Stanley Morain Dep. Exhs.
10/26/81
DD 2541(1-11)
Extra

RESUMÉ FOR

STANLEY A. MORAIN
(Certified Photogrammetrist)

April 1981

EDUCATION

Ph.D. Geography, University of Kansas, Lawrence, 1970

B.A. Geography, University of California, Riverside, 1963

EMPLOYMENT

1979 - Present. President, EarthScan International, Inc., Albuquerque, New Mexico.

1976 - Present. Director, Technology Application Center and Associate Professor of Geography, University of New Mexico, Albuquerque, New Mexico.

1974 - 1976. Manager, Natural Resources Program, Technology Application Center.

1970 - 1974. Assistant Professor and Research Associate, The University of Kansas Center for Research Remote Sensing Laboratory.

INTERNATIONAL SHORT COURSES AND WORKSHOPS
(last 5 years)

April, 1980. USAID Mission to Senegal with South Dakota State University. Workshop on Remote Sensing. Dakar, Senegal.

October, 1979. USAID with South Dakota State University. Workshop on Remote Sensing. Khartoum, Sudan.

September, 1979. USAID Mission to Costa Rica. Evaluation of Remote Sensing Project work in Natural Resources. San Jose, Costa Rica.

April, 1979. USAID Mission to Nepal. Prepare Project Paper on National Remote Sensing Training Center. Kathmandu, Nepal.

February, 1979. USAID Design Team to Central America. Design parameters for Regional Remote Sensing Training Center. San Jose, Costa Rica.

May, 1978. USAID with South Dakota State University. Workshop on Remote Sensing. Kathmandu, Nepal.

DEFT. EX. DD-2541
DATE: 10/26/81
REPORTER: A. J. GASDOR

July, 1976. UN/FAO Seminar on Applications of Remote Sensing for Natural Resources Survey, Planning and Development. University of Reading, England.

February, 1976. Thailand Remote Sensing Training Project. U.S. State Department and USGS/OIG. Bangkok, Thailand.

February, 1976. Introductory Remote Sensing Workshop. U.S. State Department, USGS/OIG and UNDP. Kathmandu, Nepal.

PANELS, COMMITTEES AND SELECTED CONSULTING
(last 5 years)

PANELS:

March, 1980. Witness for U.S. House of Representatives Committee on Science and Technology. Albuquerque, New Mexico.

August, 1976. NASA Active Microwave User's Workshop. Design of SEASAT/SAR Experiments. Houston, Texas.

COMMITTEES AND OFFICES HELD:

Correspondent for Commission VI, International Society of Photogrammetry and Remote Sensing, 1980 - 1984.

Chairman, Student Affairs Committee, American Society of Photogrammetry, 1980.

Chairman, Education Committee, American Society of Photogrammetry, 1979 - Present.

Chairman, Subcommittee on Textbooks, Committee on Education and Interpretive Skills, American Society of Photogrammetry, 1978 - 1980.

Chairman, Committee on Education and Interpretive Skills, Remote Sensing and Interpretation Division, American Society of Photogrammetry, 1976 - 1978.

Past President, Rio Grande Chapter, American Society of Photogrammetry.

Member, New Mexico State Land Use Advisory Committee, 1975 - 1978.

Member, Remote Sensing Committee, Association of American Geographers, 1975 - 1978.

Deputy Director and Technical Program Chairman, American Society of Photogrammetry, Fall Convention, October, 1978.

New Mexico Interagency Range Committee, 1976 - 1978.

SELECTED CONSULTING:

Agency for International Development, Office of Science and Technology. Design projects in Southeast Asia and Central America; and research design for global deforestation program.

University Space Research Association, Peer Review Support Office.

Washington University, St. Louis, Department of Engineering. Five-state survey on remote sensing applications.

Asia Foundation, "The Contribution of Satellite Data in Estimating Agricultural Output in Laos."

REMOTE SENSING PUBLICATIONS
(10 most relevant selected from over 35)

Contributor to New Mexico in Maps, published by the University of New Mexico. Williams & McAllister, eds. Maps and texts for Soils of New Mexico; Vegetation of New Mexico; and Land Use of New Mexico, 1980.

Morain, S.A. and B. Klankamsorn, "Forest Mapping and Inventory Techniques Through Visual Analysis of Landsat Imagery: Examples from Thailand." Proceedings of the 12th International Symposium on Remote Sensing of Environment, Manila, The Philippines, April 20-27, 1978.

Morain, S.A. with S. Wacharakitti, "Procedures for Land Use Analysis in Developing Countries: Examples from Southeast Asia." Proceedings of the 12th International Symposium on Remote Sensing of Environment, Manila, The Philippines, April 20-27, 1978.

Morain, S.A. with R. Hooley and R. Hoffer, "Estimating Agricultural Production by the Use of Satellite Information: An Experiment with Laotian Data," Amer. Jour. Agric. Econ., 59(4): 722-727, 1977.

Morain, S.A., Radar Image Interpretation. Chapter III in "Remote Sensing Laboratory Exercises," ed. by R.D. Rudd, Remote Sensing of the Electromagnetic Spectrum, 4(1):10-17, 1977.

Morain, S.A., "Mapping New Mexico's Resources: Toward Better Management Through Remote Sensing." Symposium on Remote Sensing and Land Management in the South and Southwest. Texas A&M University, pp. 65-80, 1976.

Morain, S.A. and D.L. Williams, "Wheat Production Estimates Using Satellite Images," Agronomy Journal, 67:361-364, 1975.

Morain, S.A., "Phenology and Remote Sensing," Phenology and Seasonality Modeling, ed. Helmut Lieth, Springer Publishers, pp. 55-75, 1974.

Morain, S.A. and J.B. Campbell, "Reconnaissance Soil Surveys Using Radar Imagery," Proceedings Soil Science Society of America, 38(5):818-826, 1974.

Simonett, D.S. and S.A. Morain, "Remote Sensing from Spacecraft as a Tool for Investigating Arctic Environments," Arctic and Alpine Environments, ed. by H.E. Wright, Jr., and W.H. Osburn, Indiana University Press, pp. 295-306, 1967.

Biographical Sketch

Dr. Stanley A. Morain

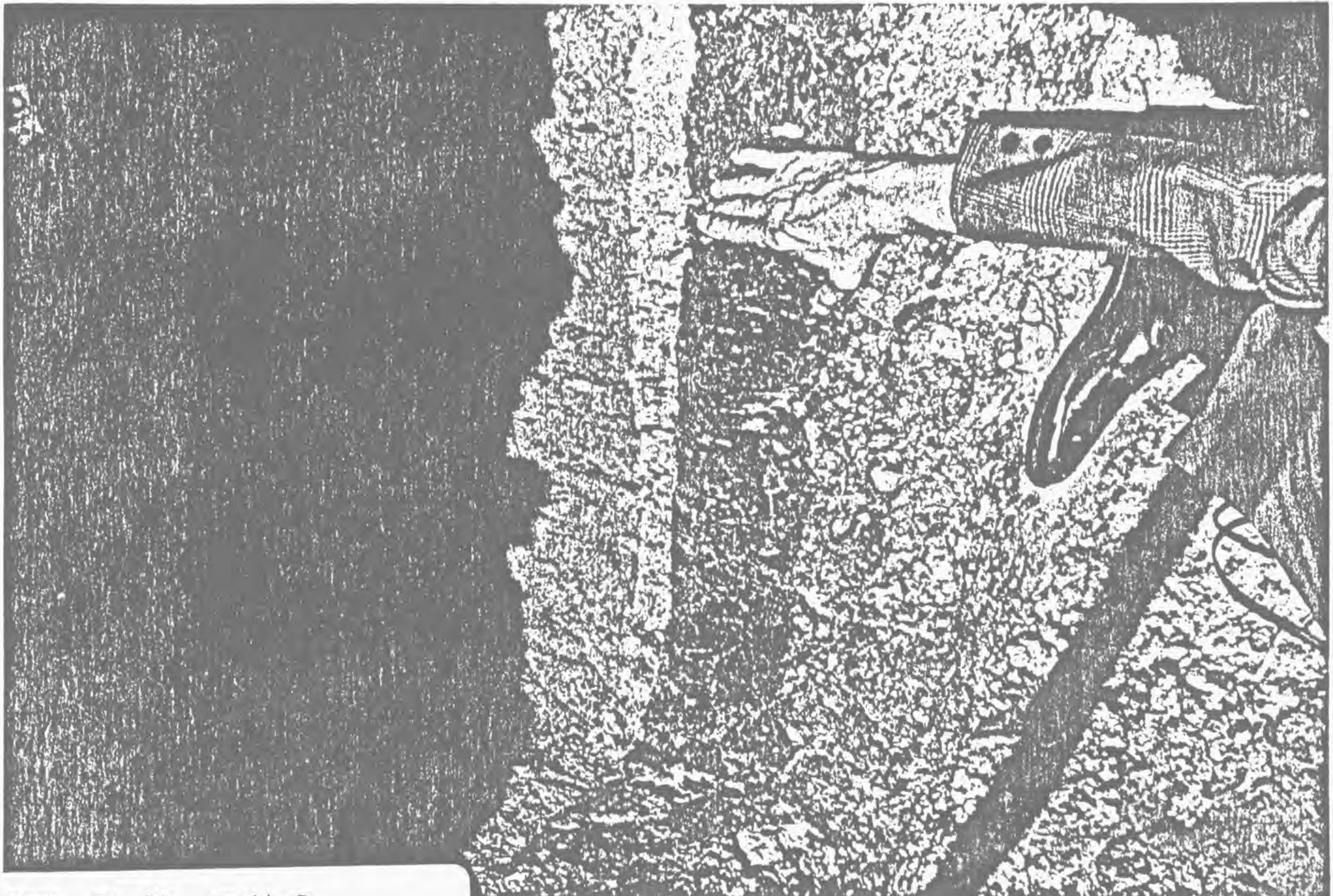
Dr. Morain received his Ph.D from the University of Kansas in 1970 with a research emphasis on applications of satellite and radar technology for natural resources inventory. His first appointment was to the Center for Research Incorporated as a research associate where he assisted in the proof of concept for satellite-based crop inventories. In 1974 he relocated to the University of New Mexico Technology Application Center (TAC) as a program manager for Remote Sensing and Natural Resources. Since then he has concentrated on transferring this NASA generated technology to the public and private sectors in the Southwest, and has become a regular participant to international efforts to assist Developing Countries in Asia, Africa, and Latin America to adopt the technology in their resource inventories.

In 1976 Dr. Morain was appointed Director of TAC which, in addition to the Remote Sensing Division, includes an Industrial Division and a Business/Accountability Division. Through these expanded responsibilities he has become widely familiar with the technical needs of the small business community and the various mechanisms of technology transfer and innovation.

ASP Activities

1.	Past President, Rio Grande Chapter	1977-1978
2.	Deputy Director and Technical Program Chairman, ASP Fall Technical Meeting, Albuquerque, New Mexico	1978
3.	Chairman, Committee on Education and Interpretive Skills, RSD	1976-1978
4.	Chairman, Subcommittee on Textbooks, Committee on Education, RSD	1978-1980
5.	Chairman, Ad Hoc Committee on Student Affairs	1980-present
6.	Chairman, Education Committee, ASP	1979-present
7.	Correspondent for Commission VI, ISP	1980-1984
8.	Program Planning Committee for Thermosense I, II, III	1978, 1979, 1980
9.	ASP Representative to Pecora VII Program Planning Committee	1981

DEFT. EX. DD-2541-1
DATE: 10/26/81
REPORTER: ALBERT J. GASDOR



DEFT. EX. DD-2541-2
DATE: 10/26/81
REPORTER: ALBERT J. GASDOR

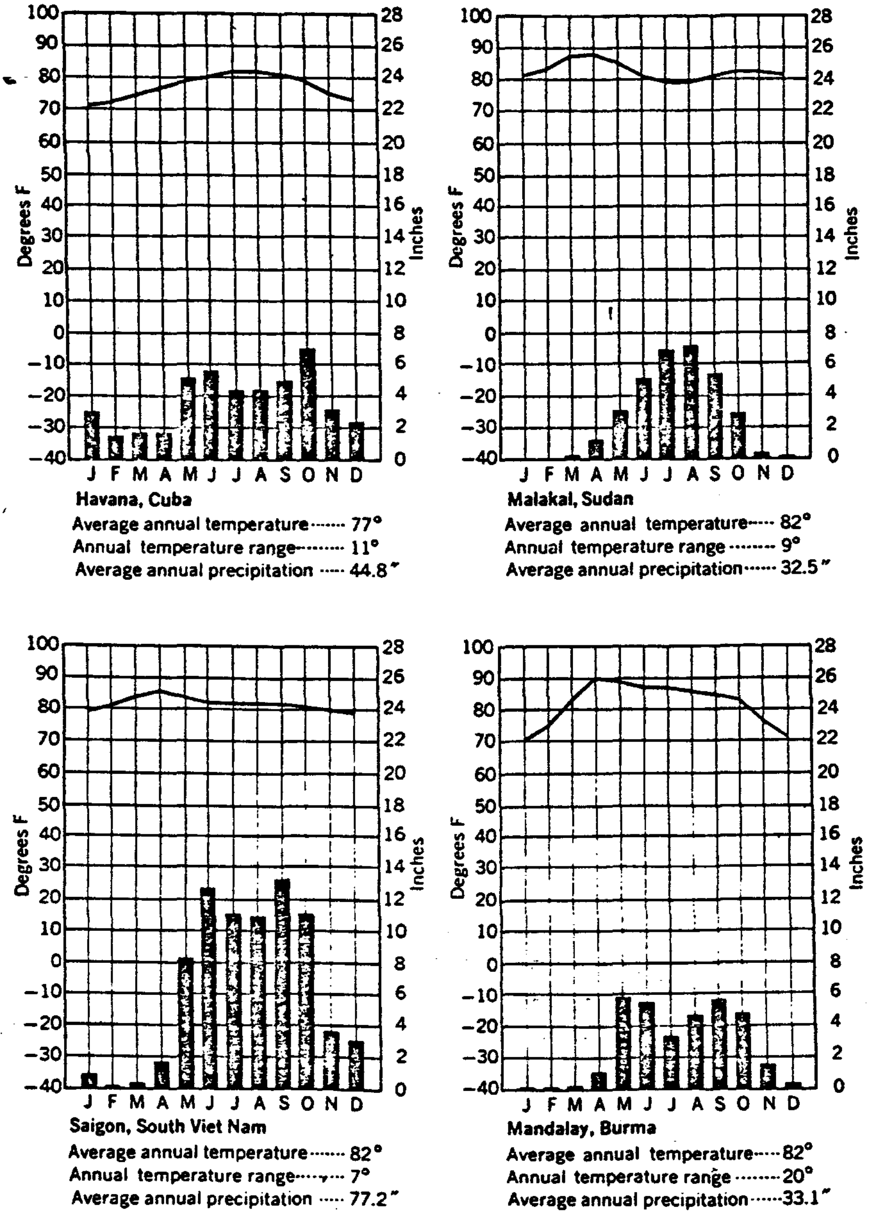


Fig. 8-5. Climatic graphs for Havana, Malakal, Saigon, and Mandalay, all wet-and-dry tropical stations.

DEFT. EX. DD- 2541-11

DATE: 12/20/81

REPORTER: ALBERT J. GASDOR

1:1,000,000

Dense fore

Rừng rậm, rừng tái sinh hỗn hợp
Dense forest and secondary forest closely mixed

Rừng tái sinh
Secondary forest

Rừng thưa
Clear forest

Tre
Bamboo

Thông
Pine forest

Đồng cỏ
Mountainous grasslands

Thảo mộc trên bãi cát bờ biển
Vegetation of sand dunes on the sea shores

Lùm bụi
Brushwood

Rừng Sát và bần
Mangroves

Rừng tràm
«Tram» forest

Đồn điền các loại cây kỹ nghệ và cây ăn trái
Plantation : industrial plants and orchards

Đồn điền cao su
Plantation : rubber

Đồn điền cà phê
Plantation : coffee

Đồn điền trà
Plantation : tea

Ruộng lúa, ruộng màu, vườn cây
Rice fields, dry crop, fruit tree

Cây cỏ sinh lầy
Swamps vegetation

Cây cỏ sinh lầy Đồng Tháp Mười
Vegetation of swamp areas in Đồng Tháp Mười

Cây cỏ sinh lầy vùng Hậu Giang
Vegetation of swamp areas in Mekong delta

DEFT. EX. DD- [illegible]
DATE: 10/26/[illegible]
REPORTER: ALBERT J. GASDOR

LEGEND
LÉGENDE

Undifferentiated alluvial soils.
Sols alluviaux, non différenciés.

Saline alluvial soils.
Sols alluviaux salins.

3 Acid alluvial soils (acid sulphate soils).
Sols alluviaux acides (sols sulfatés acides).

Very acid alluvial soils (strongly acid sulphate soils).
Sols alluviaux très acides (sols sulfatés très acides).

5 Brown alluvial soils of the river levees.
Sols alluviaux bruns des berges.

6 Regosols on white and yellow dune sand.
Régosols sur sable dunal blanc et jaune.

7 Regosols on old red sand.
Régosols sur sable rouge ancien.

8 Shallow regurs and latosols, generally shallow, on basalt; variable topography.
Régurs squelettiques et latosols généralement peu profonds, sur basalte ; topographie variable.

9 Non calcic brown soils on acid rocks; undulating to rolling topography.
"Non calcic brown soils" sur roches acides ; topographie ondulée à fortement ondulée.

10 Non calcic brown soils on old alluvial sediments ; plane to undulaling topography.
"Non calcic brown soils" sur alluvions anciennes ; topographie plate à ondulée.

11 Sandy podzolic soils on acid rocks ; plane to rolling topography.
Sols podzoliques sableux sur roches acides ; topographie plate à fortement ondulée.

12 Red and yellow podzolic soils on acid rocks ; plane to rolling topography.
Sols podzoliques rouges et jaunes sur roches acides ; topographie plate à fortement ondulée.

Red and yellow podzolic soils on old alluvial sediments ; plane to undulating topography.
Sols podzoliques rouges et jaunes sur alluvions anciennes ; topographie plate à ondulée.

Gray podzolic soils on old alluvial sediments ; plane to undulating topography.
Sols podzoliques gris sur alluvions anciennes ; topographie plate à ondulée.

Low humic gley soils on old alluvial sediments ; plane topography.
"Low humic gley soils" sur alluvions anciennes ; topographie plate.

16 Podzolic soils and regurs on old alluvial sediments ; plane to undulating topography.
Sols podzoliques et régurs sur alluvions anciennes ; topographie plate à ondulée.

17 Complex of podzolic soils on old alluvial sediments and alluvial soils ; plane to undulating topography.
Complexe de sols podzoliques sur alluvions anciennes et de sols alluviaux ; topographie plate à ondulée.

18 — Complex of mountainc ɔils, mostly red and yellow podzolic soils and hosolic soils.
Complexe de sols montagneux, généralement sols podzoliques rouges et jaunes sols squelettiques.

19 — Reddish brown latosols on basalt ; plane to rolling topography.
Latosols brun-rouge sur basalte ; topographie plate à fortement ondulée.

20 — Red and yellow latosols on basalt ; undulating to rolling topography.
Latosols rouges et jaunes sur basalte ; topographie ondulée à fortement ondulée.

21 — Earthy red latosols on basalt ; undulating to rolling topography.
Latosols rouges terreux sur basalte ; topographie ondulée à fortement ondulée.

Shallow latosols on basalt ; plane to undulating topography.
Latosols squelettiques sur basalte ; topographie plate à ondulée.

23 — Reddish brown latosols and red latosols on basalt ; rolling topography.
Latosols brun-rouge et latosols rouges sur basalte ; topographie fortement ondulée.

24 — Reddish brown latosols and compact brown latosols on basalt ; plane to rolling topography.
Latosols brun-rouge et latosols bruns compacts sur basalte ; topographie plate à fortement ondulée.

25 — Peat and muck soils.
Sols tourbeux.

SPECIAL SYMBOLS – *SYMBOLES SPÉCIAUX*

L L L — Frequent occurrence of lateritic concretions near the surface.
Présence fréquente de concrétions latéritiques près de la surface.

▲ ▲ ▲ — Frequent occurrence of alluvial and related hydromorphic soils.
Présence fréquente de sols alluviaux et de sols hydromorphes apparentés.

E. M. BRIDGES
Lecturer in Geography at
University College of
Swansea

WORLD SOILS

CAMBRIDGE · AT THE UNIVERSITY PRESS · 1970

10 INTRAZONAL AND AZONAL SOILS

Although the zonal soils considered in the previous chapters have their development influenced by all the factors of soil formation, that of climate exerts an overriding influence producing a pattern which is roughly comparable with the climatic zones. Within the various zones are areas of well-developed soils, which reflect, however, the local dominance of a single factor such as parent material or drainage conditions. When a particular type of parent material exerts a strong influence over soil formation, as in the case of limestones, soils with *calcimorphic* characteristics are developed. In a similar manner, the continued presence of water in the soil causes the development of the features of gleying associated with *hydromorphic* soils. The presence of soluble salts in the soil confers upon it chemical, physical and biological features which require a special consideration in any classification. These are the *halomorphic* soils. These three groups of soils, calcimorphic, hydromorphic and halomorphic, form the main divisions of the intrazonal order of soils. Already they have been mentioned in the consideration of the associated zonal soils, but for completeness they are considered together in this chapter.

Calcimorphic soils

The stability conferred upon a soil as the result of the presence of calcium has already been commented upon (p. 13). This property, together with the slightly alkaline pH values, results in a particular profile form and justifies the classification of calcimorphic soils as intrazonal. The profile of a soil on a limestone, compared with an adjacent soil on a non-calcareous parent material, is usually less leached and lacks strong horizon differentiation.

Several features of calcareous soils make them distinct from brown earths with which they can be linked in a maturity sequence. In the first place, the vegetation growing upon these soils is usually a form which produces a leaf-litter which is rich in bases. Thus, there is a continual return of bases to the surface of the soil. Secondly, the faunal population of these soils is numerous, encouraged by the more nutritious leaf-litter. Thirdly, the presence of calcium-saturated clays and free calcium carbonate in the soil inhibits the movement of soil constituents by the formation of stable calcium compounds which remain flocculated. Fourthly, because of their stability these soils are usually fairly rich in organic matter, have black or dark reddish-brown colours and stable structural aggregates in the form of crumb or blocky peds. Lastly, because they are formed upon rocks which have little insoluble residue, these soils are usually shallow and have low moisture reserves. As they occur over limestone, calcareous soils are invariably freely drained; however, on calcareous boulder clays transitional soils to hydromorphic soils occur, called calcareous gley soils. The two main types of profile seen are the *rendzina* and the *brown calcareous soil* (Fig. 7.9). The name rendzina, which is derived from a Polish peasant name, is widely used. Soils of this nature are described from almost all parts of the world from the temperate regions to the humid tropics. Brown calcareous soils are described from Britain and Europe, where there is some overlap with the name brown forest soils.

The rendzina is a shallow soil rich in organic matter and biological activity. It has a stable crumb structure and is dark in colour. It is a relatively simple soil with an A horizon directly overlying a C horizon which is the limestone parent material. The humus is well incorporated in the mull form, and micro-morphological evidence shows that these soils are largely composed of the faecal pellets of soil arthropods and the casts of earthworms (Plate 28).

Profile of a rendzina from the Hartz foothills, Germany
(Parent material – chalk)

A	0–25 cm.	Brownish-black, strongly humose, calcareous stony clay loam with crumb structure
C	25 cm.+	Greyish-white, laminated fissured chalk

(After Muckenhausen)

Profile of a brown calcareous soil from Nottinghamshire, England
(Parent material – Permian limestone)

Ap	0–23 cm.	Dark reddish-brown (5YR3/2) sandy loam with occasional angular fragments of limestone and rounded quartzite stones; fine to medium sub-angular blocky structure; friable; moderate amount intimate organic matter; abundant fibrous roots; sharp boundary
(B)	23–35 cm.	Reddish-brown (5YR4/2) sandy clay loam with occasional fragments of limestone and rounded quartzite stones; weak medium sub-angular blocky structure; friable organic matter confined to earthworm channels; calcareous; sharp boundary
C	35 cm.+	Weathering limestone

(After E. M. Bridges)

Brown calcareous soils are characteristically formed over Jurassic limestones in Britain, but they are also described from Africa, U.S.A. and other areas of the world. These soils develop on limestones with a larger insoluble residue, and therefore they become deeper than the rendzina having a (B) horizon developed between the A horizon with its mull humus and the limestone C horizon. The A horizon is usually dark reddish-brown, crumb structured and moderately rich in organic matter, with a neutral or slightly acid reaction. The (B) horizon is distinguished by a more ochreous coloration caused by stable iron compounds. Although these soils are deeper than the rendzinas, they are seldom more than 75 cm. from the surface to the rock beneath. This gives them greater moisture reserves, and they are considered to be good agricultural soils.

Because of their shallowness, both rendzinas and brown calcareous soils may not have supported dense vegetation in the past. In Britain, the rendzina is typical of the downland of south-east England, but examples can be seen also where erosion has reduced the depth of soils on other limestones. Areas of brown calcareous soils in Britain were probably scrub woodland and many limestone districts still bear the name 'heath' as in the county of Lincolnshire. It is only in relatively recent times that these soils have proved to be excellent arable soils.

Hydromorphic soils

Poor drainage can be observed in the soils of most regions of the world and as such represents the most widely spread of the processes of soil formation, leading to the formation of *gley* or *hydromorphic soils*. Often these soils are analogous with soils of similar parent material on freely drained positions of the landscape, and a complete range from freely-drained to poorly-drained soils can be seen (Fig. 5.3). Hydromorphic soils can be found in association with all zonal soils, anywhere in fact where water can gather in sufficient volume and for sufficient time to produce the effects of gleying.

Gleying occurs when water saturates a soil, filling all the pore spaces and driving out the air. Any remaining oxygen is soon used by the microbiological population, and anaerobic conditions are established. At the same time, the soil water contains the decomposition products of organic matter. In the reducing conditions brought about by the absence of oxygen and in the presence of organic matter, iron compounds are chemically reduced from the ferric to the ferrous state. In the ferrous form iron is very much more soluble, and is removed from the soil leaving the colourless minerals behind. This gives gley soils their characteristic grey coloration.

Hydromorphic soils can be sub-divided into those which have continually saturated conditions, and those which have a temporary period of saturation only. Generally, this division distinguishes those soils with a permanent water-table within the soil from those that are slowly permeable. European pedologists have referred to the former as *gley soils*, and the latter as *pseudogley soils*. In Britain these have been called *ground-water gley* and *surface-water gley* soils.

Surface-water gley soils are those in which the drainage is impeded above an impervious or very slowly permeable sub-soil horizon (Fig. 10.1 and Plate 29). This leads to the development of grey colours along the fissures and pores of the soil, particularly in the B horizon and the lower parts of the E horizon. Usually these soils are developed from fine-grained parent materials in which clay movement has taken place to form a textural B horizon. However, not all surface-water gley soils have clay skins in their B horizons, and the calcareous gley soils in particular differ from them in this way.

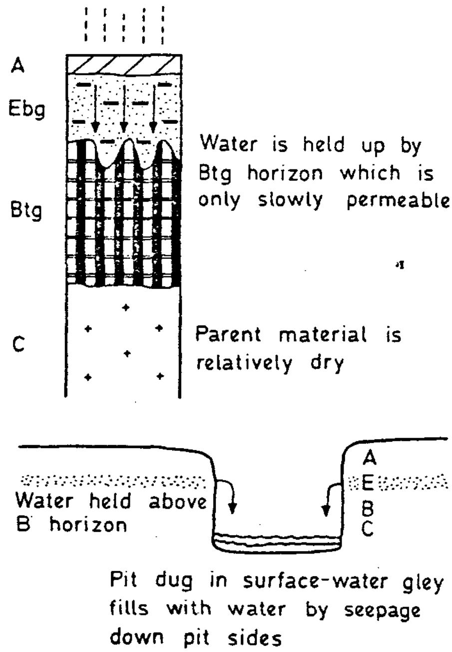
Profile of a surface-water gley soil from Derbyshire, England

(Parent material – glacial drift)

L		Discontinuous litter of beech, sycamore and oak leaves
F	2·5–0·5 cm.	Comminuted leaf fragments, darker and more humified towards the base of the horizon
H	0·5–0·0 cm.	Black amorphous humus
A	0·0–1·5 cm.	Very dark grey (10YR3/1) stoneless sandy loam with bleached sand grains; medium sub-angular blocky structure; friable; high amount organic matter; abundant fibrous roots; narrow irregular boundary
Eb	1·5–23 cm.	Brown (10YR5/3) slightly stony sandy clay loam with medium sub-angular blocky structure; common woody roots; narrow boundary
Ebg	23–35 cm.	Mottled yellowish-brown (10YR5/4) to strong brown (7.5YR5/8), with greyish-brown (10YR5/2) on structure faces; slightly stony sandy clay loam with medium angular blocky structure; firm; low amount organic matter, few roots; earthy iron and manganese concretions; narrow boundary
Bg	35–75 cm.	Dark brown (7.4YR4/4) mottled to pale olive (5Y6/3) on structure faces; slightly stony clay with coarse prismatic structure; firm, plastic when wet; low amount organic matter, few roots; black manganiferous patterning; merging boundary
Cg	75 cm.+	Dark brown (7.5YR4/4) mottled to pale olive (5Y6/3) stony firm clay with structure no longer obvious; firm, plastic when wet; no visible organic matter, no roots; slightly calcareous

(After Bridges)

Most gley soils may become aerated occasionally in the event of a prolonged drought. As a result they may have the colours of ferric iron



10.1 Diagrammatic profile of a surface-water gley soil

compounds present as a mottling in the Bg horizons. Gleying can best be seen along the fissures and pores where the effects are most concentrated; the internal parts of the peds often remain aerated and in the ferric state. In the A horizon of most gley soils, grass roots frequently become coated with iron in the form of rusty sheaths.

Ground-water gley soils include those in which there is a water-table which rises to within 60 cm. of the soil surface (Fig. 10.2). Usually these soils are formed from rather permeable parent materials such as alluvial sands and gravels which overlie an impervious sub-stratum upon which water accumulates. Therefore, these soils occur in the lower parts of the landscape and are often transitional to organic soils. In the natural state these soils have well-developed grey colours caused by continual anaerobic conditions, but as many of these have been artificially drained mottling can often be seen.

Halomorphic soils

In semi-arid and arid parts of the world soils are developed under the influence of soluble salts or with sodium as the dominant exchangeable

The Geography of Soils

formation, distribution, and management

DONALD STEILA

East Carolina University

Prentice-Hall, Inc., Englewood Cliffs, New Jersey

INCEPTISOLS

The Inceptisols include soils of widely differing environments in which a variety of pedogenic processes are operative. Some are weathered sufficiently to produce altered horizons that have lost either bases or iron and aluminum, but still retain weatherable minerals. At the same time they normally lack illuvial horizons that have been enriched with either silicate clays containing aluminum or amorphous mixtures of aluminum and organic carbon. Smith refers to these soils as "primarily eluvial," that is, losing material throughout the profile.[3] Inceptisols are generally found in humid climates where leaching is active (Figure 6.6). In short, Inceptisols are beginning to exhibit pedogenic characteristics associated with weathering, but these features are too weak to be considered maturely developed.

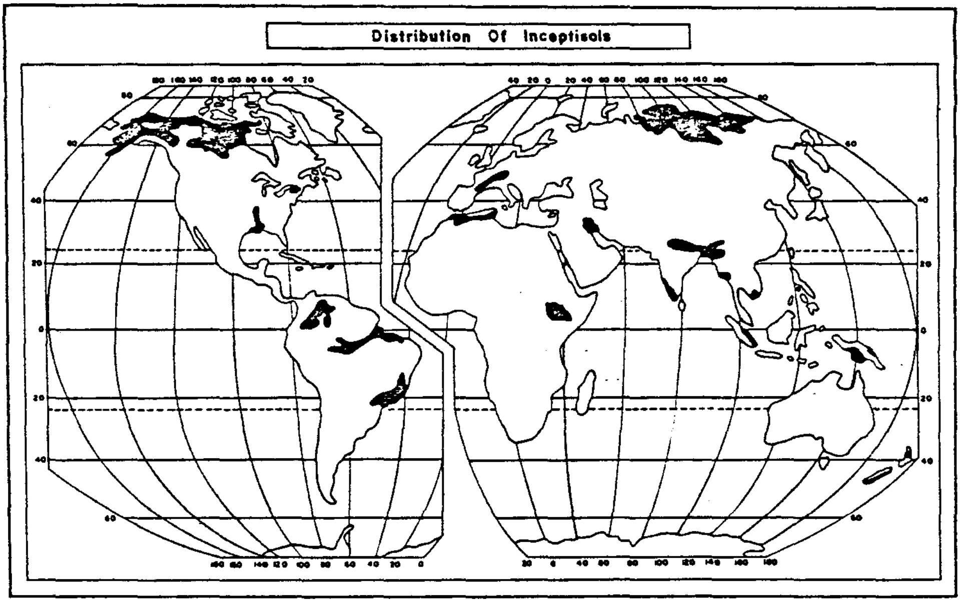


Figure 6.6 World distribution of Inceptisols.

There are six suborders of Inceptisols (Figure 6.7):

1. *Andepts* are relatively freely drained. They have a low bulk density and are usually formed in pyroclastic materials (such

[3] Guy D. Smith, "Lectures on Soil Classification," *Pedologie*, IV (Ghent, Belgium: State University of Ghent, 1965), 33.

INCEPTISOLS

These soils have altered horizons that have lost bases or iron and aluminum but retain weatherable minerals and that lack illuvial horizons either enriched with silicate clays that contain aluminum, or those enriched with amorphous mixtures of aluminum and organic carbon.

ANDEPTS

Inceptisols that are relatively freely drained and have appreciable amounts of allophane or pyroclastic materials.

Cryandepts are the cold Andepts of high mountains or high latitudes.

Durandepts have a duripan within 40" of the surface.

Dystrandepts have large amounts of organic carbon and amorphous materials, and a small amount of bases.

Eutrandepts have large amounts of organic carbon and amorphous materials, and an ample supply of bases.

Hydrandepts have perudic moisture regimes.

Placandepts have placic horizon.

Vitrandepts have the largest amounts of vitric ash and pumice and the lowest amounts of their weathering products.

AQUEPTS

These are wet Inceptisols with poor drainage.

Andaquepts are formed in pyroclastic materials.

Cryaquepts are found in arctic and subarctic regions.

Fragiaquepts have a fragipan.

Halaquepts are sodic and saline soils.

Haplaquepts are light colored, gray Aquepts, mostly of humid climates.

Humaquepts are nearly black or peaty, very wet, acid Aquepts.

Placaquepts have a placic horizon.

Plinthaquepts have plinthite present.

Sulfaquepts are acid sulfate soils.

Tropaquepts are found in the tropics.

OCHREPTS

Inceptisols that are freely drained and light in color.

Cryochrepts are found in the cold areas of high mountains or high latitudes.

Durochrepts have a duripan in the upper 40".

Dystrochrepts are brownish, acid soils of humid and perhumid regions.

Eutrochrepts are brownish, base rich soils of humid regions.

Fragiochrepts have a fragipan.

Ustochrepts are found in subhumid to semiarid regions.

Xerochrepts are found in Mediterranean climates.

PLAGGEPTS

Inceptisols that have a plaggen epipedon composed of crystalline rather than pyroclastic materials.

TROPEPTS

Inceptisols that are freely drained, brownish to reddish, and found in intertropical regions.

Dystropepts are acid Tropepts of high rainfall regimes.

Eutropepts have high base saturation and are rarely dry for extended periods.

Humitropepts are found in cool humid regions of high altitude.

Sombritropepts are dark, humus rich Tropepts of perhumid cool, hilly or mountainous regions.

Ustropepts are base rich Tropepts of subhumid regions.

UMBREPTS

Inceptisols which are acid, dark reddish or brownish, freely drained, and organic rich.

Cryumbrepts are found in high latitudes or high altitudes.

Fragiumbrepts have a fragipan.

Haplumbrepts are freely drained and have either a short or no dry season during the summer.

Xerumbrepts are found in Mediterranean climatic regimes.

as volcanic ash or pumice), although certain sedimentary and basic extrusive igneous rocks can also serve as the parent material. Andepts are rich in either glass or allophanes, such as amorphous clays. Glass is a unique parent material in that it is relatively soluble in comparison to the crystalline aluminosilicates, and weathers rapidly to produce amorphous products. Found in any latitude, the location of these soils is restricted to areas in or near mountains with active volcanoes. Repeated ash falls are quite common in Andepts, and these soils may have two or more buried horizons within 40" (1 meter) of the surface.

2. *Aquepts* (L. *aqua*, water) are wet Inceptisols. The natural drainage of these soils is poor or very poor and the ground water table usually stands close to the surface at some time during the year. The surface horizons are dominantly gray to black, and subsurface horizons are dominantly gray.
3. *Ochrepts* (Gr. *ochros*, pale) are light-colored, brownish, and relatively freely drained Inceptisols of middle to high latitudes. They are formed in crystalline parent materials and in a moisture regime with an annual excess of precipitation over evapotranspiration.
4. *Plaggepts* (Ger. *plaggen*, sod) include all freely drained soils that contain a plaggen epipedon, except for a few Andepts:

The plaggen epipedon is a man-made surface layer, more than 50cm thick, that has been produced by long-continued manuring. In medieval times, sod or other materials were commonly used for bedding livestock and the manure was spread on the field being cultivated. The mineral materials brought in by this kind of manuring eventually produced an appreciably thickened Ap, as much as 1 meter or more in thickness.

Colors and contents of organic carbon depend on the sources of the materials used for bedding. If the sod was cut from the heath, the plaggen epipedon tends to be black or very dark gray, to be rich in organic matter, and to have a wide carbon-nitrogen ratio. If the sod came from forested soils, the plaggen epipedon tends to be brown, to be lower in organic matter, and to have a narrower carbon-nitrogen ratio.

The plaggen epipedon may be identified by several means. Commonly it contains artifacts, such as bits of brick and pottery throughout. Chunks of diverse materials, such as black and light gray sand as large as the size held by a spade, may be present. The plaggen epipedon normally shows spade marks throughout as well as remnants of thin stratified beds of sand that were probably produced on the surface by beating rains and later buried by spading. The polypedons that have plaggen epipedons tend to be straight-sided rectangular bodies, and they are usually higher than adjacent polypedons by as much or more than the thickness of the plaggen epipedon.[4]

5. *Tropepts* (Gr. *tropikos*, of the solstice) are found within the tropics and include freely drained Inceptisols that are brownish to reddish in color. They normally have an ochric epipedon or a cambic horizon and lack significant amounts of active amorphous clays or pyroclastic materials. Within this soil's climatic regime:

Biologic activity is continuous unless there is a pronounced dry season. Cultivated soils cannot remain bare and exposed to erosion for long periods, for if there is rain the plants start to grow. The continuous biologic activity is reflected in the nature of the organic matter in at least two important ways. One is that for any given kind of soil, C-N ratios tend to be lower in tropical than temperate regions. C-N ratios of virgin soils in the humid tropics compare with those of Aridisols in temperate regions; often they are extremely low. The other difference is that the amount of organic matter is not well reflected by the color of the soil. Black soils may have little organic matter; light-colored soils may be very rich in organic matter, or very poor.[5]

6. *Umbrepts* (L. *umbric*, shade) are acidic, dark reddish or brown, freely drained, organic rich Inceptisols that occur in humid regions of the middle to high latitudes. These soils have much more organic matter than the Ochrepts, but their base saturation is too low to classify them as Mollisols. They occur in hilly to mountainous regions with relatively high precipitation, even though many experience a distinct dry season during the summer.

LAND-USE AND MANAGEMENT PROBLEMS

Because they occur in varied sites and climates on a multitude of parent materials, Entisols, Vertisols, and Inceptisols have many uses and pose many diverse management problems. The most significant of these soils, in terms of areal occurrence, are the

[4] National Cooperative Soil Survey, *Soil Taxonomy*, pp. 3-6.
[5] Smith, "Soil Classification," p. 41.

Vertisols, the Entisol suborders Aquents, Fluvents, and Psamments, and the Inceptisol suborder Aquepts. Just as water is the primary agent in the formation of the aquic and fluvial suborders (Aquents, Aquepts, and Fluvents), its management is also a major factor in making these soils agriculturally productive. Under natural conditions most have supported a forest cover of water-tolerant trees. When the lands are cleared for agricultural purposes, flooding and poor drainage pose a constant threat to the stability of the crop yields and are the chief causes of crop failure unless surface and subsurface drainage systems and flood control measures are effectively employed to remove and regulate the surplus water.

Crops grown on these immature soils include: cotton, soybeans, corn, oats, wheat, barley, sugarcane, rice, and vegetables. The success of crop production after drainage is largely dependent upon the physical condition of the soil and the availability of nutrients for plants.

The primary factors that are detrimental to the soil's physical properties are: loss of organic matter, erosion, inadequate drainage, improper management practices, and equipment traffic.[6] In areas of relatively high temperatures and surplus moisture (such as the Mississippi Delta region), organic materials rapidly decompose when aerated. As a consequence, such soils lose a major portion of their original organic matter shortly after being brought under cultivation. This results in reduced stability of soil structure, decreased water infiltration, and increased surface runoff. The same conditions responsible for the depletion of organic material also create difficulties in replenishing or maintaining this soil component.

Although the landscapes of the aquic and fluvial environments normally have gentle slopes, erosion can be a serious problem.

> Most of the organic matter was in the top few inches and has been most affected by erosion. Furthermore, the ratio of sand, silt, and clay in the surface soil provided better physical conditions than the deeper soil. The removal of the surface layer by sheet erosion leaves material with less desirable physical properties exposed or near the surface.[7]

Man's manipulation of these soils may also lead to their deterioration. If cultivated when too wet, soil structure may break down. In other instances, *pressure pans* may develop from the

[6] The following summary of land-use and management problems is largely derived from Perrin H. Grissom, "The Mississippi: Delta Region," *The 1957 Yearbook of Agriculture: Soil* (Washington, D.C.: U.S. Govt. Ptg. Office, 1957), pp. 524-30.

[7] Ibid., p. 527.

movement of heavy equipment over wet ground.[8] The resulting compacted layer resists the vertical movement of water and root penetration. Consequently, plants may suffer from too much water during rainy periods and from a lack of moisture during interprecipitation periods. One possible solution is *deep tillage*, or subsoiling, which temporarily eliminates the compacted zone. When deep tillage is practiced on compacted soils, the water infiltration rate, field capacity, and root development all increase and crop yields are generally higher.

Many farmers, in an attempt to improve the physical condition of their soil, have grown winter legumes, which they plow under prior to planting a summer crop. This reduces erosion, and increases organic matter and available nitrogen.

As is true with all soils, the availability of nutrients to meet plant demands is an additional factor in the management of the aquic and fluvial lands. The usual primary deficiencies are nitrogen, phosphorus, potassium, and lime. Nitrogen is required for practically all nonleguminous crops, and may be supplied either by crop rotations that include legumes or by commercial inorganic materials. Generally, it is more economical to use commercial nitrogen on cultivated crops.

Psamments may be stabilized sand dunes or soils developed on sandy deposits. In most instances they are of extremely limited agricultural use. Due to the soil's low moisture-holding capacity and low organic content, coupled with a deficient nutrient supply, potential crop yields are usually low. Psamments' primary use has been for livestock grazing, although in favored climates some soils have been modified by man and now support truck farms and citrus groves.

Vertisols have their maximum occurrence between latitudes 45° North and South, and are most extensively developed in Australia, India, and the Sudan.

> Agriculturally the soils have great potential where power tools, fertilizers, and irrigation are available. The natural fertility level can be considered quite high, although the use of nitrogen and phosphorus is beneficial. Tillage of the soil is difficult with primitive tillage tools. The "blacklands" of Texas and Alabama are some of the best agricultural lands in the

[8] A pressure pan is a subsurface horizon or soil layer having a higher bulk density and a lower total porosity than the soil directly above or below it, as a result of pressure that has been applied by normal tillage operations or by other artificial means. It is frequently referred to as plow pan, plow sole, and traffic pan.

United States. Worldwide Vertisols are used mainly for cotton, wheat, corn, sorghum, rice, sugarcane, and pasture.[9]

The major problems with using Vertisols relates to their high shrink-swell capacity. The stress created by the alternate expansion and contraction of their clays has been known to crack building foundations and road surfaces, and to be a menace to grazing animals that may be injured by stepping into cracks in the soil.

THE NATURE AND PROPERTIES OF SOILS

SEVENTH EDITION

HARRY O. BUCKMAN
Late Professor of Soil Technology Emeritus, Cornell University

NYLE C. BRADY
Professor of Soil Science and Director of Research and Director of the Cornell University Agricultural Experiment Station

REVISED BY NYLE C. BRADY

The Macmillan Company / Collier-Macmillan Limited, London

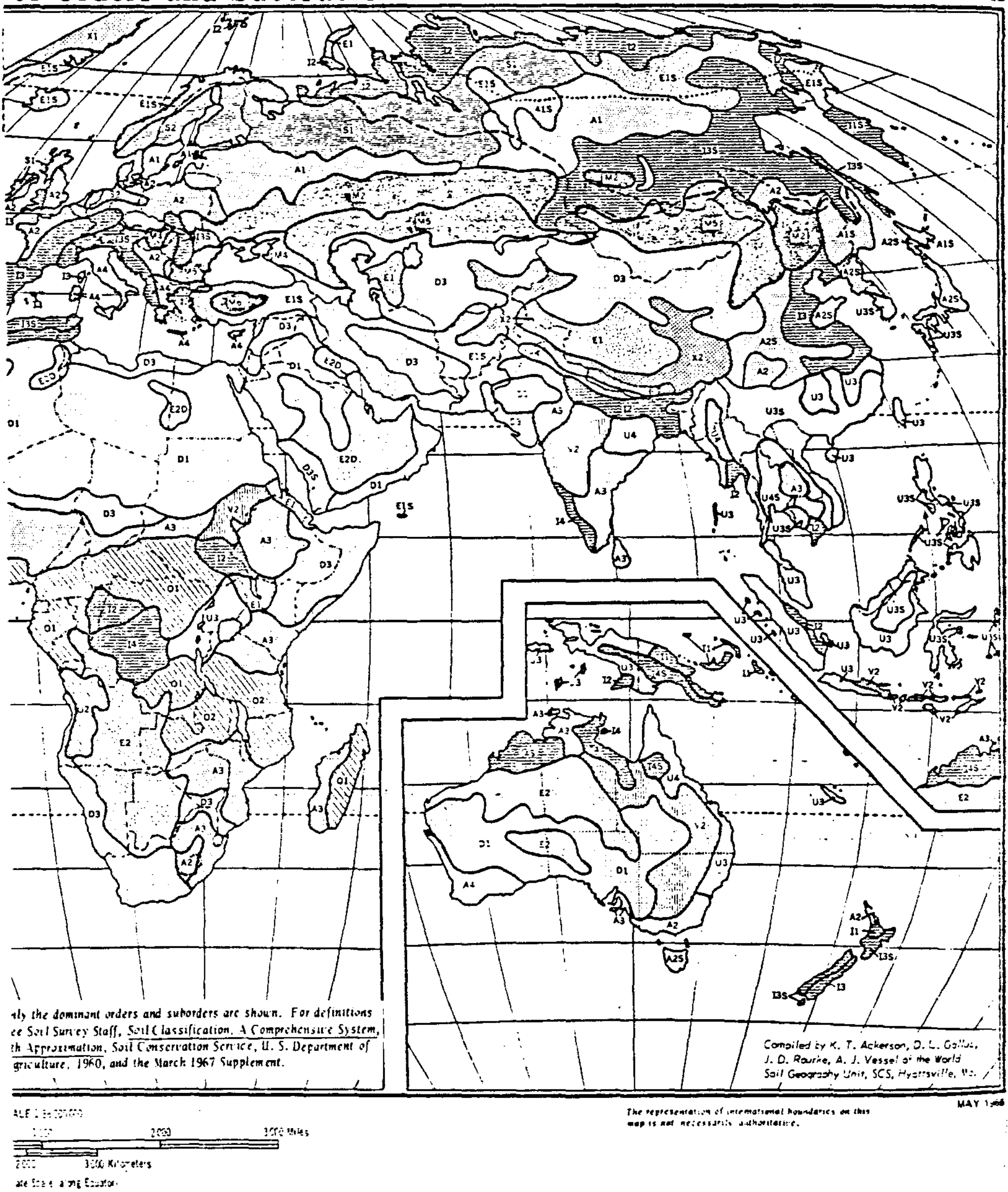
Table 12:2. The Names of Soil Orders in the New Comprehensive Soil Classification System, Their Derivation, and Approximate Equivalents in the Old System.

	Formative Element[a]		
Name[b]	*Derivation*	*Pronunciation*	*Approximate Equivalents in the old system*
Entisol	Nonsense symbol	rec*ent*	Azonal, some Low-Humic Gley soils
Vertisol	L. *verto*, turn	in*vert*	Grumusols
Inceptisol	L. *inceptum*, beginning	in*cept*ion	Ando, Sol Brun Acide, some Brown Forest, Low-Humic Gley, and Humic Gley soils
Aridisol	L. *aridus*, dry	ar*id*	Desert, Reddish Desert, Sierozem, Solonchak, some Brown and Reddish Brown soils and associated Solonetz
Mollisol	L. *mollis*, soft	mo*ll*ify	Chestnut, Chernozem, Brunizem (Prairie), Rendzinas, some Brown, Brown Forest, and associated Solonetz, and Humic Gley soils
Spodosol	Gk. *Spodos*, wood ash	*Pod*zol; odd	Podzols, Brown Podzolic soils, and Groundwater Podzols
Alfisol	Nonsense symbol	Ped*alf*er	Gray-Brown Podzolic. Gray Wooded, and Non-Calcic Brown soils, Degraded Chernozems, and associated Planosols and some Half-Bog soils
Ultisol	L. *ultimus*, last	*ult*imate	Red-Yellow Podzolic soils, Reddish-Brown Lateritic soils of the U.S., and associated Planosols and Half-Bog soils
Oxisol	F. *oxide*, oxide	*ox*ide	Laterite soils, Latosols
Histisol	Gk. *histos*, tissue	*hist*ology	Bog soils

[a] The italicized letters in the pronunciation column are used in the suborder and great group categories to identify the order to which they belong.
[b] Note that all orders end in sol (L. *solum*, soil).

THE WORLD
of Orders and Suborders

SOIL CONSERVATION SERVICE



nce of orders and suborders according to the new
.S. Soil Conservation Service.)

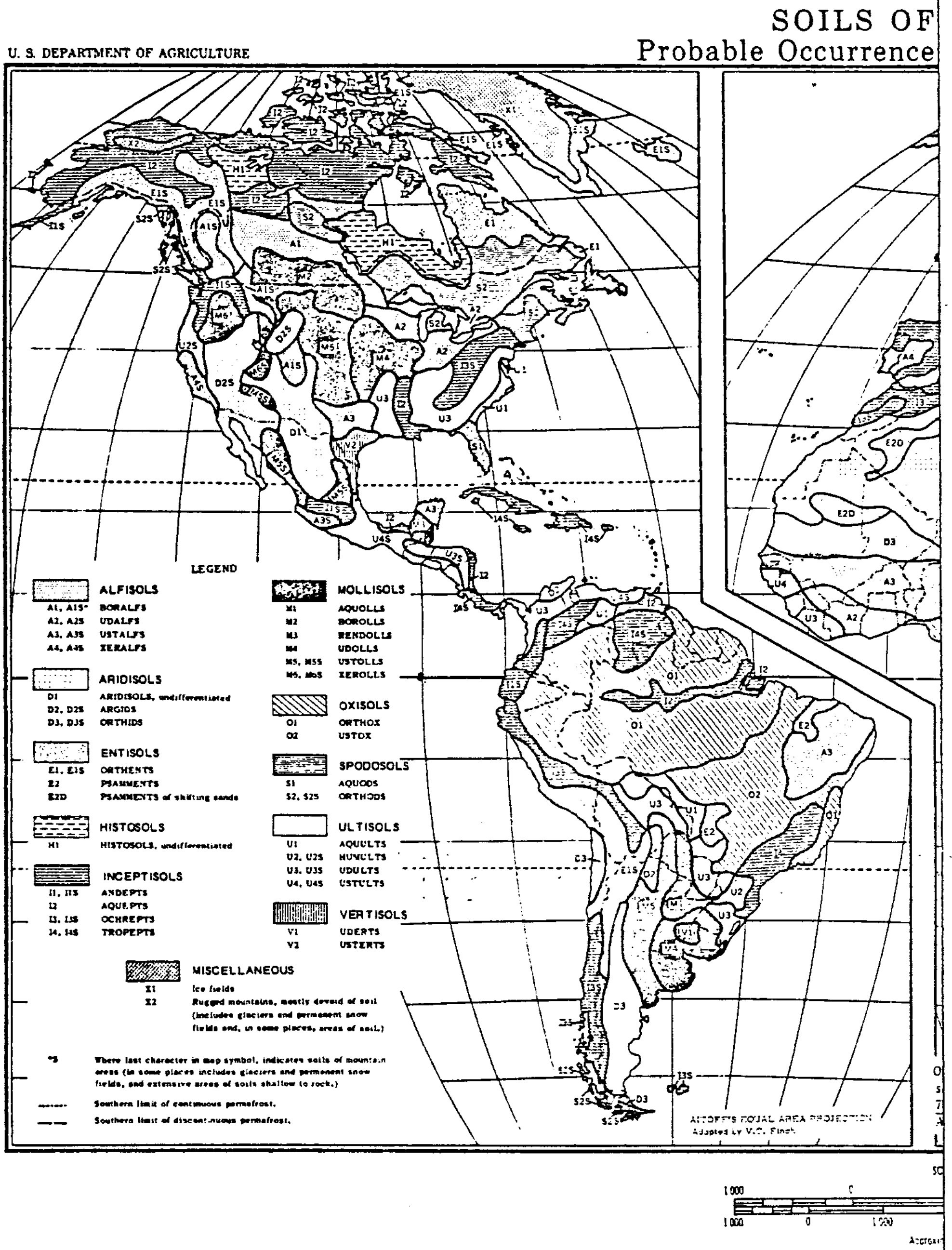


Figure 12:5. A generalized world soil map showing the probable occurre
comprehensive classification system. (Map courtesy Soil Survey Division U

In spite of their limitations, Vertisols are widely tilled, especially in India and in the Sudan. Sorghum, corn, millet and cotton are crops commonly grown. Unfortunately, the yields are generally low. Further research and timely soil management are essential if these large soil areas are to help produce the food crops these countries so badly need.

INCEPTISOLS (L. INCEPTUM, BEGINNING). Inceptisols may be termed young soils since their profiles contain horizons that are thought to form rather quickly and result mostly from alteration of parent materials. The horizons do not represent extreme weathering. Horizons of marked accumulation of clay and iron and aluminum oxides are absent in this order. The profile development of soils in this order is more advanced than that of the Entisol order, but less so than that of the other orders.

Soils formerly classified as Brown Forest, Ando, and Sols Brun Acide typify this order. Many agriculturally useful soils are included, along with others whose productivity is limited by factors such as imperfect drainage (see Table 12:2).

Inceptisols are found in several of the United States and in each of the Continents. (See Figs. 12:4 & 12:5). For example some Inceptisols called Andepts (productive soils developed from Volcanic ash) are found in a sizeable area of Oregon, Washington and Idaho, and in Ecuador and Columbia in South America. Some called Ochrepts (Gr. *Ochros*, pale) with thin, light colored surface horizons extend from southern New York through central and western Pennsylvania, West Virgina and eastern Ohio. Ochrepts dominate an area extending from southern Spain through central France to central Germany. They are also present in north Africa, eastern China and western Siberia.

Tropepts (Inceptisols of tropical regions) are found in northwestern Australia, central Africa, southwestern India and in southwestern Brazil. (See Fig. 12:5). Areas of wet Inceptisols or Aquepts (L. *Aqua*, water) are found along the Amazon and Ganges rivers.

As might be expected there is considerable variability in the natural productivity of Inceptisols. For example, those found in the Pacific Northwest are quite fertile and provide us with some of our best wheat lands. In contrast, some of the low-organic-containing Ochrepts in southern New York and northern Pennsylvania are not naturally productive. They have been allowed to reforest following earlier periods of crop production.

ARIDISOLS (L. ARIDUS, DRY). These mineral soils are found mostly in dry climates. Except where there is ground water or irrigation, the soil layers are dry throughout most of the year. Consequently, they have not been subjected to intensive leaching. They have an ochric epipedon which is generally light in color and low in organic matter. They may have a horizon of accumulation of calcium carbonate

Agricultural Development: Soil, Food, People, Work

by CHARLES E. KELLOGG

1975

Published by

Soil Science Society of America, Inc.

Madison, Wisconsin, USA

Curiously, since about 1964 the hazard of laterite[3], which does appear in some tropical soils, and in paleosols now under different climates, has been enormously exaggerated by a few researchers. It is an interesting phenomenon of some local importance here and there in the tropics and even as relicts in present temperate regions.

The areas of soil with laterite are commonly small. As the reader looks at the maps in Figures 8 and 9, he sees that the tropical areas, as a whole, have other kinds of soil, many of which are highly responsive to management for farming.

Laterite (or plinthite) is formed over a long time in or beneath soils on very old, smooth, stable landscapes in the tropics that have pronounced wet-dry seasons and water tables that fluctuate from near the surface in the wet season down to considerable depths in the dry season. The soil material is thus leached of its bases, such as calcium and magnesium, and then of its fine silica. Iron oxide and alumina accumulate from the losses of the other elements. In many areas with laterite, additional iron and alumina has been added from the water table by accumulations from seepage out of adjacent higher landscapes (Alexander and Cady, 1967). (See Figures 23, 24, and 25).

So long as the surface layers remain intact, the lateritic material remains fairly soft or doughy. Those made up of nearly pure alumina are good sources of bauxite for making aluminum. Those very rich in iron oxide can be used for smelting iron.

Once this doughy laterite is exposed to wetting and drying it hardens irreversibly to rock. This happens after geological uplift and a new erosion cycle and from the deepening of a stream and its tributaries. If the vegetation is removed and accelerated soil erosion is permitted to expose the material, it hardens to rock called laterite crust. Curiously, the people of Kerala State of southern India learned over two thousand years ago that they could farm soils with doughy laterite beneath *provided* they never plowed the soil nor exposed it to sun and rain. They grow a wide variety of herbaceous and woody crops in mixed culture with all harvesting and planting by hand.

3. *Laterite* is an old term, presumably derived from the Latin word *later* suggesting *brick* because some people use it for bricks. Later the words *laterite* and *lateritic* were applied to many tropical soils both with and without "laterite." So the word *plinthite* was coined to substitute for it in the new classification (Soil Survey Staff, 1960). But here I shall use the old term.

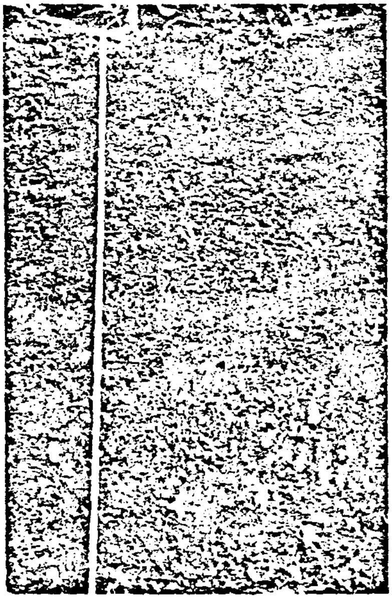


FIGURE 23

This is a profile with doughy laterite (plinthite) about 50 cm below the surface. The lower material is commonly called the "mottled zone." Near Lubumbashi, Zaire.

FIGURE 24

This is the associated landscape of Figure 23 with laterite beneath and termite mounds above. If the tops of these mounds are smoothed, vegetables can be grown on them.

FIGURE 25

A large tree pushed a few roots through cracks in the laterite layer. As the roots grew they forced boulders of laterite to the surface. South of Perth in Australia.

Many people in the tropical areas that have doughy laterite uncover it and cut it into bricks, usually about 75 to 100 cm long, about 30 cm wide and roughly 15 cm thick (Figure 26). These become very hard after direct exposure to sun and rain for a few months. Some even cut out circular well curbings and statues.

In places where the total iron and alumina in the material is too low for doughy laterite, concretions only may form. In a later cycle of soil formation, in the tropics, where such soils are on low-lying terraces they may receive additional alumina and iron from seepage and be hardened into "pisolithic laterite."

The natural exposures and crusts of laterite are dramatic. I have even seen beautiful specimens under geologically younger sandstone near Lincoln, Nebraska, and in other parts of North America. Examples can be seen under the soils of the Sahara where it could not form now. Specimens may be seen along the Malabar Coast of India, near Calcutta, in Indochina, in Brazil, in much of Africa and Australia, and elsewhere. But the point I want to emphasize is that its total area and importance have been greatly exaggerated.

With a good soil survey in advance of land development, which is essential anyway, soils with laterite near the surface are easily avoided as well as much larger areas of other kinds of unresponsive soils. Notions that great areas of soils of the Zaire and Amazon river basins are very hazardous for farming because of the potential of laterite crust are absurd. But, of course, some areas do exist in both places. In special situations with a little additional surface soil, some soils with laterite are used (Figures 27 and 28).

Acid sulphate soils or "cat clays"

Since these special soils are not so dramatic as those with potential laterite, they are even more likely to cause trouble in development without soil surveys. The soils are not limited to tropical and subtropical areas. They do not represent a widespread problem but are mentioned because of the potential for some serious local mistakes from which a few people near the sea have suffered costly failures. Now they are easily recognized by most soil scientists.

Most, but not all, of these are small areas fairly near the sea in low-lying coastal plains or deltas where sediments added by the streams are from nonlimy materials. These are wet soils that may be largely or partly organic. Hurricanes and typhoons from the sea bring in salty water with sulphate. Under wet conditions with abundant organic matter, the sulphates are reduced to sulphides

FIGURE 26

An Indian cultivator is cutting doughy laterite (plinthite) into bricks. Kerala State, India.

FIGURE 27

Cashew nuts are growing with laterite a few centimeters below the surface. West Bengal, India.

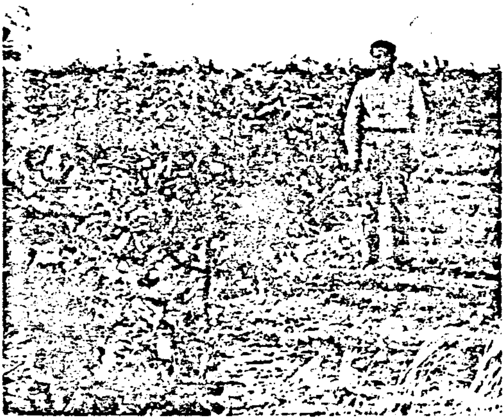
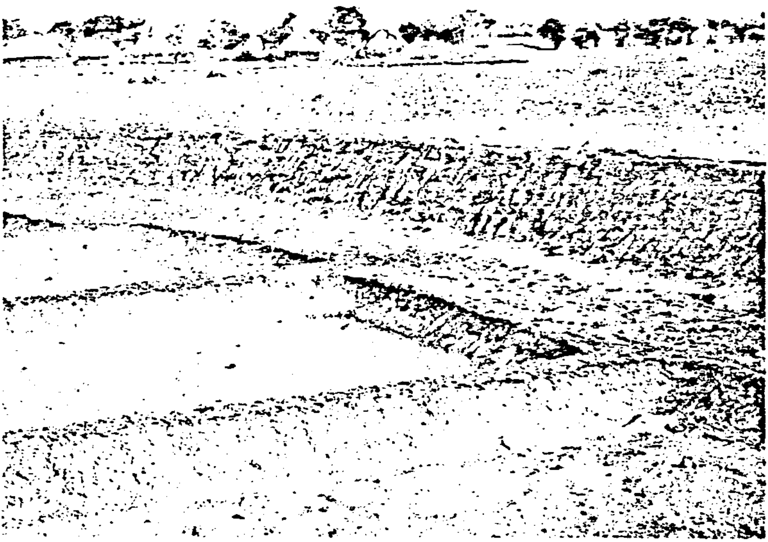


FIGURE 28

Hand-made terraces appear in West Bengal with laterite some 30 cm below. The pattern permits an inspector to check the amount of earth moved.



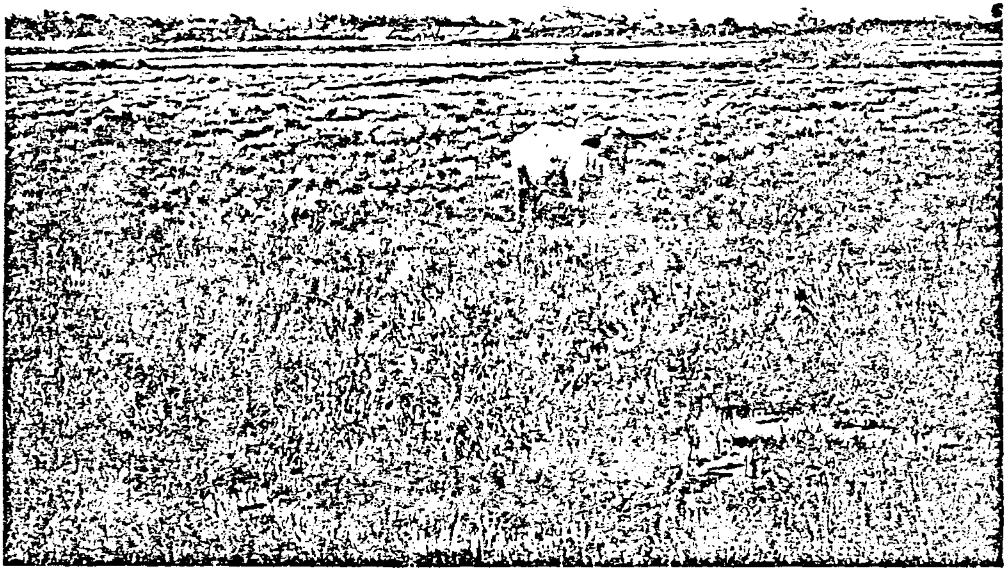


FIGURE 29

Typical landscape of rushes on acid sulphate clays in the Mekong Delta near Saigon, Vietnam.

FIGURE 30

This cut of a bit more than 1 meter is in a clayey alluvial soil with acid sulphate clays in the lower one-half. These can be used for growing rice. Mekong Delta near Saigon in Vietnam.

and iron pyrite. So long as the soil remains wet, nothing seems to happen. The surface 5 to 10 cm may even have fresh water from streams and support "fresh-water" plants.

But if the soil is drained, the sulphides oxidize to give sulphuric acid; the soils become extremely acid and have highly toxic soluble aluminum, with pH values as low as 2 or even less in a few extreme instances. The ditch banks have large mottles of white and brown after drying.

The very acid soils, certainly those below pH 3, are difficult to reclaim because of the enormous amounts of lime that would be required. And such amounts would raise difficult problems with secondary plant nutrients. Where the mistake has been made, wildlife areas can be restored only by routing the fresh water over the soils.

Some acid sulphate clays are used for rice by keeping the soil wet most of the time except a short period during harvest, as was done in the old days of rice production south of Charleston, South Carolina. And I have seen rice growing on these soils near Cochin, India, and elsewhere.

These small areas of acid sulphate soils are a hazard for both farming and construction in many low-lying areas near the sea in West Africa, Indochina (especially in the delta of the Mekong River), Malaya, India, northeastern South America, North America, and elsewhere (Figures 29 and 30). Any attempt to use such areas should be preceded with detailed soil surveys backed up by a good laboratory (Edelman and Van Stavern, 1958; Moormann et al., 1961; and Dost, 1973).

Extremely acid soils can also be expected in other places where pyrite is near the surface or where water that has leached deposits containing it enter the soil.

Organic soils

Many soils are developed almost wholly from peat. With these the earthy parent material consists of a wide assortment of organic remains, including the feces of aquatic animals as well as the remains of plants, along with some earthy material washed in during floods, blown in, or dropped as volcanic ash or cinders. These soils are especially prominent in geologically young areas along low-lying ocean shores, in large river deltas, and especially in regions covered by the last continental glaciation. Enormous numbers of small lakes have been filled with peat, in parts of northern United States and in Canada, for example. Many of the larger lakes can be expected to fill in future years.

TROPICAL SOILS

A critical study of soil genesis as related to climate, rock and vegetation

BY

E. C. J. MOHR

FORMER PROFESSOR OF SOILS, UNIVERSITY OF UTRECHT

AND

F. A. VAN BAREN

SOILS ADVISOR, ROYAL TROPICAL INSTITUTE, AMSTERDAM
FORMER PROFESSOR OF AGROGEOLOGY AND MINERALOGY,
UNIVERSITY OF INDONESIA, BOGOR, JAVA

UNDER THE AUSPICES OF
THE ROYAL TROPICAL INSTITUTE, AMSTERDAM

N.V. UITGEVERIJ W. VAN HOEVE – THE HAGUE AND BANDUNG
INTERSCIENCE PUBLISHERS, LTD. – LONDON
INTERSCIENCE PUBLISHERS, INC. – NEW YORK
1954

TABLE 31 SOIL MOISTURE UNDER BARE AND FORESTED LAND IN INDO-CHINA (after Henry, 1931)

	Layer	1929				1930							
		Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
		%	%	%	%	%	%	%	%	%	%	%	%
	0–15 cm	26.4	24.5	27.5	20.3	20.6	19.4	16.7	23.9	25.9	27.6	24.5	27.5
Bare	15–30 ,,	27.2	26.1	28.2	22.6	22.7	22.3	20.3	24.9	27.3	*28.6*	26.1	28.0
land	30–60 ,,	29.3	28.7	*29.4*	26.2	25.7	23.9	22.6	22.7	*29.0*	*30.0*	28.9	29.4
	100–130 ,,	*29.6*	*30.0*	*29.8*	*27.4*	*26.0*	*25.6*	*26.0*	*25.4*	*30.4*	*30.5*	*30.3*	*30.6*
Forested	0–30 ,,	*28.5*	27.0	27.1	22.7	22.8	21.7	21.2	25.2	27.3	27.5	*28.3*	29.1
land	30–60 ,,	27.6	26.4	25.6	23.4	22.6	21.9	21.4	22.2	26.9	24.1	28.3	28.6
	100–130 ,,	27.6	26.3	25.4	24.4	23.7	22.0	21.6	21.4	26.3	24.0	27.2	28.2
Rainfall in mm		425	195	147	28	16	32	13	80	321	229	336	346

'If in soils of that kind, with a high content of fine constituents but in crumb structure, there are influences at work which do not favour that structure or even work against it, then the rainwater penetrating into the soil can take away from the seed-shaped soil particles a part of the clay. In deeper layers the narrowing capillaries or the presence of flocculating agents precipitate this clay... Also the crumb structure of the surface layer is in part destroyed by the tropical rains beating upon unprotected soils; ...crumbs which are present become beaten to bits, washed away in the rainwater, and are carried into the pores of the soil. Proofs of this are to be found in the results of the 19th century investigations of Pitsch, Wollny, Fesca, Ramann, and others. For the Indies J. Beumé calls attention to this.'

Thus, it is quite conceivable that in Tonkin, on bare soils, an infiltration of clay from upper to lower layers has taken place. By this means, the intake of water of the upper layers was increased, and consequently a higher water content was found in deeper horizons.

Returning to the outcome of the investigation in French Indo-China, it must be pointed out that in many localities of Central Europe a distinct difference of ground water level was established. This was after comparing adjoining plots of the same sort of soil, partly occupied by forest, partly bare or at most carrying some thin grass. In short, let the conclusion be stated thus: under forests and, in general, under all kinds of intensive vegetative cover, a lower ground water level may be expected and is, indeed, found.

Rawitscher (1946) reports on the important role of the vegetation in the process of the downward and upward movement of water in the soil.

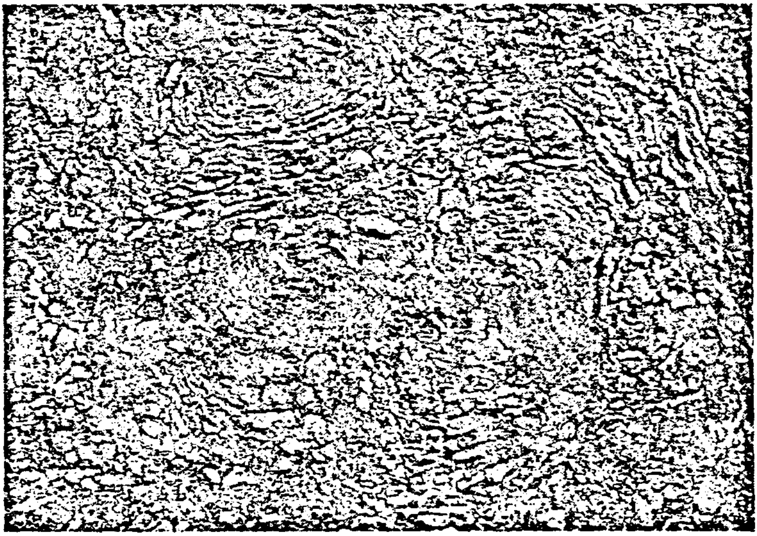


FIG. 22c AN ADVANCED STAGE OF DECOMPOSITION OF DACITE. EARTHY LAYERS ARE FORMED BETWEEN THE FLAKES, WHICH TEND TO DISSOCIATE THEMSELVES
Photo Vo-An-Ninh, by courtesy of E. M. Castagnol, 1952

rock, which showed the well-defined, symmetric structures similar to the familiar organ-pipes met with in basalt. In fact, the transformation often brings this 'pre-existent' structure to light, whereby the disintegrated shells reveal polygonal contours, closely resembling the prisms forming the base of the organ-pipes (see fig. 21, page 171).

Decomposition in concentric shells is not a fixed rule, but seems to depend on the humidity of the surrounding earth. It is possible, therefore, that one may find, especially on slopes, voluminous spheroids without any layer of flaky fragments, but only covered by a very thin film of yellowish-white material, which can easily be rubbed into very fine sand (gibbsite?). This type of transformation seems to represent the limit of the process of decomposition into flakes, whenever the humidity of the environment falls below a certain level.

The same phenomenon, though now referring to dacite and basalt, was described by Castagnol (1952) in his treatise on the basaltic and dacitic red earths of South Indo-China. The photographs above clearly illustrate the various stages of the spheroidal decomposition of a dacite in a red earth profile, near the experimental station on Darlac Plateau.

Although both the basalt and the dacite clearly evidence the characteristics of spheroidal disintegration, Castagnol reports that the flakes of the decomposed dacite are generally thicker than those of the basalt, and are apparantly transformed into red earth less easily.

As a substantial part of Castagnol's paper is devoted to the katamorphism of basalt, we will return to this rock and study the results yielded by chemical research, chiefly because they are so unexpected in view of the data discussed up to now. By means of alkaline fusion, this investigator determined the content of the usual elements as oxides, of the kernel of the basalt and the adjacent greyish and ferruginous shells respectively. He also repeated this procedure in respect of the subjacent and superjacent layers of red earth. The results are reproduced in the following table:

TABLE 59 CHEMICAL COMPOSITION OF BASALT, ITS WEATHERED SPHEROIDAL SHELLS AND ADJACENT RED EARTH FROM INDO-CHINA (after Castagnol, 1952)

No.	Type of material	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	K_2O %	Na_2O %	Loss of ignition
1	Red earth 50 cm above boulder (10 cm below the surface)	36.3	28.38	20.30	1.37	1.42	0.52	0.04	11.50
2	Red earth 30 cm above boulder	36.4	28.60	21.40	1.22	1.20	0.47	0.04	11.11
3	„ „ 20 „ „ „	36.6	28.16	21.84	1.22	1.20	0.47	0.03	11.50
4	„ „ 10 „ „ „	36.7	27.60	20.08	1.22	1.20	0.47	0.03	12.50
5	Kernel of basalt	52.2	5.36	24.64	9.38	7.98	0.87	0.05	1.00
6	Greyish zone	48.7	7.36	25.14	7.36	5.76	0.87	0.04	4.10
7	Ferruginous crust of boulder	36.1	11.16	30.80	7.86	6.16	2.90	0.10	7.00
8	Red earth 10 cm below boulder	35.0	30.64	19.26	1.53	1.06	0.53	0.04	12.80
9	„ „ 20 „ „ „	35.0	29.96	20.24	1.53	1.40	0.53	0.04	12.80
10	„ „ 30 „ „ „	35.6	30.64	19.36	1.53	1.40	0.40	0.04	12.70
11	„ „ 55 „ „ „	36.2	28.92	20.08	1.53	1.40	0.40	0.04	12.40
12	„ „ 80 „ „ „	36.2	30.31	19.68	1.53	1.40	0.40	0.03	12.60

In turn, Castagnol computed the loss or gain of the elements analysed by taking the composition of the core of the basaltic boulder as norm 1 for each of the components, the calculations being based on a water-free basis. A decrease in content of one of the compounds yields a figure < 1, while an increase results in > 1. For example, taking 52 % of SiO_2 in the basic core of the basalt as being 1, this leads to a figure of 0.749 for the silicon dioxide content of the ferruginous crust of the spheroid, etc. When No's 1–7 in the above table are computed in this way and drawn in the form of a graph, we get the following picture:

TABLE 101 TIME AS A FACTOR IN SOIL FORMATION IN THE LESSER ANTILLES (after Hardy and Rodriguez, 1941)

	A. NEWER EJECTA (Recent to Pleistocene)			B. OLDER EJECTA (Pliocene to Miocene)		
1. PARENT ROCKS:	Loose, unconsolidated, uncemented (Agglomerates, cinders, stones, ash, sand, dust)			Coherent, consolidated, cemented (Conglomerates, breccias, cinder-beds, gravel-beds, tuffs)		
2. PARENT SOIL MATERIALS: Content of:–						
A. UNALTERED MINERALS	100%	75%	50%		25%	0
B. CLAY	0	25%	50%		75%	100%
3. DERIVED SOIL-TYPES:						
A. JUVENILE	1. *Lithosols* 2. *Alluvial*	3. *Yellow-Earth*			7. *Terre-Grasse*	
B. ADOLESCENT		4. *Brown-Earth*	5. *Terras*			
C. SENILE				6. *Shoal*	8. *Red-Earth*	
		Calomorphic		Hydromorphic	Lateritic	
Soil reaction	pH 7.0	pH 6.5	pH 6.0	pH 5.5	pH 5.0	pH 4.5
	AZONAL	INTRAZONAL			ZONAL	

are the old lateritic soils on marine shales and argillaceous marls (Miocene 'Telisa' beds and Old-Pliocene 'Under Palembang' beds) in Sumatra.

Gourou (1945) expresses the same view in his treatise on the soils of Indo-China. Laterite and lateritic soils are considered to be the result of a weathering process of geologic duration.

Indirect evidence that the formation of laterites belongs to a by-gone cyclus of weathering could, in a sense, be derived from the fact that many of the red earths and red crusts, which now cover large areas of the earth's surface in tropical and sub-tropical regions, must be regarded as fossil, i.e. of non-contemporaneous origin.

In his study on the 'black regur' soils of Ujjain, Gwalior State, India, thick weathering profile of the pseudoliparitic contact-breccia, this bauxite crust of 7 metres is undoubtedly the eluvial rest product of the rock previously mentioned. Such deep weathering is the result of the most favourable circumstances governing the geological history of Bintan Island.

The fact that several authors apportioned considerable emphasis to the dry season type of climate as a pre-requisite, was based on the assumption that the iron crust is developed on the surface of the earth by capillary rise of ground-water and its subsequent evaporation from the surface during the dry season. This only occurs in rare cases in which the ground-water lies close to the earth's surface. An example of this is probably the 'bienhoa' of Indo-China, used, under the name of laterite, for the construction of buildings such as the temple of Angkor. Blondel (1927) inclined to the opinion that temporary marshy conditions were a prerequisite for the formation of this laterite.

Further, as Marbut also points out, capillary rise of ground-water, frequently cited as the only possible explanation for surface concentrations of iron-oxide, is a factor in the movement of soil water which could hardly be instrumental in the development of a lateritic crust.

In spite of the fact that the present authors are unaware of any experimental data on this aspect in respect of tropical soils, this conclusion may, nevertheless, be deduced from the observations of Keen (1928) and of the many soil physicists quoted by Zunker (1930) and, more recently, by Baver (1940). They demonstrate conclusively that the capillary rise of water to the soil surface is of a limited nature and are opposed to the widely held opinions that the reverse is the case.

It should be pointed out as a final point having a direct bearing on the scientific problem in hand, that the greatest ascent actually observed in soils which lend themselves particularly to water movement by capillary rise, is from 2 to 2.5 metres. The water takes at least a month to cover this distance. If the ground-water is 2.5 metres or more below the point from which water can be withdrawn by evaporation, ascent is virtually out of the question. It is an established fact that, as far as texture is concerned, the highest capillary activity is shown by soils consisting mainly of particles varying in diameter from 20 to 50μ, i.e. coarse silts. With an increasing clay content of 1 to 2μ-particle size, the capillary rise potential increases indeed to a theoretical height of 50 metres, but at least two years are needed for a rise of even one metre. This is of no practical significance, of course, with regard to the rise of water during a dry season.

The whole issue is further complicated by the fact that water rise by capillarity presupposes replenishment, either sideways or from below. If no such supply is available, then capillary rise is not possible at all.

This is also of paramount importance to root activity and influences not only evaporation dependent on capillary rise, but also transpiration through the green vegetation on the soil above. This is a point of special interest in the whole mechanism of water movement (see also chapter I, page 51 on evaporation).

Marbut's observation that profiles examined by him in several hundred places show a definite podzolic character was cited on page 368. Van der Voort (1950) also mentions the occurrence of an eluvial A_2-horizon richer in SiO_2, especially when the lateritic profile had developed under an evergreen forest on parent material rich in silica.

Erhart (1947) even describes a 'podzolized horizon' as an essential part of the profiles of lateritic clays occurring extensively in many parts of the evergreen forest zone of Tropical Africa. Pendleton and Sharasuvana (1942), however, object to the use of 'podzolic' or 'podzolized' with reference to lateritic soils with a bleached top layer, since they consider that the use of those terms should be restricted to lixivation processes leading to the formation of true podzol profiles. According to these authors, laterite soil profiles developed in materials rich in quartz, usually have bleached eluvial horizons, whereas those developed from basic rocks have red eluvial horizons (see further, chapter XIII).

A standard profile which may be considered to be representative in respect to the point raised by Erhart, is to be found in Madagascar. It has the following features:

1. Vegetational cover:	5–10 cm of plant offal in course of decomposition (F-layer of Jenny, 1930)
2. Podzolic zone:	Before attaining the soil surface, the red horizon 3 generally merges into a more or less strongly decoloured horizon, mostly light pink or salmon coloured.
3. Red zone:	A deep red clay which is less red at the bottom. In the lower part, the original structure of the rock can still be recognized.
4. Mottled zone:	Original rock structure still present, more noticeably at lower levels. Red, yellow and violet spots are frequent. They are irregularly spread in the case of a biotite gneiss, the spots correspond to the biotite flakes, whereas the feldspar layers are still white.
5. Zone of decomposition:	An horizon is to be observed just above the parent rock, which is more or less white or greyish and in which the minerals are very much altered, although the original structure is fairly intact. This horizon may be several metres in extent.

THE AGRICULTURAL SYSTEMS OF THE WORLD

An Evolutionary Approach

D. B. Grigg

CAMBRIDGE UNIVERSITY PRESS

CAMBRIDGE

LONDON · NEW YORK · MELBOURNE

CHAPTER 6

WET-RICE CULTIVATION IN ASIA

Wet-rice cultivation is perhaps the most distinctive of the types of agriculture discussed in this book, and certainly one of the most important, for it supports a majority of the rural population of the Far East. It is the dominant mode of farming in China as far north as the Hsin Ho; in South Korea; in most of Japan; in Taiwan; in the Tonkin delta and the Annamite coastlands in North Vietnam; in the Mekong delta and around the Tonlé Sap; in the Central Plain of Thailand; the Irrawaddy delta; the Ganges–Brahmaputra delta, the lower Ganges plain, the deltas of the eastern coast of India, and in Kerala; in Sri Lanka (Ceylon) it is important in both the Dry and Wet Zones. In the islands of South East Asia wet-rice cultivation is less widespread than on the mainland, but it is found in Java and the central plain of Luzon (Fig. 12).

Although wet-rice cultivation supports much of the rural population of the Far East, it occupies but a small part of the total area. Rice is tolerant of a wide range of soils. It requires high temperatures in the growing season, with mean monthly temperatures of at least 20 °C for three or four months, but this does not greatly restrict its range, and it is grown as far north as Korea and Hokkaido. Nor are the minimum moisture requirements excessive, although ideally it requires at least 1778 mm during the growing season, which is, throughout the area under discussion, the period of the summer monsoon.[1]

None of these requirements greatly limits the distribution of wet-rice; it is tolerant of a wide range of environmental conditions, and there are a multitude of varieties adapted for many different macro- and micro-environments. Perhaps the most striking of these are the 'floating rices' of southern Indo-China. However, unlike upland rice, which is grown in much the same way as other cereals, it has to be submerged beneath slowly moving water to an average height of 100–150 mm for three-quarters of its growing period. This restricts wet-rice cultivation to flat lands near to rivers. Ideally the water in the fields should be the same height upon the stalks, and so wet-rice is normally grown in small, levelled fields, surrounded by low earthen bunds which keep the water in, and which can be easily breached to drain the field. Most wet-rice cultivation is thus found in deltas or the lower reaches of rivers. In these areas little cost is involved in levelling the fields – the elaborate terracing of valley slopes is not typical of most rice-growing areas – and a water supply is nearby. Water for the *sawahs*, as the small fields are called in Java, can come simply from the rainfall of the monsoon, as it does, for example, in the Malayan rice areas, but more commonly this is supplemented by river floods. Sometimes inundation canals are built to carry flood waters to more distant fields; the water is then lifted from the canal into the maze of small ditches that bring water to each field.

From early times wet-rice farmers have attempted, first to protect their farms from floods by embanking the major rivers, and second to ensure their water supply by using irrigation. Irrigation of wet-rice should be distinguished from the water control methods which direct river floods and from the ditches which drain the water away before harvest, and, indeed, from the embanking of rivers. This distinction is not always made in contemporary literature, although it must be admitted that it is one that is difficult to make. But irrigation implies some form of storage of water, even if it be only in ponds; canals that carry water from rivers; weirs or barrages that divert river waters, and methods of lifting water from one level to another.

The ease of levelling land for *sawahs,* and the nearness of a water supply, whether it be irrigation from canals or wells, clearly make river plains favourable

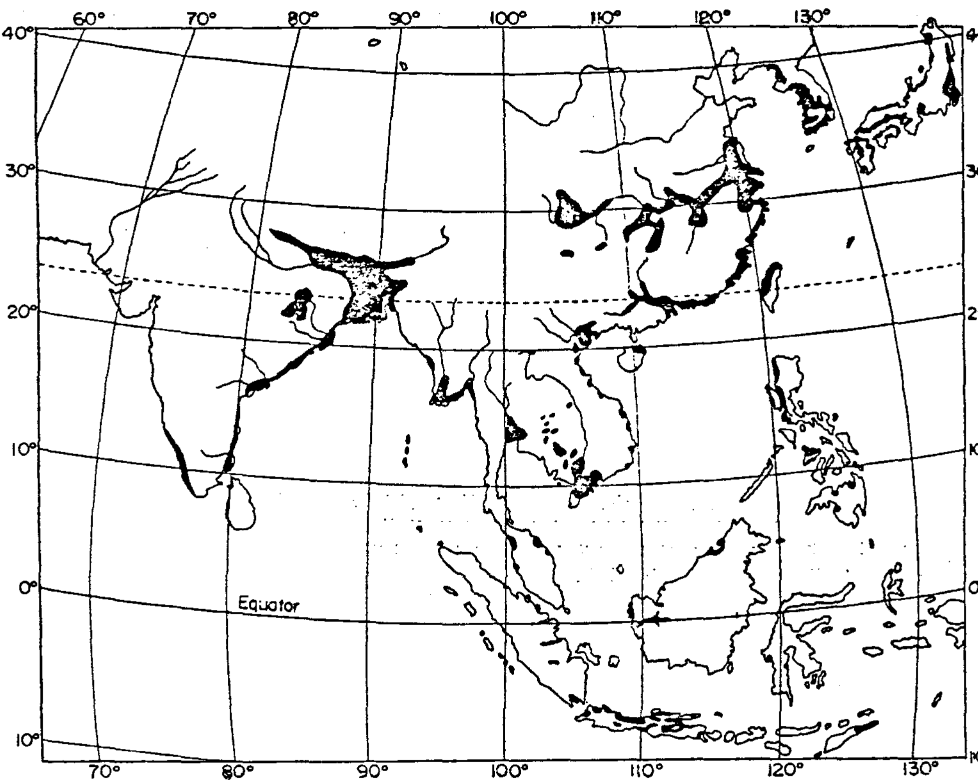


Fig. 12. The distribution of wet-rice cultivation in Asia. [Source: Ginsburg, 1958, 88, 136, 174, 326, 340, 380, 399, 411, 446, 512, 514]

sites for wet-rice. Furthermore wet-rice requires an impermeable sub-soil, else the water in the *sawahs* will soon drain away. Rice also yields best on heavy soils. As rivers deposit mainly fine-grained material in their lower reaches, heavy soils predominate.[2]

The micro-environment of the *sawah* also helps to explain the ability of the wet-rice cultivator to produce constant crop yields from the same field for year after year, often without the use of manures or rotations. in contrast to the upland farming of the Far East, where shifting cultivation is practised. This phenomenon has not been satisfactorily explained, but a partial explanation can be offered. First, the water-covered *sawah* is protected from high temperatures, the direct impact of tropical raindrops, and high winds; soil erosion is thus reduced to a minimum. Second, the high water table reduces the vertical movement of water and thus limits the leaching of plant nutrients. Third, both floods and irrigation water bring silt in suspension and other plant nutrients in solution, renewing soil fertility each year. Fourth, the water in the *sawahs* contains blue-green algae which promote the fixation of nitrogen. Nonetheless in the last thirty or forty years rice yields have shown signs of decline in parts of the Far East, particularly where double-cropping has been introduced.

Until the 1960s changes in traditional wet-rice agriculture had been few: increases in output were obtained by expanding the area under cultivation and by greater labour inputs. Only in a few areas had modern engineering allowed the creation of dams, reservoirs and canals. Yet since the mid 1960s there have been the beginnings of radical change. The central feature of the so-called Green Revolution in Asia has been the adoption of hybrid varieties of rice bred initially at research stations in the Philippines. These varieties give a much higher yield than traditional varieties and have a shorter growing season, thus making double-cropping easier. But they only yield well if there is an abundant supply of irrigation water and liberal supplies of fertiliser. In the late 1960s it was thought that these new varieties would revolutionise wet-rice cultivation and solve Asia's food problems. Yet comparatively few farmers have adopted the new varieties, and it is difficult to assess how great the changes have been in the last decade. Hence the description of current practices in wet-rice cultivation which follows refers mainly to the 1950s – before the Green Revolution.[3]

General characteristics of wet-rice cultivation

There are great variations in the way in which rice cultivation is carried on. Indeed one writer has identified thirty-six different sub-types in Malaysia alone.[4] Nonetheless some generalisations are possible.

First, farms are small, and fields invariably small and widely scattered. The typical rice farmer has only one or two hectares (Table 9). Only in the more recently settled areas of the lower Irrawaddy, Menam and Mekong are farms larger, averaging 4–6 hectares. Most wet-rice farms consist of a number of scattered fields; in Japan the average rice farm consists of fifteen separate fields,

TABLE 9 *Characteristics of wet-rice farming in Asia*

	Yield (tons/ hectare)	% of cultivated area in rice	% of rice irrigated	% of rice transplanted	% of land double cropped	% of land double cropped with rice	Average size of farm (hectares)	Chemical fertilisers; tons/ 1000 hectares of arable
Japan	5.1	54	96	95	35	0.3	1.0	392
South China	4.5	68	62	–	66	13–15	1.12	–
Taiwan	3.2	62	79	–	93	42	1.4	322
South Korea	3.3	60	58	100	28	–	1.2	200
Tonkin Delta	2.5	90	46	–	–	50	0.4	–
Mekong Delta	2.1	90	20	80	low	10	8.9	40
Thailand	1.5	79	24	80	low	–	4.8	9
Cambodia	1.2	80	–	–	–	–	–	2
Lower Burma	1.6	90	11	90	low	–	–	4
Malaya	2.4	17	11	94	low	6	0.8	30
Java	1.7	45	49	79	25	15–20	0.5	17
Philippines	1.2	42	30	80	–	16	3.0	25
Bangla Desh	1.7	71	12	74	24	–	1.4	13
Sri Lanka	1.7	28	60	6	–	32	–	56
India	1.5	23	20	–	13	–	–	10

Sources: Based on a wide variety of sources, mainly dating from about 1950. This table therefore represents conditions before the Green Revolution and in southern China, six. Again the more recently settled rice areas have less fragmentation. The average Thai farm, for example, consists of only 2.7 plots. Rapid population growth combined with inheritance laws that require the equal division of property are the main causes of fragmentation.[5]

Most wet-rice farms are operated by family labour alone. In pre-war China, for example, 85 per cent of all farm work was carried out without hired labour; it is equally rare in modern Japan.[6] The very rapid growth of population in rural Asia in this century has, however, created a class of landless labourers who are sometimes hired in the critical periods of harvesting and sowing. The exception to this is in Japan, where industrialisation has syphoned off the surplus rural labour, and where consequently the rural population has been stagnant since 1886. India has a rather longer history of landless labourers, for lower castes were not allowed to own land, and often supplemented their living by working on farms.[7]

Wet-rice farmers are usually described as subsistence farmers; and indeed about one-half of the world's rice is consumed on the farms where it is produced.[8] In the 1930s only about one-tenth of the rice produced in the Tonkin delta was marketed. Before the Second World War about three-quarters of all the rice farmers in South East Asia were primarily subsistence producers. Even now two-thirds of the farmers in the Mekong delta, an area more commercialised than most, can still be described as subsistence producers.[9]

Most wet-rice areas support very high population densities; parts of the Ganges and Tonkin deltas, together with a few areas in Java, have densities of more than 1500 per km^2 although these are admittedly exceptional; nonetheless very high densities are sustained over large areas. The average density in the delta lands of Bangla Desh exceeds 390 per km^2 and few parts of the lower Ganges plain in Bihar have less than this. The state of Kerala has an average density of 428 per km^2.[10] Densities are higher of course when total population is related to the cultivated area, that is, the nutritional density.[11]

The principal exceptions to the high densities of wet-rice areas are the deltas of the Irrawaddy, Menam and Mekong, where average densities are much lower than in East Asia, India or Java.[12] But even in these areas densities are much higher than in most agricultural areas. Thus, for example, the densities of these deltas in the 1930s were some six or seven times those in eastern England. Indeed the only densities in the rest of Asia comparable with those of the wet-rice regions are in the upper Ganges and in northern China, where rice is grown but is not the major crop.[13]

Rice is the dominant crop in the wet-rice farming system, a fact not always clearly shown when figures are only available for countries. It is virtually a monoculture in Kwantung, the Tonkin delta, the lower Mekong, the lower Menam, the lower Irrawaddy, the delta of the Ganges–Brahmaputra and the coastlands of Orissa. Away from these rice bowls it occupies less of the cultivated area but is still the major crop, occupying about two-thirds of the crop-land in Korea, the rest of southern China, south-western Japan and

Taiwan. In the rest of India and in Sri Lanka, Malaya, Java and the Philippines a greater variety of crops are grown. Nonetheless, even in these regions, rice is almost a monoculture in some areas, such as the north east and north west coasts of Malaya, the central plain of Luzon and in north west Java.[14]

One of the most distinctive features of wet-rice farming is the intensive use of land and the high inputs of labour. A distinction can be made between East Asia, the area influenced by China, on the one hand, and the Indian sub-continent and South East Asia, on the other.

1. *Irrigation*

The difficulty of distinguishing between the natural supply of water for the *sawahs*, by flooding and rainfall, and the artificial supply, irrigation, has already been touched upon. Thus the figures in Table 9 should perhaps be treated with some scepticism. However a clear distinction is apparent between East Asia, where at least half the wet-rice acreage is irrigated, and South East Asia and the Indian sub-continent, where the irrigation of rice is less common. Most of the rice in the lower Mekong and the lower Menam is grown with flood water, together with monsoon rainfall. In the Irrawaddy delta the monsoon is reliable enough for most of the supply to come from rainfall alone, and the major problem of the Burmese is to prevent the Irrawaddy floods damaging the rice fields. The Ganges–Brahmaputra delta and the Orissa coast rely upon the heavy monsoon rainfall together with natural inundation. Indeed outside East Asia only Sri Lanka and Java have much irrigated rice land.[15]

2. *Multiple cropping*

A distinction must be made between double-cropping, where a rice crop is grown in the summer and a dry crop taken in the winter on the drained *sawah*, and the growth of two rice crops in the year on the same *sawah*. The latter is unusual, and is important only in Kwantung, the Tonkin delta and Taiwan, although the introduction of hybrid rices with shorter growing periods has made this more common. In Japan the shortness of the growing season confines the growth of two rice crops a year to the extreme south west, although the recent development of early maturing – but not hybrid – varieties may extend the range.[16] Elsewhere in Asia a shortage of water is the principal limiting factor, although shortage of labour may also be important in some places. Double-cropping of rice and a winter crop is much more widespread, particularly in East Asia (Table 9), where wheat and barley are grown on the *sawahs* in winter. Again temperature is a limiting factor in Korea, China and Japan, but equally important is the difficulty of draining the *sawahs* quickly enough for the winter crop. Traditionally double-cropping was rare in the mainland of South East Asia, but of some significance in the wet-rice areas of the Indian sub-continent, particularly in the lower Ganges (Table 10).[17]

the Khorat plateau.[86] But it is in the Central Plain that most attention has been paid to increasing irrigation facilities, most of which depend upon the Chainat barrage at the head of the delta, which was completed in 1956. Thai farming methods show Chinese influence, particularly in the ways of lifting water, and also in the use of a single buffalo in ploughing, but unlike the Chinese the Thais have no knowledge of terracing.[87] Methods are relatively extensive. Most rice is transplanted, except in areas of heavy flooding, where 'floating' rice is broadcast, but little fertiliser is used, nor is much labour expended in cultivation. Indeed from the 1920s until the mid-1950s rice yields showed a perceptible downward trend as inferior land was brought into cultivation. This has been halted by the extension of irrigation and the introduction of new rice varieties. Farms are still well above the average size for East Asia, at 3–5 hectares, in spite of the increase in population, for this has been matched by the continued expansion of the cultivated area. In 1960 the nutritional density for all Thailand was only 269 per km^2. Yet there are recent signs that population is beginning to increase more rapidly than output, and this may threaten Thailand's exports in the near future.[88]

When the French annexed Cochin-China in 1862 the Annamites had occupied the Mekong delta as far as the Bassac distributary (Fig. 16), but effective settlement dated only from the eighteenth century, and the average density of population was no more than 20 per km^2.[89] Beginning in 1870, the French constructed a series of major canals which eased the problems of flooding as well as carrying irrigation water, although only the areas near the canals were effectively irrigated. The trans-Bassac territories were then open to settlement, but whereas in Burma and Thailand colonisation was undertaken by peasant freeholders, in the Mekong delta the land was sold off in large estates of up to 1000 hectares. The estates however were divided up into farms of four to six hectares operated by share-cropping tenants, the *ta dien*. This contrasted with the smaller peasant-owned farms of between one and five hectares found east of the Bassac. In spite of the rapid growth of population in the delta as a whole, the difference between the territories to the east and those to the west of the Bassac has persisted.[90]

TABLE 20 *Rice area and exports in Cochin-China, 1880–1970*

	Rice area (thousand hectares)	Exports (thousand metric tons)
1880	486	284
1900	1052	747
1920	1821	1200
1939	2185	1454
1957	2711	812
1966	2226	–
1970	2510	–

Sources: Fisher, 1964*a*, 540, 578; Fryer, 1970, 407; F.A.O. *Production yearbook*, vol. 25, 1971

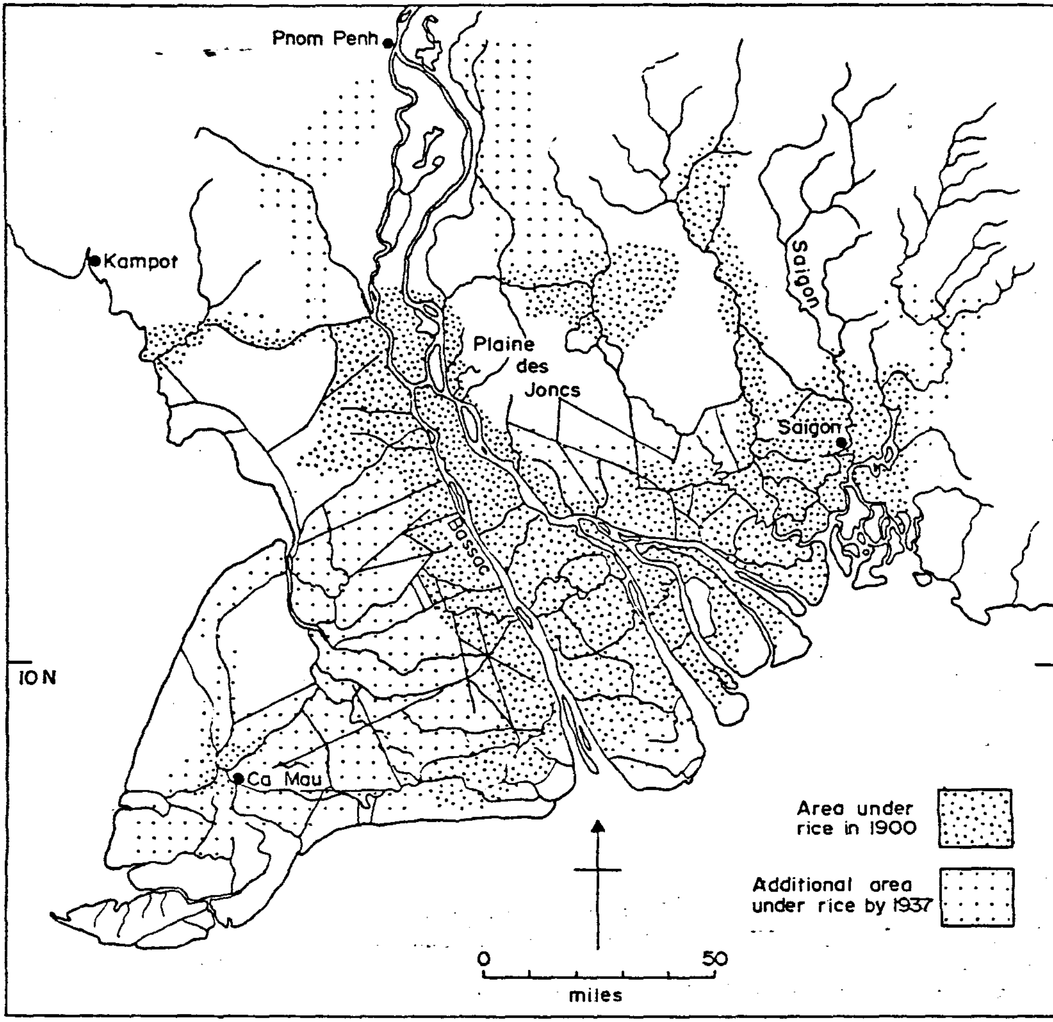


Fig. 16. The Mekong delta. [Source: Dobby, 1950, 302]

Again, as in Thailand, the expansion of the rice area in the lower Mekong was slow in comparison with the colonisation of the lower Irrawaddy (Table 20), although by the 1930s southern Vietnam's rice exports were comparable with those of Thailand. Methods were far less intensive than in northern Vietnam and yields significantly lower. Transplanting is the dominant mode of planting, although to the north of the delta where the floods are exceptionally high, 'floating' rice is grown, and in a few areas double transplanting is practised. Since 1945 some new land has been reclaimed but this has not compensated for the decline in the cultivated area due to the war, and since 1964 South Vietnam has had to import rice. This is particularly tragic, not only in that the Mekong delta has much land capable of reclamation, particularly in the Plaine des Joncs, but also because the international control of the Mekong would increase the area irrigated and raise yields. The decline of the cropped area in the delta, together with population increase, the influx of refugees from the north and the unequal distribution – the Plaine des Joncs and the coastal areas have always been very thinly populated – has meant that the nutritional densities in the old settled areas of the delta are now much higher than in the Menam and the Irrawaddy.[91]

Malaya and the Philippines

Malaya and the Philippines have much in common with Burma, Thailand and South Vietnam, in that they were without wet-rice civilisations in the sixteenth century, and that they have also experienced a considerable expansion of their rice area in the last hundred years, but this has not been for export. Rather it has been to feed a rapidly growing population whose economic interests have been in the export of plantation crops, and, in the case of Malaya, tin as well.

Rice was grown in Malaya in the early Christian period; some writers believe that wet-rice cultivation was practised,[92] but it is more commonly held that only dry-rice was grown by *ladang* methods, until the sixteenth century, when wet-rice methods were introduced into Kedah from Thailand.[93] Immigrants from Sumatra also introduced wet-rice methods into Selangor in the late eighteenth century, but it was not until the nineteenth century that they were widely adopted. The development first of tin and later of rubber in Malaya attracted Chinese, Indian and Indonesian immigrants into the country in the second half of the nineteenth century, and the total population increased rapidly from 400 000 in 1835 to 2 600 000 in 1911, 4 500 000 in 1930 and 7 000 000 in 1960. This remarkable expansion has been largely a result of immigration, and not only of Chinese and Indians. In 1957 half the 'indigenous' Malay population were either immigrants from Indonesia or descendants of recent immigrants. Further, the expansion of rice cultivation has, until recently, taken second place to the expansion of commercial crops, and in particular rubber. The major rice areas are in the Kelantan and Trengganu deltas of the north east, and in Kedah in the north west, areas which are among the oldest settled in Malaya.[94] Most wet-rice cultivation is unirrigated although transplanted, and double-cropping is rare, but of growing importance in the post-war reclamation schemes.[95] These have been necessary both to settle the rapidly growing population, to reduce the substantial rice imports upon which Malaya depends, and also to try and increase the incomes of the *padi* growers who are almost all Malays.[96]

The Philippines provide an interesting case of the problems of tracing the history of rice-growing. In the northern mountains of Luzon the Ifugao peoples have long terraced hillsides and irrigated their rice, but used the hoe and not the plough. They are thought to have arrived from China perhaps 4000 years ago.