some andic subgroups to the order Andisols was prepared by Dr. G.D. Smith in 1978. It is intended to better accommodate the soils developed from volcanic ash. The proposed definition reads:

Andisols are mineral soils that do not have an aridic moisture regime or an argillic, natric, spodic, or oxic horizon unless it is a buried horizon, but have one or more of a histic, or umbric epipedon, or a cambic horizon, a placic horizon, or a duripan; or the upper 18 cm, after mix-

ing, have a color value moist of three or less and have three percent or more organic carbon in the fine earth; and, in addition, have one or more of the following combination of characteristics:

1. Have, to a depth of 35 cm or more, or to a lithic or paralithic contact that is shallower than 35 cm but deeper than 18 cm, a bulk density of the fine earth fraction of less than 0.85 g/cm^3 (at 1/3-bar water retention of undried samples); and the exchange complex is dominated by amorphous materials.

2. Have, in the major part of the soil between a depth of 25 cm and 1 m or a duripan, a placic horizon, or a lithic or paralithic contact that is deeper than 35 cm but shallower than 1 m, a bulk density of the fine earth fraction of less than 0.85 g/cm^3 (at 1/3-bar water retention of undried samples); and the exchange complex is dominated by amorphous materials.

3. Have 60% or more, by weight, of noncalcareous vitric volcanic ash, pumice or pumice-like fragments, cinders, lapilli, or other vitric volcaniclastic materials either to a depth of 35 cm or more, or in the major part of the soil between 25 cm and 1 m, or a lithic or paralithic contact that is shallower than 1 m, and the pH of 1 g of fine earth from the major part of these horizons is 9.2 or more after two minutes in 50 ml of 1 N NaF.

4. Have a weighted average (by thickness of subhorizons) in the major part of the soil between a depth of 25 cm and 1 m, or a duripan or paralithic or lithic contact shallower than 1 m, a water retention of undried fine earth at 15-bar pressure of 40% or more; and either a ratio of 15-bar water percentage (undried) to the meq exchangeable bases is 1.5 or less, or the pH of 1 g of fine earth in 50 ml of 1 N NaF is 9.4 or more after two minutes, or both.

The intent of Item 1 is to accommodate the shallower volcanic ash soils, while Item 2 accommodates deep soils which may have low amorphous material in the surface horizons. Item 3 clarifies the classification of soils formed in ash belonging to the other soil orders. Item 4 defines additional properties of the volcanic ash soils. It is particularly intended to accommodate soils like the Eutrandepts of Hawaii that meet the definition of Andisols, except for the pH in NaF requirement because the test may be meaningless owing to the calcareous lower horizon. Item 4 also requires a low ratio of 15-bar water percentage to exchangeable bases to suit the relatively high exchangeable bases and low 15-bar water content of undried materials of the Eutrandepts.

Exchange Complex Dominated by Amorphous Material (ECDAM) is proposed as a criterion for Andisols.

The required conditions of ECDAM as proposed by Blakemore (1978) reads:

1. The bulk density of the fine earth fraction should be < 0.85 g/cm^3 at 1/3-bar tension, with undried samples.

2. If there is enough clay to have a 15-bar water content of 15% or more in air dried samples, the pH of a suspension of 1 g soil in 50 ml 1 N

NaF is > 9.4 after two minutes.

3. The Phosphate Retention value should be > 90%.

4. The Variable Charge should be > 0.7 of the CEC at pH 8.2 (using $BaCl_2$).

The above proposal was tested in many parts of the world and from these tests various amendments have been suggested (ICOMAND CL Nos. 1-4).

The latest proposed definition of the order Andisols (ICOMAND CL No. 5, 1983) reads:

Andisols are mineral soils that do not have an argillic, natric, or oxic horizon unless it is a buried horizon occuring at a depth of 50 cm or more, and which have soil material beginning at, or within 25 cm of the surface, in which all subhorizons have andic and/or vitric soil properties throughout a continuous thickness of 35 cm or more.

Here the exclusion of an aridic moisture regime has been deleted for the reason that volcanic ash soils have been reported from an aridic moisture regime in Syria.

Argillic, natric, spodic, or oxic horizons are permitted in Andisols but must be 50 cm deep or deeper; and they must be buried horizons. The rationale is that dominant soil process is reflected by that diagnostic horizon nearest the surface. Soils, with any of the above diagnostic horizons between 50 and 100 cm, which are not buried will be andic or vitric subgroups of the other orders.

One or more horizons of a histic, mollic, umbric, cambic, or placic were eliminated to simplify the definition because, after all, soils with these diagnostic features will be accommodated in their taxonomy at an appropriate lower category.

Low color value and high organic carbon content were excluded because this is not a serious concern. It may be simpler and more appropriate to classify such soils on the basis of the physical and chemical properties used to define vitric and andic. Tests also suggest that in Andisols, color and carbon content of the epipedon can be associated with the distinction between melanic properties and mollic or umbric properties. It will also permit recognition of ochric properties at subgroup level.

The thickness criterion for Andisols was suggested to be amended requiring a minimum continuous thickness of andic or vitric materials of 35 cm within the upper 60 cm. The basis for this proposal was that the behavior and use of the soil are greatly influenced within such limits. Reference to lithic or paralithic contacts within 35 cm of the surface have been excluded, suggesting that these are Entisols.

Item 4 of the 1978 Andisols proposal is intended to clarify the classification of the Eutrandepts of Hawaii. This was eliminated in the 1983 proposal because the definition is complicated and the NaF test used is debatable particularly when the soils are calcareous. The Waimea soils in Hawaii classified as Typic Eutrandepts illustrates this case. It meets the bulk density and pH in NaF requirement but fails to

satisfy the P-retention and water retention requirements.

Recel (1980) proposed two alternatives in deciding the placement of these soils.

In the first case, since the Waimea soils fell short of the P-retention and the 15-bar water retention requirements and barely met the pH in NaF test, they may be excluded from the Andisols. In the second case, the Waimea soils may be accommodated for the reason that these soils behave very much like Andisols (Uehara, personal communication). This can be done by requiring a 15-bar water retention of undried fine earth of 40% or more; or a ratio of 15-bar water to exchangeable bases of 1.5 or less; and the pH in NaF $>$ 9.4. On this basis, the second alternative is suggested.

It was suggested in the 1983 proposal that the pH in NaF should be excluded as one of the criteria that define the andic and vitric properties.

Here the andic and vitric properties are suggested to take the place of ECDAM. In this case andic soil properties are defined as materials that have:

1. A bulk density of 1/3 bar water retention of the fine earth fraction of less than 0.9 g/cm^3.
2. A phosphate retention value of more than 85%
3. Either an acid oxalate extractable Al value of 2.0% or more, or a 4 M KOH extractable Al value of 1.5% or more.

Vitric soil properties, on the other hand, are one in which the soil material has —

1. More than 60% cinder, pumice or pumice-like material by volume of the whole soil or more than 40% volcanic glass by weight of the sand fraction (0.05-2mm)
2. Either an acid-oxalate extractable Al value of 0.4% or more, or a 4 M KOH extractable Al value of 0.3% or more.

Here andic soil properties is proposed to define the more weathered Andisols. It satisfies three conditions: one physical, and one chemical with strong soil fertility implications. It was developed from the proposed definition of ECDAM by Blakemore. Bulk density is retained as a criterion, but the limit of $<$ 0.85 is changed to $<$ 0.9 g/cm^3. Tests showed that the P-retention criterion is consistent and provides the additional advantage of a direct significance to soil fertility.

The intent of using bulk density is that its low value is associated with the porous character of amorphous volcanic ash material (Kanno, 1962) and high organic matter content (Swindale, 1965). Hence, the purpose of P-retention is to separate the amorphous material from the organic material, when the P-retention value of organic materials is relatively lower than those of amorphous materials. The pH in NaF is another indicator of the dominance of short-range order materials (SROM) in the exchange complex.

The vitric soil property will be used to characterize the younger Andisols. It satisfies two conditions: a mineralogical and chemical proper-

ty. The definition has been developed from the provisions of Item 3 of the 1978 Andisol definition. The first requirement is restricted to cinders, pumice or pumice-like material, or volcanic glass. The second requirement is the extractable Al which is suggested to replace the pH in NaF test. The latter, however, has not been discarded entirely because it can be measured quickly and cheaply. There are, however, many sources of errors in the methodology that has to be corrected so that the value of extractable Al appears to be more unique for the Andisols, and it is reported to satisfactorily discriminate the Andisols from the relatively unweathered soils on volcanic ash or the Entisols.

Briefly, it may be said that the andic/vitric concept has been developed to replace the ECDAM mainly because of the lack of consensus on the definition of an amorphous material and lately, because of the exclusion of the pH in NaF criterion.

Amorphic mineralogy is also suggested in Soil Taxonomy in order to accommodate some soils of other orders which are excluded from Andisols and from andic subgroups by bulk density requirements, but may have enough "amorphous materials" to have a pH of 11 or more in NaF and have P-retention values > 90% (ICOMAND CL No. 5, 1983). Its placement in the key to Mineralogy class *Soil Taxonomy* p. 387 is immediately after the gypsic mineralogy.

Amorphic class is proposed to be defined as: *Enough active aluminum to have an acid oxalate extractable Al value of more than 1% throughout the control section in the whole soil less than 2 mm in diameter.*

PROPOSED SUBORDERS

In the original proposal of Smith (1978) six suborders were provided such as "Aqu", "Bor", "Ust", "Trop", and "Ud".

The 1983 proposal excluded the "Trop" taxon but included two new others. The main objection to the "Trop" taxon is that it is used redundantly at the suborder and family level. Furthermore, there is little room for subdivision of Andisols in some small tropical countries because almost all would be placed as Tropands.

Suborder Alland was introduced to separate the soils having low pH, high extractable acidity, and high aluminum saturation in the upper part of the solum. Al toxicity is reported in these soils. Al content, therefore, is an appropriate criterion because these soils are infertile and difficult to manage. They are reportedly distinctive in Japan and they are expected to occur in other regions of the world (ICOMAND CL No. 5, 1983).

Suborder Torrands was also included based on experiences in Syria. These soils are formed from volcanic ash, aeolian silt, and alluvium. They have a calcic horizon, pH in NaF > 9.4 and 60% or more cinders or other vitric pyroclastic materials. However, it should be tested to determine any significant extent.

Proposed Great Groups

The proposed great groups of Andisols are shown in Table 1. There are eight great groups provided in Andisols, and the number varies in the different suborders (ICOMAND CL No. 5, 1983).

Table 1. The proposed great groups of Andisols

Suborders	Aquands	Allands	Borands	Torrands	Xerands	Ustands	Udands
Great Groups							
Trop	1						3
Dur	2				1	1	
Vitr	3		3	1	2	2	5
Melan	4	1	1				4
Hapl	5	2	4	2	3	3	6
Cry			2				
Plac			3				1
Hydr							2

Subgroups

Currently, the proposed classification of Andisols has not yet extended in the subgroup level. More data representing various parts of the world has yet to be assembled to achieve ; end.

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Alfisols and Ultisols

RODRIGO B. BADAYOS

Alfisols

Alfisols include those soils that have an argillic horizon with a high base saturation. They are generally moist. From the old USDA schemes and other classification systems, Alfisols are named as Gray-Brown Podzolic, Gray Wooded, Noncalcic Brown, Degraded Chernozem, Associated Planosols and Half Bog, Terra Rossa Estruturada, Eutric Red-Yellow Podzolics, Latosols, and Lateritic soils.

Buol, Hole, and McCracken (1973) summarized the processes that may contribute to the formation of Alfisols, as follows:

1. Concentration of clay in the Bt by mere removal of carbonates from the initial materials of that horizon
2. Eluviation of initial (and progressively added eolian) clay from the A horizon
3. Illuviation of clay into the Bt horizon
4. Formation of clay in the B by weathering of feldspars, micas, and ferromagnesian minerals
5. Differential loss by leaching of materials, so that A is more depleted, particularly in clay, than is the Bt, but both are depleted
6. Initial arrangement of a coarse material over a fine material, producing a pseudo profile resembling that of a bona fide Alfisol

From the above processes, it appears that clay formation and their subsequent translocation to the B horizon is a prerequisite to the development of Alfisols. It follows, therefore, that Alfisols would require a humid climate, as well as warm temperature; for they both favor the faster weathering of primary minerals. Also, at some period in a year, water in excess of the field capacity must be available in order to move clay from the A to the B horizon. Indeed in temperate regions, Alfisols are most extensive in humid and sub-humid land surfaces that have been stable and relatively free of pedoturbations and erosion for long periods of time. In the tropics, Alfisols together with Ultisols and Oxisols are associated with udic or rainy areas.

Alfisols are commonly associated with forest vegetation. In forested areas, trees deliver the bulk of their annual production of organic matter above ground, including the litter which is not as deeply incorporated as in grass-covered soils. Melanization is not substantial enough to form mollic epipedon. Where podsolization is favored as in areas with coniferous trees, Alfisols may show albic horizon overlying the argillic horizon.

The higher base saturation of Alfisols relative to Ultisols, indicates that leaching of bases in Alfisols is still not so extensive. Biocycling of nutrients from subsoil to O and A1 horizon can also keep the bases of the surface horizon of Alfisols at higher level.

Generally, Alfisols in temperate countries have the following genetic horizon sequence, namely: A1/A2/Bt. There are several soils in the Philippines that are now classified as Alfisol. These include Lipa, Annam, Ibaan, Bolinao, and Catbalogan. Compared with the typical Alfisols in temperate countries, these soils do not have the albic (A2) horizon. Parent materials of Alfisols in the Philippines vary from igneous rock (Annam-basaltic to andesitic), volcanic tuff (Lipa and Ibaan), limestone (Bolinao), to sandstone of mixed mineralogy (Catbalogan). Like other Alfisols, they are mostly found in relatively stable landscape under grassland, if not grown to commercial crops or under virgin forest. Alfisols are considered as the best upland soils here in the Philippines. The relatively high base saturation of the pedon and the presence of notable reserves of plant nutrients indicate the outstanding fertility of these soils. Appendix 1 shows a typical characteristics of the Ibaan series.

Alfisols are divided into five suborders, namely:

1. Aqualfs are Alfisols that have aquic moisture regime, or if artificially drained may show evidence of former wetness, such as mottles, low chroma, and Fe-Mn concretions greater than 2 mm in diameter.
2. Boralfs are those found in cool areas (mean annual soil temperature is less than 8°C).
3. Ustalfs are found in areas with ustic moisture regime. Annually Ustalfs are dry for less than 60 consecutive days.
4. Xeralfs are those Alfisols in areas that have wet winter and dry summer.
5. Udalfs are Alfisols that have udic moisture regime.

Subdivision of these five suborders to great groups are mostly based on the following factors: mean summer soil temperature at 50 cm and range of soil temperature between summer and winter (e.g. Tropaqualfs); tonguing of A2 into Bt, such as in Glossudalfs; abruptness of A2/Bt transition, such as in Albaqualfs where textural change from albic to argillic horizon is quite abrupt; thickness of Bt; reddish hue of Bt (e.g., Rhodustalfs); presence or absence of fragipan, duripan, natric, or petrocalcic horizon; presence or absence of iron nodules or plinthite; and percent base saturation in the Bt.

Common formative elements used to describe the subgroups of Alfisols reflect the relationship of these soils with other orders. Some of the formative elements used in Alfisol subgroups include Aeric, Arenic, Mollic, Vertic, Udollic, Umbric, Abruptic, Andeptic, Aquic, Lithic, and Psamments.

Ultisols

Ultisols are similar to Alfisols in having the argillic horizon. They differ from Alfisols in having a low base saturation (less than 35%) at 125 cm below the top of the argillic horizon or 180 cm below the surface.

Ultisols from the old USDA schemes and other classification systems are called Red Yellow Podzolics, Reddish Brown Lateritic, Humic Latosols, Associated Planasols, Half Bogs, Latosols, Lateritic soils, Terra Rossa, and Ground-Water Laterites.

The presence of the argillic horizon and the low base saturation of most Ultisols are indicative of an extensive leaching in these groups of soils. Ultisols are mostly associated with humid areas where the mean annual soil temperature is above 8°C. Where leaching of Fe on the surface horizon is favored, Ultisols may develop an albic horizon overlying the argillic horizon. Because of extensive leaching coupled with high temperature, there is a rapid alteration of weatherable minerals into secondary clays and oxides which account for the reddish color of most Ultisols. Most often kaolinite dominates the type of clay in Ultisols, with some amount of gibbsite and intergrades of chlorite-vermiculite.

The recycling of bases of plants may somehow counteract the total leaching of bases in the Ultisols, resulting in partial enrichment of bases in the surface horizon.

In the field, Ultisols generally show a light-colored surface horizon with a slight darkening through melanization.

Under a tropical climate, Ultisols are associated with Oxisols, with Oxisols occupying the older land surface. They are also associated with Alfisols and Entisols in areas where sediments are too young for Oxisols to form. Two of the most extensive Ultisols here in the Philippines are the Luisiana and Adtuyon soil series. They are generally thick and have a strongly developed structure. The reddish color, especially in the argillic horizon, is quite prominent in these soils. Most of these soils are under grassland if not grown to perennial crops or under forest vegetation. The low fertility and low base status of Ultisols are still the major problems when it comes to utilizing these group of soils for agriculture, especially in the developing countries like ours.

Ultisols are subdivided into five suborders on the basis of profile wetness and organic matter content. Ultisols that are either saturated with water at some period of the year or are artificially drained are grouped under Aquults. As an indication of wetness, Aquults may show mottles, iron-manganese concretions larger than 2 mm in diameter, or chroma of 2 or less below any Ap or A2 horizon. Humults are Ultisols that have high organic matter contents and do not have other characteristics of wetness. They contain more than 2.5% organic matter in the upper 15 cm of the argillic horizon. Udults are Ultisols that have udic moisture regime. In most of these soils, water table remains below the solum most of the year. Ustults are Ultisols that are dry for 90 or more cumulative days in some layers between 18 cm and 50 cm in most years. Because of a longer dry period, Ustults are generally low in organic matter. Xerults are Ultisols in areas where the rainy period coincide with a colder temperature, while summer is relatively dry.

Appendix 2 shows the typical characteristics of Luisiana which is quite extensive in the hilly to mountainous areas here in the Philippines.

Appendix 1. Typical characteristics of Ibaan soil series[a]

Series Name: *Ibaan*
Classification: *Typic Tropudalf*
Location: *Bo. San Agustin, Ibaan, Batangas. About 1 km from San Agustin Elem. School going to Ibaan*
Parent Material: *Volcanic tuff*
Physiographic Position: *Upland plain*
Topography: *Undulating to slightly rolling*
Slope of profile site: *0-1%*
Climate: *Type I, 1185 mm annual rainfall*
Drainage: *Internal — well drained*
External — well drained
Vegetation: *Coconut, vegetables*

Morphology		
Horizon	Depth, cm	Profile Description
A1	0 — 15	Dark brown (7.5YR 3/2) moist, clay; moderate medium angular and subangular blocky to fine granular structure; sticky, plastic, and firm; common fine and medium roots; clear wavy boundary.
B2t	15 — 40	Brown to dark brown (7.5YR 5/4-4/3) moist, clay; moderate to strong medium and angular and subangular blocky structure; very sticky, very plastic, and very firm; few spherical yellowish brown tuff concretions; common medium and fine roots; clear wavy boundary.
B3	40 — 60	Very dark grayish brown (10YR 3/2) moist clay; moderate to strong medium angular blocky breaking into granular structure; sticky, plastic and firm; common fine and medium distinct clear dark yellowish brown (10YR 4/4) mottles; common soft and hard spherical and angular tuff concretions; few fine and very fine roots; gradual wavy boundary.
C	60 — 80	Very dark grayish brown (10YR 3/2) moist, clay; moderate to strong granular structure; sticky, plastic and firm; many yellowish and reddish brown highly and partially weathered tuff gravelly materials; very fine roots; abrupt smooth boundary.
R	80 — below	Hard tuff layer

[a]Source: Montecillo, L.A. Undated. Soil profile properties and classification. Mimeographed handout for Soil Science 210. University of the Philippines at Los Baños. 67 pp.

Profile properties of the Ibaan pedon

Properties	Horizon			
	A1	B2t	B3	C
Depth, cm	0 — 15	15 — 40	40 — 60	60 — 80
Particle size distribution				
Sand	14.6	9.3	19.1	27.6
Silt	36.0	18.9	28.7	24.8
Clay	49.4	71.8	52.2	47.6
Textural class	clay	clay	clay	clay
Bulk density, g/cm^3	1.18	1.09	1.09	0.83
pH (H_2O)	4.93	5.41	5.65	5.85
Organic matter, %	1.64	1.15	0.61	0.43
Available P, ppm	3.05	4.80	10.44	9.83
Exchangeable bases, me/100g				
K	0.96	0.16	0.19	0.16
Ca	15.04	21.39	28.91	19.98
Mg	11.99	10.82	11.04	18.10
Na	0.55	0.87	0.98	1.20
Sum of bases	28.54	33.24	41.12	39.44
CEC (NH_4OAc), meq/100g	49.13	61.08	57.13	60.98
BS (NH_4OAc), %	58.0	54.4	71.9	64.6

Appendix 2. Typical characteristics of Luisiana soil series[a]

Series name: *Luisiana*
Classification: *Orthoxic Tropudult*
Location: *Caliraya Plateau, Km 117 (Bo. San Salvador) about 4 km to Luisiana town, 270 m elevation*
Parent material: *Basalt-Andesite*
Physiographic Position: *Upland severely eroded*
Topography: *Rolling to hilly*
Slope of Profile Site: *8-12%*
Climate: *Type IV, 2250 mm annual rainfall*
Drainage: *Internal — well drained*
External — moderate
Vegetation: *Shrubs under coconut*

Horizon	Depth, cm	Profile Description
A1	0 — 7	Dark brown (7.5 YR 4/6) moist, clay loam; moderate fine and medium granular structure; sticky, plastic, friable and hard; many fine and medium roots; abrupt smooth boundary.
B21t	7 — 42	Reddish yellow (7.5 YR 6/6) moist, clay; strong fine and medium granular structure; very plastic, very sticky, friable and hard; few thin clay skins on vertical cracks; gradual smooth boundary.
B22t	42 — 62	Strong brown (7.5 YR 4/6) moist, clay; strong fine and medium columnar structure; sticky, plastic, friable, very hard; few fine and medium roots; gradual smooth boundary.

Horison	Depth, cm	Profile Description
B23t	62 — 117	Strong brown (7.5 YR 4/6) moist, clay; strong medium columnar structure; sticky, plastic, slightly friable and hard; few medium and coarse roots; diffuse smooth boundary.
B3	117 — 200	Yellowish red (5 YR 4/8) moist, clay, moderate to strong fine and medium columnar structure; sticky, slightly plastic, friable and hard; few medium and coarse roots; diffuse smooth boundary.
C	200 — below	Yellowish red (5 YR 4/6) moist, clay; moderate to strong fine and medium columnar structure; sticky, slightly plastic, friable and hard; few medium and coarse roots.

[a]Source: ibid

Profile properties of the Luisiana pedon

Properties	Horizon				
	A1	B21t	B22t	B23t	B3
Depth, cm	0-7	7-42	42-62	62-117	117-200
Particle size distribution, %					
Sand	18.2	16.8	16.5	13.9	15.8
Silt	27.2	21.0	22.5	19.6	17.7
Clay	54.6	62.2	61.0	66.5	66.5
Textural class	clay	clay	clay	clay	clay
Bulk density, g/cm^3	1.02	1.22	1.25	1.17	1.17
15 bar moisture, %	35.7	40.6	41.1	41.7	41.0
pH (H_2O)	4.9	4.9	4.8	5.1	4.9
Organic matter, %	4.14	1.33	0.86	0.42	0.31
Exchangeable bases, meq/100 g					
K	0.06	0.01	0.01	0.02	0.02
Ca	2.4	1.8	1.0	1.2	1.4
Mg	3.33	2.34	2.35	2.74	2.54
Na	0.01	0.01	0.01	0.02	0.02
Sum of bases	5.80	4.17	3.37	3.96	4.95
CEC (NH_4OAc), meq/100g	32.1	27.9	32.0	28.3	37.2
BS, %	18.0	14.9	10.5	14.1	10.6

Inceptisols

MODESTO R. RECEL

Inceptisols occur in a wide range of latitudes having subhumid to humid climates on old, as well as on young, surfaces where the precipitation exceeds potential evapotranspiration every month. In areas where evapotranspiration exceeds precipitation at some time of the year. Inceptisols are restricted to post-pleistocene surfaces. Those on old surfaces develop where cold temperature slow down the decomposition of minerals, thus inhibiting the rapid process of soil development; while those on young surfaces, such as the recently accumulated alluvial deposits, form fast enough to develop clear pedogenic horizons.

Some important features of areas where Inceptisols occur include a highly resistant parent material, abundance of volcanic ash, steep lands and depressions, and young geomorphic surfaces where soil development is limited (Buol, et al. 1973).

Inceptisols are permitted to have many kinds of diagnostic horizons but not an argillic, spodic, oxic, gypsic, petrogypsic, salic, shallow plinthite, and natric horizons. They may have any kind of epipedon although the mollic epipedon is rare. Commonly they have an ochric epipedon over a cambic horizon with or without any underlying fragipan, or an umbric epipedon overlying a duripan or fragipan. They are the only soils having a plaggen epipedon.

Attributes of the Order

The unique properties of the Inceptisols are the altered horizons that have no illuvial horizon, enriched either with silicate that contain aluminum or with an amorphous mixtures of aluminum and organic carbon. The clay fraction has moderate to high cation retention capacity. They contain an appreciable amount of weatherable minerals and have a soil texture finer than loamy sand.

The complete definition of the Inceptisols may be found in Soil Taxonomy (1975), pages 227-228 and the succeeding discussion is adopted from these pages.

Limits Between Some Other Orders

Inceptisols are distinguished from Alfisols by the absence of an argillic or natric horizon, unless it is a buried soil horizon, or the absence of a fragipan that has 1 mm thick of clay skins in some part.

They are distinguished from the Entisols in having an Exchange Complex Dominated by Amorphous Materials (ECDAM), or an n value of 0.7 or less, or less than 8% clay. They must not have any sulfidic materials within 50 cm of the mineral soil surface and must have one or more of the permissible diagnostic horizons.

Suborders

The Inceptisols have six suborders, although the Andepts are proposed to be elevated to the order category as Andisols.

The Aquepts are Inceptisols that are identified with their characteristic wetness; the Andepts for their low bulk density or their high contents of vitric volcanic ash, cinders or other pyroclastic materials; the Plaggepts for their plaggen epipedon; the Tropepts for their warm humid temperature regime; and the Ochrepts for their ochric epipedon or an umbric or mollic epipedon of less than 25 cm thick and a mesic or warmer soil temperature regime. All others that do not meet the above characteristics are the Umbrepts. The classification of the plaggepts, however, has not been developed because they do not occur in the U.S.A.

The Great Groups

The Inceptisols are provided with 18 great groups (Table 1). Here, the numbers indicate the sequence of their placement in the key to the great groups.

The "Frag" great groups have a brittle pan in the subsurface which are management limitations in the "Aqu", "Ochr", and "Umbr" subgroups.

The pan in the "Dur" great groups is usually massive and interferes with the development of most roots and water movement although it is relatively not strongly indurated as those in the other orders.

Table 1. The Great Groups in Inceptisols

	Suborders					
Great Groups	Aqu	And	Plagg	Trop	Ochr	Umber
Frag	4				1	1
Dur		2			2	
Cry	5	1			3	2
Ust				3	4	
Xer					5	3
Hydr		3				
Plac	2	4				
Eutr		6		4	6	
Dystr		7		5	7	
Virt		5				
Sulf	1					
Hala	3					
Plinth	6					
And	7					
Huma	9			1		
Trop	8					
Sombr				2		
Hapl	10					4

The "Cry" great groups are in the suborders "Aqu", "And", "Ochr" and "Umbr". They are the soils having cryic or pergelic soil temperature regime.

The "Ust" great groups are in the suborders "Trop" and "Ochr". They are recognized by their ustic moisture regime and a base saturation of 50% or more at certain depths.

The "Xer" great groups are in the "Ochr", and in the "Umbr" suborders. They are identified with a xeric soil moisture regime.

The "Hydr" great groups are only in the suborder "And". They are associated with a very high, well-distributed rainfall, and a perudic soil moisture regime.

The "Plac" great groups are only in the suborders "Aqu" and "And". They are identified with a placic horizon which is normally located within 25-50 cm of the mineral soil surface. They are associated with very humid climates and evenly distributed rainfall throughout the year or with no dry season.

The "Eutr" great groups are in the suborders "And", "Trop", and "Ochr". They have a base saturation $>$ 50% in some or in all subhorizons. The Eutrochrepts, however, must have $\geqslant$ 60% base saturation because their parent material is usually calcareous.

The "Dyster" great groups are in the same suborders as those in the "Eutr" great groups. They are identified with a base saturation $<$ 50% or $<$ 60% in the case of the "Ochr" suborders.

The "Vitr" great groups are only in the suborder "And". They are associated with areas with a 15-bar water retention $<$ 20% in the fine-earth fraction of the whole soil at certain days.

The "Sulf" great groups are only in the "Aqu" great groups. They are the acid sulfate soils which are usually found in drained coastal marshes near the mouths of rivers that are almost free of carbonates. Their classification has not been fully developed.

The "Hala" great group is only in the "Aqu" surborder. This consists of soils with a shallow ground water wherein capillary rise and evapotranspiration result in the deposits of sodium or other salts in the surface. They are the sodic or saline soils that are identified with $\geqslant$ 13 sodium adsorption ratio (SAR) or sodium saturation of $\geqslant$ 15%.

The "Plinth" great group is only in the "Aqu" suborder. It is identified with a plinthite that forms a continuous phase or constitute more than half the matrix within some subhorizon at 30 cm-125 cm of the soil surface.

The "And" great group is only in the "Aqu" suborder. It has an SAR $<$ 13 or $<$ 15% sodium saturation with a bulk density of $<$ 0.85 g/cm^3 (at 1/3-bar water retention) of the fine earth fraction and an exchange complex dominated by amorphous materials.

The "Hum" great groups are in the suborders "Aqu" and "Trop". They have an umbric, a mollic, or a histic epipedon in the "Aqu" suborder or a base saturation $<$ 50% but have $\geqslant$ 12 kg organic carbon

in the "Trop" suborder.

The "Trop" great group is only in the suborder "Aqu". It has an isomesic or warmer iso temperature regime but the soil temperature regime is not a constraint to soil use.

The "Sombr" great group is only in the suborder "Trop". It is recognized by the presence of a sombric horizon. The classification of the soil has not been fully developed.

The "Hapl" great groups are in the suborder "Aqu" and "Umbr". They are the soils that do not have the diagnostic properties of the other great groups.

The Subgroups

Following the great group in the key is the subgroup category. Here, the subgroup name consists of the great group name that is modified by one or more adjectives which indicate that they are integrades or extragrades.

The intergrades have properties of their great group including some properties of another taxon, while the extragrades indicate the nature of the aberrant properties.

The number of subgroups of the order Inceptisols is too many to permit a detailed discussion of each. There are 40 subgroups, excluding those having multiple subgroup names.

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Entisols

MODESTO R. RECEL

The Entisols are mineral soils with an AC profile set-up. They are extensive in the inter-tropical region and occupy about 20% of the earth's land area (Buol, et al. 1973). These soils show little or no evidence of development of pedogenic horizons. Horizons have not been formed because time has been too short. Some of these soils are steep and actively eroding, while others are on flood plains that frequently receive new deposits of alluvium. There are also some Entisols that are very old, the parent material of which, is mainly quartz or other resistant minerals that do not alter to form horizons. However, buried horizons may be permitted if they are 50 cm or more deep. They do not have the combination of pergelic temperature regime and an aquic or peraquic moisture regime.

The succeeding material is adopted from Soil Taxonomy, pages 197-209.

The Entisols are defined as mineral soils that meet requirement 3 and either 1 or 2:

1. They have sulfidic materials, within 50 cm of the mineral soil surface, or above a layer that is frozen about two months after the summer solstice, or have an *n* value of more than 0.7 and more than 8% clay in all subhorizons between 20 and 50 cm below the mineral surface and do not have a permafrost;

2. They do not have a diagnostic horizon, unless it is a buried horizon other than an orchric epipedon and anthropic epipedon, a histic epipedon consisting of organic materials, an albic horizon, a spodic horizon that has its upper boundary deeper than 2 m, or the amorphous material is not dominant in the exchange complex; and may have any of the following subject to the requirements stated:

- A salic horizon, except that, if the soil is saturated with water within 1 m of the surface for one month or more in some years and has not been irrigated, the upper boundary of the salic horizon must be 75 cm or more below the surface;
- If the soil is saturated with water within 1 m of the surface for 1 month or more when not frozen in any part, the sodium adsorption ratio (SAR) may exceed 13% (or sodium saturation, 15%) in more than half of the upper 50 cm only if SAR increases or remains constant with depth below 50 cm;
- A calcic or gypsic horizon or duripan if its upper boundary is more than 1 m below the surface (these are presumed to be buried soil horizons or layers of geologic origin);
- If the texture is loamy fine sand or coarser to a depth of 1 m; plinthite may be present in the form of discrete nodules or discon-

nected soft red mottles if it constitutes less than half the volume in all subhorizons;

- Buried diagnostic horizons may be present if the surface of the buried soil is at a depth between 30 and 50 cm and the thickness of the buried soil is less than twice the thickness of the overlying deposits, or if the surface of the buried soil is deeper than 50 cm; or
- Ironstone at any depth.

3. If the soil temperature regime is mesic, isomesic, or warmer and if there are cracks in most years as wide as 1 cm at a depth of 50 cm when not irrigated, are Entisols if after the upper soil to a depth of 18 cm is mixed, have less than 30% or more clay in some subhorizon within a depth of 50 cm or do not have any of the following:

- Gilgai;
- At any depth between 25 cm and 1 m, wedge-shaped natural structural aggregates that have their long axes tilted 10°-60° from the horizontal; or
- At any depth between 25 cm and 1 m, slickensides close enough to intersect.

Different criteria are provided to separate the Entisols from all other orders.

1. The Entisols are distinguished from Alfisols by the absence of an argillic horizon, unless it is a buried horizon in the former.

2. The Entisols are distinguished from the Aridisols in not having the following:

- A salic horizon if its upper boundary is within 75 cm of the surface and the soil is saturated with water within 1 m of the surface for one month or more at some time of the year;
- A calcic or petrocalcic horizon, a gypsic or petrogypsic horizon, or a duripan, if the upper boundary of any of them is within 1 m of the surface, unless it is a buried horizon; or
- A cambic, argillic, or natric horizon, unless it is a buried soil horizon.

3. Entisols are distinguished from the Inceptisols by the following:

- They have one of the following:
  1. An *n* value of more than 0.7 and at least 8% clay in all subhorizons between a depth of 20 and 50 cm below the mineral surface without permafrost; or
  2. Sulfidic materials within a depth of 50 cm below the mineral surface.
- They do not have any of the following:
  1. A mollic, umbric, or plaggen epipedon;
  2. A histic epipedon consisting of minerals rather than organic soil materials;
  3. A calcic or petrocalcic horizon or a duripan if the upper boundary of any of them is within 1 m of the soil surface, unless it is a buried horizon;

4. A cambic horizon;
5. A fragipan;
6. A sulfuric horizon that has its upper boundary within 50 cm of the mineral soil surface; or
7. Sodium saturation that is more than 15% in more than half of the upper 50 cm, unless the sodium saturation increases or remains constant with depth or unless the soil is not saturated with water within 1 m of the surface for as long as 1 month at a season when the soil is not frozen in any part.

4. Entisols are distinguished from Histosols by meeting the definition for mineral soils.

5. To distinguish Entisols from Mollisols, Entisols must not have a mollic epipedon.

6. To distinguish Entisols from Oxisols, Entisols must not have an oxic horizon and must not have plinthite that forms a continuous phase within 30 cm of the surface of the soil, if the soil is saturated with water at sometime of the year within that depth.

7. To distinguish Entisols from Spodosols, Entisols must not have a spodic horizon that has its upper boundary within 2 m of the surface of the soil.

8. To distinguish Entisols from Ultisols, Entisols must not have an argillic horizon, unless it is a buried soil horizon.

9. To distinguish Entisols from Vertisols, Entisols must have a frigid or colder temperature regime, or must meet one or both of the following requirements:

- Must not have cracks that are as wide as 1 cm at a depth of 50 cm in most years; or
- Either:
  1. After the surface soil to a depth of 18 cm is mixed, have $<$ 30% clay in some subhorizons above a depth of 50 cm; or
  2. Do not have gilgai, do not have slickensides close enough to intersect, and do not have wedge-shaped peds that have their long axes tilted 10°-60° from the horizontal.

The Suborders

The Entisols have five suborders. They are the Aquents, Arents, Psamments, Fluvents, and Orthents.

The *Aquents* as the taxon "Aqu" indicate, are the Entisols that have aquic or peraquic soil moisture regime. They are continuously saturated with water, such as those in tidal marshes, in deltas or soils saturated at some time of the year.

The *Arents* are the Entisols that are deprived of horizons because they are deeply mixed by plowing, spading or movement of human activity. Unlike the other suborders, the Arents do not have great groups and typic subgroup.

The *Psamments* are the Entisols that have, at a certain depth, 35% by volume of rock fragments and have a loamy fine sand or coarser in

all subhorizons. They are poorly graded (well sorted) sands of shifting or stabilized sand dunes. When dry and bare, they are subject to blowing and drifting and could hardly support wheeled vehicles.

The *Fluvents* are the Entisols that form in recent sediments deposited by water that have organic carbon content that decreases regularly with depth if the texture is homogenous. They can have any vegetation, any moisture regime, and any temperature regime, except pergelic. They are the alluvial soils in the 1938 classification.

The *Orthents* are the Entisols that do not have the diagnostic properties defining the other suborders. They are on recent erosional surfaces.

The Great Groups

The 12 great groups of the order Entisols are summarized in Table 1. The number of great groups varies from one suborder to another while the numbers in the Table indicate their sequences in the key.

The general description of the great groups are as follows:

The "Sulf" great group is only in the suborder Aquents. They are recognized by the presence of sulfide materials within 50 cm of the mineral soil surface.

The "Hydr" great group is only in the suborder "Aqu". They have an *n* value of > 0.7 and have at least 8% clay in all subhorizons between a certain depth. They must have a mean annual soil temperature $> 0°C$.

The "Cry" great groups are in the suborder Aquent, Psamments, Fluvents, and Orthents. They are the cold wet soils of high mountains or tundra without permafrost or of cold coastal marshes. They are generally identified with a cryic soil temperature regime. The Pergelic temperature is not permitted in the Aquents and Fluvents but allowed in the Psamments.

The "Fluv" great group is only in the suborder Aquents. They are commonly identified with a soil temperature regime warmer than cryic,

Table 1. The great groups in Entisols

	Suborders				
Great Group	Aquents	Arents	Psamments	Fluvents	Orthents
Sulf	1				
Hydr	2				
Cry	3		1	1	1
Fluv	4				
Trop	5		5	5	4
Psamm	6				
Hapl	7				
Torr			2	4	2
Quartz			3		
Ud			4	6	5
Xer			6	2	3
Ust			7	3	6

an *n* value of 0.7 or less, or have a clay content less than 8% at a certain depth. Certain textural limit and organic carbon content are also required to firm up their identification.

The "Trop" great groups are in the Aquents, Psamments, Fluvents, and Orthents. (The definition of the Tropaquents has not been tested and is provisional). They are commonly identified with an iso temperature regime. The Tropaquents. on the other hand, are the permanently warm and wet soils in depressions of intertropical regions, while the Tropopsamments have udic soil moisture regime (This classification is still provisional and incomplete).

The "Psamm" great group is only in the suborder Aquents. They are characterized with a sandy texture and the water table is at or near the surface for long periods unless they are artificially drained.

The "Torr" great groups are in the suborder Psamments, Fluvents, and Orthents. They have arid climates and are identified with a torric soil moisture regime.

The "Quartz" great group is in the suborder Psamments. They are the freely drained quartz sand of humid to semi-arid regions in mid or low latitudes. They are identified with a sand fractions that is 95% or more quartz, zircon, tourmaline, rutile, and other non-weatherable minerals.

The "Ud" great groups are in the suborders Psamments, Fluvents, and Orthents. They are commonly identified with a udic soil moisture regime and are usually found in humid regions in the middle latitudes.

The "Xer" great groups are in the suborders Psamments, Fluvents, and Orthents. They are commonly identified with a xeric soil moisture regime.

The "Ust" great groups are in the suborders Psamments, Fluvents, and Orthents. They are recognized by their ustic soil moisture regime.

The Subgroups

The subgroup name is formed by the great group name that is modified by one or more adjectives. There are 29 subgroup names provided in Entisols, but no subgroups have been provided for the great groups "Sulf" and "Cry". Their classification in Soil Taxonomy is provisional. On the other hand, suborder Arents have no great groups, but two subgroups are provided.

Limit between Entisols and Oxisols

To distinguish Entisols from Oxisols, Entisols must not have an Oxic horizon and must not have Plinthite that forms a continuous phase within 30 cm of the surface of the soil if the soil is saturated with water at some time of the year within that depth.

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Principles of Soil Survey Interpretations

RONALD D. YECK

One of the strengths of a comprehensive soil classification system such as Soil Taxonomy is that the classification infers a large number of soil properties on which interpretations for use of that soil can be made. Although the soil classification, other than the series name, may not appear with the interpretations, the classification is the vehicle with which soil properties are systematically grouped for interpretation.

Although we will have examples of specific kinds of interpretations, we should be more concerned with the process and principles rather than the interpretations themselves. These interpretations were developed for uses of soils in the U.S., under U.S. climatic conditions. Your soil interpretations must be made for uses of soils in the Philippines, under Philippine climatic conditions.

The definition of soil survey interpretations is as follows: *Soil survey interpretations are predictions of soil behavior for specific land uses and specified management practices.*

Two salient points of the definition should be emphasized. First, interpretations are made for specified uses (i.e. woodland, local roads, and streets) and, if applicable, the level of management is specified. Management levels are especially important when the interpretation involves production systems, such as crop production.

The purpose of soil survey interpretation is to organize and present to land users information about soil properties and predictions of soil behavior, so that they can bring about effective and productive use and management of land and water resources.

Perhaps the central point of this purpose is that soil survey interpretation materials become useful and effective only through their application by land users. That is achieved only if the information is placed in the hands of the user in an organized, understandable, and convincing manner so it can and will be used.

The units on which interpretation are made are flexible. They may be made on taxonomic units or on map units. Commonly they are made for soil series and phases of series which are the taxonomic counterparts of mapping units. They may be made for map units as a whole or for components of map units.

Either generalized or specific interpretation may be made. Examples of general uses are cropland or urban development uses, whereas specific uses include irrigation of cropland or septic tank absorption fields. They are broadly grouped into agricultural and nonagricultural uses. Table 1 shows some examples of uses within each group.

Table 1. Examples of kinds of soil survey interpretation

General	Specific
Agriculture	
Cultivated crops	Erodibility
Forage crops	Suitability for drainage
Wood crops	Suitability for irrigation
Wildlife habitat	Terraces
General	**Specific**
Non-Agricultural	
Engineering	Septic systems
Camp areas	
Trails and paths	Corrosion of uncoated steel
Embankments	

First drafts of soil interpretation commonly originate at the local level where the most specific knowledge is available about soils that occur there. They are then reviewed at regional and state levels.

Tables are developed for uses of soils that list soil properties that may adversely affect the use specified. One example is Table 603-19 of the *USDA-SCS National Soils Handbook* (NSH). This table lists properties that relate primarily to excavation and stability, properties important for road construction and road stability. Another example is shown in NSH Table 603-29, which lists properties important to soil drainage. In this table, in addition to depth and stability factors, a number of chemical properties are considered, since they adversely affect plant growth on the drained sites. For all soils in a given area, tables are developed to show interpretation for each soil. Interpretations are for the soil uses important in that area.

Another rating system that can be used to supplement or, in some cases, replace the one just discussed is the soil potentials system. The definition of soil potential ratings is as follows: *Soil potential rating are classes that indicate the relative quality of a soil for a particular use compared with other soils in a given area. Yield or performance levels and relative costs of overcoming limitations are primary features of this system. It is intended to be a positive approach for use of soils, despite the limitations that occur in some soils for specified uses.*

The purpose of the potential ratings system is stated as follows:

Soil potential ratings are developed primarily for planning purposes and are not intended as recommendations for soil use.

Table 603-19. Local roads and streets

Property	Limits			Restrictive Feature
	Slight	Moderate	Severe	
USDA Texture	—	—	Ice	Permafrost
Total Subsidence	—	—	>12	Subsides
Depth to Bedrock (in):				Depth to Rock
Hard	>40	20-40	<20	
Soft	>20	<20	—	
Depth to Cemented Pan (in):				Cemented Pan
Thick	>40	20-40	<20	
Thin	>20	<20	—	
[9] Shrink-Swell	Low	Moderate	High, Very High	Shrink-Swell
[5, 9, 10] AASHTO Group Index Number	<5	5-8	>8	Low Strength
Depth to High Water Table (ft)	—	—	+	Ponding
	>2.5	1.0-2.5	<1.0	Wetness
Slope (Pct)	<8	8-15	>15	Slope
Flooding	None	Rare	Common	Flooding
Potential Frost Action	Low	Moderate	High	Frost Action
[1] Fraction > 3 in (Wt Pct)	<25	25-50	>50	Large Stones
Downslope Movement	—	—	II	Slippage
Formation of Pits	—	—	III	Pitting
Differential Settling	—	—	V	Unstable Fill

[1] Weighted average to 40 inches.
[5] If in kaolinitic family, rate one class better if experience confirms.
[9] Thickest layer between 10 and 40 inches.
[10] GIN = (F-35)[.2 + .005 (LL-40)] + .01 (F-15) (PI-10) where F = % passing No. 200 sieve. If F ≤ 35 and PI ≥ II, use only part 2 of equation. Use median values.
[II] If the soil is susceptible to movement downslope when loaded, excavated, or wet, rate "SEVERE-SLIPPAGE."
[III] If the soil is susceptible to the formation of pits caused by the melting of ground ice when the ground cover is removed, rate "SEVERE-PITTING."
[V] If the soil is susceptible to differential settling, rate "SEVERE-UNSTABLE FILL."

Table 603-29. Drainage.

Property	Limits	Restrictive Feature
USDA Texture	Ice	Permafrost
[26]Depth to High Water Table (ft)	>3 [IX]	Deep to Water Ponding
Permeability (in/hr) (0-40")	<0.2	Percs Slowly
Depth to Bedrock (in)	<40	Depth to Rock
Depth to Cemented Pan (in)	<40	Cemented Pan
Flooding	Common	Flooding
Total Subsidence	Any Entry	Subsides
[6] Fraction>3 in (Wt PCT)	>25	Large Stones
Potential Frost Action	High	Frost Action
Slope (PCT)	>3	Slope
[6] USDA Texture	COS, S, FS, VFS, LCOS, LS, LFS, LVFS, SG, G	Cutbanks Cave
Salinity (mmhos/cm) (any depth)	>6	Excess Salt
Sodium Adsorption Ratio (0-40") or Great Group Or Phase)	>12 (Natric, Halic, Alkali Phases)	Excess Sodium
Sulfidic Materials (Great Group)	Sulfaquents, Sulfihemists	Excess Sulfur
Soil Reaction (pH) (Any Depth)	<3.6	Too Acid
Downslope Movement	[X]	Slippage
Complex Landscape	[XI]	Complex Slope
Availability of Outlets	[XII]	Poor Outlets
	None of above	Favorable

[6] Thickest layer between 10 and 60 inches.
[26] If DEEP TO WATER, disregard other properties.
[IX] If irrigated, consider other restrictive features if the water table is between 3 and 5 feet.
[X] If the soil is susceptible to movement downslope when loaded, excavated, or wet, list "SLIPPAGE" as a restrictive feature.
[XI] If complex and irregular slopes cause difficulty in design, installation, or functioning of the system, list "COMPLEX SLOPE" as a restrictive feature.
[XII] If good outlets are difficult to find, list "POOR OUTLETS" as a restrictive feature

A number of positive features of this system are listed below:

- identify corrective measures needed to overcome limitations
- enable local preparation of soil interpretations
- provide information that emphasizes feasibility instead of avoidance of problems
- make soil surveys and related information more applicable and easily used in resource planning.

It should be emphasized that these ratings are tailored to local conditions and technologies and thus may be different from one location to another.

The components for developing the potential ratings are expressed as —

$$SPI = P - (CM + CL)$$

where:

SPI = soil potential rating
P = performance
CM = corrective measures
CL = continuing limitations

Corrective measures are the initial requirements to overcome soil limitations for a given use, and continuing limitations continue as long as the soil is used for the designated purposes. These factors are expressed on a common basis. For example, if performance is expressed as yield, say kilograms of corn per hectare per year, the CM and CL costs are also expressed in terms of kilograms of corn per year. This can best be shown by an example. Exhibit 603-9 of the NSH shows a worksheet for preparing soil potential ratings for woodland production and exhibit 603-8 explains the worksheet. The standard yield of 130 ft^3/yr, is indexed at 100. Soils in a given area are rated qualitatively and arrayed in the manner shown in exhibit 603-8 of the NSH. This, and perhaps any interpretation system is most successful when local users are convinced that it is a creditable and useful system.

In summary, two approaches to developing and presenting soil survey interpretations have been discussed. First, the traditional rating system that points out limitations for specified uses of soils; and secondly, the potential rating system which emphasizes feasibility of soil use for a specified purpose.

Also, in closing, we should emphasize that perhaps soil survey interpretations is the most practical and productive manifestation of soil survey and soil classification activities. Additionally, since it requires the incorporation of knowledge from technical areas related, but not part of soils (agronomy, engineering, etc), perhaps nowhere else in the soil survey program is there a greater need for an interdiciplinary approach and cooperation.

Reference: USDA-SCS National Soils Handbook (NSH) 430-VI-NSH, July 1983, 222 pp.

Exhibit 603-8. Explanation of worksheets for preparing soil potential ratings (woodland-Beta County)

A worksheet is prepared for each soil map unit.

The yield standard (130) is adjusted to a performance standard Index of 100 to provide a range of soil potential indexes from 0 to 100. Productivity of 130 cubic feet per acre (loblolly pine, site index 90) meets the performance standard index of 100; e.g., the Guyton and Ruston map units. Productivity of 110 cubic feet per acre (loblolly pine, site index 80) is substandard performance (110/130 x 100 = 85) and is considered a continuing limitation if corrective measures fail to overcome the yield limitation; e.g., the Alaga and Cadeville map units. Productivity of 152 cubic feet per acre (loblolly pine, site index 100) is performance above the yield standard (Quachita map unit). To reflect this yield level, SPI is increased by 17 (152 — 130/130 X 100 = 17).

Enter evaluation factors from table of raising criteria prepared for the soil use (exhibit 603-3).

Enter soil and site conditions for the map unit for each evaluation factor. Enter the degree of limitation from the table of evaluation criteria (exhibit 603-3).

Enter effects of the soil and site conditions to serve as a basis for identification of corrective measures.

Enter feasible alternative measures for overcoming the effects of limiting soil or site conditions. Technical guides are useful references. Note that measures are identified wherever possible to overcome effects of limitations in preference to carrying the problems on to unresolved continuing limitations.

In this example, index values for measures and continuing limitations are a percentage of the value of the harvested crops. Whether the costs occur only one time or several times in the period between planting and harvest is considered.

The factor that accounts for substandard yield of the Cadeville soil is not known. The substandard yield is noted as a continuing limitation without relation to a soil factor.

Index values for corrective measures (CM) and continuing limitations (CL) are summed for deduction from the performance standard index (P) to determine the soil potential index (SPI).

The soil potential indexes are arrayed from high to low, and ratings assigned as follows:

SPI	Rating	Soil map unit
116	Very high	Ouachita silt loam
100	High	Ruston fine sandy loam, 1 to 3 percent slope
85	High	Guyton silt loam
78	Medium	Alaga loamy fine sand, 8 to 13 percent slope
77	Medium	Cadeville fine sandy loam, 15 to 25 percent slope

Exhibit 603-9. Worksheet for preparing soil potential ratings (woodland-Beta County)

Soil Use: Woodland — Area: Beta County

Mapping Unit: Cadeville fine sandy loam, 15 to 25 percent slope — Yield standard 130 ft^3/ac/yr; Yield estimate 110 ft^3/ac/yr

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures: Kinds	Corrective Measures: Index	Continuing Limitations: Kind	Continuing Limitations: Index
Slope (percent)	15-25%	Moderate	Equipment limitation, Erosion	Safety Precautions[2]	4	None	
				Road design	3	Road maintenance	1
Depth to high water table (ft.)	>2'	Slight	None				
Flooding	None	Slight	None				
Available water capacity (5 ft. depth), (in)	>8'	Slight	None				
Surface texture	Loamy	Slight	None				
						Moderate Yield[3]	15
				Total	7	Total	16

Performance Standard Index		Measure Cost Index		Continuing Limitation Cost Index		Soil Potential Index[1]
100	—	7	—	16	—	77

[1] If performance exceeds the standard increase SPI by that amount.

[2] Special equipment not considered practical

[3] Substandard yield not accounted for in evaluation factors. Corrective measures not known. Yield is 15% below standard.

Problems with Low Activity Clay Soils

MODESTO R. RECEL

Soils in the warm humid tropics are subjected to intensive weathering, leaving a clay fraction that is dominantly of the 1:1 layered clay minerals and oxides-hydroxides of Fe and/or Al. These clays are referred to as low activity clays (LAC), which pertains to a low cation exchange capacity (CEC) value of less than 16 meq per 100 g clay (ICOMLAC CL No. 13, 1980).

Two classes of low activity clays are recognized by Uehara (1980). One has a high specific surface containing allophane, imogolite, and other non-crystalline or poorly crystalline soil colloids. The other has crystalline, low specific surface minerals, such as kaolin. Al-interlayered secondary chlorites and oxides and hydrous oxides of Fe, Al, Ti, and Si. According to Uehara, the former behave differently due to their high specific surface that accounts for a high variable charge. Here, their CEC by NH_4OAc at pH 7 is high, but generally unrelated to the cation retention capacity in the field. They have a high water retention capacity, high water permeability, and low bulk density.

Soils with LAC differ from the soils with high activity clays (HAC) in the origin of their surface charge and in their management requirements. The surface charge of the LAC arises from the adsorption of potential determing ions (p.d.i.). The most important p.d.i.'s are the H^+ and the OH^-. For example, an acid medium causes an excess of H^+ and an alkaline medium causes an excess of OH^- to be adsorbed. Hence, soils with LAC are referred to as pH-dependent charge soils, because the surface charge is influenced by the pH of the soil solution. The CEC of these soils may be increased by increasing the electrolyte concentration, the counter ion valence, and the pH, or by lowering the zero point of charge (Uehara, 1975). It could be lowered by P fertilization or raised by high Fe oxide in the clay fraction.

Soil Taxonomy classifies the LAC soils at three categorical levels. They are recognized at the order level in the Oxisols where low activity clay is one of the requirements of the oxic horizon. The LAC Ultisols and Alfisols including the LAC Inceptisols and Mollisols are recognized in the oxic and orthoxic subgroups and finally they are distinguished in the mineralogy classes of the family category.

Soil Taxonomy is a classification system that has potential for worldwide application. One of its major advantages over the other systems of classification is that it is quantitative and permits individuals familiar with the system to arrive at the same classification of a given soil and extract the same kinds of information from the taxa. Its appeal is evidenced by countries adopting it to classify their soils.

As other countries begin to fit their soils into the system, some limitations were uncovered. This is not surprising because our knowledge of soils is still incomplete (Beinroth, 1978); and at the time that Soil Taxonomy was being developed, there were limited data on soils with LAC, there was limited knowledge about the methods of their study, and the pressing need to use the system to classify the soils of the U.S.A. left little time and limited funds for the study of tropical soils with LAC.

Hence, Soil Taxonomy needed refinement in the classification of these soils.

Problems in the classification of the Oxisols .

The limitation of Soil Taxonomy in the classification of the Oxisols is clearly reflected on p. 323 which reads, "The classification of Oxisols that follow seems to produce satisfactory groups of the Oxisols in Hawaii and Puerto Rico. It needs to be tested more widely, for it is far from completion and is certain to have many shortcomings".

The definition of the Oxisols and the soils it should encompass continue to be debated; the definition of the oxic horizon is not adequate; the class limits are not precise; and the number of taxa is limited (Recel, 1983).

Concept of Oxisols

Oxisols in various regions of the world have been investigated in considerable detail. They are generally described as reddish, yellowish, or grayish soils on old surfaces weathered and transported sediments of ancient age on younger surfaces in the tropics. They occur on old stable geomorphic surfaces (Eswaran, 1980) where deep weathering and almost complete pedological transformation have occurred, resulting in almost no variation in profile, color, texture; and in the absence of clear boundaries between horizons.

Extreme weathering has reduced the Oxisols to a mixture of 1:1 alumino-silicate clays, free oxides, and quartz; so that almost no minerals were left that can weather to release plant nutrients. The hot and humid climate of the tropics enhance the removal of the more soluble elements of the rocks, such as Ca, Mg, Na, and K in solution. Consequently, silica, iron, and aluminum are liberated and reorganized into a more stable form, such as kaolinite or the 1:1 lattice alumino-silicates. The silica, however, continue to leach with time, leaving only the Fe and some Al that eventually precipitate as oxides or hydroxides resulting in oxic soil materials.

The oxic horizon is a mineral subsurface horizon that has been, more or less, mineralogically completely weathered and has been reduced to kaolin and free oxides. It has been weathered in a very advanced state, such that the enormous length of time has led to the formation of a horizon that is at least 30 cm thick and that is practically

devoid of weatherable minerals. It is also characterized with gradual change in profile, color, and texture indicating prolonged weathering and that no other pedogenic processes has operated.

The ICOMOX Proposals

Because of the limitations of the classification of the Oxisols, the International Committee on Oxisols (ICOMOX) was organized in 1978. The mandate was to develop a clear concept of an Oxisols, redefine the oxic horizon, examine the validity of the present taxa, and propose improvement.

Definition of the Oxic Horizon

The latest proposal of ICOMOX to define the oxic horizon that was taken from ICOMOX CL No. 10 (1983) reads as follows:

1. Is at least 30 cm thick;
2. Has a fine-earth fraction ($<$2mm) that has an apparent ECEC (NH_4OAc bases plus *N* KCl extractable Al/% clay) less than 12 meq per 100 g clay or has an apparent CEC (CEC in NH_4OAc at pH 7/% clay) of 16 meq per 100 g clay or less, whichever is lower;
3. Has a pH value in *N* NaF (1:50) of less than 9.4;
4. Has weatherable mineral content less than 10% of the 50-250 micron fraction if that size fraction constitute at least 20 percent of the soil material less than 2 mm in diameter or contains less than 40 meq of K + Mg + Ca + Na per 100 g soil on a total elemental analysis basis after coated gravel removal, if soils have less than 20 percent fine sand and very fine sand (50-250 microns);
5. Has a texture of sandy loam or finer in the fine-earth fraction and has 8% or more clay;
6. Has a diffuse upper textural boundary (i.e., less than 1.2 x clay increase within a vertical distance of 12 cm);
7. Has less than 5% by volume that shows a rock structure, unless the lithorelics containing weatherable minerals are coated with sesquioxides;
8. No soil material with 85% gravel, by volume, is considered an oxic horizon;

Item 2 deletes the cation retention capacity by *N* NH_4Cl in Soil Taxonomy; increases the ECEC limit from 10 to 12 meq per 100 g clay; and uses the CEC by NH_4OAc at pH 7 as an alternate criterion to CEC.

Item 3 requires a pH in NaF of 9.4 to provide a dividing line between the Oxisols and the Andisols.

Item 4 provides a limit of 10% weatherable minerals in the 50-250 micron fraction to remove the qualitative and subjective term "trace" in Soil Taxonomy.

Item 5 lowers the percentage limit from 15 to 8% clay to make it closer to the midrange of the sandy/loamy family or to make the lower texture limit of the oxic to correspond to the upper limit of the Psam-

Table 1. The pH in NaF of some Pedons of Oxisols[a]

Depth (cm)	Horizon	pH in NaF
Pedon OX-59, Wahiawa series, Eutrustox, Waipio, Oahu, Hawaii (BSP original pit)		
0-10	Ap1	8.7
10-27	Ap2	8.8
27-40	B	9.3
40-65	Bw	9.3
65-90	Bw1	9.4
90-120	Bw2	9.5
120-150	Bw2	9.5
Pedon OX-60, Wahiawa series, Eutrustox, Waipio, Oahu, Hawaii (BSP new pit)		
0-23	Ap1	9.3
23-38	Ap2	9.0
38-53	B	8.9
53-91	Bw	9.2
91-125	Bw1	9.5
125-147	Bw2	9.4
147-178	Bw2	9.4
Pedon OX-33, Molokai series, Torrox, Molokai, Hawaii (BSP experimental survey pit)		
0-23		9.5
23-47		9.6
47-64		9.5
64-87		9.4
87-104		9.2
Pedon OX-13, Farmhill series, Acrohumox, South Africa[b]		
0-16	A1	10.6
16-28	A2	10.9
28-62	B1	9.7
62-113	Bt1	9.4
113-149	Bt2	9.4
149-165	Bt3	9.4
Pedon OX-46, Haplohumox, Aneityum Island, Hew Hebrides[c]		
0-10	A1	8.4
10-120	B2	9.1

[a]Recel, 1980.
[b]Analyzed by the NSSL, Soil Conservation Service, USDA.
[c]Source: Leamy *et al.* (1979).

Test of Criteria of Oxisols

The ICOMOX's proposed key definition of Oxisols reads:

1. Other soils that either have less than 40% clay in the upper 18 cm, after mixing, and an oxic horizon with its upper boundary within 1 m of the soil surface and not overlain by an argillic or kandic horizon; or

Table 1. The pH in NaF of some Pedons of Oxisols[a]

Depth (cm)	Horizon	pH in NaF
Pedon OX-59, Wahiawa series, Eutrustox, Waipio, Oahu, Hawaii (BSP original pit)		
0-10	Ap1	8.7
10-27	Ap2	8.8
27-40	B	9.3
40-65	Bw	9.3
65-90	Bw1	9.4
90-120	Bw2	9.5
120-150	Bw2	9.5
Pedon OX-60, Wahiawa series, Eutrustox, Waipio, Oahu, Hawaii (BSP new pit)		
0-23	Ap1	9.3
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[a]Recel, 1980.
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[c]Source: Leamy *et al.* (1979).

Test of Criteria of Oxisols

The ICOMOX's proposed key definition of Oxisols reads:

1. Other soils that either have less than 40% clay in the upper 18 cm, after mixing, and an oxic horizon with its upper boundary within 1 m of the soil surface and not overlain by an argillic or kandic horizon; or

2. Have 40% or more clay in the upper 18 cm of the soil, after mixing, and either an oxic or a kandic horizon with an apparent CEC of the clay fraction $<$ 16 meq per 100 g clay (NH_4OAc, pH 7 method), the upper boundary of which is within 1 m of the soil surface.

One of the rationale for the less than 40% clay content is to place more importance on the clay content increase in light soils than on heavy soils. Another is the fact that the identification of clay films in heavy soils is less certain than in light soils. Hence, the argillic horizon takes precedence over the oxic properties.

In terms of management, the coarser textured overlying horizon in light soils have better tilth and root proliferation, while the finer textured subsurface horizon(s) increases the capacity of the soil to retain more moisture and plant nutrients.

Item 1, however, excludes some Oxisols because of the inadequate definition of the oxic horizon which is being used as one of the criteria in this item.

The suggested amendment reads, *Other soils that have acric soil materials within 1.25 m of the soil surface or have $<$40% clay in the upper 18 cm, after mixing, and an oxic horizon within the upper boundary within 1.5 m of the soil surface and which do not meet the clay increase requirements of an argillic or kandic horizon.*

Here, the LAC Inceptisols having a Δ pH of -2 or more positive will not be affected because the Andisols will key out before the Oxisols.

Item 2 is employed to accommodate the fine textured ($>$ 40% clay) LAC Ultisols that have kandic horizon into the Oxisols. Here, the high degree of weathering as evidenced by the LAC is more important to soil behavior than clay movement. Furthermore, the evidence of a soil with high clay content, yet have CEC $\leqslant$ 16 meq per 100 g clay indicate the dominance of oxic materials in the soil. In this case, the low cation exchange capacity of the oxic soil materials overrides the benefits of the clay increase with depth of the argillic horizon or the kandic horizon.

Problems in the Classification of the LAC Alfisols and Ultisols

The recognition of the LAC Ultisols and Alfisols at a very low categorical level do not permit meaningful taxonomic groupings. Consequently, the limited number of taxa inhibit the freedom to make further separation, resulting in the groupings of unlike soils in the same taxon.

The Alfisols and the Ultisols are identified by an argillic horizon or a horizon with an accumulation of clay as described in Soil Taxonomy, but the pedogenic significance of this criterion has been questioned (Isbell, 1979).

An argillic horizon is defined by the presence of illuvial layer lattice clays, that has a specified clay increase compared to the eluvial horizon and by the presence of clay skins or oriented clay or both. The near presence or near absence of clay skins in the LAC Ultisols and

Alfisols is very subjective. Furthermore, clay skins are not unique to the LAC Ultisols in the wet equatorial udic and perudic climates. This is aggravated by the lack of appropriate equipment for micromorphological analysis that may be used to confirm the presence of clay skins. There is also the continuing problem of ascertaining whether a clay "bulge" is a result of clay illuviation or some other processes.

Clay skins or clay orientation are usually the indicators of clay movement from the upper to the lower horizons. Lack of clay skins, however, may not necessarily mean that there was no movement of clay because there are other possible causes, such as a high biological activity that could lead to the destruction of clay skins faster than they are formed.

On the other hand, the clay "bulge" may be a result of selective erosion of clay-sized particles from the surface layer or by deposition layering or both. These may be mistaken for an argillic horizon. The difficulties of ascertaining clay illuviation and the positive identification of clay skins and aggravated by an argillic horizon that has oxic properties.

The clay skins, as defined in Soil Taxonomy, pp. 21-24, are not unique to LAC soils, particularly the Ultisols with udic or perudic moisture regime (ICOMLAC CL No. 3. 1976). This is illustrated by some soils with a subsurface horizon that has the chemical and mineralogical properties of an Oxisol and the clay content increase of an argillic horizon that has no clay skins. This makes the separation of the Oxisols from the LAC Alfisols and Ultisols very vague.

The LAC Ultisols and Alfisols

Most of the LAC soils have B horizons with the clay content increase of an argillic horizon. They are presently placed in the order Ultisols and Alfisols (ICOMAND CL No. 13, 1980). In these soils the predominance of LAC is an indication of an advanced state of weathering. It is also a factor that limits soil response to fertilizer and lime.

The LAC Ultisols and Alfisols both have low CEC and possess some characteristics of an oxic material. The two are differentiated by the base saturation by sum of cations at specified depths.

The Argillic Horizon

The mere movement of clay may not bear significance in the argillic horizon. It is the cause and effect that tells a lot of information about the soil.

For example, Eswaran (1981) considered the value of argillic horizon in terms of the conditions in the surface horizon that should be conducive to dispersion, that the dispersed clay should be translocated to the subhorizon, and that the translocated clay should be able to form clay skins. According to Eswaran, the significance of the argillic horizon in soil management is that the coarser textured overlying

horizon provides better tilth and favorable root proliferation, while the finer textured surface horizon increases the water retention capacity of the soil. In addition, the clay skins which are the evidence of clay movement hold more nutrient elements than the ped interiors. Soleon, *et al.* (1964), however, reported that thick and continuous clay skins may cover all the ped surfaces and root channels, thus restricting nutrient uptake of roots. On the other hand, the Ca content on ped coatings may draw the roots deeper into the lower horizons for more available water during the dry periods.

The Kandic Horizon

A kandic horizon is a subsurface horizon that has more clay content than the overlying horizon(s). Such clay content increase may be associated with one or more processes acting simultaneously or sequentially on the soil causing textural differentiation. Such processes may be —

- Clay eluviation and illuviation in which the higher clay content in the B horizons cannot be shown by micromorphological analyses to have accumulated by illuviation;
- Clay skins that are evidences of illuviation may be completely absent because of lack of orientation of clay-size particles as a result of a high amount of Fe. Oxy-hydroxides in the clay fraction or destruction of clay skins by biological activity;
- Destruction of clay by the weathering of layered-lattice clay silicates;
- Selective erosion in which the finer soil particle may be moved further from a point of origin due to rain drop splash, leaving a coarser surface material;
- Sedimentation of coarser textured surface materials in which it may overlie a fine textured strata; and
- Biological activity where earthworms, termites, and ants rework the soil resulting to a coarser textured surface (ICOMLAC CL No. 13, 1980).

The textural differentiation resulting from the above processes can not be identified as an argillic horizon because it is difficult to show that the higher clay content in the subsurface horizon comes from the overlying horizon.

The significance of the kandic horizon is related to its use as a basis for differentiating soils with clay accumulation in the subsoil where the argillic horizon alone is not adequate to differentiate some LAC Ultisols and Alfisols from Oxisols and LAC Inceptisols.

It is suggested, however, that the kandic horizon should not be used as a diagnostic horizon in soils having $>$ 40% clay in the surface because the increase of clay content losses much of its significance in soils with clayey surface.

The presence of a kandic horizon indicates a high degree of weathering of a soil and the high degree of weathering relates to the

dominance of 1:1 layered-lattice clays and sesquioxides of Fe and Al and the absence of 2:1 layered clays. Here, the formative element, "kandi" was derived from Kandite which refer to the 1:1 lattice clays, specifically the kaolinite with varying amounts of oxy-hydrates of Fe and Al.

The problems in the classification of the Ultisols and Alfisols with LAC necessitated the creation of the International Committee in the Classification of LAC Alfisols and Ultisols in 1975.

ICOMLAC Proposal

Varied proposals were made to upgrade the classification of LAC soils. One is the placement of the LAC soils in a new soil order. Another idea was to place together the LAC Alfisols and LAC Ultisols in the order Ultisols but defined to contain high activity clay (HAC) and low base saturation, as well as soils with LAC irrespective of base saturation.

Such ideas, however, did not prosper because they would cause an overhaul of the major parts of Soil Taxonomy.

The latest consensus was to upgrade the LAC Alfisols and Ultisols at the great group level by employing the "kandi" taxa. Here, the required changes are kept to the minimum.

Proposed Summary of Properties of the Kandic Horizon

The following is the proposed definition of the kandic horizon taken verbatim from ICOMLAC report dated June 1, 1983:

The kandic horizon is a subsurface horizon which has a CEC of $<$16 meq per 100 g clay (by NH_4OAc or have ECEC $<$ 12 (sum of bases plus KCl extractable Al) in the fine earth fraction at a depth of 50 cm below the top of the horizon or immediately above a lithic, paralithic, or petroferric contact that is shallower.

The kandic horizon has the following properties:

1. It has a coarser textured surface horizon. The minimum thickness of the surface horizon is 18 cm after mixing, or 5 cm if the transition to the kandic horizon is abrupt.

2. It has more total clay than the overlying horizon and the increased clay content is reached within a vertical distance of 12 cm or less as follows:

   a. If the surface horizon has less than 20% total clay, the kandic horizon must contain at least 4% more clay; or

   b. If the surface horizon has more than 20% total clay, the kandic horizon must have 1.2 times more clay than the overlying horizon or at least 8% more clay.

3. It has a thickness of at least 30 cm, or at least 15 cm if a lithic, paralithic, or petroferric contact occur within 50 cm of the mineral soil surface.

4. The layers or horizons overlying the kandic horizon do not show fine stratification, and the content of organic carbon does not decrease irregularly with increasing depth.

5. It lacks clay skins tnat are thick and continuous in all parts, and the cross section has <5% oriented clay to a depth of 125 cm below the mineral soil surface or 75 cm below the top of the kandic horizon, whichever is deeper.

Test of the Kandic Horizon

The proposed charge properties of the kandic horizon so far have not been opposed. The proposed criteria appear to be adequate, except for Item 5 which does not permit clay skins that are thick and continuous in all parts. Item 5 is subjective and a constraint to LAC Ultisols, hence, it might be better to delete this provision.

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SOILS AND THEIR MANAGEMENT IN THE PHILIPPINES

The Soils of the Philippines: Their Association with Geology and Landforms

MARTIN E. RAYMUNDO, ARTURO A. DAYOT, AND CRISOSTOMO B. ALCALDE

Briefly presented here are the products of geologic phenomena, namely: volcanism and endogenetic rock formation, erosion and sedimentation, and continental drift as they affect the landforms and distribution of materials which differ in ages and composition. Some of the soils confirmed or approximated to serve as examples under the different orders and subsequent categories in Soil Taxonomy are provided.

The presentation attempts to provide the participants of this forum some insights on the relation of landforms and the kind and age of parent materials to the expected occurrence and the taxonomic classification of the soils in the country.

Igneous rock formation (Plutonics and Volcanics), erosion and sedimentation, and the continental drift are the three major geologic phenomena responsible for the dominantly rugged and directed landforms and physiography, and the kind and distribution of materials on which and from which the soils of the country have developed.

Igneous Intrusion and Extrusion

Igneous extrusive rocks, the oldest of them being of the Jurrasic and Cretaceous ages, are found in Rizal and Northern Quezon provinces in Luzon (probable site of Oxisols), Eastern Mindanao, Samar, Cebu. and Bohol. There are probably more areas, but these may have been overlain by younger materials from more recent volcanic activities. Relatively younger basic and ultrabasic intrusives are found in all the major islands, but the most extensive area is the Zambales mountain range (associated with the Balaoen and Antipolo series).

Acid igneous rocks are found in Batangas province; in the Northern Cordillera and Sierra Madre ranges in Luzon; Iloilo in Panay Island; the Zamboanga province, Maguindanao, and Eastern Davao in Mindanao; and in much smaller areas in Oriental Mindoro, Negros Occidental, Cebu, and Bohol.

Soils derived from igneous intrusives are mostly associated with the rugged mountain areas and are of little significance for agricultural uses, except for the contribution of materials transported from these areas to the properties of the soils formed elsewhere. They are of considerable interest to pedologists and perhaps silviculturists.

The volcanic or igneous extrusives are important parent materials of soils both in forms of terrestrial deposits as volcanic ash, pumice,

and lava flows, as well as waterlaid pyroclastics and tuffs which are now exposed.

Pryoclastics of varying ages from Cretaceous to Pleistocene are found all over the archipelago most of which are in association with marine sediments and reef limestone. The locations of these older volcanics are in the following:

1. The Cretaceous and Paleocene meta-volcanic are extensively found on the higher and rugged ranges as the: (a) Cordillera, Caraballo and Sierra Madre Mountains in Luzon; (b) in Mindoro, Masbate, Negros, Palawan; and (c) in the Zamboanga Peninsula, Sultan Kudarat, South Cotabato, and along the Bukidnon-Agusan boundary in Mindanao. Most of these are on unsurveyed or undifferentiated soil areas.

2. The Paleocene and Oligocene formations are in the: (a) Ilocos Norte-Ilocos Sur area: (b) Quezon boundary with Nueva Ecija, Bulacan, and Rizal; (c) Caramoan Peninsula and Catanduanes in Bicol; (d) southern parts of Mindoro, Northern Panay and Guimaras; and (e) Davao Oriental in Mindanao. These are undifferentiated soil areas or mapped as soil complexes.

3. Late Oligocene and Miocene volcanics generally occupy the rolling to hilly foot hills which are mostly pyroclastics associated with marine clastics and sandstones. These are the intermediate uplands immediately above the coastal plains of the Ilocos Region, Zambales, Mindoro, Palawan, Panay, and many parts of Mindanao.

The Oligocene volcanics generally occupy the higher and more eroded hills, while the Miocene are on the more gently sloping areas at lower positions. These volcanics may occupy higher landscape positions than the Pliocene and Pleistocene pyroclastics, if present, and most often occupy the uplands immediately above the broad Quarternary alluvial plains as those in Central plains of Luzon and the Mindanao Plains (Agusan, Allah, and Cotabato valleys) and most of the fringing coastal alluvium.

Recent volcanic deposits are found in association with the active and dormant volcanic peaks. Mts. Arayat, Samat, Maquiling and Banahaw; Taal Volcano, Mayon Volcano; Iriga, Irosin all in Luzon; Mt. Kanlaon in Negros; Mt. Hibok-hibok in Camiguin Island; and Mts. Kitanlad and Apo in Mindanao are the more prominent of these land marks.

There are numerous Quarternary volcanic centers, such as in the Central Luzon and Bataan Peninsula; Laguna and Batangas, Bicol Peninsula, Mindoro, and Negros Islands; and in Central and Western Mindanao. These volcanic deposits are either sources of or have strong influence on the soils utilized for agricultural production.

Igneous rocks of various ages as expected make up the core of many smaller islands around which marine pyroclastics, sediments, and reef limestone were deposited or formed prior to emergence.

Erosion and Sedimentation

The Quarternary alluvial materials are the most common parent materials of the cultivated lowlands and the areas most extensively and intensively used for crop production. These are mostly in the inland valleys of Ilocos Norte, Central Plains of Luzon, the Bicol River Basin, Agusan and the flatlands in the Cotabato-Maguindanao-Sultan Kudarat area. The narrow and interrupted coastal plains brought about by the proximites of vast mountain to the sea, such as those in Zambales, Mindoro, Panay, Negros, Davao, and other smaller areas are also of these materials.

The Cagayan Valley and the Agusan Valley, except for the river floodplains, and the undulating to gently rolling intermediate uplands in Palawan, Mindoro and the five major islands of the Visayas are of the Pliocene-Miocene sediments. These are the locations of soils that are less fertile than on the Quarternary alluvium. A number of soils on these Quarternary sediments have fertility problems, particularly those which were eroded from the older rock formation.

It is believed that some of these materials in Northern Luzon, Mindoro, and Palawan have undergone more than one cycle of erosion and deposition. Hence, the materials have been washed off the bases and other micronutrients. The most problematic soil on this type of material is the Aborlan series of Palawan. In many cases, however, the associated reef limestone on higher physiographic positions and the influence of volcanic ash help rejuvenate most of the soils derived from some of these materials.

Among the soils associated with these materials, whether pyroclastics or marine sediments are (a) the Prensa and Tarlac series in Central Luzon; (b) the Ilagan, Bago, Cauayan, and Carig series in Cagayan Valley; (c) the Antipolo, Novaliches, and the ash rejuvenated Lipa, Carmona, Ibaan, Guadalupe, and Tigaon series in Southern Luzon and Bicol; and (d) the Tugbok, Kidapawan, Adtuyon, and Jasaan in Mindanao. These are but few examples of the soils generally associated with these Quarternary sediments and volcanics.

Reef limestone formations in association with different rock ages are found high in the mountains as in Baguio Sagada, Lagaue areas of the Cordillera range, and along the Sierra Madre in Luzon. They are also found associated with shorter ranges of Mindoro, Panay, Negros, Cebu, Leyte, Samar islands, and along the common border of Bukidnon-Agusan, South Cotabato, and Davao Oriental in Mindanao.

The hilly areas of Bondoc Peninsula, the south western coastal areas of Bicol Peninsula, major areas of Cebu and Bohol, and many coastal areas in Mindanao, are of coralline limestone. There are many of these island atolls, like those of the Hundred Islands off the coast of Pangasinan and those still under shallow waters between Cebu and Bohol islands. Some of these reef limestones are dolomitic. The Faraon

and Sibul series are associated with calcic limestone, while the Alit iodian series are from dolomitic formations.

The metamorphic rocks from igneous and sedimentary origin are invariably found in association with older rock formation particularly in orogenic areas subject to folding and faulting. Major areas of metamorphic rocks are in Northern Palawan, Busuanga, and Mindoro; in some parts of the Sierra Madre range and Caramoan Peninsula in Luzon; and in the Zamboanga Peninsula. Because of the rugged topography and acquired resistance to weathering processes, these metamorphics are of very little importance as parent materials of soil for agricultural production.

Continental Drift

The drift of the Indian subcontinent and the Australian continent from the southwest and south, respectively, is claimed to have considerable influence in the formation of and the physiographic conditions of the Philippine archipelago. The emergence of most parts of the country's smaller islands and the faulting and folding processes are attributed to this phenomenon. Some of the intermediate upland terraces normally of almost similar elevation (13 meters AMSL or less) are partly attributed to an interglacial period when the ocean water was much higher than the present level.

Taxonomic Classification in the Philippines

The inventory of soil resources was started in the Philippines as early as 1903 in Batangas by Clarence W. Dorsey which was focussed on the soils grown to abaca. There was not much progress until the late 1920's when Dr. Robert L. Pendleton worked on the surveys of sugar lands, particularly in Negros island, and simultaneously trained several students of the UP College of Agriculture in the persons of Mamisao, Posell, and Sarot Montrakon.[1] Consequently, the interest generated resulted in the increase in soil survey activities in the late 1930's and the surveys were more vigorously pursued in late 1950's and early 1960's.

To date, there is a complete soil map of the country normally on a 1:500,000 reconnaissance scale. The mapping units used are "soil types" but there is a very urgent need for much more efforts in the correlation of these mapping units.[2] The challenge is now. Soil Taxonomy can cope with this challenge and is available in the absence of a national system. This classification system is based mainly on quantifiable soil properties for differentiation or association among soils to facilitate a better understanding of the relationships among the various

[1] A Filipino who worked with Pendleton in and adopted the citizenship of Thailand. He is considered one of the outstanding pedologist in Thailand.

[2] This is an expression of need and a challenge but not to degrade previous works done.

soils within and among countries. It provides a better interpretation of soils units for more appropriate and efficient utilization; a timely anticipation and study of problems; immediate and long-term; a systematic development of solutions to these problems; and a reliable exchange of experience or technology transfer.

The fertile and productive soils are presently all being utilized, and the decrease in extent of productive soils is accelerating due to urban expansion. Increased production brought about by new varieties and better cultural management is anticipated to exhaust nutrients and create some nutrient imbalance in our present fertile lands. A good soil classification system can predict solutions to these problems.

Need for Soil Classification

The Benchmark Soils Project has demonstrated satisfactorily that Soil Taxonomy can be used appropriately and effectively as a medium for agrotechnology transfer. Time, manpower, and financial resources utilized in repetitive experimentation can be reduced advantageously. There is a need for a classification of soils on the unsurveyed and previously undifferentiated areas which are the frontiers for expansion in agricultural production, and for the refinements in the classification of soils in the areas which have been previously surveyed and classified, if the country is expected to cope with the needs of her people for the year 2000 and beyond.

The association between soils and landforms (parent materials) has been the basis of the initial classification of soils both for utilization as well as academic interest, which ought not be separated. It is hoped that this section would serve as a guide in future soil classification activities. Different landforms, parent materials, and topographic positions have greater influences on the local variability of soils than in the soil differentiations among regions.

The soil orders and suborders in Soil Taxonomy have in many cases differentiated or grouped the soils according to the broad environmental factor, climate. Hence, localized factors for prediction of the existence of particular soils are needed for a more systematic, accurate, and detailed differentiation or grouping. Presented in the following discussions are the soil-orders anticipated to occur in the Philippines and some local soil names as actual or probable examples for particular categories are by no means final.

The Histosols

The non-mineral soils or organic soils in the Philippines exists in very limited areas. The Dolongan series in Samar and the tinambulan peat in South Cotabato are some of those identified as mapping units. But there are other relatively big areas near the Liguasan marsh in Cotabato, some areas of the Candaba swamps in Pampanga, the Sab-a Basin in Northern Leyte, the lower and upper Agusan Valleys, limited

areas at the eastern and north eastern shorelines of Laguna de Bay, and depressions which perhaps are old, filled-in volcanic craters with low elevations in a number of areas. There are many others in the swamps on low elevation along the coastal areas and perhaps in depressions on higher slopes and high mountain crests.

The classification of Histosols has not received any considerable attention to date. Some studies have been done on utilization of peat soils from a few Histosol areas planted to vegetables and rice.

The Andisols (Andepts)

The volcanic origin is a major determinant in the physiographic conditions of the country and a good number of soils have been previously classified as Andepts. Hydric Dystrandepts (inclusion of the Tigaon series) are found on the slopes of Mt. Isarog; the Hydrandepts, around 800 m elevation in Mt. Makiling (unclassified) area; and possibly Eutrandepts, over the slopes of many volcanic peaks. The Tagaytay, Taal, and Tupi series in South Cotabato may fit into Andisols. ICOMAND must soon come up with the key to the order Andisols. Andepts at elevations of less than 500 m are generally for a wide varieties of annual crops, including perennials wet land rice on terraced paddy systems.

The Vertisols

The Vertisols are mainly on the level clayey areas. San Fernando, Bantog, Candaba, Bigaa, Guadalupe, and Binangonan (lowland phases) are Pellusterts; while the Pili, Isabela, and Sta. Rita series are mainly Pelluderts. Makato, Medellin, Mahipon, and some of the Prensa soils are verified as Chromusterts; while some areas of the Maapag series are Chromuderts. Most of these are utilized for wetland rice. Vertisols, however, are not restricted to the low-level areas, as they have been also identified in plateau position such as those in Bukidnon.

Some deep phases of the Bani, Sevilla, Faraon, and Sibul soils derived from calcareous material, and those of the Bauang and Buenavista series from pyroclastics deposits could also be Vertisols. When terraced, these areas can also be utilized for wetland rice, although some are planted to vegetable crops and melons to utilize the residual moisture after rice.

The Ultisols

The Ultisols are primarily on the upper Miocene and older landforms that are normally on third interfluves from the floodplains or higher in the landscape. Similar to Alfisols, Ultisols have developed an argillic horizon but extensive leaching of bases in the subsoil has taken place during the process of weathering. They are characterized by brown and generally red, colors, although poorly drained Aquults may be formed due to favorable localized farming conditions. Most of the red soils of

the Adtuyon (Paleudults), Tugbok (mostly Tropudults), Castilla (Paleudults), and Luisiana (Tropohumults) series are on the Udic regimes; while the Antipolo and Alaminos (Paleustults) series are of the Ustic moisture regimes.

All these soils have different degrees of P-deficiency (even when planted to irrigated wetland rice). Udults and Humults at elevations less than 1000 m are able to support reasonably good coconut crops, but not the Ustults. Mangoes are more productive in the Ustults than in the Udults. The existence of more than these Great Groups of Ultisols mentioned is expected.

The Alfisols

A number of red soils, particularly those derived from and influenced by high base materials and have retained a high base saturation and pedogenic clay accumulation in the B horizon, qualify as Alfisols. The Kidapawan, Alimodian, and Jasaan series are examples of these. Annam, Miral, Carmona, and some of the Lipa series are Alfisols formed on the immediate upland; while some Quingua, Maligaya, and heavier textured Tarlac (lowland phase) series formed on older terraces are probably wet Alfisols or Aqualfs. It is a common observation, however that, like the Ultisols, a strong morphological cutanic evidence associated with these soils are generally weakly developed, so that soil taxonomic placement is therefore based primarily on physical characterizations.

The Inceptisols

This soil order perhaps is the dominantly used soils in agricultural production. Wetland rice areas are predominantly Inceptisols. The majority of the areas mapped, as San Manuel, Camansa, Mailag, Marikina, Calumpang, Calape and many others, are Inceptisols in the Aquic or Aeric subgroups. Many of the intermediate uplands can either be Eutropepts or Dystropepts, depending on the amount of base retained in the profile. The wet Inceptisols (Aquepts) are associated with impeded drainage, high water table on alluvial area, depressions, and some of Lacustrine origin with diversities of profile satisfaction and solum depths.

The Entisols

Tropofluvents, Fluvaquents, Troporthents, Tropopsamments, and Ustipsamments are perhaps the readily expected great groups of Entisols that are in the country. The Angeles, La Paz, Pangasinan, and Obando series on very recent river terrace deposits are Entisols. Beach sand dunes and unweathered or very slightly weathered volcanic ash will fall under this soil order.

The Mollisols, the Oxisols and the Spodosols

Some of the Lipa (clay loam), Maahas, Miral (clay loam), Faraon, and

Valencia soils may be classified as Mollisols. Typical Oxisols are perhaps rarely found, except in the hinterlands on very old deposits or in association with some of the Ultisols. The existence of any Spodosols in the country has not been reported; but the probability of their existence, even in very limited areas, can not be totally discounted.

Recommended Action

The trend in the study of our soils in the past is more towards land-use classifications which do not consider an in-depth analysis of the soils and their properties and the development of our capabilities to interpret these properties for as many uses as possible.

According to Dr. Hari Eswaran, the Philippines ranks fourth, excluding Brunei and Singapore, among the ASEAN countries in terms of status of soil resources studies and laboratory support. I rather believe that our inability to attract the attention of the government for support on pedological aspects, is primarily due to the lack of priorities.

Unlike those of our ASEAN neighbors, our agricultural lands, especially rice lands are on young fertile soils which is a negative factor in the pursuit of pedologic research (Kawaguchi and Kyuma, 1970). Pedologic research seldom produce spectacular results. In contrast, fertilizer studies produce immediate results; hence, pedologic researches can not generate attractive impact projects saleable for funding by the government and other funding institutions.

In Malaysia, the production areas for their export crops are mainly on Oxisols and Ultisols. Investments on research can be highly justified by expected returns from increased production.

Leadership in scientific endeavor is an expensive proposition which the country can ill afford at this time. We have to invest in researches on marginal areas which are the frontiers for agricultural production. If we know our resources in these areas, technology from similar areas which may now be available can be directly imported and utilized to our advantage. Developed countries can take the lead, but we have to be prepared to benefit from them by knowing exactly what we have in order that we can implement an imported technology where and when they are needed. This can mean increased production and savings from repititious experimentations.

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Rice Soils of the Philippines

MARTIN E. RAYMUNDO

The area of wetland rice soils in the Philippines, based on the reconnaissance soil surveys until the late 1960's is about 2.7 million hectares. National Food and Agriculture Council statistics for 1975-76 report a rice production area of about 2.6 million hectares of wetland rice and about 0.33 million hectares of dryland rice. The regional distribution of wetland rice areas is as follows: Luzon, 60%, Visayas, 15%; and Mindanao, 25%. The dryland rice areas follow the same distribution trend.

Wetland rice production is mainly on low elevations (50 m or lower) and on a few areas of low, terraced paddies on the intermediate upland slopes, and in isolated spots on the terraces of mountain slopes. The common physiographic positions of wetland rice areas are the coastal plain areas ranging from narrow fringes to broad coastal plains, the river basins associated with the big and small river systems, and the broad depositional plains.

Dryland rice areas are on steeper slopes and higher topographic positions. The parent materials of wetland rice soils are mainly the recent alluvium and Pleistocene marine sediments. In the higher topographic positions are the Miocene and Pliocene sediments. The parent materials have been rejuvenated by recent volcanic activities in many places.

By extrapolations from limited studies and interpretations from reconnaissance surveys, the wetland soils are distributed among the Entisols, Inceptisols, Vertisols, and Alfisols and are dominantly of the aquic and udic moisture regimes. Dryland rice soils also include Mollisols and Ultisols, and are primarily of the udic and ustic moisture regimes. Ustic moisture regimes, particularly in wetland rice soils, are limited to areas with four or more continuously dry months.

The main textural classes of wetland rice soils are fine loamy and finer. Coarser textures are also used whenever puddling and ponding can be facilitated by the presence, or combinations, of a shallow water table during the wet part of the year, slowly permeable plow pans, or continuous water supply.

Fully irrigated wetland soils grow two or more crops of rice annually. Partially irrigated wetland rice soils are limited to one crop of rice a year; and, at times preceded, but mostly followed by dryland crops during the drier part of the year. Two crops of rice annually in some partially irrigated or rainfed wetland rice areas were made possible recently by the introduction of early maturing, photo-period-insensitive modern varieties.

Dryland rice areas generally grow one rice crop a year, and other crops are grown during the drier part of the year. A shift from rice to

other dryland crops, or vice versa, is dictated by the economic advantage.

The Philippines an archipelago of about 7,000 islands scattered between latitudes 4°30' and 21°30' North and longitudes 116° and 127° East, is wholly in the humid tropical belt. Only 12 of the 7,000 islands have individual areas of more than 1,000 km^2. About 50% of the country's 30 million hectares are cultivated lands. Of the total area about 10% is in rice production.

Mean annual rainfall ranges from 1,200-4,600 mm, while mean annual temperature at medium and low elevations ranges from 25.8-27.9°C. Climatic differences at medium and low elevations are primarily due to rainfall distribution influenced by typhoonic and monsoon rains that generally affect the Luzon and Visayas area, whereas the Mindanao area is primarily under tropical rain forest.

Distribution of Rice Soils in the Philippines

The reconnaissance soil surveys of the Philippines, with a few semi-detailed surveys done until the late 1960's, have established more than 1,000 soil types as mapping units based on the USDA concept (DANR, 1969). These soil types are grouped into about 260 soil series, 60 of which have soil types generally rated as suitable for wetland rice production. The geographical distribution of soils for wetland rice is shown in the map (Figure 1), which is derived from the compilation of provincial reconnaissance soil maps.

Figure 1 and data from the National Food and Agriculture Council rice profile statistics for cropping year 1975-76 (NFAC, 1976) show some degree of agreement (Table 1). More than 60% of the wetland rice areas are in Luzon, about 15% in the Visayas, and about 25% in Mindanao, i.e., about 2.7 million hectares according to soil suitability estimated. From NFAC statistics, the wetland rice production areas for 1975-76 were about 2.26 million hectares.

Some discrepancies in hectarage between soil-survey area estimated and production-area statistics are expected. The surveys in the Cagayan Valley were made before the region was explored and developed. Many of the undifferentiated soils areas are now under production. Furthermore, soil data for the rice terraces in the mountain subprovinces were only recently included in the region. In the Central Luzon, sugarcane competes with rice production and many of the lighter-textured, low-lying flat areas are shifted to sugarcane production. Similar reasons hold true for the Southern Tagalog and the Bicol Regions.

Furthermore, some of the soil areas suitable for wetland rice have not yet been developed in the islands of Palawan and Mindoro, which are parts of the Southern Tagalog region, because of the generally low fertility of the soils and the relatively low population pressure. On the other hand, western Visayas has a high population pressure; and

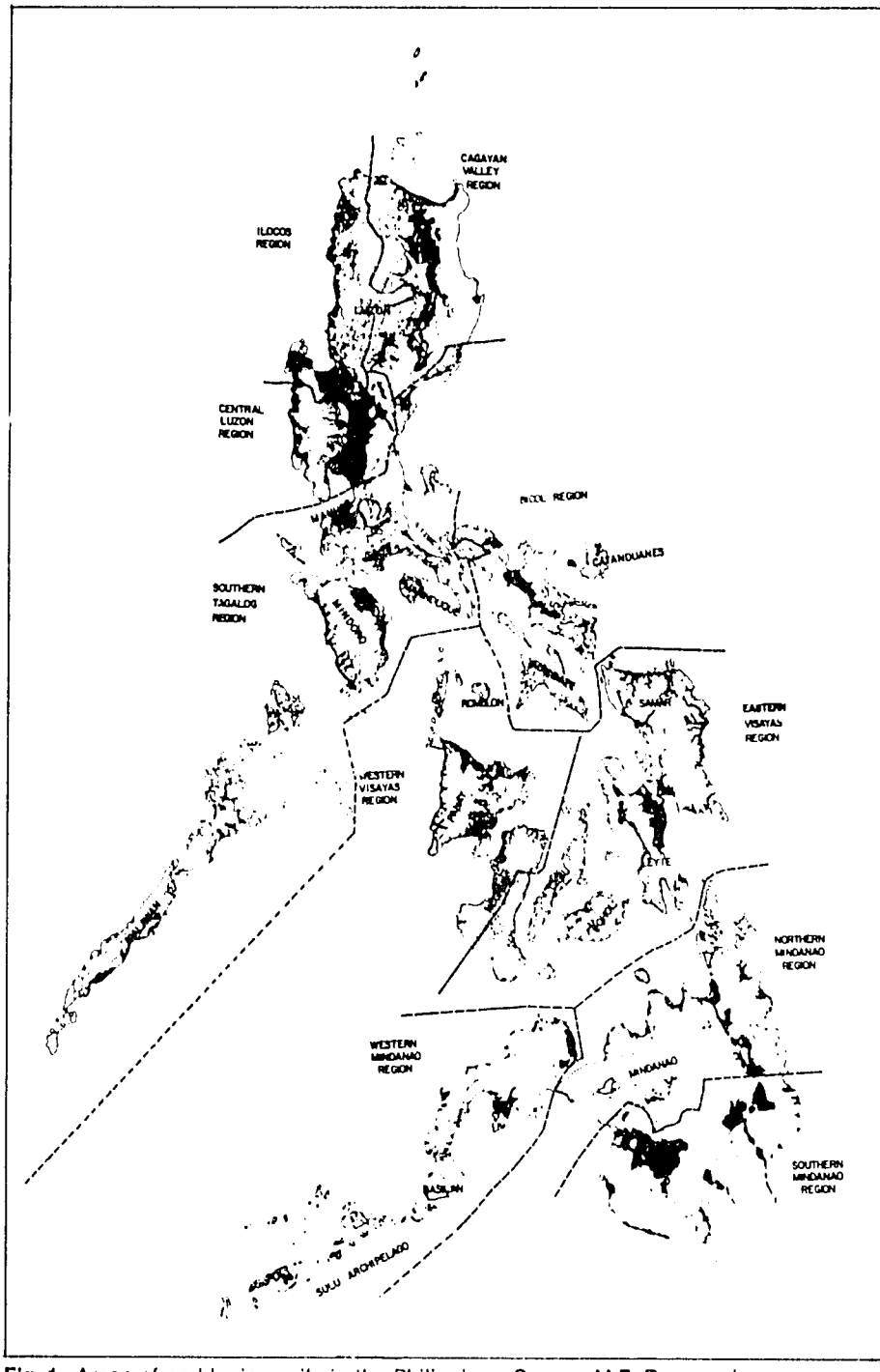

Fig. 1. Areas of paddy rice soils in the Philippines. Source: M.E. Raymundo.

Table 1. Estimates of soil areas suitable for the statistics of area devoted to wetland rice production by region

Region	Soil Areas			
	Estimated from Survey Report		1975-76 Statistics	
	thousand hectares	%	thousand hectares	%
Ilocos	320	12.3	302	13.4
Cagayan Valley	228	8.7	306	13.5
Central Luzon	557	21.4	516	22.9
Southern Tagalog	385	14.8	206	9.2
Bicol	171	6.6	118	5.2
Western Visayas	242	9.3	269	11.9
Eastern Visayas	176	6.7	117	5.2
Western Mindanao	24	0.9	89	3.9
Northern Mindanao	248	9.5	155	6.9
Southern Mindanao	257	9.8	176	7.9
Total	2,608	100	2,254	100

marginal soils, particularly in Panay, have been developed into wetland rice soils since the reconnaissance soil surveys were made.

In Western Mindanao more areas are in rice production than the soil surveys indicate because data for soils in those areas are limited. The Northern and Southern Mindanao regions have bigger soil areas suitable for rice production than are being used for rice. The Agusan Valley in Northern Mindanao is still undergoing development; and crops, such as bananas, abaca, rubber, and coconuts compete strongly with rice for the choice lands in Southern Mindanao. Swampy areas in Davao, which are ordinarily suited for wetland rice development, have been drained for the production of bananas for export.

Dryland export comprises about 330,000 million hectares (13%) of the total rice production area of the country. The hectarage distribution of dryland rice by region in 1975-76 is shown in Table 2.

The Southern Tagalog region has the largest area of dryland rice, about 30% of the total for the country. These main areas are in the provinces of Batangas, (33,000 ha), Mindoro (18,999 ha), Cavite (17,000 ha), Quezon (17,000 ha), and Palawan (12,000 ha). The Western Mindanao upland rice area is second largest (about 14%) and is concentrated in the provinces of Zamboanga del Sur (44,000 ha). In the Ilocos Region (about 11%), upland rice is produced mainly in Pangasinan.

Environment of Rice Soils in the Philippines

The Philippines lies wholly in the low latitudes, and temperatures of rice-growing areas are generally warm to hot. Average annual temperature ranges from 25.8-27.9°C. Cooler temperature as influenced by altitude are at higher elevations — the site of the rice terraces.

The most recent Philippine rainfall map, based on the number of dry

Table 2. Dryland rice production areas by region, 1974-75[a]

Region	Area (thousand hectares)	Rice Area (%)	Total Upland Rice Area (%)
Ilocos	37	10.9	11.2
Cagayan Valley	11	3.5	3.3
Central Luzon	10	2.0	3.1
Southern Tagalog	98	32.1	29.8
Bicol	31	21.0	9.4
Western Visayas	31	10.3	9.4
Eastern Visayas	8	6.4	2.4
Western Mindanao	45	[illegible]	13.7
Northern Mindanao	28	15.3	8.5
Southern Mindanao	30	13.4	9.1
Total	329		99.9

[a]From NFAC Rice Profile of the Philippines 1975-76 (NFAC, 1976).

months (less than 100 mm/month), shows that the Ilocos, Cagayan Valley, and Central Luzon regions are primarily subject to five to six dry months a year (Figure 2). Southern Luzon is partly under the influence of five to six dry months, and partly under only two to four dry months annually. The rest of the rice lands are in areas of a short dry season (two to one months), or with virtually no dry season (less than two months)

Parent Material. The parent material of soils developed for wetland rice (Bureau of Mines, 1962) in the order of extent are the following:

1. Recent alluvium on the lowest positions;
2. Marine and terrestrial sediments of the Pliocene and Pleistocene on slightly higher positions;
3. Marine clastics normally overlain by pyroclastics and calcareous sandstones and siltstones; and
4. Mixed marine-shelf deposits of the upper Miocene and Pliocene at the highest of the "lowland" locations.

These relatively young materials were rejuvenated by eruptive volcanic activities in many areas. Many of the eruptions were dated only from the mid-14th century and were mostly basic ejecta (Andal and Yambao, 1966). The areas subjected to volcanic influences are Central Luzon, Southern Luzon, the Bicol Peninsula, Negros Island in the Visayas, and extensive areas in Central Mindanao. Basic igneous rock, commonly found as the cores of the major islands of the Visayas, is almost always ringed by coralline limestone formations. The limestone formations are generally at higher positions in the intermediate uplands.

Physiography of wetland rice areas. Wetland rice areas in the Philippines are mainly on flat, gently undulating to slightly sloping lowlands below 50 m in elevation.Smaller wetland rice areas are found on terraced slopes and in some small, elevated mountain valleys. Extensive wetland rice areas are on the broad inland plains of Central Luzon, Min-

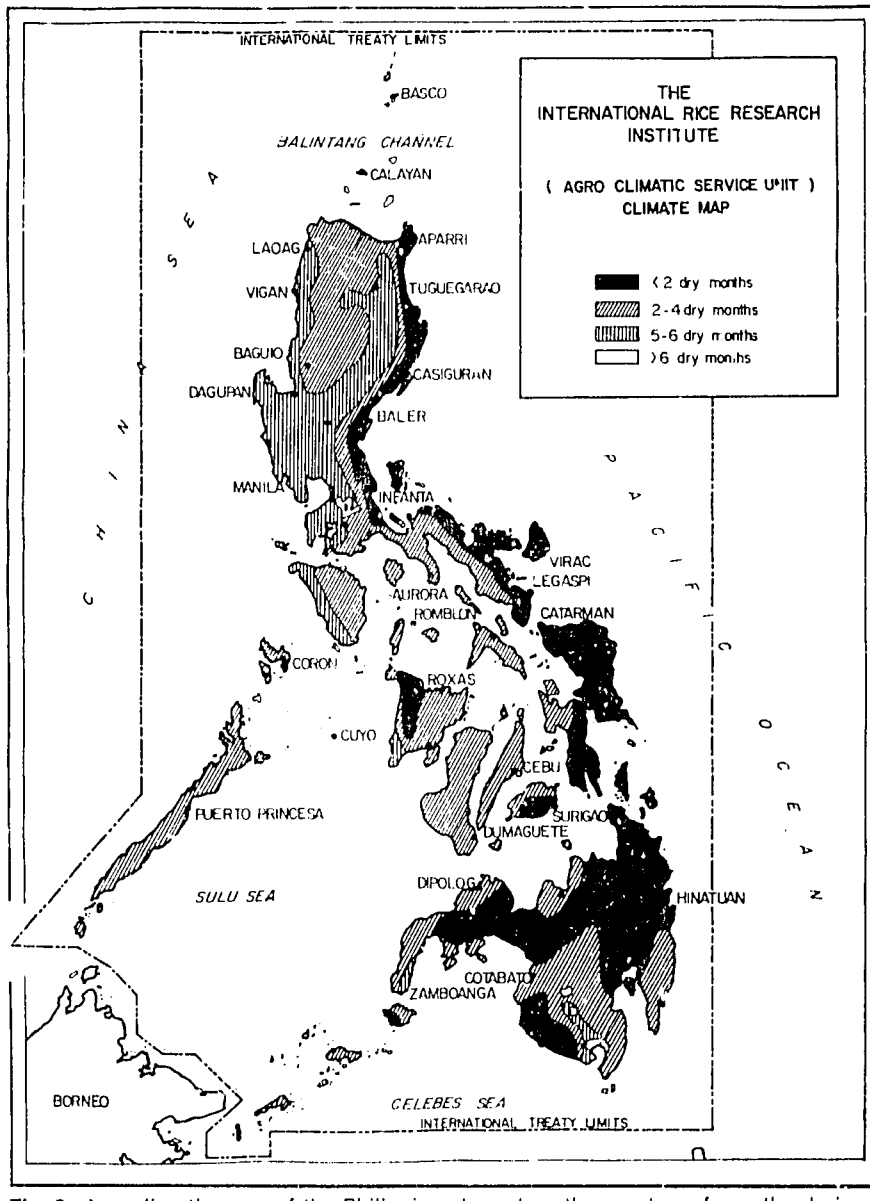

Fig. 2. Agroclimatic map of the Philippines based on the number of months during the year when average rainfall is less than 100 mm/month. Source: E.B. Manalo.

danao, the Cagayan and Agusan Valleys, the Bicol River Basin, and the Sab-a basin in Leyte. Of lesser individual extent but of sizeable total area are the wetland rice fields on the coastal plains, which vary in extent from the broad coastal plains of Mindoro and Panay islands to the narrow, fringing coastal plains of the western coastline of Northern Luzon, Central Luzon, Mindoro, Panay, and the much smaller isolated pockets of lowlands on all the bigger islands (Figure 1).

Terraced wetland rice fields are on the slopes of intermediate uplands between the lowland and the foothills. At much higher elevation are the rice terraces of Baguio, Bontoc, and Banaue, the less extensive terraced areas of Southern Luzon, and the wetland rice fields on small waterways on plateaus and associated with the head water along the slopes of main valleys.

The Ilocos region. The wetland rice areas of the Ilocos region, except the province of Pangasinan, are on the relatively continuous fringing coastal plain areas along a regular coastline and on a few narrow and slightly higher inland valley plains. The narrow coastal plains are associated with short intermittent streams that drain small watershed of the western slopes from the Cordillera mountains, while wide plains are extensions of inland valleys associated with relatively longer river systems. These major rice areas are on low-lying, flat land. Small areas of terraced paddy systems are developed on slopes up to 10% or more. Paddies on steep to very steep foothills may be strictly rainfed or partly supplemented by water from intermittent mountain streams. The province of Pangasinan, although included in this region, is physiographically related to the broad plains of Central Luzon.

The Cagayan region. Wetland rice areas are mainly on the long and broad inland valley plains, or basins, of the Cagayan River system and on the fringing coastal plains at the north. Most of the paddies in the upper two-thirds of the valley are developed on the second and third level terraces above the frequently flooded terraces. The much-publicized Ifugao rice terraces in this region are on the steep mountain slopes, and water is continuously supplied by mountain streams diverted into the paddy systems. On lesser gradients and in the absence of a water supply from springs, terraced paddies on intermediate uplands are strictly rainfed.

The Central Luzon region. The most extensive wetland rice area of the Philippines is in Central Luzon. In the provinces of Bataan and Zambales, the wetland rice systems are developed on narrow coastal plains similar to those of the Ilocos region. The more extensive wetland rice areas are on a broad peneplain.

The plain of Central Luzon is a depositional area of two meandering river systems. The Pampanga River systems, which influences the eastern half of the plain, drains from the Caraballo mountains at the north, in part from the Sierra Madre on the east. The deposits from the Angat and Peñaranda tributaries of the Pampanga at the east and southeast are clayey materials. The Pampanga River meanders at the southeastern half of the plain before draining toward Manila Bay.

The Agno River, which originates from the Cordillera mountains and in part from the Caraballo mountains, empties into the Lingayen Gulf. The deposits of this river are generally sandy and loamy materials influencing the northwestern section of the plain. The materials carried by streams from the mountains in southern Zambales and those com-

ing from Mt. Arayat, are generally basic volcanic materials. These deposits influence the central and the southwestern section of the central plains and the southern section of Zambales and Bataan provinces.

The wetland rice areas in the Central Plains are generally on low-lying plains, ranging from almost sea level to about 30 m in elevation. Considerable areas of terraced paddy systems have developed on intermediate uplands of older marine sediments in the eastern section of the plains, and to a lesser extent, on the foothills of the volcanic areas in the north central and northwestern sections of the plain.

The Southern Tagalog region. The Southern Tagalog region ranks second in area of potential wetland rice soils. The low-lying wetland rice soils in this region are associated mainly with depositional coastal plains. The broader marine coastal plain areas are found in Oriental Mindoro and along the Batangas-Quezon boundary. The rest are on narrow coastal plains and small river valleys. The wetland rice areas around Laguna de Bay are level to very gently sloping lacustrine deposits exposed recently after the lake water receded. In some parts, the wetland rice areas flooded by lake waters during the height of the rainy season. Wetland rice areas developed recently and still being developed in the islands of Mindoro and Palawan are mainly on marine coastal plains. On the island of Palawan, alluvia from dioritic uplands show considerable amounts of quartz in the sand fractions, while those in the provinces of Batangas, Cavite, Laguna, and parts of Quezon are derived mainly from and influenced by recent basic volcanics. Small areas of wetland rice soils are found on terraced intermediate uplands in the provinces of Cavite, Laguna, Quezon, and in higher elevations (200m or more) associated with steeper slopes similar to Banaue and with narrow waterways on the steeply rolling foothills of the southern Sierra Madre Range.

The Bicol region. The Bicol River basin is the major wetland rice area of the Bicol Peninsula. The basin is an inland valley that runs northwest to southeast on the peninsula. The valley is flanked at the northeast by a series of volcanic peaks and intermediate uplands, and by uplifted corals and calcareous sedimentaries at the southwest. Fringing coastal plains, intermediate uplands, and the narrow waterways and swales at slightly higher elevations are generally developed into rainfed paddies.

The Western Visayas region. The wetland rice areas in the western Visayas region are in three physiographic groups: the fringing coastal plains in western Panay and the broader plains in western Negros islands; the coastal lowlands, which in many parts tongue into inland valley plains in northern Panay; and the broad coastal plains that gradually slope from the intermediate upland toward the southeastern coast of Panay.

The Eastern Visayas region. The Eastern Visayas has a generally rough topography. The only significant area of wetland rice is in the

Sab-a basin in central Leyte. The basin is a short trough that is bound by sedimentaries and volcanics in both the northeast and the west and terminates at the east-central coast. Smaller paddy areas are commonly found in isolated small plains formed near river outlets and which, in many locations, are connected by narrow coastal plains that abruptly terminate at the foot of steep-sloped hills. Narrow valleys are the common wetland rice sites on the island of Samar.

The Western Mindanao region. Western Mindanao is generally rugged and mountainous and has limited, low-lying, flat lands suitable for wetland rice. Isolated paddy areas along the coast of Zamboanga and the bigger islands of the Sulu Archipelago, a low-lying plain area in Zamboanga del Sur, and a gently sloping area in Misamis Occidental make up the major wetland rice areas of the region.

The Northern Mindanao region. Northern Mindanao is the most extensive area developed into paddies and still has considerable potential for paddy development in the long, relatively broad Agusan River Valley, which originates from eastern Davao and drains north into the Mindanao Sea. The eastern side of the valley is mainly sedimentary, with occasional metavolcanics, while the western side is mainly basic volcanics and sedimentaries derived from those basic materials. The valley floors are of recent alluvium. Older alluvial and marine deposits occupy the intermediate uplands between the valley floor and the foothills.

Isolated coastal plains and river deposits are characteristics of the northern and eastern coastline of the region. Wetland rice systems are also developed to a lesser extent on river floodplains of the upper Pulangi River, and in some broad depressions on the Bukidnon Plateau where small streams provide water.

The Southern Mindanao region. The most extensive wetland rice areas of the Southern Mindanao region are in the Mindanao Valley, an inland plain around the Liguasan Marsh. The valley walls at the southwest are dominantly sedimentaries and coralline limestone, while the northern and eastern borders are mainly of recent volcanics. The Pulangi River, the main tributary of the Mindanao River from the north, originates from the Bukidnon Plateau.

A less extensive area, with potential for further development into paddies is the Davao plains. As in many other islands, wetland rice fields along coastal areas in this region are found in isolated spots associated with the deposits of small river systems.

Physiography of dryland rice areas. The dryland rice soils referred to here are those with a high degree of permanency of cultivation and do not include the *kaingin* or slash-and-burn, shifting type of rice cultivation. The land is prepared dry, never puddled, and rice is seeded in dry soil. In some areas, such as in Batangas, bunds or dikes are used only for soil and water conservation.

In general, dryland rice is grown all over the country on landforms

where water accumulation is not sufficient to enable puddling of the soils for wetland rice. The major dryland rice-growing areas are on relatively undulating and slightly rolling intermediate uplands and on moderately well to well drained soils on low-lying level areas. The intermediate uplands are typified by the dryland rice-producing areas, such as those in Southern Luzon, the gentle slopes of the Bukidnon Plateau toward Cotabato, and the Zamboanga Peninsula. In Cagayan Valley and in Pangasinan, the well-drained intermediate uplands and the low-lying areas associated with the coarser river deposits are used for dryland rice.

Classification of Rice Soils in the Philippines

Some work on classification of paddy soils according to Soil Taxonomy (USDA, 1975) and the Food and Agriculture Organization classification started in the early 1970's. Later investigation shifted to the Land Suitability Classification with minor regard to soil classification *per se*. The classification of wetland rice soils that follow is primarily an extrapolation based on some studies conducted jointly by the FAO-UNDP and the Bureau of Soils, Department of Agriculture, Philippine (DANR, 1969), and the Interpretation of soil survey reports on a provincial scale plus other unpublished information.

The majority of the wetland rice soils of the country can be classified according to Soil Taxonomy into at least four orders: Entisols, Inceptisols, Vertisols, and Alfisols. Limited areas of Histosols, and perhaps Ultisols, also grow wetland rice. The classification and properties of some wetland rice soils are shown in Table 3.

The dryland rice areas are generally on steeper and more complex slopes and at higher elevations where prolonged ponding is unattainable. An IRRI study identified Mollisols and Ultisols in addition to the soil orders involving the paddy soils (Garrity, 1976).

Aquic and udic are the dominant moisture regimes of wetland rice soils. Dryland rice soils are primarily on the udic and ustic moisture regimes.

The wetland rice soils of the Philippines, especially those developed from mixed alluvia, often differ suddenly from adjacent soils even with slight change in topographic conditions and position. As such, the series or soil types used as mapping units in the reconnaissance soil surveys of the country are actually soil associations at the higher or broader soil category. In effect these mapping units seldom conform with past definitions for a soil series or types. Consequently, several subgroups can be considered when more detailed classification of the soils is done (Table 3; Figure 3, 4).

The Entisols. The wetland rice soils on Fluvaquents, Tropaquents, and Tropfluvents are generally found in swales and backswamps of beach ridges on coastal areas, on young alluvial fans, in cut-off meanders in peneplains, and on the level plains immediately around in-

Table 3. Classificati[illegible] phys[illegible]raphic position, and some chemical properties of some wetland soils in eastern Central Luzon[a]

Soil Series	Subgroup	Texture family	Physiographic position	pH[b]	O.M.[b] (%)	CEC (meq/100 g)	Ca (meq/100 g)	Mg (meq/100 g)	K (meq/100 g)	Available p (ppm)
Awayan	Entic Chromusterts	Clayey	Dissected fan terraces	6.1/6.1	1.0/0.6	31	12	3.8	0.08	18
Bantog	Udorthentic Pellusterts	Fine clayey	Very slightly dissected alluvial terraces	6.1/6.7	2.1/1.0	42	19	10	0.19	22
Bigaa	Udorth[illegible]ntic Pellusterts	Fine c[illegible]layey	-do-	5.8/6.3	2.3/1.7	44	22	12	0.28	32
Candaba	Udic Pellusterts	Fine clayey	-do-	5.7/6.6	3.1/2.1	54	18	15	0.37	4
Kapalangan	Vertic Tropaquepts	Clayey	Local narrow valleys alluvium	5.7/5.9	1.1/0.5	51	15	5.3	0.10	5
Mah[illegible]oon	Entic Chromusterts	C[illegible]ey	Dissected fan terraces	5.5/6.2	1.2/0.8	33	15	2.9	0.06	13
Malimba	Udorthentic Pellusterts	Fine clayey	Very slightly dissected alluvial terraces	5.7/6.3	2.0/1.0	51	24	16	0.22	15
Prensa	Entic Chromusterts	Clayey	Dissected fan terraces	4.3/4.2	0.9/0.3	11	4	0.6	0.06	tr
Quingua	Typic Tropudalfs	Clayey	Slightly dissected continental river terraces and levees	6.3/6.5	1.7/0.8	30	17	6.2	0.31	4

(continued on next page)

Table 3. continued

San Manuel	Typic Eutropepts	Fine Loamy	Moderately elevated alluvial terraces	6.0/7.1	1.6/0.9	34	18	7.3	0.58	12
Tagulod	Typic Tropaquepts	Clayey	Very slightly dissected alluvial terraces	4.8/5.9	1.9/0.7	28	11	8.9	0.29	tr
Zaragosa	Vertic Eutropepts	Clayey	Low continental river terraces and floodplains	5.4/7.2	2.4/0.6	40	28	6.2	0.58	28

[a]UNDP, FAO Tech. Rep. 3, 1972. Soil Survey and Land Classification of Peñaranda Irrigation System Area.
[b]Numerators are for surface soils; denominators for subsoils.

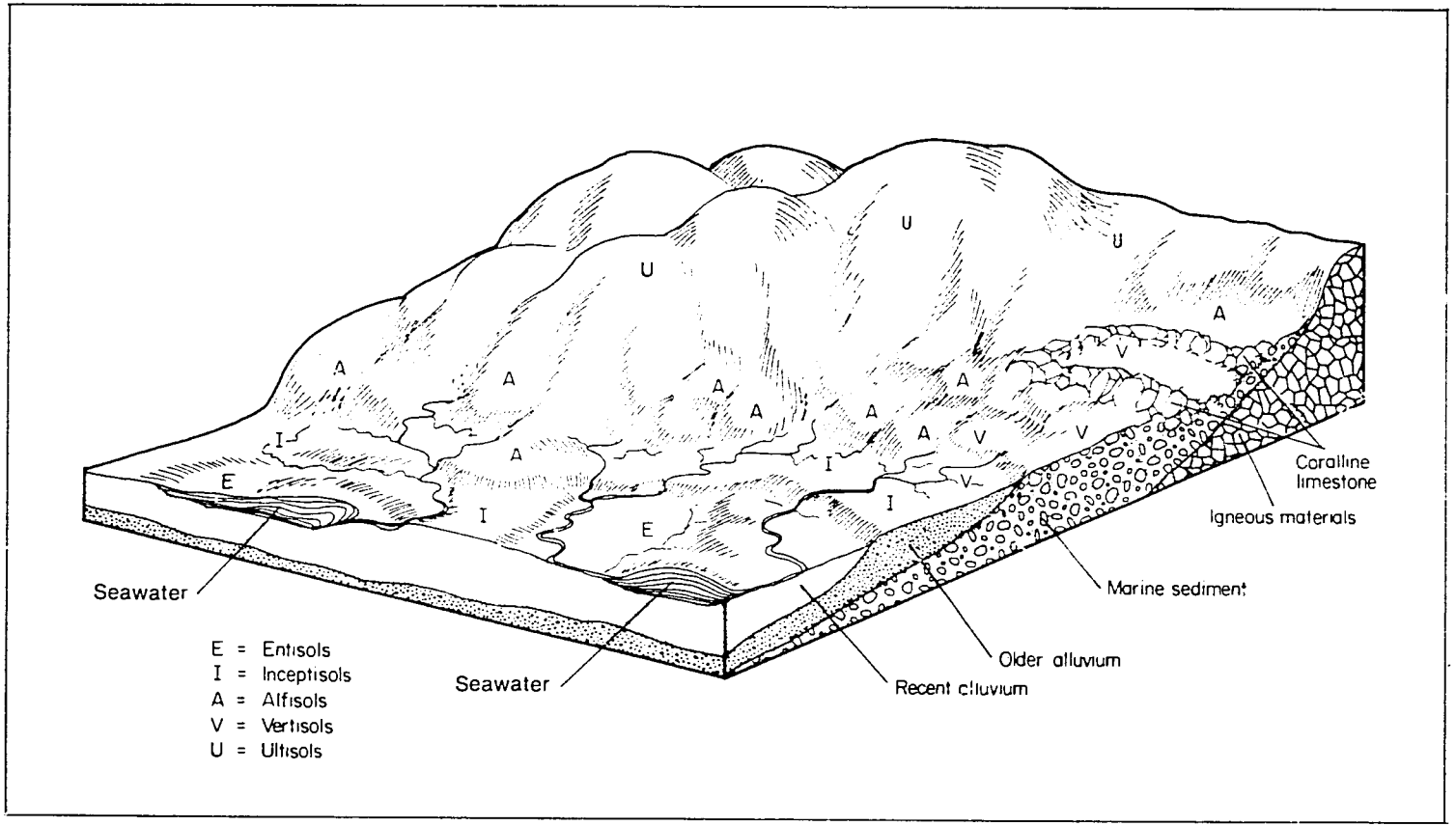

Fig. 3. Paddy soilscapes on a coastal plain physiography. Source: M.E. Raymundo, 1976.

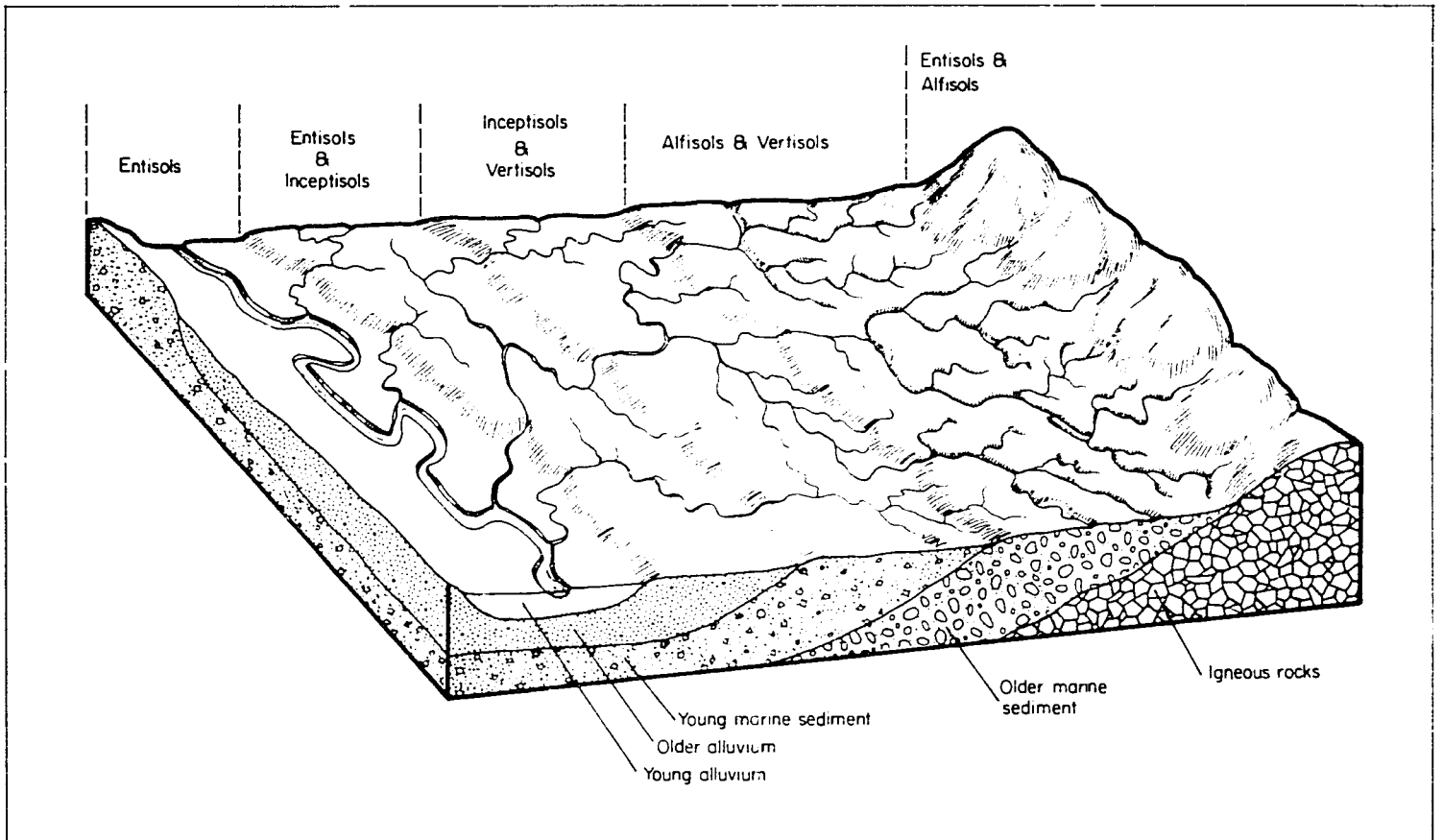

Fig. 4. Paddy soilscapes on a broad river valley. Source: M.E. Raymundo, 1976.

land lakes and marshes. They are found lowest in the toposequence and normally at slopes of 1.5% or less. A few small areas of Sulfaquents have been identified by the IRRI staff (Bernardo and van Breemen, 1977).

On these soils, wetland rice fields are generally developed on fine loamy or finer particle-size classes. Wetland rice systems on coarse loamy or coarser particle-size classes are limited to low areas and depressions subject to the influence of a fluctuating water table that rises close to or slightly above the land surface. Water levels that rise above the bunds or dikes of paddies are common. On the La Paz soils in Central Luzon and in narrow coastal areas, rice is grown in swales between knolls, which are natural dryland crops areas because of high permeability of the soil. Broader areas of coarser-textured soils associated with the Obando, Luisita, San Miguel, Palo, and Umingan soils subject to fluctuations of the water table are utilized for wetland rice.

The Inceptisols. Wetland rice fields on Tropaquepts, Fragiaquepts, and Eutropepts are normally on alluvial toeslopes of narrow coastal plains and small river valleys leading to the coastal areas and plains. On the plains of Central Luzon and in wide river valleys like that of the Cagayan Valley, Agusan, and Bicol River basin, these soils are slightly above the normal flood levels of the main rivers. When exceptionally high floods occur, the rivers swell and flood the area; but these floods normally involve weak currents and a small amount of siltation. The Inceptisols are higher in the toposequence than the associated paddies on the Entisols.

Wetland rice areas are generally on fine loamy and finer particle size classes. Some extensive areas of coarse loamy associates of Bago and Cauayan in the Cagayan Valley are able to retain water for wetland rice cultivation mainly because of the presence of plow pans. The Bago and Cauayan associates have either fine or very fine clayey subsoils within 40 cm below the surface of fragipans. A number of these soils have plow pans induced by puddling. Wetland rice soils are generally limited to slopes of 1.0% or less except in some clayey Fragiaquepts, which can be ponded even at slopes of 1.5-2.0%. Many of these soils, especially the Eutropepts associated with volcanics and calcareous materials, are of the Vertic subgroup (e.g., some of the Maahas and some of the calcareous San Manuel).

The Vertisols. Pelluderts, Chromuderts, Pellusterts, and Chromusterts are extensively used for wetland rice production. They are found in all landscape positions generally used for paddies, such as low areas associted with former lagoons and backswamps, on level to moderately dissected terraces, and on gentle to moderately rolling slopes. The former lagoons (San Fernando and Isabela) may have been subjected to biological calcification prior to complete immergence originally associated with calcareous parent materials (Bani and Sta. Rita) or with sediments of basic volcanic origin (Guadalupe).

Wetland rice soils on Vertisols are developed on fine and very fine clayey materials ranging in position from low-lying recent alluvia to elevated older marine terraces associated with calcareous sediments and basic volcanics. Wetland rice fields on slopes up to 30% are common among these particle-size classes, which are deep or shallow Lithic subgroups.

The Alfisols. Tropaqualfs, Fragiudalfs, and Tropudalfs are generally found highest in the toposequence in the wetland rice system. They are on slightly to severely dissected marine terraces, which developed into the intermediate uplands, terraced paddies, and terraced mountain slopes. The Tropaqualfs are on the slightly dissected, more level lower slopes that receive considerable water enrichment from the higher paddies on the steeper slopes. The Fragiudalfs are associated with level wetland rice systems on slightly dissected marine terrace landscapes and on steep slopes in severely dissected intermediate uplands (Prensa and Buenavista). Wetland rice fields developed on high mountain slopes and located in areas with no dry season can be considered Anthraquic Tropudalfs because man has modified the slope and the moisture regime by diverting small mountain streams into the systems.

Wetland rice soils on these great groups are mainly in fine loamy or finer textural classes. The Tropudalfs on higher and slightly dissected areas are developed into wetland rice soils in the presence of subsurface water enrichment from surrounding uplands, and on mountain slopes continuously supplied by water from mountain streams.

Fertility Status of Rice Soils in the Philippines

Wetland rice soils in the Philippines are generally high in natural fertility because of the geologically younger parent materials and because of periodic rejuvenation from volcanic ash, which readily weathers and releases nutrients in the humid tropical climate. The eruption of Taal Volcano in 1965 deposited ash as much as 6 m thick, which was observed to support grass vegetation within 3 — 4 years. Kawaguchi and Kyuma (1975) rated 48 — 54 profile samples collected from the Philippines to have a high fertility level. They also found the soils to be generally montmorillonitic.

Some chemical properties of a few wetland rice soils are shown in Table 4. Fertilizer experiments conducted to date by many researchers have established that a majority of wetland rice soils in the Philippines need mainly nitrogen. In newly developed paddies in Davao (Tropaquepts) 30 kg nitrogen/ha has been found sufficient even with the use of modern rice varieties (MV). In other areas, MV require 100 kg nitrogen/ha for optimum production. Some Usterts, Fragiaquepts, and Udalfs require phosphorus, in addition to nitrogen for optimum production. Reproducible responses to potash have been obtained in Fragiaquepts of the Cauayan series.

Phosphorus deficiencies were found in the Guadalupe series (Pellusterts); in the wetland rice associated of the Luisiana series

Table 4. Some chemical properties of wetland rice soils[a]

Soil Series	Soil Order	pH	O.M. (%)	CEC	Ca (meq/100)	Mg
La Paz	Entisols	5.6	0.9	7.6	4	3
Legaspi	Entisols	6.5	2.5	4.4	2	3
Luisita	Inceptisols	6.7	1.2	18.8	12	9
Quilada	Entisols	5.7	1.6	14.0	7	3
Kabacan	Inceptisols	5.8	3.8	26	14	7
Maligaya	Alfisols	5.9	2.0	25	15	8
Quingua	Alfisols	6.0-7	1.5-2.5	32-37	18-22	14-17
San Manuel	Inceptisols	6.0-7.2	1.0-2.5	30-34	22-25	12-13
Buenavista	Alfisols	5.8	0.8	19	10	7
Maahas	Inceptisols	5.7	3.0	32	16	7
Matina	Vertisols	5.6	3.7	36	22	8
Pili	Vertisols	5.8	4.9	33	17	7
Timaga	Vertisols	6.7	5.8	52	40	13
Toran	Inceptisols	5.7	1.6	14	7	3
Bigaa	Vertisols	5.2	2.5	38	20	15
Bantog	Vertisols	6.2	1.9	36	16	16
San Fernando	Vertisols	6.0-6.7	3.0	46-50	23-30	23-35
Guadalupe	Vertisols	5.7	3.2	35	19	12

[a]Analytical data from the Department of Soil Science, College of Agriculture, University of the Philippines at Los Baños, College, Laguna; 1976.

(Tropodults) in southern Luzon; in the Prensa, Annam, and Buenavista series (Fragiaqualfs) in eastern Central Luzon; in almost all soil of Palawan and some parts of Mindoro; and in the Bago and Cauayan series (Fragiaquepts) in the Cagayan Valley.

Zinc deficiency has been observed in relatively extensive areas of Tropaquents and Tropaquepts of Agusan Valley and Davao plains in Mindanao. The deficiency was corrected in some places by improving drainage. On a smaller scale, zinc deficiency is associated with poorly drained Histosols, Tropaquepts, Tropaquents, and Hydraquents (Orticio and Ponnamperuma, 1977). Some of the Aquents and Aquepts are subject to chemical or biological calcification associated with high $Ca(HCO_3)_2$ in irrigation water or in upwelling seepage water (Moormann et al., 1976; Van Breemen and Bernardo, 1977).

Salinity exists to a limited extent in tidal flats, which frequently are not used for wetland rice.

The more permanent dryland rice production areas, and many of the rice areas with the shifting, slash-and-burn system are generally on soils that were initially fertile. In Southern Luzon, the Bicol region, and the eastern section of the Northern and Southern Mindanao regions, dryland rice areas are mainly on volcanic ash-influenced Entisols, Inceptisols, Mollisols, Vertisols, Alfisols, and Ultisols. The fertilizer recommendations for local dryland varieties used are much less than for the associated wetland soils. Where improved varieties are used, fertilizer recommendations are comparable to those for the associated wetland soils.

Uses of Rice Soils in the Philippines

Temperaturewise, crops can be produced year-round in all topographically suitable areas of the Philippines. Rice soils occupy the prime of level lands, but lack or excess of water in a few cases limits the year-round production potential. During the drier part of the year, crops requiring less soil moisture than rice are grown prior to, but mostly after, a rice crop. The extent and intensity of production of other crops on rice soils are often dictated by economics, agronomic suitability, and management needs.

Irrigated wetland rice areas. Of a total 2.57 million hectares of rice land in the Philippines, about 670,000 ha had sufficient irrigation water supply for two or more rice crops in 1975-76. The areas under this irrigation class constitute about 25% of the total rice area and about 30% of the total wetland rice area.

About 413,000 ha of wetland rice receive only partial irrigation and are generally limited to one rice crop a year. That area is about 38% of the total area of irrigated rice, which is in the order of 1.08 million hectares. Where the physical conditions of the soil permit, these are the areas with a potential for one or two dry-seasons dryland crops after rice. In these areas high-value annual crops are grown during the dry season. These are the main areas for tobacco and for the developing cotton production in the Ilocos, Cagayan Valley, and Central Luzon regions. Onions and lowland cabbages are grown, particularly on the medium-textured soils in Central Luzon.

Where physical conditions of the soil make land preparation after rice difficult for upland crops even with irrigation, low-management crops like mungo and cowpea, are generally grown with minimum tillage or no tillage. This system of upland crop production in paddies is practiced more widely in rainfed paddy areas where risks due to uncertainty of moisture supply are much greater even if the physical conditions of the soil are favorable.

Rainfed wetland rice areas. The rainfed wetland rice area constitutes about 45% of the total rice area and about 51% of the total wetland rice area. Increasing the number of rice crops is the objective of present research efforts on rainfed wetland rice. The potential appears to be much less in areas with four dry months or more, and limited, if ever, to soils with the capability to provide adequate water for the dry-season crops. Highly perishable crops, like watermelon, cantaloupe, string bean, tomato, and other vegetables, are grown after rice near market centers but on a comparatively small scale. Water to start the seedlings in the field is hauled or comes from shallow wells. Tobacco is grown commercially in some rainfed paddies on the low-lying areas using this practice of minimal irrigation.

Dryland rice areas. Dryland rice areas, which are about 13% of the total rice area are limited to one crop of rice a year. Intercropping of corn and beans with rice, mainly for domestic consumption, is a com-

mon practice. Some vegetable crops are relayed with rice. The more common practice is growing one or more crops after dryland rice. In many parts of the country dryland rice is planted under coconuts. Most of that is on soils of volcanic origin in southern Luzon, Bicol Peninsula, Negros, and in parts of Mindanao.

Many dryland rice areas, and even some wetland rice areas physically suitable for rice production, are diverted to plantation crops that give better economic returns. It is common to note shifts from rice to sugarcane and other annual crops, and vice versa. With better yields obtained from MV and with improvements in irrigation, dryland rice areas have diminished in many parts of the country. The present extent of dryland rice areas is maintained only in sections of the country where there is limited area for wetland development.

Proposed Direction

Classification of natural bodies, including soil bodies, is an essential feature in any research, development, planning and implementation efforts because an adequate classification, although a device of the mind and subject to changes, provides the means for an orderly and systematic approach to certain problems. When such classification exists, researchers can readily relate their individual efforts to real systems.

Man-made soil systems, such as paddies, are as yet unknown units in Soil Taxonomy, but they are real bodies and should be amenable to a modified system of soil classification when necessary. This is not only at the higher categories but, more important, at the lower levels where characterization and subsequent classification must necessarily relate to the requirements of production. Such a system will facilitate transfer of experience or technology.

Intensification of studies on rice soils under varying physiographic and climatic conditions existing in the Philippines accelerate exploitation of potentials to fullest utilization for food production. Capability classification is a product of soil classification. The development of varieties which are high yielding; early maturing; and resistant to pest, disease, and drought; and the advances in agrotechnology have intensified the demand for information on the basic resource, the land, of which the soil is a major component.

A thorough understanding of specific soil areas could generate greater benefits, as for example, from the use of fertilizers and irrigation water, both of which are becoming scarce during critical periods, but which are indispensable in food production.

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Properties of Soils Planted to Sugarcane and their Management

EDUARDO HOMBREBUENO

The total area cultivated to sugarcane has reached a peak area of 553,153 ha. in CY 1975-76. The resulting increase in cost of production coupled with the depressed sugar prices in the world market had caused the decline in the total area now on sugarcane to 395,382.16 ha. in CY 1980-81.

These sugar areas are distributed in about 18 provinces in the country: 9 in Luzon, 8 in Visayas, and 3 in Mindanao with their own distinctive ranges of soil types.

The suitability and profitability of these soils for sugarcane growing, however, varies and are highly dependent on their properties and their management.

This paper aims to (1) focus attention on the characteristic properties of the principal soils currently grown to sugarcane and (2) point out the attendant management practices towards improving their productivity.

Distribution

The principal soil series currently cultivated to sugarcane are shown in Table 1 and 2. These soil series constitute about 15% of the total number of soil series established by the Bureau of Soils. The San Manuel series appeared to be the most widely distributed in a number of provinces.

Properties

The characteristic physical features and properties of the different soil series are tabulated in Table 3. For convenience in determining the best management practices to employ on these different soils, these were grouped into soil profile classes established by the Bureau of Soils (Nartea, 1977). Ratings for the relatively stable properties of the soils, such as depth of solum, soil texture, and land slopes were also calculated (Hombrebueno and Fernandez, 1980), to indicate their relative suitability for sugarcane cultivation.

The chemical analysis of representative soil series of each soil profile classes are shown in Table 4.

Of the dominant soil series being cultivated to sugarcane eight were classified into profile class A (recent alluvial), namely: the San Manuel, Quingua, Siaton, Sara, Angeles, La Paz, Luisita, Umingan, and

Table 1. Dominant soil series, their classification and the provinces where they are grown to sugarcane in the Luzon area[a]

Dominant Soil Series	Soil Order	Province
Lipa	Alfisol	Laguna, Batangas
Macolod	Ultisol	Laguna, Camarines Sur
Carmona	Alfisol	Laguna, Cavite
Tagaytay	Andisol	Laguna, Cavite
Calumpang	Inceptisol	Laguna, Batangas
Sibul	Vertisol	Batangas
Guadalupe	Vertisol	Batangas
Magallanes	Alfisol	Batangas, Cavite
Taal	Inceptisol	Batangas
San Fernando	Vertisol	Pampanga
Angeles	Entisol	Pampanga, Zambales
La Paz	Entisol	Pampanga, Zambales, Tarlac
Tarlac	Alfisol	Pangasinan
San Fabian	n.d.	Pangasinan
Alaminos	Ultisol	Pangasinan
Antipolo	Ultisol	Pangasinan
Tupi	Andisol	Pangasinan
Quingua	Alfisol	Zambales, Pampanga
Luisita	Inceptisol	Tarlac
Pili	Vertisol	Camarines Sur
Tigaon	Vertisol	Camarines Sur
San Manuel	Inceptisol	Pangasinan, Tarlac
Umingan	Inceptisol	Pangasinan

[a]Sources: Montecillo, L.A. 1983. Soil properties and classification (mimeographed handouts). Department of Soil Science, University of the Philippines at Los Baños, Laguna. 67 pp.

Raymundo, M.E. 1984. Rice soils of the Philippines (mimeographed handouts).

Personal Communication, Bureau of Soils.

[b]n.d. = no data.

Calumpang series. A perfect rating for physical properties has been indicated for the San Manuel and Quingua soil series which were also classified by the Bureau of Soils as Class A land, based on its capability.

The profile of these soils is not well-developed because alluvium is deposited over the surface almost every year. Their texture is coarse to medium coarse, and it is uniform from the surface to the substratum. The soil solum is moderately deep (50-90 cm) to deep (90-150 cm). The relief of the land varies from level to slightly undulating (1-3% slope) to gently rolling (3-8% slope).

Classified into soil profile class B (older alluvial) are eight soil series, namely: the Isabela, Silay, Sta. Rita, Maligaya, Mandaue, Calumpang, San Fernando, and Pili series. Ratings for the physical properties of these soils appear to be relatively equal, except the Calumpang, Maligaya, and Pili series which are relatively lower.

These soils are poorly drained. Although their relief is level to slightly undulating with slopes up to 3% which enhances surface drainage,

Table 2. Dominant soil series, their classification and province where they are grown to sugarcane in the Visayas and Mindanao area[a]

Dominant Soil Series	Soil Order	Province
Guimbalaon	n.d.[b]	Negros Occidental, Leyte
San Manuel	Inceptisol	Negros Occidental, Negros Oriental, Leyte, Capiz
Luisiana	Ultisol	Negros Occidental, Leyte, Capiz
Umingan	Inceptisol	Negros Occidental, Leyte
Isabela	Vertisol	Negros Occidental, Negros Oriental
La Castellana	n.d.	Negros Occidental, Negros Oriental
Faraon	Vertisol (Mollisol)	Negros Oriental, Cebu, Capiz
Silay	n.d.	Negros Occidental
Slaton	n.d.	Negros Oriental
Bolinao	Alfisol	Negros Occidental, Negros Oriental, Cebu
Mandaue	n.d.	Negros Oriental, Cebu
Sta. Rita	Vertisol	Iloilo, Capiz
Sara	Alfisol	Iloilo, Capiz
Alimodian	Alfisol	Iloilo, Capiz
Barotac	Alfisol	Iloilo
San Rafael	n.d.	Iloilo; Capiz
Maligaya	Alfisol	Capiz
Lugo	n.d.	Negros Oriental, Cebu, Leyte
Medellin	Vertisol	Cebu, Leyte
Tugbok	Ultisol	Davao
Kidapawan	Alfisol	Davao
Miral	Alfisol	Davao
Cabantian	n.d.	Davao
Madunga	n.d.	Davao
Bantay	Inceptisol	Negros Occidental

[a]Sources: Montecillo, L.A. 1983. Soil properties and classification (mimeographed handouts). Department of Soil Science, University of the Philippines at Los Baños, Laguna. 67 pp.

Raymundo, M.E. 1984. Rice soils of the Philippines. (Mimeographed handouts)

Personal Communication: Bureau of Soils

[b]n.d. — no data

the clayey B horizon which is sticky, plastic, and compact cause slow to very slow percolation of water into the soil. The soil solum is moderately deep (50-90 cm) to deep (90-150 cm).

The soil series classified into profile class C (volcanic ejecta) are Guadalupe, Magallanes, Taal, Tagaytay, Lipa, San Fabian, and Tupi series. An equal higher ratings were indicated for the Lipa, Taal, and Magallanes series.

These soils are well-drained because surface drainage and percolation rate into the soil are moderately fast. They occur on nearly level (1-3% slope) to slightly rolling relief (8-15% slope). They do not have boulder outcrop. These soils are grayish brown to nearly black.

The 12 soil series classified into profile class D (igneous rocks) are as follows: Miral, Kidapawan, Tigaon, Tugbok, Guimbalaon, Luisiana, La Castellana, Barotac, San Rafael, Macolod, Antipolo, and Alaminos, Rated high in their physical properties are Barotac and San Rafael

Table 3. Characteristic features and properties of dominant soil series planted to sugarcane

Soil Series	Origin & Formation (Profile Class)	Depth (cm) & Texture of A & B Horizons	Relief	Drainage Condition	Rating (%)	Capability Class
San Manuel	Recent alluvial	A — 25-40 SiL, SiCL, FSL, L, CL B — 70-100 SiL	Nearly Level	External-Fair to good Internal-Fair to good	100	A
Quingua	— do —	A — 25-40 SiL B — 85-114 SiCL, CL	Level to Nearly Level	External-Fair to good Internal-Fair to good	100	A
Siaton	— do —	A — 20-35 SL B — 80-90 SC	Nearly Level to undulating	External-Good Internal-Good	80	Be
Sara	— do —	A — 13-17 CL, C B — 75-80 SiL	Level to gently rolling	External-Fair Internal-Fair	64	Be
Angeles	— do —	A — 25-30 FS, S B — 105-110 S	Nearly Level to gently undulating	External-Good to Excessive Internal-Good to Excessive	57	Be
La Paz	— do —	A — 25-30 S, FS B — 95-100 FS	Level to nearly level	External-Good Internal-Good	57	Bs
Luisita	— do —	A — 30-50 FS, SL, FSL B — 80-90 FS	Nearly level	External-Good Internal-Good	57	Bs
Umingan	— do —	A — 20-45 FS, SL B — 50-100 SL	Nearly level to very slightly undulating	External-Good to very good Internal-Good to very good	95	Bs
Calumpang	Older alluvial (B)	A — 15-40 CL B — 40-140 CL, C	Level to rolling	External-Poor to fair Internal-Poor	56	Be
San Fernando	— do —	A — 20-25 CL B — 95-100 C	Generally flat	External-Poor Internal-Poor	70	Bw
Mandaue	— do —	A — 20-30 CL B — 110-120 CL	Almost flat	External-Fair Internal-Poor	80	Bw
Isabela	— do —	A — 25-35 C, SL B — 95-100 C	Almost flat	External-Poor Internal Poor	70	Bw
Silay	— do —	A- 15-20 C, L B- 55-60 SiL	Almost level	External-Poor Internal-Poor	76	Bw
Sta. Rita	Older Alluvial (A)	A — 20-25 CL, C B — 92-97 C	Nearly Level	External-Fair to poor Internal-Fair to Poor	70	Bw

Mangaya	— do —	A — 20-23 C B — 55-70 C	Nearly level to gently undulating	External-Poor Internal-Poor	63	Bw
Pili	Older alluvial (A)	A — 20-30 C, CL B — 55-60 C, CL	Generally level to gently undulating	External-Poor to fair Internal-Poor to fair	63	Bw
Guadalupe	Volcanic ejecta (C)	A — 25-35 CL B — 50-80 C	Generally roughly rolling with some almost flat areas	External-Good to excessive Internal-Poor	53	Be
Magallanes	— do —	A — 15-30 L B — 70-80 CL	Gently undulating to slightly rolling	External-Good Internal-Good	70	De
Taal	Volcanic ejecta (C)	A — 30-45 L, SL B — 110-120 FS, FSL	Level to mountains	External-Good to excessive Internal-Good	72	Ce
Tupi	— do —	A — 15-30 SL, SiL B — 55-70 FS	Nearly flat to rolling	External-Good to excessive Internal-Good	53	Ce
San Fabian	— do —	A — 20-30 CL B — 30-45 C	Rolling to hilly with small level areas	External-Good to excessive Internal-Poor to fair	54	Ce
Carmona	— do —	A — 20-35 C B — 125-140 C	Level to rolling	External-Poor to good Internal-Poor	49	De
Tagaytay	— do —	A — 12-50 SL B — 40-60-CL, C	Rolling to hilly	External-Good to excessive Internal-Fair to good	53	M
Lipa	— do —	A — 25-30 L B — 115-120 L, CL	Slightly rolling to hilly	External-Good to excessive Internal-Poor	70	M
Tugbok	Igneous rock, Residual (D)	A — 30-35 C B — 95-100 CL	Undulating to gently rolling	External-Good Internal-Fair to Poor	56	Ce
Kidapawan	— do —	A — 20-25 CL B — 100-120 C	Rolling to hilly and mountains	External-Good to excessive Internal-Good	56	Ce
Guimbalaon	— do —	A — 25-30 C B — 65-70 C	Undulating to steep	External-Fair to excessive Internal-Fair	56	Ce
La Castellana	Igneous Rock (D)	A — 15-30 C, CL B — 40-50 C	Rolling to hilly with some level areas	External-Good to excessive Internal-Fair	50	Ce
Tigaon	— do —	A — 25-35 CL B — 45-55 C	Undulating to mountainous	External-Good to excessive Internal-Fair	53	Ce
Alaminos	— do —	A — 20-35 CL B — 40-100 CL	Rolling to hilly with level areas	External-Good to excessive Internal-Fair	64	Ce

(continued on next page)

Table 3. continued.

Soil Series	Origin & Formation (Profile Class)	Depth (cm) & Texture of A & B Horizons	Relief	Drainage Condition	Rating (%)	Capability Class
Antipolo	Igneous rock (D)	A — 20-30 C B — 50-90 C	Rolling to mountainous, some portions are slightly rolling to almost flat	External-Good to excessive Internal-Poor	42	M
Barotac	Igneous rocks (D)	A — 20-30 C B — 100-110 CL	Roughly hilly mountainous	External-Good to excessive Internal-Fair	70	M
San Rafael	— do —	A — 10-12 L B — 28-30 L	Hilly to mountainous	External-Excessive Internal-Fair	76	Ce
Macolod	— do —	A — 30-60 CL B — 55-100 CL	Roughly rolling to hilly with small intervening flat areas	External-Good to excessive Internal-Fair	46	M
Luisiana	— do —	A — 25-30 C B — 50-70 C	Rolling to mountainous	External-Good to excessive Internal-Fair to good	46	M
Miral	— do —	A — 20-25 CL B — 45-40 C	Moderately rolling to hilly	External-Fair to excessive Internal-Fair	44	M
Cabantian	Soft shale residual (E)	A — 15-18 C B — 40-50 C	Undulating to hilly	External-Excessive Internal-Poor	44	Ce

Madunga	Shales, sandstone (E)	A — 15-20 CL B — 45-50 C	Moderately rolling to hilly	External-Good to excessive Internal-Poor	44	M
Alimodian	— do —	A — 25-30 CL, SiL B — 55-60 CL	Rolling to hilly and mountainous	External-Good to excessive Internal-Fair	61	M
Bantay	Shales, residual (E)	A — 15-20 L B — 55-60 CL	Gently undulating to hilly	External-Good to excessive Internal-Poor	56	M
Medellin	Limestone and Shale (E)	A — 25-30 C B — 55-60 C	Flat to gently undulating upland	External-Poor to very poor Internal-very poor	53	Be
Sibul	Limestone and Shale (F)	A — 25-30 C B — 55-60 C	Flat to gently undulating upland	External-Very poor Internal-Poor to very poor	53	Be
Faraon	Coralline, Limestone (F)	A — 15-30 C B — 35-45 C	Rolling to hilly	External-Good to excessive Internal-Poor to fair	48	Ce
Lugo	Lime Shale (F)	A — 15-20 C B — 30-35 C	Roughly rolling to almost hilly	External-Good Internal-Poor	39	M
Bolinao	Coralline limestone (F)	A — 20-35 C B — 40-80 C	Mildly rolling to rolling to hilly and mountainous with some level areas	External-Good to excessive Internal-Poor	46	M
Tarlac	Tuffaceous sandstone (G)	A — 30-60 CL B — 55-110 CL	Roughly rolling to hilly with small intervening flat areas	External-Good to excessive Internal-Poor	64	Ce

Table 4. Chemical analyses of representative series for each profile class

Soil Profile Class	Soil Series	pH	N (%)	$P_{(ppm)}$	$K_{(ppm)}$
A	San Manuel	6.0	0.08	23	170
	Quingua	5.6	0.06	67	67
	La Paz	4.3	0.02	16	38
	Luisita	6.0	0.05	5	86
B	Calumpang	5.7	0.09	32	233
	San Fernando	5.4	0.06	84	97
	Silay	5.2	0.06	21	150
	Isabela	6.1	0.18	83	223
C	Guadalupe	5.8	0.08	24	222
	Lipa	5.9	0.09	24	235
	Magallanes	5.9	0.07	19	237
	Tupi	5.2	0.18	8	118
D	Guimbalaon	5.2	0.09	5	165
	La Castellana	4.7	0.17	5	190
	Luisiana	5.1	0.10	4	127
E	Bantay	5.05	0.12	8	100
	Alimodian	4.85	0.20	6	202
F	Faraon	7.0	0.11	50	74
	Bolinao	6.7	0.15	19	134

series.

These soils are moderately deep (50-90 cm) to deep (90-150 cm), friable and reddish in color. They are well-drained because their permeability is moderate and because they are found on rolling to steeply rolling relief which makes surface drainage fast.

Many of these soils have boulder outcrops which interfere with cultivation.

Classified into profile class E (shales) are 4 soil series, namely: Cabantian, Mandunga, Alimodian, and Bantay series. Of these, the Alimodian series was rated the highest in physical properties.

These soils are deep with reddish brown to brown color. They are well-drained. Their permeability is slow because they are clayey, but surface drainage is fast because the relief ranges from undulating (3-8% slope), to hilly (40% slope), to mountainous (60% slope), making it susceptible to erosion.

Unlike the basic igneous rock class, they have no boulder outcrops. The five soil series belonging to profile class F (limestone) are: Lugo, Faraon, Bolinao, Medellin, and Sibul series. These series were all rated low in their physical properties.

These soils are shallow, generally black, sticky, and plastic clay. Because they are clayey their permeability is very slow. Their being found on rolling (8-15% slope) to steeply rolling (18-20% slope) areas makes surface drainage fast, keeping it relatively well-drained, but very

susceptible to erosion. In fact, in many places the limestone parent material is exposed.

Classified into profile class G (sandstone) is the Tarlac series. This is deep, nearly black, or dark gray, fine, granular, sticky, and gritty clay loam. Surface drainage is good to excessive; but internal drainage is poor, making it susceptible to erosion.

Management Practices and Yield

Considering the varying characteristics and properties of the soils currently used, specific cultural-management practices are employed to suit crop requirement for satisfactory yield. The extent to which these practices are employed is dependent on the availability of resources and the economics of its use.

Land preparation and cultivation. Soil series of older alluvial deposits and from limestone are relatively the most difficult group of soils to work with because of their fine texture. They are sticky and plastic when wet, and hard and cloddy when dry. For proper maintenance of good soil tilth necessary for good seedpiece germination and development, proper timing of land preparation and cultivation must be considered.

To improve internal drainage in level areas, in addition to allowing plant roots to go deeper, these soils have to be subsoiled. Subsoiling loosens the lower layers of the soil without bringing up the infertile subsoil to the surface. According to research findings, fields which have undergone deep tillage usually show an additional annual yield of 10 PS/ha.

Efficient utilization of farm implements is affected by the presence of boulder outcrops in soils developed from basic igneous rocks. Land forming and removal of rock outcrops would improve the workability of these kind of soils. Most big plantations with complements of heavy equipment can afford to undertake such operations.

In general topography has a lot of bearing on the possibility of mechanized sugarcane culture. Plantation with profile classes A, B, and C will not encounter problems on this. Machines for cultivation in general can still operate in slopes of up to 30%.

Better yields have been obtained with the use of machinery in actual commercial use, primarily due to better control of the environmental conditions affecting the growth of sugarcane.

The trend towards the use of mechanical harvesters would be limited by the topography of the land. Estimates in hectares of area currently planted for mechanical harvesting are: Negros Occidental — 100,000; Luzon — 46,000; Panay — 9,000; Mindanao — 13,000; Leyte — 6,000; and Cebu — 4,000 ha; or a total of about 178,000 ha.

Contour cultivation to control erosion must be carefully considered with soils classified in profile classes C, D, E, F, and G.

Irrigation and drainage. Of the groups of soils currently cultivated to sugarcane, those of recent alluvial deposits are the most well drained, but would require a relatively sustained irrigation, particularly during the drier months. This is because of the coarse to medium coarse texture of these soils which is uniform from the surface to the substratum. Specifically this is a problem for the Angeles, La Paz, and Luisita soil series. Increase in yield obtained due to irrigation is about 19-25 PS/ha. However, only about 9% of the total area planted to sugarcane in the Philippines are irrigated.

A satisfactory system of drainage is a necessity for the older alluvial soils because of the clayey nature of their B and C horizons. In practice, infield canals are being made to get rid of excess water. Surface drainage can improve the yield by as much as 20 PS/ha.

Organic matter build-up. Generally, the loose sandy soils formed from alluvial deposits need organic matter build-up to improve their water-holding capacity and their ability to retain added fertilizer nutrients. Organic matter content of about 3-5% is desired for sugarcane (Hernandez, 1966). The sandy soils of Tarlac and Pampanga where the organic matter content is less than 2% have been reported to be the least productive of all the sugarcane soils in the Philippines (Wenstedt and Spencer, 1967 as cited by Tomaneng, 1977). They produce about 30 to 80 PS/ha. However, with good farm management practices yields of 100 — 150 PS/ha may be obtained.

The Isabela series often referred to as the black calcareous soils of San Carlos, Bais, part of Davao, and BISCOM districts in Negros Island is by far the most fertile sugarcane soils in the Philippines. It has organic matter of 4-8%, is fairly high in phosphorus, potash, and in its moisture-holding capacity. The yield of sugarcane ranges from 150-250 PS/ha.

Liming and fertilization. Soils developed from limestone have pH and calcium content favorable to sugarcane. The optimum pH requirement for sugarcane ranges from 6.2-7.8.

On the other hand, soils developed from igneous rocks which are acidic and have a high P-fixing capacity, need to be limed for profitable sugar production. The critical pH level for sugarcane in the Victorias mill district is at pH 4.5 (Tabayoyong, 1957). One cannot grow sugarcane profitably with pH below 4.5, unless enough lime is applied to the soil.

Other soil groups would require the judicious application of lime. An increase in sugar yield due to liming varied from 12-32% (Escobar and Lacson, 1964). The application of nitrogen is a necessity for all the soil groups to be able to grow a good crop of cane.

The application of phosphorus is needed for soils developed from igneous rocks and from shales. Rock phosphate application would be beneficial for these soil groups. Application of mudpress, a kind of mill waste, was observed to be beneficial for these soils.

Potassium is relatively low in soils developed from alluvial deposits. For the loose sandy soils of recent alluvial deposit, the application of N and K fertilizer is split.

The optimum level of NPK nutrients in the soil are N-0.30%. P-30 ppm (Truog P) and K — 150 ppm (Peech and English). Depending upon the degree of nutrient deficiency in a given soil, as much as 60% increase in yield due to fertilization of NPK may be realized.

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Properties of Soils in Coconut Areas

WILFREDO C. COSICO

The coconut palm (*Cocos nucifera* L.) is said to be a very adaptable crop because it is found growing in widely diverse soils. In the Philippines coconut grows in flatlands and steep upland, in coastal areas and far inland, in well drained and poorly drained soils, in sandy and clayey soils, in highly fertile and marginal soils, and in acidic and alkaline soils.

However, although coconut survives in apparently adverse conditions, productivity is greatly affected. For instance, it is generally observed that the palm grows poorly in poorly drained and in compacted soils. On the other hand, it thrives along sea coasts, in alluvial plains, and in coarse to medium-textured soils. The degree by which the different land and soil qualities affect the productivity of coconut has been the subject of numerous studies, but it is likely that a combination of these properties determines the performance of the coconut.

Root Habits of the Coconut Palm

The coconut belongs to the family Palmae. It is monocotyledon characterized by a fibrous root system with no tap root, an unbranched stem with a single growing point, and a crown of compound leaves.

The base which is thickened into a bole in tall cultivars produces numerous thick roots radiating from all sides. The main roots average 6 m but can grow to as long as 25 m. The diameter is about 8 mm. In old trees and in waterlogged areas the roots die starting from the apex and proceeding upwards.

Menon and Pandalai (1958) stated that the length and the spread of roots are largely controlled by the nature of the tree, soil moisture conditions, nature of the soil, and cultural management. In general, most of the roots are spread laterally within 150—180 cm radius of the base. Vertical roots of a 60-year old tree have been found to penetrate 6 m below a deep sandy loam soil. An adult palm has 2,000—3,000 main roots. One main root can absorb about 2 cu. cm of water in 24 hours. Thus, each palm can absorb as much as five liters of water per day.

Effect of Land Qualities

Climate. The coconut palm is essentially a tropical plant and therefore is most extensive in such countries as the Philippines, India, Sri Lanka, Indonesia, South Sea Islands and Malaya. Worldwide observations show that the farther the area from the equator, the more coconut is limited to lower elevations, indicating a considerable in-

fluence of temperature. It appears that at the latitude of the equator, the limiting elevation for coconut is 750 m. Productivity gradually starts to decrease at elevation beyond 300 m. Cooke (1936) said that the limit for commercial cultivation in the Philippines is at 600 m. The most favorable temperature for coconut is about 27°C.

The coconut palm apparently loves not only warm temperature but also sunlight, moderate wind, and high moisture (but with good drainage). A high relative humidity for extended periods can cause budrot. A relative humidity of less than 70% is favorable. A long period of sunshine favors copra formation. A dry and windy atmosphere favors the growth of coconut palms, provided soil moisture is adequate. This condition is generally present in coastal areas.

According to the report of the United Coconut Association of the Philippines (UCAP, 1979) the ideal rainfall level for coconut growing is 125 mm — 192 mm/month. The country's rainfall level does not depart very much from the ideal range, having a normal level of 218 mm. During the period of 1968-78 the Philippines' rainfall level exceeded the upper limit of 192 mm only 10% of the time. Distribution of rainfall matters more than the total amount that falls during the year.

The UCAP report (1979) indicates that coconut will not suffer from drought with a rainfall of 1500 mm/year (125 mm/month) more or less evenly distributed. Palms will tolerate only three consecutive months of this level of rainfall. In his study of crop occurrence according to Corona's climatic types, Philipson, et al. (1972) found that the coconut in different regions of the Philippines predominates as a primary crop wherever the area has no dry season or where only short dry periods occur. Copeland (1931), and Espino and Juliano (1924) stated that the rate of water absorption or requirement of a coconut palm is 16-24 liters/day.

One of the early studies to relate coconut yield with rainfall was done by Balasubramanian (1956) in Madras State. Correlations were made between yields and rainfall from 29-year records. The study showed that rainfall affects coconut yields in particular months of the year, and that there is also an interaction with the type of soil. In Ceylon, Abeywardena (1968) pointed out that the previous years' rainfall only partially explains variations in coconut yield. He explained that the exogenous environment, e.g., temperature and humidity which interact with rainfall within the critical period of one year, can influence moisture sensitivity of coconut palms appreciably.

Land form. In his study of coconut areas in the Philippines, Cosico (1983) found that the yearly average nut yield in coastal flatlands were significantly higher (40.2 nuts/tree) than those in other land forms (Table 1). This supports the worldwide observation that coconuts perform better in coastal areas. The lowest mean yield yearly of 33.9 nuts/tree was obtained in inland upland areas. However, the average nut yields between inland flat and coastal upland were not significantly different. In other words, the coastal areas are better than inland (beyond 2 km of the seashore) only where the coast is flat.

Table 1. Influence of land form on copra and nut yields[a]

Physiographic Position	N[b]	Mean Yield[c] Kg Copra/ha Yearly	Mean Yield[c] Nuts/tree Yearly
Coastal flat	317	1,348[a]	40.2[a]
Inland flat	315	1,291[ab]	37.0[b]
Coastal upland	236	1,226[b]	34.9[bc]
Inland upland	300	1,109[c]	33.9[c]

[a]Cosico, 1983

[b]N = number of observations

[c]Mean yields followed by the same letter are not significantly different at the 5% level.

Menon and Pandalai (1958) stated that the advantage of coastal areas stems from the more humid and stable temperature in the seacoast. Furthermore, the seacoast is likely more fertile due to the flow of nutrients from the uplands. This also partly explains why the coastal flat rather than coastal upland has the greatest edge over other areas in terms of nut productivity. However, it must be noted that the yearly difference in nut yield between coastal flat and inland flat was only three nuts per tree. This implies that nearness to shore is not a decided advantage and that inland flat areas are also suitable for the palms.

Copra yield followed the same trend, except that there was no significant difference between coastal flat and inland upland.

Drainage. The coconut palm is adversely affected by prolonged waterlogging. In Laguna, Celino (1947) observed that coconut leaves were yellowish in waterlogged areas. The soil was shallow and very slowly impermeable to water. Fajardo (1953) noted that the healthy palms in Laguna were those growing in well-drained sandy loam or clay loam soils.

Persistent waterlogging usually occurs in bottom lands. Here, the palm is harmed when the water table does not sink at least a foot below the surface within about three weeks of flooding. In other words, temporary stagnation does not harm the roots, but continuous

Table 2. Influence of external drainage on nut and copra yield[a]

External Drainage	N	Mean Yield[b] Nuts/tree yearly	Mean Yield[b] Kg Copra/ha yearly
Well-drained	975	46.0[a]	1,278[a]
Fairly-drained	153	42.7[ab]	1,187[ab]
Poorly-drained	41	35.2[b]	978[b]

[a]Cosico, 1983.

[b]Mean yields followed by the same letter are not significantly different at 5% level.

Table 3. Influence of internal drainage on nut yield[a]

Internal Drainage	N	Mean Yield[b] (Nuts/Tree yearly)	Equivalent Nuts/ha yearly[c]
Well-drained	233	40.8[a]	6,365
Fairly-drained	163	37.1[b]	5,788
Poorly-drained	102	34.1[b]	5,320

[a]Cosico, 1983. Internal drainage is based on the characteristics for the soil series under which the site was classified in the reconnaissance soil survey maps of the Bureau of Soils.

[b]Mean yields followed by the same letter are not significantly different at 5% level.

[c]Based on a population of 156 trees/ha

submergence causes them to decay. In a comprehensive survey of coconut growing in several countries, Teiwes (1962) concluded that the best soils were light, deep, permeable, and well aerated.

In his study, this author found that significantly higher mean yields were obtained in areas with good external and internal drainage than those which are poorly drained (Tables 2 and 3). The difference between areas with good internal drainage and those which are poorly drained was 6.7 nuts/tree yearly or an equivalent of 223 kg copra/ha yearly. The difference between those with good external drainage and those with poor external drainage was 300 kg copra/ha yearly.

This suggests that both external and internal drainage are nearly equally important to coconut palms. External drainage is primarily dictated by the topography of the land, while internal drainage is principally determined by the morphological characteristics of the soil solum. The importance of good drainage was emphasized by Sampson (1923) when he stated that a deep soil of low fertility but with good drainage is preferable to a fertile soil which is poorly drained. Prolonged saturation in water causes coconut roots to decay.

Slope. Many coconut plantations in the Philippines are in uplands with slopes ranging from moderate to very steep. However, better yields are generally observed in flat alluvial pans which are well-drained. The study by Cosico (1983) showed that higher yields were produced in more level areas than those in steep slopes (Table 4). Plantations with slopes of 0-8% and 8-18% gave mean yields of 46.2 and 41.5 nuts/tree yearly, respectively. The difference between the 0-8% and 18-30% slope was 14.2 nuts/tree yearly which is equivalent to 2,130 nuts/ha yearly. The higher yield of relatively flat areas may be attributed to their soil fertility and water storage compared to the uplands.

Effects of Soil Properties

Texture and Structure. Since coconut grows best in well-drained and aerated soils, it follows that relatively coarse and loose soils are best for the palm. Copeland (1921) reported that the normal length of roots of mature palms was 5 m in firm soil and 7 m in sandy soil.

Table 4. Influence of land slope on nut yield [a]

Slope (%)	Mean Yield[b] (Nuts/Tree/Year)
0- 8, level to undulating	46.2[a]
8-18, undulating to rolling	41.5[ab]
18-30, rolling to hilly	32.0[b]

[a]Cosico, 1983

[b]Means followed by the same letter are not significantly different at the 5% level.

In his study of plantations in Alaminos, Laguna, Carandang (1956) observed that soils in relatively poor-yielding areas (50-60 nuts/tree yearly) were clayey; and that soils in the good area (60-75 nuts/tree yearly) were deep, silty clay to silty clay loam and with strongly developed fine subangular blocky structure. Cordova (1965) reported that the high-yielding areas in Tiaong, Quezon had silt loam soils. In Gumaca, Quezon, Escritor (1954) reported that the good-yielding soils were sandy clay loam with clay loam subsoil.

In many countries, coconut palms do best in alluvial soils from river or estuarine deposits high in sand and silt contents. In his study of over a thousand sites in the Philippines, Cosico (1983) found that, on the average, higher nut yields were produced in coarse to medium-textured soils than in fine textured soils (Table 5). The difference between coarse and fine-textured soil was four nuts/tree yearly. This is equivalent to about 600 nuts/ha yearly.

Soil depth. A deep soil provides the palm roots more volume for nutrient and water storage and for stronger anchorage of the coconut. Cordova (1965) observed that poor-yielding areas of Quezon had less than 1 m of topsoil, whereas high-yielding areas had more than 1.5 m thick of topsoil.

This author's study of various sites in the country showed that regardless of landform (flatland or upland), the lowest yields were produced in areas with only 50 cm thick of topsoil (Table 6). The data show that for better yields, the depth of soil solum should be at least 80 cm.

Table 5. Influence of surface soil texture on nut yield[a]

Textural Group[b]	Mean Yield[c] (Nuts/Tree yearly)
Coarse	39.1[a]
Medium	39.9[a]
Fine	35.9[b]

[a]Cosico, 1983

[b]Coarse texture: sand, loamy sand, sandy loam.
Medium texture: silt loam, loam.
Fine texture: sandy clay loam, clay loam, silty clay loam, sandy clay loam, sandy clay, silty clay, clay.

[c]Means followed by the same letter are not significantly different at 5% level.

Table 6. Effects of solum depth on nut yield in flat and upland areas.[a]

Landform	Depth (cm)	Mean[b] (Nut/Tree yearly)
Flatland	120	42.2[a]
	80	50.9[a]
	50	23.6[b]
Upland	120	40.8[a]
	80	42.7[a]
	50	23.2[b]

[a]Cosico, 1983.

[b]Means followed by the same letter are not significantly different.

Bulk density, porosity, field capacity, and available moisture. Early works do not place much importance on bulk density as a factor affecting growth of coconut palms. The studies of Peñaflor (1956), Marcaida (1956), and Carandang (1956) indicated that there was no difference in profile characteristics, moisture equivalent, and bulk density of soils between poor and high-yielding coconut areas. They noted that root distribution was not affected significantly.

On the other hand, Bruce (1956) in his study of coconut areas in Magdalena, Laguna reported that bulk density of poor-yielding soils (30-50 nuts/tree each year) was significantly higher than good-yielding soils (60-80 nuts/tree each year). The author's own study revealed that bulk density of the subsoil was negatively correlated with nut yield (Table 7). There was no correlation between bulk density of topsoil (first foot) and nut yield. Nut yield decreased with increasing porosity of soil. The lower values indicated that other factors exert more dominant effect on yield. From his experiments, Felizardo (1972) observed that plowing of the soil produces an increase in nut yields.

Chemical properties of soil. (a) *Soil pH.* Coconut grows under a wide range of soil pH. The PCA survey from 1974-75 of more than 1,000 farms nationwide revealed extreme soil pH values of 3.6-8.7 in coconut farms. Cooke (1950) explained that coconuts are generally very tolerant of both strongly acid and strongly alkaline soils. Many plantations in tropical Asia are derived from coralline limestone. In Sri Lanka, most of the coconut soils are acidic, but the palms are growing well.

On the other hand, neutral to alkaline pH may be more favorable for coconuts in some cases. The author observed that nut yield increased substantially as pH increased from less than 5.0 to nearly 8.0 in coastal flatlands where the topsoil was coarse-textured and belonging to Climate Type 2 (Figure 1).

(b) Nutrient requirements. The coconut tree appears to have the highest requirements for both potassium and nitrogen. Cooke (1950) reported that the following amounts of nutrients (kg/ha) were removed from a plantation with 144 trees per hectare having an average production of 25 nuts/tree: N, 29.0; P_2O_5, 9.0; K_2O, 27.0; MgO, 22.5; Ca, 14.5; and

Table 7. Matrix correlation (r) among coconut yields and some physical properties of soil[a]

	BD_1	BD_2	PS_1	PS_2	FC_1	FC_2	AM_1	AM_2	NUTS	COPRA
BD_1		0.491***	-0.986***	-0.501***	0.443***	0.475***	0.161	0.438***	-0.182	-0.186
BD_2			-0.466***	-0.997***	-0.016	-0.092	0.111	-0.015	-0.314***	-0.238*
PS_1				0.475***	0.475	-0.434***	-0.130	-0.407***	0.179	0.177
PS_2					0.021	0.091	-0.101	0.009	0.308**	0.237*
FC_1						0.457***	0.847***	0.661***	-0.141	-0.215*
FC_2							0.457***	0.779***	-0.119	-0.158
AM_1								0.625***	0.048	0.014
AM_2									-0.122	-0.122

[a]Cosico, 1983. Ungrouped data, N = 45-60.

BD — bulk density
PS — pore space
FC — field capacity
AM — available moisture
1 — topsoil
2 — subsoil
*** — significant at 1% level
** — significant at 5% level
* — significant at 10% level

Na_2O, 4.5. On the other hand, Bondar (1955) calculated that one hectare with 156 trees producing 100 nuts/tree each year can remove from the soil and store in the nuts the following: 130 Kg N, 43 kg P_2O_5, and 139 kg K_2O.

Nitrogen promotes the growth of leaves and the formation of female flowers. Experiments in Sri Lanka, however, showed that excessive application of nitrogen was harmful. Phosphorus appears to have a decisive role in increasing the yield of copra per unit area and is necessary in the synthesis of sugars, starch, oil and fibers. The amount of calcium required is small, but in laterites of Sri Lanka liming showed favorable effect. Magnesium requirement is also small, but it is essential for the development of wood tissue in young coconut palms.

Sodium appeared earlier to be important in coconut nutrition because the palm was often been observed to grow best on coastal strips where salt water was present. However, Teiwes (1962) pointed out that this was more likely due to potassium in the sea water rather than to NaCl.

Antagonisms and synergisms also exist among nutrients that are essential to coconut. Wallace (1928) showed that excessive application of K fertilizers induced N deficiency. Salgado (1948) pointed out that heavy application of phosphate appeared to impair absorption of potash. Experiments in Sri Lanka indicated that application of Ca as lime induced increased absorption but eventual depletion of K. Experiments in the Ivory Coast showed that antagonism existed between Mg and K which meant that a high level of one depressed the uptake of the other. From researches in India, Mathew (1977) suggested that Mg deficiency could occur under continued application of highly refined potash fertilizers along with ammonium and Ca salts,

In the Philippines, the general recommendation is to apply 2-6 kg

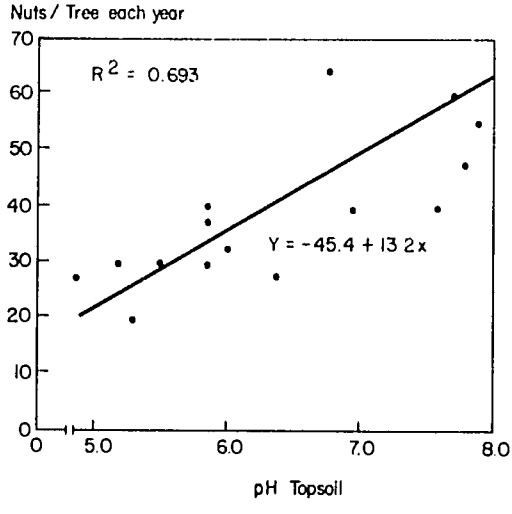

Fig. 1. Effect of increasing pH of topsoil on nut yield in coastal flatland under Climate 2 with coarse-textured topsoil

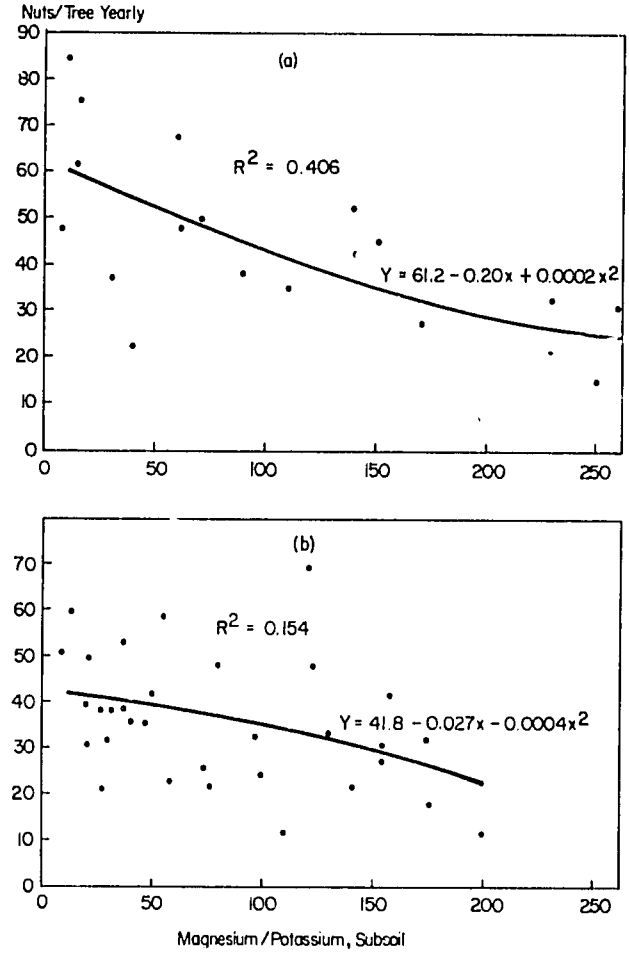

Fig. 2. Effect of increasing Mg/K ratio of subsoil on nut yield in coastal flatland and inland flatland, under Climate 2 with fine-textured topsoil

complete fertilizer per tree, split at the beginning and at about the end of the wet season. On worldwide scale for plantations of 150 trees/ha, Teiwes (1962) gave a general recommendation of equivalent of 1.67-3.3 kg complete fertilizer per tree per year.

(c) *Effects of management practices on productivity.* Management practices, such as fertilizer application, cultivation, cleaning, and cover cropping have decidedly beneficial effects on coconut productivity.

Felizardo (1972) reported that 45-year old trees in Pagbilao, Quezon increased their annual yield from 33-68 nuts per tree in five years through fertilization. He also stated that eight year old trees in Bago Oshiro, Davao City increased in yield from 89-135 nuts/tree yearly.

In India, poor-yielding palms growing on deep, red loam soils give a yield increase of 31 nuts/tree each year owing to fertilizer alone and 42 nuts owing to fertilizer plus regular cultivation. In their study of yellowing coconuts in silt loam soils in Sta. Cruz, Laguna, Felizardo and Galvez (1960) found that merely digging an area with a radius of 2.5 m

Table 8. Matrix of correlation (r) among coconut yields and nutrient content of coconut leaves[a]

	N	P	K	Ca	Mg	Na	Cl	S	Nuts	Copra
N		-0.110**	-0.084	0.326***	-0.290***	0.095	0.410***	0.498***	0.240***	0.149***
P			0.359***	0.090	-0.135**	-0.409***	-0.312***	0.167***	0.181***	0.056
K				-0.150**	-0.652***	-0.644***	-0.275***	0.153**	0.115*	0.048
Ca					-0.085	-0.026	-0.236***	0.190***	0.076	0.068
Mg						0.357***	0.122*	-0.348***	-0.189***	-0.130**
Na							0.365***	-0.131**	-0.079	-0.039
Cl								0.049	-0.033	0.166***
S									0.287***	0.220***

[a]Cosico, 1983. Ungrouped data, N = 209.

* — significant at 10% level.

** — significant at 5% level.

*** — significant at 1% level.

Table 9. Differences in mean nut yields among selected combinations of landform, climate, and texture of topsoil (N = 20)[a]

Physiography/Climate/Texture[b]	Mean Yield[c] (Nuts/Tree Yearly)
$P_1C_4T_1$ — coastal flat, climate 4, coarse	48.0[a]
$P_2C_4T_3$ — inland flat, climate 4, fine	46.7[ab]
$P_1C_3T_3$ — coastal flat, climate 3, fine	46.2[abc]
$P_2C_1T_3$ — inland flat, climate 1, fine	44.4[abcd]
$P_2C_2T_2$ — coastal flat, climate 2, medium	40.6[abcd]
$P_1C_1T_1$ — coastal flat, climate 1, coarse	40.6[abcd]
$P_1C_2T_3$ — coastal flat, climate 2, fine	40.1[abcd]
$P_3C_3T_3$ — coastal upland, climate 3, fine	38.7[abcd]
$P_1C_4T_3$ — coastal flat, climate 4, fine	36.4[abcd]
$P_4C_3T_3$ — inland upland, climate 3, fine	36.4[abcd]
$P_2C_3T_3$ — inland flat, climate 3, fine	35.5[bcde]
$P_4C_4T_3$ — inland upland, climate 4, fine	34.3[de]
$P_3C_2T_3$ — coastal upland, climate 2, fine	33.6[de]
$P_4C_1T_3$ — inland upland, climate 1, fine	33.2[de]
$P_1C_2T_1$ — coastal flat, climate 2, coarse	32.9[de]
$P_2C_2T_3$ — inland flat, climate 2, fine	32.4[de]
$P_4C_2T_3$ — inland upland, climate 2, fine	31.7[e]
$P_3C_1T_3$ — coastal upland, climate 1, fine	31.5[e]

[a]Source: Cosico, 1983.

[b]Note: a) Other combinations were excluded due to insufficiency of observations.
b) $P_1C_3T_1$ (coastal flat, Climate 3, coarse-textured topsoil) had mean yield of 51.3 nuts/tree yearly but excluded in DMRT because there were only six observations.
c) Only the sites with good external drainage were selected.

[c]Means followed by the same letter are not significantly different.

around the tree improved yield; and farmers claimed that the cultivation of old plantations doubled the yield. In Kasaragod, India cultivation alone increase yield by about 170%.

Researchers of PCA in Davao have studied intensively the K and Cl nutrition of coconuts. Studies of Prudente et al. (1978) done in Davao del Norte showed that highest nut production was observed in N-P-K fertilized trees and also those receiving KCl even in coastal flat areas. Similarly, Mendoza and Prudente (1978) found that a difference of 60-100 nuts/tree was observed from KCl treated trees over those without KCl.

Frequent cultivation of compacted and clayey soils results in loosening of the surface which aids in better absorption of moisture and release of nutrients, such that plowing the land twice annually could be as beneficial as fertilization. Magat (1977) proposed that the primary benefit of cultivation is removal of weeds which compete with coconut for soil moisture and nutrients.

Correlation between nut yields and leaf composition reveals some interesting aspects of coconut nutrition (Table 8). The author's data show that N, P, K and S were positively correlated with nut yields while N, Cl, and S were positively correlated with copra yields. It appears that

Mg is somehow involved in an antagonistic or unbalanced relationship with an important cation namely, K (r = -0.652). Thus, in the study of coconut nutrition, close attention must be given to Mg/K ratio. Figures 2a and 2b show that as Mg/K of subsoil ratio increases nut yields in coastal and inland flat lands decreased.

Combined effects of landform, climate and soil texture. Landform, climate and texture of topsoil were found to exert a significant effect on nut yield (Table 9). It appears that the best yields are produced in coastal flat areas with coarse-textured topsoil under Climate 4 (uniformly distributed rainfall). The lowest yields were obtained from the uplands with fine-textured topsoil under Climate 1 or Climate 2.

Based on this author's study and those done elsewhere, the following general conditions may be considered ideal for coconut growing:

1. There is a uniformly distributed rainfall or a short dry season,
2. Landform is coastal flat, or if inland, is also relatively flat but well drained.
3. Soil pH is near neutral.
4. Depth of soil solum is at least 80 cm.
5. Soil texture is coarse to medium.
6. There is optimum balance of cations, particularly Mg and K.
7. The soil is sufficiently fertile.

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Properties and Management of Soil for Corn Production

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Corn production in the Philippines has expanded during the last 20 years but its efficiency has remained static. Our national average production has not changed appreciably despite the government program (e.g. "Masaganang Maisan") to deliver improved production technology to corn farmers which include the use of improved varieties, fertilizer application, and pest and disease control.

The average corn yield in the Philippines is one of the lowest in Asia, outranked by those of Malaysia, Indonesia, Pakistan, Vietnam, India, Nepal, and Thailand (Samonte, 1977). Average production in 1963 was 0.65 t/ha, increasing to 0.83 t/ha in 1970, and to 0.97 t/ha in 1982 (Table 1). The average yield is still very low compared to more than 5 t/ha obtained in research stations.

The following presentation aims to provide some information regarding soil-related constraints to corn production in the Philippines, first, by reviewing the soil requirements for corn production, then the properties of major soils planted to corn in the Philippines, and finally, the management practices for corn production in the Philippines.

Table 1. Area and production for corn in the Philippines[a]

Crop Year	Area (1,000 ha)	Production (1,000 t)	Average Yield (t/ha)
1963	1949	1273	0.65
1964	1898	1293	0.60
1965	1923	1313	0.60
1966	2106	1380	0.65
1967	2167	1435	0.66
1968	2248	1617	0.72
1969	2256	1733	0.77
1970	2420	2008	0.83
1971	2392	2005	0.84
1972	2432	2013	0.83
1973	2325	1837	0.79
1974	2763	2288	0.79
1975	3062	2523	0.84
1976	3257	2767	0.85
1977	33.21	2843	0.86
1978	3227	2855	0.88
1979	3327	3167	0.95
1980	3319	3176	0.96
1981	3426	3247	0.95
1982	3361	3290	0.97

[a]PCARRD Philippines Recommends for Corn, 1975
BAEcon Preliminary Summary Report, 1983

Root Characteristics of Corn

The corn consists of a branching primary and a secondary system. The primary system is relatively sparse and extends rapidly to depths of 1.0-1.5 m. The growth of the secondary root system is initiated only several weeks after emergence and until the period of internode elongation. The secondary system grows rapidly when favorable soil moisture exists.

Studies by Hall et al. (1953) with the use of the tracer technique showed that by the end of four weeks after planting, the corn root system develops into an almost hemispherical shape that extends over 45 cm in depth to 60 cm in radius. Prior to maturity the roots extend beyond 76 cm laterally. On the basis of this extensive root system, Hall et al. (1953) indicated that (1) for maximum production, a fertile soil of considerable depth may be needed; (2) the ordinary methods of fertilizer placement for corn are relatively insignificant except from the standpoint of germination and early growth; (3) cultivation should be done as early and as shallow as practical to reduce root injury; and (4) top dressing does not have to be placed at any particular location for greatest efficiency.

Sensitivity to Water Stress

Corn generally exhibits tolerance to appreciable moisture stress, except during the growth period from tassel emergence to completion of pollination (Robins and Domingo, 1953). Inadequate soil water prior to tasseling of corn reduces vegetative growth. If water stress induces marked wilting before, during, and immediately after tasseling, vegetative growth is greatly reduced. Severe stress markedly reduces plant height and subsequent yield, particularly if the stress is prolonged or serious to cause severe wilting.

Moderate stress that results in wilting during tasseling, silking, and pollination periods may drastically reduce grain yield. The yield reduction may be due to pollination failure probably due to dessication of either the pollens or the organs that receive and transmit the pollen (Robins and Domingo, 1953).

Sensitivity to Poor Aeration

Poor aeration may result from excess soil water or soil compaction. In general, corn is tolerant of soil water contents above the normal field capacity. Reduced root aeration is associated with a low O_2 and a high CO_2 in the rhizosphere. Studies by Williamson (1964) showed that high yields of corn were obtained at O_2 diffusion rates of approximately 15 x 10^{-8} g/cm^2/min. At about 15 cm water table depth, O_2 diffusion rates were below 5 x 10^{-8} g/cm^2/min., a condition which reduced sweet corn and field corn yield by 65 and 75%, respectively. The diffusion coefficient of oxygen in water is about 2.56 x 10^{-5} and 1.89 x 10^{-1} cm^2/sec in air (Kristensen and Lemon, 1964).

The effect of CO_2 on growth of corn and soybean was studied by Grable and Danielson (1965). The results indicated that a high concentration of CO_2 of 20% or more, was necessary to depress the growth of corn and soybean seedlings. A high level of CO_2 caused chlorosis and decreased the iron uptake by corn.

Soil compaction markedly reduces growth and yield of corn (Phillips and Kirkham, 1962). Mechanical impedance to root penetrations as measured by bulk density and needle penetration, was the physical property most highly correlated with reduction in growth and yield of corn. Bulk density values at 0-15 cm depth of about 1.5 g/cm^3 markedly reduced root growth. Root weight was also found highly correlated with corn growth. The effect of high-strength soil layers on corn was also investigated by Syarifuddin and Zandstra (1978) in the Philippines and by Fiskell et al. (1968) in Florida, USA.

Nutrient Removal by Corn Crop

Table 2 shows the nutrient removal of the corn crop at low, medium, and high yield levels. Among the three major plant nutrients, nitrogen and potassium are taken up in larger quantities in the grains and stover than phosphorus. In the U.S. a good corn crop of 180 Bu/a (about 11.5 t/ha) takes up about 240 kg N/ha, 100 kg P_2O_5/ha and 240 kg K_2O/ha (Better crops with Plant Food, 1972). For this crop, the N, P_2O_5, and K_2O uptake at various stages of growth are shown in Table 3.

The corn crop takes up about 43% of its N requirement during the first 50 days while it is developing into the tasseling and silking stages when the ears and grains will be formed. Nitrogen uptake reaches a maximum of 3.6 kg/ha daily about 40 days after emergence. Since

Table 2. Nutrient removal by the corn crop

Part	Yield t/ha	Nutrient Removal (kg/ha)					
		N	P	K	Ca	Mg	S
Low:							
Grains	1.0	25	6	15	3.0	2	0.6
Stover	1.5	15	3	18	4.5	3	0.9
Total	2.5	40	9	33	7.5	5	1.5
Medium:							
Grain	4.0	63	12	30	8.0	6	3.2
Stover	4.0	37	6	38	10.0	8	3.2
Total	8.0	100	18	68	18	14	6.4
High:							
Grains	7.0	128	20	37	14.0	11	4.2
Stover	7.0	72	14	93	17.0	13	4.2
Total	14.0	200	34	130	31	24	8.4

Table 3. Nutrient uptake of a corn crop yielding 11.5 t/ha at various stages of growth.

	Period (25-Days)					
	1 (Early)	2 (Growths)	3 (Silking)	4 (Grains)	5 (Maturity)	Total
N	19	84	75	48	14	240
P_2O_5	4	27	36	25	8	100
K_2O	22	104	72	36	6	240
Dry matters	468	3,212	5,687	6,022	1,338	16,727
	% Total					
N	8	35	31	20	6	
P_2O_5	4	27	36	25	8	
K_2O	9	43	30	15	2	

nitrogen is essential for ear filling, adequate quantities must be available during grain formation.

The corn crop takes up 30% of its total P_2O_5 requirement during the first 50 days. Crop uptake for phosphorus is slow during the first 50 days but it peaks at 1.5 kg/ha daily after about 60 days.

Potassium is important in opening the leaf stomata and producing and translocating sugars to the developing ears. Thus, a corn crop suffering from potassium stress exhibits poorly developed grains. The crop takes up over 50% of its K_2O requirement during the first 50 days, peaking at 4.5 kg/ha daily during the second 25-day period.

Soil Properties Important for Corn Production

When climate and soil are favorable for corn production, maximum yields can be attained with the use of hybrid seeds, mineral fertilizers, effective pest control, and irrigation. However, yield levels in the tropics are generally low, the major problem being that the night time temperatures are high, particularly in the lowland areas. A low evening temperature for corn production may be met at higher elevations in the tropics where (knowing that temperature drops roughly by one degree for every 90 m rise in height) the average temperature is low.

Feuer (1970) identified 10 major factors affecting productivity of corn in the Philippines in relation to the soil. These factors are summarized below:

SOIL FACTOR	REQUIREMENT
Drainage	well drained
Depth	at least 80 cm
Texture	silt loam; but will suit well in sandy, loamy, and clayey textured soils
Topography	level to nearly level landscape for ease of cultivation

SOIL FACTOR	REQUIREMENT
Tilt	well granulated soils for favorable air-water relationship
Organic matter	high organic matter most favorable
Moisture retention	large amount of water needed at ear emergence to dough stage
Fertility level	generally needing only nitrogen and phosphorus. Few Philippine soils require potassium (these include San Manuel, Faraon, Sibul, Lugo, and Bolinao)
Acidity	soil pH ranging from 5.3-7.0 are optimum
Seasonal moisture condition	during the dry or "second" crop season, or towards the end of the rainy season

The most productive soils for corn in the Philippines according to Feuer (1970) are those found in flood plains, low terraced plains, and upland areas with textures ranging from fine sand to clay and with good drainage. Without fertilization, these soils produce from 250 to 1000 kg/ha with local varieties and from 1000 to 3500 kg/ha with improved varieties and with fertilizer.

Protz (1981) listed soil properties needed for corn production as follows:

SOIL CRITERIA	REQUIREMENT
Slope	0-6°
Effective soil depth	750 cm
Soil texture	exclude sand and clay
Drainage	well to imperfectly drained
Water release	good in growing season
Salinity	<2 in top 50 cm
pH	>5.0
Depth to acid sulphate	>125 cm
Thickness of peat (drained)	no restrictions
Workability	no restrictions

Corn Growth as Related to Exchangeable Calcium and Soil pH

Aluminum concentration in the soil solution increases with decreasing pH. One of the reasons for low yield of sensitive crops under acid soil condition is the presence of toxic concentration of aluminum in the soil solution. There is a fairly good relationship between soil solutions aluminum and percentage aluminum saturation. Table 4 shows the relationship between corn yields and percentage aluminum saturation.

In the Philippines, relative yields of corn on acid soils with relatively

Table 4. Relationship between soil acidity parameters of Puerto Rico soil and relative yield of corn[a]

Soil Order	Initial pH	meq. Al/100g	Al Saturation %	Relative Corn Yield[b] %
Ultisols	4.3	9.9	6.8	10
Ultisols	3.9	6.3	66.0	22
Ultisols	4.2	6.9	63.0	18
Ultisols	4.3	4.5	47.0	47
Oxisols	4.6	0.9	40.0	61
Ultisols	4.6	5.5	35.0	62
Oxisols	4.2	1.1	33.0	85
Oxisols	4.8	0.4	18.0	85

[a]Abruna et al., 1975.
[b]Compared to that with limed treatment

Relative yield = 122.0 − 1.58 (% Al saturation); r = 0.97
Relative yield = 222.6 + 62.1 (soil pH), r = 0.60

high aluminum saturation was low. Soils with low aluminum saturation had responses to liming ranging from 10 to 22%. High aluminum saturation rather than pH per se appears to be the main reason for low yield of corn in acid soils (Table 5).

Philippine Soils Planted to Corn

Corn is grown throughout the country, but production is largely in the Visayas and Mindanao (Table 6). More than 50% of the total corn production area is in Mindanao and only about 21% is in Luzon.

The major Philippines soils considered best for corn production are given in Table 7. The parent materials and areas mapped by the Bureau of Soils are also shown. The majority of the soils are derived from alluvial materials. A few soils, although of wide coverage, are derived from limestone.

Table 8 shows the typical texture, usual landscape positions, color of surface soil, location (provinces), drainage class, and fertility level of Philippine soils planted to corn.

Table 5. Relative yield of corn on nonlimed soils in the Philippines[a]

Soil pH	Exch. Al meq./ 100g	Al Saturation %	Relative Corn Yield %
4.4	2.5	46	49
4.8	0.9	22	90
4.7	0.8	8	87
4.7	0.7	3	80
4.8	0.2	2	78

[a]Kamprath, 1980.

Table 6. Area planted to corn by region in the Philippines [a]

Region	Area (1000 ha)	Production (1000 Cav.)
Ilocos	15.0	150.6
Cagayan Valley	133.5	2,053.8
Central Luzon	58.4	639.1
Southern Luzon	117.8	1,226.9
Bicol	95.9	1,255.6
Eastern Visayas	402.6	3,573.4
Western Visayas	271.5	2,741.2
Northern and Eastern Mindanao	253.3	3,116.2
Southern and Western Mindanao	899.6	13,609.4
Whole Philippines	2,247.9	28,366.2

[a]BAEcon, 1969.

Table 7. Major Philippine soils considered best for corn

Soil	Area (ha)
San Manuel	
Old Alluvium	48,859
Recent Alluvium	990,271
Recent coastal deposit	41,596
Mandaue	
Recent Alluvium	19,071
Recent coastal deposits	11,925
Umingan	
Recent Alluvium	186,412
Recent coastal deposits	20,749
Quingua	
Recent Alluvium	348,473
Recent coastal deposits	25,220
Angeles	
Recent Alluvium	111,142
Bangar	
Recent Alluvium	26,290
Dadiangas	
Recent Alluvium	37,500
Tupi	
Andesite	30,640
Basalt-andesite	13,281
Sand and gravel	62,500
Old Alluvium	37,981
Taal	
Unspecified volcanic rocks	15,586
Tuff	48,549

(continued on next page)

Table 7. continued.

Soil	Area (ha)
Lugo	
Shale	145,016
Shale-sandstone	11,713
Recent Alluvium	1,029
Catigan	
Limestone	63,308
Ubay	
Shale-sandstone-conglomerates	338,441
Magallanes	
Tuff	67,726
Lipa	
Volcanic rock	7,765
Tupi	83,362
Adtuyon	
Basalt-andesite	552,369
Luisiana	
Undifferentiated	226,143
Basalt	4,602
Basalt-andesite	243,992
Kidapawan	
Undifferentiated	59,099
Andesite	61,596
Basalt-andesite	139,886
Guinobatan	
Basalt	144,133
Unspecified volcanic rocks	56,293
Old Alluvium	110,866
Castilla	
Unspecified volcanic rocks	18,544
Calcareous-basalt agglomerates	75,553
Basalt-agglomerates	9,313
Calcareous tuff-clay materials-basalt agglomerates	11,062
Bolinao	
Limestone	843,352
Faraon	
Limestone	1,012,836

Management of Soils for Corn Production in the Philippines

The present recommendation for corn production in the Philippines were derived from years of researches in various research stations (Table 9). Those studies can be summarized as follows:

1. All soils respond to nitrogen application. Early studies involved

Table 8. Philippine soils considered best for corn[a]

Soil Series Name	Typical Texture	Usual Landscape Position	Color of Surface Soil	Representative Provinces	Drainage Class	Probable Corn Response to[b] N	P_2O_5	K_2O	Estimated Yield Cavans Per Hectare Local Var: No Fert.	Improved with Fert.
San Manuel	silt loam	floodplain	Brown	Most	well	H	L	O	15-20	40-70
San Manuel	fine sandy loam	floodplain	Brown	Most	well	H	L	M	10-15	40-50
Mandaue	clay loam	floodplain	Brown	Cebu Masbate	well	H	M	H	15-20	40-50
Umingan	silt loam	low terrace	Brown	Nueva Ecija	well	H	M	M	15-20	40-60
Umingan	fine sandy	low terrace	Brown	Pangasinan Iloilo Agusan Leyte	well	H	M	M	10-15	40-50
Quingua	silt loam and clay loam	low terrace	Brown	Isabela Cagayan Misamis Occ. Nueva Ecija	well	H	M	L	15-20	40-60
Angeles	fine sand	low terrace	Gray	Pampanga Tarlac Zambales	somewhat excessive	H	H	H	5-20	30-40
Banga	sandy loam	high terrace or plain	Dark-brown	Cotabato	well	H	H	M(?)	10-15	40-50
Dadiangas	sandy loam	high terrace or plain	Brown	Cotabato	well	H	H	M(?)	10-15	40-50
Tupi	silt loam	Upland Near volcanoes	Black	Cotabato	well	H	H	M(?)	15-20	40-60
Tupi	fine sandy loam		Black	Negros Occ. Negros Or.	well	H	H	H	10-15	40-50

[a]Feuer, R. (UPCA), M.E. Raymundo (UPCA), J.A. Mariano (BS), and S.N. Tilo (UPCA). Adopted from Feuer, R. 1970. Representative Philippine Soils for Corn. *In* Philippine Recommends for Corn, 1970-1971.

[b]H = High M = Moderate L = Low O = No response

Table 8 (continued)

Soil Series Name	Typical Texture	Usual Landscape Position	Color of Surface Soil	Representative Provinces	Drainage Class	Probable Corn Response to[b]			Estimated Yield Cavans Per Hectare	
						N	P_2O_5	K_2O	Local Var: No Fert.	Improved with Fert.
Taal	fine sandy loam	Upland near volcanoes	very dark brown	Batangas	well	H	M	M	10-15	40-50
Lugo		Upland, applies only to gentle slopes, uneroded	Black	Cebu Bohol	well	H	M	L	10-15	40-50
Cataingan	clay	Upland, gentle slopes	Black	Masbate	well	H	M	O	10-15	40-60
Ubay	clay	Upland, gentle slopes	Brown	Bohol	well	H	M	M	10-15	40-50
Ubay	sandy loam	Upland, gentle slopes	Brown	Bohol	well	H	H	H	5-10	30-40
Magallanes	loam, clay loam	Upland, gentle slopes	Brown	Batangas Cavite	well	H	L	O	15-20	40-60
Lipa	loam and clay loam	Upland	Brown	Laguna Batangas	well	H	L	O	15-20	40-60

Adtuyon	clay and loam	Upland	Red to reddish brown, Red areas require liming for corn	Bukidnon Lanao del Sur, Lanao del Norte Zamboanga del Norte, Zamboanga del Sur	well	H	M	O	15-25 Red soil areas should be limed, recently cleared give highest yield	40-70
Luisiana	clay	Upland, gentle slopes	Reddish brown	Many Provinces	well	H	M	O	15-20	40-60
Kidapawan	clay loam	Upland, gently slopes	Reddish brown	Bukidnon Davao Cotabato	well	H	M	O	15-20	40-60
Guimbalaon	clay	Upland, gently slopes	Red, reddish brown to dark brown, Red areas extremely acid	Leyte Negros Occ.	well	H	M	O	15-20 Red soil areas should be limed for corn	40-60
Castilla	clay loam	Upland, gently slopes	Reddish brown	Sorsogon	well	H	M	O	10-15	40-50
Bolinao	clay	Upland, level moderately deep areas	Red	Many Provinces	well	H	M	M	5-15	20-30
Faraon	clay	Upland, level moderately deep areas	Black	Many Provinces	well	H	M	M	5-15	20-30

Table 9. Fertilizer recommendations for corn[a]

		Kg N + P_2O_5 + K_2O Per Hectare			
		Improved Variety		Local Variety	
Agroclimatic Region/Province	Soil Type	No. of Expts.	Recommendation	No. of Expts.	Recommendation
Northern Luzon:	Nueva Viscaya, La Union, Ilocos Sur and Norte				
Batanes	Umingan clay loam			3	45 + 45 + 45
	Basco clay loam			3	45 + 45 + 0
Cagayan	San Manuel silt loam			8	45 + 0 + 0
	Quingua silt loam			4	45 + 0 + 45
	Quingua clay loam			12	45 + 0 + 45
Isabela	San Manuel loam			6	45 + 45 + 0
	San Manuel sandy loam			3	45 + 0 + 0
	Sta. Rita clay			6	45 + 0 + 45
Mt. Province	Quingua clay			3	45 + 0 + 45
Other Soils			60 + 0 + 0	N — 117 P_2O_5 — 117 K_2O — 117	45 + 0 + 0
Central Luzon:	Bulacan, Nueva Ecija, Pampanga, Tarlac				
Pangasinan	San Manuel fine sandy loam			26	45 + 0 + 0
	San Manuel silt loam			8	45 + 0 + 0
Other Soils			60 + 0 + 0	N — 38 P_2O_5 — 38 K_2O — 38	45 + 0 + 0
Southern Luzon:	Laguna, Rizal, Quezon, Cavite, Mindoro Occ. and Orientai, Marinduque				
Batangas	Lipa clay loam	1	60 + 45 + 0		45 + 45 + 0
	Ibaan clay loam	1	60 + 0 + 0		
	Ibaan loam	1	60 + 0 + 0		
Palawan	Aborlan fine sandy loam	40	60 + 45 + 45		45 + 45 + 45
Bicol Peninsula and Islands:	Sorsogon				
Albay	Sevilla clay			4	45 + 0 + 0
Camarines Norte	San Manuel loam			3	45 + 0 + 0
Camarines Sur	Pili clay loam			6	45 + 45 + 0
Catanduanes	Calatagan clay			5	45 + 0 + 45
Masbate	Panganiran clay			3	45 + 0 + 0
	Ubay clay	2	60 + 0 + 0		45 + 0 + 0
Other Soils			60 + 0 + 0	N — 36 P_2O_5 — 36 K_2O — 36	

Table 9. (continued)

Agroclimatic Region/Province	Soil Type	Kg N + P_2O_5 + K_2O Per Hectare: Improved Variety No. of Expts.	Improved Variety Recommendation	Local Variety No. of Expts.	Local Variety Recommendation
Eastern Visayas:	Bohol, Samar, Romblon				
Cebu	Bolinao clay			12	45 + 0 + 0
	Mandaue clay	1	60 + 0 + 45	4	45 + 45 + 0
	Faraon clay			12	45 + 0 + 0
	San Manuel silt loam			12	45 + 0 + 0
Leyte	Palo clay loam			8	45 + 0 + 0
Other Soils			60 + 0 + 0		45 + 0 + 0
Central Visayas:	Negros Occidental				
Negros Oriental	Faraon clay			4	45 + 0 + 0
	San Manuel sandy loam			11	45 + 45 + 0
Negros Occidental	Bago fine sandy loam	1	60 + 0 + 0		
Other Soils			60 + 0 + 0		45 + 0 + 0
Western Visayas:	Capiz, Antique				
Aklan	Bantog clay			13	45 + 0 + 0
Iloilo	Umingan fine sandy loam	1	60 + 0 + 60	53	45 + 45 + 45
	Alimodian clay loam			4	45 + 0 + 0
	Sara sandy loam			4	45 + 45 + 45
	San Manuel silt loam			9	45 + 0 + 45
	Sta. Rita clay	1	60 + 0 + 0		
Other Soils			60 + 45 + 45	N — 64 P_2O_5 — 64 K_2O — 64	45 + 45 + 45
Northeast Mindanao:	Surigao				
Agusan	Alimodian clay loam			4	45 + 45 + 0
	Camansa clay loam			5	45 + 45 + 0
Other Soils			60 + 0 + 0	N — 19 P_2O_5 — 19 K_2O — 10	45 + 0 + 0
North Central Mindanao:					
Bukidnon	Adtuyon clay			18	45 + 45 + 0
	Jasaan clay			3	45 + 45 + 0
Misamis Oriental	Jasaan clay			3	45 + 45 + 0
Other Soils			60 + 0 + 0	N — 45 P_2O_5 — 45 K_2O — 45	

(continued on next page)

Table 9. (continued)

Agroclimatic Region/Province	Soil Type	Kg N + P_2O_5 + K_2O Per Hectare: Improved Variety, No. of Expts.	Improved Variety, Recommendation	Local Variety, No. of Expts.	Local Variety, Recommendation
West Mindanao:	Zamboanga del Norte Misamis Occidental				
Zamboanga Del Sur	Adtuyon loam			4	45 + 45 + 0
	San Manuel sandy loam			5	45 + 0 + 0
Other Soils			60 + 0 + 0	N — 12 P_2O_5 — 12 K_2O — 12	
South Central Mindanao:					
Cotabato	San Manuel silty loam			5	45 + 0 + 0
Other Soils			60 + 0 + 0	N — 34 P_2O_5 — 34 K_2O — 34	45 + 0 + 0
South Eastern Mindanao:					
Davao	Cabangan clay		60 + 45 + 45	13	45 + 45 + 0
	Cabantian clay			3	45 + 0 + 0
	San Manuel silty clay loam			24	45 + 0 + 0
	Tugbok clay			30	45 + 45 + 0
	Miral clay loam			5	45 + 0 + 0
Other Soils			60 + 0 + 0	N — 55 P_2O_5 — 55 K_2O — 55	

[a]Bureau of Soils and College of Agriculture of the University of the Philippines at Los Baños. Nuestro, I.N., C. Barile, L.M. Villegas, and R. Feuer. 1970. Guides to corn fertilizer. *In:* The Philippine Recommends for Corn, 1970-1971.

evaluation of different nitrogen fertilizers namely: ammonium sulfate, urea, ammonium chloride, ammonium sulfate-nitrate, calcium nitrate, anhydrous ammonia, and dilute ammonium hydroxide. Table 10 gives a summary of the effects of various sources of N on yield of corn from studies conducted from 1959-1965. The results indicated that ammonium sulfate was consistently better than ammonium chloride or urea during the dry season. The 1964-65 study showed that anhydrous ammonia was as effective as urea and ammonium sulfate. The highest corn yield was obtained at 135 kg N/ha.

Proper timing of N application affects efficiency of N fertilizer applied to corn. Results of study conducted in 1962 indicated that splitting the application of 90 kg N/ha was effective during the wet season, but not during the dry season (Table 11).

Table 10. Effects of various sources of nitrogen on yield of corn in the Philippines (1959-1965)

Source	1959-1960 Dry Season	1961-1962 Dry Season Cav./ha	1963-1965 3 Rates
Ammonium sulfate	58	59	57
Ammonium chloride (28% N)	52	54	—
Ammonium sulfate nitrate (26% N)	—	54	—
Calcium ammonium nitrate (20.5% N)	—	49	—
Urea (45% N)	47	50	57
Ammophos (16-20-0)	—	49	—
Anhydrous ammonia (82.2% N)	—	—	55

2. In P deficient soils of the Philippines, application of phosphorus fertilizer at rates as high as 80 kg P_2O_5/ha is often necessary to increase yield.

Early studies on phosphorous application on P-deficient soils in the Philippines have shown the addition of over 20 kg P_2O_5/ha, more than double the yield of corn. Response to P application in Ilagan, Isabela; La Carlota, Negros Occidental, Limay, Bataan; and Pili, Camarines Sur were observed.

3. Generally, soils in the Philippines do not respond to potassium application.

Table 11. Yield of corn at different rates and time of N application (1966 dry)[a]

N Application		
Rate (Kg/ha)	Time	Grain Yield
90	all at planting	79.1
90	split	71.1
180	all at planting	71.7
180	split	67.8
270	all at planting	74.9
270	split	75.3
Control		47.4
LSD		13.9

[a]Vicente, P.R. and F.L. Valbuena, 1963.

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Land Evaluation

ROGELIO N. CONCEPCION

When population growth approaches the critical limit, land resources become over exploited; and consequently, the social cost exceeds the economic benefit because of reduced quality of life resulting from a series of environmental degradations. In addition, serious conflicts in land use becomes unavoidable. With more people to feed, the animal population must increase to provide protein and more lands suitable for food and feed crops must be cultivated.

The chaos in land-use allocation can only be alleviated by a systematic assessment of land resources and their potential. Besides, lands with similar potentials or capability do not occur continuously over a significant distance. The exploitation and utilization of land is fragmented and this results in a myopic approach to the study of the environment and its implications for development.

The study of land resources must be total and should involve the analysis of the interrelationships between the bio-physical and the socio-economic factors.

Land Evaluation

Land evaluation is the process of assessing land performance for specific purposes and involves the execution and interpretation of surveys and studies of landforms, soils, vegetation, climate, and other aspects of land in order to identify and compare promising kinds of land use according to the objectives of the evaluation.

The following are the basic principles governing evaluation:

- Land suitability is assessed and classified with respect to specific uses.
- Evaluation requires a comparison of the benefits obtained and the inputs needed on different types of land.
- A multidisciplinary approach is required.
- Evaluation is made in terms relevant to the physical, economic and social context of the area concerned.
- Suitability refers to use on a sustained basis.
- Evaluation involves the comparison of more than a single kind of use.

Land evaluation is a basic tool in land use planning, since it records and assesses present land performance. The evaluation process also includes the effects of whatever changes there are on the land or on land use itself.

A number of issues have to be considered in land evaluation, such as the following:

1. What are the present management practices and what will happen if they remain unchanged?

2. What improvements in management practices are possible?
3. What other uses of lands are physically possible?
4. Which of these uses offer possibilities of sustained production and other benefits?
5. What adverse effects — physical, economic, or social — are associated with each use?
6. What recurrent inputs are necessary to bring about the desired production with minimum adverse effects?
7. What are the benefits of each form of use?

Definition of Basic Terms

Land—an area of the earth's surface, the characteristics of which embrace all reasonably stable, or predictably cyclic attributes of the biosphere. Vertically above and below this include the atmosphere, soil and underlying geology, hydrology, plant and animal populations, and results of past and present human activities, to the extent that these attributes exert a significant influence on present and future uses of the land by man.

Land characteristics—an attribute of land that can be measured or estimated.

Land mapping unit—an area of land demarcated on a map, and possessing specified land characteristics and/or qualities.

Land quality—a complex attribute of land which acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified kind of use.

Land suitability—the fitness of a given type of land for a specified kind of land use.

Land suitability classification—an appraisal and grouping, or the process of appraisal and grouping, of specific types of land in terms of their absolute or relative suitability for a specified kind of use.

Land utilization type—a kind of land use described or defined in a degree of detail greater than that of a major kind of land use.

Levels of Land Resources Studies

In general, the type of land evaluation is directly related with the state of developments of the end-users. In Figure 1, it will be noted that as the policy statements become more specific, the type of study becomes more detailed, and consequently, the working scale increases correspondingly.

Figure 2 illustrates the land mapping expressed in Ecogeographic Units required for each type of land evaluation study.

This situation could be easily explained by the fact that in site-specific projects, the amount of information is more and are obtained at closer intervals than one should in reconnaissance studies.

The three levels of land resources studies are the following:

1) The *reconnaissance survey* is generally used for bigger land

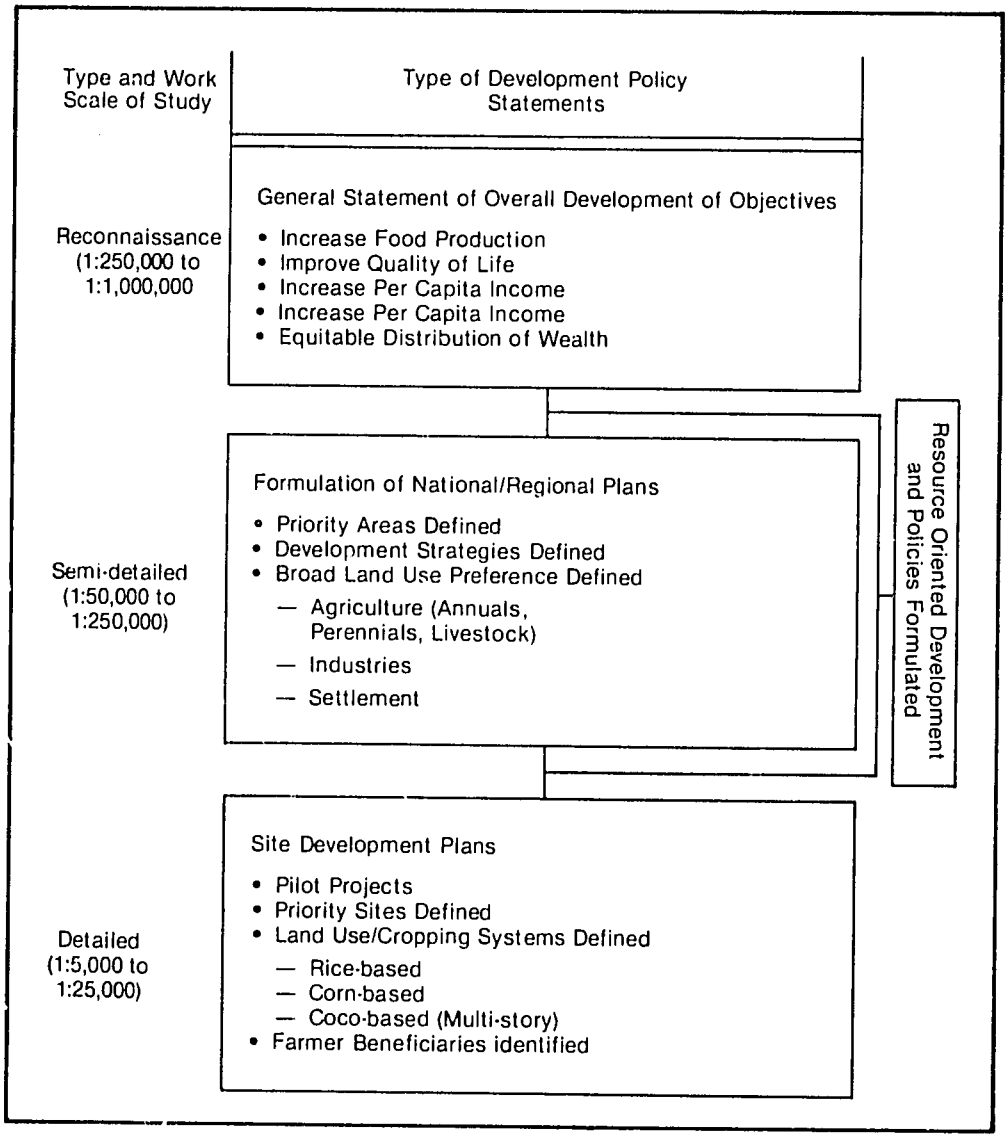

Figure 1. Different levels of land resource studies

areas, such as provinces, regions, and nationwide and where data and information is practically not available.

2) The *semi-detailed survey* is generally used for areas where programs are established, but the individual viable projects are yet to be established and documented.

3) The *detailed survey* is generally done on small areas, such as municipality and barangay or even smaller land areas, where projects and activities are well defined.

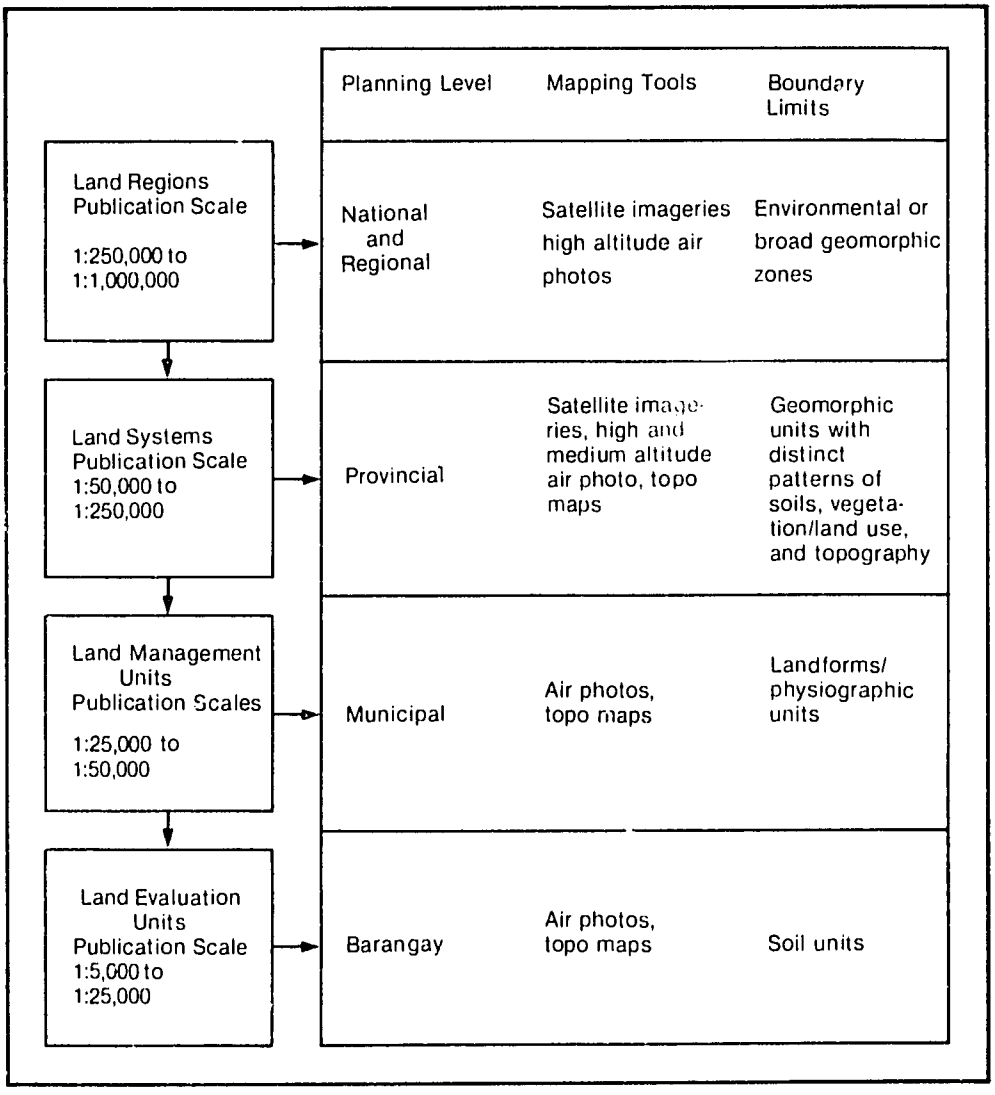

Figure 2. The land systems and other ecogeographic units in the environmental heirarchy

The various activities pursued vigorously by the ALMED, Bureau of Soils are shown in Figure 3. The most recent output in the flow chart is the nationwide mapping of various land use opportunities. The land use opportunity map shows the location and distribution of:

Agricultural areas. These are lands that are actively utilized for various agricultural activities. These also include various development infrastructures, such as roads, bridges, irrigation, and human settlement areas.

Expansion areas. These are idle, less utilized lands that have

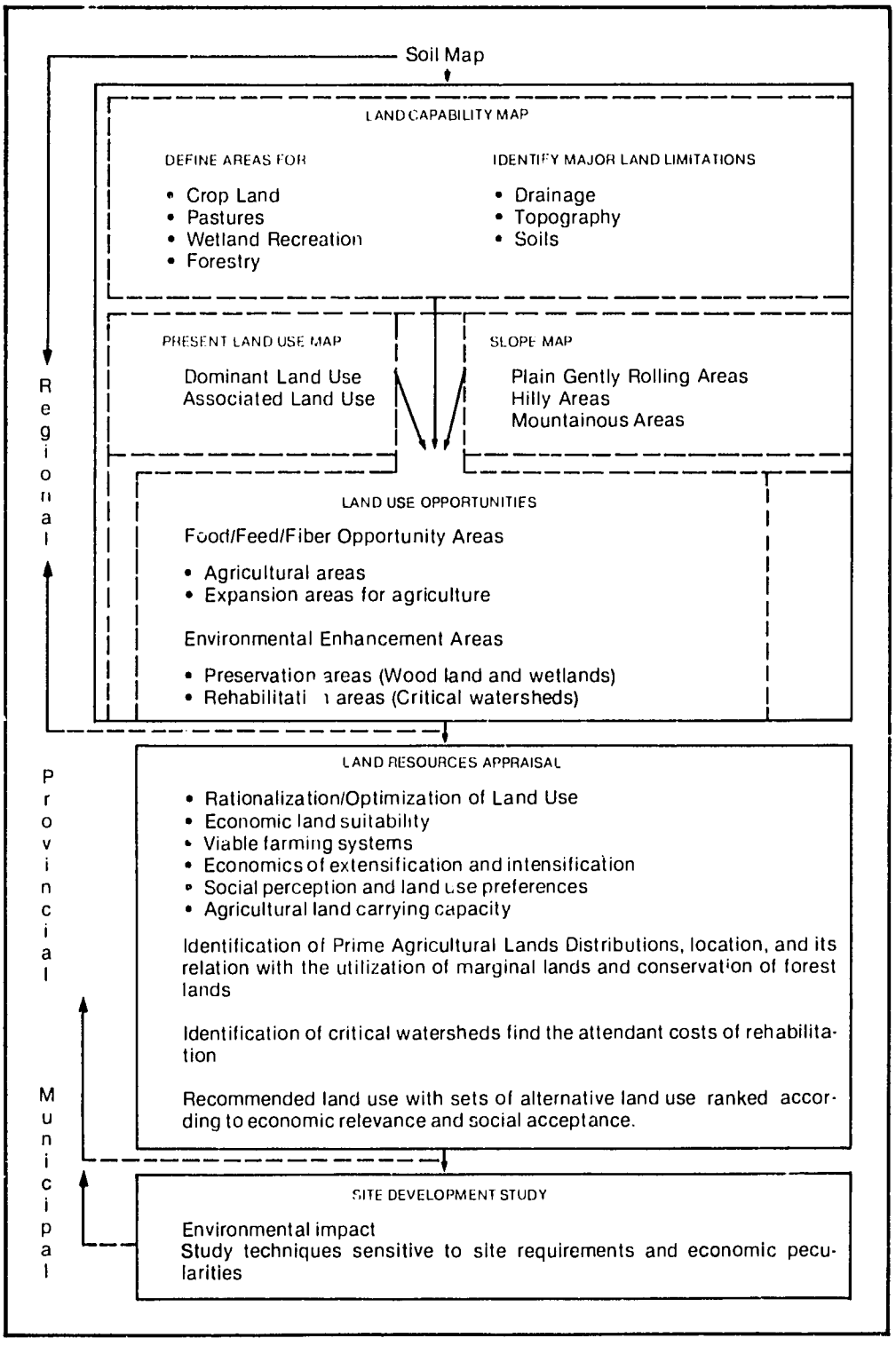

Figure 3. Activities of the Agricultural Land Management and Evaluation Division (ALMED)

potential for various forms and well-managed agricultural uses. These include sloping lands that basically needs low to moderate land development cost. In some cases, accessibility is a major problem. In general, the best use of these lands are for economic trees with minimum use for annual crops, like rice and corn. However, when land treatments, such as terracing, stone walls, treelines, contouring are feasible, the use of these lands for high income annuals is economically viable.

Rehabilitation areas. These areas represent lands within the critical watersheds seemingly subjected to various forms of land-use abuses. Various forms of active and inactive erosional processes are very evident. For ecological reasons, these areas are at the moment best used for trees, either forest or economic trees (preferrably the former). Reverting these areas into its former forest conditions is rather expensive both in time and labor requirements.

Preservation areas. These are areas primarily covered with trees or dominated by woody-type vegetation. These represent areas that should be permanently retained as a forest environment. By all means, human activities should be minimized to perpetuate and sustain the growth and desired density of the woody vegetation. These refer to watershed regions and, therefore, should be protected from any intrusion of human and agricultural elements.

Conceptual Framework of Land Evaluation

The land evaluation being done by the BS through the Agricultural Land Management and Evaluation Division (ALMED) is basically multidisciplinary. The study sectors (technical disciplines) commonly involved are:

1. Soils
2. Agronomy
3. Farm economics (interaction of land use, farming systems, and production economics)
4. Agro-hydrology
5. Climate
6. Water resources
7. Marketing
8. Socio-economics
9. Agro-forestry
10. Pasture/livestock
11. Fisheries

Figure 4 illustrates the flow chart of the framework. As an example of the application of the framework in the figure, the procedures used in evaluating land resources for the identification of projects under the Executive Order No. 803 are presented in Annex "A".

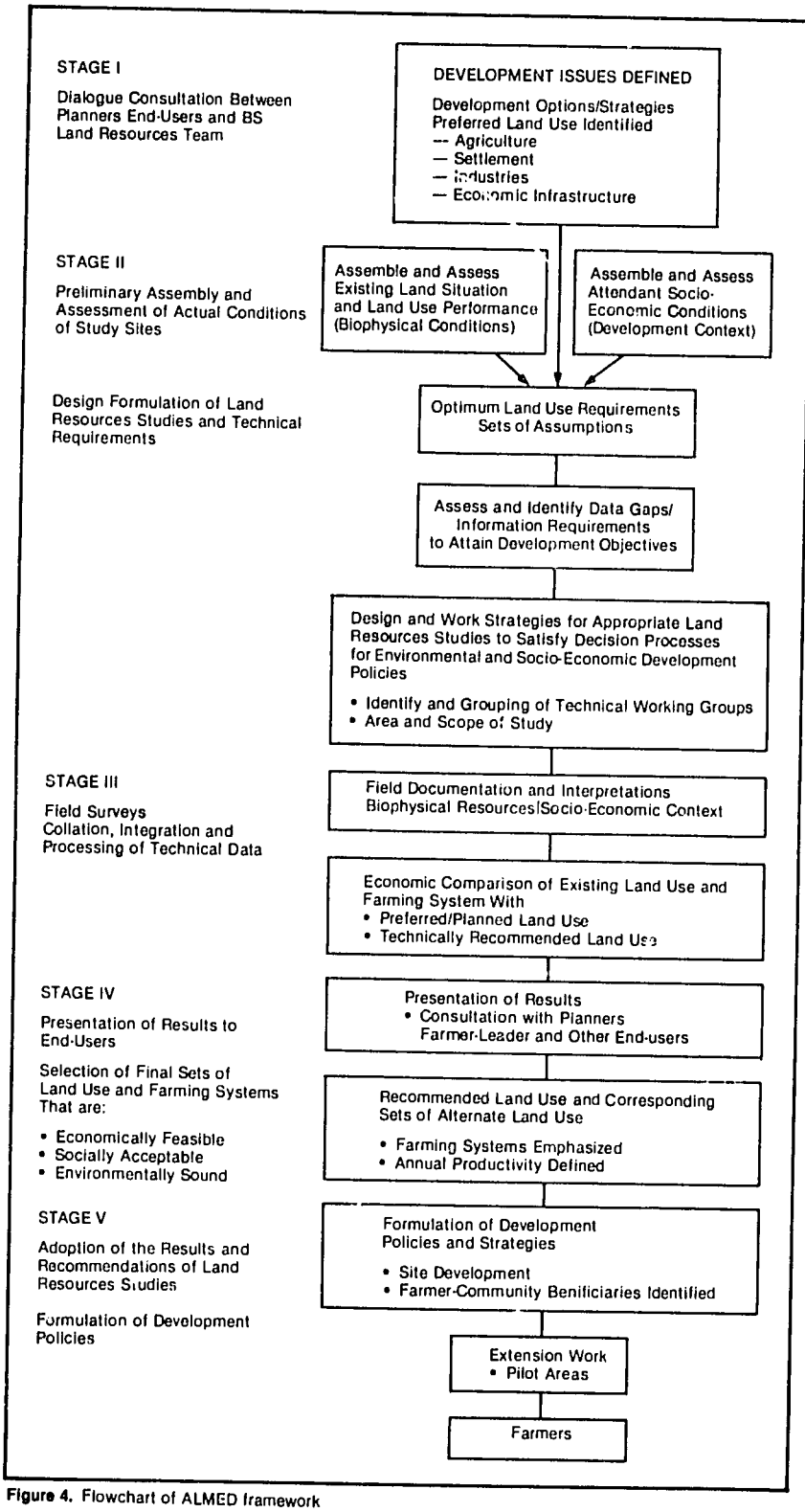

Figure 4. Flowchart of ALMED framework

BUREAU OF SOILS
PRELIMINARY LAND EVALUATION GUIDELINES
FOR EXECUTIVE ORDER 803 PROJECTS

BY THE STAFF AGRICULTURAL LAND MANAGEMENT AND EVALUATION DIVISION

Project Site Analyses Using the Results of E.O. 803 Workshop (Preparatory Activities)

a. Update the land use opportunity map by plotting the various use opportunities (agricultural, expansion, rehabilitation, and preservation areas) on a 1:50,000 topographic map and aerial photographs.

a.1 For agricultural areas, indicate:

- Irrigated rice-based lands
- Rainfed rice-based lands
- Corn-based lands
- Upland rice-based lands
- Coconut-based lands
- Vegetable-based lands
- Banana-based lands
- Oil-palm-based lands
- Pineapple-based lands
- Livestock-based lands
- Brackish-water-fish lands
- Other major agri-based lands

For each land use category, indicate percentage occurrence of associated crops. For example:

Corn-based lands with 15% legumes, 10% rainfed rice (wet season)

a.2 For expansion areas, indicate:

- Natural vegetation and specify species (i.e., grass or tree species)
  - — Land use; specify crops as mapped in agricultural areas
  - — Erosional features such as rills, gullies, etc.

a.3 For rehabilitation areas, indicate:

- Natural vegetation and specify species and respective percentage of occurrence
- Agricultural land use as mapped on agricultural uses
- Erosional features

a.4 For preservation areas, indicate:

- Tree species, grass species
- Other biological activities (kaingin, settlements, roads, etc.)

a.5 For other unique uses, such as:

- Lakes with areas similar to Agusan Marsh, Bulusan Lake, etc.

b. Prepare slope map from 1:50,000 topographic sheets

c. Identify major land uses (crops, livestock, and fisheries that need documentation:

c.1 Either from the results of E.O. 803 workshop or updated land use opportunity, rank the commodity according to area (if crops) and to volume of production (if livestock or fisheries)

c.2 Select the top 20 for crops and top 5 each for livestock and fisheries and related activities

d. Examine the production and demand situation of each commodity in all municipalities in the province. For each commodity, group municipalities into surplus and deficit areas.

e. Estimate the production per hectare of each commodity in each municipality. Identify which municipality has production levels below the provincial average taken from the PDS or MA.

f. Prepare a tabulated list of municipalities whose production is lower (marginal areas) or higher (prime production areas) than the provincial average.

Sampling Design

a. The land management unit (LMU) is the basic sampling area.

b. From the prepared land map units, estimate individual areas of various major land uses.

c. Estimate the number of farmers in the derived land use areas for each LMU using the average landholding in the crops being considered.

Calculations are as follows:

$$\text{No. of farmers} = \frac{\text{E.O. 803 land use area}}{\text{average landholding}}$$

Example: Rice area = 1,000 hectares

Average landholding for rice in the municipality = 2

Therefore:

$$\text{No. of farmers} = \frac{1{,}000 \text{ has}}{2 \text{ ha/farmer}} = 500 \text{ hectares}$$

d. From the total estimated farmers' population, use 20% as the actual number of respondents or samples for the selected commodity. The minimum number of respondents for each commodity is set at 20 farmers. In cases where a given commodity has less than 20 respondents, then a total enumeration is required.

e. It is important that the respondents are selected at random throughout the study area, giving primary consideration for the actual locations and distributions of the LMU.

f. Identify the location of the farm of the best producing farmer and the poor or marginal producers. This can be done quickly by interviewing

the barangay officials or the resident extension officers of the MAO. From these local sources, gather list of names of good and marginal producers/farmers. It is also needed to determine from these local sources, the primary reasons for having low or high productions.

Data Generation/Field Work

a. Agricultural areas:

Situation 1: Surplus municipalities (potential production centers) with production average higher than the estimated provincial average.

Disciplines: Marketing, socio-economics, production economics, and farming system

Implications:

1. Study sites are dominated by prime lands for the commodity
2. Study sites are well serviced by production incentive, socio and marketing infrastructures, including industries that processed the commodity into a finished secondary product.
3. The farming community is generally receptive to new technologies/changes.
4. Agricultural technologies must be based on marketing, post-harvest and agri-business expertise. Therefore, price and production monitoring mechanisms should be well emphasized.

a.1 Marketing group:

- Gather prices and volumes of selected commodities from traders and buyers. The offices of NFA and Municipal Treasurer can provide the list of traders and buyers for each commodity with additional information about their volume of annual transactions.
- Gather monthly transactions/activities of the traders and buyers and patterns in the price and volume during the months/periods of production as well as three months before and after the production periods. Prepare a procurement/pricing graph for each commodity for analyses and subsequent actions for the physical group (i.e., soils, climate, agronomy, farming systems) (see Figures A and B).

  The adjusted pattern should result in stable prices and, therefore, more financial returns to the small farmers. The adjustments, however, shall be done after a follow-up documentation by the physical group which should be crops, soils, and climate relationship and come up with a possible new cropping pattern and new varieties.

a.2 Production economics:

- Study/document the crop budget and the estimated net income and net farm income. Include household income as indicator.

- Prepare an estimated aggregate net income from the commodity in a given LMU.

a.3 Socio-economics:

- Study the primary reasons for the ability of the farmers to attain the present productivity levels (i.e., surplus and higher average production). Reference could be made on access to market, credit, higher educational levels, availability of reliable technology, seeds, etc.

a.4 Farming Systems:

- In each LMU, study the crop unit(s), crop distribution (specify area devoted for each crop) and their respective management practices. Include a crop calendar for the entire farm system.

Situation 2. Surplus areas whose production average is lower than the estimated provincial production average;

Disciplines: Land use, marketing, production economics, socio-economics, soils, agronomy, farming systems, climate, agro-hydrology.

Implications:

1. Land as a production resource is not a limiting factor of production (extensive areas available).
2. Commodity is a basic part of the family diet (i.e., staple crops) and the market facilities are uncertain if not adequate. Such situation could well indicate that the financial returns of the activity is not commensurate with the efforts of the farmers.
3. It is possible that variety is a factor (i.e., preponderance or preference of native varieties over HYVs).
4. There is physical limitations on the land (i.e., suitability problems).
5. Extension strategy must emphasize production technology.

Situation 3: Deficit areas whose production average is higher than the estimated provincial average.

Disciplines: All disciplines, except the forestry group, involved with the primary purpose of establishing bases by possible improvement in productivity through better management. Likewise, it is important that the group estimate additional areas needed to narrow the demand gap.

Implications:

1. Land is a limiting resource (i.e., available arable lands are not adequate to meet the production volume of the commodity as required in the community)
2. General receptiveness of the farming community is generally receptive to new technologies/changes.
3. There is a need to locate new areas to meet the production gap

(i.e., expansion areas have to be studied conjointly with the identified deficiency sites). This further implies that when studying the deficit areas for a given crop (say, rice), suitability of similar crops must be immediately considered by the group working in the expansion areas for agriculture.

The prospective outputs are:

1. Identification of management leads for possible adoption in the expansion areas
2. Identification of physical potential of land to react favorably to more intensive management systems (i.e., improve per unit production capacity)
3. New cropping calendar
4. New varieties
5. Importance of commodity to the farm families
6. Estimate of additional produce if new management will enhance production
7. Net income of present situation and future situation where new management systems are assumed feasible.

Situation 4: Deficit areas whose production average is lower than the estimated provincial productivity.

Disciplines: All disciplines are involved, except the forestry group.

Implications:

1. Marginal (both physically and economically) lands dominate the agricultural areas.
2. The commodity is primarily of subsistence level and are grown only to satisfy food needs of the farm family
3. Production technology is of primary importance and is the extension services of the MA and other institutions.
4. and is a limited resource.
5. Nutrition is a major problem.

The expected outputs are as follows:

1. Inventory and evaluation of the physical, economic and social factors affecting production
2. Sets of viable and acceptable suitable crop/land use alternatives
3. Management problems and recommendations
4. Commodity/crop budgets
5. Relationship with the proposed expansion areas within the study site

Agricultural Expansion Areas

These areas are sloping lands that basically need low to moderate land development cost. In some cases, accessibility is a major problem. In general, the best use of these lands are for economic trees and with minimum of use for annual crops like rice and corn. However, when

land treatments, such as terracing, stone walls, treelines, and contouring, are feasible, then high income annuals might be available.

Basic problems in using expansion areas

- Soil acidity
- Shallow soils
- Soil erosion
- Accessibility to production factors
- Compact soils
- Low water-holding capacity
- Cost-effective soil conservation
- Narrow choice for common agricultural crops that have stable, year-round market
- Inadequate water for human, plant, and animal requirement
- Inadequate services (e.g., technicians)
- Inadequate benchmark studies as to their viability

Disciplines involved

Physical group (land use, agronomy, soils, soil conservation, land development and erosion, climate, agro-hydrology, livestock, forestry).

Site information needed

1. Soil texture, slope, soil depth, drainage, surface impediments, erosion
2. Land use and vegetation pattern (grass and trees species)
3. Road network or distance to nearest road system (expressed in density, km/km^2)
4. Land development cost (include soil conservation and maintenance cost)

Rehabilitation Areas

These areas represent lands that are logged-over and seemingly subjected to various forms of land use abuses. Various forms of active and inactive erosional processes are very evident. For ecological reasons, these areas are at the moment best used for trees, either forest or economic trees (preferably the former). Reverting these areas into their former conditions is rather expensive both in time and labor requirements.

Disciplines: Soils, forestry, livestock, agro-hydrology, climate, soil conservation (erosion and development cost)

Site information needed

1. Species of trees and grasses
2. Human activities (kaingin settlements, roads, trails, etc.)
3. Soil texture, pH, depth, drainage, slope
4. Soil erosion, land development costs (e.g., gully stabilization)
5. Distance to nearest access roads to the lowlands

Preservation Areas

These are areas primarily covered with trees or dominated by woody-type of vegetation. These represent areas that should be permanently retained for forest environment. By all means, human activities should be minimized to perpetuate and sustain the growth and desired density of the woody vegetation. These refers to watershed regions and therefore should be protected from any intrusion of human and agricultural elements.

Disciplines: Soils, forestry, erosion, sociology

Site information needed

1. Tree species and other biological life (moss, ferns, lichens, wildlife, etc.)
2. Extent of kaingin cultivations
3. Erosional sites
4. Density of roads, trails, and other human activities

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AGROTECHNOLOGY TRANSFER

Principles and Concepts of Agrotechnology Transfer

BERNARDINO G. CAGAUAN JR.

The many forms of agrotechnology make it a very unique subject to discuss in conceptual terms. Agrotechnology can be in the form of a seed, knowledge or information, skilled manpower, a new product or machinery, or just a new method of growing a crop, such as in a shade or by exposing the seeds to cold temperature. The path of transfer of these agrotechnologies could be either horizontal or vertical (Uehara, 1983). Agrotechnology transfer among scientists of various countries, or among research centers and experiment stations, is generally accepted as *horizontal transfer.* The transfer of information or agrotechnology from the experiment station, extension agent, or agricultural salesman to the farmer is generally considered *vertical transfer.*

The mechanisms of this transfer, the factors affecting it, the approaches, and the nature of technologies which are transferable provide the framework from which principles and concepts of agrotechnology transfer can be distilled. The purpose of this paper is to attempt of crystallize some experiences and concepts into principles to better understand agrotechnology transfer.

Rationale

It is cheaper to copy, borrow, buy or adopt an existing agrotechnology than to develop a new one. A farmer, in general, does not have the resources and technical capability to develop his own technology for the purpose of improving his crop yield or farming operations. Because of these limitations experiment stations and research centers have been established by governments or resource-rich organizations, such as the Rockefeller and Ford Foundations, all over the farming world to serve the technology needs of the farmers. These institutions are now responsible for the development and transfer of new or improved technologies for the resource-poor farmers. The transfer process-getting the farmers to adopt the new or improved technologies — is not always an easy task.

The potential for tremendous increases in food to feed the world's billions is greater today than say, 20 years ago, because of better-yielding plant cultivars which respond very efficiently to the application of fertilizers, and the development of technologies for more efficient use of irrigation water. How to transfer these technologies to the small farmers, especially in the less developed countries (LDC's), remains the most challenging job of both the agricultural scientist and the agricultural extension agent.

Factors Influencing Agrotechnology Transfer

Whether or not an agrotechnology is transferrable depends on a number of factors which can be categorized into socio-economic, government or political, technological, and environmental factors. Where the transfer involves regions and whole populations, an administrative factor may be added to this list. These factors do not operate independently of each other and their relative importance depends on various situations.

The *socio-economic factors* may be the most difficult and perhaps the most costly to overcome in agrotechnology transfer. These factors are also influenced by other factors, including the cultural and religious background of the individual farmer, the community, or the whole nation. A technology which fits the socio-economic norms or needs of a community is the ideal technology which must be transferred. Such a technology may be adopted with a high degree of success, even though it involves large scale changes in attitudes and aspirations of local residents.

To support the technology, massive infrastructural changes might also take place, like the building of roads and irrigation systems, as well as making available the resource requirements, like labor, capital input, machinery, market, and storage facilities for the products. This transfer can happen in a few months or several years or may take a very slow and evolutionary phase. If the acceptance of the technology was governed by socio-economic reasons, the same reasons would alo determine its long-term use.

The reason for the demise of certain technologies, however, is largely economics, although social and other factors may also be responsible. In general, the sustained use of a technology depends on its ability to serve the socio-economic needs of a community until it is phased out by government laws or policies for other reasons. Examples are the use of certain pesticides which pose health and safety hazards and those that persist in the environment polluting the air and drinking water or affecting the ecology of wildlife.

Government or political factors determine the necessary conditions to catalyze the transfer of agrotechnology through the promulgation of favorable policies or incentives. One example is the granting of tax exemptions to corporations or individuals who would like to grow certain crops that are vital to the economy of the country. The government can also provide the land or expedite the acquisition of lands in which to grow the crops. Liberal credit policies, price subsidies, and sometimes market protection through import restrictions, are some of the well-known government policies to encourage the adoption of new technologies. Likewise, governments have been known to impede or even stifle the adoption of a technology through restrictive regulations and taxation.

The technological factors relate, not only to the technology being transferred, but also to the associated technologies that the farmer has

to use in conjunction with the new technology. The new technology must be learned by the farmer and should match his technical capability in order for it to succeed. In general, a complex technology has a lesser chance to be adopted or the rate of adoption is slower than a simple one. The associated technologies are sometimes more complex than the main technology itself. For example, hybrid corn requires a high application of fertilizers. Irrigation must also be provided and insect pests and diseases must be controlled in order to realize the yield potential of the hybrid. In LDC's all these associated technologies must be learned and applied by the farmer himself.

In the past, certain IRRI rice varieties were sensitive to zinc deficiency. A farmer had to learn how to recognize this deficiency symptom and had to apply zinc fertilizer, if he wanted to continue using these varieties. The many technological requirements of high-yielding varieties of rice and corn may be one of the more important reasons why a large percentage of farmers still continue to use the traditional varieties which require minimum use of modern technology.

The associated technology for the modern varieties of rice and corn, as example, must be satisfied for a successful transfer to take place. In giving advice to the rice and corn farmers, extension agents in LDC's make it a point to remind farmers to spray their fields against insect pests on a regular basis. And so, farmers must learn the new technology. But more important, perhaps, than learning the new technology is the added burden of carrying 18 liters of water and walk about the field for almost the whole day. If a rice farmer follows a government technician's recommendation of preventive spraying at two-week interval until the grains fill, this new technology indeed, could break a farmer's back.

As a strategy for the rapid transfer of technology, some means must be devised to remove the technological burdens away from the farmer's operational activities. This is being done in many developed countries. Custom plowing, custom spraying of pesticides by airplanes, application of fertilizers, and harvesting along with the production of high quality seeds are handled by private companies at a much cheaper cost than if the farmers were to produce the seeds or do the other operations himself. As Uehara (1983) pointed out, "the success of modern agriculture has largely come about by freeing the farmer from technology and enabling him to concentrate on production".

The transfer of agrotechnology is affected by *environmental factors*. The environment as used in this article includes the soil and the atmosphere above it. The technology must match the environment where it will be used. It is now possible to predict the environment where a technology is to be transferred with the use of Soil Taxonomy (1975). This is a system of soil classification and of interpreting the results of soil surveys. With this system, the soil is given a name.

The resulting characterization of the soils implies properties of the soil, its average temperture and moisture regimes and, to some extent,

the quality of solar radiation that would prevail in the soil. Knowing these properties is sufficient to determine whether or not it is possible to grow a crop at a given location. This means that if the soil is classified according to Soil Taxonomy, one can extract information in regard to the required management of that soil in relation to the crop to be grown.

What makes Soil Taxonomy universally significant is the fact that the taxonomic names are the same anywhere in the world. Scientists and planners irrespective of national origin can now communicate with a common language in describing the environment of a given crop. This is a very important step towards the transfer of agrotechnology, since results of experiments can now be compared with the same or similar environments in mind. The studies conducted by the Benchmark Soils Project (1978, 1979, 1982) confirm that similar soils would require similar management practices if the same crops were grown. In planning, therefore, an agronomist who is familiar with Soil Taxonomy would be able to predict the requirements of a given crop in relation to the soil which will be used even without any previous test in that area, as long as the taxonomic name of that soil is known.

Soil Taxonomy, however, is not an absolute index for judging the potential performance of a certain crop. The taxonomic information should be supplemented by studies made elsewhere on similar soils, seasonal weather patterns, incidence of pest and disease, and the most suitable planting date for the area. The latter information cannot be extracted from the taxonomic name.

Since it is not feasible to modify the environment for large-scale crop production, a strategy that has been used by farmers since ancient times is to choose the crop that matches the environment of their farms. How to do this in a systematic manner without trial and error is gaining the worldwide attention of scientists. The International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) project is one example of an international effort to expedite the transfer of technology by properly matching the crop to its environment. With the use of crop models and high-speed computers, the project aims to provide performance data of at least 10 major crops when grown under various environments.

An *administrative factor* or constraint becomes important to agrotechnology transfer when many segments of the community are involved. Examples are the Bimas program of Indonesia (Adjid, 1983), and the Masagana 99 of the Philippines (Davide, 1983). Both programs were aimed to produce sufficient rice for each country. Government institution, private industries, research centers, input suppliers, extension agents, political leaders, and the farmers themselves were involved in the programs.

In the Masagana 99 program coordination and administration were made possible through the National Food and Agriculture Council

(NFAC) of the Ministry of Agriculture. The entire responsibility for the program was given to the Council. It has been claimed that the administrative skills of the program leaders were responsible in making the program a success (Iglesias, 1977). Davide (1983) describes it very fittingly as the ultimate result of government determination to succeed. There were criticisms against the Masagana program but it made the Philippines into a rice-exporting country in a period of less than seven years.

The Bimas program is still facing many problems and the chain of administrative command is discussed by Abdul Adjid (1983). Rice continuous to be imported by the Indonesian government. Management and administrative problems seem to be the two most important setbacks of the program because of the huge population of farmers in relation to the number of people providing the support services.

Approaches to Agrotechnology Transfer

The transfer of agrotechnology in most developing countries seems to revolve around three major strategies, namely, the government program, the corporate approach, and the individual-farmer strategy.

In a national or regional scale the *government program* appears to be the dominant force in directing or mobilizing all available resources needed in the transfer process. A program generally begins as a small project in selected pilot areas. If it is successful the trials are expanded to include more farmers and larger areas before the project becomes national in scope.

All government programs are designed to remove or minimize the constraints to technology transfer. The main considerations are potential benefits to the country's economy and the anticipated social impact once the program is implemented. This approach is the most complex and the most difficult to administer relative to the desired results. Success is seldom measured in terms of returns on investment but on the attainment of desired social goals irrespective of cost. A strong, dedicated and honest leadership is almost always a prerequisite to make a government program attain its objectives. Such leadership must be demonstrated from the top to be credible and lasting.

National government programs on agrotechnology transfer are usually preceded by crisis situations which serve as the sole motivation for justifying or creating the program. Crisis is the single most important prime mover for any government to act for its people.

The *corporate approach* to agrotechnology transfer is the most rapid and the most efficient way of transferring an agrotechnology. Corporations are usually organized for profit and are highly motivated to transfer a technology. They have the resources to do large-scale agrotechnology transfer and have their own research and development staff. Application of research results is almost immediate, since only a few key personnel must be convinced to adopt any new technology. Rarely do social, cultural or political factors interfere with the transfer

process. In some cases these factors are even used to advantage in transferring the technology.

Another version of the corporate approach is the *nucleus estate farm* of Indonesia and Malaysia on rubber and oil palm. Soebiapradja and Sumardjan (1983) describes the nucleus estate farm strategy in the transfer of agrotechnology. The estate farm consists of company-operated farms (serving as the nucleus) which are surrounded by farms owned by individuals who have marketing contracts with the company. Technology is transferred from the corporate farm to the perimeter farms through technical services provided by the farmer. The estate farm serves as the nucleus or center for transferring agrotechnology hence, the name. Since the farmers have marketing contracts with the company and technical services are also provided, they can concentrate on production activities according to technologies provided by the corporation.

Corporate farms are characterized by large acreages, a corporate or structured management, availability of technical manpower, and have access to financing and market outlets without relying on outside assistance. It has the ability to borrow, buy, or develop any technology that it needs.

Individual farmers on the other hand, especially those with small acreages, depend on outside sources, usually the government, for technical, financial, and marketing assistance in their farming operations. Because of their large numbers the individual farmers are the most difficult to reach in terms of technological information campaign. Farm demonstrations, radio broadcasts, and farm meetings have been employed to inform the farmer of the benefits of any new or improved technology.

The small (less than one hectare) individual farmers compose the bulk of farmers throughout the developing world. The aggregate total of their farms hold the largest potential for increased production through proper application of agrotechnology. It is for this reason that all government programs are targeted toward individual farmers. Agrotechnology transfer, therefore, has to be approached via the small individual farmer. In many instances, the reasons for designing the program for them are political as well as economic.

For the traditional crops, the greatest barrier to technology transfer in the developing countries is the individual farmer himself. Such a farmer can be described as one who has not gone beyond grade school, has limited access to new technological information, is undercapitalized, possess very little aspirations, and has a large family. That same farmer, however, has the capacity to be self-sufficient in food without additional need for technology, and in case of large scale starvation, he may be the last to experience hunger.

Society wants the small farmer to absorb and use more sophisticated technology to produce enough food for its non-farming

citizens. This is a paradox and will remain a paradox because society itself has not invested in the development of the small farmer in order to absorb and be more capable of using the technology that increased production requires. Society must first learn to reward farming as a profession in the same league as medicine, law and engineering, before it can expect what it needs from the small farmers. The reward mechanism, perhaps, is the most important factor for a farmer to use new or improved technology.

In the United States, the high cost of using technology on a small farm (less than 100 hectares) has already made farming unprofitable. Corporation are gradually coming in to consolidate the operations of small farms. This brings us to the principle that a transferrable technology must be within the means of the individual farmer.

Foreign Aid, Technical Assistance, and Agrotechnology Transfer

Foreign aid and technical assistance programs from developed countries have been gradually modified during the last 30 years, from a dole-out posture to a training approach, in order to be more responsive to country-recipient needs. The training aspect has been the most lasting and least subject to graft and corruption. Technical assistance programs now appear to be the standard approach to the transfer of agrotechnology from the developed to the developing countries.

The Soil Management Support Services (SMSS) is one example of a technical assistance project from the United States Department of Agriculture. This is a project funded by the United States Agency for International Development (USAID). Any developing country in the Free World can make a request through its USAID mission to avail of the services of SMSS. There are no strings attached nor cost-sharing or counterpart funding required. The project provides manpower and laboratory services to classify soils according to Soil Taxonomy. Training workshops are also conducted by SMSS in cooperation with host countries to train local experts on the use of Soil Taxonomy for agrotechnology transfer. Six such workshops or forums have been conducted in a period of three years.

Foreign aid and technical assistance programs will continue to contribute a significant force in accelerating the flow of technology from the developed to the developing countries. In order to remove the demeaning connotation that has been associated with foreign aid program over the years, it has been modified and called by various names, such as grants, long-term loans, fellowships and scholarships, institutional development project exchange programs, etc. The original intent of assisting the less developed nations, however, has not changed.

SUMMARY

Agrotechnology transfer may be viewed as the last frontier to produce enough food for this planet. It follows certain principles and concepts which determine its success or failure, and the speed with which it can be done. The transfer process depends on a number of interdependent factors. On a global scale, it is still the small individual farmer that must be motivated and properly awarded to make the transfer in order that society may benefit. Simultaneously, society must develop strategies to reward farming as a profession in the same status as other highly rewarding professions. Until such time, corporate farming is, perhaps, the only viable strategy for accelerating agrotechnology transfer.

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Principles and Concepts of the Benchmark Soils Project

BERNARDINO G. CAGAUAN JR.

The Benchmark Soils Project is a collective name of a research project of the United States Agency for International Development (USAID) administered by the University of Hawaii from May 1974 to May 1984, and by the University of Puerto Rico from January 1975 to December 1981. This project is entitled, "Crop production and land capabilities of a network of tropical soil families." It was implemented in Hawaii by the Department of Agronomy and Soil Science, College of Tropical Agriculture and Human Resources (CTAHR); in the Philippines by the Philippine Council for Agriculture and Resources Research and Development (PCARRD) through the supervision of its Farm Resources and Systems Research Department and the Philippine Bureau of Soils; in Indonesia through the Center for Soils Research (CSR); and in Cameroon through the General Delegation for Scientific and Technical Research (DGRST) which attached the project to the Institut de la Recherche Agronomique (IRA) research stations at Ekona and Barombi-Kang.

The conduct of the project in the above countries was covered by agreements with the University of Hawaii. The University of Puerto Rico parallel project was implemented in Puerto Rico by the Department of Agronomy and Soils, College of Agricultural Sciences; and in Brazil through the Empresa de Pesquisa Agropecuraria de Minas Gerais (EPAMIG). The Brazil counterpart was covered by an agreement with the University of Puerto Rico. Experimental sites were identified and established in all these countries and field experiments were conducted throughout the life of the project. These experimental sites belong to three soil families classified according to Soil Taxonomy (Soil Survey Staff, 1975).

The objectives of the project were: 1) to determine scientifically the transferability of agroproduction technology among tropical and subtropical countries; 2) to assist tropical countries in assessing the potential of upland areas for intensive cropping and intensive soil management; and 3) to demonstrate the value of soil and land classification in formulating agricultural development plans in selected areas.

Soil Classification — A Basis for Predicting Crop Management and Its Transfer

The project hypothesis. It is common knowledge that crops have certain environmental preferences for optimum growth and development. The object of research is to identify a system whereby one can

pinpoint with confidence the location of the optimum environment for a given crop performance or yield. A systematic description of crop environment which include most of the factors affecting crop growth is necessary to attain this objective.

Soil Taxonomy, a system for describing and classifying soils and interpreting and making soil surveys, provides most of the criteria for a systematic description of crop environments. At the soil family category of Soil Taxonomy, the soil name provides information on textural classes, mineralogy, soil temperature regimes, along with information which can be extracted, such as soil fertility, concentration or absence of certain soil nutrients or elements, and energy and soil moisture conditions during most or certain parts of the year. The nomenclature system is organized in order that knowledge about soils may be recalled in a systematic manner.

The project hypothesis is based on the premise that crop management practices or agrotechnology can be predicted on the basis of soil classification, according to Soil Taxonomy. To test this hypothesis scientifically, the Benchmark Soils Project conducted a series of maize trials called *transfer* experiments in a network of benchmark soils in four different countries. The experiments were conducted in the same manner at each site of the three soil families. The expectation was that, similar soils would behave similarly and would be reflected by similar crop performance. Likewise, different soils would behave differently and crop performance would be different.

Twenty four experimental sites were established and every site was equipped with weather monitoring instruments. A full-time project leader was assigned to each country and supported by administrative and field personnel employed by the project. It was an international research effort to test an innovative approach to agricultural research that was made possible by the additional manpower and financial contribution provided by its cooperators. The project's long-term goal is to show that site-specific repetitive research can be minimized once its hypothessis is validated.

Soil Taxonomy as a vehicle of transfer. The project selected the family category level of Soil Taxonomy to group similar soils. It is at this category that most of the general information needed for crop growth can be extracted from the soil name. An example of interpretation of soil properties from Soil Taxonomy name is presented in Table 1.

Because of the advantage of Soil Taxonomy over all other soil classification systems in providing the basic information for planning crop production of widely separated land areas of the world, it is a means to transfer agrotechnology or information. For example, scientists and planners in different countries can now have a common language with which to describe soils. A Eutrustox in Brazil is the same Eutrostox in Hawaii. The properties of this soil in both places are identical. If crop performance can be keyed to the taxonomic classi-

fication of soils, it would be easy to compare this performance under various environments.

Persons making the comparison would be guided by the attributes, as well as the limitations or constraints of the soil thus classified. Hence, transfer or prediction of crop management requirements can be rationally made without waiting for the results of experimentation. To emphasize this point, a soil that is classified as Dystrandepts will always be infertile anywhere in the world in its native state, unless the soil has been modified by previous cropping. Connotation of soil infertility is provided by the prefix *dystr* from *dystrophic*, a word that means faulty nutrition. In Soil Taxonomy this word connotes low base saturation.

Table 1. Interpretation of soil properties from Soil Taxonomy names[a]

Soil category	Example of taxonomic name in each category	Explanation or interpretation of the taxonomic name
Order	*Oxi*sol	The name connotes presence of oxide minerals, such as those of iron and aluminum. Abundance of these minerals sometimes indicates low fertility status of the soil.
Suborder	*Ust*ox	This is still an Oxisol, but there is additional information about the soil with the prefix *ust*, from *combust* meaning, to burn. This is, therefore, an Oxisol with a dry environment.
Great Group	*Eutr*ustox	The prefix *eutr* is related to such a word as eutrophication, which means enrichment. This is a dry Oxisol that is enriched in bases.
Subgroup	*Tropeptic* Eutrustox	An adjective is now introduced in the subgroup name to indicate a gradation from a central or typical Eutrustox. *Tropeptic* describes an Eutrustox with a moderate to strong aggregated structure in the B horizon and/or one that is somewhat shallow.
Family	*clayey, kaolinitic, isohyperthermic* Tropeptic Eutrustox	There are three more adjectives added to denote the family name of this particular Tropeptic Eutrustox. These adjectives indicate that the soil has a *clay* texture with a mineral composition of *kaolinite* and an average annual temperature greater than 22°C *(isohyperthermic)* at a depth of 50 cm. This mean annual summer and mean annual winter temperatures do not vary by more than 5°C.
Series	Wahiawa	The soil series name Wahiawa itself does not give information on any soil properties. Thus, a person encountering the soil series name for the first time would require additional information for interpretation.

[a]Cagauan, Tsuji and Ikawa (1982) as adapted from *Soil Taxonomy* (Soil Survey Staff (1975).

Obviously, knowledge of Soil Taxonomy is essential in order to classify soils according to this system. To further create awareness on the importance of this subject, the project conducted three workshops on Soil Taxonomy and agrotechnology transfer in the countries it was operating. Middle-management soil scientists, agronomists, and planners attended the training workshops. Over 75 participants mostly from the government agricultural agencies, universities, and colleges participated in the training courses that lasted from two to four weeks.

Recognizing the importance of soil classification for agrotechnology transfer spawned by the Benchmark Soil Project, the USAID funded another project starting in 1979 which is called Soil Management Support Services (SMSS). The creation of this project was catalyzed by BSP's effort to teach the new system of soil classification. The new project's primary function is to assist the developing countries classify their soils according to Soil Taxonomy. Since SMSS became operative in 1980, it has already conducted seven international training workshops on Soil Taxonomy and Agrotechnology Transfer. Its technical assistance program consist of providing a limited number of soil scientists from the Soil Conservation Service of the United States Department of Agriculture (USDA) to work with government personnel of countries that request the assistance from the local AID mission. There is generally no cost to these services. Assistance on soil analysis is also provided by SMSS.

Test of Transferability of a Soil-Based Crop Technology

Experimental Design. A workshop was organized at the University of Hawaii on May 20-24, 1974 to assist the project to develop a reliable methodology for generating data sets to be used in scientifically determining the transferability of agrotechnology (Silva, 1981). During this workshop, papers presented were on the description of the Benchmark Soils Project, approaches to field experimentation in developing countries, and experimental designs suitable for soil fertility experiments. In subsequent meetings of subject investigators and consultants, the following experimental design was evolved:

1. *Site and soil selection.* Two soil families belonging to the orders Oxisols and Inceptisols which are common upland soils in the tropics were selected. Later on a soil family belonging to the order Ultisols was added at the request of the governments of the Philippines and Indonesia. Ultisols are extensive in both countries. It was planned to locate these soils in the tropical areas of Asia, Latin America, and Africa. The specific soil families and their locations are listed in these Proceedings. (See "Experimental Aspects of the Benchmark Soils Project" by the same author.)

2. *Number of sites per soil family:* A minimum of eight sites per soil family was considered sufficient, or two sites for each soil family per country.

3. *Test crops:* Maize, soybean, and cassava were initially selected as test crops; but the volume of work needed to implement the transfer experiments with the three crops was not manageable, considering the project manpower resources. Soybean and cassava were dropped and only maize was used across the network. The best adapted variety in each country was decided as the cultivar to be used. Variety experiments, therefore, were initially conducted to determine the best adapted variety. After four years of experimentation, the Pioneer Hybrid X304C was the cultivar used across the Oxisols and Ultisols network.

4. *Treatment variables:* Lime and phosphorus were the treatment variables. These variables were determine to be related to the chemical and mineralogical properties of the test soils. Initial experiments conducted did not show any response to lime applications. Lime as a variable was dropped and replaced by nitrogen.

5. *Treatment design.* The treatment combinations of the two variables (nitrogen and phosphorus) were arranged in a 5^2 partial factorial modification by Escobar (Laird and Turrent, 1981). A diagram of this design is shown in Figure 1. The treatments are given in coded levels from -.85 to + .85. Each coded level is a percentage of the middle treatment coded as "O".

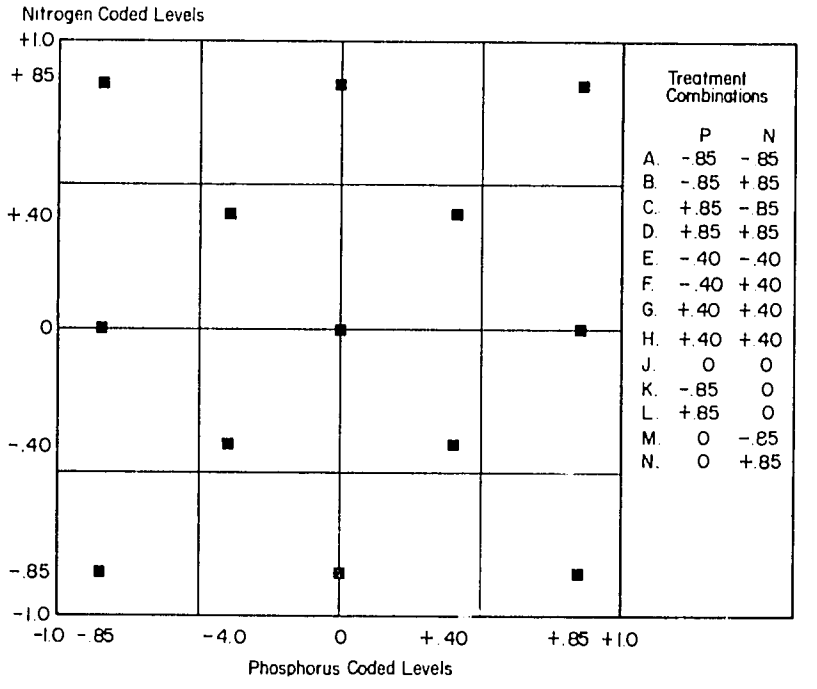

Fig. 1. Diagram of treatment design for 5^2 partial factorial modification by Escobar and the 13 treatment combinations used for the two-factor transfer experiments of the Benchmark Soils Project

Determining the middle value for each set of treatments was the key in obtaining the rates which gave a yield response to each variable. Nitrogen rates were based on a middle value of 100 kg N per hectare. P rates were based on the amount that must be added to a soil sample which will give a P in solution of .05 ppm, following the isotherm method recommended by Fox and Kamprath (1970) for maize. This P in solution of .05 ppm was defined by Fox and Kamprath as the external P requirement to give 99 percent of maximum yield.

BSP investigators determined that this level correspond to the middle value of the treatment design ("O" coded level). After two years of using the isotherm method, it was found that the P rates were too high, and the inconsistent response to applied P was noted. Extraction methods were investigated and calibrated which eventually replaced the isotherm method.

Calibration of a soil test for phosphorous. The soil test for P was crucial in generating the field data which showed response to applied P. It made possible the setting of the appropriate P rates for the test crop. If the rates determined from a soil test are beyond these "response" rates, a flat relationship of yield versus P applied would result. This would lead to the wrong conclusion that the soil has adequate P. The P response curves that were obtained using the modified Truog extraction curves provided the data base for the quantitative analysis of transferability (BSP, 1982 and Cady et al., 1982). This extraction curve method for determining the P treatments and calibrating it to suit the treatment design was a key achievement of the project. A brief discussion of this method is, therefore, appropriate.

The modified Truog extractant (Ayres and Hagihara, 1952) was used to construct extraction curves which became the basis for calculating all succeeding P rates in the BSP experiments. The P extraction method consisted of adding incremental amounts of P to 1-gram soil samples, shaking the soil solution for one day then extracting the P taken up by the soil with the extractant (0.25 N H_2SO_4 plus .38% $(NH_4)_2SO_4$). A plot of P-added in ug/g in the Y-axis versus the extractable P in ppm in the X-axis determined the curve from which the P rate calculations were based.

A field experiment on maize in the Hydric Dystrandept has shown that doubling the P-added at 95% of maximum yield corresponded to an extractable P of around 25 ppm and coincided with the + 1.00 coded level of the treatment design. This value was called the critical level of P application and was used as the starting point for calculating the P rates. The value of P-added corresponding to the critical extractable P of 25 ppm was calculated by substituting 25 for X in the linear equation: $Y = A + B\sqrt{X}$, where Y is the P-added in ug/g; A, the intercept; B, the slope; and X the extractable P in ppm. This is the general equation of the extraction curves. The calculated value of P-added after substituting 25 ppm, is the amount of P corresponding to the + 1.00 coded value

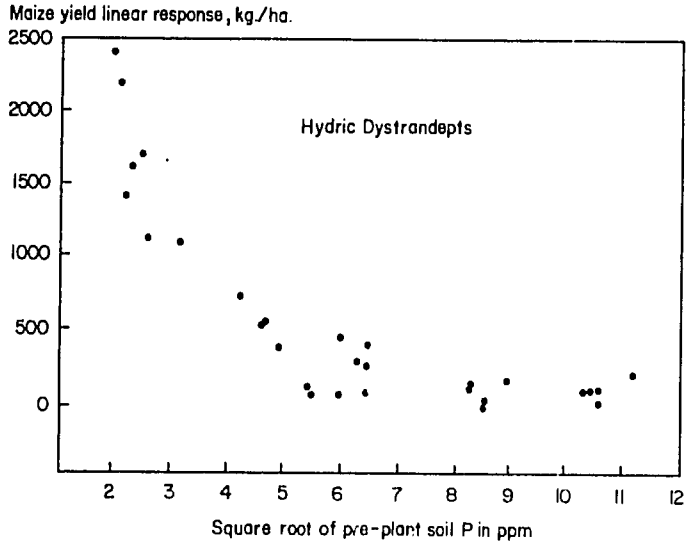

Fig. 2. Maize yield response to applied P in the Hydric Dystrandepts as influenced by pre-plant soil P determined by the modified Truog extraction method (Adapted from Cady et al, 1982)

of the treatment design (Fig. 1). Dividing this calculated by 2 provides the "O" coded or middle value. Percentages of this middle value from —.85 (15%) to +.85 (185%) were calculated to determine the other P treatments. Actual amounts of P were adjusted based on the weight of the upper 15-cm soil surface.

The consistent response to applied P was demonstrated in all experiments with P rates calculated from the extraction curves. There was response to applied P whenever pre-plant soil P was very much lower than the critical value of 25 ppm extractable P. On the other hand, no response was obtained to applied P whenever the pre-plant soil P was close to or greater than 225 ppm. This relationship or pre-plant soil P by modified Truog and maize yield response to applied P is shown in Figure 2. Table 2 shows the yield analysis of P treatments from the extraction curves for representative experiments conducted in all three soil families.

A few experiments which did not require P according to the extraction curves were given P treatments, spaced according to the treatment design based on the range of treatments that were found to show yield response in other experiments. This test was necessary to further confirm how valid were the treatments derived from the extraction curves. These are the experiments on blocks WAI B10 and WAI G10 in the Tropeptic Eutrustox. There was no response to P applied in these experiments which supported what was indicated by the extraction equation. Both blocks have a negative Y value (P-added) with the substitution of 25 ppm for X. Whenever Y is negative or close to zero, no P treatment is needed and any application of P would not show any yield response (Table 2).

Analysis of transferability. The connection between the transfer of

Table 2. Analysis of maize yield of representative experiments with P treatments determined by modified Truog extraction curves.

Soil Family and Block Symbol	Extraction curve equation $Y = A + B\sqrt{X}$			Range of P Applied, kg/ha		Significance of yield
	A	B	Y, ug/g if X = 25 ppm	—.85	+.85	P > t
A. Hydric Dystrandepts, thixotropic, isothermic						
IOLE K10	—176	44	42	4	44	.0021
PUC K10	—226	68	115	18	222	.0001
PAL E10	—134	62	175	11	139	.0001
BUR E10	—153	68	185	9	108	.0001
B. Typic Paleudults, clayey, kaolinitic, isohyperthermic						
SOR A10	— 62	30	87	11	136	.0001
NAK J10	— 39	18	50	8	101	.0001
BUK D10	— 40	21	62	8	97	.0001
CAM C10	—151	36	29	3	38	.0389
C. Tropeptic Eutrustox, clayey, kaolinitic, isohyperthermic						
MOL J10	—134	28	5	1.5	19.5	.2268 N.S.[b]
MOL M10	— 95	29	49	5	67	.0001
WAI B10	—210	33	— 45	8[a]	104[a]	.8125 N.S.[b]
WAI G10	—118	23	— 1.65	2[a]	28[a]	.6526 N.S.[b]

[a]These rates were not based on the extraction curves. See text for explanations.

[b]N.S. — Not significant.

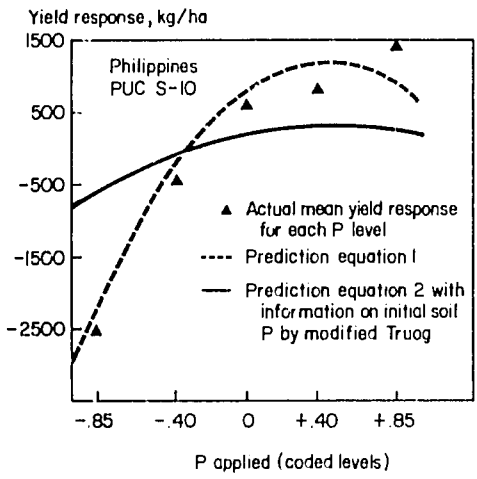

Fig. 3. Comparison of actual and predicted maize yield responses by two prediction equations. Responses are plotted as deviations from the mean yield of the experiment. Adapted from BSP Progress Report 3 (BSP, 1982)

P application and soil classification may not be explicit. P as a variable was selected because its behavior in the three soils is governed or affected by the mineralogy of these soils. Mineralogy is one of the properties that determine a soil family name. In the Hydric Dystrandepts, mineralogy is hidden in the thixotropic modifier. Thixotropy, although it is a physical property, implies that the soil is dominated by amorphous mineralogy. Soils containing abundant amounts of amorphous

materials require large applications of P fertilizers. The same behavior can be said of the kaolinitic mineralogy of the Tropeptic Eutrustox and Typic Paleudults in the BSP network, although P requirements are not as large as the Hydric Dystrandepts.

By compairing the shape of the response surface from sites of the same soil family, the responses were found out not to differ significantly by using a statistical methodology developed by the Benchmark Soils Project (BSP, 1979 and 1982; Wood and Cady, 1981; Beinroth, 1982; and Cady et al., 1982). This validates the hypothesis that similar soils behave similarly in terms of crop response. Similar response in this case does not refer to absolute yields, but rather to three-dimensional surfaces whose shape do not differ significantly from each other. The parameters (technology that generated these response surfaces) were taken collectively in applying the statistical analysis of transferability.

Requirements for Predicting Transferability

Soil classification. It is evident that in order to make use of the principles and concepts developed by the Benchmark Soil Project, the soil must be classified according to Soil Taxonomy. This classification system provides the basis for judging the potential of the soil environment relative to its ability to support crops. Soil classification provides the tool to stratify soils that will respond similarly, and consequently determine the transferability of a given soil-based agrotechnology.

Once the soil has been classified, technology information generated from other similar soils can be used with the expectation that similar results will be obtained. This transfer process should minimize repetitive trials if technology can be obtained elsewhere. Technology verification on a limited scale, however, may be needed before the technology is recommended for large-scale application. The economy that can be derived by using the BSP concept is in avoiding the costs of developing or rediscovering a technology which may already exist, or the costs of conducting several site-specific experiments were none to only a few may be necessary. Similarly, the pitfalls in adopting a technology may be avoided by knowing the information provided by soil classification.

Matching crop requirements. The crop dictates where and how it should be grown in order to manifest its maximum potential yield. This means that crop requirements match the environment where the crop will be grown. This principle is well known and basic to crop production planning. The unsuccessful planting of *Leucaena leucocephala* in the Philippines (Halos, 1980) might be attributed to failure to match the crop requirements to the soil environment. Leucaena is a crop that requires high calcium in the soil, adequate soil moisture during most of its entire growth, and an annual average temperature not lower than 22°C (isohyperthermic temperature regime). This tree crop, however,

would grow outside these environments, but yields or performance would be marginal.

BSP's cropping system experiments demonstrated the importance of matching crop requirements to the environment. Irish potato, for example, could not be grown in the warm and wet environment of the Typic Paleudults in the Philippines, Cameroon, and Indonesia; but was grown successfully in the cool and wet environment of the Hydric Dystrandepts in the Philippines, Indonesia, and Hawaii. It was also successfully grown in the hot and dry environments of the Tropeptic Eutrustox in Hawaii during the months when soil temperature was low (less than 22°C) and irrigation was provided. Potato cultivars that are commercially available today require average soil temperatures in the isothermic regime (15-22°C) for the tubers to develop.

These results are just a few of the many examples that can be cited which stress the importance of matching crop requirements to the environment. Knowing these results in advance without experimentation is the philosophy behind the concept of the Benchmark Soils Project.

An International Network of Experiment Stations

The results of experiments conducted on various crops in the experiment stations of the world which have accumulated over the years can be of benefit to most developing countries in producing their food requirements, if a system can be developed to share these results in the most rapid and timely way. As suggested in this article, the soils from which these experiments were conducted must first be classified according to Soil Taxonomy in order to have a common basis for information exchange. Common or similar environments (identical taxonomic names) must be grouped and keyed to crop performance. High-speed computers can then be used to store and retrieve the soil and crop data for planning or research purposes. This forms the data base from which decisions can be made with regard to technology transfer.

To develop such a system is one of the aims of the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT), another USAID Project which started in September 1982 and is administered by the University of Hawaii. It is a collaborative research project involving national and international research institutions located mostly in the tropics and subtropics. Its primary aim is to develop and test crop models which can be used to predict the performance of the ten most important food crops in the developing countries. These crop models will integrate crop, soils, and weather data using microcomputers for the purpose of accelerating the flow of agrotechnology among and within countries. Benchmark sites will be classified according to Soil Taxonomy with the assistance of SMSS. Where the required data are lacking, simple field experiments will be conducted to generate crop and environmental data to feed the models.

SUMMARY

A benchmark soils approach to field research is discussed which demonstrated the value of soil classification in agronomic management and planning. The research project hypothesized that Soil Taxonomy stratified environmental niches which are likely to respond in a predictable manner upon the application of a crop management input or technology. Using maize as a test crop, it was successfully shown that soils within a soil family, which was the soil category used to identify similar soil environments, do not differ in their ability to respond to the application of phosphorus fertilizer — the technology that was selected to test the hypothesis. Phosphorus, one of the variables selected, is affected by the mineralogy and chemistry of the three soil families in the test sites. Since each soil family differed in their requirements for P, the challenge that was posed to the researchers was how to determine treatments that would generate comparable results without resorting to trial and error or arbitrary guesswork. This was successfully overcome by adopting a treatment design in conjunction with a soil test. The treatment design used relative rates rather than absolute amounts for all the sites. The relative rates were kept in phase with the yield response surface by a soil test which determined the appropriate range of P application

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Experimental Aspects of the Benchmark Soils Project

BERNARDINO G. CAGAUAN JR.

The primary objective of the Benchmark Soils Project was to test the hypothesis that management practices could be predicted on the basis of soil classification. This required the conduct of field experiments in different locations on soils that were classified according to Soil Taxonomy (1975) at the soil family category. Test crops, growing techniques, and experimental designs were identical in order to generate comparable experimental data. The project personnel who implemented and managed the project were trained and calibrated according to the requirements of the experiments. Training of project personnel was a continuous activity during the course of field experimentation, until they were proficient in every aspect of the field experiments.

This paper describes some general procedures and guidelines in the conduct of field experiments in a network of benchmark site using the experience of the Benchmark Soils Project.

Establishing a Network of Benchmark Sites

Benchmark sites may be established with various objectives in mind. One such objective may be the establishment of verification trials within a given agro-climatic zone. Or the experiment station itself could be the benchmark site which represents a fairly large farming area within a given geographic zone or watershed, such as a valley or a plateau. Whatever the objectives are, each benchmark site should be identifiable on the map in terms of its properties which are useful in predicting the growing conditions for a given test crop. This is where soil classification units become very useful as descriptors of a benchmark sites.

The soil family category of Soil Taxonomy has been used to designate the experimental sites of the Benchmark Soils Project (Table 1). Each family is distinct from the other families in terms of physical, chemical, and environmental properties. All these measurable properties affect crop growth and development.

Site selection begins with a soil survey, collection of soil samples, and classification of the selected area into the desired soil category. This normally takes six months to over a year, but the time can be considerably reduced if there are no leases to be negotiated with landowners. In some cases, several trips to one location are necessary to verify certain soil classification criteria which were overlooked during the first visit.

The task of site selection can be expedited if the location is already mandated for the desired purpose and the only activity to be done be-

Table 1. Soil family network of experimental sites of the Benchmark Soils Project[a]

Location	Site	Reference Abbreviation	Type of Site
Soil Family A: thixotropic, isothermic Hydric Dystrandepts			
Hawaii	Niulii, Iole, North Kohala, Hawaii	IOLE	Primary
	Kukaiau, Honokaa, Hawaii	KUK	Secondary
	Niulii, Halawa, North Kohala, Hawaii	HAL	Secondary
Philippines	Philippine Union College, Panicuason, Naga City	PUC	Primary
	Palestina, Pili, Camarines Sur	PAL	Secondary
	Burabod, Calabanga, Camarines Sur	BUR	Secondary
Indonesia	ITKA, Cisarua, Java	ITKA	Primary
	PLP, Lembang, Java	PLP	Secondary
	Segunung, Cipanas, Java	LPH	Secondary
Soil Family B: clayey, kaolinitic, isohyperthermic Tropeptic Eutrustox			
Puerto Rico	Isabela	ISA	Primary
	Isabela	ISA-2	Secondary
	Isabela	ISA-3	Secondary
Brazil	Paraná, Jaiba	PAR	Primary
	Bahia, Jaiba	BAH	Secondary
	Ceará, Jaiba	CEA	Secondary
Hawaii	Maunaloa, Molokai	MOL	Primary
	Waipio, Oahu	WAI	Secondary
Soil Family C: clayey, kaolinitic, isohyperthermic Typic Paleudults			
Philippines	Davao, Mindanao	BPI	Primary
	Sorsogon, Luzon	SOR	Secondary
Indonesia	Lampung, South Sumatra	NAK	Primary
	Lampung, South Sumatra	BUK	Secondary
	Lampung, South Sumatra	BPMD	Secondary
Cameroon	Barombi-Kang	CAM	Primary
	Southwest Province	BAK	Secondary

[a]Benchmark Soils Project (1982b).

fore its actual use is to classify the soil. This is usually the case of already established experiment stations. Selecting a site is more difficult if the soil survey team is looking for a particular soil, as well as a particular site, for the experiment.

The *test crop* may be a major crop that is grown extensively or has economic importance in the farming region or community. It can also be a group of crops which are suitable in a particular season of the year. In multiple-cropping experiments it is customary to use a group of crops as test crops. The number of crops to use depends on manpower availability, knowledge on the cultural requirements of the crops, and financial resources available to install and manage the experiments, as well as process the data that will be generated. It is always better to concentrate on one test crop and do a good job of growing that crop.

It is recommended that the same variety or cultivar be used in all test sites. This eliminates the possibility of having to deal with geno-

type and environment interaction later. Test crops should be of relatively short duration (less than one year) which can be replicated a number of times during the life of the research project. Examples are grains, roots, and vegetable crops. Tree crops, however, are better integrators of environmental influence over a long-term period. Their limitation lies in the long duration in which experimental data can be obtained.

Monitoring the Weather

Weather parameters are uncontrolled variables which affect crop performance. At least, rainfall and temperature data should be recorded daily during crop growth. Where project funds would allow, solar radiation, relative humidity, and wind speed may also be recorded.

Self-recording weather stations are available that monitor rainfall, temperature, relative humidity, wind speed, and wind direction. These weather data provide the only proof of the weather conditions existing during the progress of the experiment. Hence, they are useful in explaining the differences or variations in crop performance from site to site of even from one season to another. They may also serve to guide the scheduling of future experiments on the benchmark sites.

Manpower

A well-trained manpower is probably the most important component in establishing a network of benchmark experimental sites. In the Benchmark Soils Project, a full-time project leader is employed in each country to manage all phases of project activities. Each project leader is further supported by a team of administrative and field personnel who are responsible for the routine activity of the project. A team or project leader is necessary for each group of benchmark sites to have a smooth coordination of research or operational activities.

From BSP's experience it is quite difficult to conduct a well-managed experiment when the leader or supervisor is hundreds of kilometers away and decisions have to be made in the field in regard to pest and disease control, processing of harvest, or recording of important experimental data. In the end, it will be very difficult to evaluate the project if nobody is given the total responsibility for managing the project in each site. It is also important, that if results from a group of widely separated Benchmark sites are going to be compared, every person assigned to each site must be properly trained on installation procedures, gathering of data, and management of the experiments. This will insure that the experiments are conducted and cared for in the same way, making the data comparable. A detailed set of procedures must be prepared before the installation of experiments, not during or after; and personnel have already been properly briefed about these procedures.

It requires about a month to properly orient the team or project leaders on field procedures before releasing them to their respective stations. This orientation is necessary to have a uniform conduct of the

experiments. Inspection visits to the project leader's station are also needed to determine whether experiments are being conducted according to plan. Some project leaders may develop other objectives which may be contrary to the objectives of the experiments.

One major purpose of inspection visits by project managers is to correct any deviations from set procedures which may affect the results of the experiments. There are project leaders, who, despite all efforts to make them follow exactly the procedures as outlined, would insist on their own way of doing experiments. Such project leaders are better kept in other jobs rather than manage experiments in a network of benchmark sites.

Conduct of the Experiment

Selecting the experimental sites. Once the benchmark experiment stations are determined, the specific area or location for installing the experiments are selected. Normally, the area should not have more than 3% slope, unless this is the characteristic of the benchmark site itself. There are many factors that determine the orientation of the experimental plots, such as the existing road boundaries or fence and the shape of the land, in addition to the prevailing physical slope. In such cases one should use common sense in orienting the experimental plots. The statistical design, for example, would require that rows be made along a major gradient in order to sample the entire variability of that gradient. If this will result in a serious erosion problem this requirement should be ignored and the rows should be made across the major gradient.

Experiments should be conducted away from trees which can cause shading of plots and away from old compost or garbage pits, buried canals, or former animal corrals. The experiment should be protected from damage by farm animals. In windy areas, protective windbreaks, like bananas and fast-growing trees or shrubs, may be planted.

Depending on the objective for conducting the experiments, irrigation should be available. In the Benchmark Soils Project, irrigation was provided by drip method. BSP's objective is to be able to grow a crop under optimum input conditions, and the only way to insure a successful crop was to provide irrigation. It has, however, separate experiments which monitored the performance of various crops with and without irrigation.

Description of the experiment. There is no universal type of experiment which should be used to test the similarity of response from similar soil environments. It could be a simple variety, fertility or management-oriented experiment. The number of responses or performance indices that will be measured determines the complexity of the experiment. The BSP approach is to determine a continuous response function over a range of critical input treatments which are related to the nature of the soils in the experiments. Phosphorus, for example, is

chosen as one of the two treatment variables because the three soils families selected all required high amounts of P by reason of their mineralogies.

It is easy to design the experiments in a benchmark site if one keeps in mind that the results should be applicable or transferrable to other similar sites. The premise is that, if the soil name is known, one can infer with a high probability of being correct, what constraints should be remedied or ameliorated to have a successful crop. There are soils that have few or no constraints and the task of the researcher becomes even simpler. All that is required is to grow the test crop under replicated treatments and get a measure of the crop performance.

Any treatment can be selected which will give widely spaced differences in performance or yield. In choosing the treatments, the researcher must be aware that such treatments are necessary and, indeed, a response is a realistic expectation from the treatments. Liming experiments, for example, have been conducted on soils that do not require lime and on crops that are not sensitive to liming. It is this kind of experiment that one must avoid in a benchmark site, since it is an imprudent application of scarce research funds.

Uniformity test. As pointed out earlier, fields which are heterogeneous as regards soil fertility must be avoided. Pockets of fertile areas can cause so much variability in the experimental data which will be gathered. A fairly uniform field can be selected by installing a uniformity test. An entire field can be planted to a close-growing crop, such as upland rice or sorghum. It is generally required that no fertilizer must be applied especially those elements which will be used in the treatments. Crop growth should pinpoint the areas that must be avoided owing to their abnormally high or low fertility status. The uniformity test will also give an indication whether the intended fertility treatments are necessary or not. A visual judgment on the uniformity of the field based on the crop stand is usually sufficient. Yield data are not normally collected unless the research project has other additional objectives.

Sometimes it is faster to determine which areas are desirable for laying out the experimental plots through soil analysis. The field is divided into grids which will serve as sampling areas. These grids can measure from ten to a hundred square meters in size. The grid size depends on the size of the experimental plots. Judging the field uniformity based on soil analysis may not be as easy as judging a standing crop. If there is sufficient lead time (about two to three months) before installing the experiment, it is preferred to grow the crop first without any fertilizer treatment, then confirm the uniformity test by soil analysis on the elements which will be used as the treatments. A uniformity test will save the researcher much time and effort if later on the area is found to be unsuitable for the experiment.

Staking the plots. The plot corners must be squared to get a true

measure of the plot area. The 3-4-5 method is a very convenient technique for plotting 90° angles on the ground. Permanent wooden stakes about 24 inches above the ground are generally used to mark corners of the experimental blocks. The stakes should at least last for the duration of the experiment. For long-term experiments, painting the stakes with coal tar increases the life of the stakes about four-fold. This treatment is recommended in termite-infested areas.

Installing the experiments. It is extremely important that the team or project leader is present during the installation of the experiments. Sufficient seeds, inputs, and treatment materials must be prepared prior to installation. Planting must be completed in one day for all the replications. The leader must also insure that there is adequate labor to do all the planting and application of treatments. If it is probable that the experiment cannot be installed in one day because of lack of materials and labor, or because of other reasons, postpone the installation to some other time.

Field workers should not be given the responsibility of installing the experiments by themselves, even if they have undergone orientation and training. This is a responsibility of the project leader which cannot be delegated to a less competent person. Mistakes are easy to commit during the installation of the experiment. Unless these mistakes are prevented before the crop is planted, there is no way to correct them once the experiment is already installed. Examples of serious mistakes by field workers are interchanging the treatments and plot numbers, applying the fertilizer only to a portion of the plot, burying the seeds too deeply, running out of seeds in the middle of the row then starting another row when the worker comes back with the seeds, mixing the seeds with the fertilizer, and forgetting to apply the treatments. The project leader should develop a system to check or prevent all possible errors in installation which will render the experiment useless.

Insects, diseases, and weed control. During the progress of the experiment pests and diseases must be controlled where control is possible, preferably at an early stage. Livestock and pets must be kept away from the experiments. Weeding or cultivating and spraying of chemicals must also be completed in one day in all the replications, as well as the application of irrigation water or side dressing of fertilizer treatments. Weeds should not be allowed to grow tall unless this is part of the treatment. As a general rule, weeds are best controlled (post-emergence) at the 2-3 leaf stage.

Data Recording and Monitoring

Procedures for collecing the data, frequency of recording, and monitoring must be fully described and understood as part of the experimental plan. Forms must be developed to record the data and personnel must be trained to use these forms. An example of a harvest data form is shown in Figure 1. Data reported must be reviewed by the person in

HARVEST WORKSHEET:

soil/country: _____

season/year: _____

site/sequence mode: _____

signature/date: _____

Rep Plot	Plants lodged	Plants discarded	Plants harvested (no.)	Ears missing	Ears harvested	Ear weight (kg)	Stover weight (kg)	Stover sample weight
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								

Tare: _____

Comments:

Figure 1. Example of data form for recording the harvest data from a corn experiment (Benchmark Soils Project, 1982b)

charge (the project or team leader) before submitting them to a central location, such as a computer facility. This will eliminate wasted time in clarifying questionable data once the data are submitted for processing. Also, reviewing the data before they are transmitted can uncover certain deficiencies, such as an instruments not properly operating or instrument not correctly read. In some cases, the data trend can reveal certain errors in installation.

SUMMARY

The conduct of field experiments in a network of benchmark soils involves thorough preparation, from the identification of objectives to the training of required field personnel. Benchmark soils must be classified according to Soil Taxonomy to enable users to make predictions on their properties which will influence plant or crop performance. Experiments that will be conducted must be carefully selected in order to relate or compare the results among and within the selected benchmark sites or stations. A competent training in field experimentation is a must and the only requisite in obtaining useful experimental data. This training is the only insurance that research funds are utilized most efficiently.

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Crop Production Capabilities of a Volcanic Ash Soil and Tropical Latosols in the Philippines

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Volcanic ash soils are in general believed to be productive soils. Tropical Latosols on the other hand broadly include a great number of soils processing a wide range of properties and production potentials which are dependent on the combinations of soil-forming factors interacting locally. Some soils belonging to these two broad groups are problem soils but others are not.

The Soil Taxonomy (1975), from the Soil Order to the Soil Family category provides a system of nomenclature reflective of soil properties which could be an asset or a constraint in crop production. The Dystrandepts and the Paleudults great groups are connotative of low fertility volcanic ash soils and latosols, respectively.

These two soils were part of the network of experimental sites established in the implementation of the USAID-supported Benchmark Soils Project, the popular title of the study being "Crop Production and Land Capabilities of the Network of Tropical Soil Families". The project as a part of an international network was implemented in the Philippines cooperatively by the University of Hawaii and the Philippine Council for Agriculture and Resources Research and Development (PCARRD), through the Bureau of Soils, Ministry of Agriculture. The data and information presented in this paper constitute a very small portion of the voluminous compilation obtained in the Philippine operations. Some data from the operations of other countries are included for comparison and emphasis.

The Soils: Their Environment and Land Use

The volcanic ash soil in the Philippine Union College (PUC) at Naga City, Camarines Sur and the Latosols found in Pilar, Sorsogon, and in Davao City, compose the sites. The first two sites are in the island of Luzon and the third is in the island of Mindanao.

The volcanic ash soil which according to the Soil Taxonomy (1975), is classified under the thixotropic, isohyperthermic family of the Hydric Dystrandepts can be considered as marginal soils for crop production. The Latosols are composed of two soil families. That in Sorsogon belongs to the clayey, mixed, isohyperthermic family of the Typic Paleudults, while that in Davao belongs to the clayey, halloysitic, isohyperthermic family of the Typic Tropudults.

Some information on the environment and land use of the three sites are presented in Table 1. The PUC and the Sorsogon sites are situated between 12° and 14°N Latitude and are subject to slight variations in atmospheric temperatures between the cooler months (December to February) and the rest of the year. Weekly mean maximum temperatures (Figure 1) range from 28°—34°C and the minimum range from 19°—24°C in the PUC site which is at about 350 m in elevation. On the other hand, temperature maxima range from 28°—36°C and minima range from 20°—24°C in the Sorsogon site which is at about 70 m elevation. Rainfall in these two sites which are normally over 3000 mm annually, are brought about by the monsoons from May to August and by typhoons from September to December. The rainy seasons are associated with cloudiness and low solar radiation, particularly in PUC. Rain periods are normally spread over a number of days.

Daily soil temperature measurements at 50 cm depth range from 22°—27°C in PUC and from 24°—27°C in Sorsogon. Hence, they are both within the isohyperthermic temperature regimes.

The Davao site which is situated at about 7°N Latitude is consistently warm with weekly mean maximum air temperatures ranging from 31°—36°C and the minima are within 22°—24°C. The mean annual rainfall is in the order of 2100 mm with the least rains in March and April. Orographic rains normally occur late in the afternoons and evenings, so that days are generally sunny even during the wet months. The drier part of the year is mostly associated with high clouds and hazy atmosphere.

Soil temperature observations at 50 cm depth range from 26°—29°C in the Davao site.

Geomorphically, the Dystrandept is on the lower uppermost interfluve shoulder of Mt. Isarog, while the Paleudult and the Tropudult are on the lower and middle of the third interfluve, respectively. The parent materials are moderately weathered volcanic ejecta presumably of the Pleistocene age for both the Paleudult and Tropudult. The ashes are primarily andesitic.

All the sites are on upland ridges in level to undulating uplands. The Dystrandept area is associated with wider spaced waterways and perennial streams with steep valley walls. The Tropudults, on the other hand, are associated with relatively shallower and more gently sloped valley walls of water ways and perennial streams, compared with those associated with the Paleudult.

The three sites were in the past presumably under Dipterocarp forests as evidenced by trees remaining in the areas. The denudation of the forest and subsequent cultivation resulted in the take-over of grasses once the area was abandoned. The dominant grass species in the PUC area is the *Saccharum spontaneum* or wild sugar cane while the *Imperata cylindrica* is dominant in the Sorsogon area. A combina-

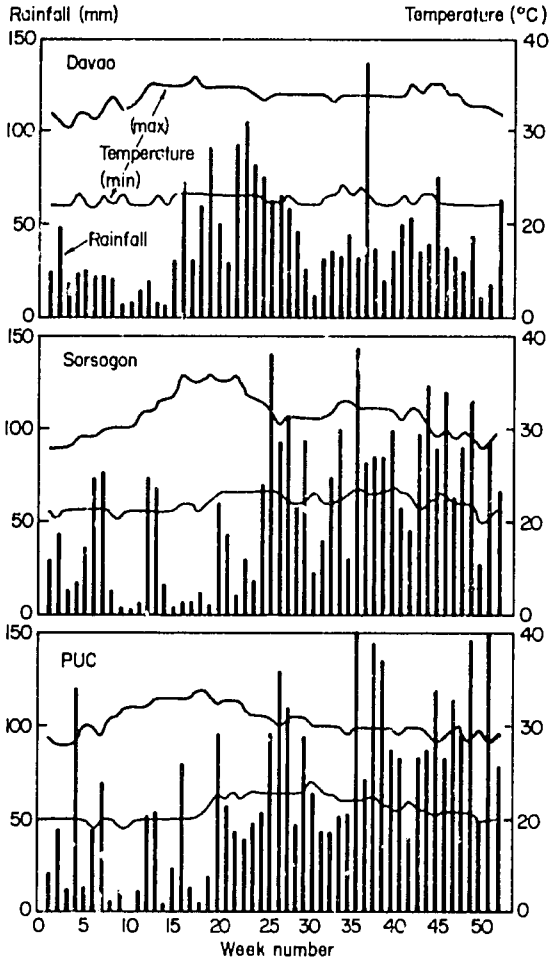

Fig. 1. Mean weekly rainfall and temperature at the BSP sites

tion of the two species is found in the Davao areas, but the latter is more associated with highly eroded areas.

Coconuts are grown extensively in all the three areas. Sugar cane however, is rapidly replacing the coconuts in the Dystrandept area, on account of the inherently low productivity when compared with the Udult areas which are comparable in productivity for coconuts. Corn are hardly grown in the Dystrandept and the Paleudult areas, while white maize as staple in the Davao area is commonly grown in small open spaces and as an intercrop under the coconuts. Cassava which is a common crop in the Paleudult area is also grown on a relatively smaller scale in the other two areas.

Upland (dryland) rice is a common crop in the Dystrandept and the Paleudult areas but not in the Tropudults. This is more a reflection of the demand for this crop as staple. Wetland rice is grown on waterways associated with the Udults but are extensive in the Dystrandepts where and when reliable sources of irrigation water are available. The land-

Table 1. Soils, environment, and land use of the Benchmark sites, Philippines

Soil Family	Thixotropic, isohyperthermic Hydric Dystrandept	Clayey, mixed, isohyperthermic Typic Paleudult	Clayey, halloysitic, isohyperthermic Typic Tropodult
Soil Series	Previously identified as Isarog soil	Associate of Castilla series	Mapped as Tugbok series
Site Identification Location	(PUC) Philippine Union College, Panicuason, Naga City, Camarines Sur	(SOR) Del Rosario Farm Bual, Pilar, Sorsogon	(DAV) Bureau of Plant Ind., Davao Expt. Station Bago, Oshiro, Davao City
Coordinates	13°40'N Latitude 123°25'E Longitude	12°50'N Latitude 123°40'E Longitude	7°05'N Latitude 125°30'E Longitude
Elevation	About 350 m asl	About 60-75 m asl	About 100 m asl
Rainfall	0-1 dry (-50 mm) month 3-4 intermediate (50-100 mm) months and more than 7 wet (+100 mm) months Rainfall = 3400 mm	Similar pattern and about the same amount of rainfall Rainfall = 3200 mm	Similar in pattern but less in amount of rainfall Rainfall = 2100 mm
Temperature:			
Minimum	19-26°C	21-27°C	22-28°C
Maximum	25-36°C	26-37°C	29-34°C
Vegetation/ Land Use	Originally dipterocarp forest; large tracts on coconut and sugar cane; small tracts on upland crops and vegetables; paddy rice with irrigation; coffee and abaca intercrop under coconuts; some pastures	Originally dipterocarp forest; large tracts on coconuts with coffee, cacao and abaca intercrops; rice and cassava	Same as Sorsogon, except for more corn and fruit trees planted.

scape positions of the Udults make irrigation to support wetland rice production difficult.

Characteristics of the Soils

The thixotropic, isohyperthermic family of the Hydric Dystrandepts are characterized by (a) the smeary character and watery feel of apparently dry soil when worked well between the fingers; (b) the high organic matter content; (c) high water retention which can be twice or more of the weight of the soil; (d) the low base saturation but high CEC; (e) the low bulk density (less than 0.9 g/cm^3) and high amounts of volcanic glass; and (f) consistently higher (than 22°C) soil temperatures at 50 cm depth.

The soil has excellent tilth and drainage conditions. Despite the high permeability of this soil, scouring along the waterways are common when high intensity typhoon rains come. In the presence of manageable irrigation, the soil is readily convertible from dryland to wetland cultures and vice versa. They are moderately acidic, low in KCl extractable Al, and high in CEC.

The soil of the Sorsogon site belong to the clayey, mixed, isohyperthermic family of the Typic Paleudult. As such, it is characterized by: (a) the intense weathering that leaves less than 10% weatherable minerals; (b) the dense, clayey, and deep B horizon, (c) the low CEC and low base saturation; and (d) its highly erodible quality when cultivated. On the other hand, the soil of the Davao site which also qualify as tropical Latosol did not qualify as Paleudult because of (a) the relatively high CEC (almost 20 m.e./100g) and high base saturation of more than 35%. Neither of the two soils qualified into the kaolinitic mineralogy as originally required by the Project.

Some of the chemical and physical properties of the soils are presented in Table 2. Aside from the thixotropic nature of the Dystrandept, the high organic carbon contents down to 80 cm depth, the high CEC, and very low base saturation easily differentiate it from the Udults. The relative intensity of the phosphorus problem associated with the soil is markedly expressed by the percentage P retention.

The comparative reliability of expressing base saturation either by the NH_4OAc or by sum of cations is also shown in the table. It is apparent that the two ways of expressing the percentage base saturation tend to differ at the higher ranges of values but are closer when dealing with the lower ranges of values.

Field Experimentation

Experiments conducted in the network of soils were all geared towards the establishment of the production capabilities of the soil families, even if the concentration was on the test on agrotechnology transfer based on the soil family. The "transfer experiments" constituted the main bulk of the activities. Management experiments, such as NPK trials, variety tests, plant population studies, P sources, rates and

Table 2. Some chemical, and physical properties of the soils of the BSP network in the Philippines[a]

Soil Properties	Depth (cm)	Dystrandept[b]	Depth (cm)	Paleudult	Depth (cm)	Tropodult
% Organic C	0-20	9.90	0-12	1.60	0-8	1.43
	20-45	3.92	12-30	1.09	8-22	1.14
	45-80	1.99	30-55	0.73	22-45	0.56
% Extractable Fe[c]		1.9 - 2.6		7.2 - 7.6		5.2 - 5.5
Bases (m.e./100 g)		1.3 - 3.3		2.7 - 3.8		10.5 -16.6
Extractable Acid (m.e./100 g)		29.3 -46.1		12.6 -14.0		3.1 -10.0
Extractable Al (m.e./100 g)		.03- .28		0.12 - .42		.01- .05
CEC: NH_4OAc (m.e./100 g)		34-44		15-17		17-20
Sum (m.e./100 g)		32-47		16-18		20-2[illegible]
% Bases Sat.						
NH_4OAc		3-10		18-22		60-82
Sum		3-10		17-22		20-24
pH (H_2O)		5.3 - 5.6		4.8-4.9		5.3-5.4
% P Retention		99-100		60-64		45-52
% Clay				66-76		49-56

[a]The morphological descriptions and the laboratory characterization of the soils presented in this paper were obtained with the assistance of the USAID-USDA Soil Management Support Services Project through the Soil Conservation Service Laboratory at Lincoln, Nebraska.

[b]Analyses were done on air-dried samples also.

[c]Minimum and maximum within the depth indicated for % organic carbon.

placement, were conducted to generate/verify technologies supportive of the transfer experiments.

Cropping systems trials and tree (planting) trials were conducted in support of the transfer hypothesis and the determination of the production capabilities of the soils.

The transfer experiments. The Escobar modification of the 5^2 partial factorial, as shown in Figure 2, was the design used for the transfer experiments with phosphorus and nitrogen as the variables. The amounts of N added at specific coded N levels were the same all throughout (seasons and sites), but the added P levels at specific P code vary according to the soil P levels as determined by the modified Troug prior to the establishment of individual experiments. The procedures followed in the conduct of the experiments from land clearing to harvesting and processing were allowed the least variation within the network. The procedures and guidelines which are now in the published form emphasize the need for strict adherence to the methodologies. KCl, sulfates of magnesium and zinc, and borax were added to minimize the limitations of elements other than N and P. Drip irrigation was provided in all the experiments to eliminate water stress as a variable.

The cropping systems. The cropping systems trials, also in support of the transfer hypothesis, involve the evaluation of the performance of the crops in the soil family for which the pattern was designed, as well as the performance of these crops in another soil family. That is, the pattern designed for the Dystrandept was also tested in the Paleudult and Tropudult sites, and vice versa; the pattern for the Paleudult was also tested in the other two sites. The crops in the patterns as programmed in sequence over a year period are illustrated in Table 3.

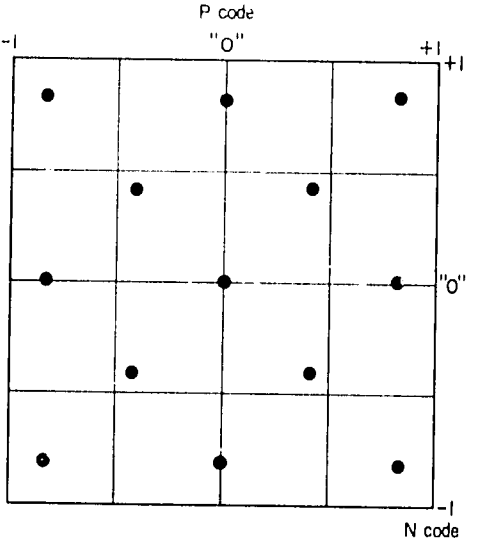

Fig. 2. Escobar modification of 5^2 partial factorial

Table 3. Cropping patterns tested in Dystrandept and Paleudult

Soil/Site	Cropping Pattern[a] 1st Cycle	2nd Cycle	3rd Cycle	Long-term Crop[b]
Dystrandept	Root crops	Vegetable crops	Grain crops	Taro
	Irish potato	mustard cabbage/ green corn/ bush bean	soybean peanut	
	Vegetable crops			
	cabbage/ carrot/ bushbean			
Paleudult	Grain crop upland rice/corn	Grain crop soybean peanut	Grain crop cowpea mung-bean	Cassava

[a]Crops separated by / are intercropped; others are monocrops.
[b]Planted along borders of plots or border crops.

The tree trials. In cooperation with the study on nitrogen-fixing trees (NFTs) being carried out by Dr. James L. Brewbaker of the University of Hawaii, the trial was conducted to assess the species x soil family (genotype x environment) interaction of trees with potentials for a variety of uses. This trial was conducted in the Tropudult site only, as planting materials were insufficient for all the three sites in the Philippines. Seedlings were propagated in a nursery before they were transplanted in the field. The leguminous entries were inoculated during seedling establishment. No other treatments were made in the field. Water was provided only to assure the initial survival of the trees in the field. There were five replicated entries (species) and 12 non-replicated entries. These are as shown below:

Replicated entries	Non-replicated entries
Acacia auriculiformis	*Acacia mangium*
Calliandra calothyrsus	*Acrocarpus fraxinifolius*
Leucaena diversifolia	*Albizia falcataria*
Leucaena leucocephala	*Albizia procera*
Sesbania grandiflora	*Casuarina equisitifolia*
	Dalbergia sissoo
	Enterilobium cyclocarpum
	Erithrina poeppigiana
	Eucalyptus saligna
	Gliricidia sepium
	Mimosa scabrella
	Samanea saman

The other experiments conducted are relevant, but the number makes the presentation of the designs and procedures impractical in this paper. It is, however, necessary that the support of the IFDC and the support and participation of PCARRD and UPLB in the conduct of P fertilizer management studies be acknowledged. They were conducted by David Harris, graduate assistant from the University of Hawaii and by Dr. Angelina M. Briones, associate professor of Soil Science from the University of the Philippines at Los Baños, in cooperation with the Benchmark Soils Project.

Crop Production Capabilities of the Soils

Quantification of the crop production capabilities of the different soils under several levels of management was achieved in the network of sites with maize as the main test crop. Other grain crops, vegetable crops, and tree crops as additional test crops complemented the quantification in support of the use of Soil Taxonomy as a tool in the: (a) identification of the problems associated with particular soils or groups of soils; (b) design and testing of appropriate agrotechnology for the soils; and (c) transfer of agrotechnology among identical or similar soils as a means of reducing the repetition of expensive field experimentations.

The transfer experiments. Table 4 shows the results of the selected transfer experiments from the three sites in the Philippines.

Supplying the phosphorus to attain 20 ppm level by modified Troug and 88 kg N/ha were considered sufficient to attain the optimum levels of corn production. This treatment is represented by P code "O" and N code "O". Yields obtained at various combinations of P and N levels, as coded, are measures of the potential production under different levels of fertilization. The data from the control plots indicate that providing good management, suitable HYV, proper cultural practices, appropriate crop protection, and if water is not a constraint, the Tropudults has an inherent potential of about 5 t/ha of maize; while the Dystrandepts and the Paleudults are not suitable for outright maize production, unless the critically low P levels are corrected.

The application of P (optimum) alone or with very minimal N (—1.0 or —.85) and proper management are sufficient to attain decent maize production levels of 3.5 and 4.0 t/ha from the Dystrandepts and Paleudults sites, respectively. The potentials under optimum rates of fertilization are 6.5, 7.0, and 8.0 t/ha in the Paleudults, Dystrandepts, and Tropudults, respectively. The absolute amounts of added P for the same treatment code level follow the order of Tropudults < Paleudults < Dystrandepts.

The potential yields within the same soil can vary in absolute values as influenced by variation in site factors, namely: (a) the varieties used; (b) the season in which cloudiness, occurrence of strong winds, and other microclimatic variations are of prime consideration; and (c) the in-

Table 4. Yields of transfer experiment in the Benchmark sites, in kg/ha

Treatment Code		PUC sites		SOR sites		DVO sites	
P	N	PUC S 20	PUC K 20	SOR B 10	SOR B 20	DVO N 10	DVO L 10
—.85	—.85	4791	3357	2620	2162	6838	6657
—.85	+.85	3502	3224	2425	523	8253	5949
+.85	—.85	6567	5233	3945	4949	7446	6055
+.85	+.85	8496	6289	7723	7661	9313	8454
—.40	—.40	6140	4513	5124	5250	7752	7682
—.40	+.40	6894	5050	6396	5124	8840	6690
+.40	—.40	6668	5698	5253	5738	8236	7555
+.40	+.40	7236	6327	6479	6697	8046	8235
"0"	"0"	7993	6210	6392	6559	8602	7739
—.85	"0"	6115	4080	2902	1523	7599	5921
+.85	"0"	7984	6322	6532	7101	7509	8226
"0"	—.85	4799	5460	3710	4630	6131	6996
"0"	+.85	8369	6271	7425	7222	8260	7863
—1.0	—1.0	415	2879	0	869	5348	5098
"0"	—1.0	3634	----	3297	3900	4601	4997
—1.0	"0"	426	2947	0	244	3877	4414
Variety		X304 C	X304 C	X304 C	X304 C	X304 C	X304 C
Mean Yield (kg)		6581	5223	5214	5011	7910	7232
LSD (kg)		943	689	1092	857	1364	994
C.V. (%)		8.96	8.51	10.71	12.29	9.49	8.31
Season		Dry 81	Wet 81	Dry 81	Dry 82	Off-Wet 81	Off-Wet 82

cidence of pests and diseases despite the programmed crop protection measures.

The capability that the incidence of downy mildew of maize can be stratified was experienced. High frequency of downy mildew infestation causing crop failures is a normal occurrence in the warm humid conditions of the Tropudults and Paleudults. The disease is rare and of lesser gravity in the cooler although humid conditions in the Dystrandepts, since the soils border are cooler limits of the isohyperthermic temperature regime.

The evidences in support of the transferability of maize response to phosphorus fertilization have been presented in a number of publications of the Benchmark Soils Project, the latest was in 1982 (1). Yield predictions can be made within 300 kg/ha of actual yields when sufficient data base are available. Responses can even be predicted from one season to another, and from one site to another within the same soil family (Figure 3).

Cropping systems. The results of the two years involving six cropping enabled the quantified assessment of various crops and their suitability to different environmental conditions. Indications are that upland rice, green corn, soybeans, peanuts, and cowpea can be grown favorably in all the sites, provided that proper nutrition and optimum management are taken into critical consideration.

Irish potatoes and cabbage are total failures in the Tropudults and the Paleudults, but have good potentials during the cooler months in the Dystrandept site. For them to be viable, these crops, however, need higher inputs and more sophisticated management than those grown in the isothermic temperature regimes. Mulching which tends to lower the

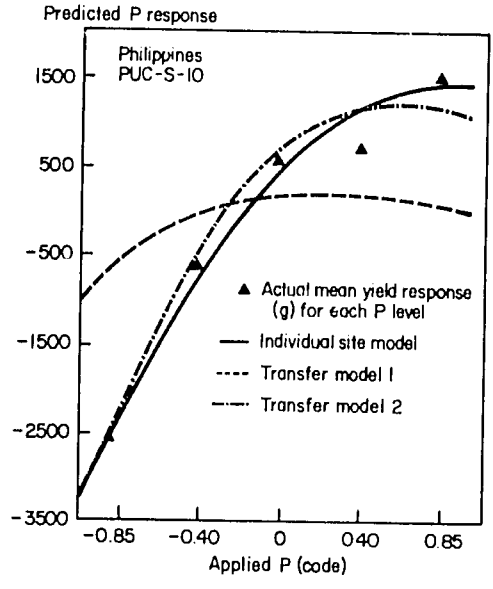

Fig. 3. Predicted yield response expressed as deviations from mean yield

temperatures of the soil at the rhizosphere of potatoes has contributed to better tuber formation. Genotypes suitable to warmer temperature can contribute to the production of these crops which normally are in demand.

On the other hand, mungbean which normally yielded 800-1200 kg/ha in the Ultisol sites yielded only about 400 kg/ha when grown during the wet months in the Dystrandept site. Bushbeans could have yielded better if not for the pest (bean fly) and disease (bacterial wilt) which consistently infested the crop, resulting in the inability to develop a uniform stand.

The yields of the long-term crops on the border of the plots varied according to the soils. Cassava planted at 3 m between rows and 50 cm apart within the row yielded about 14 t/ha (fresh) in the Tropudult and only about 6 t/ha in the Paleudult and the Dystrandept. The taro border crop, using the same spacing as that of cassava, produced 4, 6, and 9 t/ha in the Paleudult, Tropudult, and Dystrandept sites, respectively.

The limited time for testing the cropping systems coupled with the difficulty in the management of systems compared to that of simpler experiments were constraints in the comparison of relative production potentials of the different crops in the patterns in relation to the different soils. The results, however, indicate strongly that our ability to satisfy the needs of the ever increasing world population will greatly depend on the thorough understanding of the crop requirement and our capability to delineate the environment to which these requirements will fit. The appropriate technology and inputs have to be established for specific soil areas of well-defined categories in order to attain the most desirable levels of production.

Tree experiment. The tree experiment can be viewed in a number of aspects, namely: (a) as nitrogen-fixing trees to provide a natural source of nitrogen; (b) as direct or alternative energy source; (c) as an approach to facilitate the rehabilitation of denuded forest areas; (d) as support in the practice of soil conservation; or (e) as a combination of these aspects in support of an agro-forestry — based farming system.

The performance of the five experimental tree species are graphically illustrated in Figure 4. The data on the Tropudults were the only ones obtained from the Philippines. The others are from Indonesia (Paleudults) and Hawaii (Dystrandept and Eutrostox).

In terms of height, the *Leucaena diversifolia* and the *Leucaena leucocephala* are the fastest growers among the five replicated entries in all the sites, except in the Dystrandept, attaining the height of more than 4 m six months after transplanting in the Tropodult site (Davao). An exception is that the *L. leucocephala* grew slightly taller than *L. diversifolia*. The height relationships among the entries were maintained up to one year of age, and changes in these relationships may not be expected within three years, the scheduled harvest age of the trees. Very similar trends were observed in the Paleudults of Sumatra but of

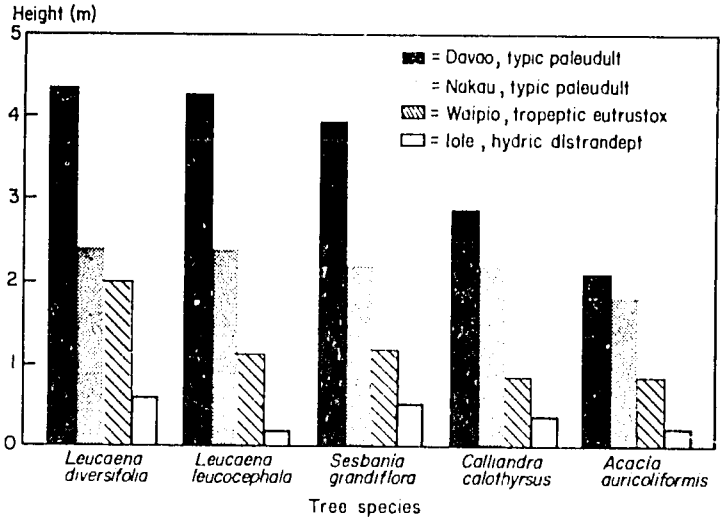

Fig. 4. Average height of replicated species, six months after planting

lesser absolute heights. In the Eutrustox, *L. diversifolia* and *Sesbania grandiflora* outgrew the other three entries at least in the first six months of growth.

The droughts that lasted for seven months in 1982 in Sumatra and for six months in Davao in 1983 accidentally became a test for drought tolerance among the entries. The relatively high drought tolerance of *L. diversifolia* exhibited in the Eutrustox of Hawaii was confirmed in the Udult sites. But highest tolerance was observed on *Acacia auriculiformis* which remained green; the leaves barely fell off. *Sesbania grandiflora* and *Calliandra calothyrsus* suffered die back of the branches and almost total loss of the leaves. Almost all the species planted, except for the *Acacia spp.*, reverted to the state of dormancy by shedding off their leaves during periods of prolonged water stress. They all recovered when the rains came later.

Intensification of similar studies on genotype x environment relationship is recommended. Such studies will be supportive in the exploration of ways to utilize areas which are marginal in terms of soil properties, slopes, and weather/climatic constraints.

Impact Assessment

Aside from the quantitative evidences in support of the transfer hypothesis based on taxonomic classification of soils and other technical information obtained, there are a number of indirect benefits that was evolved by the Project. Among these are the following:

1. A wealth of experience is gained in the management and coordination of controlled field experimentation conducted over an international network of soils which are spread over different locations involving a considerably wide range in variability of social, cultural, and

political conditions.

2. The presence of well-defined guidelines and procedures in conducting the field experiments, well coordinated planning, and intensive training of field personnel can reduce the variability of results to a desirable minimum.

3. There is an increase in the government's interest and support on the program of soil inventory and classification in the Philippines.

4. Interest and support on the research on trees in support of the rainfed upland and hilly land farming systems can be expected. These areas are the last frontiers in many developing countries from which the future generation is to depend for their livelihood.

5. The farmers' acreage planted to corn in the vicinities of the PUC and Sorsogon site has considerably increased after it was demonstrated that corn and some other crops can be profitably grown in the area, provided that the inherent deficiency problem was corrected.

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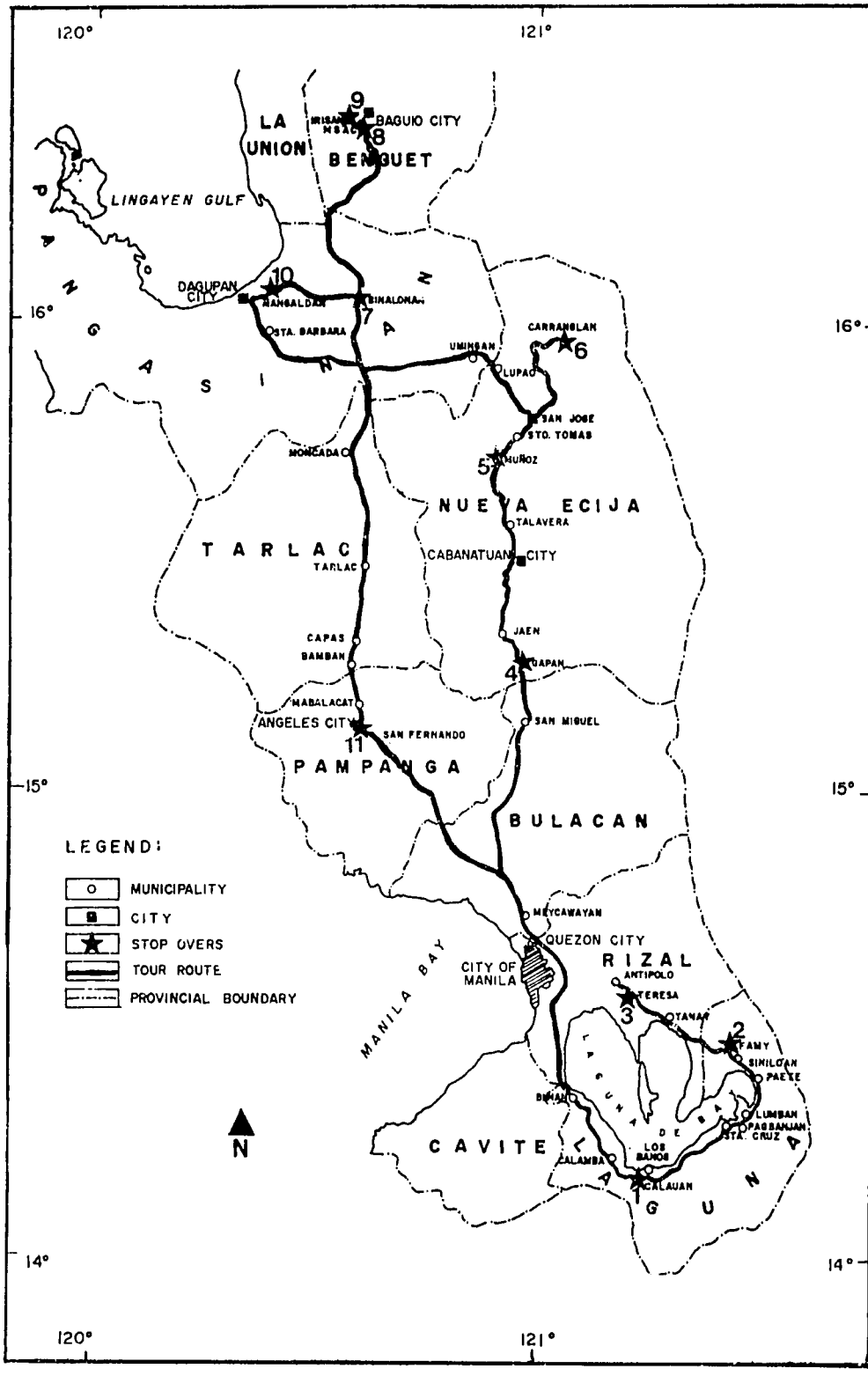
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Information on Tour Route and Stops

From Los Baños to Calauan, Laguna

The areas on both sides of the road immediately after leaving the UPLB campus were generally grown to sugarcane and coconut in the past. These are now rapidly developed into housing areas. From the northern side of IRRI eastward, the area is characterized by the dominance of rice farms on the alluvial plain with strips of coconut areas along the better drained river banks. This narrow strips of coconut areas down to the lake shore broadens up the slopes of the alluvial plain.

Stop No. 1. The Calauan site about 200 m north of the Bay — Calauan road occupies the crest of a narrow ridge (knoll) in the microlandscape. This position facilitates better drainage control. Zinc deficiency is normally observed in the area after the wet-season crop. Near neutral soil pH and prolonged submergence apparently induce zinc deficiency.

The cooperator claims that yields of 4.5-5 t/ha on his area is mainly due to sufficient fertilizer inputs. The neighboring farms produce only 3-3.5 t/ha.

The area is serviced by an adequate irrigation system throughout the year, since the 1930's.

From Calauan to Famy, Laguna

The tour proceeds eastward and then north along the foothills of Mt. Atimbiya in Calauan and then to the intermediate uplands. Coconut is the main cover. Pineapple and other fruit trees in open areas and under the coconuts is a common cropping system in the area.

A strip of sugarcane area which extend several kilometers eastward is traversed. Coconut, upland and wetland rice crop areas are interspersed along the way to Victoria.

The tour passes through the towns of Pila, Sta. Cruz, Pagsanjan, Lumban, Kalayaan, and Paete. Victoria and Pila have similar clayey alluvial soil. From Sta. Cruz to Lumban, on the other hand, the soil is loamy alluvium.

Wetland rice areas are naturally poorer in drainage areas than in coconut plantations. However, with irrigation and a shorter dry season some of the better drained areas are also utilized as rice lands. Once wetland rice is grown under the coconuts, the trees gradually suffer and ultimately die. Coconuts are tolerant to slow permeability but not to stagnant water.

From Lumban to Paete the tour goes north along the foot of the scarp which ends abruptly on the low-lying alluvial plains. The face of the scarp is generally rocky and planted to coconuts intercropped with lanzones. Wet and peaty soils are common along the immediate shore-

SERIES: Calumpang NSSL ID #: 84P0054
SOIL SURVEY # S83FN-725-005
LOCATION: Near Calauan, Laguna.
LATITUDE: 14°09'55"N LONGITUDE: 121°18'12"E
PHYSIOGRAPHY: Terrace; stream or lake in River valley
SLOPE CHARACTERISTICS: $<1\%$ ELEVATION: 30 m
PRECIPITATION: MAP: 1,962 mm; 4 dry, 8 wet months
WATER TABLE DEPTH (cm): Flooded
DRAINAGE: Very poorly drained PERMEABILITY: Slow
STONINESS: None
EROSION OR DEPOSITION: None
PARENT MATERIAL: Alluvium
CLASSIFICATION: fine-loamy, mixed, nonacid, isohyperthermic Aeric Tropaquept
DIAGNOSTIC HORIZONS: Ochric epipedon; cambic
DESCRIBED BY: A. Dayot; R. Haberman. SAMPLE DATE: 09/83

Farmed for several decades; flooded at least 200 days a year.

Apg — 0 to 8 cm; very dark gray (5Y 3/1), silty clay loam; gray (5Y 5/1) dry; massive; very hard, very firm, slightly sticky, plastic; common to many fine roots; neutral; gradual wavy boundary.
84P0237

ABg — 8 to 20 cm, very dark gray (5Y 3/1), silty clay loam; gray (5Y 5/1) dry; moderate medium subangular blocky with some moderate coarse subangular blocky structure; slightly sticky, plastic; few dark reddish brown (5YR 3/4) stains along root pores; common fine roots; few fine tubular pores; mildly alkaline; clear wavy boundary.
84P0238

Bwg — 20 to 40 cm; dark gray (5Y 4/1), loam; gray (5Y 5/1) dry; weak medium subangular blocky structure; non sticky, plastic; dark brown (10YR 3/3) coatings on ped faces; dark reddish brown (5YR 3/4) stains along root pores; few fine roots; few medium tubular and common fine tubular pores; mildly alkaline; gradual wavy boundary.
84P0239

Btg1 — 40 to 70 cm; dark gray (5Y 4/1), sandy clay loam; weak fine to medium subangular blocky with some weak coarse subangular blocky structure; non sticky, plastic; few thin clay films on ped faces; dark brown (10YR 3/3) coatings on ped faces; few medium tubular and common fine tubular pores; few shale fragments and few fine pebbles; mildly alkaline; gradual wavy boundary.
84P0240

Btg2 — 70 to 107 cm; olive (5Y 4/3), sandy loam; few to common fine distinct dark gray (5Y 4/1) mottles; weak coarse subangular blocky parting to weak fine subangular blocky structure; non sticky, non plastic; porous; few thin dark gray (5Y 4/1) clay films in pores; many fine tubular pores and on ped faces; few medium irregular coarse fragments; few pebbles; mildly alkaline; clear wavy boundary.
84P0241

Cg — 107 to 118 cm; 51 (2.5Y 5/1), sandy loam; common fine distinct dark brown (10YR 3/3) mottles; massive; few shale fragments; few fine pebbles; mildly alkaline.
84P0242

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lines of the area and on seepage spots close to the base of the scarp.

On the broader plain farther north to Famy and Mabitac, the soils are of reddish clay alluvial deposits, presumably from the red upland soils on the top and the backslopes of the scarp. The general area appears to have been a part of Laguna de Bay's east finger which formerly extended into the low northeastern plains of Laguna Province. Hills protruding over the plains are pyroclastics and conglomerate materials.

Stop No. 2. Prior to the modern non-seasonal rice varieties, the Famy site area, a reddish clayey alluvium was planted to only one late-

Calumpang
Classification: fine-loamy, mixed, nonacid isohyperthermic Aeric Tropaquept
S 83FN-725 -005 Date: 06/29/84
SMSS — Philippines
General Methods: 1B1A, 2A1, 2B

Sample No. 84P 237- 242
Pedon No. 84P 54
Project No. 84P 14

U.S. Department of Agriculture
Soil Conservation Service
National Soil Survey Laboratory
Lincoln, Nebraska 68508

Sample No.	Hzn No	Depth (CM)	Horizon	Total Clay Lt .002	Total Silt .002 -.05	Total Sand .05 -2	Clay Fine Lt .0002	Clay CO_3 Lt .002	Silt Fine .002 -.02	Silt Coarse .02 -.05	Sand VF .05 -.10	Sand F .10 -.25	Sand M .25 -.50	Sand C .5 -1	Sand VC 1 -2	Coarse Fractions (MM) Weight 2 -5	5 -20	20 -75	.1-75	(>2MM) Wt PCT of Whole Soil
				PCT of (<2MM) (3A1)												—PCT of <75MM (3B1)—				
84 237	1S	0- 8	APG	47.5	41.2	11.3	27.7		26.3	14.9	4.0	5.3	1.3	0.5	0.2	—	—	—		7	—
84 238	2S	8- 20	ABG	45.4	37.9	16.7	25.7		24.7	13.2	7.1	1.6	0.5	0.2	—	—	—		9	—	
84 239	3S	20- 40	BWG	24.6	42.2	33.2	9.0		26.8	15.4	12.8	15.4	3.6	0.9	0.5	—	—	—	20	—	
84 240	4S	40- 70	BTG1	2.02	42.3	37.5	7.1		26.5	15.8	15.7	15.6	4.1	1.5	0.6	TR	TR	—		22	TR
84 241	5S	70-107	BTG2	14.8	38.9	46.3			24.7	14.2	14.9	18.5	6.0	3.4	3.5	4	1	—		35	5
84 242	6S	107-118	CG	20.9	43.7	35.4			30.2	13.5	10.9	10.8	5.6	4.6	3.5	1	—	—		25	1

Sample No.	Hzn No.	Orgn C 6A1C	Total N 6B3A	Extr P	Total S 6R3A	Dith-Cit Extractable Fe 6C2B	Al 6G7A	Mn 6D2A	Ratio/Clay CEC 8D1	15 Bar 8D1	Atterberg Limits LL 4F1	PI 4F	Bulk Density Field Moist 4A3A	1/3 Bar 4A1D	Oven Dry 4A1H	COLE Whole Soil 4D1	Water Content Field Moist 4B4	15 Bar 4B2B	1/3 Bar 4B1C	15 Bar 4B2A	Wrd Whole Soil 4C1
		PCT of (<2MM)									PCT<0.4MM		G/CC			CM/CM	PCT of (<2MM)				CM/CM
84 237	1	4.32	0.358			0.9	0.1	TR	0.87	0.85	76	34						48.3		40.6	
84 238	2	2.07	0.184			1.6	0.1	0.1	0.90	0.82	73	34		1.01	1.46	0.131		42.9	52.2	37.2	0.15
84 239	3	0.38	0.049			2.4	0.2	0.2	1.42	1.06				0.95	1.11	0.053		40.6	51.3	26.0	0.24
84 240	4	0.37							1.68	1.24				0.89	1.04	0.053		40.2	53.2	25.0	0.25
84 241	5	0.23	0.030			2.3	0.2	0.1	2.18	1.61				0.89	1.04	0.052		31.7	51.1	23.8	0.24
84 242	6	0.21							1.65	1.23				0.95	1.08	0.043		36.6	51.5	25.8	0.24

Calumpang S 83 FN-725-005 Date: 06/29/84 Pedon No. 84P 54 National Soil Survey Laboratory

Sample No.	Hzn No.	Ca 5B5A 6N2E	Mg 5B5A 602D	Na 5B5A 6P2B	K 5B5A 6Q2B	Sum Bases	Acidity 6H5A	Sum Cats 5A3A	NH_4 OAc 5A8B	Exch Na 5D2	SAR 5E	Base Saturation Sum 5C3	Base Saturation NH_4OAc 5C1	Carbonate as $CaCO_3$ <2MM 6E1G	Carbonate as $CaCO_3$ <20MM 6E4	$CaSO_4$ as Gypsum <2MM 6F1A	$CaSO_4$ as Gypsum <20MM 6F4	pH Sat Paste 8C1B	pH $CaCl_2$ .01M 8C1F 1:2	pH H_2O 8C1F 1:1
		(NH_4OAc Extractable Bases)						(CEC)												
		MEQ / 100 G								PCT		PCT		PCT		PCT				
84 237	1	22.1	16.8	0.7	0.9	40.5	9.6	50.1	41.1	1	1	81	99					6.6	6.4	6.5
84 238	2	21.3	17.1	0.8	0.8	40.1	8.1	48.1	40.7	1	1	83	98						6.7	6.8
84 239	3	17.9	14.5	0.9	0.8	34.1	8.3	42.4	34.9			80	98	—					6.4	7.0
84 240	4	17.8	14.5	0.9	0.9	34.1	5.8	39.9	34.0			85	100	—					6.4	7.1
84 241	5	16.4	13.5	0.7	1.0	31.6	6.3	37.9	32.2			83	98	—					6.4	7.1
84 242	6	16.9	14.4	0.9	1.1	33.3	7.5	40.8	34.4			82	97						6.3	6.9

Sample No.	Hzn No.	Ca 6N1B	Mg 601B	Na 6P1B	K 6Q1B	CO_3 6I1B	HCO_3 6J1B	Cl 6K1C	SO_4 6L1C	NO_3 6M1C	H_2O 8A	Total Salts Est. 8D5	Elec. Cond. 8A3A MMHOS /CM	Clay X-ray <2u 7A2I	Clay X-ray <2u 7A2I	Clay X-ray <2u 7A2I	Clay X-ray <2u 7A2I	Clay DTA <2u 7A3	Clay DTA <2u 7A3	Total Res 7B1A	Dom Weath 7B1A
		(Water extracted from saturated paste)												(Mineralogy)							
		MEQ / Liter									PCT			Relative Amounts						PCT	
84 237	1	5.0	5.0	1.4	0.3	—	9.8	0.5	1.3	—	103.9	0.1	0.03	MT 4	KH 3	FD 1		KH27			
84 238	2										5		0.19	MT 4	KH 3	FD 1		KH22			
84 239	3												0.09	KH 3	MT 2	FD 1		KH21			
84 240	4												0.08	KH 3	MT 2	FD 1		KH24			
84 241	5												0.07	MT 1	KK 1			KK36			
84 242	6												0.07								

Family Control Section: Depth 25-100; PCT Clay 19; PCT 1.-75MM, 27
MMHOS/CM of 1:2 Water extract (8I) for layers 2, 3, 4, 5, 6,
Analyses: S = All on sieved <2MM basis
Mineralogy: Kinds of mineral — MT = Montmorill; KH = Halloysite; Fd = Feldspar; AR = Aggregates, KK = Kaolinite
Relative amount — 6 = indeterminate; 5 = dominant; 4 = abundant; 3 = moderate; 2 = small; 1 = trace

Supplemental Data Sheet — Chemical

National Soil Survey Laboratory

Sample No.	Hzn No.	P Retent *	Acid Oxalate Extractable Al *	Acid Oxalate Extractable Si *	Acid Oxalate Extractable Fe *	Na Pyro Extractable Fe 6C5A	Na Pyro Extractable Al 6G5A	pH NaF 8CID	pH KCl 8CIG 1:1	pH $CaCl_2$ Moist 8CIF 1:2	pH H_2O Moist 8CIF 1:1
		PCT of <2MM									
840237	1	41	0.2	0.1	0.3	0.16	0.05	8.6	5.4	6.1	6.8
840238	2	40	0.3	0.1	0.5	0.10	0.05	8.9	5.5	6.7	6.8
840239	3	48	0.4	0.2	0.9	0.05	0.05	9.1	5.4	6.4	7.4
840240	4	44	0.4	0.1	0.8	0.05	0.05	9.1	5.4	6.5	7.4
840241	5	43	0.3	0.1	0.5			9.1	5.3	6.4	7.4
840242	6	42	0.3	0.1	0.5			9.0	4.9	6.3	7.2

*New Zealand Procedure

CP84FNO22

Sample No.	Hzn No.	Mineralogy: Optical Sand/Silt FA 7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	X-RAY Clay 7A2I	7A2I	7A2I	7A2I	7A2I	DTA 7A3	7A3	(Tot Anal) K_2O 7A3	Fe 7A3
		PCT											Relative Amounts					PCT			
84P 237	1																				
84P 238	2	COSI	43	OT52	GA 4	GC 1						MT 4	MT 4	KH 3	FD 1			KH27		0.3	8.0
84P 239	3												KH 3	FD 1				KH22		0.3	8.4
84P 240	4	VFS	3	AR49	FP17	GA10	GS 6	PR 5	BT 4	CL 2	HN 1	FE 1	KH 3	MT 2	FD 1			KH21		0.2	7.9
84P 241	5												KH 3	MT 2	FD 1			KH24		0.2	8.1
84P 242	6												MT 1	KK 1				KK36	0.0	6.8	

Analyses: S = All on Sieved < 2MM Basis
Mineralogy: FA = Fraction Analyzed; RE = Resistant
Kind of Mineral: FD = Feldspar; MT = Montmorillonite; KH = Halloysite; PO = Plant Opal; GA = Glass Aggregates; OT = Other
GC = Glass Coated Grain; FE = Iron Oxides; AR = Weathered Aggregates; BT = Biotite; CL = Chlorite
FP = Plagioclase Feldspar; GS = Glass; HN = Hornblende; PR = Pyroxene; KK = Kaolinite
Relative Amount: 6 = Indeterminate; 5 = Dominant; 4 = Abundant; 3 = Moderate; 2 = Small; 1 = Trace
Mineralogy Based on Sand/Silt:
Mineralogy Based on Clay:
Family Placement:

SERIES: Maligaya NSSL ID #: 84P0058
SOIL SURVEY # S83FN-725-007
LOCATION: Near Famy, Laguna.
LATITUDE: 14°26'N LONGITUDE: 121°27'E
PHYSIOGRAPHY: Terrace; stream or lake in River valley
SLOPE CHARACTERISTICS: < 1% ELEVATION: 10 m
PRECIPITATION: MAP: 2,458 mm; 4 dry, 8 wet months
WATER TABLE DEPTH (cm): Flooded
DRAINAGE: Very poorly drained PERMEABILITY: Very slow
STONINESS: None
EROSION OR DEPOSITION: None
PARENT MATERIAL: Alluvium
CLASSIFICATION: fine, mixed, nonacid, isohyperthermic Vertic Tropaquept
DIAGNOSTIC HORIZONS: Ochric epipedon; cambic
DESCRIBED BY: A. Dayot; A. Marqueses; R. Haberman SAMPLE DATE: 09/83

Classification assumes cracks when dry. Clay increase too gradual and fine clay too uniform for argillic.

Ap1 — 0 to 15 cm; dark gray (5Y 4/1), silty clay; very thin brown (10YR 3/3) surface layer with common fine faint brown (10YR 4/3) and common fine faint brown (7.5YR 4/4) mottles; massive; very hard, very sticky, plastic; many fine and many very fine roots; slightly acid; gradual wavy boundary.
84P0259

Ap2 — 15 to 31 cm; dark gray (5Y 4/1), silty clay; massive; firm, very sticky, plastic; few fine roots; slightly acid; gradual wavy boundary.
84P0260

Bg1 — 31 to 45 cm; dark gray (5Y 4/1), silty clay; colors look gray at first then after exposure for a short period common fine prominent brown (7.5YR 4/4) mottles appear; moderate medium to coarse subangular blocky structure; firm, slightly sticky, plastic; very few very fine roots; few fine tubular pores; slightly acid; gradual wavy boundary.
84P0261

Bg2 — 45 to 64 cm; very dark gray (5Y 3/1) silty clay; colors look gray at first then after exposure for a short period common fine prominent brown and few fine prominent brown (7.5YR 4/4) mottles appear; moderate medium subangular blocky parting to moderate fine subangular blocky structure; firm, slightly sticky, plastic; few discontinuous thin dark gray (5Y 4/1) coatings on ped faces; very few very fine roots; few fine and a few medium tubular pores; slightly acid; gradual wavy boundary.
84P0262

Btg — 64 to 94 cm; dark grayish brown (2.5Y 4/2), silty clay; weak coarse subangular blocky structure; firm, slightly sticky, plastic; few fine and few medium tubular pores; common yellowish red (5YR 5/6) iron (?) stains in pores and on ped faces; few very dark gray (2.5Y 3/0) stains in root channels; few moderately thin gray (5Y 5/1) clay films in pores; coarse fragments, 02% greater than 2 mm from mixed lithology; mildly alkaline; gradual wavy boundary.
84P0263

Cg — 94 to 130 cm; dark grayish brown (2.5Y 4/2), clay; few fine prominent yellowish red (5YR 5/6) mottles; weak medium subangular blocky parting to moderate fine subangular blocky structure; firm, slightly sticky, plastic; few black (2.5Y 2/0) coatings on ped faces; common yellowish red (5YR 5/6) pipes about 1 and 1/2 cm in diameter and of varying lengths through which water is moving; few pipes have light gray (10YR 7/1) clay coatings around the hole in the center of the pipes; common fine tubular pores; coarse fragments, 02% greater than 2 mm from mixed lithology; mildly alkaline.
84P0264

Maligaya
Classification: fine, mixed, nonacid, isohyperthermic, Vertic Tropaquept
S 83PN-725-007 Date: 06/29/84
SMSS — Philippines
General Methods: 1B1A, 2A1, 2B

Sample No. 84P 259- 264
Pedon No. 84P 58
Project No. 84P 14

U.S. Department of Agriculture
Soil Conservation Service
National Soil Survey Laboratory
Lincoln, Nebraska 68508

Sample No.	Hzn No.	Depth (CM)	Horizon	Total Clay Lt .002	Total Silt .002 -.05	Total Sand .05 -2	Clay Fine Lt .0002	Clay CO_3 Lt .002	Silt Fine .002 -.02	Silt Coarse .02 -.05	Sand VF .05 -.10	Sand F .10 -.25	Sand M .25 -.50	Sand C .5 -1	Sand VC 1 -2	Coarse Fractions (MM) Weight 2 -5	5 -20	20 -75	.1- 75	(>2MM) Wt PCT of Whole Soil	
				PCT of < 2MM (3A1)												PCT of <75MM (3B1)					
84 259	1S	0- 15	AP1	49.3	47.1	3.6	26.5		36.0	11.1	1.9	0.7	0.4	0.2	—	—	—		2	—	
84 260	2S	15- 31	AP2	50.9	45.4	3.7	27.6		35.3	10.1	2.1	0.9	0.4	0.3	—	—	—	—		2	—
84 261	3S	31- 45	BG1	55.4	41.7	2.9	29.4		32.2	9.5	1.8	0.9	0.2	—	—	—	—	—		1	—
84 262	4S	45- 64	BG2	56.3	40.7	3.0			32.3	8.4	1.8	1.0	0.2	—	—	—	—	—		1	—
84 263	5S	64- 94	BTG	58.4	40.6	1.0	31.4		33.5	7.1	0.8	0.2	—	—	—	—	—	—		TR	—
84 264	6S	94-130	CG	56.4	40.9	2.7			32.6	8.3	1.3	0.7	0.4	0.3	—	TR	—	—		1	TR

Sample No.	Hzn No.	Orgn C 6A1C	Total N 6B3A	Extr P	Total S 6R3A	Dith-Cit Extractable Fe 6C2B	Al 6G7A	Mn 6D2A	Ratio/Clay CEC 8D1	15 Bar 8D1	Atterberg Limits LL 4F1	PI 4F	Bulk Density Field Moist 4A3A	1/3 Bar 4A1D	Oven Dry 4A1H	COLE Whole Soil 4D1	Water Content Field Moist 4B4	15 Bar 4B2B	1/3 Bar 4B1C	15 Bar 4B2A	Wrd Whole Soil 4C1
		PCT of < 2MM									PCT < 0.4MM		G/CC			CM/CM	PCT of < 2MM				CM/CM
84 259	1	2.27	0.189			4.4	0.2	0.1	0.56	0.61	64	22								30.0	
84 260	2	1.54	0.126			4.3	0.2	0.1	0.49	0.57	63	23								28.8	
84 261	3	0.44	0.057			6.0	0.3	0.2	0.39	0.57				1.10	1.41	0.086			48.7	31.3	0.19
84 262	4	0.38							0.39	0.55				1.08	1.39	0.088			44.7	30.9	0.15
84 263	5	0.37	0.053			5.2	0.4	0.2	0.38	0.54				1.10	1.43	0.091			41.5	31.3	0.11
84 264	6	0.35							0.40	0.57			1.03	1.37	0.100			52.2	32.2	0.21	

Maligaya S 83FN-725-007 Date: 06/29/84 Pedon No. 84P 58 National Soil Survey Laboratory

Sample No.	Hzn No.	NH4OAc Extractable Bases Ca 5B5A 6N2E	Mg 5B5A 602D	Na 5B5A 6P2B	K 5B5A 6Q2B	Sum Bases	Acidity 6H5A	Extr. Al 6G9A	CEC Sum Cats 5A3A	CEC NH4 OAc 5A8B	Bases + Al 5A3B	Al Sat 5G1	Base Sat. Sum 5C3	Base Sat. NH4 OAc 5C1	CO3 as CaCO3 < 2MM 6E1G	Res. Ohms /CM 8E1	Cond. MMHOS/CM 8I	pH NaF 8C1D	pH CaCl2 0.1M 8C1F 1:2	pH H2O 8C1F 1:1
		MEQ / 100 G										PCT								
84 259	1	11.3	5.9	0.4	0.5	18.1	17.9		36.0	27.7			50	65			0.11	8.6	4.7	5.3
84 260	2	10.3	5.8	0.4	0.1	16.6	15.0		31.6	25.0			53	66			0.08	8.8	4.8	5.3
84 261	3	9.7	4.6	0.6	0.1	15.0	15.1		30.1	21.5			50	70			0.04	8.9	4.7	5.4
84 262	4	10.9	5.0	0.6	0.1	16.6	13.6		30.2	21.9			55	76			0.04	8.9	4.8	5.3
84 263	5	12.2	5.4	0.4	0.2	18.2	12.5		30.7	22.2			59	82			0.05	9.0	5.3	5.7
84 264	6	11.7	5.4	0.6	0.1	17.8	11.5		29.3	22.3			61	80		0.07	9.2	5.5	6.0	

Sample No.	Hzn No.	Mineralogy: Clay X-Ray < 2u 7A2I	7A2I	7A2I	7A2I	DTA < 2u 7A3	7A3	Total Res 7B1A	Dom Weath 7B1A
		Relative amounts				PCT			
84 259	1	KK 4	MT 3			KK71			
84 260	2	KK 4	MT 2			KK70			
84 261	3	KK 4	MT 1			KK75			
84 262	4	KK 3	MT 1			KK80			
84 263	5	KK 4	MT 1			KK66			
84 264	6	KK 3	MT 1			KK66			

Family Control Section: Depth 25-100; PCT Clay 57; PCT. 1-75MM. 1.
MMHOS/CM of 1:2 Water extract (8I) for layers 1, 2, 3, 4, 5, 6.
Analyses: S = All on sieved < 2MM basis
Mineralogy: Kind of minerals — KK = Kaolinite; MT = Montmorill
Relative amount — 6 = indeterminate; 5 = dominant; 4 = abundant; 3 = moderate; 2 = small; 1 = trace

Supplemental Data Sheet — Chemical

National Soil Survey Laboratory

Sample No.	Hzn No.	P Retent *	Acid Oxalate Extractable Al *	Acid Oxalate Extractable Si *	Acid Oxalate Extractable Fe *	Na Pyro Extractable Fe 6C5A	Na Pyro Extractable Al 6G5A	pH NaF 8CID	pH KCl 8CIG 1:1	pH $CaCl_2$ Moist 8CIF 1:2	pH H_2O Moist 8CIF 1:1
		PCT of < 2MM									
840259	1	75	0.3	0.2	4.9	0.82	0.29		8.6	4.3	
840260	2	72	0.4	0.2	4.2	0.36	0.17		8.8	4.2	
840261	3	65	0.4	0.2	1.8	0.15	0.14		8.9	4.1	
840262	4	56	0.3	0.2	1.2	0.15	0.28		8.9	3.6	
840263	5	48	0.3	0.2	1.1				9.0	4.6	
840264	6	51	0.3	0.2	1.0				9.2	4.8	

*New Zealand Procedure

CP84FNO22

Sample No.	Hzn No.	Mineralogy: Optical Sand/Silt FA 7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	X-RAY Clay 7A2I	7A2I	7A2I	7A2I	7A2I	DTA 7A3	Tot Anal 7A3	K_2O 7A3	Fe 7A3
		PCT											Relative Amounts					PCT			
84P 259	1												KK 4	MT 3				KK71		0.0	6.3
84P 260	2	COSI	5	0T92	PO 5	GS 2	GA 1	GC 1					KK 4	MT 2				KK70		0.0	6.0
84P 261	3												KK 4	MT 1				KK75		0.0	8.0
84P 262	4	COSI	3	OT94	PO 3	GS 2	GA 2						KK 3	MT 1				KK80		0.0	8.0
84P 263	5												KK 4	MT 1				KK66		0.0	8.0
84P 264	6												KK 3	MT 1				KK66		0.0	7.1

Analyses: S = All on Sieved < 2MM Basis
Mineralogy: FA = Fraction Analyzed; RE = Resistant
Kind of Mineralogy: MT = Montmorillonite; KK = Kaolinite; PO = Plant Opal; GA = Glass Aggregates; GS = Glass; OT = Other
GC = Glass Coated Grain
Relative Amount: 6 = Indeterminate; 5 = Dominant; 4 = Abundant; 3 = Moderate; 2 = Small; 1 = Trace
Mineralogy Based on Sand/Silt:
Mineralogy Based on Clay:
Family Placement:

maturing seasonal rice crop a year because of inadequate water during the months of low rainfall. The present production practice require the addition of phosphorus. Nitrogen alone results in very poor yields. Low areas and the tract close to the lake were subject to deep floods during wet periods in the past. The diversion of the water for irrigation has reduced flooding; and so, the farmers are able to plant most of the areas even during the flood seasons.

From Famy, Laguna to Teresa, Rizal

The tour goes westward on elevated roads across the low-lying rice fields of Mabitac before the winding climb to the Jala-jala highlands which is about 340 m elevation at the highest point on the road.

The eastern slopes of this highland are relatively wetter (Type II climate, short dry season) and are generally covered by green vegetation, coconuts, and some orchards. The drier area (Type I, distinct wet and dry season) begins near the Laguna-Rizal boundary. The highlands are now generally eroded after the forest had been cut and shifting cultivation took place. The grasslands which are essentially *Imperata cylindrica* and *Saccharum spontaneum* are used generally as pastures with a very low carrying capacity. *Glericidia sepium* and *Leucaena spp.* planted in the area become almost dormant during the dry season because of a five-to-six month drought and a severely eroded soil. Tree crop systems increase downward into Pilillia area. The trees are harvested towards the end of the wet season. Attempts in the past to utilize the area for pineapple, coconut and various orchard trees have all failed.

Lithologically, the area is dominated by pyroclastics and basaltandisite flows that also occupy the lower hills in the Tanay and Morong areas. The lower hills are generally vegetated by bamboo, shrubs, and low-growing trees. Patches of mango and banana trees are on deeper soils on less eroded areas witn some colluvial deposits. The coastal lowlands which are almost totally under rice cultivation during the wet months and abruptly on the foot of the hills where pyroclastic materials are often quarried for building blocks (adobe).

The limestone ridges of the Binangonan formation are clearly visible southeast of Tanay. A slightly winding climb from Morong brings the tour to Teresa which is a short, narrow valley of calcareous clayey sediments, a mixture of materials from pyroclastic materials and limestone. The rice area is mainly on the level to very slightly undulating topography, although some terraced paddies are found on the more gentle slopes of the foothills.

Stop No. 3. The Teresa site is located on a knoll slightly higher than the surrounding rice fields. Irrigation is available by pumping water from nearby stream. Zinc deficiency results mainly when continuous rice cropping (submergence) is practiced; seldom when limited water is available for irrigation. The cooperator and the surrounding farmers claims yields on about 4-5 t/ha.

From Los Baños, Laguna to Gapan, Nueva Ecija

A portion of the circumferential alluvial areas underlain by diogenic volcanic tuff through Los Baños and Manila, traverses some important rice land. A great portion of the agricultural land near Manila has been rapidly converted into subdivisions owing to uncontrollable population growth and industrialization. This mixed land utilization extends to areas of Bulacan bordering Manila and the lowland rice areas of Bulacan.

Bulacan is predominantly ustic, but large wet-season flooded areas are being utilized for urban purposes. This is attributed to the very low

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SERIES: Binangonan NSSL ID #: 84P0059
SOIL SURVEY # S83FN-725-008
LOCATION: Near Teresa, Rizal.
LATITUDE: 14°33'14"N LONGITUDE: 121°12'30"E
PHYSIOGRAPHY: Terrace; stream or lake in River valley
SLOPE CHARACTERISTICS: < 1% ELEVATION: 55 m
PRECIPITATION: MAP: 2,804 mm; 4 dry, 8 wet months
WATER TABLE DEPTH (cm): Flooded
DRAINAGE: Very poorly drained PERMEABILITY: Very slow
STONINESS: None LAND USE: Irrigated
EROSION OR DEPOSITION: None
PARENT MATERIAL: Alluvium
CLASSIFICATION: fine, montmorillonitic, isohyperthermic Udorthentic Pellustert
DIAGNOSTIC HORIZONS:
DESCRIBED BY: A. Dayot; A. Marqueses; R. Haberman. SAMPLE DATE: 09/83

First 3 horizons one deposition, 4th horizon another; 5th horizon is a third; March 15, 1984 — 1 cm wide cracks to 50 cm in nearby dry plot. March 30, 1984 — the landowner and Bureau of Soils scientists stated that cracks in the dry soil are open less than 150 days in most years.

Ap1 — 0 to 10 cm; gray (5Y 5/1), silty clay; common fine prominent reddish brown (5YR 4/4) mottles; massive; very firm, very sticky, plastic; many very fine roots; moderately alkaline; gradual wavy boundary.
84P0265

Ap2 — 10 to 29 cm; gray (5Y 5/1), silty clay; common fine prominent reddish brown (5YR 4/4) mottles; moderate medium angular blocky structure; very firm, very sticky, plastic; many very fine roots; many fine tubular pores; moderately alkaline; gradual wavy boundary.
84P0266

ACg — 29 to 51 cm; olive gray (5Y 5/2), silty clay; few fine faint grayish brown (2.5Y 5/2) mottles; moderate coarse angular blocky structure; firm, very sticky, plastic; common prominent discontinuous intersecting slickensides that are 5 to 7.5 cm wide; few very fine roots; few fine tubular pores; moderately alkaline; gradual wavy boundary.
84P0267

Cgc — 51 to 82 cm; grayish brown (2.5Y 5/2), clay; weak medium and coarse subangular blocky structure; firm, very sticky, plastic; some stress oriented coats; few very fine roots; few fine tubular and few very fine tubular pores; iron-manganese concretions that make up about 12 percent of the upper horizon and about 20 percent of the lower part; stoneline with pebbles 1 to 2 cm in longest axis at the top of horizon; moderately alkaline; clear wavy boundary.
84P0268

ACgb — 82 to 122 cm; dark gray (5Y 4/1), silty clay; strong coarse angular blocky structure; firm, very sticky, plastic; common continuous intersecting slickensides; many medium calcareous concretions; moderately alkaline.
84P0269

Binangonan
Classification: fine, montmorillonitic, isohyperthermic Udorthentic Pellustert
S 83FN-725 -008 Date: 06/29/84
SMSS — Philippines
General Methods: 1B1A, 2A1, 2B

Sample No. 84P 265- 269
Pedon No. 84P 59
Project No. 84P 14

U.S. Department of Agriculture
Soil Conservation Service
National Soil Survey Laboratory
Lincoln, Nebraska 68508

Sample No.	Hzn No.	Depth (CM)	Horizon	Total Clay Lt .002	Total Silt .002 -.05	Total Sand .05 -2	Clay Fine Lt .0002	Clay CO_3 Lt .002	Silt Fine .002 -.02	Silt Coarse .02 -.05	Sand VF .05 -.10	Sand F .10 -.25	Sand M .25 -.50	Sand C .5 -1	Sand VC 1 -2	Coarse Fractions (MM) Weight 2 -5	5 -20	20 -75	.1- 75	(>2MM) Wt PCT of Whole Soil
				PCT of < 2MM (3A1)												PCT of<75MM (3B1)				
84 265	1S	0-10	AP1	56.0	37.8	6.2	36.5		25.6	9.3	2.6	1.9	0.8	0.6	0.3	—	—	—	4	—
84 266	2S	10- 29	AP2	60.1	33.8	6.1	37.6		26.1	7.7	2.2	1.6	0.7	0.7	0.9	—	—	—	4	—
84 267	3S	29- 51	ACG	48.4	30.6	21.0	22.2		23.4	7.2	3.2	3.6	3.3	4.3	6.6	2	—	—	19	2
84 268	4S	51- 82	CGC	41.3	36.5	22.2	7.7		28.6	7.9	3.5	3.0	2.5	3.5	9.7	2	—	—	20	2
84 269	5S	82-122	ACGB	65.6	25.9	8.5	19.7		21.1	4.8	1.5	1.5	1.2	1.8	2.5	3	3	—	13	6

Sample No.	Hzn No.	Orgn C 6A1C	Total N 6B3A	Extr P	Total S 6R3A	Dith-Cit Extractable Fe 6C2B	Al 6G7A	Mn 6D2A	Ratio/Clay CEC 8D1	15 Bar 8D1	Atterberg Limits LL 4F1	PI 4F	Bulk Density Field Moist 4A3A	1/3 Bar 4A1D	Oven Dry 4A1H	COLE Whole Soil 4D1	Water Content Field Moist 4B4	1/10 Bar 4B1C	1/3 Bar 4B1C	15 Bar 4B2A	Wrd Whole Soil 4C1
		PCT of < 2MM									PCT<0.4MM		G/CC			CM/CM	PCT of < 2MM				CM/CM
84 265	1	1.26	0.100			2.3	0.2	0.1	0.62	0.47	71	41		1.11	1.69	0.150			46.1	26.3	0.22
84 266	2	0.44	0.039			2.3	0.2	0.2	0.65	0.46	74	45		1.26	1.83	0.132			36.9	27.5	0.12
84 267	3	0.31	0.031			1.3	0.2	0.2	1.10	0.66				1.08	1.74	0.170			48.9	31.0	0.18
84 268	4	0.36							1.24	0.91				0.87	1.36	0.161		51.8	66.5	37.6	0.25
84 269	5	0.18	0.011			1.5	0.2	0.1	0.69	0.48				1.03	1.77	0.191			50.0	31.2	0.19

Binangonan S 83FN-725-008 Date: 06/29/84 Pedon No. 84P 59 National Soil Survey Laboratory

Sample No.	Hzn No.	(NH4OAc Extractable Bases) Ca 5B5A 6N2E	Mg 5B5A 602D	Na 5B5A 6P2B	K 5B5A 6Q2B	Sum Bases	Acidity 6H5A	(CEC) Sum Cats 5A3A	NH4 OAc 5A8B	Exch Na 5D2 PCT	SAR 5E	Base Saturation Sum 5C3	NH4OAc 5C1	CO3 as CaCO3 <2MM 6E1G PCT	Res. Ohms /CM <2MM 8E1	CaSO4 as Gypsum <20MM 6F1A	6F4	(pH) Sat Paste 8C1B	CaCl2 .01M 8C1F 1:2	H2O 8C1F 1:1
		MEQ / 100 G										PCT				PCT				
84 265	1	29.5	7.5	0.5	0.6	38.1	5.4	43.5	34.9	1	1	88	100	TR				6.6	6.9	7.2
84 266	2	28.6	10.1	0.8	0.3	39.8	7.0	46.8	38.9			85	100	TR					6.8	7.2
84 267	3	36.0	14.2	1.7	0.3	52.2	7.7	59.9	53.3			87	98						6.7	6.7
84 268	4	35.8	14.6	1.8	0.4	52.6	6.6	59.2	52.4			89	100	TR					6.7	7.1
84 269	5		15.1	1.0	0.5				45.5	2	1			6	1,100			7.4	7.7	7.8

Sample No.	Hzn No.	(Water extracted from saturated paste) Ca 6N1B	Mg 601B	Na 6P1B	K 6Q1B	CO_3 6I1B	HCO_3 6J1B	Cl 6K1C	SO_4 6L1C	NO_3 6M1C	H_2O 8A	Total Salts Est. 8D5	Elec. Cond. 8A3A	(Mineralogy) Clay X-ray <2u 7A2I	Clay DTA <2u 7A2I	Clay 7A2I	Clay 7A2I	(Total Res) 7A3	(Dom Weath) 7A3	(Total Res) 7B1A	(Dom Weath) 7B1A
		MEQ / Liter									PCT		MMHO /CM	Relative Amounts				PCT			
84 265	1	1.8	1.6	1.6	0.2	—	3.3	0.6	1.2	—	90.3	TR	0.54	MT 5	KK 4			KK33			
84 266	2												0.19	MT 4	KK 4			KK37			
84 267	3												0.24	MT 4	KK 4	FD 1		KK31			
84 268	4												0.17	MT 4	KK 3			KK26			
84 269	5	2.5	1.2	1.9	0.1	—	3.6	0.4	1.7	—	111.7	TR	0.56	MT 5	KK 4			KK35			

Family Control Section: Depth 25-100; PCT Clay 50; PCT 1.-75MM, 18
MMHOS/CM of 1:2 Water extract (8I) for layers 2, 3, 4
Analyses: S = All on sieved < 2MM basis
Mineralogy: Kinds of mineral — MT = Montmorill; KK = Kaolinite; FD = Feldspar
Relative amount — 6 = indeterminate; 5 = dominant; 4 = abundant; 3 = moderate; 2 = small; 1 = trace

Supplemental Data Sheet — Chemical **National Soil Survey Laboratory**

Sample No.	Hzn No.	P Retent *	Acid Oxalate Extractable Al *	Acid Oxalate Extractable Si *	Acid Oxalate Extractable Fe *	Na Pyro Extractable Fe 6C5A	Na Pyro Extractable Al 6G5A	pH NaF 8C1D	pH KCl 8C1G 1:1	pH $CaCl_2$ Moist 8C1F 1:2	pH H_2O Moist 8C1F 1:1
		PCT OF < 2MM									
84 265	1	46	0.2	0.1	0.7	0.36	0.27	9.0	6.0		
84 266	2	35	0.2	0.1	0.3	0.31	0.36	9.3	5.6		
84 267	3	33	0.3	0.1	0.1	0.31	0.46	9.3	4.9		
84 268	4	28	0.2	0.1	<0.1	0.05	0.10	9.4	5.3		
84 269	5	46	0.1	0.1	0.1			9.7	6.7		

*New Zealand Procedure

CP84FN022

Sample No.	Hzn No.	FA 7B1A	RE 7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7A2I	7A2I	7A2I	7A2I	7A2I	7A3	7A3	K_2O 6Q3A	Fe 6C7A
		Mineralogy																			
		Optical											X-RAY					DTA		Tot Anal	
		Sand/Silt											Clay								
		PCT											Relative Amounts					PCT			
84P 265	1												MT 5	KK 4				KK33		0.2	8.7
84P 266	2		COSI 23		OT71	PO23	GS 5	GA 1					MT 4	KK 4				KK37		0.1	8.4
84P 267	3												MT 4	KK 4	FD 1			KK31		0.1	7.6
84P 268	4												MT 4	KK 3				KK26		0.1	7.1
84P 269	5		COSI 8		OT90	PO 8	GS 2	GA 1					MT 5	KK 4				KK35		0.1	8.5

Analyses: S = All on Sieved < 2MM Basis

Mineralogy: FA = Fraction Analyzed RE = Resistant

Kind of Mineral: MT = Montmorillonite KK = Kaolinite PO = Plant Opal GA = Glass aggregates
GS = Glass OT = Other FD = Feldspar

Relative Amount: 6 = Indeterminate 5 = Dominant 4 = Abundant 3 = Moderate 2 = Small 1 = Trace

Mineralogy Based on Sand/Silt:

Mineralogy Based on Clay:

Family Placement:

topographic position of the province in general. The government is able to minimize flooding by constructing gigantic flood control measures and irrigation systems for lowland rice production. These areas extend and widen toward one of the rice granaries of the Philippines, Nueva Ecija, where Pantabangan Dam is supporting a two-rice cropping pattern per year.

Stop No. 4. The Gapan site is a broad clayey alluvial plain very close to the main irrigation canal. The cooperator claims yields of 5-6 t/ha in spite of the increase in the cost of fertilizers. To augment his in-

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SERIES: Tagulod NSSL ID #: 84P0060
SOIL SURVEY # S83FN-725-009
LOCATION: Near Gapan, Nueva Ecija.
LATITUDE: 15°17'55"N LONGITUDE: 120°55'58"E
PHYSIOGRAPHY: Terrace, stream or lake in River valley
SLOPE CHARACTERISTICS: $<1\%$ ELEVATION: 35 m
PRECIPITATION: MAP: 1,750 mm; 6 dry, 6 wet months
WATER TABLE DEPTH (cm): Flooded
DRAINAGE: Very poorly drained PERMEABILITY: Very slow
STONINESS: None
EROSION OR DEPOSITION: None
PARENT MATERIAL: Alluvium
CLASSIFICATION: fine, mixed, nonacid, isohyperthermic Aeric Tropaquept
DIAGNOSTIC HORIZONS: Ochric epipedon; cambic
DESCRIBED BY: A. Dayot; A. Marqueses; R. Haberman. SAMPLE DATE: 09/83

In rice at least 50 years; water rushing in at 100 cm. Reaction is thought to have been moderately alkaline for all horizon, however, notes were not kept.

Apg1 — 0 to 8 cm; dark grayish brown (10YR 4/2) and dark brown (7.5YR 4/2), silty clay; massive; slightly sticky, plastic; many very fine and few fine roots; clear wavy boundary.
84P0270

Apg2 — 8 to 19 cm; dark gray (10YR 4/1), silty clay; few fine distinct dark brown (7.5YR 4/4) mottles; weak medium subangular blocky parting to moderate fine subangular blocky structure; slightly sticky, plastic; few very fine roots; few fine tubular pores; gradual wavy boundary.
84P0271

BAg — 19 to 38 cm; dark gray (10YR 4/1), silty clay; few to common fine distinct dark brown (7.5YR 4/4) mottles; weak medium and coarse subangular blocky parting to moderate fine subangular blocky structure; slightly sticky, plastic; very few very fine roots; few fine tubular pores; gradual wavy boundary.
84P0272

Bw — 38 to 64 cm; dark grayish brown (10YR 4/2), silty clay; few fine distinct dark yellowish brown (10YR 4/4) and few fine faint dark gray (10YR 4/1) mottles; weak medium and coarse subangular blocky parting to moderate fine subangular blocky structure; slightly sticky, plastic; few gray (10YR 5/1) coatings in root channels and pores; few fine tubular pores; gradual smooth boundary.
84P0273

Bt1 — 64 to 86 cm; dark brown (10YR 4/3), silty clay; few fine distinct gray (2.5Y 5/1) and common fine faint brown (7.5YR 4/4) mottles; weak fine and medium subangular blocky structure; slightly sticky, plastic; few thin gray (10YR 5/1) clay films in pores; few gray (2.5Y 5/1) coatings in root channels; common prominent discontinuous slickensides about 7.5 cm in width; few fine and few very fine tubular pores; gradual wavy boundary.
84P0274

Bt2 — 86 to 150 cm; dark gray (10YR 4/1) and dark brown (7.5YR 4/4), clay loam; few fine gray (2.5Y 5/1) mottles; weak medium subangular blocky structure; slightly sticky, plastic; common dark gray (10YR 4/1) clay films on ped faces; common dark gray (10YR 4/1) clay films in pores; many fine tubular pores.
84P0275

Tagulod
Classification: fine, mixed, nonacid, isohyperthermic Aeric Tropaquept
S 83FN-725 -009 Date: 06/29/84
SMSS — Philippines
General Methods: 1B1A, 2A1, 2B

Sample No. 84P 270- 275
Pedon No. 84P 60
Project No. 84P 14

U.S. Department of Agriculture
Soil Conservation Service
National Soil Survey Laboratory
Lincoln, Nebraska 68508

Sample No.	Hzn No.	Depth (CM)	Horizon	Total Clay Lt .002	Total Silt .002 -.05	Total Sand .05 -2	Clay Fine Lt .0002	Clay CO_3 Lt .002	Silt Fine .002 -.02	Silt Coarse .02 -.05	Sand VF .05 -.10	Sand F .10 -.25	Sand M .25 -.50	Sand C .5 -1	Sand VC 1 -2	Coarse Fractions (MM) Weight 2 -5	5 -20	20 -75	.1- 75	(>2MM) Wt PCT of Whole Soil
				PCT of < 2MM (3A1)												PCT of<75MM (3B1)				
84 270	1S	0- 8	APG1	47.4	42.4	10.2	22.9		33.3	9.1	7.2	2.6	0.3	0.1	—	TR	—	—	3	—
84 271	2S	8- 19	APG2	39.3	47.4	13.3	14.5		35.4	12.0	7.9	4.3	0.8	0.3	—	—	—	—	5	—
84 272	3S	19- 38	BAG	46.7	38.9	14.4	13.8		29.1	9.8	9.1	4.6	0.4	0.3	—	—	—	—	5	—
84 273	4S	38- 64	BW	41.2	38.5	20.3			25.7	12.8	12.5	7.4	0.3	0.1	—	—	—	—	8	—
84 274	5S	64- 86	BT1	33.6	37.3	29.1	10.1		23.5	13.8	17.7	11.0	0.4	—	—	—	—	—	11	—
84 275	6S	86-132	BT2	30.8	36.2	33.0			22.3	13.9	18.4	14.2	0.4	—	—	—	—	—	15	—

Sample No.	Hzn No.	Orgn C 6A1C	Total N 6B3A	Extr P	Total S 6R3A	Dith Cit Extractable Fe 6C2B	Al 6G7A	Mn 6D2A	Ratio/Clay CEC 8D1	15 Bar 8D1	Atterberg Limits LL 4F1	PI 4F	Bulk Density Field Moist 4A3A	1/3 Bar 4A1D	Oven Dry 4A1H	COLE Whole Soil 4D1	Water Content Field Moist 4B4	1/10 Bar 4B1C	1/3 Bar 4B1C	15 Bar 4B2A	Wrd Whole Soil 4C1
		PCT of < 2MM									PCT<0.4MM		G/CC			CM/CM	PCT of < 2MM				CM/CM
84 270	1	1.81	0.143			1.8	0.2	0.1	0.83	0.65	63	31								30.7	
84 271	2	0.79	0.062			2.0	0.2	0.2	1.00	0.65	58	30		1.49	1.79	0.063			28.4	25.7	0.04
84 272	3	0.54	0.050			2.1	0.2	0.2	0.97	0.56										26.0	
84 273	4	0.32							1.08	0.61				1.34	1.74	0.091			31.1	25.0	0.08
84 274	5	0.24	0.025			2.3	0.2	0.1	1.29	0.69										23.2	
84 275	6	0.19							1.43	0.71				1.40	1.58	0.041			28.7	21.9	0.10

Tagulod S 83FN-725-009 Date: 06/29/84 Pedon No. 84P 60 National Soil Survey Laboratory

Sample No.	Hzn No.	NH4OAc Extractable Bases Ca 5B5A 6N2E	Mg 5B5A 6O2D	Na 5B5A 6P2B	K 5B5A 6Q2B	Sum Bases	Acidity 6H5A	Extr. Al 6G9A	CEC Sum Cats 5A3A	CEC NH4 OAc 5A8B	Bases + Al 5A3B	Al Sat 5G1	Base Sat. Sum 5C3	NH4 OAc 5C1	CO3 as CaCO3 <2MM 6E1G	Res. Ohms /CM 8E1	Cond. MMHOS /CM 8I	pH NaF 8C1D	pH CaCl2 0.1M 1:2 8C1F	pH H2O 1:1 8C1F
		MEQ / 100 G										PCT								
84 270	1	27.0	8.6	0.5	0.3	36.4	10.2		46.6	39.4			78	92	—		0.15	8.7	5.8	6.1
84 271	2	28.9	10.2	0.6	0.4	40.1	7.4		47.5	39.2			84	100	—		0.11	9.1	6.6	7.1
84 272	3	30.8	15.1	0.6	0.5	47.0	5.8		52.8	45.1			89	100	—		0.09	9.2	6.9	7.3
84 273	4	27.8	15.3	0.6	0.4	44.1	6.1		50.2	44.6			88	99	—		0.07	9.2	6.8	7.1
84 274	5	27.3	14.2	0.6	0.4	42.5	6.1		48.6	43.4			87	98	—		0.07	9.1	6.7	7.2
84 275	6	28.6	14.3	0.5	0.4	43.8	5.8		49.6	43.9			88	100	—		0.06	9.1	6.7	7.2

Sample No.	Hzn No.	Mineralogy Clay X-Ray <2u 7A2I	7A2I	7A2I	7A2I	DTA <2u 7A3	7A3	Total Res 7B1A	Dom Weath 7B1A
		Relative amounts				PCT			
84 270	1	MT 4	KK 3	VR 1	MI 1	KK31			
84 271	2	MT 3	KK 3	VR 2	MI 1	KK21			
84 272	3	MT 3	VR 3	KK 3	MI 1	KK19			
84 273	4								
84 274	5	MT 3	VR 3	KK 3	MI 1	KK23			
84 275	6								

Family control section: Depth 25-100; PCT Clay 38; PCT .1-75MM. 10.
MMHOS/CM of 1:2 Water extract (8I) for layers 1, 2, 3, 4, 5, 6.
Analyses: S = All on sieved<2MM basis
Mineralogy: Kind of minerals — MT = Montmorill; KK = Kaolinite; VR = Vermiculite; MI = Mica
Relative amount — 6 = indeterminate; 5 = dominant; 4 = abundant; 3 = moderate; 2 = small; 1 = trace

Supplemental Data Sheet — Chemical **National Soil Survey Laboratory**

Sample No.	Hzn No.	P Retent *	(— —Acid Oxalate— —) Extractable Al *	Si *	Fe *	(— —Na Pyro— —) Extractable Fe 6C5A	Al 6G5A	(— — — — — —pH— — — — — —) NaF 8C1D	KCl 8C1G 1:1	$CaCl_2$ Moist 8C1F 1:2	H_2O Moist 8C1F 1:1
		— — — — — — —PCT OF <2MM— — — — — —									
84 270	1	55	0.2	0.3	0.5	0.26	0.06	8.7	4.8		
84 271	2	35	0.4	0.3	0.5	0.10	0.06	9.1	5.4		
84 272	3	33	0.4	0.3	0.2	0.10	0.08	9.2	5.5		
84 273	4	33	0.3	0.2	0.1	0.00	0.03	9.2	5.2		
84 274	5	29	0.3	0.2	0.1			9.1	4.9		
84 275	6	31	0.3	0.2	0.1			9.1	4.9		

*New Zealand Procedure

CP84FN022

Sample No.	Hzn No.	FA 7B1A	RE 7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7A2I	7A2I	7A2I	7A2I	7A2I	7A3	7A3	K_2O 6Q3A	Fe 6C7A
		(Mineralogy)																			
		(Optical Sand/Silt)											(X-RAY Clay)					(DTA)		(Tot Anal)	
		PCT											Relative Amounts					PCT			
84P 270	1												MT 4	KK 3	VR 1	MI 1	FD 1	KK31		0.5	7.8
84P 271	2	COSI 21		OT79	PO21	GS 1							MT 3	KK 3	VR 2	MI 1	AM 1	KK21		0.5	7.8
84P 272	3												MT 3	VR 3	KK 3	MI 1		KK19		0.5	7.9
84P 273	4	COSI 23		OT76	PO23	GS 2															
84P 274	5												MT 3	VR 3	KK 3	MI 1		KK23		0.5	8.6
84P 275	6																				

Analyses: S = All on Sieved <2mm Basis

Mineralogy: FA = Fraction Analyzed RE = Resistant

Kind of Mineral: FD = Feldspar MI = Mica MT = Montmorillonite VR = Vermiculite KK = Kaolinite

PO = Plant Opal AM = Amphibole GS = Glass OT = Other

Relative Amount: 6 = Indeterminate 5 = Dominant 4 = Abundant 3 = Moderate 2 = Small 1 = Trace

Mineralogy Based on Sand/Silt:

Mineralogy Based on Clay:

Family Placement:

come, as well as provide his needs for some other crops, the farmer utilizes parts of his farm for onion, vegetable, and some other upland crops.

From Gapan to Maligaya to Carranglan, Nueva Ecija

From Gapan to Muñoz is a long stretch of alternate fallow and cropped wetland rice fields. The Peñaranda Irrigation System services the strip along the Pampanga River going north which covers the towns of Cabiao and San Isidro, Nueva Ecija. Around Talavera and Muñoz, onions and other vegetable crops are grown in place of rice, even if serviced by irrigation. This practice increases in acreage toward San Jose City in the north where the system replaces 50%-60% of the rice areas, especially on sandy soils during the dry season.

Going to Carranglan, the route traverses the area where the uplands of horizontal sediments and the rolling to hilly foothills are almost devoid of tree vegetation. The foothills are generally bare of any cultivated crops and are covered with dry grasses.

Stop No. 5. The Maligaya site is within the experimental farm of the Maligaya Rice Research and Training Center (MRRTC). It is one of the main rice research stations mandated to conduct improvement and testing of varieties and, subsequently, to produce foundation and certified seeds for dispersal to accredited seed producers and farmers, respectively. The activities of the center, however, is also hampered by the lack of irrigation water attributed to the 1983 drought that brought the water level at the Pantabangan Multipurpose Dam to a critically low level.

Stop No. 6. The Carranglan site lies on the slope of a foothill in the mountain range separating Nueva Ecija and the Cagayan Valley. The area is part of the CLSU's Carabao Research and Development Center. At present, the whole compound and surrounding areas are mostly covered by dry grass vegetation; and the livestock kept in the center are sustained only with hay mixed with feed concentrates. Adjacent lowlands to the south are supposed to be served by an irrigation system from the Pantabangan Dam, but probably because of water shortage or non-serviceability of the area, only very few patches are utilized for crop production.

From Carranglan to Binalonan, Pangasinan

West to the Pangasinan area is virtually undulating topography. Most agricultural areas are terraced for rainfed rice production. At this time of the year, however, most of the fields are fallowed. From Lupao, Nueva Ecija to Umingan, Pangasinan, mango, peanut, corn, and cassava are but few of the standing crops. Some isolated irrigated areas are planted to rice. Tobacco appears to be a promising cash crop in Pangasinan. It is grown in the northern portion of Umingan, and extensively in Manaoag, San Jacinto, and Urdaneta after the wet-season rice, particularly when irrigation water is scarce.

Stop No. 7. The Binalonan site is a broad plain similar to that of Urdaneta. The farm is owned and administered by Don Ramon Guico, Mayor of Binalonan, and who has received a good number of citations and awards, one of which is the Outstanding Farmer of the Year Award for consistent high yields obtained from his farm. His farm serves as demonstration farm for new varieties, modern farming practices, and innovative projects and experiments conducted on his own initiative or in cooperation with IRRI and other government research agencies.

From Binalonan to MSAC, La Trinidad, Benguet

From Binalonan, Pangasinan the tour follows an abrupt climb to Baguio City in the mountain province of Benguet where a sudden change in the agroclimatic condition will be observed. Baguio City, the

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SERIES: Maligaya NSSL ID #: 84P0061
SOIL SURVEY # S83FN-725-010
LOCATION: Near Maligaya, Nueva Ecija.
LATITUDE: 15°40'21"N LONGITUDE: 120°53'26"E
PHYSIOGRAPHY: Terrace; stream or lake in River valley
SLOPE CHARACTERISTICS: <1% ELEVATION: 35 m
PRECIPITATION: MAP: 2,022 mm; 6 dry, 6 wet months
WATER TABLE DEPTH (cm): Flooded
DRAINAGE: Very poorly drained PERMEABILITY: Very slow
STONINESS: None
EROSION OR DEPOSITION: None
PARENT MATERIAL: Alluvium
CLASSIFICATION: fine, montmorillonitic, isohyperthermic Entic Pellusvert
DIAGNOSTIC HORIZONS: Ochric epipedon; cambic
DESCRIBED BY: A. Dayot; A. Marqueses; R. Haberman. SAMPLE DATE: 09/83

No fertilizer used for at least the last 20 years; using Azolla; very fine sand on ped faces.

Apg1 — 0 to 8 cm; dark gray (5Y 4/1), silty clay; massive; slightly sticky, plastic; few medium and common very fine to fine roots; few fine tubular pores; moderately alkaline; clear wavy boundary.
84P0276

Apg2 — 8 to 27 cm; dark gray (5Y 4/1), silty clay; weak coarse angular blocky structure; slightly sticky, plastic; common to many dark reddish brown (5YR 3/4) coatings on ped faces and in pores and root channels; few oblong blocky soil fragments; few medium and common very fine to fine roots; few fine tubular pores; medium acid; clear wavy boundary.
84P0277

Bg — 27 to 53 cm; dark gray (5Y 4/1), silty clay; weak medium and coarse angular blocky structure; slightly sticky, plastic; few to common dark reddish brown (5YR 3/4) coatings in root channels; few fine and many very fine tubular pores; moderately alkaline; gradual wavy boundary.
84P0278

Btg — 53 to 101 cm; dark gray (5Y 4/1), silty clay; weak medium and coarse angular blocky structure; slightly sticky, plastic; few distinct slickensides; few thin dark gray (2.5Y 4/0) clay films on ped faces; very few dark reddish brown (5YR 3/4) coatings in root channels; few fine tubular and few to common very fine tubular pores; few fine manganese concretions; moderately alkaline; gradual wavy boundary.
84P0279

Bt — 101 to 140 cm; dark brown (10YR 3/3), silty clay, few fine distinct gray (10YR 5/1) mottles; weak medium and coarse subangular blocky structure; slightly sticky, plastic; many moderately thick dark gray (2.5Y 4/0) clay films in pores and filling root channels up to 7.5 mm in diameter; moderately alkaline.
84P0280

Maligaya
Classification: fine, montmorillonitic, isohyperthermic Entic Pellustert
S 83FN-725-010 Date: 06/29/84
SMSS — Philippines
General Methods: 1B1A, 2A1, 2B

Sample No. 84P 276-280
Pedon No. 84P 61
Project No. 84P 14

U.S. Department of Agriculture
Soil Conservation Service
National Soil Survey Laboratory
Lincoln, Nebraska 68508

Sample No.	Hzn No.	Depth (CM)	Horizon	Total Clay Lt .002	Total Silt .002 -.05	Total Sand .05 -2	Clay Fine Lt .0002	Clay CO_3 Lt .002	Silt Fine .002 -.02	Silt Coarse .02 -.05	Sand VF .05 -.10	Sand F .10 -.25	Sand M .25 -.50	Sand C .5 -1	Sand VC 1 -2	Coarse Fractions (MM) Weight 2 -5	5 -20	20 -75	.1-75	(>2MM) Wt PCT of Whole Soil
				PCT of<2MM (3A1)												PCT of<75MM (3B1)				
84 276	1S	0- 8	APG1	44.0	50.5	5.5	26.3		35.4	15.1	3.4	1.3	0.5	0.3	—	TR	—	—	2	TR
84 277	2S	8- 27	APG2	42.0	52.3	5.7	25.2		36.5	15.9	3.5	1.4	0.5	0.2	0.1	TR	TR	—	2	—
84 278	3S	27- 33	BG	46.5	48.8	4.7	26.9		35.0	13.8	2.7	1.2	0.6	0.2	—	—	—	—	2	—
84 279	4S	33-101	BTG	48.5	46.9	4.6			34.1	12.8	2.5	0.8	0.5	0.4	0.4	—	—	—	2	—
84 280	5S	10-140	BT	35.0	60.0	5.0	12.7		39.2	20.8		0.5	0.3	0.2	0.2	TR	—	—	1	TR

Sample No.	Hzn No.	Orgn C 6A1C	Total N 6B3A	Extr P	Total S 6R3A	Dith-Cit Extractable Fe 6C2B	Al 6G7A	Mn 6D2A	Ratio/Clay CEC 8D1	15 Bar 8D1	Atterberg Limits LL 4F1	PI 4F	Bulk Density Field Moist 4A3A	1/3 Bar 4A1D	Oven Dry 4A1H	COLE Whole Soil 4D1	Water Content Field Moist 4B4	1/10 Bar 4B1C	1/3 Bar 4B1C	15 Bar 4B2A	Wrd Whole Soil 4C1
		PCT of<2MM									PCT<0.4MM		G/CC			CM/CM	PCT of<2MM				CM/CM
84 276	1	2.56	0.187			1.2	0.2	0.1	0.73	0.65	60	37								28.5	
84 277	2	1.33	0.087			1.4	0.2	0.1	0.75	0.55	63	41		1.33	1.84	0.114			34.8	23.0	0.16
84 278	3	0.54	0.036			1.6	0.2	0.1	0.72	0.47										22.0	
84 279	4	0.41							0.92	0.49				1.34	1.94	0.131			33.4	23.7	0.13
84 280	5	0.23	0.016			1.9	0.2	0.1	1.22	0.72				1.41	1.71	0.066			29.3	25.1	0.06

Maligaya S 83FN-725-010 Date: 06/29/84 Pedon No. 84P 61 National Soil Survey Laboratory

Sample No.	Hzn No.	NH4OAc Extractable Bases Ca 5B5A 6N2E	Mg 5B5A 602D	Na 5B5A 6P2B	K 5B5A 6Q2B	Sum Bases	Acidity 6H5A	CEC Sum Cats 5A3A	CEC NH4OAc 5A8B	Exch Na 5D2	SAR 5E	Base Saturation Sum 5C3	NH4OAc 5C1	Carbonate as CaCO3 <2MM 6E1G	<20MM 6E4	CaSO4 as Gypsum <2MM 6F1A	<20MM 6F4	pH Sat Paste 8C1B	CaCl2 .01M 8C1F	H2O 8C1F
		MEO / 100 G								PCT		PCT		PCT		PCT			1:2	1:1
84 276	1	17.4	8.4	0.5	0.1	26.4	11.9	38.3	32.3			69	82						5.2	5.5
84 277	2	21.1	11.0	0.5	0.3	32.9	7.5	40.4	31.3	1	1	81	100					6.8	6.5	6.6
84 278	3	19.8	14.2	0.7	0.4	35.1	4.6	39.7	33.4			88	100	TR					7.0	7.2
84 279	4	24.8	19.8	1.1	0.5	46.2	4.3	50.5	44.5			91	100	—					7.2	7.4
84 280	5	24.3	17.7	0.9	0.3	43.2	4.7	47.9	42.8			90	100	—					6.9	7.4

Sample No.	Hzn No.	Water extracted from saturated paste Ca 6N1B	Mg 601B	Na 6P1B	K 6Q1B	CO_3 6I1B	HCO_3 6J1B	Cl 6K1C	SO_4 6L1C	NO_3 6M1C	H_2O 8A	Total Salts Est. 8D5	Elec. Cond. 8A3A	Mineralogy Clay X-ray <2u 7A2I	7A2I	7A2I	7A2I	DTA <2u 7A3	7A3	Total Res 7B1A	Dom Weath 7B1A
		MEO / Liter									PCT		MMHOS /CM	Relative Amounts						PCT	
84 276	1												0.19	MT 4	KK 3	VR 1	MI 1	KK30			
84 277	2	3.8	2.7	1.6	0.1	—	3.3	0.3	4.7	—	75.8	TR	0.80	MT 3	KK 3	VR 2	MI 1	KK19			
84 278	3												0.20	MT 4	KK 3	MI 1		KK19			
84 279	4												0.14								
84 280	5												0.10	MT 4	VR 3	KK 2	MI 1	KK13			

Family Control Section: Depth 25-100; PCT Clay 48; PCT .1-75MM. 2
MMHOS/CM of 1:2 Water extract (8I) for layers 1, 3, 4, 5
Analyses: S = All on sieved < 2MM basis
Mineralogy: Kinds of mineral — MT = Montmorill; KK = Kaolinite; VR = Vermiculite; MI = Mica
Relative amount — 6 = indeterminate; 5 = dominant; 4 = abundant; 3 = moderate; 2 = small; 1 = trace

Supplemental Data Sheet — Chemical **National Soil Survey Laboratory**

Sample No.	Hzn No.	P Retent *	(— —Acid Oxalate— —) Extractable Al *	Si *	Fe *	(— —Na Pyro— —) Extractable Fe 6C5A	Al 6G5A	(— — — — — —pH— — — — — —) NaF 8C1D	KCl 8C1G 1:1	$CaCl_2$ Moist 8C1F 1:2	H_2O Moist 8C1F 1:1
		— — — — — — —PCT OF <2MM— — — — — — —									
84 276	1	48	0.2	0.1	0.3	0.31	0.05	8.4	4.4		
84 277	2	28	0.2	0.1	0.3	0.10	0.10	9.0	5.5		
84 278	3	35	0.2	0.1	0.1	0.05	0.10	9.2	5.7		
84 279	4	28	0.2	0.1	<0.1	0.00	0.03	9.3	5.6		
84 280	5	28	0.3	0.2	0.1			9.2	5.2		

*New Zealand Procedure

CP84FN022

Sample No.	Han No.	FA 7B1A	RE 7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7A2I	7A2I	7A2I	7A2I	7A2I	7A3	7A3	K_2O 6Q3A	Fe 6C7A
		(Mineralogy)																			
		(Optical)																			
		(Sand/Silt)											(X-RAY)					(DTA)		(Tot Anal)	
		(Clay)																			
		PCT											Relative Amounts							PCT	
84P 276	1	COSI	6	OT93	PO	6	GS	1					MT	4	KK	3	VR	1	FD	1	KK30	0.4	8.8
84P 277	2												MT	3	KK	3	VR	2	MI	1	KK19	0.4	8.7
84P 278	3	COSI	2	OT98	PO	2	GS	1					MT	4	KK	3	MI	1			KK19	0.4	8.3
84P 279	4																						
84P 280	5												MT	4	VR	3	KK	2	MI	1	KK13	0.5	8.0

Analyses: S = All on Sieved <2MM Basis

Mineralogy: FA = Fraction Analyzed RE = Resistant

Kind of Mineral: PO = Plant Opal FD = Feldspar GS = Glass MI = Mica MT = Montmorillonite
VR = Vermiculite OT = Other KK = Kaolinite

Relative Amount: 6 = Indeterminate 5 = Dominant 4 = Abundant 3 = Moderate 2 = Small 1 = Trace

Mineralogy Based on Sand/Silt:

Mineralogy Based on Clay:

Family Placement:

summer capital of the Philippines, is well known as the cleanest city in the country and is commonly visited by tourists, as well as Filipinos, from various parts of the country especially during the summer months. A few kilometers down to La Trinidad Valley is the Mountain State Agricultural College.

Stop No. 8. The MSAC site is an experimental area of the college where researches on strawberry and a variety of vegetables and or-

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SERIES:
SOIL SURVEY:
LOCATION: CLSU Ranch (Carabeef Research and Development Center), Carranglan, Nueva Ecija
LATITUDE: 15°45'N LONGITUDE: 120°55'E
PHYSIOGRAPHY:
SLOPE CHARACTERISTICS: 5-8% convex, short slope ELEVATION: 300 m
PRECIPITATION: MAP: 1,842 mm; 6 dry, 6 wet months
WATER TABLE DEPTH (cm): Not detected
DRAINAGE: Well drained PERMEABILITY: Moderate
STONINESS: Few
EROSION OR DEPOSITION: Slightly eroded
PARENT MATERIAL: Volcanic rock, shales, andesitic rock
CLASSIFICATION: fine, mixed, isohyperthermic Plinthudic Paleustalf
DIAGNOSTIC HORIZONS: Ochric epipedon; argillic subsurface horizon
DESCRIBED BY: M. Recel, N. Marasigan, T. Reyes, C. Incillo and G. Huelgas
DATE OF EXAMINATION: March 17, 1984

Pasture area of Carabeef Research and Development Center. Vegetation and land use are cogon grass, pasture grasses and ipil-ipil.

A11 — 0 to 5 cm; very dark grayish brown (10YR 3/2) moist, brown to dark brown (10YR 4/3) dry, silty clay loam; moderate subangular blocky, breaking to fine granular structure; common fine and very fine roots; few fine biopores; distinct wavy boundary.

A12 — 5 to 19 cm; yellowish brown (10YR 5/4) moist; light yellowish brown (10YR 6/4) dry; silty clay loam; weak medium to fine subangular blocky, breaking to fine granular structure; common medium roots; common biopores; few large ants' nests; distinct irregular boundary.

B11cn — 19 to 36/40 cm; yellowish brown (10YR 5/4) moist; fine gravelly clay loam; with a few large stone in the upper part of the horizon; gravel composed of petroplinthite; large stone composed of partially weathered andesitic rock fragments; few fine roots, common biopores, no clay skins; gradual wavy boundary.

B12cn — 36/40 to 60 cm; brown (10YR 5/3) moist, gravelly silty clay; fine subangular blocky; very few fine roots, common biopores; gravel composed essentially of petroplinthite; practically no andesitic stones; no clay skins; diffuse wavy boundary.

B13cn — 60 to 70 cm; light yellowish brown (10YR 6/4) moist, fine gravelly silty clay; gravel composed of moderately soft petroplinthite; very few fine roots; common biopores; structure between gravel is very fine, subangular blocky structure; clay skins difficult to determine; distinct wavy boundary.

B21t — 70 to 96 cm; light yellowish brown (10YR 6/4) moist; fine gravelly silty clay, strong coarse subangular blocky, continuous moderate clay skin in pores and patchy thin clay skin on ped faces; yellowish red (5YR 4/6) very fine petroplinthite gravel; plinthite slightly hardened but easily scratched with knife; very few very fine roots; common biopores; relatively distinct wavy boundary.

B22t — 96 to 132 cm; light yellowish brown (10YR 6/4) moist; clay, strong very coarse angular blocky breaking to strong coarse subangular blocky structure with continuous plinthite 25%; very fine roots, common coarse biopores, thick clay skins in pores, continuous clay skin on ped faces; diffuse wavy boundary.

B23t — 132 to 150 cm; light yellowish brown (10YR 6/4) moist; clay; strong coarse angular blocky structure; very few very fine roots; thick clay skin on ped faces; plinthite reddish yellow (7.5YR 6/8) 25%.

SND
Classification: fine, mixed, isonyperthermic Plinthudic Paleustalf

Sample No.	Hzn No.	Depth (CM)	Horizon	Total Clay Lt .002	Total Silt .05 -.05	Total Sand .05 -2	Clay Fine .0002	Clay CO_3 Lt .002	Silt Fine .002 -.02	Silt Coarse .02 -.05	Sand VF .05 -.10	Sand F .10 -.25	Sand M .25 -.50	Sand C .5 -1	Sand VC 1 -2	Coarse Fractions (MM) Weight 2 -5	5 -20	20 -75	.1- 75	(>2MM) Wt Pct of Whole Soil
				PCT of < 2MM (3A1)												PCT of < 75MM (3B1)				
D3.1-A	1	0-5	A11	16.19	16.0	67.8					24.80	6.80	9.00	17.20	10.00	5.80	0	94.20		
D3.2-A	2	5-19	A12	16.19	20.0	63.88					28.70	4.50	6.60	12.80	11.20	9.63	0	90.37		
D3.3-A	3	19-36/40	B11 cn	30.19	10.0	59.80					18.00	2.40	2.20	10.20	27.00	49.16	17.53	33.31		
D3.4-A	4	36/40-60	B12 cn	38.19	8.72	53.08					6.00	0.08	2.20	12.80	32.00	53.57	0	46.43		
D3.5-A	5	60-70	B13 cn	42.19	12.72	45.08				16.06	1.60	5.00	6.60	15.80	15.80	21.35	0	78.65		
D3.6-A	6	70-96	B12T	56.19	8.53	35.27					11.47	1.40	2.00	4.60	15.80	13.46	0	86.54		

Sample No.	Hzn No.	Orgn C 6A1C	Total N 6B3A	Extr P	Total S 6R3A	Dith-Cit Extractable Fe 6C2B	Dith-Cit Extractable Al 6G7A	Dith-Cit Extractable Mn 6D2A	CEC 8D1	Ratio/Clay 15 Bar 8D1	Atterberg Limits LL 4F1	Atterberg Limits PI 4F	Bulk Density Field Moist 4A3A	Bulk Density 1/3 Bar 4A1D	Bulk Density Oven Dry 4A1H	COLE Whole Soil 4D1	Water Content Field Moist 4B4	Water Content 1/10 Bar 4B1C	Water Content 1/3 Bar 4B1C	Water Content 15 Bar 4B2A	Wrd Whole Soil 4C1
		PCT of <2MM									PCT<0.4MM		G/CC			CM/CM	PCT of < 2MM				CM/CM
D3.1-A	1	3.53	0.304																		
D3.2-A	2	2.49	0.215																		
D3.3-A	3	1.46	0.215																		
D3.4-A	4	0.82	0.075																		
D3.5-A	5	0.44	0.038																		
D3.6-A	6	0.35	0.030																		

SND

Sample No.	Hzn No.	(NH4OAc Extractable Bases) Ca 5B5A 6N2E	Mg 5B5A 6O2D	Na 5B5A 6P2B	K 5B5A 6Q2B	Sum Bases	Acidity 6H5A	(CEC) Sum Cats 5A3A	NH4-OAc 5A8B	Exch Na 5D2	SAR 5E	Base Saturation Sum 5C3	NH4OAc 5C1	Carbonate as CaCO3 <2MM 6E1G	<20MM 6E4	CaSO4 as Gypsum <2MM 6F1A	<20MM 6F4	(pH) Sat Paste 8C1B	CaCl2 .01M 8C1F 1:2	H2O 8C1F 1:1
		MEQ / 100 G								PCT		PCT		PCT		PCT				
D3.1-A	1			0.136	2.40				20.30											
D3.2-A	2			0.273	0.80				16.10											
D3.3-A	3			0.327	0.40				37.10											
D3.4-A	4			0.327	0.40				25.40											
D3.5-A	5			0.327	0.40				16.40											
D3.6-A	6			0.818					16.50											

Sample No.	Hzn No.	(Water extracted from saturated paste) Ca 6N1B	Mg 6O1B	Na 6P1B	K 6Q1B	CO3 6I1B	HCO3 6J1B	Cl 6K1C	SO4 6L1C	NO3 6M1C	H2O 8A	Total Salts Est. 8D5	Elec. Cond. 8A3A	(Mineralogy) Clay X-ray <2u 7A2I	Clay X-ray <2u 7A2I	Clay X-ray <2u 7A2I	Clay X-ray <2u 7A2I	Clay Dta <2u 7A3	Clay Dta <2u 7A3	(—) Total Res 7B1A	(-) Dom Weath 7B1A
		MEQ / Liter									PCT		MMHOS /CM	Relative Amounts						PCT	
D3.1-A	1																				
D3.2-A	2																				
D3.3-A	3																				
D3.4-A	4																				
D3.5-A	5																				
D3.6-A	6																				

namental plants are being undertaken. The pedon site is a colluvial flat, the soil material of which comes from the adjacent outlying foothills and mountains.

From MSAC to Irisan, Benguet

A few kilometers away, along the Naguillan Road is the Irisan site which represents the mountain landscape of the Benguet Province. The general topography, including slopes, is the primary limitation to agricultural use.

Stop No. 9. The profile described in Irisan, Baguio City (about 1,450 m asl) is a road cut parallel to a ridge formed by erosion. The specific site is being developed for house or building construction. Not much

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SERIES: San Manuel NSSL ID #: 84P0063
SOIL SURVEY # S83FN-725-012
LOCATION: Near Binalonan, Pangasinan.
LATITUDE: 16°02'59"N LONGITUDE: 120°34'55"E
PHYSIOGRAPHY: Terrace; stream or lake in River valley
SLOPE CHARACTERISTICS: < 1% ELEVATION: 3 m
PRECIPITATION: MAP: 1,816 mm; 4-6 dry, 3-4 wet months
WATER TABLE DEPTH (cm): Flooded-water rushing in at 90 cm
DRAINAGE: Very poorly drained PERMEABILITY: Slow
STONINESS: None
EROSION OR DEPOSITION: None
PARENT MATERIAL: Alluvium
CLASSIFICATION: coarse-loamy, mixed, isohyperthermic Fluvaquentic Haplustoll
DIAGNOSTIC HORIZONS: Mollic epipedon; cambic
DESCRIBED BY: A. Dayot; A. Marqueses; R. Haberman. SAMPLE DATE: 09/83

Vegetation-Jute; Kangkong; dactylon; common fine and very fine sand throughout profile. Reaction is thought to have been moderately alkaline on all horizons. On March 17, 1984, thickness of Ap1 and Ap2 (combined) was found to range from about 20 to more than 40 cm with the average about 30 cm.

Ap1 — 0 to 10 cm; very dark gray (10YR 3/1), silty clay loam; dark gray (10YR 4/1) dry; massive; hard, firm, slightly sticky, plastic; many fine and many very fine roots; clear smooth boundary.
84P0287

Ap2 — 10 to 23 cm; very dark gray (10YR 3/1), silty clay loam; dark gray (10YR 4/1) dry; strong coarse subangular blocky structure; dense; slightly sticky, plastic; common fine and common very fine roots; clear smooth boundary.
84P0288

Bw — 23 to 38 cm; dark gray (10YR 4/1) and brown (10YR 5/3), silty clay loam; grayish brown (2.5Y 5/2) dry; very few fine faint dark yellowish brown (10YR 4/4) mottles; moderate fine subangular blocky structure; slightly sticky, plastic; common fine roots; clear smooth boundary.
84P0289

BC — 38 to 78 cm; light olive brown (2.5Y 5/4), very fine sandy loam; few to common fine prominent strong brown (7.5YR 5/6) mottles; weak medium subangular blocky structure; non sticky, non plastic; few grayish brown (10YR 5/2) coatings on ped faces; few grayish brown (10YR 5/2) coatings in root channels, and in krotovinas; common fine roots; common fine and very fine tubular pores; clear wavy boundary.
84P0290

C — 78 to 132 cm; yellowish brown (10YR 5/4), silt loam; few to common fine distinct strong brown (7.5YR 5/6) mottles; weak medium subangular blocky structure; non sticky, non plastic; few fine roots; few to common medium pores (pipes) 5 to 10 mm in diameter.
84P0291

San Manuel
Classification: coarse-loamy, mixed, isohyperthermic Fluvaquentic Haplustoll
S 83FN-725-012 Date: 06/29/84
SMSS — Philippines
General Methods: 1B1A, 3A1, 2B

Sample No. 84P 287-291
Pedon No. 84P 63
Project No 84P 14

U.S. Department of Agriculture
Soil Conservation Service
National Soil Survey Laboratory
Lincoln, Nebraska 68508

Sample No.	Hzn No.	Depth (CM)	Horizon	Total Clay Lt .002	Total Silt .002-.05	Total Sand .05-2	Clay Fine Lt .0002	Clay CO_3 Lt .002	Silt Fine .002-.02	Silt Coarse .02-.05	Sand VF .05-.10	Sand F .10-.25	Sand M .25-.50	Sand C .5-1	Sand VC 1-2	Coarse Fractions (MM) Weight 2-5	5-20	20-75	.1-75	(>2MM) Wt PCT of Whole Soil
				PCT of < 2MM (3A1)												PCT of<75MM (3B1)				
84 287	1S	0- 10	AP1	38.3	47.0	14.7	10.6		31.4	15.6	6.2	5.7	2.2	0.5	0.1	—	—	—		8	—
84 288	2S	10- 23	AP2	33.7	52.4	13.9	5.9	TR	32.7	19.7	7.3	4.6	1.6	0.4	—	—	—	—		8	—
84 289	3S	23- 38	BW	22.0	61.0	17.0	3.6		34.7	26.3	12.4	0.8	0.2	—	—	—	—		5	—	
84 290	4S	38- 78	BC	8.0	78.3	13.7	1.2		31.7	46.6	11.6	1.1	0.3	0.2	0.5	TR	—	—		2	—
84 291	5S	78-132	C	13.6	81.6	4.8	1.2	1	52.6	29.0	3.2	1.3	0.3	—	—	—	—	—		2	—

Sample No.	Hzn No.	Orgn C 6A1C	Total N 6B3A	Extr P	Total S 6R3A	Dith-Cit Extractable Fe 6C2B	Dith-Cit Extractable Al 6G7A	Dith-Cit Extractable Mn 6D2A	Ratio/Clay CEC 8D1	Ratio/Clay 15 Bar 8D1	Atterberg Limits LL 4F1	Atterberg Limits PI 4F	Bulk Density Field Moist 4A3A	Bulk Density 1/3 Bar 4A1D	Bulk Density Oven Dry 4A1H	COLE Whole Soil 4D1	Water Content Field Moist 4B4	Water Content 15-Bar 4B2B	Water Content 1/3 Bar 4B1C	Water Content 15 Bar 4B2A	Wrd Whole Soil 4C1
		PCT of < 2MM									PCT < 0.4MM		G/CC			CM/CM	PCT of < 2MM				CM/CM
84 287	1	2.09	0.188			0.8	0.2	0.1	1.55	0.78	65	35								30.0	
84 288	2	1.59	0.143			0.8	0.1	0.1	1.70	0.90	67	37		1.33	1.87	0.120			35.7	30.2	0.07
84 289	3	1.18	0.093			1.0	0.1	0.1	2.15	1.04										22.9	
84 290	4	0.25						3.91	1.65				1.26	1.31	0.013			30.8	13.2	0.22	
84 291	5	0.26	0.022			1.1	0.1	0.2	3.78	1.60										21.7	

San Manuel S 83FN-725-012 Date: 06/29/84 Pedon No. 84P 63 National Soil Survey Laboratory

Sample No.	Hzn No.	NH_4OAc Extractable Bases Ca 5B5A 6N2E	Mg 5B5A 602D	Na 5B5A 6P2B	K 5B5A 6O2B	Sum Bases	Acidity 6H5A	CEC Sum Cats 5A3A	CEC NH_4OAc 5A8B	Exch Na 5D2 PCT	SAR 5E	Base Saturation Sum 5C3	Base Saturation NH_4OAc 5C1	Carbonate as $CaCO_3$ <2MM 6E1G	Carbonate as $CaCO_3$ <20MM 6E4	$CaSO_4$ as Gypsum <2MM 6F1A	$CaSO_4$ as Gypsum <20MM 6F4	pH Sat Paste 8C1B	pH $CaCl_2$ .01M 1:2 8C1F	pH H_2O 1:1 8C1F
		MEQ / 100 G										PCT		PCT		PCT				
84 287	1	75.3	8.9	0.6	0.5		3.1	59.4	1	1			100	TR						
84 288	2		9.2	0.5	0.4			57.3		1	1			3				7.2	7.6	7.8
84 289	3		7.6	0.5	0.4			30.5						8				7.5	7.7	7.9
84 290	4		4.9	0.5	0.2			30.5						13				7.6	7.6	8.0
84 291	5		8.1	0.5	0.4			51.4					9						7.6	8.1
																			7.7	8.1

Sample No.	Hzn No.	Water extracted from saturated paste Ca 6N1B	Mg 601B	Na 6P1B	K 6Q1B	CO_3 6I1B	HCO_3 6J1B	Cl 6K1C	SO_4 6L1C	NO_3 6M1C	H_2O 8A	Total Salts Est. 9D5	Elec. Cond. 8A3A	Mineralogy Clay X-ray <2u 7A2I	Clay X-ray <2u 7A2I	Clay X-ray <2u 7A2I	Clay X-ray <2u 7A2I	DTA <2u 7A3	DTA <2u 7A3	Total Res 7B1A	Dom Weath 7B1A
		MEQ / Liter									PCT		MMHOS /CM	Relative Amounts				PCT			
84 287	1	2.2	1.7	1.4	0.1	—	3.8	0.7	0.9	—	78.5	TR	0.53	MT 4	VR 2	KK 1	CL 1	KK5			
84 288	2	2.0	1.2	1.2	0.1	—	3.6	0.3	0.9	—	79.2	TR	0.44								
84 289	3	2.3	1.0	—	4.1	0.3	0.7	—	71.8	TR	0.47	MT 5	VR 2	KK 1		KK 5					
84 290	4												0.18								
84 291	5												0.22	MT 4	VR 2	KK 1	CA 1	KK			

Family Control Section: Depth 25-100; PCT Clay 11; PCT 1.-75MM, 2
MMHOS/CM of 1:2 Water extract (8I) for layers 4, 5
Analyses: S = All on sieved < 2MM basis
Mineralogy: Kinds of mineral — MT = Montmorill; VR = Vermiculite; KK = Kaolinite; CL = Chlorite; CA = Calcite
Relative amount — 6 = indeterminate; 5 = dominant; 4 = abundant; 3 = moderate; 2 = small; 1 = trace

Supplemental Data Sheet — Chemical

National Soil Survey Laboratory

Sample No.	Hzn No.	P Retent *	Acid Oxalate Extractable Al *	Acid Oxalate Extractable Si *	Acid Oxalate Extractable Fe *	Na Pyro Extractable Fe 6C5A	Na Pyro Extractable Al 6G5A	pH NaF 8CID	pH KCl 8CIG 1:1	pH $CaCl_2$ Moist 8CIF 1:2	pH H_2O Moist 8CIF 1:1
		PCT of < 2MM									
840287	1	25	0.2	0.1	0.1	0.05	0.04	9.4	6.6		
840288	2	25	0.2	0.1	0.1	0.00	0.06	9.6	6.6		
840289	3	25	0.2	0.1	0.1<	0.05	0.05	9.8	6.6		
840290	4	45	0.1	0.1<	0.1	0.04	0.04	9.9	6.6		
840291	5	30	0.2	0.1	0.3			10.0	6.5		

*New Zealand Procedure

CP84FNO22

Sample No.	Hzn No.	Mineralogy: Optical Sand/Silt FA 7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	X-RAY Clay 7A2I	7A2I	7A2I	7A2I	7A2I	DTA 7A3	7A3	Tot Anal K_2O 7A3	Tot Anal Fe 7A3
		PCT											Relative Amounts					PCT			
84P 287	1												MT 5	VR 2	KK 1	CL 1	KK 5			0.3	5.8
84P 288	2	COSI	1	OT88	GA 8	GS 3	PO 1														
84P 289	3												MT 5	VR 2	KK 1		KK 5			0.2	5.2
84P 290	4																				
84P 291	5												MT 4	VR 2	KK 1	CA 1	KK 1			0.1	4.9

Analyses: S = All on Sieved < 2MM Basis
Mineralogy: FA = Fraction Analyzed; RE = Resistant
Kind of Mineral: CL = Chlorite; MT = Montmorillonite; VR = Vermiculite; KK = Kaolinite; PO = Plant Opal
GA = Glass Aggregates; GS = Glass; OT = Other; CA = Calcite
Relative Amount: 6 = Indeterminate; 5 = Dominant; 4 = Abundant; 3 = Moderate; 2 = Small; 1 = Trace
Mineralogy Based on Sand/Silt:
Mineralogy Based on Clay:
Family Placement:

agriculture is observable in general, except for some terraced vegetable patches.

From Mangaldan to Angeles City

From Irisan the tour goes downward to Pangasinan Province. Coconuts, mango, and other fruits grown some distance from the highway are common along this route. Tobacco, mungbean, and peanut are also

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SERIES: Not Designated NSSL ID #: 84P0075
SOIL SURVEY # S83FN-725-022
LOCATION: Near Baguio City.
LATITUDE: 16°25'11"N LONGITUDE: 120°32'23"E
PHYSIOGRAPHY: Hillside in Mountains or deeply dissected plateaus
GEOMORPHIC POSITION: on a slope Backslope
SLOPE CHARACTERISTICS: 55% complex ELEVATION: 1300 m
PRECIPITATION: MAP: 3,422 mm; 4 dry, 8 wet months
WATER TABLE DEPTH (cm): > 165 cm
DRAINAGE: Well drained PERMEABILITY: Moderate
STONINESS: None
EROSION OR DEPOSITION: Slight
PARENT MATERIAL: Eolian 'ejecta' from tuff breccia material
CLASSIFICATION: fine, mixed, isothermic Andic Palehumult
DIAGNOSTIC HORIZONS: Ochric; Argillic
FAMILY CONTROL SECTION: 029 to 079
DESCRIBED BY: A. Dayot; A. Marqueses; R. Haberman SAMPLE DATE: 09/83

Vegetation-Fern and unnamed grasses.

A — 0 to 16 cm; dark reddish brown (5YR 3/2), loam; dark reddish gray (5YR 4/2) dry; moderate fine granular structure; slightly hard, very friable, non sticky, non plastic; common fine and common very fine roots; few very fine tubular pores; rock fragments, 01% greater than 2 mm from mixed lithology; pebbles 10 mm in size; medium acid; clear smooth boundary.
84P0354

BA — 16 to 29 cm; yellowish red (5YR 4/6), loam; yellowish red (5YR 5/6) and reddish brown (5YR 5/4) dry; weak medium subangular blocky structure; slightly hard, very friable, non sticky, non plastic; few thin olive (5Y 4/4) clay coatings in root channels and/or pores; common very fine and few fine roots; few very fine tubular pores; medium acid; clear smooth boundary.
84P0355

Bt1 — 29 to 50 cm; yellowish red (5YR 4/6), clay loam; reddish brown (5YR 5/4) and yellowish red (5YR 5/6) dry; weak medium subangular blocky structure; somewhat hard, firm, slightly sticky, plastic; few thin olive (5Y 4/4) clay coatings in root channels and/or pores; common very fine roots; few to common very fine tubular pores; strongly acid; clear smooth boundary.
84P0356

Bt2 — 50 to 89 cm; red (2.5YR 5/8), silty clay loam; light red (2.5YR 6/8) dry; moderate medium subangular blocky structure; somewhat hard, firm, slightly sticky, plastic; few thin reddish yellow (5YR 6/8) clay coatings in root channels and/or pores; few very fine roots; few to common very fine tubular pores; very strongly acid.
84P0357

Bt3 — 89 to 123 cm; like above horizon separated for sampling purposes; gradual smooth boundary.
84P0358

Bt4 — 123 to 165 cm; red (2.5YR 4/8), silty clay loam; red (2.5YR 4/8) dry; weak medium subangular blocky parting to weak fine subangular blocky structure; somewhat hard, firm, slightly sticky, plastic; few to common very fine tubular pores; very strongly acid.
84P0359

SND
Classification: fine, mixed, isothermic, Andic Palehumult
S 83FN-725 -022 Date: 06/29/84
SMSS — Philippines
General Methods: 1B1A, 2A1, 2

Sample No. 84P 354- 359
Pedon No. 84P 74
Project No. 84P 14

U.S. Department of Agriculture
Soil Conservation Service
National Soil Survey Laboratory
Lincoln, Nebraska 68508

Sample No.	Hzn No.	Depth (CM)	Horizon	Total Clay Lt .002	Total Silt .002 -.05	Total Sand .05 -2	Clay Fine Lt .0002	Clay CO_3 Lt .002	Silt Fine .002 -.02	Silt Coarse .02 -.05	Sand VF .05 -.10	Sand F .10 -.25	Sand M .25 -.50	Sand C .5 -1	Sand VC 1 -2	Coarse Fractions (MM) (>2MM) Weight 2 -5	5 -20	20 -75	.1- 75	Wt PCT of Whole Soil	
				PCT of < 2MM (3A1)												PCT of<75MM (3B1)					
84 354	1S	0- 16	A	54.9	31.9	13.2	17.7		23.8	8.1	5.6	5.0	1.4	0.7	0.5	TR	1	—		9	1
84 355	2S	16- 29	BA	26.6	40.1	33.3	3.6		23.7	16.4	16.8	13.5	2.3	0.4	0.3	1	TR	—		17	1
84 356	3S	29- 50	BT1	30.0	35.2	34.8	4.8		21.0	14.2	16.2	14.8	2.9	0.6	0.3	TR	—	—		19	—
84 357	4S	50- 89	BT2	43.8	37.9	18.3			27.4	10.5	9.3	6.3	1.5	0.6	0.6	—	—	—		9	—
84 358	5S	89-123	BT3	42.9	43.6	13.3	8.6		33.0	10.8	8.1	3.6	0.8	0.4	—	—	—		5	—	
84 359	6S	123-165	BT4	36.6	49.3	14.1			37.0	12.3	8.7	4.2	0.7	0.2	—	—	—	5	—		

Sample No.	Hzn No.	Orgn C 6A1C	Total N 6B3A	Extr P	Total S 6R3A	Dith-Cit Extractable Fe 6C2B	Dith-Cit Extractable Al 6G7A	Dith-Cit Extractable Mn 6D2A	Ratio/Clay CEC 8D1	Ratio/Clay 15 Bar 8D1	Atterberg Limits LL 4F1	Atterberg Limits PI 4F	Bulk Density Field Moist 4A3A	Bulk Density 1/3 Bar 4A1D	Bulk Density Oven Dry 4A1H	COLE Whole Soil 4D1	Water Content Field Moist 4B4	Water Content 15 Bar 4B2B	Water Content 1/3 Bar 4B1C	Water Content 15 Bar 4B2A	Wrd Whole Soil 4C1
		PCT of < 2MM									PCT<0.4MM		G/CC			CM/CM	PCT of < 2MM				CM/CM
84 354	1	5.15	0.404			4.0	1.2	TR	0.79	1.07	0.111		45.1	56.8	33.3	0.20					
84 355	2	1.88	0.189			4.4	1.4	TR	1.14	1.05	53	9		0.81	1.19	0.136		62.5	28.0	0.28	
84 356	3	1.45	0.156			4.4	1.3	TR	1.02	0.95								50.9		28.4	
84 357	4	0.86							0.88	0.74	62	18		1.00	1.44	0.129		52.3	57.0	32.6	0.24
84 358	5	0.64	0.057			5.3	1.2	TR	0.98	0.80									55.3		34.4
84 359	6	0.52							1.31	1.03				0.89	1.60	0.216		59.4	66.4	37.7	0.26

SND S 83FN-725-022 Date: 06/29/84 Pedon No. 84P 74 National Soil Survey Laboratory

Sample No.	Hzn No.	(NH_4OAc Extractable Bases) Ca 5B5A 6N2E	Mg 5B5A 602D	Na 5B5A 6P2B	K 5B5A 6Q2B	Sum Bases	Acidity 6H5A	Extr-Al 6G9A	CEC Sum Cats 5A3A	CEC NH_4 OAc 5A8B	CEC Bases + Al 5A3B	Al Sat 5G1	Base Sat Sum 5C3	Base Sat NH_4 OAc 5C1	Base Sat $CaCO_3$ < 2MM 6E1G	CO_3 as $CaCO_3$	Res. Ohms /CM 8E1	Cond. MMHOS/CM 8I	pH NaF 8C1D	pH $CaCl_2$ 0.1M 8C1F 1:2	pH H_2O 8C1F 1:1
		MEQ / 100 G										PCT									
84 354	1	3.3	1.7	TR	0.4	5.4	37.4		42.8	43.2			13	12				0.04	10.0	4.1	4.8
84 355	2	0.7	0.5	TR	0.1	1.3	33.9		35.2	30.2			4	4				0.01	10.4	4.2	5.0
84 356	3	0.5	0.3	TR	0.1	0.9	34.4		35.3	30.5			3	3				0.01	10.4	4.1	4.9
84 357	4	0.7	0.4	TR	0.2	1.3	40.5		41.8	38.4			3	3				0.01	10.4	4.3	4.7
84 358	5	0.6	0.4	TR	0.2	1.2	44.9		46.1	42.2			3	3				0.01	10.4	4.3	4.8
84 359	6	0.6	0.5	0.1	0.3	1.5	51.5		53.0	47.9			3	3				0.01	10.5	4.2	4.8

Sample No.	Hzn No.	Mineralogy: Clay X-Ray <2u 7A2I	Clay X-Ray <2u 7A2I	Clay X-Ray <2u 7A2I	Clay X-Ray <2u 7A2I	Clay DTA <2u 7A3	Clay DTA <2u 7A3	Total Res 7B1A	Dom Weath 7B1A
		Relative amounts				PCT			
84 354	1	KH 4	VR 1	GI 1		KH43	GI		
84 355	2	KH 3	GI 2	VR 1		KH32	GI 6		
84 356	3	KH 4	GI 2	VR 1		KH42	GI 7		
84 357	4								
84 358	5	KH 2	VR 1	GI 1		KH45	GI 3		
84 359	6								

Family Control Section: Depth 29-29; PCT Clay 38; PCT .1-75 MM, 13.
MMHOS/CM of 1:2 Water extract (8I) for layers 1, 2, 3, 4, 5, 6,
Analyses: S = All on sieved <2MM basis
Mineralogy: Kind of minerals — KH = Halloysite; VR = Vermiculite; GI = Gibbsite; HN = Hornblende; MI = Mica
Relative amount — 6 = indeterminate; 5 = dominant; 4 = abundant; 3 = moderate; 2 = small; 1 = trace

Supplemental Data Sheet — Chemical

National Soil Survey Laboratory

Sample No.	Hzn No.	P Retent *	Acid Oxalate Extractable Al *	Si *	Fe *	Na Pyro Extractable Fe 6C5A	Al 6G5A		pH NaF 8CID	KCl 8CIG 1:1	$CaCl_2$ Moist 8CIF 1:2	H_2O Moist 8CIF 1:1
		PCT of < 2MM										
840354	1	95	1.0	0.1	1.2	0.52	0.67		10.0	3.8	4.2	5.2
840355	2	98	1.3	0.1	1.0	0.47	0.66		10.4	3.9	4.5	5.2
840356	3	98	1.2	0.1	0.7	0.47	0.61		10.4	3.9	4.5	5.1
840357	4	96	0.8	0.1	0.3				10.4	3.6	4.0	5.1
840358	5	97	0.9	0.1	0.2	0.11	0.50		10.4	3.5	4.0	5.0
840359	6	98	0.9	0.1	0.2			10.5	3.4	4.5	5.0	

*New Zealand Procedure

CP84FNO22

Sample No.	Hzn No.	Mineralogy: Optical Sand/Silt FA 7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	X-RAY Clay 7A2I	7A2I	7A2I	7A2I	7A2I	DTA 7A3	7A3	(Tot Anal) K_2O 7A3	Fe 7A3
		PCT											Relative Amounts					PCT			
84P 354	1	VFS	82	KH56	QZ16	HN11	MG 6	FP 4	HE 3	GS 2	PO 1	GA 1	KH 4	VR 1	GI 1			KH43	GI	1 0.2	7.9
84P 355	2	VFS	89	KH78	QZ 8	HN 2	MG 2	FP 1	MI 1	PO 1	GC 1	G-S 2	KH 3	GI2	VR 1			KH32	GI	6 0.1	8.5
84P 356	3												KH 4	GI 2	VR 1			KH42	GI	7 0.1	8.2
84P 357	4																				
84P 358	5	VFS	98	KH94	QZ 3	MI 2	OP 1	AM 1	PO 1				KH 2	VR 1	GI 1			KH45	GI	3 0.2	11.6
84P 359	6																				

Analyses: S = All on Sieved < 2MM Basis
Mineralogy: FA = Fraction Analyzed; RE = Resistant
Kind of Mineral: GI = Gibbsite; HE = Hematite; MG = Magnetite; PO = Plant Opal; QZ = Quartz; FP = Plagioclase Feldspar
GA = Glass Aggregates; GS = Glass; HN = Hornblende; VR = Vermiculite; KH = Halloysite; MI = Mica
GC = Class Coated Grain; OP = Opaques; AM = Amphibole
Relative Amount: 6 = Indeterminate; 5 = Dominant; 4 = Abundant; 3 = Moderate; 2 = Small; 1 = Trace
Mineralogy Based on Sand/Silt:
Mineralogy Based on Clay:
Family Placement:

commonly raised after the wet-season rice, particularly in the areas which cannot be serviced by irrigation.

In Mangaldan, rice is the main crop most of which are rainfed; while Dagupan is essentially an urbanized community almost surrounded by fish ponds and rice fields on sandy soils.

Carlos P. Romulo Highway, traverses, southward, through Pangasinan to western Tarlac Province. This road passes through the intermediate uplands in most parts. The intermediate uplands are essentially the same as that of southwestern Tarlac. Rice is still the main crop during the wet season in the bottomlands and on gentle slopes in terraced paddies. In few areas where irrigation from small streams is available, rice is grown during the dry season.

The town of Camiling is a small inland valley bordered by intermediate uplands, except on the north where the valley extends to the broad plains of Pangasinan Province. Part of the valley is irrigated during the dry season. The crops grown in the unirrigated rice fields are quite similar to those grown in similar conditions in Pangasinan Province.

SERIES: Quingua
SOIL SURVEY:
LOCATION: MSAC Experiment Station (La Trinidad, Benguet)
LATITUDE: LONGITUDE:
PHYSIOGRAPHY: Colluvial flat adjacent to limestone foothill landscape
SLOPE CHARACTERISTICS: 1% ELEVATION: 1,211 m
PRECIPITATION: Nine months rainy season; three months dry season
WATER TABLE DEPTH (cm): Not encountered
DRAINAGE: Well drained PERMEABILITY: Moderate
STONINESS: None
EROSION OR DEPOSITION: No evidence of erosion
PARENT MATERIAL: Alluvium/colluvium derived from limestone
CLASSIFICATION: fine, mixed, isothermic Typic Tropudalf
DIAGNOSTIC HORIZONS: Ochric epipedon; argillic
DESCRIBED BY: C. Alcalde, E. Rocella, R. Cagmat, N. Marasigan, S. Pascua, Jr.
DATE OF EXAMINATION: March 18, 1984

Planted with vegetables — cabbages, asparagus, carrots and sweet pea.

Ap — 0 to 17 cm; dark yellowish brown (10YR 3/4) moist, light yellowish brown (10YR 6/4) dry, silty clay, no mottles; moderate coarse angular blocky breaking to fine granular; few fine and medium biopores; common fine roots; abrupt smooth boundary.

Bt1 — 17 to 38 cm; dark yellowish brown (10YR 4/4) moist, silty clay; many fine and medium distinct clear red (2.5 YR 4/8) mottles; moderate coarse angular blocky breaking into medium subangular blocky; slightly sticky, slightly plastic, slightly firm; few Fe/Mn materials; few small biopores; few fine roots; clear wavy boundary.

Bt2 — 38 to 58 cm; grayish brown (10YR 5/2) moist clay; many fine distinct clear yellowish brown (10YR 5/8) mottles; strong coarse angular blocky; sticky plastic, firm, common Fe/Mn concretion; few small biopores; very few fine roots clear wavy boundary.

Bt3 — 58 to 81 cm; brown (10YR 5/3) moist, clay; common medium distinct clear dark brown (7.5YR 4/4) mottles; strong coarse angular to subangular blocky; very sticky, very plastic, firm; few small soft Mn concretions; few fine roots; diffuse smooth boundary.

Bt4 — 81 to 105 cm; grayish brown (10YR 5/2) moist, clay; many fine distinct clear strong brown (7.5YR 4/6) mottles, strong medium angular blocky; very plastic, very sticky, firm; very few small biopores; many Fe/Mn materials; thin patchy clay skin between ped faces; diffuse smooth boundary.

Quingua

Classification: fine, mixed, isothermic Typic Tropudalf

Sample No.	Hzn No.	Depth (CM)	Horizon	Total Clay Lt .002	Total Silt .002 -.05	Total Sand .05 -2	Clay Fine Lt .0002	Clay CO_3 Lt .002	Silt Fine .002 -.02	Silt Coarse .02 -.05	Sand VF .05 -.10	Sand F .10 -.25	Sand M .25 -.50	Sand C .5 -1	Sand VC 1 -2	Coarse Fractions (MM) Weight 2 -5	5 -20	20 -75	.1- 75	(>2MM) Wt PCT of Whole Soil
				PCT of < 2MM (3A1)												PCT of <75MM (3B1)				
1	0-20			37.0	23.8															
2	20-127			44.2	32.0	23.8														
3	127-150			46.2	30.0	23.8														

Sample No.	Hzn No.	Orgn C 6A1C	Total N 6B3A	Extr P	Total S 5R3A	Dith-Cit Extractable Fe 6C2B	Dith-Cit Extractable Al 6G7A	Dith-Cit Extractable Mn 6D2A	Ratio/Clay CEC 8D1	Ratio/Clay 15 Bar 8D1	Atterberg Limits LL 4F1	Atterberg Limits PI 4F	Bulk Density Field Moist 4A3A	Bulk Density 1/3 Bar 4A1D	Bulk Density Oven Dry 4A1H	COLE Whole Soil 4D1	Water Content Field Moist 4B4	Water Content 15 Bar 4B2B	Water Content 1/3 Bar 4B1C	Water Content 15 Bar 4B2A	Wrd Whole Soil 4C1
		PCT of < 2MM									PCT <0.4MM		G/CC			CM/CM	PCT of < 2MM				CM/CM
	1																		11.60	10.15	
	2																		26.81	21.62	
	3																		33.57	27.52	

Sample No.	Hzn No.	NH_4OAc Extractable Bases Ca 5B5A 6N2E	Mg 5B5A 602D	Na 5B5A 6P2B	K 5B5A 6Q2B	Sum Bases	Acidity 6H5A	CEC Sum Cats 5A3A	CEC NH_4-OAc 5A8B	Exch Na 5D2 PCT	SAR 5E	Base Saturation Sum 5C3	Base Saturation NH_4OAc 5C1	Carbonate as $CaCO_3$ <2MM 6E1G	Carbonate as $CaCO_3$ <20MM 6E4	$CaSO_4$ as Gypsum <2MM 6F1A	$CaSO_4$ as Gypsum <20MM 6F4	pH Sat Paste 8C1B	pH $CaCl_2$ .01M 8C1F 1:2	pH H_2O 8C1F 1:1
		MEQ / 100 G										PCT		PCT		PCT				
	1	29.2	7.0	0.2	0.2	36.6	13.6	50.2	28.7			73							5.2	5.6
	2	29.5	8.7	0.2	0.1	35.5	14.5	53.1	31.9			72							5.6	6.0
	3	38.7	7.7	0.2	0.1	36.2	14.4	52.6	34.1			69							5.8	6.0

Sample No.	Hzn No.	Water extracted from saturated paste Ca 6N1B	Mg 601B	Na 6P1B	K 6Q1B	CO_3 6I1B	HCO_3 6J1B	Cl 6K1C	SO_4 6L1C	NO_3 6M1C	H_2O 8A	Total Salts Est. 8D5	Elec. Cond. 8A3A	Mineralogy Clay X-Ray <2u 7A2I	Clay X-Ray <2u 7A2I	Clay X-Ray <2u 7A2I	Clay Dta <2u 7A3	Clay Dta <2u 7A3	Total Res 7B1A	DOM Weath 7B1A
		MEQ / Liter									PCT		MMHOS /CM	Relative Amounts					PCT	
	1													0.17						
	2													0.16						
	3													0.17						

All throughout the rolling intermediate uplands of western Tarlac, which is dry from November to April, uplands are rarely cultivated during the dry season. Gentle slopes and bottomlands which may have a few short-season upland crops during the late wet to early dry season are almost entirely dependent on residual moisture and seepage from the surrounding uplands. The small and intermittent streams hardly make possible the development of large-scale irrigation systems similar to those in the northern and eastern part of the Central Plains of Luzon. Most of the irrigation systems are small communal diversion types and are used mainly as supplementary to rainfall for the wet-season rice crops.

Tarlac. Tarlac sits on the edge of the rolling intermediate uplands which borders the broad central plain at the west. Patches of upland crops, mainly tomatoes, mungbean, and some vegetables, occur on patches where irrigation is not available during the dry season.

From Tarlac to Pampanga and the Angeles site, the route is grown to sugarcane in sandy soils with level and slightly undulating topography. Across the river boundary, the uplands of horizontal sediments are almost devoid of tree vegetation. The foothills are generally bare of any cultivated crops and are covered with sparse vegetation during the dry season, except on some irrigated bottomlands and gentle slopes with terraced paddies. The terraced paddy system west of the highway are mainly on clayey soils, while the bottomlands are more often medium-textured soils which extend to the level areas east of the highway. The areas on both sides of the highway were formerly on sugarcane production. At present the rice area has increased considerably even if only a wet-season crop is grown yearly.

Stop No. 10. The Mangaldan site is a loamy alluvium which grades very gradually to the tidal flats. Since there is no source of sufficient irrigation, there is no rice crop during the dry season. Tobacco, vegetables, and peanuts are the most common crops grown after rice. Irrigation for these crops are generally from shallow open wells or small, shallow well pumps.

Stop No. 11. The Angeles site is sandy alluvium at about 20 m elevation and is primarily a sugarcane area. Small patches and strips of wetland rice is claimed to yield as much as 3-4 tons on urea fertilizer alone, provided that water is available.

SERIES: La Paz NSSL ID #: 84P0078
SOIL SURVEY # S83FN-725-025
LOCATION: Near Angeles, Pampanga.
LATITUDE: 15°05'37"N LONGITUDE: 120°37'41"E
PHYSIOGRAPHY: Terrace
SLOPE CHARACTERISTICS: < 1% plane ELEVATION: 20 m

PRECIPITATION: MAP: 2,035 mm; 5 dry, 7 wet months
WATER TABLE DEPTH (cm):
DRAINAGE: Moderately well drained PERMEABILITY: Moderate
STONINESS: None
EROSION OR DEPOSITION: None
PARENT MATERIAL: Alluvium from volcanic materials
CLASSIFICATION: sandy, mixed, nonacid, isohyperthermic Aquic Ustifluvent
DIAGNOSTIC HORIZONS:
DESCRIBED BY: A. Dayot; A. Marqueses; R. Haberman. SAMPLE DATE: 09/83

Ap1 — 0 to 13 cm; very dark gray (10YR 3/1), sandy loam; gray (10YR 6/1) dry; weak fine granular structure; slightly hard, friable, non sticky, non plastic; many very fine and few fine roots; slightly acid; clear smooth boundary.
84P0377

C5 — 71 to 124 cm; dark gray (10YR 4/1), loamy sand; common fine distinct dark brown (7.5YR 4/4) and few fine distinct strong brown (7.5YR 5/6) mottles, single grain; loose, non sticky, non plastic; few to common very fine roots; few very fine tubular pores, few to common very fine gold colored particles; neutral; clear smooth boundary.
84P0383

C6 — 124 to 154 cm; dark gray (10YR 4/1), loam; few fine distinct strong brown (7.5YR 5/6) mottles; massive; hard, firm, non sticky, non plastic; few to common very fine roots; common very fine tubular pores; neutral.
84P0384

Ap2 — 13 to 22 cm; dark grayish brown (10YR 4/2), sandy loam; few to common fine faint dark yellowish brown (10YR 4/4) mottles; massive and breaks into soil fragments about 2.5 cm in size; hard, firm, non sticky, non plastic; many very fine roots; very few very fine tubular pores; few dark yellowish brown (10YR 4/4) soft accumulations in root channels; slightly acid; clear smooth boundary.
84P0378

C1 — 22 to 33 cm; grayish brown (10YR 5/2), sandy loam; few fine prominent yellowish red (5YR 4/6) and few to common fine prominent reddish brown (5YR 4/4) mottles; massive and breaks into soil fragments about 2.5 cm in size; hard, firm, dense, non sticky non plastic; common reddish brown (5YR 4/4) coatings in root channels; few to common very fine roots; very few very fine tubular pores; slightly acid; clear smooth boundary.
84P0379

C2 — 33 to 40 cm; pale brown (10YR 6/3), sandy loam; common fine and medium faint yellowish brown (10YR 5/6) mottles; massive and breaks into soil fragments about 2.5 cm in size; slightly hard, friable, dense, non sticky, non plastic; few to common very fine roots; few very fine tubular pores; few fine and medium dark yellowish brown (10YR 3/4) accumulations; slightly acid; clear smooth boundary.
84P0380

C3 — 40 to 57 cm; very dark grayish brown (10YR 3/2) and dark grayish brown (10YR 4/2), loamy sand; common fine distinct brown (7.5YR 4/4) mottles; single grain; loose, non sticky, non plastic; few to common very fine roots; few very fine tubular pores; rock fragments, 08% greater than 2 mm and less than 2 cm in diameter from mixed lithology; common very fine and few fine gold colored particles; neutral; clear smooth boundary.
84P0381

C4 — 57 to 71 cm; dark gray (10YR 4/1), loamy sand; common fine distinct dark brown (7.5YR 4/4) and few fine distinct strong brown (7.5YR 5/6) mottles; single grain; loose, non sticky, non plastic; few to common very fine roots; few very fine tubular pores; common very fine gold colored particles but less than above horizon; neutral; clear smooth boundary.
84P0382

La Paz
Classification: sandy, mixed, nonacid, isohyperthermic, Aquic Ustifluvent
S 83FN-725 -025 Date: 06/29/84
SMSS — Philippines
General Methods: 1B1A, 2A1, 2B

Sample No. 84P 377- 384
Pedon No. 84P 78
Project No. 84P 14

U.S. Department of Agriculture
Soil Conservation Service
National Soil Survey Laboratory
Lincoln, Nebraska 68508

Sample No.	Hzn No.	Depth (CM)	Horizon	Total Clay Lt .002	Total Silt .002 -.05	Total Sand .05 -2	Clay Fine Lt .0002	Clay CO_3 Lt .002	Silt Fine .002 -.02	Silt Coarse .02 -.05	Sand VF .05 -.10	Sand F .10 -.25	Sand M .25 -.50	Sand C .5 -1	Sand VC 1 -2	Coarse Fractions (MM) Weight 2 -5	5 -20	20 -75	.1-75	Wt PCT of Whole Soil	
				PCT of < 2MM (3A1)												—PCT of <75MM (3B1)—					
84 377	1S	0- 13	AP1	5.4	35.4	59.2			16.1	19.3	25.4	17.2	8.0	6 1	2.5	1	TR	—		34	1
84 378	2S	13- 22	AP2	5.3	34.0	60.7			15.5	18.5	23.1	17.5	9.0	6.8	4.3	1	TR	—		38	1
84 379	3S	22- 33	C1	4.4	33.0	62.6			14.6	18.4	23.5	17.3	9.2	7.5	5.1	1	—	—		40	1
84 380	4S	33- 40	C2	2.5	35.5	62.0			13.9	21.6	22.1	14.1	10.9	10.5	4.4	1	—	—		41	1
84 381	5S	40- 57	C3	1.7	15.5	82.8			7.0	8.5	12.0	17.6	24.0	21.6	7.6	4	TR	—		72	4
84 382	6S	57- 71	C4	2.8	21.2	76.0			10.5	10.7	20.9	24.6	13.9	11.3	5.3	1	—	—		56	1
84 383	7S	71-124	C5	2.8	21.2	76.0			5.8	12.2	46.4	29.5	3.2	1.3	0.3	—	—	—	34	—	
84 384	8S	124-154	C6	6 8	40.2	53.0			19.5	20.7	17.3	11.7	9.5	8.5	6.0	1	—	—		36	1

Sample No.	Hzn No.	Orgn C 6A1C	Total N 6B3A	Extr P	Total S 6F3A	Dith-Cit Extractable Fe 6C2B	Al 6G7A	Mn 6D2A	Ratio/Clay CEC 8D1	15 Bar 8D1	Atterberg Limits LL 4F1	PI 4F	Bulk Density Field Moist 4A3A	1/3 Bar 4A1D	Oven Dry 4A1H	COLE Whole Soil 4D1	Water Content Field Moist 4B4	15-Bar 4B2B	1/3 Bar 4B1C	15 Bar 4B2A	Wrd Whole Soil 4C1
		PCT of < 2MM									PCT <0.4MM		G/CC			CM/CM	PCT of < 2MM				CM/CM
84 377	1	1.04	0.079			0.3	0.1		1.20	0.83		NP								4.5	
84 378	2	0.56	0.041			0.4	0.1		0.92	0.87			1.37	1.37	—		12.1		4.6	0.10	
84 379	3	0.43	0.041			0.5	0.1	TR	1.05	1.05				1.36	1.36	—			12.6	4.6	0.11
84 380	4	0.32							1.68	1.60										4.0	
84 381	5	0.19	0.010			0.4	TR	TR	1.94	1.71				1.33	1.33	—			17.7	2.9	0.19
84 382	6	0.17							1.32	1.07										3.0	
84 383	7	0.11	0.008			0.5	0.1		3.00	2.15		NP		1.26	1.26	—			12.1	2.8	0.12
84 384	8	0.15							1.21	0.84				1.32	1.34	0.005			27.3	5.7	0.28

La Paz S 83FN-725-025 Date: 06/29/84 Pedon No. 84P 78 National Soil Survey Laboratory

Sample No.	Hzn No.	Ca 5B5A 6N2E	Mg 5B5A 602D	Na 5B5A 6P2B	K 5B5A 6Q2B	Sum Bases	Acidity 6H5A	Sum Cats 5A3A	NH_4 OAc 5A8B	Exch Na 5D2	SAR 5E	Base Saturation Sum 5C3	Base Saturation NH_4OAc 5C1	Carbonate as $CaCO_3$ <2MM 6E1G	Carbonate as $CaCO_3$ <20MM 6E4	$CaSO_4$ as Gypsum <2MM 6F1A	$CaSO_4$ as Gypsum <20MM 6F4	pH Sat Paste 8C1B	pH $CaCl_2$ 01M 8C1F 1:2	pH H_2O 8C1F 1:1
		MEQ / 100 G								PCT		PCT		PCT		PCT				
84 377	1	2.2	0.6	TR	0.5	3.3	6.3	9.6	6.5			34	51				0.14	8.5	4.6	5.3
84 378	2	1.4	0.3	TR	0.1	1.8	5.1	6.9	4.9			26	37				0.02	8.2	4.4	5.2
84 379	3	1.8	0.4	0.1	0.1	2.4	4.7	7.1	4.6			34	52				0.02	8.5	4.7	5.6
84 380	4	1.8	0.4	0.1	0.1	2.4	4.0	6.4	4.2			37	57				0.02	8.7	5.1	5.7
84 381	5	1.9	0.5	TR	TR	2.4	2.5	4.9	3.3			49	73				0.01	8.0	5.2	5.9
84 382	6	2.5	0.7	TR	TR	3.2	1.9	5.1	3.7			63	86				0.02	7.9	5.3	6.1
84 383	7	2.5	0.9	0.1	TR	3.5	1.6	5.1	3.9			69	90				0.02	7.9	5.5	6.3
84 384	8	5.2	2.2	TR	0.1	7.5	2.2	9.7	8.2			77	91				0.02	8.1	5.6	6.5

Sample No.	Hzn No.	Mineralogy: Clay X-Ray <2u 7A2I	Clay X-Ray <2u 7A2I	Clay X-Ray <2u 7A2I	Clay X-Ray <2u 7A2I	Clay DTA <2u 7A3	Clay DTA <2u 7A3	Total Res 7B1A	Dom Weath 7B1A
		Relative amounts				PCT			
84 377	1	VR			1				
84 378	2								
84 379	3	KK			1VR				1
84 380	4								
84 381	5	KK			2MT				1
84 382	6								
84 383	7	KK			1MI				1
84 384	8								

Family Control Section: Depth 25-100; PCT Clay 2; PCT .1-75MM, 48.
MMHOS/CM of 1:2 Water extract (8I) for layers 1, 2, 3, 4, 5, 6, 7, 8,
Analyses: S = All on sieved < 2MM basis
Mineralogy: Kind of Mineral — VR = Vermiculite; KK = Kaolinite; MT = Montmorill; FO = Oligoclase; MI = Mica
Relative Amount — 6 = indeterminate; 5 = dominate; 4 = abundant; 3 = moderate; 2 = small; 1 = trace

Supplemental Data Sheet — Chemical

National Soil Survey Laboratory

Sample No.	Hzn No.	P Retent *	Acid Oxalate Extractable Al *	Acid Oxalate Extractable Si *	Acid Oxalate Extractable Fe *	Na Pyro Extractable Fe 6C5A	Na Pyro Extractable Al 6G5A		pH NaF 8CID	pH KCl 8CIG 1:1	pH $CaCl_2$ Moist 8CIF 1:2	pH H_2O Moist 8CIF 1:1
		PCT of < 2MM										
840377	1	4	0.1	0.1	0.1	0.1	0.15	0.06		8.5	4.1	
840378	2	10	0.1	0.1	0.2	0.20	0.06		8.2	4.0		
840379	3	11	0.1	0.1	0.3	0.20	0.06		8.5	4.3		
840380	4	11	0.1	0.1	0.3				8.7	4.5		
840381	5	2	0.1	0.1	0.1	0.10	0.03		8.0	4.5		
840382	6	6	0.1	0.1	0.1				7.9	4.6		
840383	7	—	0.1	0.1	0.1	0.05	0.02		7.9	4.5		
840384	8	2	0.1	0.1	0.1				8.1	4.5		

*New Zealand Procedure

CP84FNO22

Sample No.	Hzn No.	FA 7B1	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7A2I	7A2I	7A2I	7A2I	7A2I	7A3	7A3	K_2O 7A3	Fe 7A3
		(Mineralogy)																			
		(Optical)											(X-RAY)					(DTA)		(Tot Anal)	
		(Sand/Silt)											(Clay)								
		(PCT)											(Relative Amounts)					(PCT)			
84P 377	1												VR 1							1.6	4.4
84P 378	2	COSI	10	GS44	OT24	GC14	PO10	GA 8													
84P 379	3												KK 1	VR 1						0.2	4.1
84P 380	4																				
84P 381	5	VFS		FO24	GS21	GA17	FD12	AH11	HN 9	BT 4	MI 3	PR 1	KK 2	MT 1						0.1	3.3
84P 382	6																				
84P 383	7												KK 1	MI 1						1.1	4.9
84P 384	8																				

Analyses: S = All on Sieved < 2MM Basis
Mineralogy: FA = Fraction Analyzed; RE = Resistant
Kind of Mineral: VR = Vermiculite; PO = Plant Opal; GA = Glass Aggregates; GS = Glass; OT = Other; GC = Glass Coated Grain
KK = Kaolinite; AH = Anthophyllite; BT = Biotite; FD = Feldspar; FO = Oligoclase; HN = Hornblende
MI = Mica; MT = Montmorillonite; PR = Pyroxene
Relative: Amount: 6 = Indeterminate; 5 = Dominant; 4 = Abundant; 3 = Moderate; 2 = Small; 1 = Trace
Mineralogy Based on Sand/Silt:
Mineralogy Based on Clay:
Family Placement:

SERIES: Bigaa NSSL ID #: 84P0064
SOIL SURVEY # S83FN-725-013
LOCATION: Near Mangaldan, Pangasinan.
LATITUDE: 16°03'44"N LONGITUDE: 121°23'15"E
PHYSIOGRAPHY: Terrace; stream or lake in River valley
SLOPE CHARACTERISTICS: > 1% ELEVATION: 3 m
PRECIPITATION: MAP: 2,579 mm; 4-5 dry, 5-6 wet months
WATER TABLE DEPTH (cm): Flooded
DRAINAGE: Very poorly drained PERMEABILITY: Very slow
STONINESS: None
EROSION OR DEPOSITION: None
PARENT MATERIAL: Alluvium
CLASSIFICATION: fine, montmorillonitic, isohyperthermic Typic Pellustert
DIAGNOSTIC HORIZONS:
DESCRIBED BY: A. Dayot; A. Marqueses; R. Haberman. SAMPLE DATE: 09/83

Vegetation-Sedges and Echinochloa; area is rainfed; very fine sand throughout; some cracks in other places in the pit extend to one meter. In March 1984, the following observations were made: Sinuous "bow" structure of slickenside patterns that were expressed horizontally for at least two meters, amplitude is about 10 cm. Slickensides occur between 23 and 93 cm with intersecting ones between 50 and 93 cm. Cracks 1-2 cm wide extending from the surface to 110 cm.

Ap1 — 0 to 10 cm; dark grayish brown (10YR 4/2) and dark gray (10YR 4/1) silty clay; few fine prominent reddish brown (5YR 4/4) mottles; massive; very sticky, very plastic; common very fine and fine roots; few snail shells; moderately alkaline; clear smooth boundary.
84P0292

Ap2 — 10 to 23 cm; very dark grayisn brown (10YR 3/2) silty clay; few fine distinct dark brown (7.5YR 4/4) mottles; moderate medium and coarse subangular blocky structure; very sticky, very plastic; few black (2.5Y 2/0) stains in root channels; common fine and very fine roots; common fine tubular pores; few snail shells, moderately alkaline; gradual wavy boundary.
84P0293

Ag — 23 to 50 cm; dark gray (10YR 4/1) silty clay; few fine distinct dark brown (7.5YR 4/4) mottles; moderate medium subangular blocky structure; very sticky, very plastic; few distinct slickensides; few snail shells; few fine roots; common very fine and few fine tubular pores; moderately alkaline; clear smooth boundary.
84P0294

ACg1 — 50 to 70 cm; very dark gray (10YR 3/1) silty clay; few fine distinct brown to dark brown (7.5YR 4/4) mottles; moderate medium subangular blocky structure; very sticky, very plastic; cracks 5 to 7.5 cm wide containing soil from above horizon extends through horizon; few snail shells; few fine roots; few very fine and very few fine tubular pores; moderately alkaline; gradual wavy boundary.
84P0295

ACg2 — 70 to 93 cm; dark gray (10YR 4/1) silty clay; common fine distinct brown (7.5YR 5/4) mottles; moderate medium subangular blocky structure; very sticky, plastic; few brown (7.5YR 4/4) stains in root channels; common prominent intersecting slickensides; few snail shells; few to common very fine tubular pores; moderately alkaline; gradual wavy boundary.
84P0296

C — 93 to 148 cm; grayish brown (10YR 5/2) silty clay; common to many fine distinct strong brown (7.5YR 5/6) mottles; weak fine to medium subangular blocky structure; very sticky, plastic; few to common gray (10YR 5/1) gel-like coatings in root channels and/or pores; few gray (10YR 5/1) coatings on ped faces; few fine tubular and common to many very fine tubular pores; few fine black concretions and few fine black masses; moderately alkaline.
84P0297

Bigaa
Classification: fine, montmorillonitic, isohyperthermic Typic Pellustert
S 83FN-725 -013 Date: 06/26/84
SMSS — Philippines
General Methods: 1B1A, 2A1, 2B

Sample No. 84P 292- 297
Pedon No. 84P 64
Project No. 84P 14

U.S. Department of Agriculture
Soil Conservation Service
National Soil Survey Laboratory
Lincoln, Nebraska 68508

Sample No.	Hzn No.	Depth (CM)	Horizon	Total Clay Lt .002	Total Silt .002 -.05	Total Sand .05 -2	Clay Fine Lt .0002	Clay CO_3 Lt .002	Silt Fine .002 -.02	Silt Coarse .02 -.05	Sand VF .05 -.10	Sand F .10 -.25	Sand M .25 -.50	Sand C .5 -1	Sand VC 1 -2	Coarse Fractions (MM) Weight 2 -5	5 -20	20 -75	.1- 75	(>2MM) Wt PCT of Whole Soil
				PCT of<2MM (3A1)												PCT of<75MM (3B1)				
84 292	1S	0- 10	AP1	46.6	47.7	5.7	18.8		34.8	12.9	3.3	1 9	0.4	0.1	—	—	—	—	2	—
84 293	2S	10- 23	AP2	47.4	47.2	5.4	11.8		35.0	12.2	3.3	1 8	0.3	—	—	—	—	—	2	—
84 294	3S	23- 50	AG	46.6	49.2	4.2	4.8		40.0	9.2	2.1	1.3	0.3	—	0.5	TR	—	—	2	—
84 295	4S	50- 70	ACG1	52.7	42.5	4.8	4.8		34.0	8.5	2.5	1 9	0.4	—	—	—	—	2	—	
84 296	5S	70- 93	ACG2	48.0	47.1	4.9	7.6		37.3	9.8	2.5	2 1	0.3	—	—	—	—	—	2	—
84 297	6S	93-148	C	34.9	61.1	4.0			50.0	11.1	2.1	0 8	0.3	0.3	0.5	TR	—	—	2	TR

Sample No.	Hzn No.	Orgn C 6A1C	Total N 6B3A	Extr P	Total S 6F3A	Dith-Cit Extractable Fe 6C2B	Al 6G7A	Mn 6D2A	Ratio/Clay CEC 8D1	15 Bar 8D1	Atterberg Limits LL 4F1	PI 4F	Bulk Density Field Moist 4A3A	1/3 Bar 4A1D	Oven Dry 4A1H	COLE Whole Soil 4D1	Water Content Field Moist 4B4	1/10 Bar 4B1C	1/3 Bar 4B1C	15 Bar 4B2A	Wrd Whole Soil 4C1
		PCT of<2MM									PCT<0.4MM			G/CC		CM/CM	PCT of<2MM				CM/CM
84 292	1	1.79	0.090			1.3	0.2	0.1	0.96	0.67	61	33								31.4	
84 293	2	1.07	0.056			1.4	0.2	0.1	1.02	0.51	62	32		1.42	1.83	0.088			30.2	24.3	0.08
84 294	3	0.74	0.057			1.5	0.2	0.1	1.10	0.55				1.32	1.80	0.109			34.0	25.5	0.11
84 295	4	0.84							1.11	0 54										28.7	
84 296	5	0.66	0.040			1.5	0.2	0.1	1.10	0.58				1.24	1.76	0.124			39.0	27.7	0.14
84 297	6	0.37							1.17	0.81				1.24	1.63	0.095			39.0	28.1	0.14

Bigaa S 83FN-725-013 Date: 06/29/84 Pedon No. 84P 64 National Soil Survey Laboratory

Sample No.	Hzn No.	NH_4OAc Extractable Bases Ca 5B5A 6N2E	Mg 5B5A 602D	Na 5B5A 6P2B	K 5B5A 6O2B	Sum Bases	Acidity 6H5A	CEC Sum Cats 5A3A	CEC NH_4OAc 5A8B	Exch Na 5D2	SAR 5E	Base Saturation Sum 5C3	Base Saturation NH_4OAc 5C1	CO_3 as $CaCO_3$ <2MM 6E1G	Res. Ohms /CM <2MM 8E1	$CaSO_4$ as Gypsum <2MM 6F1A	$CaSO_4$ as Gypsum <20MM 6F4	pH Sat Paste 8C1B	pH $CaCl_2$ .01M 8C1F 1:2	pH H_2O 8C1F 1:1
		MEQ / 100 G								PCT		PCT		PCT		PCT				
84 292	1	33.5	10.1	0.5	0.6	44.7	8.0	52.7	44.7			85	100						6.4	6.7
84 293	2	39.5	10.2	0.8	0.6	51.1	6.4	57.5	48.4			89	100						7.1	7.2
84 294	3	44.5	9.1	1.2	0.7	55.5	1.8	57.3	51.3	2	2	97	100	TR				7.4	7.4	7.5
84 295	4	56.4	11.2	1.5	0.7	69.8	3.6	73.4	58.3	2	2	95	100	TR				7.4	7.5	7.6
84 296	5	55.9	10.9	1.6	0.6	69.0	1.6	70.6	52.7	3	2	98	100	TR				7.5	7.5	7.7
85 297	6	49.0	7.1	1.1	0.4	57.6	1.9	59.5	40.8	2	2	97	100	TR	1,700			7.7	7.7	8.0

Sample No.	Hzn No.	Water extracted from saturated paste Ca 6N1B	Mg 601B	Na 6P1B	K 6Q1B	CO_3 6I1B	HCO_3 6J1B	Cl 6K1C	SO_4 6L1C	NO_3 6M1C	H_2O 8A	Total Salts Est. 8D5	Elec. Cond. 8A3A	Mineralogy Clay X-ray <2u 7A2I	Clay X-ray <2u 7A2I	Clay X-ray <2u 7A2I	Clay X-ray <2u 7A2I	Clay X-ray <2u 7A3	DTA <2u 7A3	Total Res 7B1A	Dom Weath 7B1A
		MEQ / Liter									PCT		MMHO /CM	Relative Amounts						PCT	
84 292	1												0.15	MT 4	VR 3	KK 3	CL 1	KK23			
84 293	2												0.21	MT 5	VR 3	KK 3	CL 1	KK17			
84 294	3	2.8	0.8	2.2	0.1	—	2.7	0.7	2.7	—	75.9	TR	0.61	MT 4	VR 3	KK 3	CL 2	KK18			
84 295	4	3.5	1.0	2.8	TR	—	2.3	1.1	4.0	—	81.1	TR	0.75	MT 4	VR 3	KK 3	CL 1	KK18			
84-296	5	3.5	1.0	2.9	TR	—	2.6	1.0	3.8	—	77.1	TR	0.76	MT 4	VR 3	KK 3	CL 1	KK19			
84-297	6	[illegible]	0.6	2.0	TR	—	2.3	0.6	1.7	—	77.5	TR	0.48								

Family Control Section: Depth 25-100; PCT Clay 48; PCT .1-75MM; 2
MMHOS/CM of 1:2 Water extract (8I) for layers 1, 2
Analyses: S = All on sieved < 2MM basis
Mineralogy: Kinds of mineral — MT = Montmorill; VR = Mermiculite, KK = Kaolinite; Cl = Chlorite
Relative amount — 6 = indeterminate; 5 = dominant; 4 = abundant; 3 = moderate; 2 = small; 1 = trace

Supplemental Data Sheet — Chemical

National Soil Survey Laboratory

Sample No.	Hzn No.	P Retent *	(— —Acid Oxalate— —) Extractable Al *	Si *	Fe *	(— —Na Pyro— —) Extractable Fe 6C5A	Al 6G5A	(— — — — — —pH— — — — — —) NaF 8C1D	KCl 8C1G 1:1	$CaCl_2$ Moist 8C1F 1:2	H_2O Moist 8C1F 1:1
		— — — — — — —PCT OF <2MM— — — — — —									
84 292	1	32	0.3	0.1	0.8	0.16	0.05	8.9	5.1		
84 293	2	24	0.3	0.1	0.7	0.05	0.05	9.3	5.6		
84 294	3	24	0.3	0.1	0.5	0.00	0.05	9.4	6.1		
84 295	4	22	0.4	0.1	0.3	0.00	0.05	9.6	6.0		
84 296	5	24	0.3	0.1	0.2			9.7	6.1		
84 297	6	24	0.3	0.1	0.2			9.8	6.4		

*New Zealand Procedure

CP84FN022

Sample No.	Hzn No.	FA 7B1A	RE 7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7B1A	7A2I	7A2I	7A2I	7A2I	7A2I	7A3	7A3	K_2O 6Q3A	Fe 6C7A
		(Mineralogy)																			
		(Optical)																			
		(Sand/Silt)											(X-RAY)					(DTA)		(Tot Anal)	
		(Clay)																			
		PCT											Relative Amounts					PCT			
84P 292	1												MT 4	VR 3	KK 3	CL 1	MI 1	KK23		0.7	6.9
84P 293	2												MT 5	VR 3	KK 3	CL 1	MI 1	KK17		0.7	7.8
84P 294	3												MT 4	VR 3	KK 3	CL 2	MI 1	KK18		0.9	7.1
84P 295	4												MT 4	VR 3	KK 3	CL 1	MI 1	KK18		0.7	7.3
84P 296	5												MT 4	VR 3	KK 3	CL 1	MI 1	KK19		0.7	7.5
84P 297	6																				

Analyses: S = All on Sieved <2MM Basis

Mineralogy: FA = Fraction Analyzed RE = Resistant

Kind of Mineral: CL = Chlorite MI = Mica MT = Montmorillonite VR = Vermiculite KK = Kaolinite

Relative Amount: 6 = Indeterminate 5 = Dominant 4 = Abundant 3 = Moderate 2 = Small 1 = Trace

Mineralogy Based on Sand/Silt:

Mineralogy Based on Clay:

Family Placement:

Comments on Philippine Data and Specific Pedons

RONALD D. YECK

Site data. Several locations show only general climatic data. Local input is needed to make all of this information as complete as possible for each site. Where latitude and longitude are shown only in degrees and minutes, they were estimated from maps and need to be refined. Also, missing elevation data should be added.

Field pH. These data shown on earlier descriptions have been deleted. The values appeared to be elevated but not uniformly. Apparently the water used with the field measurement varied in pH, giving the inconsistent results.

Indicators of volcanic influence. Several analyses were used jointly to assess the influence of volcanic materials. Sodium fluoride pH values in excess of 9.2 suggest amorphous materials, however the presence of free carbonates causes elevation of this pH, thus NaF pH is not a useful indicator when free carbonates are reported. Phosphorus absorption in excess of 85% also indicates volcanic components. High 15-bar to clay ratios (greater than about 0.6) are indicative of poor dispersion, in this case probably volcanically derived amorphous material. Presence of glass in the sand and silt fractions reported by optical mineralogy and micromorphology indicate volcanic influence. Halloysite in the clay fraction in association with glass does also. Some pedons have values reported for 15-bar water retention on samples that were air-dried, as well as ones that were retained field moist. The more these values differ, the larger the influence of components that dry irreversibly which may also relate to volcanic influence.

Additional data and rerun. Sodium fluoride pH was determined on all samples on which it had not been determined. Additional optical and clay mineralogy analyses were added to several pedons. Thus far, we have not related the plant opal to other soil properties or to management practices but hope to in the future. Some rerun analyses were made on selected samples for particle size analysis, organic carbon, 1/3-bar moisture retention, 15-bar moisture, and pH.

Classifications. The classification of pedons observed on the wetlands tour are discussed in the report of tour group A. If the classifications that follow are different, the reasons will be indicated.

S83FN-725-005, Calumpang. Fine-loamy, mixed, nonacid, isohyperthermic Aeric Tropaquept. Volcanic influence in this pedon is indicated by 15-bar: clay ratios larger than one, NaF pH values near 9, glass in the sand fraction, and halloysite in the clay fraction. The soils that this pedon represents are very responsive to nitrogen fertilization. Soil

physical properties are not restrictive to rooting. This is a very productive paddy rice soil.

S83FN-725-007, Maligaya. Fine, mixed, nonacid, isohyperthermic Vertic Tropaquept. Total to fine clay ratios do not support the presence of an argillic horizon. CEC: clay ratios suggest that the percent montmorillonite is 10% or more, thus making the mineralogy mixed instead of kaolinitic. Phosphorus and potassium additions are required in addition to nitrogen for a good yield response.

S83FN-725-008, Binangonan. Fine, montmorillonitic, isohyperthermic Udorthentic Pellustert. With sufficient water, this soil responds to both phosphorus and nitrogen fertilizer.

S83FN-725-009, Tagulod. Fine, mixed, nonacid, isohyperthermic Aeric Tropaquept. The Bw horizon has a high COLE value but there is insufficient additional evidence to place this pedon into the vertic subgroup. There are less than 50 cm with COLE larger than 0.9. This soil has high inherent fertility. It responds to nitrogen, but not to phosphorus or potassium fertilization.

S83FN-725-010, Maligaya. Fine, montmorillonitic, isohyperthermic Entic Pellustert. The color value is too high (greater than 3.5) for the typic subgroup. This pedon is from an area of long-term fertilizer trials. Some depletion of nutrients is indicated by lower levels of Ca, Mg, and K and lower percentage base saturation in the surface horizon. Nutrient depletion may occur in other plots but could be masked by floodwater rich in bases.

S83FN-725-012, San Manuel. Coarse-loamy, mixed, isohyperthermic Fluvaquentic Haplustoll. The high NaF pH in this pedon seems most attributable to the presence of free carbonates. This soil responds to nitrogen and has responded well to Azolla as nitrogen source.

S83FN-725-013, Bigaa. Fine, montmorillonitic, isohyperthermic Typic Pellustert. This pedon exhibits extremely strong properties characteristic of Vertisols. Slickensides occur in a horizontally oriented sinuous pattern, often referred to as "bow" structure. The surface manifestation of this property is undulation which is recognized as gilgai if they are not destroyed by cultivation. This is considered a good soil for paddy rice production despite some tillage difficulties. Inherent fertility is good and response to nitrogen fertilizer is also good. Traces of free carbonates may elevate the NaF pH values.

S83FN-725-022, Series Not Designated. Fine, mixed, isothermic Andic Palehumult. The surface particle size analysis was rerun and confirmed. Particle size distribution throughout is affected by poor dispersion. The surface horizon apparently was not formed in place but added, probably as local colluvium. There is clear evidence of slumping and colluvial action in the immediate area. Halloysite in the sand fraction is considered part of the resistant mineral suite because it does not weather to release nutrients for plant growth. This is a key factor in placing this pedon into the Pale great group and an interpretation with

which there is disagreement. The high P retention, acid oxalate, low bulk density, and NaF pH suggest this pedon is highly weathered volcanic material. The Andic subgroup is implied for this great group in Soil Taxonomy but not presently recognized.

S83FN-725-025, La Paz. Sandy, mixed, nonacid, isohyperthermic Aquic Ustifluvent. Although no volcanic influence is implied by the classification, this pedon contains considerable volcanic glass in the sand fractions. For a sandy soil, it has better than expected water retention properties, also a result of the influence of volcanic materials. This soil is considered very good for sugarcane production.

Farmers and researchers; the microregional formulation of a Land Pollution

Dr. [illegible] soil horizonation and [illegible] the [illegible] soil profile

APPENDICES

APPENDIX 1

Participants' Reports

REBECCA CAGMAT

The participants from the different colleges and universities are grateful to the organizers, resource persons, and most especially to the lecturers who did their best in sharing their skills and knowledge in Soil Taxonomy and agrotechnology transfer. We positively believe that these skills and knowledge we gain in this forum would be of great help in upgrading our respective capabilities in our threefold function: instruction, research, and extension. The field activity was very useful to us in instruction because we usually base our classification on theoretical description without actual observations and field descriptions. This may be due to several drawbacks in the system. In most cases manpower development is concentrated on other fields of soil science, like fertility and microbiology; taxonomy usually falls in the last priority for development. The topics on agrotechnology transfer and its relationship to soil taxonomy is quite new to us, and we were able to appreciate its importance especially in our extension activities. We are also thinking of incorporating this topic in our soil taxonomy courses.

In general, the forum was well-organized and the topics were very informative and varied. However, the group feels that the two-week period was too short for an extensive discussion of the topics. We suggest that another forum of this kind be conducted to include detailed explanations of the actual soil profiles and the interpretations of the data gathered.

The forum must include the first part/phase of soil survey i.e., the establishment of mapping units discussed in detailed exercises. The soil survey interpretations should not be chopped into different lectures but instead a continuous one-to-two day lecture. Following up a particular topic is quite difficult when there are topics discussed in between.

Profiles/pits for field trips must be in both upland and wetland. Not much discussions on upland soil profiles were (less profiles on upland were observed) made in this forum.

There were few speakers so that each speaker was assigned to discuss several topics. Although the lecturers were authorities in their respective fields, their number limited participant exposure.

LILIA OGUIS

This group is as dynamic and active as the politicians of this country. Why? It is because while we were busy classifying different soils from various areas in Luzon, politicians are also busy classifying or identifying their candidates for the incoming election on May 14. However, it seems that the politicians' job is a bit simple since political aspirants are classified only into 2 main categories — whether one is in or one is out of the group. On the other hand, our job is more complicated since we have to classify soils into 5 categories from the soil order to the family level.

Well, ladies and gentlemen, my task this morning is to give you the researchers' experience in this forum. So my piece is entitled "reflections". A word which is not common to researchers. But before that, let me give you some background information about myself as a researcher.

My first love is soils, and so my BSA major is Soil Science. My father is a farmer which probably accounts for my affinity to the soil. I was simply drawn to it. However, when I was still young, learning taxonomic terms was but a mechanical exercise — just like learning the basic concept of mathematics. Nevertheless, gentlemen and ladies, I passed my BS — with flying colors.

Fortunately, I landed a job as a researcher in the soil and agronomy division of PCA in Davao which gave the opportunity to further nurture my first love. At this time, the taxonomic terms started to be meaningful. I now regard soils as dynamic system which is affected to a large extent by the way man uses it.

Before I came here, I thought that most of the participants would be men since we usually associate soil classification with survey work which is definitely a man's job. I also thought that this type of training will be focused mainly on soil taxonomy. I was so excited to come here, not expecting to go down those sticky and muddy pits under the heat of the sun.

The first part of the training was so arranged that we learned first the theories, principles, and logic of soil taxonomy. I never thought we were to characterize muddy rice fields. It was when our field practice ended on the fourth day that I had a clearer view of what Soil Taxonomy was. In our coconut researches we do not give soil much emphasis. We use leaf analysis to determine the fertility status of the soil, based on the critical level of different nutrients. From different interactions in the field among ourselves and trainors, attitudes towards Soil Taxonomy had changed and more knowledge and skills were imbibed.

Recommendations and Suggestions

1. Monitor/evaluate the day-to-day progress of the training; a built-in feedback mechanism might be able to improve the teaching and

learning process.

2. Include exposure of trainees to laboratory work for them to actually observe how some of the data were obtained.
3. Include at the last part of the workshop session where all participants come up with bright ideas on how to operationalize vertical and horizontal linkages. I believe that we could do a lot if we share and pool our resources. The effects of this training, need not fade into oblivion. It must be sustained. This is the challenge to all of us.

Thank you.

ERNESTO ALVAREZ

My task now is to provide some feedbacks on this very important training program. It will be very difficult for me to precisely convey to you the individual reactions of each and every one of the participants, but based on personal interviews I have come up with a general assessment and recommendations that would hopefully be helpful in future training courses similar to this one. But before I go further, I would like to take this opportunity to express my gratitude to the supporting agencies, in general, and to the distinguished resource speakers, in particular, for making our stay both pleasant and rewarding.

The PCARRD Secretariat attended closely to our personal needs during the entire period of the training program. This personal comfort contribute greatly to the physical and mental health, and consequently, to the learning efficiency of the participants.

The lecturers were knowledgeable and presented their topics comprehensively.

The field trips were very educational, and provided the participants not only with the opportunity to have direct contact with the soil and have a general grasp of field problems concerning profile description, but also with a chance to see beautiful places or spots, like Baguio.

The sequence of subject matter presentation was generally good. However, it would have been better if the participants were given lectures on soil analysis and soil-survey interpretation before the field tour since these two important topics are closely relevant to profile description and soil classification.

We believe that there is a need for a follow-up program (Phase II) that will deal more on soil analyses, soil survey and interpretation (including map-making) and management of the soil. Moreover, this program would give us a chance to assess its impact on our respective research programs and discuss the problems related to our research activities during the period.

I hope that the above comments or recommendations may in some measure, help in the planning of future programs similar to this one.

Finally, we are grateful for all the benefits we have received from

this forum. We assure you that these experiences and knowledge will reach the real beneficiaries (farmers) in due time in terms of management packages that would be responsive to their welfare and needs.

Thank you.

RAUL LARA

I would like to express my satisfaction on the result of this forum. I did not expect that it would be as intensive and as loaded with much information as this one.

The training module was expertly designed to meet the training needs of the participants. Lectures, as well as field trips were so provided as to give us a well-planned practical learning and theoretical experience about soil taxonomy and agrotechnology transfer. The resource persons were experts and authorities in their assigned subjects.

We also had excellent accommodations and well-arranged field trips. I enjoyed the company of my fellow participants who were all enthusiastic about the lectures and field work.

However, I feel that the forum was too short for such a subject as soil taxonomy and agrotechnology transfer. The lectures should have been longer, and there should have been more exercises in soil survey interpretation. As I saw it, we only worked on the interpretation of some laboratory data. There were times when we did not agree on some terms especially on the key to Soil Taxonomy. A longer forum would enable us to be more confident on soil survey interpretation.

On field tours the pits were mostly in rice areas. Other fields should have been included, particularly on problem soils of rainfed areas which represent a big hectarage in the country's cultivated areas.

Furthermore, in order for us to be able to formulate and implement proposed projects related to the things we learned in this forum, there is a need for a similar session for our office heads (not in the Bureau of Soils). This will make them better appreciate and our projects move them to be more supportive of our work on this aspect.

Lastly, I would like to thank the organizers, speakers, and all those involved in this fruitful forum. We are returning to our respective work more aware of the importance of soil taxonomy and agrotechnology transfer. Rest assured we will always do our best with what we have learned in this forum.

NESTOR MERJILLA

As one of the participants of this forum on soil taxonomy and agrotechnology transfer, I would like to extend my heartfelt appreciation and thanks to the management and staff of PCARRD, SMSS, and BS; to the lecturers and resource persons; and to my mother agency, the Bureau

of Soils, for sending me to this fruitful seminar for my professional development as a soil surveyor.

We were indeed enlightened on the various topics discussed. For me, the past twelve days moved very fast and seemed such a very short period. To me, a neophyte on the system of taxonomic classification, it was really a fruitful gathering.

As a soil technologist at the Bureau of Soils, I thought I had already learned a lot about soil taxonomy, but now I am only beginning to realize how important it is to technology transfer.

Inasmuch as twelve days is too short for a more thorough knowledge about soil taxonomy, it would be of great help to us if a follow-up forum would be conducted in the near future, to keep us updated with techniques and methodologies.

We, the participants are aware of development, innovations, and possibilities in our fields, and with this little knowledge learned from the forum, we will be able to develop a working knowledge for our jobs as soil surveyors.

It is indeed important to know more about soils and classify them for maximum agriculture and non-agriculture uses. This would be a great contribution to us and to the nation's thrust for self-sufficiency.

Thank you.

APPENDIX 2

Forum Summary

MODESTO R. RECEL

Eleven days ago, participants from different institutions entered this room bewildered but inquisitive about Soil Taxonomy. Some were heard saying why and what those funny-looking long taxa names were all about. However, on our way back from the field trip, they were heard saying that, "one can tell almost all the properties of a soil if one can understand the meaning of such lengthy names".

Such a dramatic change in attitude, I believe, is a very convincing evidence of a fruitful end to this forum.

This forum was carefully planned through the leadership of Dr. Amado Maglinao of PCARRD and Director Godofredo Alcasid, Jr. of the Bureau of Soils in coordination with Dr. Hari Eswaran of the SMSS in Washington D.C.

The first three and a-half days was the presentation of the logic, principles, and mechanics of Soil Taxonomy. After understanding how the system works, the participants were exposed to a five-and-a-half days of field practicum in the provinces of Laguna, Rizal, Nueva Ecija, Pangasinan, Benguet, and Pampanga. In that exercise, no one was spared from getting down into the profile pit, muddy or dry, to feel the soil, look for mottles and clay skins, and other visible properties of the soil. The experience, I believe, was rewarding. Here, participants were given the chance to apply the keys to Soil Taxonomy. They were so hungry with everything about the system that despite the hectic days work under the hot sun, they still managed to stay late in the night preparing for the next day's activity.

They organized themselves so effectively that although some were chemists, crop specialists, researchers, and university instructors, they were doing excellent jobs in classifying the profiles. In the last three days of the forum, after being able to apply the principles of Soil Taxonomy, they were oriented on the important uses of the system with particular emphasis on agrotechnology transfer.

Finally, to evaluate the whole activity, they were required to submit a written report of the classification of their respective study sites. Lately, the participants decided to continue this exercise in their respective areas of assignments and requested another similar forum for dryland soils. This is, no doubt, a healthy sign that Soil Taxonomy is here to stay.

This Forum could not have been a success without some key individuals. We are indeed fortunate to have with us one of the best minds in the world on Soil Taxonomy, in the person of Dr. Hari Eswaran. We have

also with us Dr. Ron Yeck, a well known soil scientist of the National Soil Survey Laboratory of the Soil Conservation Service in Nebraska and Dr. Bernardino Cagauan Jr. of the University of Hawaii who shared with us one of the richest information on agrotechnology transfer.

The support of the USAID through the SMSS should also be recognized. Special appreciations are also due to our forum coordinators, Ester Vergara and Theody Metra and also Odie Ilao, all PCARRD staff who were constantly with us, seeing to it that nutritious meals were served (although someone complained there were no vegetables in the menu); and that we had restful nights (although almost everybody wallowed in their own sweat and got bitten by mosquitoes during the brown-outs); and travelled in an airconditioned bus made comfortable with PG and X movies.

I would like also to recognize the serious efforts of Mr. Art Dayot, Cris Alcalde of the Bureau of Soils, and Dr. Martin Raymundo who prepared the best profile pits ever seen by Dr. Eswaran (although someone almost drowned when he fell in a deep, old, profile pit nearby in Laguna; and Hari was so unhappy because he was not able to shot a souvenir picture).

The lectures, of course had a great part in making the forum more meaningful. Above all, I would like to thank the participants for their unending enthusiasm, sincere interest, and fine discipline throughout the duration of the forum.

A few hours from now, 31 participants will got out of this room as "disciples" of Soil Taxonomy — "Go forth, therefore, and spread the good news".

Remember, however, that this is just the beginning. The great challenge awaits us to classify our Philippine soils. This forum attests that the technology is with us, but perhaps this is not enough. The mechanism of implementing a nationwide classification program has to be re-examined to insure that the task is placed in the right hands. From experience in this forum, we know that Soil Taxonomy is a system that requires tremendous field activity and considerable time, effort, and logistics to generate the quantitative data in the laboratory.

Some institutions are attempting to take the leadership in this activity, but I believe that the Bureau of Soils has the necessary manpower, the technical capability, and the equipment needed to launch a nationwide "taxonomization" of our soils. With the Bureau of Soils leading and with the sincere cooperation of other qualified institutions, I believed that Soil Taxonomy will become the primary system of classification in this country within a reasonable period of time.

Thank you.

APPENDIX 3

Commendations and Recommendations

Commendations

Proposed by: CARMELITA B. INCILLO
Bureau of Soils

Seconded by: CLARITA D. BACATIO
Bureau of Soils

We, the participants of the 7th International Forum on Soil Taxonomy and Agrotechnology Transfer, commend the Philippine Council for Agriculture and Resources Research and Development (PCARRD), the Bureau of Soils (BS) and the Soil Management Support Services (SMSS) for organizing this forum. We also gratefully acknowledge the contributions of the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) and the support provided by the United State Agency for International Development (USAID)

The new knowledge which we gained during this two-week workshop is very timely. We can use this knowledge immediately in our respective jobs. The training materials which consisted of books, technical publications, and Munsell color charts which were provided to us, made this training even more lasting. This package of references is invaluable and will sharpen our skills tremendously in applying this new knowledge on our own.

We also commend the instructors, namely: Drs. Hari Eswaran of SMSS; Ron Yeck of the National Soil Survey Laboratories of the Soil Conservation Service, US Dept. of Agriculture; and Bernie Cagauan Jr. of IBSNAT, University of Hawaii.

Our commendation also goes to the resource speakers, namely: Dr. Rodrigo Badayos, Dr. L.R. Oldeman, Dr. Modesto Recel, Dr. Martin Raymundo, Dr. Rogelio Concepcion, Mr. Alex Baloloy, Dr. Eduardo Hombrebueno, Dr. Wilfredo Cosico, Dr. Genaro San Valentin, and Dr. Romeo Obordo.

To the farmers, heads of research stations and universities go our appreciation for digging the soil pits and providing accommodations and meals during our field trips. To Cris Alcalde, Art Dayot, and Tony Marqueses of the Bureau of Soils go our special thanks for coordinating soil profiles in the various areas which are visited.

Last, but not least, we wish to record our appreciation for the support given by Dr. Amado R. Maglinao of PCARRD; Director Godofredo N.

Alcasid Jr. of the Bureau of Soils; and Dr. Ramon V. Valmayor, Executive Director of PCARRD for making this forum possible. The efforts of the following personnel of PCARRD is gratefully recognized for making all the logistic and workshop arrangements: Ms. Ester C. Vergara, Ms. Theody M. Metra, Ms. Redia N. Atienza, Ms. Digna G. Orduña, Mr. Carlos J. Andam, Ms. Teresa F. Samala, Mr. Expie Huelgas, Ms. Carina Cabral, Ms. Normita Exconde, Ms. Cynthia D. Sevilla, Mr. Alexander Iranzo, Ms. Carmen Javier, Ms. Noemi Solpico, Ms. Helen Amurao, Mr. Tomasito Aquino, Ms. Maria Reyna Quisumbing, Ms. Pura Lastimosa, Mr. Rudy Timog, Mr. Vic Caparas, Mr. Rico Gabatin, Mr. Francisco Palapala, Mr. Alex Palacpac, Mr. Cesar Frias, Mr. Narciso Banaag, Mr. Arthur Mariño, Mr. Vic Oro and Mr. Ramir Quintos.

Recommendations:

Proposed by: JOSIAS P. LABITIGAN
Bureau of Soils

Seconded by: TEODORO A. REYES JR.
ISU, Echague, Isabela, Philippines

Realizing that Soil Taxonomy is the system of soil classification used in many countries of the world; noting that the Philippines has a national commitment to classify the soils according to this system; and appreciating the fact that this system provides the basis for agrotechnology transfer;

We, the participants of the 7th Forum strongly urge PCARRD and the Bureau of Soils to organize a follow-up Forum in 1985 with the collaboration of SMSS and IBSNAT. We believe that such a training program is essential to strengthen the soil scientists of Philippines and maintain our contacts with the soil scientists of the United States.

Proposed by: GAVINA M. HUELGAS
BPI-MA, Lipa City

Seconded by: ANABELLA T. BAUTISTA
PRCRTC, VISCA, Leyte

Knowledge of the soils in the Philippines is crucial to the increase in agricultural productivity of the country and to the attainment of our goal for self-sufficiency in food and fiber production. We appreciate and commend the Bureau of Soils and other institutions in the Philippines for the challenging task they have undertaken and the contributions they have already made.

We the participants of the 7th Forum would like to contribute to this

national efforts and propose a follow-up activity for the characterization and classification of some soils in our specific regions of responsibilities. We believe that in addition to contributing to the national data base, this exercise will also form a part of our training.

We would like to urge PCARRD and the Bureau of Soils to support this activity and provide the necessary facilities to bring it to a successful completion. We would also like to propose that the activity be conducted in collaboration with SMSS and IBSNAT.

Proposed by: LILIA OGUIS
PCA, Bago-Oshiro, Davao City

Seconded by: ANTONIO A. MARQUESES
Bureau of Soils
Manila

Considering the need for standardized soil analysis for the purpose of soil classification for agrotechnology transfer, not only in the Philippines but also in the whole Southeast Asian Region, we, the participants to the 7th International Forum on Soil Taxonomy and Agrotechnology Transfer propose a training in this area with the support and participation of SEARCA in organizing this training workshop. This workshop will have as its major purpose, the creation of awareness and skill in soil analysis as an integral part of the development and exploitation of soil and land resources, which will eventually result in making funds available by national governments for the establishment of soil analysis laboratories and for the training of manpower to man these laboratories.

Proposed by: EUGENIO D. ORPIA JR.
CRDI, Batac, Ilocos Norte

Seconded by: JOSE BALAOING
MSAC, La Trinidad, Benguet

Realizing the importance of laboratory data in the accurate characterization of soils, not only for Soil Taxonomy but also for general use in research and agrotechnology transfer, we propose that the Bureau of Soils, with PCARRD providing the logistic support, conduct a project on interlaboratory crosschecks throughout the country. It will cover laboratories of all research centers and cooperating stations within the PCARRD network. The project, if implemented, will work on calibration of equipment, standardization of methods, and short trainings for the laboratory staff

APPENDIX 4

Directory of Participants

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APPENDIX 5

Program

Monday, 12 March 1984

0800	Registration	
0900	National Anthem	
0905	Opening Remarks	Dr. Alfonso N. Eusebio Deputy Executive Director for Research, PCARRD
0920	Short Talk	
	Bureau of Soils	Dir. Godofredo N. Alcasid Jr. Director, BS
	SMSS	Dr. Hari Eswaran Project Coordinator SMSS, USDA
0950	Orientation of Participants	Dr. Amado R. Maglinao Director, FRSRD PCARRD
1000	BREAK	
1030	Purpose and Scope of Forum	Dr. Hari Eswaran
1100	Basic Concepts and Philosophy of Soil Taxonomy	Dr. Hari Eswaran
1200	LUNCH	
1400	Diagnostic Horizons, Epipedon	Dr. Hari Eswaran
1500	BREAK	
1530	Diagnostic Horizon, Subsurface Horizons	Dr. Rodrigo Badayos
1730	ADJOURN	
1800	Cocktail-Buffet Reception	

Tuesday, 13 March 1984

0800	Climate of the Philippines	Dr. L.R. Oldeman
0900	Soil Moisture and Temperature Regimes	Dr. Ronald Yeck
1000	BREAK	
1030	Diagnostic Properties	Dr. Hari Eswaran

1130	Histosols and Spodosols	Dr. Ronald Yeck
1230	LUNCH	
1330	Key to Soil Order	Dr. Hari Eswaran
1400	Andisols	Dr. Modesto Recel
1500	Oxisols and Vertisols	Dr. Hari Eswaran
1600	BREAK	
1630	Ultisols and Alfisols	Dr. Rodrigo Badayos
1730	ADJOURN	

Wednesday, 14 March 1984

0800	Visit UPLB Soils Laboratory	
1000	BREAK	
1030	How to Classify Soils	Dr. Hari Eswaran
1230	LUNCH	
1400	Inceptisols and Entisols	Dr. Modesto Recel
1500	Soil Families	Dr. Hari Eswaran
1600	BREAK	
1630	Soils of the Philippines	Dr. Martin Raymundo
1730	ADJOURN	

Thursday, 15 March 1984

Field Trip and On-Site Demonstration and Practice

0800	Site 1: Calauan, Laguna	Pedon No. S83FN-725-005
1030	Site 2: Famy, Laguna	Pedon No. S83FN-725-007
1200	LUNCH	
1330	Site 3: Teresa, Rizal	Pedon No. S83FN-725-008

Friday, 16 March 1984

0900	Site 4: Gapan, Nueva Ecija	Pedon No. S83FN-725-009
1200	LUNCH	
1400	Site 5: Maligaya, Muñoz, Nueva Ecija	Pedon No. S83FN-725-010
1600	Tour of Central Luzon State University Carnpus	

Saturday, 17 March 1984

0900	Site 6: Carranglan, Nueva Ecija	Pedon No.

1230	LUNCH	
1430	Site 7: Binalonan, Pangasinan	Pedon No. S83FN-725-012

Sunday, 18 March 1984

0800	Site 8: MSAC, La Trinidad Benguet	Pedon No.
1030	Site 9: Irisan, Benguet	Pedon No. S83FN-725-022
1230	LUNCH	

Monday, 19 March 1984

0900	Site 10: Mangaldan, Pangasinan	Pedon No. S83FN-725-013
1330	LUNCH	
1430	Site 11: Angeles, Pampanga	Pedon No. S83FN-725-025
1800	End of Field Trip	

Tuesday, 20 March 1984

0800	Principles and Concepts of Agrotechnology Transfer	Dr. Bernardino Cagauan Jr.
0900	Principles of Soil Survey Interpretation	Dr. Ronald Yeck
1000	BREAK	
1030	Land Evaluation	Dr. Rogelio Concepcion
1130	Benchmark Soils Project Principles and Concepts	Dr. Bernardino Cagauan Jr.
1200	IBSNAT	Dr. Bernardino Cagauan Jr.
1230	LUNCH	
1330	Soil Potential and Crop Performance	Dr. Hari Eswaran
1400	Methodology for Agrotechnology Transfer in the Philippines	Dr. Martin Raymundo
1500	Benchmark Soils Project Experimental Aspects	Dr. Bernardino Cagauan Jr.
1600	BREAK	
1630	Results of Benchmark Soils Project (Philippines)	Dr. Martin Raymundo
1730	ADJOURN	

Wednesday, 21 March 1984

0800	Soil Survey Interpretation	Dr. Ronald Yeck
0900	Problems with Low Activity Clay Soils	Dr. Modesto Recel
1000	BREAK	
1030	Properties and Management of Soils Planted to Rice	Dr. Martin Raymundo
1130	Soil Survey Interpretation	Dr. Ronald Yeck
1230	LUNCH	
1400	Visit to International Rice Research Institute	

Thursday, 22 March 1984

0800	Soil Analyses for Soil Classification	Dr. Hari Eswaran
0900	Properties and Management of Soils Planted to Sugarcane	Dr. Eduardo Hombrebueno
1000	BREAK	
1030	Properties of Soils in Coconut Areas	Dr. Wilfredo Cosico
1130	Properties and Management of Soils for Corn Production	Dr. Genaro San Valentin
1230	LUNCH	
1400	Soil Taxonomy Exercises	Dr. Ronald Yeck

Friday, 23 March 1984

0800	PCARRD Slide Story	
0830	SEARCA and its Role in ASEAN Agriculture	Dr. Romeo Obordo
0900	Commendation and Recommendations	
0930	BREAK	
1030	Participants' Report	
1120	Forum Summary	Dr. Modesto Recel
1135	Awarding of Certificate	Dr. Ramon V. Valmayor Executive Director, PCARRD

1140	Closing Remarks	Dr. Hari Eswaran Project Coordinator SMSS, USDA Dir. Godofredo Alcasid, Jr. Director, BS Dr. Ramon V. Valmayor Executive Director, PCARRD
1230	LUNCH	