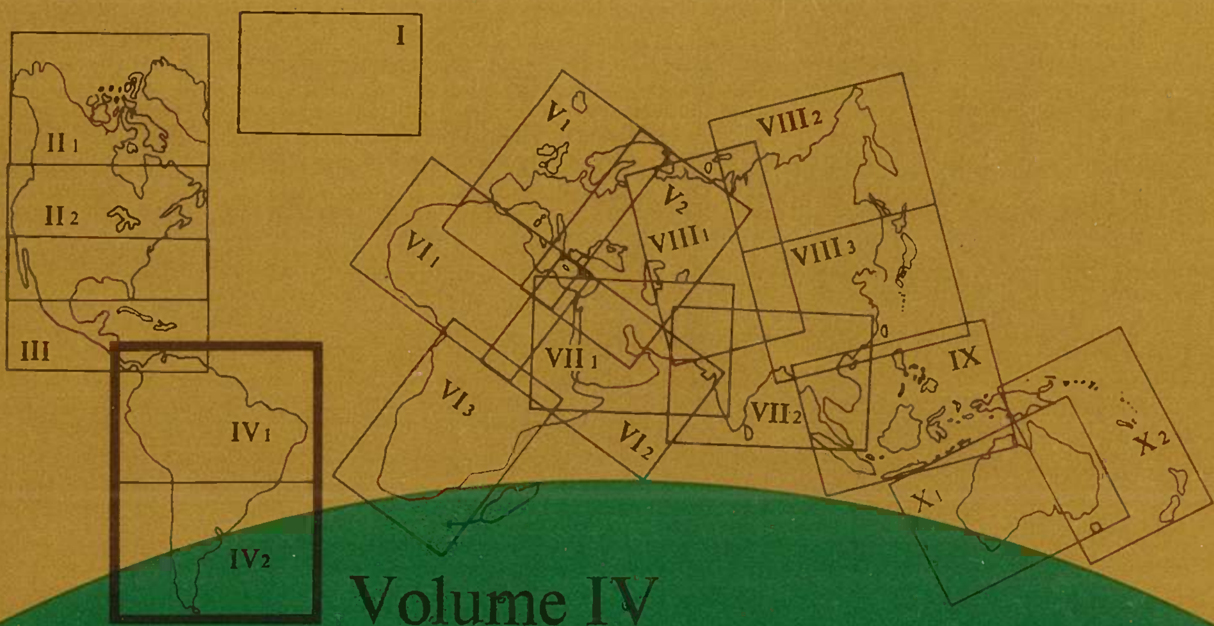
FAO-Unesco

# Soil map of the world

1:5 000 000




## Volume IV
## South America

Unesco

FAO - Unesco

Soil map of the world

1 : 5 000 000

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

FAO - Unesco

# Soil map of the world

1 : 5 000 000

Volume IV
South America

Prepared by the Food and Agriculture Organization of the United Nations

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# PREFACE

The project for a joint FAO/Unesco Soil Map of the World was undertaken following a recommendation of the International Society of Soil Science. It is the first attempt to prepare, on the basis of international cooperation, a soil map covering all the continents of the world in a uniform legend, thus enabling the correlation of soil units and comparisons on a global scale. The project, which started in 1961, fills a gap in present knowledge of soil potentialities throughout the world and provides a useful instrument in planning agricultural and economic development programmes.

The project has been carried out under the scientific authority of an international advisory panel, within the framework of FAO and Unesco programmes. The different stages of the work included comparative studies of soil maps, field and laboratory work, and the organization of international expert meetings and study tours. The secretariat of the joint project, located at FAO Headquarters, was vested with the responsibility of compiling the technical information, correlating the studies and drafting the maps and text. FAO and Unesco shared the expenses involved in the realization of the project, and Unesco undertook publication of its results. For the preparation of the Soil Map of South America, additional financial support was received from the Rockefeller Foundation; furthermore, the services of associate experts were made available by the Governments of Belgium and the Netherlands to work on the project.

The present volume, covering the soils of South America, is the fourth of a set of ten which make up the complete publication of the Soil Map of the World. The first volume records introductory information and presents the definitions of the elements of the legend which is used uniformly throughout the publication. Each of the nine following volumes comprises an explanatory text and the corresponding map sheets covering the main regions of the world.

FAO and Unesco wish to express their gratitude to the governmental institutions, the International Society of Soil Science, and the many individual soil scientists who have contributed so much to this international project.

# CONTENTS

# SUMMARIES

This volume describes the South American section of the 1 : 5 000 000 Soil Map of the World. The compilation of the Soil Map of South America was started by FAO in the 1950s and was continued and completed by FAO and Unesco in a joint project initiated in 1961.

### The maps

The two map sheets which make up the Soil Map of South America are drawn on topographic base maps of the 1 : 5 000 000 series of the American Geographical Society. The map units are associations of soil units divided into texture and slope classes. They are marked on the maps by symbols. The dominant soils are shown by colours while phase differences are shown by overprints.

A small inset map shows three grades of reliability of soil information from which the map was compiled.

Detailed definitions of the soil units and full descriptions of all the terms used may be found in Volume I of the set.

### The text

The first chapter describes the development of the project in South America and gives some notes on uses of the map. The second acknowledges the cooperation of the agencies and of the large number of people who contributed to the maps and text, and the third gives a summary of the material in Volume I on the maps and legend.

The main chapters of this volume deal with environmental conditions and use of soils and land.

#### Environmental conditions

Chapter 4 contains brief accounts with maps of the four factors of the environment that have close relationships with the pattern of soils: climate, vegetation, geomorphology and lithology.

*Climate* is discussed on the basis of seven broad climatic subdivisions. Since the criteria used in delimiting units are those that are important to crop growth, the climate map is supplementary to the soil map in the transfer of crop information from one part of the world to another. Here only the higher categories are discussed. The main climatic regions are outlined on a small-scale map (Fig. 2).

*Vegetation* is discussed on the basis of ten broad vegetation regions distinguished on the basis of the habitat (either climatic or edaphic), the physiognomy and the structure of the vegetation. These regions are then subdivided into 42 subregions which are outlined on a small-scale map (Fig. 3). The text gives some brief notes on each region and on the location and nature of its subregions.

*Geomorphology* and landscape development are then treated in terms of three main groups of regions: the Precambrian shield areas on the east of the continent, the Andean mountain ranges on the western margin and, between these, the basins of the Orinoco and Amazon rivers and the Chaco and pampa plains. A small-scale map shows the different relief elements (Fig. 4).

*Lithology* is considered under the broad headings of shields, Andes and basins. Two small-scale maps (Figs. 5 and 6) are included, one of geotectonic regions, which are considered region by region in the text, and the other of lithology. The text outlines the geological origins and nature of the main surfaces at present exposed.

#### Soils and land use

Chapters 5 and 6, describing the soils of the continent, contain an extensive table of soil associations, an account of the distribution of the main soils, and a discussion of land use and soil suitabilities for agriculture.

The table of *soil associations* lists all the map units in alphabetical order of symbols. Other columns show:

Associated soils
Inclusions
Phases
Areas of units in 1 000 ha
Climate symbols
Countries of occurrence
Vegetation
Lithology or parent materials

The *distribution of major soils* is discussed on the basis of 27 broad soil regions grouped into lowlands, uplands and mountains, and outlined on a small-scale map (Fig. 7). The main soils of each region are discussed in relation to factors of the environment, and their important characteristics are noted.

*Present land use and suitabilities for agriculture* are discussed at first in general, with a small-scale map of population distribution (Fig. 8) and an account of traditional and modern farming systems. Then the main soils are considered separately. Their present use is described, and the suitability of the land for both traditional and modern farming is outlined.

The pattern of land use shows that only a small area, no more than 5 percent, of the land is under cultivation. Most of this is on the margins of the continent and huge areas are untouched by agriculture. The cultivated land is managed generally in small units by traditional methods, yielding only slightly over subsistence. Substantial increases in agricultural production are therefore possible, both by utilizing soil resources at present unused and by making better use of soils now under cultivation.

### Conclusions

An outstanding feature of South American soils is their *low natural fertility*. Approximately 50 percent of the continent consists predominantly of various kinds of Ferralsols, Orthic Acrisols and Ferralic Arenosols, all low in cation exchange capacity and in exchangeable bases.

Another limitation which severely affects the agricultural use of the soils is *deficiency of water*. Broadly speaking, 20 percent of South America has semi-arid or arid climates, making agriculture without irrigation hazardous or impossible. The soils are mainly Yermosols, Xerosols, Regosols, Lithosols, salt-affected soils like Solonchaks and Solonetz, Ferric Luvisols and Chromic Luvisols.

There are also extensive areas with *poor drainage*, which make up about 10 percent of the continent. Here soils are mostly Gleysols, Plinthic Acrisols, Vertisols and Planosols.

The large areas of *steeplands* in the Andes make up about 10 percent of the continent. Apart from Lithosols, which are dominant, Dystric Cambisols, Andosols and Orthic Acrisols are important, their occurrence being clearly related to altitude and parent material. These are acid soils, but relatively large areas of eutrophic soils can also be found in the inter-Andean valleys and on some foothills. These include Kastanozems, Phaeozems, Chromic Luvisols and Eutric Cambisols.

Soil regions which consist mainly of soils not having these limitations are rare in South America and extend over less than 10 percent of the total area. Important soils in these regions are Phaeozems, Kastanozems, Ferric Luvisols, the Rhodic Ferrasols with medium to high base status, Eutric Nitosols and Chromic Luvisols.

However, although the area of productive soil is limited, much of it is still uncultivated or only cultivated by traditional methods. Substantial increases in agricultural production are therefore possible.

## The appendix

Site and profile data, including profile descriptions and analyses, are given in the Appendix for some of the main soil units.

Le présent volume décrit la section relative à l'Amérique du Sud de la carte mondiale des sols au 1:5 000 000. La FAO avait commencé à dresser la carte des sols d'Amérique du Sud au cours des années cinquante. Cette tâche a été poursuivie et menée à bien par la FAO et l'Unesco dans le cadre d'un projet conjoint qui avait débuté en 1961.

## Les cartes

Les deux feuilles cartographiques qui constituent la carte des sols d'Amérique du Sud ont été établies d'après les cartes topographiques de base au 1: 5 000 000 de l'American Geographical Society. Les unités cartographiques sont des associations de sols subdivisées d'après les classes de texture et de pente. Elles sont indiquées sur les cartes par des symboles. Les sols dominants sont représentés par diverses couleurs alors que les différences de phase sont indiquées en surcharge.

Une carte à petite échelle, reproduite en cartouche, indique trois degrés de fiabilité pour les renseignements pédologiques d'après lesquels la carte a été établie.

On trouvera dans le volume I de cette série des définitions détaillées des unités pédologiques et une description complète de tous les termes utilisés.

## Le texte

Le premier chapitre décrit l'évolution du projet en Amérique du Sud et donne quelques notes sur l'utilisation des cartes. Le deuxième chapitre rend hommage aux institutions et à ceux qui ont collaboré à l'établissement des cartes et du texte. Enfin, dans le troisième, on trouvera un résumé du volume I relatif aux cartes et aux légendes.

Les principaux chapitres du présent volume traitent du milieu et de l'utilisation des terres.

### LE MILIEU

Le chapitre 4 expose brièvement, à l'aide de cartes, les quatre facteurs du milieu dont dépend étroitement la répartition des sols: climat, végétation, géomorphologie et lithologie.

*Le climat* est traité sur la base de sept grandes subdivisions. Etant donné que pour délimiter les unités on a retenu les critères les plus importants pour la croissance des plantes, la carte climatique complète la carte des sols et doit être consultée pour le transfert de renseignements sur les cultures d'une partie du monde à une autre. Il n'est tenu compte ici que des catégories supérieures. Les principales régions climatiques sont indiquées sur une carte à petite échelle (fig. 2).

*La végétation* est répartie en dix grandes régions classées selon l'habitat (climatique on édaphique), la physionomie et la structure de la végétation. Ces régions sont ensuite subdivisées en 42 sous-régions qui sont représentées sur une carte à petite échelle (fig. 3). On trouvera dans le texte quelques notes succinctes sur chaque région ainsi que sur l'emplacement et la nature des sous-régions qui la composent.

*La géomorphologie* et l'évolution du modelé sont examinées dans le cadre de trois principaux groupes de régions; les régions du socle précambrien à l'est, la chaîne montagneuse des Andes à l'ouest et, entre ces deux régions, les bassins de l'Orinoco et de l'Amazone ainsi que les plaines du Chaco et de la Pampa. Une carte à petite échelle montre les divers éléments du relief (fig. 4).

*La lithologie* est également examinée sous l'angle des grandes rubriques précédentes: socles, Andes et bassins. Deux cartes à petite échelle (fig. 5 et 6) montrent l'une la lithologie, et l'autre les régions géotectoniques (examinées région par région dans le texte). Le texte indique l'origine géologique et la nature des principales surfaces qui sont actuellement exposées.

### SOLS ET UTILISATION DES TERRES

Les chapitres 5 et 6, qui décrivent les sols du continent, contiennent un tableau détaillé des associations de sols, un compte rendu de la répartition des principaux sols et un examen de l'utilisation des terres et de leur vocation agricole.

Le tableau des *associations de sols* énumère toutes les unités cartographiques dans l'ordre alphabétique des symboles. Les autres colonnes sont consacrées aux rubriques suivantes:

sols associés
inclusions
phases
superficies des unités en milliers d'hectares
symboles climatiques
répartition par pays
végétation
lithologie ou matériaux originels

La *répartition des principaux sols* est examinée en fonction de 27 grandes régions pédologiques, groupées en terres basses, terres hautes et montagnes, et indiquées sur une carte à petite échelle (fig. 7). Les principaux sols de chaque région sont traités en fonction des facteurs du milieu et leurs caractéristiques les plus importantes sont exposées.

*L'utilisation actuelle des terres et leur vocation agricole* sont examinées, d'abord d'une manière générale, à l'aide d'une carte de répartition démographique à petite échelle (fig. 8), et les secteurs agricoles traditionnels et modernes sont décrits. On passe ensuite à l'examen des principaux sols pris séparément. Leur utilisation actuelle est indiquée et leur aptitude à l'agriculture, tant traditionnelle que moderne, est analysée.

La structure de l'utilisation des terres révèle que seule une faible superficie, ne dépassant pas 5 pour cent des terres, est actuellement cultivée. La majeure partie de ces terres agricoles est située dans la zone littorale, et d'immenses régions sont encore inexploitées. Les terres cultivées sont en général divisées en petites unités exploitées selon les méthodes traditionnelles et dont les rendements ne dépassent guère ceux de l'économie de subsistance. Il est donc possible d'augmenter considérablement la production agricole, à la fois en mettant en valeur des ressources en sol encore inutilisées et en tirant meilleur parti des sols actuellement cultivés.

## Conclusions

Un trait dominant des sols de l'Amérique du Sud est leur *faible fertilité naturelle.* Environ 50 pour cent de la superficie du continent est constituée essentiellement de divers types de ferralsols, acrisols orthiques et arénosols ferraliques, qui ont tous une faible capacité d'échange en cations et sont pauvres en bases échangeables.

Un autre facteur qui limite fortement l'utilisation agricole du sol est le *manque d'eau.* D'une manière générale, on peut dire que 20 pour cent de l'Amérique du Sud a un climat aride ou semi-aride où l'agriculture est difficile ou impossible sans irrigation. Les principaux sols sont des yermosols, des xérosols, des régosols, des lithosols, des sols salins comme les solonchaks et solonetz, des luvisols ferriques et des luvisols chromiques.

Il existe également de vastes étendues *mal drainées* qui couvrent environ 10 pour cent de la superficie du continent. Dans ces régions, il s'agit surtout de gleysols, d'acrisols plinthiques, de vertisols et de planosols.

Les vastes régions *à forte pente* des Andes représentent environ 10 pour cent de la surface du continent. En dehors des lithosols qui prédominent, les cambisols dystriques, les andosols et les acrisols orthiques sont assez répandus, leur fréquence étant nettement liée à l'altitude et aux matériaux originels. Il s'agit de sols acides, mais on trouve également des zones relativement étendues de sols eutrophes dans les vallées des Andes et dans certains piémonts. Parmi ces sols on peut mentionner les kastanozems, les phaeozems, les luvisols chromiques et les cambisols eutriques.

Les régions où les sols ne comportent pas de facteurs limitants sont rares en Amérique du Sud et couvrent moins de 10 pour cent de la superficie totale. Dans ces régions, les sols les plus importants sont les phaeozems, les kastanozems, les ferralsols rhodiques avec teneur moyenne à haute en bases échangeables, les nitosols eutriques et les luvisols chromiques ou ferriques.

Toutefois, si la superficie des sols productifs est limitée, une grande partie est encore inexploitée ou cultivée selon des méthodes traditionnelles. Un accroissement considérable de la production agricole est donc possible.

## Annexe

On trouvera dans l'annexe des renseignements concernant les sites et les profils, y compris des descriptions de profils et des analyses concernant certaines des principales unités pédologiques.

Настоящий том посвящен южноамериканской части Почвенной карты мира, составленной в масштабе 1 : 5 000 000. Составление почвенной карты Южной Америки было начато ФАО в 1950-х годах, продолжено и завершено ФАО и ЮНЕСКО по их совместному проекту, начатому в 1961 г.

## Карты

Два листа карт, составляющих почвенную карту Южной Америки, составлены на основе топографических карт Американского географического общества (серия карт масштаба 1 : 5 000 000). Части карты представляют собой соединения почвенных частей, поделенных на классы по текстуре и склону. Они отмечены на картах условными обозначениями. Преобладающие почвы даны в красках, в то время как фазовые различия показаны с помощью надпечаток.

Небольшая карта-вкладка показывает три категории надежности информации о почвах, на основе которой составлялась карта.

Подробные определения видов почв и полное описание всех используемых терминов можно найти в томе I настоящего издания.

## Текст

В первой главе описывается развитие проекта в Южной Америке и приводятся некоторые замечания по использованию карты. Во второй главе выражается благодарность за сотрудничество учреждениям и большому числу лиц, которые приняли участие в составлении карт и текста. В третьей главе дается краткое содержание первого тома относительно карт и легенд.

Основные главы данного тома посвящены условиям окружающей среды и использованию почв и земли.

## УСЛОВИЯ ОКРУЖАЮЩЕЙ СРЕДЫ

В главе 4 содержится краткое описание, с картами, четырех факторов окружающей среды, которые тесно связаны с распространением почв: климат, растительность, физическая география и литология.

Климат рассматривается на основе семи широких климатических подразделений. Поскольку критерии, использованные при определении видов, являются теми критериями, которые представляют важность и в вопросе, касающемся выращивания культур, то климатическая карта служит дополнением к почвенной карте в передаче информации относительно культур из одной части мира в другую. Здесь описаны только более высокие категории. Основные климатические районы фигурируют на мелкомасштабной карте (рис. 2).

Растительность рассматривается на основе десяти обширных районов растительности, отличаемых друг от друга по месту обитания (с учетом либо климата, либо почвы), внешнему виду и структуре растительности. Эти районы затем подразделяются на 42 подрайона, которые приводятся на мелкомасштабной карте (рис. 3). В тексте даются краткие замечания по каждому району и по расположению и характеру его подрайонов.

Геоморфология и характеристика ландшафта даются по трем главным группам районов: районы докембрийского щита на востоке континента, горные хребты Анд по западному краю, а между ними бассейны рек Ориноко и Амазонки и Чако и пампасы. Мелкомасштабная карта показывает различные элементы рельефа (рис. 4).

Литология рассматривается под обширными заголовками, охватывающими щиты, Анды и бассейны. Приводятся две карты масштаба 1 : 20 000 000 (рис. 5 и 6), одна из которых касается геотектонических районов, которые каждый в отдельности описаны в тексте, и другая - литологии. В тексте содержится описание геологического происхождения и характера основных пластов, выходящих на поверхность в настоящее время.

## ПОЧВЫ И ИСПОЛЬЗОВАНИЕ ЗЕМЛИ

В главах 5 и 6, описывающих почвы континента, содержится обширная таблица сочетания почв, говорится о распространении основных почв и использовании земли, а также о пригодности почвы для сельского хозяйства.

В таблице сочетания почв перечисляются все части карты в алфавитном порядке условных обозначений. Другие колонки показывают:

Сочетающиеся почвы
Включения
Фазы
Площади частей в 1000 га
Условные обозначения климата
Страны распространения
Растительность
Литология или материнские породы

Распространение основных почв рассматривается на основе 27 обширных почвенных районов, сгруппированных в низменности, возвышенности и горы, и показано на мелкомасштабной карте (рис. 7). Главные почвы каждого района рассматриваются в связи с факторами окружающей среды, причем отмечены их важные характеристики.

Использование земли в настоящее время и ее пригодность для сельского хозяйства вначале рассматриваются в общих чертах, и при этом даются мелкомасштабная карта распространения населения (рис. 8) и данные о традиционных и современных системах ведения сельского хозяйства. Затем основные почвы рассматриваются в отдельности. Описывается их использование в настоящее время и пригодность земель как для традиционного, так и для современного ведения сельского хозяйства.

Характер использования земли показывает, что только небольшая площадь, не более 5 процентов земли, обрабатывается. Большинство этих земель находится по краям континента, и огромные районы не затронуты сельским хозяйством. Обрабатываемые земли используются в основном небольшими участками с применением традиционных методов, причем получаемый урожай лишь слегка превышает норму, необходимую для пропитания. Поэтому возможно значительное увеличение сельскохозяйственного производства как путем использования почвенных ресурсов, не используемых в настоящее время, так и путем лучшего использования обрабатываемых в настоящее время почв.

## ВЫВОДЫ

Сформулированы следующие выводы:

Отличительной чертой почв Южной Америки является их низкое естественное плодородие. Приблизительно 50 проц. континента состоит в основном из различного вида ферралитных почв, типичных акрисолов и ферралитных песчаных почв, обладающих низкой способностью к обмену катионами и недостаточным количеством обменных веществ.

Другим ограничением, которое отрицательно влияет на использование почв для сельского хозяйства, является недостаток воды. Вообще говоря, 20 проц. Южной Америки имеет полузасушливый или засушливый климат, что делает сельское хозяйство без ирригации рискованным или невозможным. Почвы в основном представлены иермосолами, ксеросолами, регосолами, литосолами, засоленными почвами, такими, как солончаки, солонцы, ожелезненные лувисолы и хромистые лувисолы.

Здесь имеются также обширные районы с плохим дренированием, которые составляют около 10 проц. континента. Почвы здесь в основном глеевые, уплотненные акрисолы, вертисолы и планосолы.

Обширные пространства низких гор и холмов в Андах составляют приблизительно 10 процентов континента. Помимо преобладающих литосолов, представляют важность дистриктовые камбисолы, андосолы и типичные акрисолы причем их местонахождение явно связано с высотой над уровнем моря и с материнской породой. Это кислые почвы, на сравнительно большие районы высокозольных почв можно также найти во внутренних долинах Анд и на некоторых нижних склонах холмов. Эти почвы включают кастаноземы, феоземы, хромистые лувисолы и эвтрические камбисолы.

Почвенные районы, которые состоят в основном из почв, не имеющих этих ограниченний редко встречаются в Южной Америке и охватывают менее 10 проц. всей территории. Важными почвами в этих районах являются феоземы, кастаноземы, ожелезненные лувисолы, родиевые феррасолы с содержанием оснований от среднего до высокого, эвтрические нитосолы и хромистые лувисолы.

Однако, хотя районы плодородных земель ограничены, многие из них все еще не обрабатываются или обрабатываются только традиционными методами. Поэтому возможно значительное увеличение сельскохозяйственного производства.

В приложениях приводятся данные о расположении и профиле, включая описание и анализ профилей для некоторых из основных почвенных частей.

En este volumen se describe la sección de América del Sur del Mapa Mundial de Suelos a escala de 1:5 000 000 que fue comenzado por la FAO en el decenio de 1950 y continuado y completado por la FAO y la Unesco en un proyecto conjunto iniciado en 1961.

## Los mapas

Las dos hojas con mapas que comprenden el Mapa de Suelos de América del Sur se han trazado sobre los mapas topográficos base de la serie a escala de 1:5 000 000 de la Sociedad Geográfica Americana. Las unidades del mapa de suelos son asociaciones de unidades de suelos divididas en clases texturales topográficas o de inclinación. Se indican en el mapa por medio de símbolos. Los suelos dominantes se muestran por colores, mientras que las diferentes fases se indican con sobreimpresiones.

Un pequeño mapa intercalado indica tres grados de fiabilidad de la información sobre los suelos, que sirvió de base para la compilación del mapa.

En el Volumen I de la serie pueden encontrarse definiciones detalladas de las unidades de suelos y descripciones completas de todos los términos utilizados.

## El texto

En el primer capítulo se describe el desarrollo del proyecto en América del Sur y se dan algunas notas sobre los usos del mapa. En el segundo, se da cuenta de la cooperación de organismos y del gran número de personas que han colaborado en los mapas y en el texto, y en el tercero se presenta un sumario del material contenido en el Volumen I sobre los mapas y la leyenda.

Los capítulos importantes de este volumen tratan de las condiciones del medio y los suelos y el uso de la tierra.

### Condiciones del medio

El Capítulo 4 contiene breves reseñas, con mapas, de los cuatro factores del medio que guardan una estrecha relación con la estructura de los suelos: clima, vegetación, geomorfología y litología.

*El clima* se estudia sobre la base de siete amplias subdivisiones, ya que los criterios que se han seguido para la delimitación de las unidades son aquellos que tienen importancia para el desarrollo de los cultivos. El mapa del clima sirve así de complemento del mapa de suelos para la transferencia de información sobre cultivos de una parte del mundo a otra. Aquí sólo se examinan las categorías superiores. Esas regiones se señalan en un mapa a escala pequeña (Figura 2).

*La vegetación* se estudia sobre la base de diez amplias regiones de vegetación distinguidas con arreglo al habitat (climático o edáfico), la fisionomía y la estructura de la vegetación. Estas regiones se subdividen luego en 42 subregiones, que se señalan en un mapa a escala pequeña (Figura 3). El texto contiene algunas breves notas sobre cada región y sobre la ubicación y naturaleza de las subregiones.

*La geomorfología* y el desarrollo del paisaje se estudian en el marco de tres grupos principales de regiones: las zonas de la plataforma precámbrica al este del continente, las cadenas montañosas de los Andes en el margen occidental, y, entre estas dos, las cuencas de los ríos Orinoco y Amazonas y las llanuras del Chaco y de la Pampa. Los elementos del relieve se presentan en un mapa a escala pequeña (Figura 4).

*La litología* se examina también dentro de los epígrafes generales de plataformas, Andes y cuencas. Se incluyen dos mapas a pequeña escala (figuras 5 y 6): uno de las regiones geotectónicas, que se examinan en el texto región por región, y el otro de litología. En el texto se señalan los orígenes geológicos y la naturaleza de las superficies principales visibles en la época presente.

### Los suelos y el uso de la tierra

Los capítulos 5 y 6, en que se describen los suelos del continente, contienen un extenso cuadro de las asociaciones de suelos, una reseña de la distribución de los suelos principales, y un estudio sobre el uso de la tierra y la adecuación de los suelos para la agricultura.

El cuadro de *asociaciones de los suelos* enumera todas las unidades del mapa por orden alfabético de los símbolos. En las otras columnas se presentan:

Suelos asociados
Inclusiones
Fases
Superficies de las unidades en 1 000 hectáreas
Símbolos de los climas
Países en que se presentan
Vegetación
Litología o materiales de partida

*La distribución de los suelos principales* se examina sobre la base de 27 regiones generales de suelos agrupadas en tierras bajas, tierras altas y montañas, y señaladas en un mapa a escala pequeña (Figura 7). Los suelos principales de cada región se estudian en relación con los factores del ambiente, y se indican sus características importantes.

*El uso actual de la tierra y su adecuación para la agricultura* se examinan primeramente de un modo general, con un mapa a escala pequeña de distribución de la población (Figura 8) y una relación de los sistemas de laboreo tradicionales y modernos. A continuación se examinan por separado los principales suelos. Se describe su uso actual y se señala la adecuación de la tierra para el laboreo tanto tradicional como moderno.

El cuadro del uso de la tierra muestra que sólo se cultiva una superficie reducida, no superior al 5 por ciento. La mayor parte de ella se encuentra en los bordes del continente y existen enormes zonas no tocadas por la agricultura. La tierra de cultivo se explota generalmente en unidades pequeñas y con métodos tradicionales, cuyo rendimiento es sólo ligeramente superior al nivel de subsistencia. De aquí que sean posibles importantes incrementos de la producción agrícola, tanto mediante la utilización de los recursos de suelos, no aprovechados actualmente, como con un mejor uso de los que ahora se encuentran bajo cultivo.

## Conclusiones

Una característica señalada de los suelos sudamericanos es su *baja fertilidad natural.* Un 50 por ciento, aproximadamente, del continente está formado principalmente por diversas clases de ferralsoles, acrisoles órticos y arenosoles ferrálicos, que tienen todos una baja capacidad de intercambio de cationes y de bases intercambiables.

Otra limitación que afecta gravemente a la utilización agrícola de los suelos es la *escasez de agua.* En términos generales, el 20 por ciento de América del Sur tiene climas semiáridos o áridos, por lo que la agricultura sin riego es aleatoria o totalmente imposible. Los suelos son principalmente yermosoles, xerosoles, regosoles, litosoles, suelos dañados por la sal, como los solonchaks y solonetz, luvisoles férricos y luvisoles crómicos.

Existen también extensas zonas de *escaso avenamiento*, que constituyen alrededor del 10 por ciento del continente. Aquí los suelos son principalmente gleysoles, acrisoles plínticos, vertisoles y planosoles.

Las extensas zonas de *tierras escarpadas* de los Andes constituyen alrededor del 10 por ciento del continente. Aparte de los litosoles, que predominan, tienen importancia los cambisoles dístricos, andosoles y acrisoles órticos, y su presencia está claramente relacionada con la altitud y con el material de partida. Se trata de suelos ácidos, pero también pueden encontrarse en los valles interandinos y al pie de algunas montañas zonas relativamente grandes de suelos eutróficos. Entre ellos figuran los kastanozems, phaeozems, luvisoles crómicos y cambisoles éutricos.

Son raras en América del Sur las regiones de suelos constituidas en su mayor parte por suelos que no presenten esas limitaciones, y su extensión es inferior al 10 por ciento de la superficie total. Son importantes suelos en esas regiones los phaeozems, kastanozems, luvisoles férricos, ferralsoles ródicos con status básico de medio a alto, nitosoles éutricos y luvisoles crómicos.

Sin embargo, aunque la superficie de las tierras productivas es limitada, una gran parte de ella no está cultivada, o sólo se cultiva con arreglo a métodos anticuados. De aquí que sean posibles sustanciales aumentos de la producción agrícola.

## Apéndice

En el Apéndice se presentan datos de emplazamientos y perfiles, con descripciones de los perfiles y análisis, de algunas de las principales unidades de suelos.

# 1. INTRODUCTION

## History of the project [1]

Recognizing the need for an integrated knowledge of the soils of the world, the 7th Congress of the International Society of Soil Science, held at Madison, Wisconsin, U.S.A. in 1960, recommended that ways and means be found for the publication of soil maps of the great regions of the world. As a follow-up to this recommendation, FAO and Unesco agreed in 1961 to prepare jointly a Soil Map of the World based on the compilation of available soil survey material and on additional field correlation. The secretariat of the joint project was located at the Headquarters of FAO in Rome. It was responsible for collecting and compiling the technical information, undertook correlation studies, and drafted the maps and text.

In June 1961 an advisory panel composed of prominent soils scientists representing various parts of the world was convened by FAO and Unesco to study the methodological, scientific, and various other problems related to the preparation of a Soil Map of the World.[2] The Soil Correlation Committee for South America, already established in 1960 at the Meeting on Soils and Fertilizers for the Latin American Region held at Raleigh, North Carolina, U.S.A., was integrated into the Soil Map of the World project as part of a global network of soil correlation to serve the needs of the project as a whole.

A first draft Soil Map of South America was presented in Madison in 1960 at a scale of 1:10 000 000. The second draft, at scale 1:5 000 000, was presented at the First Meeting on Soil Survey, Correlation and Interpretation for Latin America held in Rio de Janeiro in May 1962. This second draft reflected a considerable amount of newly acquired knowledge attained through soil survey programmes being carried out in different countries throughout the continent. However, for large areas knowledge of the soils was still very limited. In the following years an active programme of soil correlation work was pursued in South America with a view to preparing a third draft of the soil map. For the purposes of filling in some of the most important gaps in the knowledge of the soils of the continent, a number of exploratory studies were carried out in Argentina, Bolivia, Brazil, Chile, Ecuador, Guyana, Paraguay, Peru, and Uruguay. These field tours were organized, in cooperation with government pedologists, by members of the Soil Correlation Committee for South America and FAO staff.

A partial third draft of the soil map was presented at the 8th International Congress of Soil Science in Bucharest, Romania, in 1964, while the completed third draft was discussed during the Second Meeting on Soil Survey, Correlation and Interpretation for Latin America held in Rio de Janeiro in 1965. This meeting was preceded by a soil survey and correlation expedition, through central Brazil, from Rio Branco (Acre Territory), through part of the Amazon forest and the campos cerrados, to Brasilia. Both the meeting and the field trip provided ample opportunity for scientific discussions on soil classification, the map legend, correlation, and soil resources evaluation. The expedition also provided information for starting the preparation of an exploratory soil map of the interior of Brazil at the scale of 1:5 000 000, a project carried out by the Ministry of Agriculture of Brazil, in cooperation with the USAID programme (U.S. Agency for International Development).

In December 1966 the Soil Correlation Committee for South America met in Buenos Aires, Argentina. The Committee paid special attention to the discussion of the soil definitions proposed for the preparation of a uniform legend for the Soil Map of the World. Prior to this meeting, field soil correlation

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[1] This section refers mainly to the preparation of the Soil Map of South America. The history of the project as a whole is dealt with more completely in Volume I.

[2] The participants in this meeting were:
Consultants
Prof. G. Aubert (France), Mr. M. Gamargo (Brazil), Dr. J. D'Hoore (Belgium), Dr. E. Lobova (U.S.S.R.), Dr. S. P. Raychaudhuri (India), Dr. G. D. Smith (U.S.A.), Dr. C. G. Stephens (Australia), Prof. R. Tavernier (Belgium), Mr. Norman H. Taylor (New Zealand), Academician I. V. Tiurin (U.S.S.R.), Prof. F. A. Van Baren (Netherlands).
Unesco Secretariat
Prof. V. Kovda and Dr. M. Batisse.
FAO Secretariat
D. Luis Bramão, Dr. R. Dudal and Mr. F. George.

was carried out in Argentina, Brazil, Venezuela, Ecuador, Peru, Chile and Uruguay by FAO staff in cooperation with the soil scientists in these countries. As a result of the meeting and the field tours, the Soil Correlation Committee undertook to make the necessary revisions for the preparation of the fourth and final draft of the Soil Map of South America. On the basis of the new material received, the fourth draft was completed at the project centre in Rome by the end of 1969. A final phase of the work consisted in adapting and correlating the legend of the map with the one definitely agreed upon early in 1970 for the Soil Map of the World.

The main sources of information used in the preparation of the fourth draft of the Soil Map of South America are described in Chapter 3.

## Objectives

Transfer of knowledge and experience from one area of the earth to another can only be successful when allowance is made for similarities and differences in the geographical, soil and climatic conditions of the regions or countries involved. Furthermore the economic feasibility of different management techniques under prevailing socioeconomic conditions needs to be assessed before they can be recommended for adoption. In order to do so, reliable information on the nature and distribution of the major soils of the world is of fundamental importance. However, the preparation of regional and continental soil maps requires a uniform legend and nomenclature and the correlation of existing soil classification systems. One of the principal objectives of the FAO/Unesco Soil Map of the World project was to promote cooperation among soil scientists all over the world to agree on an international soil correlation system.

In South America agricultural research is centred mainly on increased output from croplands and from pastures. Vast areas exist, however, which have scarcely been touched by man and are only now being studied to evaluate their future role in growing food for the rapidly increasing population. Many experts under international and bilateral programmes are assisting the governments in this task. This continental soils study attempts to present a synthesis of the knowledge available at the present stage of development of soil science in South America. It is hoped that it will promote better understanding among soil scientists, planners and farmers, provide useful coordination of national and international soils work and stimulate research and its application in the region.

## Value and limitations of the map

The Soil Map of South America is meant to be a source of factual data, providing a basis and framework for further regional and national soil surveys at a more detailed scale. It may assist in selecting methods for reclamation, crop production, fertilizer application and general use of soils. Up till now all attempts to make overall plans or forecasts for agriculture have been hampered by lack of uniformity in the terminology, nomenclature and classification of soils and by lack of a comprehensive picture of the world's soil resources.

Through a systematic interpretation of the Soil Map of the World it will be possible to make an appraisal of the distribution and the production potential of the major soils on a continental basis and to delineate broad priority areas which deserve further study. This inventory of soil resources will bring to light the limitations and potentialities of the different regions for increased food production.

In addition, a continental soil map such as the Soil Map of South America can be a valuable teaching aid for the training of geographers, soil scientists, agronomists and all those who are involved with the study of the environment.

Although the publication of the map and text marks a significant step forward, it is necessary to point out its inherent limitations. The accuracy and detail of the information which can be shown are obviously limited by the small scale of the map and by the fact that soil data for some areas are scarce because of inadequate field correlation or lack of direct observations. On the other hand, difficulties have arisen in its use for the compilation of the continental map because of the difference in the methods of field and laboratory studies. These limitations may also apply to the interpretive data, since they can only be as accurate as the soils information on which they are based. Yet despite these shortcomings, this Soil Map of South America is the most recent and detailed inventory of soil resources based on international cooperation. Its limitations emphasize the necessity for intensified soil correlation and for obtaining better knowledge of the nature and distribution of soils in those parts of the continent where information is lacking or inadequate.

## Use of the map and explanatory text

Against the background of the topographic base the soil map shows the broad pattern of dominant soils, marked by different colours. Clusters of closely related colours have been used for soils which have similar characteristics so that major soil regions can be recognized.

More detailed information about each mapping unit can be derived from the soil association symbols. The composition of the soil associations is given in Chapter 5, in which they are listed alphabetically and numerically, together with areas, location, dominant vegetation and lithology. A table showing the composition of the soil associations is also given on the back of the maps.

The meaning of the classes for texture and topography which accompany the symbols of the mapping units is also explained on the soil map, as is the explanation of the overprints which indicate phases. These are further described in Chapter 3. The definitions of the soil units involved can be found in Volume I. The profile descriptions and analytical data in the Appendix illustrate and further clarify the soil definitions.

The geographical distribution of the soils is indicated in Chapter 5. For this purpose the continent has been subdivided into three major physiographic units: the lowlands comprising the major river basins, the uplands including the Precambrian shields, and the Andes. These elements have been subdivided into twenty-seven broad soil regions.

For information on the occurrence, land use, limitations, suitabilities and potentialities of the sol units Chapter 6 should be consulted. Here the specific management problems of the soil units are discussed.

Those who are interested not only in the nature, distribution and suitabilities of the soils (the "agricultural angle") but also in the natural environment will find additional reading in Chapter 4. This chapter deals with climate, with vegetation (which in great parts of South America can still be observed in its natural state), with physiography (supplementing information in the chapter on the distribution of soils) and with lithology.

Some general conclusions of the study may be found at the end of Chapter 6.

# 2. ACKNOWLEDGEMENTS


The preparation of the Soil Map of South America could only be accomplished with the cooperation of government institutions and many soil scientists who provided basic material and took an active part in the meetings, study tours and discussions which led to the various drafts of the map and text.

Those who gave particular help to the project are listed below. Sincere appreciation is also expressed here to all those whom it has not been possible to single out.

### Contributors

OFFICIAL AGENCIES

| | |
|---|---|
| Argentina | Centro Nacional de Investigaciones Agropecuarias (INTA), Instituto de Suelos y Agrotecnia, Buenos Aires |
| Bolivia | Ministerio de Agricultura, La Paz |
| Brazil | Ministerio da Agricultura, Departamento de Pesquisas e Experimentação Agropecuarias, Divisão de Pedologia e Fertilidade dos Solos, Rio de Janeiro |
| Chile | Ministerio de Agricultura, Servicio Agricola y Ganadero, Departamento de Conservación de Suelos y Aguas (DECSA), Santiago |
| Colombia | Instituto Geografico de Colombia "Agustin Codazzi," Bogotá |
| Ecuador | Ministerio de Agricultura y Ganadería, Departamento de Suelos, Quito |
| Guyana | Ministry of Agriculture, Division of Agricultural Chemistry and Soils, Georgetown |
| French Guiana | Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) |
| Paraguay | Ministerio de Agricultura y Ganadería, Facultad de Agronomía y Veterinaria, Departamento de Suelos, Asunción |
| Peru | Instituto Nacional de Planificación, Oficina Nacional de Evaluación de Recursos Naturales (ONERN), Lima |
| Surinam | Departement van Opbouw, Dienst Bodemkartering, Paramaribo |
| Uruguay | Ministerio de Ganadería y Agricultura, Facultad de Agronomía, Programa de Estudio y Levantamiento de Suelos, Convenio de Cooperación Técnica, Montevideo |
| Venezuela | Centro de Investigaciones Agronómicas, Sección de Suelos, Maracay |

INDIVIDUAL CONTRIBUTORS

(by country to which their work relates)

| | |
|---|---|
| Argentina | P. Arens,[1] B. Jarsun, D. Cappannini, J.P. Cornet, P. Culot,[1] P.H. Etchevehere, J.A. Ferrer, B. Jacyszyn, A.B. Lago, S.R. Laserre, H. Laya, R.R. Lores, C.R. Miaczynski, J.C. Musto, R. Purnell,[1] F. Riecken,[1] C.A. Scoppa, R.F. Valencia,[1] J.R. Vargas Gil, R.G. Wermbter |
| Bolivia | L. Arce |
| Brazil | P. Abrao, K.J. Beek,[1] J. Bennema,[1] N.J.T. Bloomfield, D. Luis Bramão,[1] J.H.S. Bruin,[1] M.N. Camargo, R. Costa Lemos, T. Day,[1] I. Falesi, F. Garcia de Freitas, I.A. Gomes, F. Gray,[1] E.H. Gross-Braun,[1] C. Hirano, J.O. Iturri, J.T. Klinger Jacomine, A. Küpper,[1] J.W. da Costa Lima, W. Mendes, F. Palmieri, H. Pierantoni, A.M. Pires Filho, G. Rangel Lima, L. Salgado Vieira, W.G. Sombroek,[1] D. de Souza Castelo, L. Vettori |


[1] FAO staff.

| | |
|---|---|
| Chile | E.M. Besoain, P. Culot,[1] C. Díaz, R. Roberts,[1] A. Valdez F., A.C.S. Wright[1] |
| Colombia | D. Goosen,[1] R. Guerrero, M. del Llano, A. Samper, C.S. Simmons,[1] V.M. Vega J., A. van Wambeke[1] |
| Ecuador | V.H. Andrade S., E. Frei,[1] A. Küpper,[1] R. Pacheco, C. Parreño Herrera, H. Peña, J. Thirion[1] |
| French Guiana | J.-M. Brugière, C. Marius, M. Sourdat |
| Guyana | C.C. Applewhite,[1] R.B. Cate Jr.,[1] T. Day,[1] E.H. Gross-Braun,[1] G.H. Robinson[1] |
| Paraguay | C.C. Applewhite,[1] N. de Barros Barreto, H. Bertoni, P. Chena, T. Sulsona |
| Peru | P. Arens,[1] M. Drosdoff, J. Echenique, R. Rossi, C. Vidalon, C. Zamora, A. Zavaleta |
| Surinam | W.L. Asin, H. Dost, J.J. van der Eyk |
| Uruguay | A.D. Duran, C.A. Fynn, B.A. Kaplan, L. de León, F. Riecken,[1] W.G. Sombroek[1] |
| Venezuela | J. Avilan Rovira, A. Bustamante, A.J. Estrada, J.A. Comerma, E. Hidalgo, O. Hernández León, M. Marino, L. Medina, F.C. Westin[1] |

**Preparation of the map**

In close cooperation with the above-listed government institutions, soil specialists and FAO field staff, four successive drafts of the Soil Map of South America were prepared at the FAO project centre in Rome. The first draft was completed in 1960 by D. Luis Bramão and P. Lemos, the second draft in 1962 by D. Luis Bramão, the third draft in 1965 by A.C.S. Wright and J. Bennema, the fourth and final draft by K.J. Beek.

The drafting and colouring of this series of maps were carried out by D. Mazzei, assisted by Miss H. Both. The areas of the mapping units were measured by J.H.V. Van Baren and Miss M. Zanetti.

Grateful acknowledgement is made of the permission given by the American Geographical Society of New York to use its 1:5 000 000 World Map as a basis for the preparation of the Soil Map of the World.

[1] FAO staff.

**Preparation of the explanatory text**

A draft explanatory text prepared in 1967-68 by K.J. Beek under the direction of D. Luis Bramão was issued in 1969 as World Soil Resources Report No. 34. One of the basic documents used was the "Soil Resources of Latin America," World Soil Resources Report No. 18, prepared by A.C.S. Wright and J. Bennema in 1965. J. Papadakis contributed to the section on climate. The other environmental factors were dealt with by J.J. Scholten. An appendix containing profile data was prepared by R.B. Miller. J.H.V. van Baren and R.B. Miller edited and assembled the text for publication.

**Soil correlation**

Considering the diversity of the basic material used and the different approaches applied to soil classification in different countries, soil correlation has been essential in the preparation of the Soil Map of South America.

The Soil Correlation Committee for South America was established in 1960 with a view to promoting correlation studies throughout the continent by means of international consultation and field work. Members of this Committee were: R. Costa Lemos, Chairman (1965-68), M.N. Camargo, former Chairman (1962-65), W.L. Asin (1965-68), J. Avilan Rovira (1965-68), J.-M. Brugière (1965-68), D. Cappannini (1966-68), C. Díaz, P.H. Etchevehere (1962-66), L. de León (1962-65), C.R. Miaczynski (1962-65), C. Zamora (1965-68).

Meetings of the Committee were held in Rio de Janeiro in May 1962 and July 1965, and in Buenos Aires in December 1966.

The responsibility for intercontinental correlation, preparation of the international legend and definition of soil units was entrusted to R. Dudal, FAO.

**Financial support**

The costs of the preparation and printing of the Soil Map of South America were shared jointly by FAO and Unesco. Acknowledgement is also made here to the Rockefeller Foundation which helped with the financing of soil correlation work in Argentina, Brazil and Uruguay in 1964 and 1965, and to the governments of Belgium and the Netherlands which made the services of several associate experts available to the project.[2]

[2] From Belgium: J.P. Cornet (1964-67); from the Netherlands: K.J. Beek (1963-66), J.H.V. Van Baren (1965-66), J.H.S. Bruin (1966-68), J.J. Scholten (1967-68).

# 3. THE MAP

### Topographic base

The Soil Map of South America was prepared on the basis of the 1:5 000 000 topographic map series of the American Geographical Society of New York, assuming an average radius of the earth of 6 378 388 metres. For South America this map is in two sheets divided between the latitudes of 20° and 22° S. A bipolar oblique conic conformal projection was used.

Areas of land surfaces measured directly on the map with a planimeter are subject to variations due to the projection of less than 8 percent. Distances between land points measured directly on the map are subject to errors of less than 4 percent. The accuracy can be greatly improved by use of the key map on the American Geographical Society map, which gives lines of equal scale departure and conversion tables based on mean scale departure ratio.

### Map units

The map unit consists of a soil unit or of an association of soil units. The textural class is indicated for the dominant soil unit while a slope class reflects the topography in which the soil association occurs. Furthermore, the associations may be phased according to the presence of indurated layers or hard rock at shallow depth, stoniness, salinity and alkalinity. In South America the mapping units occurring with a cerrado vegetation are shown as a "cerrado" phase. Cerrado vegetation is indicative of soils of extremely low fertility, but so far it has not been possible to detect soil characteristics which separate these soils from similar soils under forest vegetation. The soil units, classes and phases are defined in Volume I.

Each soil association is composed of dominant and subdominant soil units, the latter estimated to cover at least 20 percent of the delimited area. Important soil units which cover less than 20 percent of the area are added as inclusions.

The symbols of the mapping units show the soil unit, textural class and slope class as follows:

1. Soil units

The symbols used for the representation of the soil units are those shown in the list of soil units on the back of the map. They are listed also in Table 1.

2. Textural classes

The textural classes, coarse, medium and fine, are shown by the symbols 1, 2 and 3 respectively.

3. Slope classes

The slope classes, level to gently undulating, rolling to hilly, and strongly dissected to mountainous, are indicated by the letters a, b and c respectively.

TABLE 1. — SOIL UNITS FOR SOUTH AMERICA

| | |
|---|---|
| A | ACRISOLS |
| Af | Ferric Acrisols |
| Ag | Gleyic Acrisols |
| Ah | Humic Acrisols |
| Ao | Orthic Acrisols |
| Ap | Plinthic Acrisols |
| B | CAMBISOLS |
| Bd | Dystric Cambisols |
| Be | Eutric Cambisols |
| Bf | Ferralic Cambisols |
| Bh | Humic Cambisols |
| Bk | Calcic Cambisols |
| E | RENDZINAS |
| F | FERRALSOLS |
| Fa | Acric Ferralsols |
| Fh | Humic Ferralsols |
| Fo | Orthic Ferralsols |
| Fp | Plinthic Ferralsols |
| Fr | Rhodic Ferralsols |
| Fx | Xanthic Ferralsols |
| G | GLEYSOLS |
| Gc | Calcaric Gleysols |
| Gd | Dystric Gleysols |
| Ge | Eutric Gleysols |
| Gh | Humic Gleysols |
| Gm | Mollic Gleysols |
| Gp | Plinthic Gleysols |
| H | PHAEOZEMS |
| Hh | Haplic Phaeozems |
| Hl | Luvic Phaeozems |
| I | LITHOSOLS |
| J | FLUVISOLS |
| Jc | Calcaric Fluvisols |
| Jd | Dystric Fluvisols |
| Je | Eutric Fluvisols |
| Jt | Thionic Fluvisols |
| K | KASTANOZEMS |
| Kh | Haplic Kastanozems |
| Kk | Calcic Kastanozems |
| Kl | Luvic Kastanozems |
| L | LUVISOLS |
| Lc | Chromic Luvisols |
| Lf | Ferric Luvisols |
| Lo | Orthic Luvisols |
| Lp | Plinthic Luvisols |
| N | NITOSOLS |
| Nd | Dystric Nitosols |
| Ne | Eutric Nitosols |
| O | HISTOSOLS |

P PODZOLS

Pg Gleyic Podzols
Ph Humic Podzols
Po Orthic Podzols

Q ARENOSOLS

Qa Albic Arenosols
Qf Ferralic Arenosols

R REGOSOLS

Rd Dystric Regosols
Re Eutric Regosols

S SOLONETZ

Sm Mollic Solonetz
So Orthic Solonetz

T ANDOSOLS

Th Humic Andosols
Tm Mollic Andosols
To Ochric Andosols
Tv Vitric Andosols

U RANKERS

V VERTISOLS

Vc Chromic Vertisols
Vp Pellic Vertisols

W PLANOSOLS

Wd Dystric Planosols
We Eutric Planosols
Wh Humic Planosols
Wm Mollic Planosols
Ws Solodic Planosols

X XEROSOLS

Xh Haplic Xerosols
Xk Calcic Xerosols
Xl Luvic Xerosols

Y YERMOSOLS

Yh Haplic Yermosols
Yk Calcic Yermosols
Yl Luvic Yermosols

Z SOLONCHAKS

Zg Gleyic Solonchaks
Zo Orthic Solonchaks

## Cartographic representation

### SYMBOLS

The soil associations have been noted on the map by the symbol representing the dominant soil unit, followed by a figure which refers to the descriptive legend on the back of map in which the full composition of the association is outlined.

Example: Lc5 Chromic Luvisols and Chromic Vertisols
Fo2 Orthic Ferralsols and Ferralic Arenosols

Associations in which Lithosols are dominant are marked by the Lithosol symbol I combined with one or two associated soil units.

Example: I-Bd Lithosols and Dystric Cambisols
I-Lc-To Lithosols, Chromic Luvisols and Ochric Andosols

Where there are no associated soils or where the associated soils are not known, the symbol I alone is used.

If information on the texture of the surface layers (upper 30 cm) of the dominant soil is available the textural class figure follows the association figure, separated from it by a dash.

Example: Lc5-3 Chromic Luvisols, fine textured, and Chromic Vertisols
Fo2-2 Orthic Ferralsols, medium textured, and Ferralic Arenosols

Where two groups of textures occur that cannot be delimited on the map two figures may be used.

Example: Wm2-2/3 Mollic Planosols, medium and fine textured, and Pellic Vertisols

Where information on relief is available the slope classes are indicated by a small letter: a, b or c, immediately following the textural notation.

Example: Lc5-3a Chromic Luvisols, fine textured, and Chromic Vertisols, level to gently undulating

In complex areas where two types of topography occur that cannot be delimited on the map two letters may be used.

Example: Fx1-2ab Xanthic Ferralsols, medium textured, level to rolling

If information on texture is not available, then the small letter indicating the slope class will immediately follow the association symbol.

Example: I-Be-c Lithosols and Eutric Cambisols, steep

### MAP COLOURS

The soil associations have been coloured according to the dominant soil unit. Each of the soil units used for the Soil Map of the World has been assigned a specific colour. The distinction between map units is shown by a symbol on the map.

The colour selection is made by clusters so that "soil regions" of genetically related soils will show up clearly.

If insufficient information is available to specify the dominant soil unit, the group of units as a whole is marked by the colour of the first unit mentioned in the list (e.g. the colour of the Haplic Yermosols to show Yermosols in general, the colour of the Orthic Podzols to show Podzols in general and the colour of the Ochric Andosols to show Andosols in general).

Associations dominated by Lithosols are shown by a striped pattern and by the colour of the associated soils. If no associated soils are recognized (because they occupy less than 20 percent of the area or because specific information is lacking), the colour of the Lithosol unit is applied uniformly over the hatched pattern.

### PHASES

Six phases are indicated on the Soil Map of the World by overprints.

The *petric* and *petrocalcic* phases show the presence of indurated layers (concretionary horizons and petrocalcic horizons respectively) within 100 cm of the surface.

The *stony* phase marks areas where the presence of gravels, stones, boulders or rock outcrops makes the use of mechanized agricultural equipment impracticable.

The *cerrado* phase indicates the presence of cerrado vegetation as discussed earlier.

The *saline* phase shows that certain soils of the association (not necessarily the dominant ones) are affected by salt to the extent that they have a conductivity greater than 4 mmhos/cm in some part of the soil within 125 cm of the surface for some part of the year. The phase is intended to mark present or potential salinization. The *sodic* phase is used for soils which have more than 6 percent saturation with sodium in some part of the soil within 125 cm of the surface. It should be noted that Solonchaks are not shown as saline phases and Solonetz as sodic phases since these soils are saline and sodic respectively by definition. It follows that to pick out all areas with saline soils one should include saline phases plus Solonchaks, and areas with alkali soils include sodic phases plus Solonetz.

Where more than one of these phases applies, only the one causing the strongest limitations for agricultural production has been shown.

#### Miscellaneous land units

Miscellaneous land units are used to indicate salt flats, dunes and shifting sand, and glaciers and snow caps.

Where the extent of the land unit is large enough to be shown separately the sign may be printed over a blank background. In case the land unit occurs in combination with a soil association the sign may be printed over the colour of the dominant soil.

### Sources of information

A map showing the sources of information of the Soil Map of South America (Fig. 1) is shown as an inset on the Soil Map. A separation is made between the areas compiled from systematic soil surveys, soil reconnaissance and general information with local field observations.

During the period of the preparation of the fourth draft map of South America, field soil survey activities expanded considerably in the region, and the results were incorporated into the present document. About 13 percent of the continent is now covered by soil survey maps based on sufficient ground control to be placed in reliability class I. Inevitably, among these maps there is variation in accuracy depending on a number of factors such as scale, methodology and purpose of preparation. The use of diverse methods of classification also makes correlation more difficult and directly reduces the reliability of the map. Further uncertainty is introduced by the influence on soil boundaries of differing concepts used in defining the units.

Approximately 48 percent of the Soil Map in reliability class II has been prepared from exploratory soil studies designed to give, in combination with basic information on the natural environment, a fair idea of the composition of the soil pattern. Advantage was taken of marked changes in the vegetational, geomorphological, lithological and climatic patterns in the preparation of the soil maps of certain areas where there was insufficient coverage by soil surveys.

The third class of reliability, covering 39 percent of the continent, refers to areas which are unexplored, or in which occasional soil studies have not supplied sufficient basic data for the compilation of more than a rough sketch of the soil pattern, even at the 1:5 000 000 scale. To understand the soil pattern of these regions, therefore, further studies still need to be undertaken. Aerial photographs are seldom available. However, since these regions are mostly thinly populated and have poor accessibility, they usually occupy a low priority position for development. It may take a long time before the necessary data for improving the map will become available. New aerial photographs and other information that may become available through remote sensing from spacecraft and satellites may eventually be used.

In the preparation of the Soil Map of South America a very large number of documents was consulted. Although it is impossible to mention all of them, the main ones, covering substantial areas of the map or specifically prepared for the project, are recorded here by the country of origin. Comment is also made on the reliability of the maps in the areas discussed.

#### Argentina

The main source was a 1:5 000 000 soil map based partly on the third draft version, which represents the efforts of many Argentine soil scientists. It was prepared in 1967 under the supervision of D. Cappannini and P. Etchevehere of INTA (now the Centro Nacional dc Investigaciones Agropecuarias, Buenos Aires), and P. Arens of FAO, with a correlated legend. The northern part of the map includes observations made during the Soil Correlation Committee Tour of July 1964 (FAO, 1966a), and the studies undertaken by INTA with the participation of FAO staff in December 1967. Only the

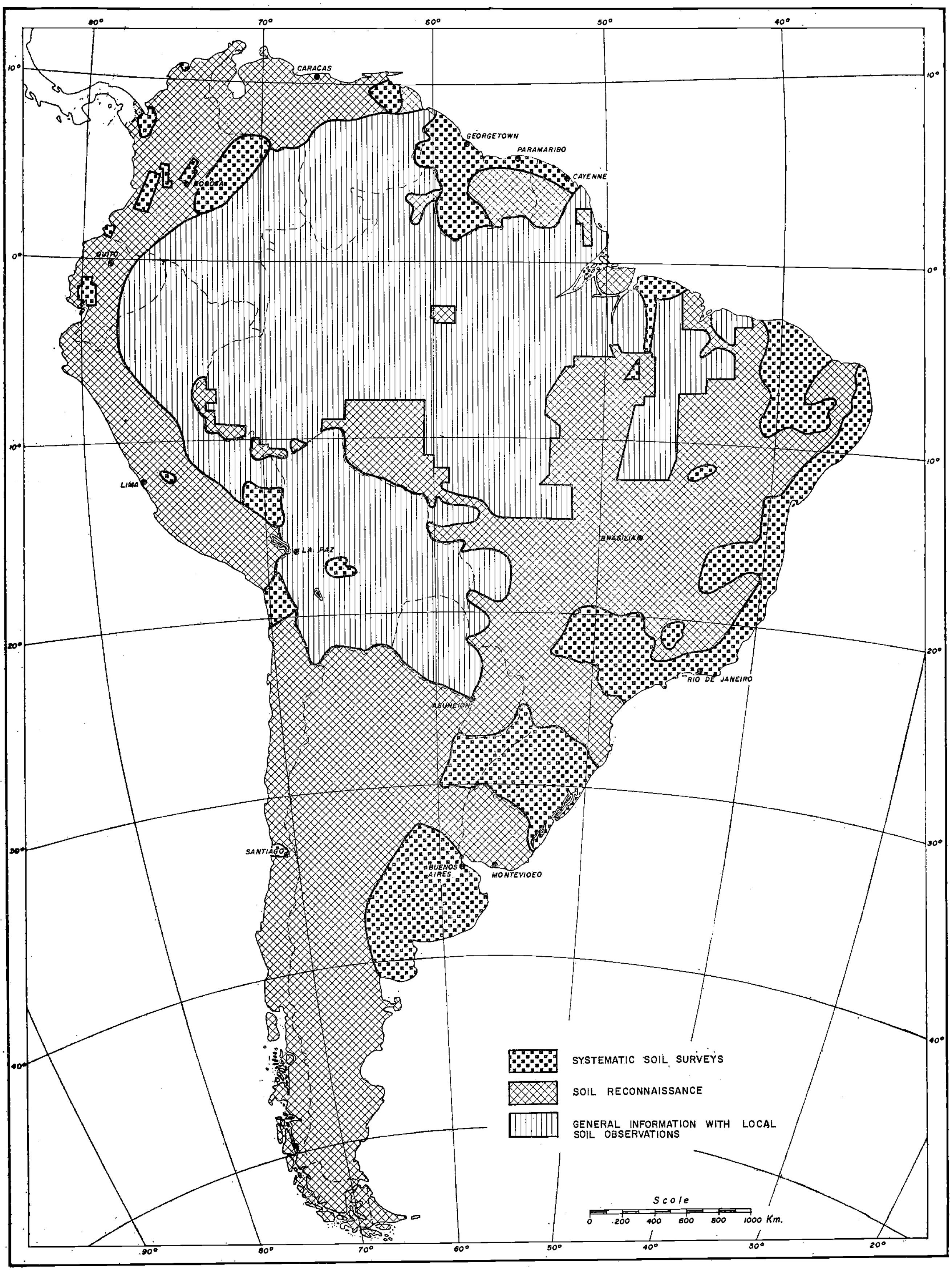


*Figure 1. – Sources of information*

Pampa region, where a systematic soil survey project is now under way, has been included in reliability class I; the remaining portion is in class II.

### BOLIVIA

The outline prepared by A.C.S. Wright of FAO, based on exploratory studies (Wright, 1964) and some information from the Ministry of Agriculture, La Paz, and from San Simón University, provided the basis for the outline of the fourth draft. The country, as a whole, falls in reliability class III. For about five percent of the country, soil capability surveys have been carried out, most of them in the eastern lowlands. The borders of the Mamore River have also been explored. The results of a reconaissance survey by a British mission (at a scale of 1:200 000) of the foothills and piedmont of the eastern lowlands were not available for inclusion.

### BRAZIL

1. A huge portion of the interior of Brazil, some six million square kilometres or two thirds of the country's surface, has been studied on an exploratory basis by the Division for Soil Survey and Soil Fertility of the Ministry of Agriculture, Rio de Janeiro, with the collaboration of the U.S. Agency for International Development (USAID) programme. FAO also took part in some of the basic exploration (Beek and Bennema, 1966). The soil map prepared for this otherwise largely unknown area has provided a wealth of new information. For various reasons, particularly the availability of aerial photographs and feasibility of penetration, both detail and reliability vary, reliability being included in classes II or III. The soil boundaries in the Amazon basin are based on a schematic outline prepared by W.G. Sombroek of FAO. Most of this area belongs to reliability class III, but along the Amazon river and along the Brasilia-Belem highway more reliable information is available. The Bragantina area east of Belem has also been more thoroughly studied by FAO (Day, 1961). As well as these, there are some smaller scattered areas on Marajo, near Manaus, in Amapa, in the Boa Vista area of the Roraima Territory, along the Alto Araguaya, in Acre between Rio Branco and the Bolivian border and some other places, all, however, too small in extent to be specially indicated on the small-scale map of soil sources.

2. A 1:5 000 000 soil map of southern Brazil has been prepared by R. Costa de Lemos, Chairman of the South American Soil Correlation Committee, for inclusion in the fourth draft of the Soil Map of South America (reliability classes I and II).

3. A 1:1 000 000 soil map of the area of Baia and Espirito Santo was prepared by the Centro de Pesquisas do Cacan, Setor de Levantamento de Solos, CEPLAC and the Division for Soil Survey and Soil Fertility. Reduction to 1:5 000 000 was done in cooperation with J. Olmos Iturri (reliability class I).

4. The remaining area of Brazil is partly compiled from reconnaissance soil maps. These include those of São Paulo (Comissão de Solos, 1960), Rio de Janeiro (Comissão de Solos, 1958), Ceara State (unpublished), parts of the San Francisco river basin (FAO, 1966b), the Jequitinhonha river area (Comissão de Solos, 1959), and the Furnas area in Minas Gerais (Comissão de Solos, 1962), and some other smaller areas which are of class I reliability. Other sources were also used, including maps of topography and environmental factors, which together with the scattered soils information permitted a delineation of soils, estimated as belonging to reliability class II. This area is very similar to that represented on the third draft soil map, for which Wright and Bennema were mainly responsible. Camargo published a sketch soil map of the country at the 1:12 500 000 scale in the Atlas de Brasil (Instituto Brasileiro de Geografia e Estatistica (IBGE), 1966).

5. For northeastern Brazil, a sketch soil map at the 1:5 000 000 scale was prepared by P. Klinger Jacomine and J.H. Bruin, with a legend in terms of the soil units used for the Soil Map of the World (reliability classes I and II).

### CHILE

The soil map of Chile closely follows the third draft soil map presentation prepared by A.C.S. Wright and based on previous maps of Roberts (FAO) and Díaz (Departamento de Conservación de Suelos y Aguas, Ministerio de Agricultura) (1959-60), Díaz and Wright (1965) and Wright (1965). It has been included in reliability class II.

### COLOMBIA

The soil map of Colombia is a compilation of a variety of soil maps from the Instituto Geografíco de Colombia "Agustín Codazzi" and from FAO. Some corrections to this map, as used in the third draft of the Soil Map of South America, were received from V.M. Vega in 1967. The principal documents consulted were reports of soil surveys by the Instituto Geografíco "Agustín Codazzi," from the Cauca valley, 1:50 000 (unpublished), Rio Mira region, 1:100 000

(1960a), Uraba region, 1:250 000 (1960b), Atlantico department, 1:50 000 (1960c), central coffee region, 1:100 000 (1962), and the Llanos Orientales Report, 1:250 000 (FAO, 1965). Numerous Colombian and FAO soil scientists took part in these surveys. Apart from the Orinoco and Amazon basins (reliability class III) the soil map of Colombia comprises areas of class I, including areas described in the reports listed previously. Class II was assumed for the remaining part, which was prepared through compilation and interpolation with some exploratory field studies.

### Ecuador

The general soil pattern is known through the work of E. Frei, J. Thirion, R. Pacheco, H. Peña and others of the Departamento de Suelos, Ministerio de Agricultura y Ganadería, and of FAO. In 1963 Pacheco revised the 1956 soil map of Frei at a scale of 1:2 000 000 for inclusion in the third draft. Included also is the map of the Guayas Basin 1:500 000 (Pan American Union, 1964). The latter has been included in reliability class I, with the remaining part of the country in class II except for the Amazon region which is virtually unknown and has been placed in class III. Information on the Galapagos Islands has been taken from J. Laruelle (1965).

### French Guiana

A large amount of detailed and semidetailed information has been published by the Office de la Recherche Scientifique et Technique Outre Mer (ORSTOM). In 1967 J.M. Brugière prepared a soil map at the scale of 1:3 000 000 with a correlated legend for inclusion in the final draft of the soil map. Reliability is assessed at class I for the coastal areas and at class II for the interior.

### Guyana

The map is a reduction of the 1:1 000 000 general soil map, prepared for a UNDP/FAO Special Fund project (FAO 1965-1966) by Cate, Day, Gross-Braun, Robinson, Applewhite, and others. The country as a whole has been included in reliability class I, since nearly the entire area has been studied from aerial photographs with field checking.

### Paraguay

The soil boundaries of this country are based on the findings of Tirado Sulsona et al. (1954), A.C.S. Wright et al. (1964), and on those of a follow-up investigation by the Soil Correlation Committee (FAO 1964). The western side of the country (the Chaco), gives a very general picture (reliability class III), whereas eastern Paraguay is better known and comes under reliability class II. The geological map by H. Putzer (1962) provided additional information. A survey of the southeast ("Plán Triángulo," 1967) provided interesting detailed information on the capabilities of the soils of this portion of the country.

### Peru

The soil map of Peru was prepared at the scale of 1:1 000 000 by C. Zamora of the Oficina Nacional de Evaluación de Recursos Naturales (ONERN) in 1967. The map has been reduced and simplified and somewhat modified, particularly in the Amazon and the Madre de Dios regions by Arens of FAO. This map is a compilation based on environmental conditions, particularly topography, altitude, and parent materials. The major part belongs to reliability class II, with some unspecified areas belonging to class I and some in the Amazon region belonging to class III.

### Surinam

Soil investigations in Surinam were carried out mainly in the coastal belt (van der Eyk, 1957). Reliable information exists for large areas, chiefly those with local development projects. Dost (1963) of the Soil Survey Division, Department of Development, prepared a soil map of Surinam at the 1:1 000 000 scale which was slightly altered and correlated with the legend of the World Soil Map by W.L. Asin in 1967. The reliability is assessed as class I in the coastal areas and class II (but including also class III) in the interior, a pattern similar to that of French Guiana.

### Uruguay

Contributions to the study of the soils of Uruguay have been made by Riecken (1959) and by C.A. Fynn et al. (1959). The Correlation Committee also studied soils there (FAO 1966a). Furthermore Duran and Kaplan of the Departamento de Suelos Facultad de Agronomia and Sombroek of FAO prepared a soil map in 1967 at the scale of 1:1 000 000 with correlated legend for inclusion in the Soil Map of South America. Important detailed soil investigations have been carried out through the FAO/UNDP project in the Lagoa Merim area, extending into southern Brazil. The latter region has been included in reliability class I and the remaining part of the country in class II.

VENEZUELA

The soil map prepared by Avilan and Bustamante of the Centro de Investigaciones Agronómicas, Maracay, and Westin of FAO (1962), at the scale of 1:2 500 000 was subsequently altered and correlated with the legend of the Soil Map of the World by Avilan in 1966. The reliability of this general map is assessed as class II north of the Orinoco river and class III south of it. There are some better known areas, including Monagas State with a soil map of the scale 1:350 000 and parts of the Orinoco delta.

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# 4. ENVIRONMENTAL CONDITIONS

In this chapter brief outlines are given of four aspects of the environment that are important in the development of soils. These are climate, vegetation, physiography and lithology.

These outlines, each of which is accompanied by a small-scale map, indicate the location and nature of the major regions in which important variants of climate, vegetation, landscape and rock types occur.

## CLIMATE

### Climatic factors [1]

The climatology, or average long-term meteorological condition, of a place depends both on what Köppen has referred to as a broad group of external factors, i.e., astronomical location, general circulation, surface features, altitude and exposure, and on a group of climatic elements which characterize each of the broad factors and are closely interrelated with them. These elements include temperature and rainfall averages and extremes, atmospheric pressures, wind speeds and directions, relative humidity and cloudiness. Since the climatic factors and elements all depend upon the daily weather conditions, the discussion of the climates of South America must necessarily draw heavily on meteorological data. It should be noted that long-term weather records are frequently unavailable for this part of the world, so that much extrapolation and interpretation must be carried out in order to arrive at a generalized idea of climate.

Among the various external factors, the astronomical location of a place is the most important in determining major climatic characteristics. In this regard South America extends through approximately 65° of latitude (12°N-55°S), reaching farther southward from its position across the equator than any other land mass. Because more than half the land mass is in the equatorial latitudes, where the continent extends across 45° of longitude (35°W-80°W) a tropical condition dominates the land area. In fact, South America has the earth's greatest continental extent of humid tropical climates, a feature which makes for special physical and cultural landscape conditions. South of the Tropic of Capricorn this continent narrows rapidly so that the middle and high latitude areas are compressed into a wedge of land that tapers to a point at the island of Tierra del Fuego. The narrowing of the land at these middle and high latitudes permits a greater maritime influence so that summer and winter temperature extremes are attenuated. Because of the small range between the hottest and coldest months in the tropical parts of South America, and the attenuated range in the nontropical parts, nowhere on this great land mass is there a significant occurrence of the continental type climate.[2] Figure 2, page 17, the climatic map of South America, shows the diverse climates with temperature and humidity regimes. Table 2 gives more detail for locations representing the climatic regions of the map.

The circulation of air over the continent is dominated by winds from the edges of the great semipermanent anticyclones in the Atlantic and Pacific oceans. These winds blow generally from the northeast in the northern hemisphere, and with an easterly component in the southern hemisphere.

The northeast trades may reach as far as 5°S in Brazil during January and blow strongly night and day over the entire north coast of the continent. In the northern hemisphere summer they remain north of the equator and weaken to gentle breezes.

In the southern hemisphere the trade winds blow toward Brazil from the South Atlantic anticyclone during summer. These (January) winds affect the coast from 15°S to approximately 3°S. In winter

[1] This general introduction on climate is extracted from "The climatology of South America" by Robert C. Eidt in *Biogeography and ecology in South America*, and reproduced here with the kind permission of the author and the editors, Junk, the Hague.

[2] A climate in which both a rigorous winter with snow cover (coldest month below freezing) and an equally authentic summer (warmest month above 10°C) occur.

they cross the equator and advance northward to 5°N. Although they blow primarily from the southeast, they have a more pronounced easterly and even northeasterly vector at times.

In order to appreciate the influence of wind movements on South American climates it is necessary to take into account the major landforms, since they bring about important changes in the expected general circulation patterns. The most prominent feature which causes irregularities in the circulation is the Andean chain of mountains. The Andes consist of a series of complex ranges which parallel the north coast of Venezuela and the entire west side of South America. Perhaps the greatest climatic effect of the Andes is that they prevent winds from the South Pacific anticyclone from entering the interior of South America, or permit them to do so only under greatly modified conditions, i.e., after large amounts of their moisture have been removed on windward mountain slopes. This results in an elongated rain shadow zone which extends east of the Andes from Bolivia south to Tierra del Fuego. The Andean barrier also produces extraordinarily high orographic rainfall on the windward slopes of the Pacific coasts of Colombia and southern Chile. A second change takes place on the inland edge of the Amazon Basin where moist east winds rise upslope in the Andes and bring about much heavier rainfall than is found at lower elevations. These winds may descend on the west slopes of the Andes and contribute to the stability of weather conditions in western Peru and Chile. Finally, the Andes are high enough to create temperate and polar climates even in the real tropics. The great snow-capped ranges in Peru, Chile and Argentina are inhospitable but act as valuable moisture reservoirs which enable man to carry on agriculture and grazing in desert and steppe climates at lower elevations.

A secondary group of variations is produced on a regional level by the Andes. Within a single cordillera, for example, there may be highland basins (Cordillera Oriental, Colombia), or between cordilleras there may be high plateaus (the altiplanos of Peru and Bolivia) whose generalized wind systems vary according to the position of the local ranges, the altitude and the exposure. In some areas there are coast ranges which alter the climate of the places between them and the higher mountains of the interior by producing dynamic drying (Colombia and Chile). In others as many as three subparallel cordilleras exist instead of one simple "chain" of Andes. Each has an effect on the winds and hence on the precipitation regime of the adjacent regions. According to the altitude and breadth of the ranges, greater or lesser variations are brought about in the local climatology.

Other major alterations in the expected circulation pattern occur in the Brazilian highlands. This mountainous terrain, sometimes called the Brazilian shield, follows the south edge of the Amazon river to the Madeira tributary, then extends along the south side of the Serra dos Parecis and southward along the uplands of eastern Paraguay, northeast Argentina and Rio Grande do Sul, Brazil, until the 30th parallel is reached. From there the border proceeds east until it reaches the Atlantic Ocean. Much of the western edge of the Brazilian highlands is an escarpment whose top is from 100 to 400 metres above the surrounding lowlands. Regional and local wind patterns are especially affected by it. Along the coast the escarpment is more continuous and abrupt, and it blocks passage of onshore winds between Porto Alegre and Baia. In fact, the escarpment collects so much orographic rainfall that this extensive coastal strip is humid throughout the year except between Rio de Janeiro and Victoria. The wetter zones, between São Paulo and Rio de Janeiro, and from Victoria to Baía, are covered by dense tropical rain forests. On the other hand, in the northeast of Brazil a group of uplands causes the southern trade winds to reach the interior of the state of Rio Grande do Norte as dry air. Dynamic warming helps create an arid climate in this area. The west side of the Rio São Francisco is bordered by a second south-north range, the Serra Geral de Goiás, which also blocks winds from the east, making its west side somewhat drier. However, almost everywhere in the interior of the Brazilian Highlands the ranges are sufficiently low so that they do not interfere generally with the stabilizing ability of the intensified "winter" trade winds to maintain a dry season at that time of year.

A third zone of mountains north of the Amazon river, the Guiana highlands, blocks the northeast trade winds and produces a dry winter condition on their high leeward slopes. The Andes and their associated coast ranges perform a similar function in the north of Venezuela. The general stabilizing effect of the trade winds during the low-sun period creates a tropical savanna climate with relatively dry "winter" which extends from western Surinam across most of Venezuela and northern Colombia.

Two other relatively high land masses in Argentina have an effect on general circulation: the Patagonian plateau and the Sierras de Córdoba. The Patagonian plateau has sufficient altitude to lower average air temperatures some 2.5°C below their normal sea level equivalents. The Sierras de Córdoba occasionally collect moisture from storms which cross Patagonia. However, the ranges are often affected by dynamically warmed winds associated with the general circulation patterns.

In addition to the five mountainous areas described there are three major lowlands which affect circulation on the continent. These are all less than 200 metres above sea level and occupy perhaps 20 percent of the total land mass. The greatest of these lowlands is the Amazon basin which is shaped like a funnel lying on its side with the spout separating the Guiana highlands from the Brazilian highlands and terminating at the Atlantic Ocean. Through this spout the tropical winds from the coast are able to enter and blow upriver where they bring large quantities of moisture to the lowland. This moisture condenses during strong convectional heating typical at these latitudes and collects in the Amazon river as well as in the region encompassed by its sizeable tributaries. The combination of orographic uplift at the inner edges of the basin and constant convection throughout makes this a moist region the year around and the largest area of tropical rain forest in the world.

Both north and south of the Amazon Basin there is a zone of extensive lowlands. The smaller of these is in the north and is named after its principal river, the Orinoco. The Llanos del Orinoco, or plains of the Orinoco, are in the savanna area of Venezuela and have a relatively dry "winter" season. The llanos are sufficiently low so that a hot tropical climate occurs.

The second, larger area south of the Amazon basin consists of the combined Mamoré, Chaco and pampa lowlands. Although the western side of this continuously low area is to the leeward of the Andes and is therefore arid, the rest has a moist climate. The northernmost sector has a dry winter regime. However, polar weather fronts, unimpeded maritime air invasions from the Atlantic Ocean, and convection provide sufficient precipitation the year around for the rest of the lowland to be classified as a humid region. The average altitude of this entire lowland is less than 200 metres, but only the northernmost extremity has a tropical climate. The rest extends well south (almost 20° of latitude) and is temperate.

Besides winds and landforms the occurrence of ocean current has a strong influence on the climate in certain parts of South America. The major cold current, known as the Humboldt current, may be detected off the west coast of South America almost as far north as the equator. During the southern hemisphere winter a lowering of water temperatures is brought about by this current partially from water transport, but primarily from upwelling of deep, cold water which replaces the transported surface water.

An important climatic phenomenon caused by cooling of air above the Humbolt current is the formation of stratus clouds at or near the surface. These clouds may be blown inland 50 km or more to the edge of the Andes. Except for a brief midsummer period they prevent extreme heating at the surface and provide a source of moisture for "fog-farming" along the coast, and for a dense growth of ephemeral plants collectively known as loma (*Tillandsia* species, for example). Fog formations are called "garúa" in Peru.

The larger part of the east coast of South America is bathed by two warm currents, both of which are components of the south equatorial current. The latter splits at Cabo Roque, Brazil, so that one branch swings north and eventually becomes part of the Gulf Stream, while the other moves south as the Brazil current. Both contribute moisture to the trade winds.

One other warm current affects the continent sometimes with violent results. It is called El Niño (the Child) since it comes to the northwest Pacific coast every year at Christmas time. It often brings heavy rains south as far as Chimbote. El Niño appears to originate as a component of the equatorial counter current which flows as far south as the Humboldt current permits. In years when the Humboldt current is displaced to the west, El Niño may extend well south of Lima and cause heavy rain damage in coast desert communities.

Altitude and exposure are two factors which play an especially important role in the climatology of South America where well over half the inhabited terrain is mountainous and much of the population lives along the extensive coastline. Two kinds of winds are produced in these areas as a rule and can be relied upon to contribute to local climatic variations. One is the mountain-valley breeze; the other the land-sea breeze. They are caused by more rapid heating (daytime) and more rapid cooling (night) of air in the higher places.

Temperature differences resulting from differences in height are the second important altitude-linked characteristic of South American climates. This phenomenon is especially significant in the tropics where the annual range of temperature is low, and it becomes possible to predict with considerable accuracy the monthly or annual temperature by knowing the altitude. In fact, the change with altitude is such a predictable phenomenon that it has been incorporated into everyday speech by the use of such terms as tierra caliente, tierra templada and tierra fría. Using Colombia as an example, tierra caliente extends from sea level to approximately 1 000 metres. Temperatures range from 30°C-24°C. This is the hot tropical landscape where bananas, cacao and coconuts are raised. Tierra templada extends from 1 000-2 000 metres and has

## KEY TO CLIMATIC MAP OF SOUTH AMERICA

| | Climate | Temperature regimes | Humidity regimes | Main locations |
|---|---|---|---|---|
| 1.1a | Humid semihot equatorial | Eq | HU Hu MO Ln 1000mm | Amazonia |
| 1.1b | Humid semihot equatorial | Eq | HU Hu MO Ln 1000mm | NE and NW coastal regions |
| 1.2 | Humid semihot tropical | Tr | HU Hu MO | Rio de Janeiro coast |
| 1.3 | Dry semihot tropical | Eq Tr | HI 0.44-1 | Dry NE and NW coastal regions |
| 1.4a | Hot tropical | EQ TR | MO Mo | Campos cerrados of Brazil |
| 1.4b | Hot tropical | EQ TR | MO Mo (inundated in humid season) | Llanos of Venezuela and Colombia, Beni of Bolivia, Mato Grosso of Brazil |
| 1.5 | Semiarid tropical | EQ Eq TR | mo | Brazilian caatinga, Venezuela, Ecuador |
| 1.7a | Humid tierra templada | Tt tt | MO | Brazilian planalto |
| 1.7b | Humid tierra templada | Tt tt | Hu | Andean countries |
| 1.8 | Dry tierra templada | Tt tt | MO Mo | Dry planalto of Brazil, NW countries |
| 1.92 | Cool winter semihot tropical | tR | Mo | West lowlands of São Paulo, Brazil |
| 2a | Low-high tierra fría | TF Tf tf | HU Hu MO Mo mo | Highlands from Argentina north, S Brazil |
| 2b | Low and high Andean | An an | HU Hu MO Mo mo | Altiplano of S Peru, Bolivia, NW Argentina |
| 3.1 | Hot tropical desert | TR | do | N Peru, Venezuela |
| 3.2 | Hot subtropical desert | SU | da do | Argentina |
| 3.34 | Cool tropical desert, summer g | tr | da | Coastal Peru |
| 3.36 | Cool tropical desert, summer 0 | tr | da | N Chile coast |
| 3.5 | Andean desert | tf An | do | Peru, Bolivia, Chile |
| 3.8 | Pampean desert | PA TE | da de di do | Argentina |
| 3.9 | Patagonian desert | Pa pa | de | Argentina |
| 4.1 | Humid subtropical | Su | HU Hu | S Brazil, Uruguay |
| 4.2 | Monsoon subtropical | SU | Mo mo (dry spring) | N Argentina |
| 4.3a | Semiarid hot semitropical | Ts | mo | Bolivia, Paraguay, N Argentina |
| 4.3b | Dry and moist monsoon, hot semitropical | Ts | Mo MO | Paraguay, N Argentina |
| 4.4 | Semihot semitropical | Ts | Hu | S Brazil, Paraguay |
| 5.1 | Typical pampean | PA | St | E Argentina |
| 5.3 | Subtropical pampean | SU Su | St | NE Argentina |
| 5.6 | Monsoon pampean | PA | Mo mo | Argentina |
| 5.7 | Semiarid pampean | PA | si | Argentina |
| 5.8 | Patagonian grassland | pa ma | St | S Argentina, S Chile |
| 5.9 | Semiarid Patagonian | Pa pa Ma TE | me si | S Argentina |
| 6.2 | Marine Mediterranean[1] | MA | ME | Central Chile |
| 6.6 | Cold temperate Mediterranean[1] | pa | ME Me | S Chile, S Argentina |
| 6.8 | Subtropical semiarid Mediterranean[1] | MA | me | Central Chile |
| 6.9 | Cold semiarid Mediterranean[1] | te | me | Central Chile, Argentina |
| 7.1 | Warm marine | MA Mm | HU Hu | Chile coast |
| 7.2 | Cool marine | Ma | HU | S Chile |
| 7.3 | Cold marine | ma | HU | S Chile |
| 7.8 | Humid Patagonian | pa | HU Hu | S Chile |

[1] "Mediterranean" refers to Mediterranean sea, not to parts of South America locally known by this term.

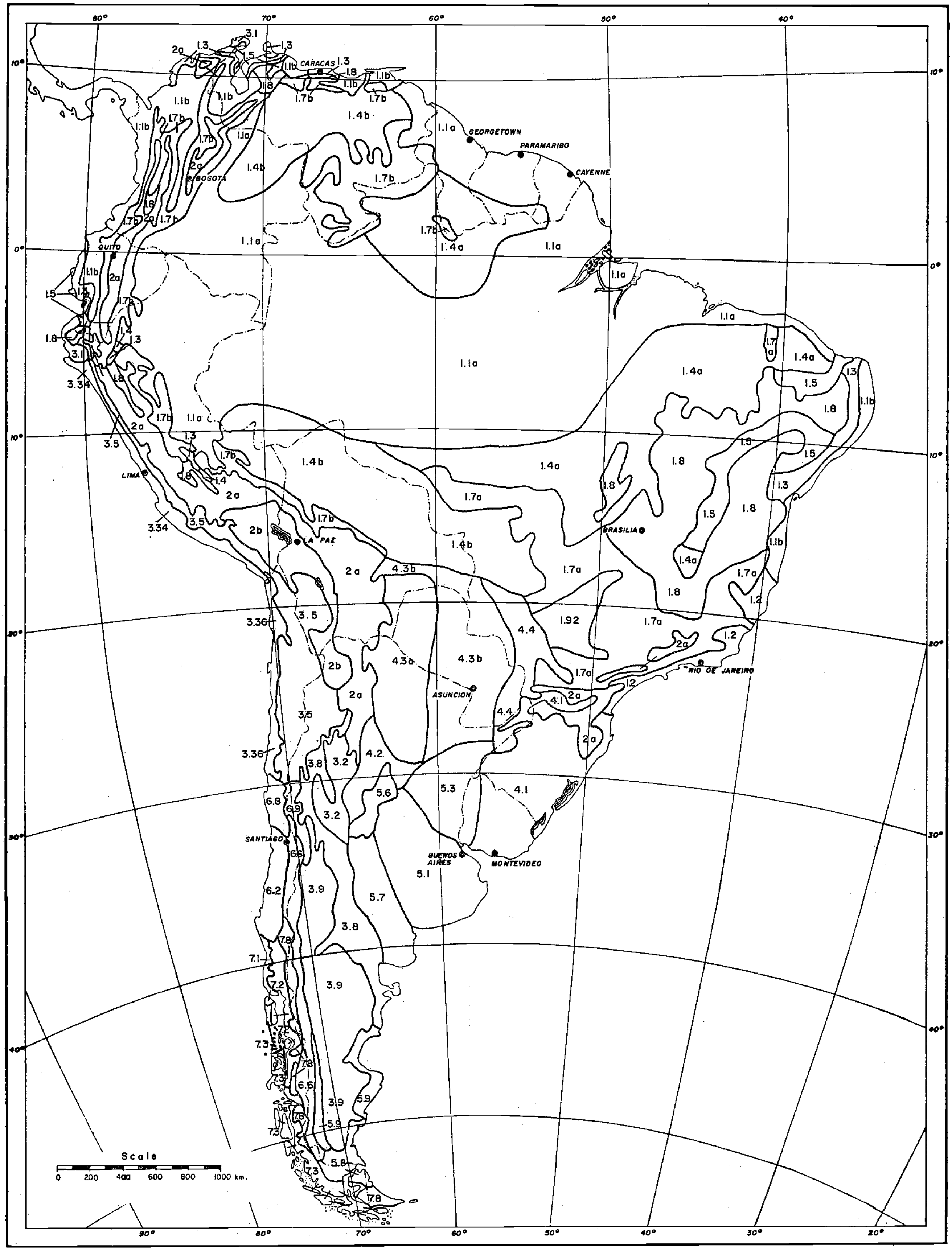


*Figure 2. – Climatic map of South America*

TABLE 2. – CLIMATIC CHARACTERISTICS OF PLACES REPRESENTING THE CLIMATIC REGIONS OF THE MAP

| Map symbol | Climate[1] | Place | Winter type | Summer type | Humid regime | Ann. pot. evap.[2] (mm) | Ann. rainfall (mm) | Leaching rainfall (mm)[3] | Drought stress[4] (mm) | Humid season[5] | Dry season[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.1a | 1.11 | São Gabriel, Br. | Ec | g | HU | 1 078 | 2 956 | 1 878 | 0 | 11–10 | 0 |
| 1.1b | 1.131 | Calabozo, Ven. | Ec | g | MO | 960 | 1 280 | 710 | 390 | 5–11 | 1–3 |
| 1.2 | 1.221 | Rio de Janeiro, Br. | Tp | g | Hu | 805 | 1 049 | 295 | 51 | 9–5 | 0 |
| 1.3 | 1.31 | Campina Grande, Br. | Tp | g | Mo | 727 | 1 164 | 129 | 566 | 3–7 | 10–1 |
| 1.4a | 1.482 | Conceição do Araguaia, Br. | Tp | G | MO | 1 717 | 1 966 | 530 | 781 | 11–4 | 6–9 |
| 1.4b | 1.42 | Coxipó da Ponte, Br. | Tp | g | Mo | 1 973 | 1 389 | 241 | 825 | 12–3 | 5–0 |
| 1.5 | 1.5 | Iguatu, Brl | Ec | G | mo | 1 953 | 827 | 165 | 1 291 | 2–4 | 7–12 |
| 1.7a | 1.77 | Piquete, Brl | tP | c | MO | 1 094 | 1 753 | 871 | 212 | 9–4 | 7–8 |
| 1.7b | 1.72 | Mérida, Ven. | Tp | c | Hu | 820 | 1 950 | 990 | 140 | 3–12 | 0 |
| 1.8 | 1.83 | Monte Santo, Br. | Tp | c | mo | 645 | 1 502 | 0 | 857 | 0 | 8–3 |
| 1.92 | 1.924 | Três Lagoas, Br. | tP | g | Mo | 1 475 | 1 340 | 240 | 375 | 11–3 | 7–8 |
| 2.a | 2.34 | Cuenca, Ecuador | Ci | M | MO | 820 | 705 | 110 | 225 | 3–5, 10 | 0 |
| 2.b | 2.51 | Puno, Peru | Av | A | MO | 870 | 607 | 200 | 463 | 12–3 | 6–11 |
| 3.1 | 3.14 | Piura, Peru | Tp | G | do | 1 970 | 118 | 0 | 1 852 | 0 | 3–2 |
| 3.2 | 3.26 | La Rioja, Arg. | Ci | G | do | 1 740 | 331 | 0 | 1 409 | 0 | 4–3 |
| 3.34 | 3.34 | La Molina, Peru | tp | c | da | 920 | 18 | 0 | 902 | 0 | 9–8 |
| 3.36 | 3.36 | Antofagasta, Chile | tp | O | da | 590 | 10 | 0 | 580 | 0 | 2–1 |
| 3.5 | 3.56 | Uyuni, Bol. | Tv | A | do | 1 160 | 190 | 0 | 970 | 0 | 2–1 |
| 3.8 | 3.82 | Mendoza, Arg. | Av | M | do | 1 320 | 195 | 0 | 1 125 | 0 | 4–3 |
| 3.9 | 3.92 | Col. Sarmiento, Arg. | Tv | t | de | 890 | 143 | 0 | 747 | 0 | 8–5 |
| 4.1 | 4.14 | Montevideo, Urug. | Ci | O | Hu | 750 | 960 | 300 | 90 | 3–10 | 0 |
| 4.2 | 4.22 | Sgo del Estero, Arg. | Ci | G | mo | 1 630 | 538 | 0 | 1 092 | 0 | 4–1 |
| 4.3a | 4.31 | Rivadavia, Arg. | Ct | G | mo | 2 160 | 540 | 0 | 1 620 | 0 | 4–3 |
| 4.3b | 4.35 | Asunción, Para. | Ct | G | Mo | 1 520 | 1 320 | 70 | 270 | 10–7 | 0 |
| 5.1 | 5.121 | Nueve de Julio, Arg. | Av | M | St | 1 130 | 846 | 10 | 294 | 9–10,5 | 1 |
| 5.3 | 5.33 | Paraná, Arg. | Ci | g | St | 1 090 | 915 | 40 | 215 | 3–5 | 0 |
| 5.6 | 5.61 | Cordoba, Arg. | Av | O | Mo | 1 340 | 684 | 0 | 656 | 0 | 5–9 |
| 5.7 | 5.71 | Victoria, Arg. | Av | M | si | 1 420 | 526 | 0 | 894 | 0 | 11–9 |
| 5.8 | 5.8 | Puerto Bories, Chile | av | P | St | 398 | 304 | 36 | 130 | 5–7 | 11–1 |
| 5.9 | 5.952 | San Julián, Arg. | av | t | me | 700 | 182 | 0 | 518 | 0 | 9–4 |
| 6.2 | 6.22 | Talca, Chile | Ci | O | ME | 1 056 | 735 | 420 | 751 | 5–9 | 12–4 |
| 6.6 | 6.66 | El Teniente, Chile | av | P | ME | 671 | 1 073 | 713 | 311 | 5–9 | 1–3 |
| 6.8 | 6.885 | La Serena, Chile | Ci | O | me | 535 | 118 | 2 | 419 | 6 | 9–4 |
| 6.9 | 6.95 | Puente del Inca, Arg. | Tv | P | me | 830 | 266 | 40 | 604 | 6–8 | 10–4 |
| 7.1 | 7.14 | Valdivia, Chile | Ci | T | Hu | 482 | 2 490 | 2 013 | 5 | 2–12 | 0 |
| 7.2 | 7.21 | Puerto Aisén, Chile | av | T | HU | 311 | 2 941 | 2 630 | 0 | 1–12 | 0 |
| 7.3 | 7.31 | San Pedro, Chile | av | P | HU | 218 | 4 266 | 4 048 | 0 | 1–12 | 0 |
| 7.8 | 7.82 | Longuimay, Chile | av | P | Hu | 732 | 1 851 | 1 265 | 146 | 3–11 | 0 |

[1] The meteorological definition of the numbers and their agricultural potentialities are given in Papadakis (1966).
[2] Annual potential evapotranspiration is computed month by month on the basis of midday saturation deficit (Papadakis, 1961).
[3] Leaching rainfall is rainfall minus potential evapotranspiration during the humid season.
[4] Drought stress is the potential evapotranspiration minus rainfall during the nondry season.
[5] A month is *humid* when rainfall exceeds potential evapotranspiration; it is *dry* when rainfall plus the water stores in the soil from previous rains covers less than half of potential evapotranspiration; and *intermediate* between these.
11-10 means that the season begins with November (11), terminates with October (10), both November and October are included, so that it covers all the year; 0 means that there is not such a season; 3-5, 10 means that the season begins with March (3) and terminates with May (5), both March and May are included; moreover, October (10) belongs to the season, so that the season lasts 3 + 1 = 4 months; months that are not mentioned in the humid or in the dry season are intermediate.

KEY TO SYMBOLS IN TABLE 2

The following types of winter are recognized:

| | |
|---|---|
| Eq | Sufficiently warm for equatorial crops (hevea, coconut) |
| Tp | Colder but frostless, too warm for cryophilous crops (wheat) |
| tP | Idem, but wheat is not entirely excluded |
| tp | Idem, but sufficiently cool for many cryophilous crops |
| Ct | Nonfrostless, but sufficiently mild for citrus, marginal for cryophilous crops |
| Ci | Idem, but sufficiently cool for cryophilous crops |
| Av | Colder, but sufficiently mild for winter oats |
| av | Idem, but winter days are cooler |
| Tv | Colder, but sufficiently mild for winter wheat. |

The following types of summer are recognized:

| | |
|---|---|
| G | Sufficiently warm for cotton, summer days very hot |
| g | Idem, but summer days less hot. It cannot be *c*. |
| c | Sufficiently warm for maize and cotton, summer days not so warm, nights cool but frostless all the year round |
| O | Cooler, but sufficiently warm for rice |
| M | Cooler, but sufficiently warm for maize |
| T | Cooler, but sufficiently warm for wheat |
| t | Idem, but the frost-free season is shorter |
| P | Cooler, but sufficiently warm for forest |
| A | More frosty, but sufficiently warm for grassland |
| a | Idem, but frosts in all months |

The following humidity regimes are recognized:

| | |
|---|---|
| HU | Ever-humid |
| Hu | Humid |
| ME | Moist Mediterranean |
| Me | Dry Mediterranean |
| me | Semiarid Mediterranean |
| MO | Moist monsoon |
| Mo | Dry monsoon |
| mo | Semiarid |
| St | Steppe |
| Si | Semiarid isohygrous |
| da | Absolute desert |
| de | Mediterranean desert |
| di | Isohygrous desert |
| do | Monsoon desert |

The meteorological definitions of winter and summer types and humidity regimes appear in Papadakis (1966).

a range from 24°C-18°C. It is the climatic realm of coffee, citrus and sugar cane. Tierra fría is the expression for land from approximately 2 000-3 000 metres with temperatures between 18°C-12°C. Wheat, potatoes and barley are typical crops. Above the upper end of this range, the páramos, or Alpine-type meadowlands are found. Beyond them is the permanent snow cover. Land at such elevations is sometimes referred to by the term tierra helada, or tierra glacial.

Variations in exposure can also bring variations in precipitation, wind and heating at the surface. Precipitation values generally increase upslope wherever orographic effects are important. Maximum values tend to occur on windward slopes near the lower tierra templada elevations. Leeward slopes may be quite dry because of rain shadow effects and dynamic warming. In fact, opposite sides of mountains may have starkly contrasting climates, a phenomenon which has already been discussed for whole ranges. Surface heating also changes on opposing sides of east-west valleys. In the subtropics and extratropical regions northern slopes receive more heat than southern. The difference is sometimes great enough to permit the planting of crops only on the sunny side at either higher latitudes or higher altitudes. Natural vegetation also reflects these differences in altitude and exposure.

## Climatic regions [3]

Figure 2 shows climatic regions. The influence of climate on agriculture is so preponderant that the type of cropping carried out in a region is to a large extent determined by its climate. However, many climatic classifications fail to show the relationships that exist between climatic regions and their agriculture because they do not take into consideration such important climatic features as winter severity, duration of frost-free season, potential evapotranspiration and humid and dry seasons. The criteria and climatic limits used have been fixed with crop requirements in mind so that the climatic regions (Papadakis 1961, 1966) delineated are of significance to agriculture.

Each region shown on the map has a number representing the climate. Since the climatic regions often correspond to well-known agricultural regions, the key gives also the usual name under which the region is known. Table 2 gives the climatic characteristics of representative points of the various regions.

[3] This section has been prepared by J. Papadakis.

The table of soil associations in Chapter 5 shows the climates of all the mapping units. These will not be discussed in this section.

Of the ten great groups of climate recognized in the classification, seven are extensive in South America. These are:

### 1. Tropical

Tropical climates are dominant in South America, occupying most of the area north of 20°S latitude.

### 2. Tierra Fria

Nonfrostless tropical highlands occupy extensive areas particularly in the Andean countries. Compared to the rest of the continent, they are well populated and therefore they have considerable importance. Before the discovery of America the greater part of the population and the more flourishing civilizations occupied these highlands and the neighbouring deserts.

### 3. Desertic

Deserts occupy large areas of Peru, Chile and Argentina, extending a little into Bolivia. Small areas with desertic climate are also encountered in Colombia and Venezuela.

### 4. Subtropical

Subtropical climates occupy a wide band between the pampean climates of middle Argentina and the tropical climate of middle Brazil.

### 5. Pampean

Climates with a steppe humidity regime are found over extensive areas in southern South America east of the Andes, but they differ considerably from the analogous climates of the northern United States and Russia. They are not continental. The annual range of temperature is limited and winter is not very cold. Grass is produced all the year round and livestock live in the open air. As a consequence costs of livestock production are lower. The annual production of natural grassland and artificial prairies is relatively high. Winter cereals are extensively grown for grazing. The climate is also good for winter and summer cereals and some other crops.

### 6. Mediterranean

The Mediterranean climates of southern America are encountered in middle Chile and adjoining areas of Argentina. ("Mediterranean" refers to the Mediterranean sea, not to areas of South America locally known by this name.)

7. MARINE

The marine climates of South America are found in Southern Chile, Tierra del Fuego and some other islands.

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## VEGETATION[4]

### The broad vegetation regions

The natural plant cover of South America may be divided into ten main ecological units. Their occurrence can be related to a number of vegetation regions spread over the continent. These regions are distinguished on the basis of the habitat (either climatic or edaphic), the physiognomy, and the structure of the vegetation. They are determined independently of the floristic species composition. However, in some regions species dominance plays an important part (e.g. *Araucaria* forest). Figure 3 is a map of the vegetation regions.

The regions are listed here.

1. Tropical wet evergreen forests
   - a. Amazon and Guiana wet evergreen forest
   - b. Baían wet evergreen forest
   - c. Pacific wet evergreen forest
2. Tropical seasonal forests
   - a. Seasonal forests of Venezuela and Colombia
   - b. Amazon, Guaraya-Chiquitana and upper Paraguay seasonal forests
   - c. Seasonal forests of East and South Brazil, East Paraguay, and Misiones (Argentina)
   - d. Mixed palm forests of Maranhão and Piaui (Brazil)
3. Tropical coastal swamp formations
   - a. Fresh-water swamp forests and savanna woodland of the equatorial Atlantic coast
   - b. Mangrove swamp forest
4. Tropical savannas
   - Savannas on the freely drained uplands
   - a. Campo cerrado of central Brazil
   - b. Guiana upland savannas
   - Savannas on the poorly drained lowlands
   - c. Roraima-Rupununi savannas
   - d. Llanos of the Orinoco
   - e. Savannas of north Colombia
   - f. Savannas of Bolivia (pampa aluviales de Mojos and Santa Cruz formation) and Peru (Gran Pajonal)
   - g. Pantanal complex
5. Andean mountain forests of the tropics
   - a. Equatorial Andean mountain forests
   - b. Bolivian and Tucuman mountain forests
6. Temperate forests
   - a. Sclerophyllous evergreen woodland of central Chile
   - *Araucaria* forests
   - b. *Araucaria angustifolia* forest of south Brazil
   - c. *Araucaria araucana* forest of the Andes
   - *Nothofagus* forests
   - d. Valdivian rain forest
   - e. Evergreen Patagonian and Magellanic forests
   - f. Deciduous Roble-Rauli forest in central Chile
   - g. Deciduous Patagonian and Magellanic forests
7. Temperate natural grasslands
   - a. Natural grasslands of south Brazil, Uruguay and Argentina (pampa)
   - b. Parque mesopotamico
   - c. Patagonian prairie
8. Semiarid formations
   - a. Agreste dry deciduous forest
   - b. Dry deciduous forest of west Ecuador
   - c. Caatinga (northeast Brazil)
   - d. Caribbean thorn woodland and cactus scrubland
   - e. Parque chaqueno (Gran Chaco)
   - f. Peripampean thorn woodland (bosque pampeano)
   - g. Peripatagonian thorn woodland
   - h. Puna formation of the Andean altiplano
9. Arid formations
   - a. Pacific coastal desert
   - b. Montane desert of the Andes
   - c. Patagonian and west Argentinian steppes
10. Subalpine and alpine formations
    - a. Paramo
    - b. Mountain meadows of the Serra Mantiqueira (Brazil) and the planaltos of south Brazil
    - c. Subantarctic tundra

[4] By J.J. Scholten.

1. TROPICAL WET EVERGREEN FORESTS

These forests can exist only if there is no prolonged dry period and if the mean annual rainfall exceeds a minimum for which estimates have varied from 1600 mm (Champion, 1936) to 1800 mm (Schimper,

1903) and 2000 mm (FAO, 1957). Moreover, the situation must be free from frosts and violent winds.

The term tropical wet evergreen forest, devised by Champion for the vegetal optimum in India and also used by FAO (1957), is equivalent to the tropical rain forest of Schimper, Richards (1952), and many others. It includes both the rain forest and evergreen seasonal forest distinguished by Beard (1944, 1955) in tropical South America.

The forest is formed by a large number of woody species of which most have evergreen foliage. The trees never shed all their foliage at the same time. Some of the tall trees are supported at the base of their trunks by plank-buttresses. Lianes and epiphytes are conspicuous, and in the American tropics the epiphytic Orchidaceae and Bromeliaceae usually form an important constituent.

### 1a. *Amazon and Guiana wet evergreen forests*

These forests, which in their entirety are often called "hileia" after von Humboldt, form the largest single geographical unit of its kind, not only in America but also in the world. The region includes almost the whole Amazon basin and parts of the Guiana and Brazilian uplands.

The most conspicuous differentiating factor in the region is the drainage condition, according to which the forests can be divided in dry land forest and swamp and seasonal-swamp forests along the water courses on the flood plains.

*Dry land forest.* The FAO forest inventories of the Amazon region (Heinsdijk and de Miranda Bastos, 1965) show the botanical families most represented in the Amazon basin as, in order, Leguminoseae, Lecythidaceae, Sapotaceae, Burseraceae, Lauraceae, and Rosaceae. Toward the Atlantic coast the Lecythidaceae become predominant over the Leguminoseae.

Sometimes the common mixed forest is replaced by a single-dominant forest. An example is the wallaba forest of Guiana, dominated by *Eperua falcata* (Leguminoseae) and two other species of Eperua (E. grandiflora, E. jenmani), which seem to be associated with leached sandy soils. Another vegetation association in which *Eperua* is a dominant tree, is the "caatinga amazônica," likewise associated with sandy soils in the catchment area of the upper and middle Rio Negro and near São Paulo de Olivença. This is a light evergreen forest of low trees and shrubs with interspersed emerging trees (caatinga alta) or shrubs and very low trees of uniform height (caatinga baixa).

*Swamp and seasonal-swamp forests.* These types of vegetation grow on flood plains which are subject to inundation. The shorter the period of inundation the nearer does the forest approach the dry land forest. The longer the period the poorer the vegetation, until aquatic swamp and open water are reached.

The swamps which are permanently inundated have a forest (Igapó forest) rather poor in tree species. Characteristic species are *Virola* (ucuuba) and *Symphonia globulifera*. Palms like *Euterpe oleracea* (açai) and *Iriartia exorrhiza* (paxiuba) are often frequent and sometimes make up the entire vegetation (Sombroek, 1966).

In the lowest spots of the flood plains treeless grasslands occur with a grass cover which is able to float during the time the water level stands high.

Among the numerous woody species in the Amazon forest many have economic value. The economy of the Brazilian Amazon region was for a long time based on the extraction of rubber from virgin areas where *Hevea braziliensis* or *Hevea benthamiana* occur more or less frequently. However, after the transfer of *Hevea braziliensis* to southeast Asia, where the cultivation takes place in plantations, the importance of the extraction of rubber in Amazonia declined. Nowadays it is concentrated in Acre and Rondônia.

The latex of *Manilkara huberi* (maçaranduba) and some other trees like *Couma* species (sorva) is intensively exploited by the chewing gum industry. Although the wood of maçaranduba has considerable commercial value, little extraction occurs (Heinsdijk and de Miranda Bastos, 1965).

The collection of pará nuts (*Bertholletia excelsa*) is a widespread activity especially along the middle course of the river Tocantins.

Other products which are collected include copaiba oil (*Copaifera* species) and cumaru seeds (*Coumarouna* species). The leaves of the piaçava palm (*Attalea funifera*) yield a good fibre. Poaia, a variety of milkwort belonging to the genus *Polygala*, yields emetin, a medicinal substance. The extraction is concentrated in south Rondônia and north Mato Grosso. The wood potential of the forests is considerable. A serious obstacle in the exploitation is the inability of most timber species to float. From the forest inventories undertaken during the period 1953-61 (Heinsdijk and de Miranda Bastos, 1965) it appeared that only about 10 percent of the 400 species identified were floatable. The principal ones are:

Valuable wood

*Aniba roseodora* (pau rose)
*Swietenia macrophylla* (mahogany)
*Cedrela odorata* (cedro)
*Cordia goeldiana* (freijó)

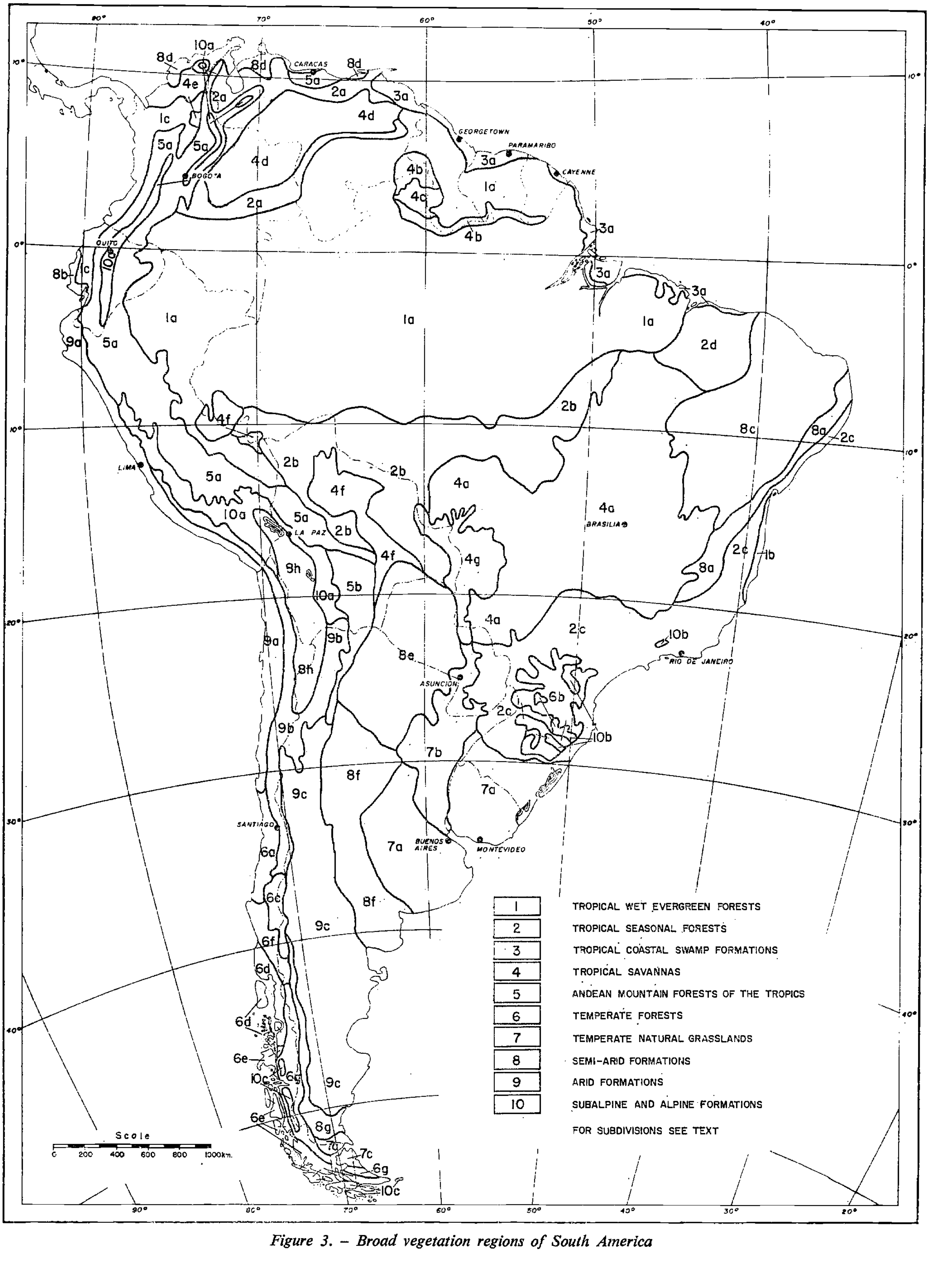


*Figure 3. – Broad vegetation regions of South America*

Good quality wood

*Carapa guianensis* (andiroba)
*Virola* species (ucuuba)

Medium quality wood

*Parahancornia amapa* (amapá)
*Cordia exaltata* (freijo-branco)
*Iryanthere* species (ucuubarana)

The valuable wood of mahogany (*Swietenia macrophylla*, Leliaceae) is in particularly strong demand because of its excellent quality for such things as luxury furniture, ship building, and musical instruments.

Finally it should be noted that Amazonia is the original area for some commercial plants now cultivated in other parts of the tropical world. The rubber tree and the cacao tree (*Theobroma cacao*, Sterculiaceae) are examples. The main cacao-producing area in South America is now located in the coastal strip of southeastern Baía.

### 1b. *Baían wet evergreen forest*

The forest occupies the rather narrow coastal strip between approximately 13° and 19°S which consists of the lowlands made up by Tertiary sediments (tabuleiro) and the bordering hill land to the west.

The forest presents a physiognomy similar to the Amazon wet evergreen forest. Some of the products which are extracted from the Amazon forests are also collected in the Baían forest, like the fibre of the piacava palm. The African oil palm dendêzeiro (*Elaeis guineensis*) yields raw materials for a number of products such as margarine and soap. The extraction of wood for domestic and industrial fuel is another important commercial activity.

### 1c. *Pacific wet evergreen forest*

The well-drained lowlands and lower slopes of the Andes facing the Pacific in Colombia and Ecuador receive more than 2000 mm of rainfall annually and have a natural vegetation of wet evergreen forest. This has as many species per surface unit as the Amazon forest but has its own specific floristic composition. However, there are species that also occur in the Amazon basin. Palms such as *Jessenia polycarpa* and *Welfia regia* are very common in the understory in the drier areas, becoming more important as precipitation increases and abounding where it exceeds 8000 mm/yr.

## 2. Tropical seasonal forests

The predominant character of the habitat of these forests is the prolonged seasonal drought causing desiccation of the topsoil and lowered atmospheric humidity. The length of the dry season determines the degree of divergence of physiognomy and structure of the seasonal forest from wet evergreen forest, prolonged drought bringing increasing poverty of the physiognomy and the floristic composition and lowering the height of the canopy. At the same time the degree of deciduousness of the trees of the upper story increases.

The tropical seasonal forests can be correlated with the tropical semievergreen and moist deciduous forests of Champion (1936), the monsoon forest of Schimper (1903), the moist deciduous forest (FAO, 1957) and the semievergreen and deciduous seasonal forests of Beard (1944, 1955).

### 2a. *Seasonal forests of Venezuela and Colombia*

This region forms a belt around the savannas of the Llanos de Orinoco (Bosques Alisios) and includes the forests on the lowland of the Maracaibo basin. The forests consist of all types intermediate between the wet evergreen forests and the thorn woodland of the Caribbean littoral. Depressed areas with poor drainage bear a swamp vegetation including Ceiba pentandra, Inga species and Erythrine species (Hueck, 1961, 1966).

### 2b. *Amazon, Guaraya, Chiquitana, and upper Paraguay seasonal forests*

The region comprises parts of the Amazon drainage basin in Brazil and Bolivia, and a part of the water divide between the Amazon and the Rio Paraguay in southeast Bolivia.

The floor of the seasonal forests closely resembles that of the wet evergreen forest of the Amazon lowlands. However, among the forests there are scattered enclosures of savanna vegetation; these mainly occupy the higher divides between the tributaries of the Amazon and have a flora closely related to that of the savannas of central Brazil.

### 2c. *The seasonal forests of east and south Brazil, east Paraguay, and Missiones (Argentina)*

The natural vegetation in this region includes the whole range of types from almost evergreen to mainly deciduous seasonal formations. Again, there are close floristic connections to the evergreen forests of Amazonia, but with more tree ferns such as Alsophila, Cyathea and Hemitelia.

In the southern part of the coastal zone, lowland forests pass gradually into lower montane formation in the coastal ranges with a tree stand mainly composed of members of the families Lauraceae, Myrtaceae, Sapotaceae, Leguminoseae and Bignonaceae. The upper limit of this forest is in the eastern part of São Paulo state in the Serra do Mar at 1200 metres and between 1400 and 1600 metres in the Serra da Mantiqueira. The forest of the lower slopes gives way with increasing altitude to a belt of montane rain and cloud forest with crooked and bent trees and abundant growth of mosses and higher epiphytes.

The tree line in the mountains stands at an extremely low level. In this part of Brazil, between 21° and 24°S, it is only as high as the tree line in the Swiss Alps between 46° and 48°N. The position of the tree line is affected by the elevation and mass of the mountain massif, among other factors. The higher and more bulky the mountain massif the higher the treeline. For example, at Itapera (Campos do Jordão, maximum elevation 2030 metres) the tree line is at 2000 metres and at Agulhas Negras (Itatiaia, maximum elevation 2787 metres) it is at 2300 metres.

In Brazil this region is one of the most populated areas, and the greater part of the primary vegetation has been cleared. Only in west Paraná and Santa Caterina may considerable areas of natural forests still be found.

In the Recife area a commercially valuable tree is the pau-brasil (*Caesalpinia echinata*), the wood of which yields pigment used in the textile industry. Other important trees in the area which are used in woodwork are the peroba (*Aspidosperma* species), jacaranda (*Dalbergia nigra*), cedro (*Cedrela* species), and canela (*Nectandra mollis*).

The peroba and the cedro appear to be associated with the occurrence of Rhodic Ferralsols (Hueck, 1966, A.L. Dias Almeide et al., 1962, D. de Amarante Romariz, 1963, A. Nagnaníni, 1965).

### 2d. *Mixed palm forests of Maranhão and Piaui (Brazil)*

This region has an intermediate position between the wet evergreen forests of Amazonia and the semiarid caatinga in northeast Brazil.

In this seasonal forest the babaçu palm (*Orbignya martiana*) is the most conspicuous tree. It and the carnaúba palm (*Copernicia cerifera*) are hygrophilic and favour moist depressed areas to stand the long seasonal drought.

The babaçu and the carnaúba both have economic value. The seed of the babaçu is rich in oil; an adult tree can produce 20 to 22 kg of oil per year. Moreover charcoal, tar, acetic acid, alcohol and fodder can be derived from the fruit. The carnaúba is a wax palm. The wax is extracted from the leaves and serves for the production of candles and soap. Further, the carnaúba yields a great number of other products such as flour, fibre, oil and cellulose. The pulp serves as vegetable, the leaves are fodder. Therefore, this very useful tree is often called "arvore providencia." Because of its economic value people leave the palm untouched when they clear the original forest, so the area of pure palm stands steadily increases.

## 3. Tropical coastal swamp formations

These coastal swamps have a habitat in which the soil is inundated for at least a part of the year. According to the quality of the water one can distinguish fresh water swamps and brackish water swamps. To the first type belong the fresh water swamp forests and savanna woodland of the Atlantic coast between the Orinoco delta and the mouth of the Rio Paraíba. The mangrove swamp forests constitute the second type.

### 3a. *Fresh water swamp forests and savanna woodland of the equatorial Atlantic coast*

The complex vegetation in this region stands on flat aggrading coastal plains with tropical seasonal climate. The different types of vegetation are closely associated with the duration of the period of inundation. In Guyana, Surinam, and French Guiana the coastal vegetation behind the mangrove belt is composed of herbaceous swamps with grasses and Cyperaceae in the low-lying areas, and different types of swamp forest intermingled with patches of grass or shrub savanna on more elevated areas like river levees and old sandy beach ridges. In Brazil the association is made up of grassland and woodland savanna.

### 3b. *Mangrove swamp forest*

Mangrove forest is made up by the Rhizophora-Avicennia-Laguncularia association. The forest flourishes on flat tropical coasts and river estuaries under the direct influence of brackish water. The extension is thus limited to the reach of the high spring tide, but in flat lowlands because of the slight fall of the large rivers the influence of the tides stretches far inland. During the dry season, when the tide is in, river water may be brackish 50 km from the river mouth (van der Eyk, 1957).

## 4. Tropical savannas

The term savanna is an Amerindian word that embraces all the mixed tree and grass types of vegetation found in tropical latitudes. In tropical America the term is applied to any grassland, with or without trees, natural or man-made.

In Brazil the whole sequence of vegetation formations from treeless grassland to woodland savanna is widely distributed, and each formation has its own typical name:

Campo limpo (treeless grassland)

Campo sujo (grassland with shrubs and scattered trees)

Campo cerrado (tall grassland with contorted trees)

Cerradão (dense woodland savanna)

Elsewhere savanna formations occur as well under different names: sabanas and chaparrales in Venezuela, pampas aluviales in Bolivia.

Most of these savanna formations have a surprisingly uniform floristic composition. They belong to the campo cerrado type of Brazil.

Besides this, palm savannas, which prefer marshy drainage conditions, are widespread in poorly drained portions of the tropical lowlands. In certain areas the vegetation pattern is intricate and many types, including forest formations, occur together as in the Pantanal formation.

### Savannas on the freely drained uplands

### 4a. *Campo cerrado of central Brazil*

The campo cerrado vegetation formation, whose appearance varies widely from "campo limpo" through "campo sujo" and "campo cerrado" to cerradão, occupies a vast continuous area in central Brazil. It covers level plateau surfaces and flat-topped "serras" which can attain maximum altitudes between 1000 and 1800 metres.

Outside the continuous savanna area of central Brazil numerous "islands" of campo cerrado project into the forests of Amazonia (commonly in water divide areas), into the forests of east and south Brazil, into the vast region of caatinga vegetation in northeast Brazil and into the coastal strip of Baía. They also occur north of the Amazon in Amapa, where the campo cerrado occurs on taboleiros of Tertiary sandstones. Further, the typical campo cerrado vegetation is an important element in many other tropical savanna areas such as the Roraíma region and the llanos of the Orinoco.

The climate is characterized by a tropical seasonal regime of rainy summers and dry winters. Strong winds are a characteristic feature of the winter season. They are felt mostly on the highest divides where the campo cerrado grades to campo sujo and campo limpo. Perhaps the combined influences of wind, drought and relatively low winter temperatures are unfavourable for tree growth. Elsewhere the climate does not appear to have direct connections with the campo cerrado vegetation complex, since it occurs in Amazonia and on the taboleiros along the humid east coast where rainfall is adequate and sufficiently well distributed to support forest.

The campo cerrado, which means "close, dense, open country" comprises a mixture of tall grasses and low contorted trees, 4-8 metres high. The trees are closely spaced, but the canopy is open so that light can freely penetrate to the ground, covered with grasses which turn brown during the long period of drought. The tree leaves, which are commonly very large, are often hard and leathery (Cole, 1960), like the pau santo (*Kielmeyera* species, Guttuferae), pau de arara (*Salvertia convallariodora*, Vochysiaceae); and pequi (*Caryocar* species, Caryocaraceae). Or the leaves may be sandpapery, like lixeira (*Curatella americana*, Dilleniaceae), or excessively hairy, like peroba de campo (*Aspidosperma* species, Apocynaceae), or murici (*Byrsonima* species, Malpighiaceae).

A conspicuous feature of the vegetation are the dwarf palms with subterranean stems (*Diplothemium littorale*).

The most common grasses are species of Aristida, Paspalum, Panicum, Andropogon, Tristachya, and Melinis. These grasses are noncryophilous (warm-loving) and therefore completely different from the cryophilous (cool-loving) species of the temperate grassland. Unlike the latter, the grasses in the tropical savanna do not form a continuous grass cover that excludes the establishment of other plants (Papadakis, 1952).

A salient feature in the distribution of the campo cerrado vegetation is its association with level terrain. As soon as the level surface becomes dissected, the campo cerrado is replaced by forest vegetation. This suggests an interrelationship between the distribution of the campo cerrado and the soil conditions. The soils of the level surfaces have unfavourable chemical properties. They are old and exhausted and soil renewal by erosion does not take place because of the absence of slope. However, where there is some slope, as in a valley or in dissected terrain, erosion can raise the fertility by renewal of the soil. Under such conditions forest trees are able to establish and maintain themselves.

By examining the relationships between the different factors of the physical environment, including the role of fire, and the distribution of the campo cerrado, it seems clear that the campo cerrado is composed of species belonging to an ancient flora which formerly had a more extensive and continuous distribution (Cole, 1960). Today only remnants survive. The large tract in central Brazil represents the core area, and the outliers indicate the former extent. By contrast the forest and the caatinga appear to be of more recent origin.

This is underlined by the evidence given by geomorphology, because the level country on which the campo cerrado vegetation exclusively occurs represents pediplains produced by ancient cyclic planation processes, i.e. "pediplanation." These are either formed over more or less horizontally disposed Cretaceous to Tertiary sedimentary rocks or cut across folded Precambrian to Palaeozoic sedimentaries and ancient crystalline rocks. Wherever these pediplains become dissected by the activities of younger erosion cycles, the forest invades the sloping ground. In the northeast of Brazil the growth of younger and lower pediplains at the expense of the older ones brought about an extension of the area subject to aridity. Consequently, there the caatinga advanced toward the interior of the campo cerrado, leaving behind islands of campo cerrado on the outlier remnants of the older pediplains (Cole, 1960).

#### 4b. *Guiana upland savannas*

This savanna vegetation occurs in an extensive area on both sides of the frontiers of Brazil with Venezuela, Guyana, Surinam, and French Guiana. The savannas cover level plains cut across crystalline rocks or overlying Cretaceous sandstones at elevations over 2000 metres. Large parts of the savannas frequently have been influenced by the degradational effects of burning.

### SAVANNAS ON POORLY DRAINED LOWLANDS

The savannas of this type have a habitat different from that of the upland savannas. This habitat is subject to seasonal ponding of the soil due to a depressed topography and lack of drainage during the rainy season. This category includes regions which lie far apart.

#### 4c. *Roraima-Rupununi savannas*

These savannas cover extensive areas of the lowlands in the Rio Branco territory (Roraima) from which they stretch into the adjacent lowlands. The vegetation consists of grasslands with and without trees with many species also common in central Brazil. *Trachypogon plumosus* is the dominant grass, associated in places with *Aristida setifolia*, *Axonopus aureum* and others (FAO, 1966).

#### 4d. *Llanos of the Orinoco*

This is the savanna vegetation of a great part of the Orinoco watershed in Venezuela and Colombia to the north and west of the Orinoco river. The region has a flat to undulating topography, and extensive areas are subject to flooding every rainy season.

The vegetation is made up of several types of savanna vegetation. The chaparrales called after the chaparro (the sandpaper tree, *Curatella americana*) closely resemble the campo cerrado. Palm savannas are widespread in the llanos. In marshy areas the tall sabal palm (*Sabal mauritiae formis*), which can reach a height of 20 metres, is dominant while better drained areas favour the "palma llanera" (*Copernicia tectorum*). The river courses are lined by gallery forests in which *Mauritia minor* (morichales) often is the most common tree (Hueck 1961, 1966). The grassland savannas can be divided into associations according to the drainage factor. In Colombia, for instance, the frequently flooded areas are characterized by Andropogon and Mesosetum. The savannas on higher country are covered by *Trachypogon vestitus*, *Azonopus purpusii* and *Paspalum pectinatum*. Locally remnants of forest occur. Characteristic extensions in the direction of the prevailing winds indicate that at least a part of the savanna has replaced forest because of the effects of fire (FAO, 1965).

#### 4e. *Savannas of north Colombia*

The savannas form an intermediate belt between the dry littoral and the humid vegetation of the Pacific coast. The vegetation is composed of different types of savannas: grassland and woodland (notably with *Curatella americana* and *Bursonima* species) and marshy palm savannas with the winepalm (*Schellea magdalenica*) and *Sabal* species. Common grasses are species of *Panicum*, *Paspalum* and *Azonopus*.

#### 4f. *Savannas of Bolivia* (*Pampas aluviales de Mojos and Santa Cruz formation*) *and Peru* (*Gran Pajonal*)

Marshy conditions prevail in the greater part of these low-lying areas as indicated by the presence of the Lago de San Luis, Lago Rogoaguado and Lago Rogagua in north Bolivia.

In the grassland savannas of north Bolivia, Arce Pereira (1963) recorded grasses of the following genera: *Sporobolus*, *Peirotia*, *Paspalum*, *Panicum* and

*Tripsacum*. In the islands of forest interrupting the savannas and in the gallery forests he noted the presence of *Hymenaea courbaril*, *Erythrina corallodendrum*, *E. falcata*, *E. cristagalli*, *Geoffraca pluviosa*, *Tecoma leucoxylum*, and species of *Bignonia*, *Bombax* and *Caesalpina*.

In the surroundings of Santa Cruz there are extensive palm savannas characterized by totai palms (*Acrocomia total*) and motacu palms (*Attalea princips*). South of Santa Cruz the savannas are mainly shrub-clad.

In Peru the marshy savannas are enclosed by tropical forests which cover the better drained areas. The savannas are composed of tall grasses and Cyperaceae with scattered clumps of the palm *Mauritia reflexa* (aguaje). (A.C.S. Wright, 1964; K. Hueck, 1966.)

4g. *The Pantanal complex*

The Pantanal complex is the vegetation which covers the vast low marshy plains of the upper Paraguay basin. The average altitude is 150 metres, and the principal feature of the landscape is the multitude of small lagoons with slight rises between them. Owing to the strongly marked seasonal distribution of precipitation and the slight grade of the rivers, wide areas are flooded for several months each year between December and May.

In this environment of alternating periods of drought and inundation the most pronounced factor differentiating the various vegetation types is the degree of inundation. Characteristic is grassland composed of *Panicum spectabile*, *Paratheria prostata*, *Setaria geniculata*, *Paspalum repens* and *P. fasciculatum*. These frequently flooded grasslands are dotted with clumps of trees, usually *Copernicia* palms and cerrado species, which sometimes grow near termite mounds in elevated positions where the risk of flooding is less. Away from the rivers in the areas situated above the level of normal floods the clumps of trees become more numerous, and there is a change to campo cerrado. The higher river levees adjacent to the main rivers are wooded and have either campo cerrado or gallery forest notably with species of *Tecoma*, *Jacaranda*, *Caryocar* and *Vochysia*.

## 5. Andean mountain forests of the tropics

These forests stand on the humid tropical slopes of the Andean mountains from the coastal range of Venezuela and the Santa Marta massif in Colombia to the Tucuman area in northwest Argentina. Generally the forests form definite altitudinal belts up to the tree line (Schimper, 1903).

The forest of the lowest (subtropical) belt still has a tropical character. At a certain level this subtropical montane forest is replaced by a temperate montane rain forest. On mountain slopes with persistent fogs the forests show a luxuriant development of epiphytic mosses. The transition from the montane to the subalpine belt is characterized by a reduction in the size of the trees, and the growth becomes irregular (elfin woodland, ceja woodland, chirivital shrubland).

Within the region dry longitudinal valleys occur between the humid mountain slopes. The precipitation in these valleys is generally low because of their enclosed position. Moreover, due to prolonged cultivation of the valleys the vegetation is degraded and has a less developed appearance than the climatic conditions would actually permit. Normally it consists of xerophytic thorny woodland and cactus scrubland.

5a. *Equatorial Andean mountain forests*

This region comprises all the mountain forests facing the Amazon and Orinoco drainage basins and the forests on the western ranges in Colombia and Ecuador. In general they cover the slopes above the 800 metres level. The treeline stands approximately between 3200 and 3500 metres.

5b. *Bolivian and Tucuman mountain forests*

These forests occur on the eastern Andean ranges and on slopes that face the Gran Chaco plain. They form the southern extent of the tropical mountain formations. The lower limit of the forest is at 450 to 550 metres, and the upper limit varies between 1400 and 2400 metres in Tucuman to between 3300 and 3800 metres in its northern extent in Bolivia.

## 6. Temperate forests

Temperate forests have a rather limited extension (besides the temperate Andean forests in the tropics) in South America. They occur in central and south Chile and in the uplands of southern Brazil.

6a. *Sclerophyllous evergreen woodland of Central Chile*

The region extends from 31° to 37°S. To the north a steppe vegetation links this region to the coastal desert of Chile and Peru. To the south it grades into the humid temperate forests of south Chile. The mild temperate climate with winter rain and summer drought is the home of evergreen woody xerophytic plants, which owing to the stiffness of their thick leathery leaves have been termed sclerophyllous. Thorns which are common in other xerophytic plants are almost unknown.

Two associations may be distinguished: A xerophytic "Lithraeon association" with stands of *Lithraea caustica*, *Peumus boldo*, *Kageneckia oblonga*, *Quillaya saponaria*, and the palm *Jubea spectabilis*; and a more humid "Cryptocaryon association" with *Cryptocarya rubra* (peumo) and *Beilschmeidia miersii* (belloto). In the latter association the flora of south Chile is represented by *Nothofagus obliqua* (Hueck, 1966). *Peumus boldo* and *Beilschmeidia miersii* supply valuable timbers. From the bark of *Quillaya saponaria* tannic acid and saponin are extracted for use in medicines.

### Araucaria forests

6b. Araucaria angustifolia *forest of south Brazil*

The *Araucaria angustifolia* (Paraná pine) forest is a forest of the uplands, with its lower limit varying from 500 metres in the south to 800 metres in its northern extent. The upper boundary of the *Araucaria* forest is remarkably clear-cut, giving way above about 900 metres to treeless grasslands (see 10b).

The climate is marked by a constant humidity with average temperatures of the warmest and coldest month over 20°C and below 15° respectively.

The tree layer of the *Araucaria* forest is mainly composed of the Coniferae *Araucaria angustifolia* and the *Podocarpus* species *P. lambertii* and *P. sellowii*. Mostly the *Podocarpus* species stand at a somewhat lower level than the canopy of the *Araucaria* trees at about 25 metres. Closely associated with these coniferous stands almost everywhere are some species of the Lauraceae (especially *Phoebe porosa*) and in the understory the important maté tree *Ilex paraguayensis* (Aquifoliaceae). The shrub layer of the forest is composed of the two tree ferns *Dicksonia sellowiana* and *Alsophila elegans* and species of Myrtaceae, Melastomataceae, and Magnoliaceae (*Drimys winteri*).

The Pinho do Paraná or curiy (*Araucaria angustifolia*) is a very important tree for the Brazilian economy as it makes up about 90 percent of Brazilian wood exports. Further, the wood forms raw material for the production of paper. The wood of *Podocarpus lambertii* (pinheirinho) and *Phoebe porosa* (imbuia) also have commercial value and are used for the manufacture of furniture. The twigs and the leaves of the maté tree serve for the preparation of maté tea. The centre of cultivation is located in Paraná along the Iguaçu and Rio Grande. However, the maté tree also occurs outside the *Araucaria* region in south Mato Grosso, east Paraguay, and Misiones (Argentina).

6c. Araucaria araucana *forest of the Andes*

The forest covers both flanks of the Andes between latitudes 37° and 40°30'S in a belt between 600 and 1600 metres altitude. *Araucaria araucana* is not able to equal the height its Brazilian counterpart attains, but even in areas where precipitation is marginal it develops a straight trunk. *Araucana* can form pure stands in which no other trees participate; however, mixed forests with *Nothofagus* species in the understory are common as well. Another conifer, *Libocedrus chilensis* (ciprés), is nearly as widespread as the *Araucaria*. In Chile the "cipresales" occupy the drier sites. Both the wood of *Araucaria araucana* and *Libocedrus* have commercial value and are used in carpentry and construction. *Araucaria* wood is also used for the production of veneer and cellulose (Hueck, 1966).

### Nothofagus forests (Hueck, 1966)

The temperate forests of the Andean mountains and foothills, the central valley, and the offshore islands south of latitude 37°S are characterized by the presence of species of the genus *Nothofagus*. Although these forests show considerable differences in physiognomy and composition, they are grouped together as "Nothophyle." Salient species of *Nothofagus* are the deciduous *N. obliqua* (roble) and *N. procera* (rauli) in the north, the evergreen *N. dombeyi* (coihue) and *N. betuloides* (guindo) in the south on the west flank of the Andes, and the deciduous *N. pumilio* (lenga) and *N. antarctica* (ñire) on the drier east flank of the Andes and near the tree line elsewhere.

6d. *Valdivian rain forest*

The Valdivian rain forest is spread from 40°S at Valdivia to 47-49°S where it merges into the Patagonian and Magellanic forests. At some places the rain forest enters Argentina, for example at the National Park of Lago Nahuel Huapí.

The climate is very humid, and the mean annual temperature ranges between 10 and 12°C.

Corresponding to variations in site, climate and altitude different associations occur. The true Valdivian rain forest has its upper limit at 500 metres. In areas with a swampy environment the common species of the rain forest are replaced by the coniferous alerce forest (*Fitzroya patagonica*) whose stands can attain a height of 50 to 60 metres. This alerce forest is not confined to this lowland environment, for it grows as well just below the treeline in the Chilean Andes. Above the rain forest, forests of different *Nothofagus* species occur which are the advance guards of the more southern forests. At

1600 to 1900 metres altitude the treeline is found. The rain forest itself is rich in species of mainly evergreen foliage. It is further characterized by a luxuriant development of lianes and epiphytes. Apparently this forest represents a relict vegetation able to maintain itself because of the constant atmospheric humidity and relatively high winter temperature.

In the Valdivian forest tique (*Aextoxicon punctatum*), a rather low evergreen tree, can occur in pure stands. Other widespread species include *Eucryphia cordifolia* (ulmo or muermo), *Persea lingue* (lingue), *Laurelia aromatica* (laurel), *L. serrata* (huahan or tepa), *Lomatia hirsuta* (radal), *Drimys winteri* (boighe). *Nothofagus* is represented by the deciduous *Nothofagus obliqua* and *N. procera*. Conifers other than *Fitzroya patagonica* which may be noted are *Saxegothaea conspicua* and *Podocarpus nubigena*.

The forest contains a number of valuable woods. Laurel and lingue are used for carpentry, and pigments are extracted from the bark of lingue. Luxury furniture and souvenirs are manufactured from the wood of radal. The alerce is used in construction, decoration, furnishing, and pencil manufacture. Due to the extremely slow growth rate, however, the alerce will become extinct if exploitation goes on as at present.

6e. *Evergreen Patagonian and Magellanic forests*

These forests cover the western slopes of the Cordillera Patagonica in southern Chile. The rocky coast rises steeply from the coastline and is intensively indented by many fjords. The climate is characterized by abundant rainfall, low evaporation rates, an equable temperature regime, and continual strong winds.

To the north the transformation of these forests into the Valdivian rain forest is gradual. The Patagonian and Magellanic forests are poorer in species and have a uniform composition. *Nothofagus dombeyi* (coihue), which can attain a height of more than 40 metres, is the most notable tree in the northern part, the smaller *Nothofagus betuloides* (guindo or ochpaya) being dominant in the south. Above a variable altitude *Nothofagus pumulio* (lenga) substitutes for other *Nothofagus* species. The treeline falls from 1200 to 1400 metres in the north to 600 metres at Ushuaia. Here tree growth is restricted to sheltered places. The wood of the *Nothofagus* species is used in woodwork and construction.

6f. *Deciduous Roble-Rauli forest in central Chile*

The Roble-Rauli forest has an intermediate position between the sclerophyllous vegetation of central Chile and the Valdivian rain forest. The change in climate from dry to wet takes place over a short distance. Thus, the extent of the forest is rather limited. Summers are still warm with mean temperatures above 14°C and annual rainfall between 1000 and 2000 mm. The upperstory of the forest is composed of *Nothofagus obliqua* (roble pellin) and *N. procera* (rauli). The understory has evergreen trees like *Persea lingue*, *Laurelia* species. The forest extends up to 1200 metres altitude. The commercial value of the wood of both *Nothofagus* species, and especially of rauli, is considerable. It is used, for example, for furniture, decoration, and construction.

6g. *Deciduous Patagonian and Magellanic forests*

The forests stand on the east slope of the Cordillera Patagonica and compose the highest forest belt of the coastal ranges and the west side of the Cordillera. Rainfall is between 500 and 1500 mm. The temperature regime is similar to that of the western slope.

The forest has a stand mainly composed of *Nothofagus pumilio* (lenga) and *Nothofagus antarctica* (ñire). The latter occupies the less favourable sites and approaching the treeline its growth becomes stunted. The treeline drops from about 1600 metres at Lago Nahuel Huapí at 41°S to 200 metres on Tierra del Fuego. Ñire is the smallest tree of the genus *Nothofagus*. Its height seldom exceeds 3 to 6 metres, while dwarf trees around the treeline hardly attain 50 centimetres.

7. Temperate natural grasslands

7a. *Natural grasslands of south Brazil, Uruguay and Argentina (pampa)*

Pampa is an Indian word meaning flat landscape. Landscapes are indeed subdued with only a few low hill ranges.

The climate is warm temperate to subtropical, but frosts are not uncommon.

The precipitation rises from about 500 mm at Baía Blanca to 1400 mm in Rio Grande do Sul with a fairly even monthly distribution. During many months of the year the monthly evaporation equals the monthly precipitation. Such climatic conditions, which do not permit a deep penetration of rain but only keep the superficial soil in a moist condition, are favourable for the establishment of a continuous grassland. This consists exclusively of herbaceous plants, dominated by species of Stipa. The winters are sufficiently cool for the growth of cryophilous grasses, which are able to prevent the invasion of other plants by creating a dense mat of roots that intoxicates all the surface soil. (Papadakis, 1952).

On the other hand, winter temperatures are mild enough for the production of herbage all the year round. This characteristic distinguishes the pampa vegetation from the grasslands with a cold winter (prairie).

Recently trees imported from different parts of the world have been planted successfully in the more humid parts of the region. Eucalyptus and Casuarina from Australia, oaks, poplars and firs from Europe, and oaks, planes and *Pinus* species from North America have grown well.

### 7b. *Parque Mesopotamico*

The Parque Mesopotamico is a region of flat alluvial plains with an excess of water during some time of the year. Mean annual rainfall is between 1000 and 1400 mm. The annual temperature averages between 16° and 22.5°C.

The plant cover forms an intricate pattern of pampean grassland, seasonal forests, gallery forests, and wet palm savannas and swamps. It contains elements of bordering regions (Hueck, 1966).

### 7c. *Patagonian prairie*

This region is situated in the far south and is shared by Argentina and Chile. It commences at about 51°S and extends into the island of Tierra del Fuego. Here the climate is cool and rather dry (at Punta Dungeness 7.2°C mean temperature and 242 mm) with a considerable portion of the precipitation falling as snow in winter. The natural vegetation of these lowlands is a prairie with some development of acid bog and moorland in low-lying areas (Wright and Bennema, 1965).

## 8. Semiarid formations

The wide range of xerophytic vegetation formations brought together under this heading are all marked by an intensive and prolonged period of seasonal drought during which time the habitat suffers a considerable water deficiency.

### 8a. *Agreste dry deciduous forest*

The Agreste forms a narrow strip between the thorny woodland of the caatinga and the seasonal forests of eastern Brazil. The annual amount of rainfall is between 700 and 1000 mm. The natural vegetation is an open deciduous forest composed of xerophytic trees which predominantly belong to the families Leguminoseae, Combretaceae and Myrtaceae. The ground cover of the forest is very scanty. Here and there palms like *Cocos comosa*, *Copernicia cerifera* (carnaúba) and *Acrocomia* species and cacti are intermingled.

### 8b. *Dry deciduous forest of west Ecuador*

In this region west of Guayaquil the rainfall is less than 1000 mm per year (Guayaquil at 12 m altitude, 976 mm, dry season from June to December). The xerophytic vegetation which forms the northern extension of the Pacific coastal desert consists of a light xerophytic forest interspersed with dry savannas.

### 8c. *Caatinga (northeast Brazil)*

This vegetation formation is a well defined phytogeographic unit in the northeastern part of Brazil. The precipitation is highly variable, averaging about 800 mm or less per year. The winter is dry, the months January to May forming the humid season.

In the caatinga are included the actual caatinga, gallery forests, carnaúba palm forests in humid depressions with a high groundwater table, Agreste forests under somewhat more humid conditions, and savannas (campo cerrado and campo limpo) on flat taboleiros.

The caatinga consists of cacti scrubland and thorny woodland. Candelabrum-shaped cacti are a feature of the landscape. *Cereus jamacaru* and *Cereus squamosus* (faxeiro) can attain a height of 10 metres. Less high are *Pilocereus gounelli* (xique-xique), *Cereus squamosus*, *Melanocactus* and *Opuntia* species. The thorny woodland (carrasco) is characterized by deciduous trees which even during the rainy period severely restrict their transpiration during the middle of the day, for example *Caesalpinia pyramidales*, *Cavanillesia arborea* (barrigudo), and species of *Mimosa*, *Cassia*, *Acacia*, *Amburana*, *Piptadenia*, and *Pithecolobium*. Only a few trees, like *Zizyphus joazeiro*, are evergreen. Along the periodically dry watercourses galleries of *Tabebuia caraiba*, *Licania rigida*, and *Caparis* species likewise retain their leaves and reflect the presence of groundwater within reach of their roots (A.L. Dias Almeida et al., 1962; Hueck, 1966).

Various plants of the caatinga region supply valuable products for domestic and industrial use. The nutlike fruit of oiticica (*Licania rigida*) yields oil for industrial use. Licuri (*Cocos coronata*) is a wax palm that produces wax on the leaves during the dry season to reduce evaporation. It also yields an oil similar to that of the babaçu. A good quality fibre is obtained from the caroa (*Neoglaziovia variegata*).

8d. *Caribbean thorny woodland and cactus scrubland*

Two predominant vegetation formations can be distinguished, the thorn woodland (espinas) and the cacti scrubland (cardonales) with all possible transitions. The thorn woodland is developed in the more humid areas and consists of thorny deciduous trees which go out of leaf for nearly six months a year. The vegetation of the cacti scrubland is still more xerophytic. The appearance is dominated by candelabrum-shaped cacti with sizes up to 8 metres *Cephalocereus moritzianus* and *Lemaireocereus griseus*) and lower species of *Opuntia*, *Cereus*, *Echinocereus*, *Melocactus* and *Mammillaria*.

Some tracts of the Peninsula Guajira and Paraguana have bare moving sand dunes (Hueck, 1961, 1966; Cabrera, 1955).

8e. *Parque Chaqueno* (*Gran Chaco*)

This region of huge extent has parts in south Bolivia (Arce Pereira, 1963), west Paraguay and north Argentina. The landscape is nearly flat, sloping gently eastward. Inundations cover vast areas of land during the rainy season.

The summers of the Gran Chaco are hot and humid, the winters mild and dry. The central part of the Chaco has the lowest quantity of rainfall (Rivadavia, 495 mm). The precipitation increases both to the west and the east.

For the greater part the Chaco has a cover of xerophytic light forests. The most unfavourable sites of these woodlands have a stand of algarrobo forest characterized by *Prosopis alba* and *P. nigra*, the *Prosopis* species accompanied by tree-shaped cacti. The algarrobo forest is able to grow close to the salt flats; the quebracho forest needs a more favourable habitat. *Apidosperma* quebracho blanco and *Schinopsis* quebracho colorado are the outstanding trees. In the upperstory *Zizyphus mistol*, *Caesalpinia paraguariensis*, *Cercidium australe* and *Bulnesia sarmientoi* are intermixed. In the understory many cacti and other xerophytic shrubs like *Acacia cavena*, *A. Riparia*, *A. aroma* and *Mimosa* species are represented. In the eastern part of the Chaco the quebracho forest is dominated by *Schinopsis balansae*, and here the forest is intermingled with swamps and wet palm savannas. In the west there is a zone transitional to the vegetation forests of the humid Andean slopes. The trees have much less pronounced xerophytic characteristics. Treeless vegetation associations occur on salt-affected depressions like the Bañados de Izozog in Bolivia, and on moving dune complexes.

The cutting of the economically valuable quebracho wood for the extraction of tannic acid, the production of charcoal and other purposes has greatly influenced the original vegetation. In Paraguay and Bolivia, however, some areas have maintained their original character because of their inaccessibility (Hueck, 1966; Kanter, 1936).

8f. *Peripampean thorn woodland*

This vegetation formation is situated immediately to the west of the pampa, where the climate becomes noticeably drier. The average precipitation figures vary between about 300 mm in the west and 500 mm in the east. To the west the vegetation passes gradually into the "Monte steppe," to the north into the Parque Chaqueno. This region gives the impression of being rather wooded (Bosque pampeano) in striking contrast with the adjacent treeless pampa. Apparently the climate has become too dry to support a continuous grass cover; instead there is a plant cover of low open tussock grassland with thickets of *Prosopia algarrobilla* (Nandubay), *P. caldinia* (Caldén), *P. alba*, species of Acacia and mimosa (the palm Butia yatay). Usually, the trees and shrubs are characterized by stunted growth, numerous thorns and a scraggy ramification. Aphyllous plants are also characteristic (Hueck, 1966; Cabrera, 1955; Papadakis, 1952).

8g. *Peri-Patagonian thorn woodland*

The region lies parallel to the foot of the Andes and forms a narrow belt along the inner margin of the Patagonian steppe. Annual precipitation figures increase very quickly to the west from about 200 to 500 mm where the thorn woodland meets the temperate *Nothofagus* forests.

In the grassy steppe the presence of *Festuca monticola*, *Agrostis pyrogea*, *Deschampsia elegantula* and *Poa ligularia* has been observed. *Mulinum spinosum*, *Nassauria aculeata* and *Berberis cuneata* are common shrubs (Cabrera, 1955).

8h. *Puna formation of the Andean altiplano*

The altiplano occupies the highland plateaus and mountains of a small portion of south Peru, southwest Bolivia, northwest Argentina and north Chile roughly between 3500 and 4500 metres.

The annual precipitation is very low in the south (62 mm at Ollagüe) and increases to about 500 mm in the vicinity of Lake Titicaca. Rains are practically confined to the summer months. The diurnal range of temperature is great, sometimes more than 20°C, and frosts may occur during the night at any time of the year. Above 4500 metres the climate becomes a cold, high-altitude mountain climate.

Characteristic for these high elevations are huge cushion mounds of Llaretia, known locally in Chile as "Llaretales."

The predominant type of vegetation of the altiplano is the shrub-clad steppe of isolated bushes of tola shrub (*Lepidophyllum* species, *Baccharis tola*) about one metre in height, and circular tufts of a stiff, hard, brushlike grass (*Stipa jehu*), with stretches of bare earth between. Cacti are less frequent. A striking vegetation type is formed by the altiplano boglands, referred to locally as "bofedales," which develop only if running water is available. Many species constitute the bogs, among them *Ephedra andina* and *Atripex retusa*. The bogs are the main grazing areas of llamas and alpacas (Wright, 1961; Cabrera, 1955).

### 9. Arid formations

Owing to the presence and configuration of the Andean Cordillera the arid vegetation formations occupy a zone that stretches from the coasts of Peru and Chile across the Andes into the steppes of Patagonia.

#### 9a. *Pacific coastal desert*

This is an area only 75 to 150 kilometres wide reaching from northern Peru (about 4°S) to slightly south of Coquimbo in Chile (31°S).

Precipitation is very low at the coast where rain does not occur every year, increases slowly in the coastal ranges and thereafter becomes almost nonexistent. The mean temperatures decrease regularly southward. Owing to the influence of the Humboldt current, which carries cold water from the south almost as far as the equator, the mean temperatures are remarkably low.

The Pacific littoral is a barren desert. Vegetation develops only along the banks of the rivers crossing the desert and on slopes blanketed in mist or moistened by drizzle during the winter.

The "Lomas" vegetation, which is nourished by moisture condensing from sea fogs induced by the presence of the adjacent Humboldt current, is found between 150 and 1000 metres above sea level mainly on the west-facing slopes. This periodical growth varies in composition from place to place but always consists of annual species with an ultrashort vegetative cycle (euphemerophytes) and plants with subterranean perennial organs (geophytes). Plants with above-ground perennial organs are rare. The development of the vegetation depends entirely on whether or not there is fog. A remarkable phenomenon is the presence of real xerophytic Lomas forest in favourable sites at elevations between 500 and 700 metres in central Peru (e.g. at Lachay, Casma, Atocongo and Lurin). At this altitude the fogs persist in winter almost the whole day, so that the trees can condense a maximum of air moisture. Although the trees are stunted they can attain heights of 6 to 7 metres. The forests include the following species: *Carica candens*, *Caesalpinia tinctoria*, *Acacia macracantha* and *Eugenia*. Because of the demand for fuel a great part of the Lomas forests has been cut (Cabrera, 1955; Hueck, 1966).

#### 9b. *Montane desert of the Andes*

This region comprises all the desertic mountains of the west-facing slopes in Peru and Chile and the desertic eastern mountain chains in Argentina. In this central section of the Cordillera the arid zone actually crosses the Andes.

Precipitation is scanty and its distribution uncertain. Averages vary between 0 and 250 mm. The diurnal range of temperature is great.

The vegetation varies from only ephemeral plants which appear after rain has fallen, to scattered cactus formations (*Opuntia* species) with tola scrub (*Lepidophyllum* species), to taller and denser xerophytic shrubland with small copses of trees (*Prosopis* species, *Acacia carena*, *Schinus molle*). The greater part of the area is devoid of perennial plants.

#### 9c. *Patagonian and west Argentinian steppes*

This region of vast extent stretches from La Rioja and Catamarca in west Argentina to approximately 50°S in Patagonia.

Precipitation is between 100 and 200 mm annually. The mean temperature figures diminish steadily southward. A noticeable feature of the climate is the occurrence of strong winds, especially in springtime.

The vegetation is formed by a remarkable uniform bushy steppe consisting of scattered grass tussocks (*Stipa* and *Festuca* species) and low thorny shrubs with small leaves or without leaves and chlorophyll-containing bark, e.g. *Larrea divaricata*, *L. cuneifolia*, *L. cuneata*, *L. nitida*, *Monthea aphylla*, *Cassia aphylla*, *Cercidium australe*, *Verbena lugistrina*, etc. Locally tree copses occur in which *Prosopis* is dominant. *Salix humboldtiana* is found along the stream courses (Hueck, 1966; Cabrera, 1955).

### 10. Subalpine and alpine formations

#### 10a. *Paramo*

The Andes highlands above the treeline between about 10°N and 20°S, which receive more than 500 mm precipitation annually, have a paramo vegetation.

Normally the treeline in these latitudes is situated between 3200 and 3500 metres. From Merida in Venezuela and the Santa Marta massif in Colombia to the Cordillera Real in Bolivia the paramo forms a discontinuous zone.

The mean monthly variation in temperature is small, but the daily range is great and night frosts and early afternoon temperatures of 18 to 24°C are common.

The paramo is a distinct plant formation that passes from low windswept Polylepis forest (sometimes called subparamo) to tussock grassland with scattered bushes and giant forms of groundsels of *Puya* and *Espletia* species (locally called "frailejon") whose densely hairy leaves form rosettes. Above about 4400 metres the paramo gives way to an open alpine herb field. The paramo encloses a number of eternal snow-covered mountain crests and summits (Hueck, 1966).

### 10b. *Mountain meadows of the Serra da Mantiqueira and the southern Brazilian planaltos*

Above the closed treeline in the Serra Mantiqueira and the southern Brazilian planaltos, mountain meadows extend up the flat-topped mountains. The location of the treeline varies considerably from about 2300 metres in the Itatiaia massif and 1800 in the Campos do Jordão to about 900 metres in the southern planaltos.

The climate is humid and temperate, without dry months.

The meadows are covered with a dense mat of Gramineae (e.g. *Chusquea pinifolia*, *Cortaderia modesta*) and Cyperaceae. Herbs and low shrubs are closely intermingled. Many of them belong to the following families: Ericocaulaceae (*Paepalanthus* species), Ericaceae (*Gaultheria* and *Gaylussacia* species), Compositaceae, Polygalaceae, Verbanaceae, and Iridaceae. The families Ericaulaceae and Ericaceae in particular have developed typical endemisms indicating that conditions have been constant and undisturbed for a long time.

Occasionally species of *Vellozia* occur in the Serra da Mantiqueira whose massive growth up to 2 metres in height physiognomically resembles the groundsels of the paramo (Hueck, 1966; Schimper, 1903).

### 10c. *Subantarctic tundra*

In the mountains of south Chile above the treeline and on the exposed windswept southernmost offshore islands, a Magellanic tundra vegetation with moor and heathland has developed.

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## GEOMORPHOLOGY [5]

The three main groups of morphostructural regions as distinguished in the description of the lithology of South America also represent definite regions (Fig. 4) characterized by a distinct landscape development. From remote geological times the stable Precambrian shield areas of the east side of the continent have held positions above sea level. They have only been affected by rather simple deformations resulting from the differential upheaval of the shields. Landscapes therefore have evolved continuously under subaerial conditions, and this has resulted in the widespread development of old erosion surfaces at different levels.

The Andean mountain ranges form an extremely youthful and unstable landscape of steep relief along the western margin of the continent. The modern ranges were elevated only during Plio-Pleistocene time by violent uplift. Volcanic activity occurred simultaneously, and in places enormous amounts of ash, tuff and lava were deposited. During the glacial periods of the Pleistocene, the Andean landscape, particularly the humid parts, was affected by glacial erosion and accumulation.

The Andean system and the shields are separated by the vast basins of the Orinoco and Amazon rivers and the Chaco and pampa plains in which enormous masses of sediments have accumulated. The bulk of these deposits are the erosion products of the former and present Andean mountain systems.

### LANDSCAPE DEVELOPMENT ON THE PRECAMBRIAN SHIELDS

The landscape of the shields is characterized by level erosion surfaces related to several successive cycles of erosion. The surfaces are usually separated from each other by sharply marked scarps. Lester C. King (1962) has satisfactorily explained the formation of such landscape forms by the process of pediplanation. This process includes, in order of appearance, river incision, slope retreat parallel to its first position, and pedimentation at the foot of the retreating slope. Thus, in the course of the process, the pediment grows at the expense of the initial surface. Only late in the cycle is the last of this surface worn away, leaving residual hills known as "inselbergs." The level surface which forms the end result of the process is called a pediplain. In an area subject to successive uplifts a stepped landscape develops. Each surface is enlarged at the expense of its predecessor, and each in turn loses area to its successor by the same process.

The landscape development in the shield areas, however, was much more complex than the formation of a series of simple steps, because the degradational processes at work proceeded at variable speed from time to time and place to place. Locally this could have resulted in the complete destruction of all the older surfaces by the advancement of a succeeding cycle. Elsewhere a surface may not have developed well due to lack of time or erosive force, or it may have become buried by an accumulation of detrital material. Moreover, differential tectonic movements occurring in the course of the evolution confuse the ideal picture, since they are responsible for the tilting and intersection of surfaces.

Lithology also plays an important part in the landscape formation. In the area of the large geological-morphological Paraná and Maranhão sedimentation basins scarps often coincide with marked differences in lithology. In the eastern part of the Paraná basin three planaltos occur at levels which decline from the Atlantic coast toward the centre of the basin.

[5] By J.J. Scholten.

Together they are called the "Planalto meridional." In the east the planalto of Curitiba, which developed over Precambrian metamorphosed rocks, is the highest. Along the coast it is confined by fault scarps. The next planalto is the Ponta Grossa comprising Paleozoic clastic rock outcrops. The third (planalto de Guarapuava) lies over the basic lava outflows of the Serra Geral formation and is bounded to the east by the Serra Geral escarpment. The planaltos include elements of different erosion cycles with fragments of the older surfaces preserved on the water divides and younger cycles penetrating progressively along the river courses.

According to Bennema et al. (1962) three major landscape categories can be recognized upon the shields. There are (1) old level land surfaces, (2) areas of residual relief that have a youthful dissected character (often associated with resistant rocks) and (3) the valley bottoms and the young sedimentary areas.

These landscape categories have important differences in the thickness, stage of weathering and the composition of the waste mantle upon the bedrock, which are of importance to soils. The waste mantle on the old erosion surfaces may be more than 30 metres thick. Its material is at an advanced stage of weathering in situ and can be millions of years old. The second landscape category is overlain by a much shallower layer of waste material including much drift (as indicated by the occurrence of stone lines in the soil profile). In places with steep relief no weathering or drift mantle is present, and the bedrock is exposed. The third category is blanketed with drift material which can attain a considerable thickness where accumulation of alluvium is pronounced. Weathering in situ in such materials is insignificant and most properties of the waste mantle are inherited.

### Brazilian and Patagonian shields

On the Brazilian shield King has recognized four major cycles of erosion and the beginning of a fifth cycle. Each new cycle started after an uplift of the area. The oldest planations have been called the Gondwana and the post-Gondwana surfaces, dating back to Jurassic and late Cretaceous times respectively. The Gondwana denudation cycle operated before the dismemberment of "Gondwanaland" at the end of the Jurassic period. (Gondwanaland is the supposed supercontinent of pre-Cretaceous age that united South America, Africa, Australia, Antarctica and the Indian subcontinent.) Next in age is the Sul-Americana surface, which is the result of an intensive erosion cycle during the early Tertiary. From this master surface most of the existing landscape of the Brazilian shield has subsequently been carved. Into it the Velhas cycle excavated broad valley floors and initial erosion surfaces during the late Tertiary. They can be found in all the main drainage basins. Later still and following the pronounced Plio-Pleistocene uparching of eastern Brazil, youthful valleys have been incised during the Paraguaçú cycle. Over large parts of Brazil the landscape is made up of only two cycles: the Sul-Americana which forms the flat-topped interfluves and the Velhas, which forms the broad valley systems incised by 100 metres or more.

Each successive cycle of denudation was followed by the accumulation of continental sandstones, which are partially of aeolian origin.

Remnants of the Gondwana and post-Gondwana planations have been preserved in the mountain land of eastern and northeastern Brazil. The surface Dresch (1957b) described on the "Planalto da Borborema" between Mimosa at 900 metres and the Moxoto Basin at 450 metres in northeastern Brazil probably originated during the Gondwana cycle. The surface underwent strong deformations and faulting. The weathering mantle, composed mainly of kaolinitic material, has mainly been removed.

The Sul-Americana planation cycle has given rise to a smooth erosion surface of great extent. However, subsequent erosion cycles have consumed the greater part of the surface, and today only remnants mark its former position and widespread distribution.

The late Tertiary Velhas cycle has destroyed much of the Sul-Americana planation in the interior of Brazil, where it has penetrated into the heads of all the major drainage basins. In the northeastern states the cycle is represented by undulating plains at an altitude of 450-550 metres between the plateau massifs of Borborema. These plains normally occur on less resistant rocks, like the mica schists of the Moxoto and Patos plains.

During the Plio-Pleistocene the Brazilian shield was elevated once more. The uplift had a marked differential character and particularly deformed eastern Brazil by producing a huge arch, rising steadily southward from the Amazon basin to a rifted crest at the São Francisco valley. From there the arch declines more steeply on a coastal monocline to the Atlantic.

The erosive forces of the Quaternary Paraguaçú cycle violently attacked the elevated country, particularly in the coastal areas with steep relief, creating youthful valleys with many knicks in their longitudinal profiles. In parts of eastern Brazil these youthful valleys have completely destroyed the preceding erosion surfaces. Commonly, two phases have been recognized, of which the older is recorded by terraces


*Figure 4. – Geomorphological map of South America*

above the valley bottoms. In central Brazil the influence of the Quaternary erosion cycle is much less clear; the area was only slightly affected by the coastal upheaval. Furthermore the relief energy in the inland part of the Brazilian shield is much reduced by the enormous distance of the drainage systems to their coastal outlets. Under recent climatic conditions the process of pediplanation seems to be active only in the semiarid area of northeastern Brazil, where the weak vegetation cover and the rainfall regime promote denudation and the formation of pediplains.

### Guiana shield

The landscape of the Guiana shield, occupying present-day Guyana, Surinam, and French Guiana, also has been modelled by a series of successive erosion cycles. The pediplains created in the course of these cycles have been intensively dissected and the resulting complex of monotonous, rolling to hilly country is known as the "Guiana peneplain." This dissected landscape is characterized by a dendritic drainage system.

In Guyana most of this relief has been carved from the Plio-Pleistocene Rupununi surface in the area northward of the Pacaraima mountains, and from the older Kwitaro surface in the southern part of the country. Remnants of the Rupununi surface are exposed just north of the Apoteri-Kumaka alluvial plain near 4° north latitude. The surface is considered to be the original surface of deposition of the continental and littoral-deltaic Berbice formation. Fragments of the older Kwitaro surface, which have been preserved between 300 and 360 metres, extend into Brazil and dominate the Amazon-Essequibo water divide. The Serra Acarai at the Brazilian border represents a relic mountainous relief of the pediplanation cycle that formed the Kwitaro surface. Still older than the Kwitaro surface is the well-defined Kopinang surface between 630 and 690 metres on both sides of the upper Ireng river in the Pacaraima mountains. This surface is developed over different rock outcrops, e.g. sandstones of the Roraima formation and intrusive basic rocks like gabbro.

In French Guiana the fragments of a number of erosion surfaces have also been recognized amid the polycyclic landscape. These erosion surfaces (called peneplains by Choubert, 1957) are preserved by the presence of a laterite cap. The laterite caps display a typical geomorphology that resembles the karst topography in carbonate rocks. Surface water easily penetrates the permeable laterite cap but becomes stagnant on top of the kaolinitic clay layer lying between the cap and the parent rock, thus creating a subterranean drainage. This type of drainage, combined with solution phenomena, causes the formation of the typical pitted surface.

Repeated uplifting and blockfaulting since the Upper Cretaceous created the relief of the Pacaraima and Kanuku mountains. The Pacaraima mountains are mainly composed of flat-lying sandstone beds which have given rise to a series of levels (mesas) bounded by scarps between 300 and 2770 metres.

### Landscape development in the Andean mountain ranges

The Andean Cordilleras form the western and northern flank of the South American continent, representing an area of youthful, highly unstable relief that extends from latitude 12°N to 56°S over a distance of more than 9000 km. The present crest of the Andes has a mean height of about 2700 metres and in places is less than 160 km from the Pacific coast. The system has its narrowest section in Ecuador with a minimum width of about 100 km. In Bolivia the mountains are at their widest (800 km) and reach farthest east. Here the ranges diverge for some distance to enclose the altiplano basin which extends from southern Peru through Bolivia into northwestern Argentina at an elevation between 2700 and 4200 metres. This highland basin has no external drainage, and the rivers have their outlets in two large lakes (Lake Titicaca and Lake Poopó of 6900 and 2800 sq km respectively) and a number of salt flats of which the Salar de Uyuni is the most extensive. At one time these and other lakes covered a much wider area.

South of Copiapo, Chile, the zone of mountains narrows, and from Aconcagua at nearly 7000 metres, highest point of the Americas, the ranges steadily decline, extending into the Strait of Magellan and Tierra del Fuego as the Cordillera Patagonica. The coastal range of Chile, which is separated from the main line of the Andes by the tectonic depressions of the Pampa del Tamarugal and the central valley, includes some old Paleozoic orogenic elements.

With the exception of the Patagonian Cordillera, the Andean mountains make up the main divide of the continent. In the western part the rivers have only short courses to the Pacific, but eastward they divide into the many headwaters of the Orinoco and Amazon rivers and several other less extensive drainage systems.

Orogenic movements along the existing trend of the Andean system commenced in the late Cretaceous, followed by a second and a third set of foldings during the early Oligocene and Miocene respectively (King, 1962).

The creation of the modern Andean ranges came only at the end with an enormous tectonic uplift, totalling about 4300 metres for the most elevated parts. The uplift was accompanied by widespread faulting and block faulting that created the Santa Marta massif, the pampean ranges, the Pampa del Tamarugal, the central valley of Chile and several other intervening longitudinal depressions (like the Bolsons of the pampean ranges), and revived the altiplano basin.

The Plio-Pleistocene uplift was interrupted by two or even three pauses, which are marked by partial plains and valley terraces (Jenks, 1956; King, 1962). The first stage of standstill in the uprising is called the Valle or Junin stage, which developed wide valley floors and flat divides as the broad pampa of Junin. The period of planation was followed by another forceful uplift causing rejuvenation of the valleys, but again the uplift was terminated by a period of predominating planation processes resulting in the formation of terraces and initial plains. They represent the Chacra stage.

In Bolivia, evidence has been found for still another pause in the uprising that left its terraces between the Chacra surface and the present valley bottoms.

Along the coasts of southwestern Ecuador, northwestern Peru and Chile northward of latitude 39°S, several marine terraces also record a sequence of uplifts with intervening periods of standstill or negative movement that occurred during the Pleistocene.

In southwestern Ecuador and northwestern Peru the terraces pertain to three distinct levels of tablazos. They show no constant elevation but decline southward due to the differential character of the uplift (Lemon and Churcher, 1961). South of latitude 39°S the youngest vertical movements were negative and resulted in land disappearing below the sea. The lower courses of the rivers show a drowned aspect. Further southward the central valley is submerged, and the coastal range has become a coastal archipelago (Wright and Espinoza, 1962).

Thus, the modelling of the relief of the modern mountains is controlled first by the internal processes of interrupted and differential vertical movements which today still find their expression through seismic and volcanic phenomena. The intensity of the external processes of erosion and deposition are determined by the relief energy created by the internal forces and further to a great extent by the distribution of climates and the related erosion processes in the past and at present.

Seismic phenomena are very active at present, especially in the coastal areas of the Andean region. According to Brüggen, quoted by Wright and Espinoza (1962), such events have modified the landscape in Chile on no fewer than 20 occasions during the past 400 years.

Volcanism has accompanied the orogenic movements in each stage of development, and large parts of the Andean mountains are composed of widely varying volcanic rocks. The last period of volcanism commenced in the late Tertiary and lasted until recent times, although with decreasing intensity. Its activities are concentrated in three major areas. The most northern is the area comprising the western and eastern Cordillera of Ecuador and the central Cordillera of Colombia. In the eastern Cordillera of Ecuador active volcanoes still occur. The zone of most intense volcanic action lies in southern Peru, where enormous amounts of lava and pyroclastics have buried the Puna erosion surface. The area also extends into northern Chile and northwestern Argentina, and there are a few volcanoes in the Bolivian altiplano. The third area of young volcanism is located in central Chile, where the volcanoes are often spaced less than 40 to 50 km apart. The active volcanoes are confined to the main line of the Andes, but formerly volcanic vents were also active in the central valley of Chile.

Above the snow line the landscape is glacial. Today large coherent firn and icecaps exist only in the Patagonian Cordillera. Here they occupy several areas of which the one between latitudes 48° and 52°S with a length of 330 km and a general width of about 40 km is the most extensive. During the glacial periods of the Pleistocene the snow line in the Andes stood at a level which was 800 to 1000 metres lower than at present. Numerous glacial erosion forms (cirques and trough valleys) and deposition forms (tills and end moraines) record the extent of these glaciations.

The glacial basin of Junin in central Peru was affected at least twice by glaciations. From the west (Sierra de Huayhuash) and the east (Cerro de Pasco) glaciers joined in this basin to form a plateau icecap. Below the glacially affected areas much glacio-fluvial material accumulated as terrace deposits along the meltwater rivers or as huge detrital fans at the border of the mountains. An important part of the sediments which filled in the central valley of Chile is of such origin. Generally these glacio-fluvial deposits are well stratified in contrast to the mud flows and other related deposits created by seismic and volcanic events.

In the arid and semiarid central portion of the Andean mountains the glacially affected areas pass rapidly downward through a periglacial belt, which had frost-weathering and mass movements (solifluction) as the main modelling agents, into a landscape in which current mechanical weathering and pedimentation processes predominate (Dresch, 1957a). The pediments are usually covered with a thin waste mantle of little-rounded material and have steep slope gradients. The coastal desertic plain along the Pacific is narrow or even absent as in places in the Atacama desert. It widens considerably only in northwestern Peru where it includes the Sechura desert, a waste of shifting sands. Landscape development under the present environmental conditions is slow. However, the state of dissection and the presence of river terraces indicate that in the course of the Pleistocene more humid periods occurred during which erosion processes were very active. Probably these periods of increased activity can be correlated with the glaciations.

In the humid parts of the Andes, erosion and dissection proceeded continuously and intensively throughout the Quaternary, although in postglacial times the erosion processes have decreased in activity due to the development of a close vegetation cover which tends to preserve the existing relief.

From the soil genetic point of view the Andean area represents a very unstable environment in which the soil-forming processes are repeatedly disturbed by erosion or accumulation, often resulting in the truncation or burying of the soil profile. Thus the greater part of the region has young slightly developed soils with properties mainly inherited from the parent material (Bennema et al., 1962).

### The Amazon and Orinoco basins and the Chaco and pampa plains

On the eastern flank the Andean mountains are bordered by an immense zone of lowlands running from the mouth of the Orinoco to Bahía Blanca in Argentina. Along the Amazon these lowlands extend across the continent toward the Atlantic bisecting the Brazilian and Guiana shields. The lowland area is made up of great parts of the drainage basins of the Orinoco, the Amazon and the combined Paraguay-Paraná-La Plata river systems, which are separated by undefined water divides.

The northern portion of the lowland region is drained by the Orinoco River and its left bank tributaries, which rise in the Andes. The Orinoco has built up a delta with over a dozen arms.

The Amazon lowlands are drained by the Amazon River and its tributaries. The river rises as the Rio Marañon in the Andes and enters the lowlands through an impressive gorge (Pongo de Manseriche). Many of the tributaries also rise in the Andes, converging on the axial course of the Amazon upstream of Manaus.

Some tributaries, like the Rio Negro and the Rio Trapajos, contain hardly any suspended material while others, like the Amazon itself and the Madeira, have turbid waters and transport a considerable load.

The Amazon is not only the longest river in the world (6280 km) but also has the most extensive catchment area of the world (about 7 million sq km). Furthermore, although the river has a relatively feeble rate of flow and a slight fall (at Manaus at 1500 km from the mouth the altitude of the river is 15 metres during the low-water season), it discharges immense quantities of water estimated at more than 100 000 cubic metres per second. The outflow is so enormous that the water of the open sea is fresh far beyond the outlet. The river was not able to construct a delta owing to gradual land subsidence in the region of its mouth. Thus, instead of a true delta an estuarine mouth has developed.

The lowlands have formed regions of subsidence and sedimentation since early times in geologic history. After the upheaval of the Andes the basins have been filled largely with the erosion products of the previous and modern Andean mountain systems. These sediments were mainly deposited under continental conditions, but marine ingressions also occurred during the Tertiary which gave rise, for instance, to the Oligocene-Miocene Santa Inés group in Venezuela and the Upper Miocene Entre Rios formation in the pampa.

### Landscape forms

The different forms of sedimentation and the phenomena of renewed incision and dissection have created a great range of landscape forms. Along the Andes an apron of alluvial fans and pediments has been formed. The latter predominate in the arid and semiarid sections of the lowlands. In the lowlands, fluvial, alluvial, and aeolian sedimentation processes are responsible for the formation of natural river levees, point bars (due to repeated sedimentation on the inner bank of a meander), interfluvial depressions and overflow plains, abandoned silted-up channels, terraces, dunes and aeolian plains with loess-like deposits.

In the Orinoco basin the older Pleistocene alluvial deposits occur in a dissected state forming a tableland of terraces (mesas). The surface of these terraces is smooth and consists of silts and loams, probably owing to wind action in the dry season. The low-lying young alluvial plains show a pattern of river courses accompanied by natural levees and intervening depressions which are frequently flooded. Aeolian deposits have been reported north and west of the Rio Meta (FAO, 1965b). The largest part of this aeolian plain is covered by a loess-like deposit overlying alluvial sediments, but longitudinal sand dunes also form complexes on the leeward side of the rivers, the sands originating from the river beaches.

In the Amazon lowlands a flat plateau stretches over large areas between 150 to 200 metres in the eastern part and at a somewhat lower elevation in the western part. It has been called the Amazon planalto by Sombroek. The planalto is capped by the Belterra clay which was probably laid down in a huge lake or sea bay during the Plio-Pleistocene, when the Calabrian sea level stood about 180 metres higher than at present. The lower elevation of the same plateau toward the Andes is probably due to subsidence of the area since the time of deposition (Sombroek, 1966). During the Pleistocene, the present Amazon river system rose and started to dissect the planalto and to form terraces below the landscape of the planalto. Besides these fluviatile terraces, coastal terraces have been distinguished. They have constant altitudes in contrast to the fluviatile terraces, which are related to the river courses of the present drainage systems. Both types seem to be associated with high sea levels during interglacial periods. For a better understanding of soil formation on the distinct landscape elements, it is important to attempt age determinations of the different terrace levels. However, such age determinations, by comparing the altitude data in Amazonia with the data of Pleistocene sea levels observed and established in other parts of the world, are hampered by the differential vertical movements which occurred in Amazonia during the Pleistocene. (In general the lowlands subsided, but the transitional areas to the shields underwent slight uplifting.) The flood plains and the valley bottoms of the Amazon and its tributaries are of Holocene age. They comprise predominantly heavy-textured sediments in contrast to the deposits of the Pleistocene levels, which mainly have a coarse-sandy texture.

The topography of the Chaco plains is flat to gently sloping. To the south, the pampas present a landscape with broad and flat depressions. The surface of these plains is formed of a thin veneer of unconsolidated continental Quaternary deposits overlying a very thick sequence of Paleozoic, Mesozoic and Tertiary sedimentaries. The older rocks come to the surface only locally as in the hill ranges of Buenos Aires. The mantle was mainly deposited during the Pleistocene under fluviatile, lacustrine, and aeolian conditions, but in the immediate neighbourhood of the Atlantic coast, marine sediments form thin intercalations. The loessic deposits of the pampa contain a considerable admixture of volcanic ash originating from volcanic vents in the southern Andes. In geologically recent times sedimentation and erosion processes have been rather inactive, and the Pleistocene materials have undergone only minor reworking.

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## LITHOLOGY

### Geotectonic regions

The description of the lithology of South America is based on the division of the continent into three main morphostructural regions which can be distinguished according to their specific internal constitution and external relief. These main groups are subdivided into thirty-eight geotectonic regions (Fig. 5.).

The three main groups are these:

1. *The ancient preorogenic shields* which crop out on the eastern side of the continent. In Figure 5 the Brazilian (1) and Guiana crystallines (2) appear separately, but structurally they form a unit bisected by the Amazon River. Farther to the south in extra-Andean Patagonia (3) the Patagonian shield is another stable area of Precambrian rocks. To the west of the pampa the pampean ranges of Argentina (4) are an intermediate element between the shields in the east and the Andean system in the west.

2. *The Andean system* (5) along the Pacific and Caribbean coasts is composed of a number of subparallel mountain ranges, intervening longitudinal basins and depressions, and coastal lowlands. The rocks of the system vary widely in age and composition. Besides sedimentary and igneous rocks and their derived metamorphics, pyroclastics form an important constituent. Although the Santa Marta massif (6) in Colombia lies along the trend of the Cordilleras, it does not form a part of the main Andean system.

3. *The Subandean depression* (7) made up by the drainage basins of the Orinoco, the Amazon, and Paraguay-Paraná-La Plata river systems is a negative zone filled in with thick layers of sediments capped by Tertiary and Quaternary deposits.

The geotectonic subgroups can be outlined as follows. The parent materials are shown in Figure 6, the lithological map, which appears on page 46.

1. Brazilian shield
   a. Precambrian basement
   b. Paraná basin
   c. Maranhão, Rio São Francisco, and Salitre basins
   d. Baía-Sergipe basin
   e. Xingu depression and Ilha do Bananal
   f. Coastal Atlantic formations
   g. Fantanal depression
   h. Serranias Chiquitanas
   i. Northern and southern hills of Buenos Aires
2. Guiana shield
   a. Precambrian basement
   b. Rupununi graben
   c. Coastal formations of Guiana
3. Extra-andean Patagonia
   a. Northern and southern (Rio Deseado) Patagonian massifs
   b. Chubut-San Jorge and Santa Cruz depressions
   c. Rio Colorado-Rio Negro depression
4. Pampean ranges
5. Andean system
   a. Caribbean coastal ranges
   b. Venezuelan Andes
   c. Falcon-Lara area
   d. Maracaibo basin
   e. Eastern Colombian Cordillera, Sierra de Perija, and Guajira Peninsula
   f. Central Cordillera of Colombia and eastern Cordillera of Ecuador
   g. Western Cordilleras of Colombia and Ecuador
   h. Rio Magdalena basin and north Colombian coastal formations
   i. Pacific coastal formations
   j. Subandean ranges and eastern Cordillera of Peru, Bolivia, and Argentina
   k. Young volcanic Andes of Peru and Chile and principal Cordillera of Argentina and Chile
   l. Altiplano basin
   m. Andean batholith and old crystalline basement of Peru and Chile
   n. Pampa del Tamarugal of northern Chile
   o. Central valley of Chile
   p. Precordillera of Argentina
   q. Frontal Cordillera of Argentina
   r. Patagonian Cordillera
6. Santa Marta Massif
7. Subandean depression and Amazon basin
   a. Orinoco basin
   b. Amazon basin
   c. Chaco-pampa basin

#### 1. THE BRAZILIAN SHIELD

The Brazilian shield extends from the Amazon basin southward to the Rio de la Plata, with outliers in the northern and southern hills of Buenos Aires.

The visible western boundary of the shield may be traced along the courses of the Uruguay and Paraguay rivers. In Bolivia the shield passes beneath the Bolivian lowlands.

### 1a. *The Precambrian basement of the Brazilian shield*

The Precambrian basement principally outcrops in two main areas: in the central part of the shield west of the huge Paraná, Rio São Francisco and Maranhão basins, and along the Atlantic coast from northeast Brazil to Uruguay.

All Precambrian rocks are metamorphosed, although the intensity of metamorphism varies widely from place to place. They have been subdivided in the literature into four divisions, ranging from early to late Precambrian P(D), P(C), P(B) and P(A). For convenience only two subdivisions are used in the lithological map (Fig. 6): Mg, corresponding to P(C) and P(D), and Ms for P(A) and P(B).

#### P(D) *Mantiqueira series or "embassamento gnaissico" or "basamento cristalino"*

This series occurs over the whole of the Brazilian shield. It consists of a thick succession of banded gneisses, strongly metamorphosed.

#### P(C) *Pre-Minas series*

The Mantiqueira series is succeeded by the pre-Minas series, a group of metasedimentary rocks. In Minas Gerais the Barbacena and Lafaiete series seem to correspond to the pre-Minas group. From Barbacena to Lafaiete the rocks form a sequence of quartz mica schists and gneisses. North of Lafaiete, in the Quadrilátero Ferrífero, a wider range of rock types occurs and includes quartzites, dolomites, conglomerates, iron formations, metavolcanics, and others.

#### P(B) *Minas series*

The Minas and its equivalent series are also widespread over the shield. They are dominantly clastic, but almost all include carbonate rocks and many include iron formations. The Minas series in Minas Gerais comprises quartzites, slates, itabirites (a variety of quartzite containing abundant iron-ore minerals), dolomites, phyllites and conglomerates.

#### P(A) *Itacolomi series*

The Itacolomi series and its equivalent formations are more restricted in their distribution than those which have been correlated with the Minas series. The Itacolomi series in east Brazil consists mainly of quartzites and some phyllites. The largest area mapped as Itacolomi is in the Serra do Espinhaço which extends several hundred kilometres through Minas Gerais to Baía. The quartzites are extremely thick in this area.

*Intrusive rocks.* There are numerous ancient intrusive rocks in the Brazilian shield, mainly granites, granodiorites and diorites. They are of different ages. The granites of Porto Velho contain tin ore. Ultra basic rocks also occur as intrusive in the pre-Minas series, altered into a variety of talcose, serpentinic and other steatic rocks. The largely andesitic rocks that form the effusive outcrop around Lascano in Uruguay have an age between Precambrian and Cambrian (Geologia Uruguaya, 1957) and Mesozoic (Carte Géologique de l'Amérique du Sud, 1963).

### 1b. *The Paraná basin*

This is a huge basin on the Brazilian shield in which marine and continental sediments of various ages from Lower Devonian to Cretaceous have been deposited (Santa Catarina system). In the central and southern parts most of the surface is covered by the extensive Serra Geral basaltic outflows. Along its western border the basin is much affected by faults.

### 1c. *The Maranhão, Rio São Francisco and Salitre basins*

These basins form a second huge area in which widely varying rocks of Paleozoic and Mesozoic age are exposed. The oldest rocks are the Silurian São Francisco or Bambui series which constitutes the bottom of the São Francisco and the adjacent Salitre basin. The basin is drained by the Salitre, Jacaré and Verde rivers, tributaries of the São Francisco river. The most characteristic constituent is a limestone which is sometimes oolitic. The series also contains slates grading to phyllites, sandstones and arkoses. The Bambui series is not represented in the Maranhão basin.

### 1d. *Baía-Sergipe basin*

This basin is in a graben between two scarps: the Salvador scarp to the east and the Maragogipe scarp to the west. It stretches from Ilheus in Baía along the coast to Todos os Santos Bay and from there northward to the Rio São Francisco and the Rio Moxito. The Cretaceous clastic sediments which made up the major part of the sedimentary infilling are flanked on both the west and east side by sediments of the Silurian Bambui series which consists of limestones, sandstones, slates and phyllites.

1e. *Xingu depression and Ilha do Bananal*

The depression of the upper Xingu river and the Ilha do Bananal, which stretches along the Araguaia river, form a depressed area in the central northern part of the Brazilian shield. They are separated from each other by a strip of older rocks of Precambrian, Devonian and Carboniferous age. In the Xingu depression Tertiary sediments predominate with strips of alluvium along the headwaters of the Rio Xingu. The sediments of the Ilha do Bananal are wholly alluvial. All these deposits are unconsolidated or poorly consolidated clastics. Perhaps the Tertiary sediments correspond to the Barreiras series of Amazonia, whereas the Holocene deposits belong to the Vasantes formation.

1f. *Coastal Atlantic formations*

Cretaceous, Tertiary and Quaternary sediments extend along the coastal border of the Brazilian shield from the mouth of the Rio Pará to the Rio Paraíba in Rio de Janeiro, forming a fringe of coastal formations. Quaternary sediments occur along the coast of southern Brazil and Uruguay from Florianopolis to Rio de la Plata. The area includes the Lagoa Mirim and the Lagoa dos Patos in Rio Grande do Sul.

1g. *The Pantanal depression*

The Pantanal is an extensive depression around the headwaters of the Paraguay river on the western border of the Brazilian shield. It occupies a great part of Mato Grosso and has extensions into Paraguay and Bolivia. The basin originated during the late Tertiary. The deposits which form the floor of this depression are Quaternary fine sands, silts and clays of the Vasantes formation.

1h. *Serranias Chiquitanas*

In southeast Bolivia at the border of the Brazilian shield the Serranias Chiquitanas extend from San José east-southeast to Corumba in Mato Grosso. The complex is formed of horst mountain ranges separated by the Chiquitos graben. In the west the main ranges are the Serrania de San José and adjacent to it the higher Serrania de Santiago (up to 900 metres). The Porton nucleus, which attains an altitude of 1425 metres, is situated at the meeting point of both ranges. North of the graben there is the Serrania de Sunsas. To the east the system is continued by the Serrania de Jacadigo, which rises to 780 metres.

The rocks in the area are predominantly early Paleozoic: Cambrian, Ordovician, Silurian and Devonian. Tertiary rocks also crop out in the Porton nucleus.

1i. *Northern and southern hills of Buenos Aires*

The northern hills of Buenos Aires or Sierra del Tandil form a low range of more or less disconnected faulted and tilted mountain blocks with an east-southeast trend extending from central Buenos Aires to near Mar del Plata. The basement consists of Precambrian gneisses intruded by diorites. These rocks are exposed along the northern border. In the south the rocks are capped by marine Upper Carboniferous grey quartzites, dolomites, varicoloured shales and blue and brown limestones, and a few metres of Upper Pliocene conglomerates. The southern hills (Sierra de la Ventana) appear as an isolated mountain block 60 km wide, 180 km long, and reaching 1200 metres altitude. Small Precambrian exposures are observed at the base of the sequence. The basement is covered with thick layer-of marine Lower Silurian, marine Lower Devonian, and glacial, marine and continental Permian sediments, totalling 5000 metres in thickness.

2. The Guiana shield

The Guiana shield is the northern extension of the Brazilian shield. Toward the northwest, west, and south the crystalline mass passes beneath the cover of the younger sediments of the Orinoco and Amazon basins. However, in the Colombia llanos small outcrops of Precambrian rocks are known to occur locally, and the Precambrian rocks of the Sierra de Macarena seem to make up a part of the Guiana crystalline basement. Unlike the Brazilian shield, no extensive epicratonic basins occur on the Guiana shield. The relatively small Rupununi graben is a tectonic feature. The cover of young Tertiary and Quaternary sediments along the coast is rather shallow, attaining considerable thickness only in the Berbice graben in Guyana.

2a. *The Precambrian basement*

The oldest rocks of the Precambrian basement occupy extensive areas especially in the middle and southern parts of the Guiana shield. These rocks consist mainly of various gneisses, granites, schists, granodiorites, pegmatites and migmatites (rocks in which a granitic component and a metamorphic component, schist or gneiss, are intimately mixed).

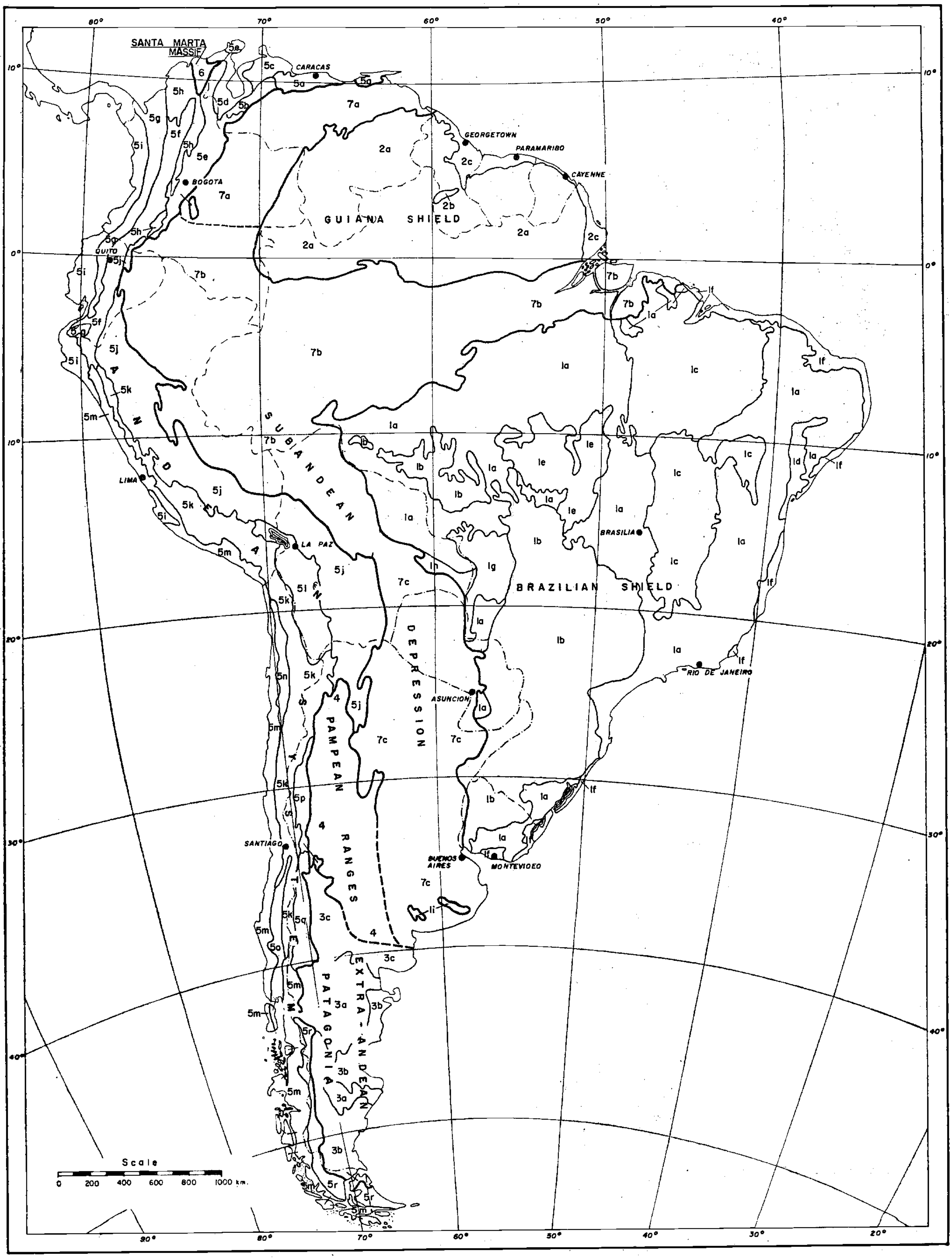



*Figure 5. – Geotectonic regions of South America*

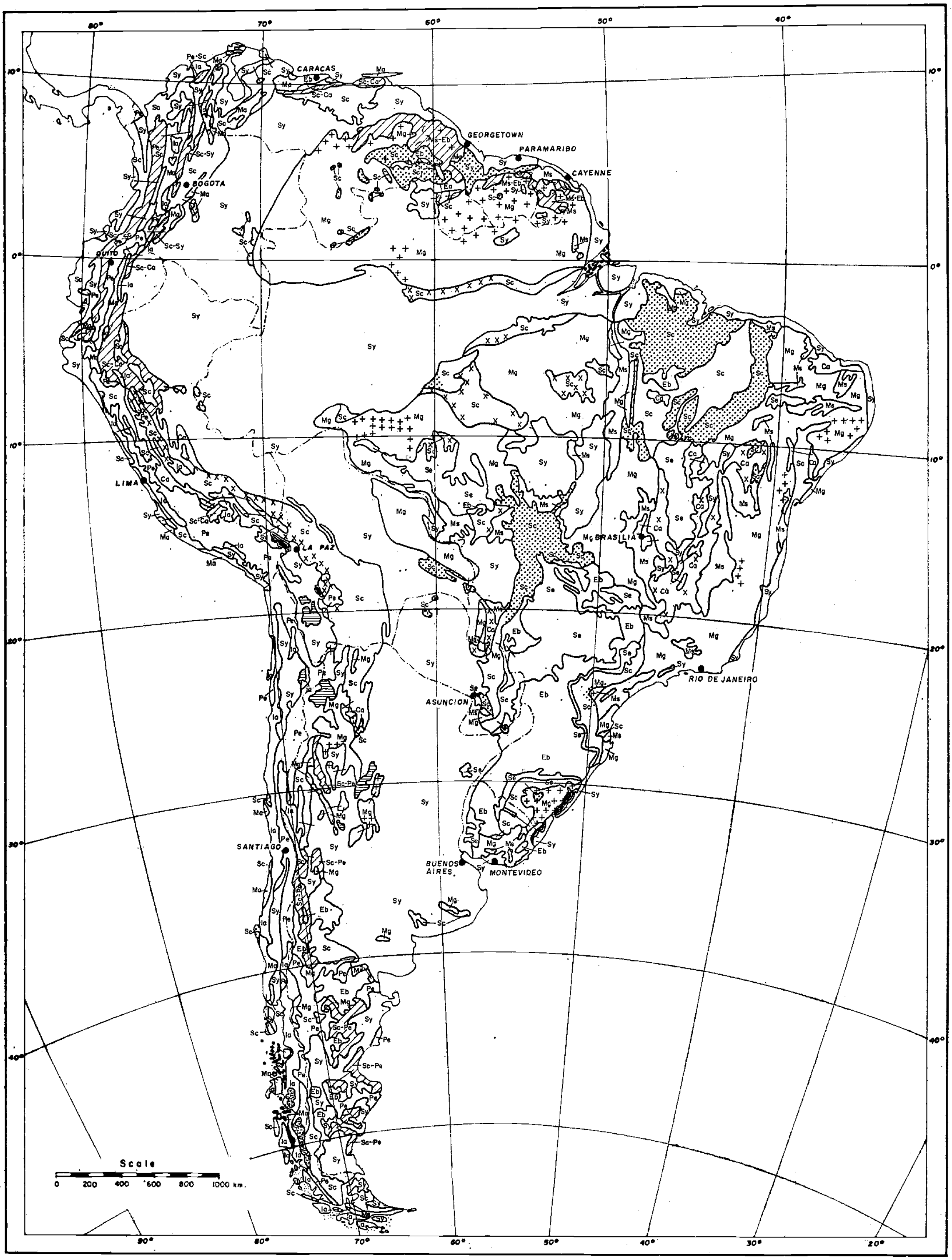



*Figure 6. – Lithological map of South America*

## *Legend to Figure 6, Lithological Map*

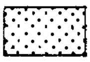
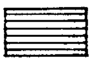
### Igneous and metamorphic rocks

| | |
|---|---|
| Mg | Metamorphic Precambrian rocks of the shields and the pampean ranges, mainly consisting of various gneisses and intrusive granites. |
| Ms | Metamorphic Precambrian rocks of the shields, mainly consisting of various schists, quartzites, phyllites, slates, and carbonate rocks. |
| Ia | Intrusive acid rocks of the Andean system, mainly consisting of granites, granodiorites, diorites. |
| Ma | Metamorphic rocks of the Andean system, mainly consisting of gneisses, schists, quartzites, phyllites, with subordinate intrusives. |
| Pe | Pyroclastic rocks with interbedded outflows of the Andean system and Patagonia. |
| Ea | Effusive acid rocks (rhyolite, quartz, and feldspar porphyries). |
| Eb | Effusive basic rocks (basalt, diabase, dolerite, andesite). |
| + | Precambrian granites in the shield areas. |
| × | Metamorphic rocks with old sedimentaries. |

### Sedimentary rocks

| | |
|---|---|
| Sc | Clastic consolidated sediments (sandstones, siltstones, shales, conglomerates) with subordinate carbonate sediments. |
| Ca | Carbonate sediments (limestone, dolomite) with clastic sediments. |
| Se | Aeolian, fluvial and lacustrine Mesozoic sandstones of the Brazilian shield. |
| Sy | Young clastic weakly consolidated and unconsolidated sediments (sands, sandstones, clays, clay-shales, gravels, conglomerates). |

*The occurrence of loess with ash admixtures is indicated with* $^{v}$v.

| | |
|---|---|
|  | Sandy facies of the clastic consolidated and unconsolidated sediments. |
|  | Salt flats. |
|  | Land ice. |
|  | Lakes. |

### 2b. *The Rupununi graben*

This graben is located between the Kanuku and Pacaraima mountains. Along the river banks of the Takutu, Ireng and Rupununi rivers the Cretaceous Takutu formation is exposed with reddish current-bedded sandstones and variegated shales. In the remainder of the graben lacustrine silts, sands and clays of Tertiary age occur.

### 2c. *The coastal formations of Guiana*

These young sediments are deposited on the northern border of the Precambrian basement in a strip roughly parallel to the coast. Within them differentiation can be made between the Berbice formation (Zanderij formation in Surinam and Série de base in French Guiana), the Coropina formation (Série de Coswine in French Guiana) and the Demerara formation.

The Berbice formation includes the oldest non-consolidated sediments, which however are not older than Miocene. They consist largely of an irregular sequence of white and brown sands and lenses of sandy clays and clays in addition to lignites. They probably originated in a fluvial or semideltaic environment. In French Guiana this formation occupies only a very small and narrow area. To the west the exposure widens, and near the mouth of the Berbice river in Guyana it has a thickness of more than 2000 metres. From there the formation thins out to the northwest. Toward the coast the continental deposits gradually disappear beneath the fluviomarine deposits. The deposition of the Coropina formation took place during the Pleistocene marine isostatic movements and forms a partially eroded coastal plain composed of clays, silty clays and sands. The Holocene Demerara formation makes up the recent coastal plain and consists of heavy blue and grey clays with sandy ridges rich in shells, and peat.

## 3. Extra-Andean Patagonia

Extra-Andean Patagonia is a morphostructural unit characterized by the presence of two stable Precambrian nuclei: the northern Patagonian and the Rio Deseado (southern Patagonian) massifs. These massifs are separated from each other by the Chubut-San Jorge depression. The Santa Cruz depression is located south of the Rio Deseado massif. Between the northern Patagonian massif and the Precambrian basement of the pampean ranges the Rio Colorado-Rio Negro depression forms another area in which the basement is deeply buried beneath a thick covering of marine and continental beds.

The region as a whole is characterized by volcanics of widely varying age, while almost all formations include intercalations and admixtures of tuffs and ashes.

### 3a. *The northern Patagonian and the Rio Deseado massifs*

In the northern Patagonian massif the Precambrian rocks (gneisses and migmatites) are exposed very well along the northern border. In the Rio Deseado massif, however, the basement is wholly concealed beneath a cover of predominantly Jurassic volcanics. These volcanics, which also cover extensive areas of the northern Patagonian massif, include rhyolitic and andesitic flows and tuffs.

### 3b. *Chubut—San Jorge and Santa Cruz depressions*

These depressions have been filled in with a wide variety of sediments of continental, marine or volcanic origin, varying in age from Carboniferous to recent. However, only some Cretaceous, Tertiary and Quaternary deposits constitute the surface of the depressions.

Quaternary deposits are extensively developed in both depressions as deposits of continental or volcanic origin. The deposits are mostly aeolian, fluvial or lacustrine with volcanic ash admixtures. Pleistocene glacial deposits occupy large parts of Tierra del Fuego, southern Santa Cruz and a fringe along the Patagonian Cordillera. They are associated with at least three glaciations.

### 3c. *Rio Colorado—Rio Negro depression*

In this depression Cretaceous sediments are exposed extensively in the western part. The most westerly outcrops belong with the Lower Cretaceous (Andean).

Apart from the scattered Tertiary exposures most of the eastern part of the depression is covered by Quaternary unconsolidated materials of different origin, similar to those of the pampean group farther north.

## 4. The pampean ranges

The name pampean is applied to the disconnected mountains which rise abruptly from the surrounding plains between southern San Luis, northern Tucumán, central Cordoba and western La Rioja. To the north the ranges grade into the eastern Andean Cordillera of Salta and Jujuy. South of San Luis the differentially uplifted and downfaulted blocks are masked by young sediments.

The isolated mountain blocks are formed mainly of later Precambrian rocks. In Salta they are composed of phyllites and meta-greywackes devoid of intrusions. Southward, gneisses and migmatites predominate with intrusions of granites belonging to a vast granitic batholith.

By far the largest part of the area of the pampean ranges is covered with a thick sequence of young materials, nearly everywhere capped by a mantle of Quaternary pampean deposits. Tertiary beds come to the surface only at a few places in San Juan, La Rioja and Catamarca. They are part of the Upper Miocene "Estrates de los Llanos" of la Rioja and the conformably succeeding Pliocene Calchouf formation. Sandstones, shales, conglomerates and tuffites are the elements of both formations.

## 5. The Andean system

The Cordillera de los Andes forms a complex of more or less parallel mountain ranges, which extend from Trinidad to Tierra del Fuego. The western flank of the complex is characterized by an elongated batholithic core which is well exposed in Peru and Chile. The eastern mountain ranges are chiefly composed of locally metamorphosed sedimentaries of widely varying age. In different parts of the Andean Cordilleras tectonic depressions are interspersed between the ranges and filled in with Tertiary and Quaternary sediments. Except for the activity in the eastern ranges of Ecuador, volcanism is practically restricted to the western ranges. The zone of most intense volcanic action lies in the western Andes of south Peru.

The evolution of the Andean Cordilleras is marked by a set of movements accompanied by the intrusion of mostly acid igneous rocks and the extrusion and ejection of lavas and tuffs. The first of these movements began in the late Cretaceous and was succeeded by tectonic stages of Oligocene and Miocene age.

The modern Andean Cordilleras, however, were created during Plio-Pleistocene times by a violent uplift of the whole system. Since that time tectonic activity has not ceased, and volcanic and seismic phenomena still occur. During the Pleistocene several glaciations spread their influence over the region and caused the deposition of a range of glacial and glacio-fluvial sediments.

### 5a. *Caribbean coastal ranges*

The Caribbean coastal ranges stretch from Barquisimete eastward to the París peninsula and the northern range of Trinidad. They are interrupted by the Rio Unare depression. The coastal ranges form the abruptly-rising northern limb of the structural basin known as the eastern Venezuelan basin. The greater part of the range is constituted of metamorphic rocks, probably of Mesozoic age.

### 5b. *Venezuelan Andes*

The Venezuelan Andes form the easternmost continuation of the Colombian Cordillera Oriental, separated from it by the tectonic cross-depression of the Tachira region near San Cristobal. At the northeast side of the Venezuelan Andes the range is bordered by another cross-depression (Yaracuy-Cojedes depression).

The Venezuelan Andes have a peripheral covering of Tertiary deposits. Eocene clastic sediments have developed as a marine facies in the northwestern part (Misoa-Trujillo province) and a brackish water-estuarine facies in the southwest (Tachira province). Next comes the "upper shales" and Miocene Uracá formation of Tachira. The Pliocene deposits are mostly of fluviatile or lacustrine origin and are difficult to distinguish from the following Quaternary deposits. The mesa gravel terraces of the interior valleys and along the outer slopes of the mountains are predominantly of glacio-fluvial origin.

### 5c. *The Falcon-Lara Area*

The region of Falcon-Lara shows the normal southwest-northwest Andean strike, and structurally it is composed of steeply folded anticlines. The greater part of the area is formed of Tertiary deposits, divided by the Miocene depression of the Rio Tocuyo and Carora into the Falcon area and the hills of Lara. At several places small patches of igneous rocks are exposed, for instance an outcrop of two mica-granites northeast of Carora and an outcrop of seyenite-granite in the northern part of the Paraguaná peninsula.

The Eocene to Miocene deposits are marine; the Pliocene is partially marine and partially continental.

### 5d. *The Maracaibo basin*

The basin enclosed between the Venezuelan Andes in the east and the Sierra de Perija in the west has been filled in with a considerable thickness of pre-Quaternary sediments. However, with the exception of late Tertiary deposits in the southern Cucuta-Labateca extension of the basin, the surface consists of recent alluvium.

### 5e. *The eastern Colombian Cordillera, Sierra de Perija, and Guajira peninsula*

In its broadest meaning, the eastern Cordillera includes the entire mountain area between the Rio Magdalena valley and the Colombian llanos. The range begins at the headwaters of the Rio Magdalena and Caquetá, a short distance from the Nudo de Pasto (Garzon massif). To the northeast the Cordillera is weakly united with the Venezuelan Andes. North of Bucaramanga the Cordillera passes into the Perija range, which continues northward until it ends abruptly at the east-striking Santa Marta-Paez fault zone. This fault zone separates the unit of the Guajira peninsula from the eastern Cordillera-Sierra Perija system. The eastern Cordillera is largely sedimentary with Cretaceous predominating but also includes some Tertiary, Jurassic, Triassic, Paleozoic and Precambrian rocks with little or no young volcanics. The Sierra de Perija has a core of Paleozoic and Precambrian crystalline rocks surrounded by younger sedimentaries.

5f. *The central Cordillera of Colombia and the eastern Cordillera of Ecuador*

The central Cordillera of Colombia is composed mainly of metamorphic and igneous rocks of Paleozoic-Mesozoic age. The range is bordered to the east by the Rio Magdalena basin and toward the west by the Rio Cauca trough; it plunges northward to disappear under the lowlands of the north coastal area near El Banco. Volcanoes were active along this trend, particularly during the Miocene, and some are still not extinct. To the south the range continues in Ecuador where the same geologic unit carries the name eastern Cordillera or Cordillera Real. The trend of the Colombian part is about 30 to 45°E but in Ecuador it is nearly north-south. The eastern Cordillera in Ecuador is flanked on its west side by the Intercordilleran depression, a huge graben bounded to the east and west by fault zones and filled in with abundant late Tertiary and Quaternary volcanics. In Ecuador the eastern Cordillera has a Precambrian core of metamorphic and igneous rocks which eastward become overlain by successive Paleozoic, Mesozoic and Tertiary sediments.

5g. *The western Cordilleras of Colombia and Ecuador*

The western Cordillera is found west of the Intercordilleran depression in Ecuador and in the Rio Cauca trough in Colombia. At the northern extremity the range splits in two, one branch swinging northeast through Bolivar and Atlántico and the other swinging west to join the Darien mountains of eastern Panama.

The range has a core of Cretaceous plutonic rocks which are exposed in a scattered pattern. The rocks, principally granodioritic, have a close resemblance to those in the Cordillera Oriental of Ecuador. Most of the surface rocks, however, are of volcanic and sedimentary origin of Jurassic and Cretaceous ages. In Colombia the volcanics are basic or ultrabasic.

5h. *Rio Magdalena basin and North Colombian coastal formations*

The Rio Magdalena basin developed during the late Tertiary as an intervening strike-valley between the central and eastern Cordilleras of Colombia. Sometimes the valley is considered to have originated as a graben, but there is little proof of this.

The coastal lowland area of Bolivar, Atlántico and Magdalena, west of the Santa Marta massif, is a separate structural unit. West of a line from Barranquilla to Sahagun, at the outskirts of the Sierra San Jerónimo, the rocks are strongly folded and faulted. East of this line the structure is much simpler. This part of the unit is still sinking along its eastern margin, particularly along the lower Cauca River. The deposits of the northern lowlands are mainly marine Tertiary. Nonmarine sediments occur along the Rio Magdalena, extending almost to its source.

5i. *Pacific coastal formations*

The Pacific coastal formations extend over the coastal regions of Colombia, Ecuador and northwestern Peru. The rocks are mainly Tertiary, but extensive areas are overlain by Quaternary deposits of various kinds. The coastal formations include some low mountain ranges such as the coastal range in Colombia north of Cabo Corrientes and the Chongón-Colonche range in southwest Ecuador.

5j. *Subandean ranges and Eastern Cordillera of Peru, Bolivia and Argentina*

This area of huge extent occupies the whole eastern part of the Cordillera de los Andes in Peru and Bolivia. Moreover, it extends southward into northwestern Argentina and northward into Ecuador. To the west it is defined by the young volcanic Andes and the Titicaca basin. At its eastern flank the region includes the Subandean ranges characterized by strong folding and minor faulting. The Napo-Galeras uplift and the Sierra de Cutucú in Ecuador are part of these frontal ranges.

The rocks of this region are mainly sedimentaries of widely varying ages, including Tertiary, Mesozoic, Paleozoic and Precambrian. The older sediments are locally metamorphosed.

5k. *Young volcanic Andes of Peru and Chile and principal Cordillera of Argentina and Chile*

This part of the Cordillera de los Andes is characterized by a covering mostly of late Tertiary to recent volcanic rocks. The zone of young volcanics attains a maximum development in southern Peru. At the Chilean border the volcanic cover is 175 km wide but narrows northwestward. In northern Peru the cover is discontinuous. There the deposits form the extension of the volcanics of the Intercordilleran depression of Ecuador, which are of similar age. In southern Peru the volcanic zone is dominated by the series of great Quaternary volcanoes — Coropuna, Ampata, Chachani, El Misti, Pichu-Pichu, Ubinas, Tutapaca and Tacora. In this area the sequence is divided into a lower member, the Tacaza group, and an upper member, the Sillapaca group. The volcanics of the former are folded and locally thrust-faulted, whereas the Sillapaca group includes all volcanics up to the products of recent eruptions. However, postglacial volcanism shows diminishing activity. The deposits range in composition from basalt to rhyolite with particularly abundant representation of andesite, trachyandesite and trachyte, and include outflows, pyroclastics, cinder cones and tuff flows. In central Peru the Rio Blanco formation possibly is the correlative of the Tacaza group.

In Chile and Argentina the late Tertiary accumulation of flows and tuffs is known as "formación liparítica." In many places there are trachyandesites above the liparite flows which indicate development of more basic members of the magma. During the Pliocene the numerous volcanoes of the Puná were formed, with ejection of augite and hypersthene andesites. Still later during the Quaternary hypersthene basalts followed, whereas the more recent eruptions produced olivine basalts.

### 5l. *The altiplano basin*

The altiplano basin begins in southern Peru and extends through the full length of Bolivia into the extreme northwestern corner of Argentina and the Puna de Atacama of northern Chile. The basin originated during the early Tertiary as a tectonic depression and was elevated to its present position at a mean altitude of 3750 to 4000 metres during the last forceful uplift of the Andean orogeny. Throughout the Tertiary and Quaternary it remained an area of depression in which vast amounts of clastic and pyroclastic deposits of distinct origin have been deposited. The oldest continental deposits are folded and truncated. They carry the name Corocoro group, which is exposed at several places in the basin but particularly in the north.

In contrast to the upper section, which is rich in material of volcanic origin, the lower part of the continental sequence is devoid of volcanic material.

### 5m. *The Andean batholith and the old crystalline basement of Peru and Chile*

One of the most striking geologic features of the Andean system is the large batholith that forms a highly continuous belt of plutonic rocks along the western edge of the Andes in Peru and Chile as far as Tierra del Fuego. In places where the rocks are not exposed there is no doubt that they occur at no great depth in the subsurface. This is the case in southern Peru and northern Chile, in particular, where the batholith is split up into a number of smaller plutons. In Chile north of latitude 38°S the batholith is mainly exposed in the coast range west of the great longitudinal depressions. South of this latitude the batholith is mostly in the Andes. The rocks which constitute the batholith are, in approximate order of abundance, granodiorite, tonalite, granite and diorite. Quartz monzonite, monzonite, syenite, gabbro and amphibolite are less frequently present. The topmost parts of the batholith show the widest range of differentiation, decreasing with depth, so that the deeply eroded parts appear to be fairly homogeneous in composition.

### 5n. *The Pampa del Tamarugal of northern Chile*

The Pampa del Tamarugal is a tectonic depression with internal drainage between the coast range and the Andes in northern Chile. It began to form during Pliocene time. Its axis is oblique to the coast so that it reaches the Pacific near Africa. The depression is largely covered by Tertiary and Quaternary alluvium and volcanics. Salt deposits of chlorides, nitrates and sulfates are widespread in the western margin of the westward down-sloping pampa.

### 5o. *The central valley of Chile*

Like the Pampa del Tamarugal the central valley of Chile originated as a tectonic depression during the Pliocene. The depression was extended during the Quaternary. At the northern end it is broken up into a number of small basins of which the Santiago basin is the most important. Southward the depression widens, and the valley attains a more uniform character. It becomes very narrow in the province of Valdivia where the coast range projects eastward almost as far as the Andes. Southward of Puerto Montt the central depression continues as a submerged trough, ending at about 46°S latitude. A great part of the floor of the central valley is made up of volcanic material, mostly of secondary origin. Beds of true volcanic ash, originating from the chain of volcanoes in the Cordillera, have only a limited extent because the prevailing southwesterly winds blow most of the ash over the mountainous region of the Cordillera. Such beds are easily recognized by typical shower banding. Formerly, most of the reworked volcanic deposits were regarded as being periglacial, glacio-fluvial or glacial sediments.

Today it is known that at least a part of all the "glacial moraine landscapes" of the central valley, previously distinguished because they show a chaotic tumbled hummocky landscape, originated as volcanic mudflows, breccia flows, and sand flows (Wright and Espinoza, 1962). Deposits of undoubted glacial origin occur between 39° and 42°S where moraine amphitheatres laid down during the last glaciation have dammed rivers and formed lakes.

Part of the volcanic material is reworked as fluvial, alluvial or lacustrine deposits. Fine material was picked up by the southwesterly winds and dropped along the foot of the Cordillera as volcanic loess. Between 37° and 40°S the remnants of eroded Tertiary volcanoes rise from the bottom of the central valley. They form the centres of lava and breccia flows of andesitic and basaltic composition.

### 5p. *The Precordillera of Argentina*

The Precordillera is a separate structural unit at the eastern border of the Andes in La Rioja, San Juan and Mendoza. Northward the unit disappears below the young volcanic Andes. Toward the south it ends abruptly west of Mendoza City. In the Sierra Pintada, west of San Rafael, the unit reappears for a short stretch to be finally lost in southern Mendoza. The Precordillera is characterized by a very thick range (25 000 metres) of widely varying marine and continental rocks. The present outline of the mountains, with uplifted longitudinal ridges and down-faulted intervening valleys, was achieved by late Pliocene and Quaternary differential movements.

### 5q. *The frontal Cordillera of Argentina*

The frontal Cordillera forms the eastern border of the principal Cordillera in Argentina between the Precordillera and the Precambrian basement of the Patagonian massif. The ranges are made up of vast masses of Triassic, Jurassic and Lower Cretaceous volcanites and sedimentaries.

### 5r. *The Patagonian Cordillera*

The Patagonian Cordillera forms the easternmost part of the Andean system at its southern extremity. The Cordillera is composed of Jurassic, Cretaceous and Tertiary rocks that are exposed in more or less parallel bands east of the crystalline outcrops of the Andean batholith and the old metamorphic basement.

## 6. The Santa Marta massif

The Santa Marta mountains, together with the César valley in northern Colombia, form a block which has been tilted southeast. The block is not an integral part of the regular Andean system. It is confined by faults separating the block from the Sierra de Perija and the Caribbean lowlands.

The massif essentially is made up of plutonic and metamorphic rocks and Triassic-Jurassic deposits with a sedimentary-volcanic facies. The intrusion of the plutonic rocks took place during several periods of igneous activity of which the last is post-Triassic to post-Liassic. The rocks exposed are granodiorites, granites, diorites, syenites, monzonites, etc. The metamorphics are Precambrian gneisses and younger Paleozoic actinolite schists or garnet amphibolites. Along the southeastern border of the massif, and in some other places, a group of sedimentary and volcanic rocks (the Giron complex) of Triassic-Jurassic age overlap the crystalline rocks. The complex includes quartzites and varicoloured shales with porphyritic flows, tuffs and volcanic breccias.

## 7. Subandean depression and Amazon basin

West of the Brazilian and Guiana shields the basement rock passes beneath a sedimentary cover of Quaternary, Tertiary and older sediments. This is the Subandean depression, extending from the mouth of the Rio Orinoco to Bahía Blanca in Argentina. The depression is made up of three linked basins: the Orinoco basin; the upper Amazon basin grading eastward into the lower Amazon and Marajo basins (which do not form elements of the Subandean depression proper); and the Chaco-pampas basin. At two points just north of the equator at the Sierra Macarena and at Santa Cruz the trough is constricted where the Andes swing east and the Precambrian massifs extend west.

### 7a. *The Orinoco basin*

The Orinoco basin occupies a position between the Caribbean ranges, the Cordillera Oriental of Colombia and the Venezuelan Andes to the north and west, and the Guiana shield in the southeast. It is a distinctly asymmetrical trough with a long gentle southeastern limb and a steeply rising northern and western limb made up of the Andean system. The filling of the basin is of considerable thickness, but over the greater part of the surface Quaternary continental deposits overlap the older Tertiary sediments.

Outside the area of Tertiary sediments, the basin is covered with the alluvial, fluvial and aeolian deposits of the Pleistocene mesa formation composed of the erosion products of the Andes formed during and after the upheaval of the Andean ranges. The slightly consolidated or loose clastic deposits (gravels, sands, sandstones, clays and claystones) belong to the alluvial fans of the piedmont area, the alluvial terraces along the rivers, the alluvial overflow plains in areas of subsidence as in Arauca and Casanare (Colombia), and the high plains and mesas formed of early Pleistocene alluvium. In the Colombian llanos, west of the Rio Meta, aeolian deposits occur as sand dunes or a loess-like mantle burying older alluvial deposits. In the Amacuro delta the mesa formation grades eastward into the Orinoco delta deposits.

### 7b. *The Amazon basin*

The Amazon basin is an ancient geosyncline of long persistence. Sedimentation started in Cambrian times and lasted as long as the Carboniferous. These rocks outcrop in long narrow belts on both the northern and southern flanks of the lower Amazon basin. The Cambrian Uatumá series forms a sequence of metamorphosed rocks consisting of compact arkosic sandstones with alkalic feldspar, quartz and biotite as the chief components.

The greater part of the whole Amazon basin is covered with Tertiary deposits. Along the foot of the Andes, Tertiary fine to coarse clastic sediments of brackish to fresh-water facies form the erosion products of Tertiary mountain systems. Particularly in the Upper Tertiary beds, there is a considerable admixture of pyroclastic material. These ashes must have originated from Mio-Pliocene volcanoes in the Andes. Eastward in Brazil the Tertiary deposits are known as the Barreiras or Alter do Châo series. The series is composed of variegated clays and friable sandstones. Over much of the flat plateau land of the basin known as the Amazon planalto this series is characterized by a topmost layer, ten to twenty metres thick, of uniform very heavy clay, the Belterra clay (Sombroek, 1966). Sedimentation of this kaolinitic clay took place during Plio-Pleistocene times in a shallow inland sea or lake. Below the level of the Amazon planalto there is a series of Pleistocene terraces at various levels above the floodplains of the Amazon and its tributaries. The Pleistocene deposits are commonly very thin and mostly consist of reworked Tertiary and older sedimentaries. The only thick Pleistocene deposits are in the Marajó area. There they attain about 250 metres thickness and consist chiefly of fine-grained deposits. In the same formation the Para sandstone occurs in nodules and loose blocks. The Quaternary deposits adjacent to the Andean system consist of extensive fanglomerates forming thick piedmont deposits marked by mesas at different levels. The mesas are made up of sandy clays, clayish sands with much volcanic material and lenses of loosely cemented conglomerates. Eastward the mesas converge and finally form a mantlelike deposit which masks the underlying Tertiary over extensive areas. The Holocene deposits consist largely of silts and clays. They cover the flood plains along the main river courses and are also found in the estuary region. They occupy only a very low percentage of the whole basin.

### 7c. *The Chaco-pampa basin*

The Amazon basin continues southward through the Bolivian lowlands, drained by tributaries of the Amazon river and covered mainly by Pleistocene alluvium, into the Chaco-pampa plains. This trough, interposed between the epicratonic Paraná basin and the Subandean and pampean ranges, is characterized by a considerable thickness of marine and continental Paleozoic, Mesozoic and Cenozoic rocks, covered by a thin veneer of continental Quaternary deposits. Older rocks appear at the surface at only a few places.

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# 5. THE SOILS OF SOUTH AMERICA

The legend of the Soil Map of South America consists of 469 map units in 387 different soil associations, each of which is composed of one or more soils occupying characteristic positions in the landscape. The sequence of their occurrence is related mainly to topography, geomorphology and lithology.

Each soil association is characterized by the dominant soil — the soil with the widest extension — and by associated soils and inclusions which occur in lesser extension. Fifty-seven different dominant soils have been indicated on the map.

For convenience and brevity the soil associations have been listed in Table 3. The following information is given:

1. The map symbol of the dominant soil, followed by the number specifying the composition of the soil association, a second number indicating the textural class of the dominant soil, and a small letter indicating the slope class of the soil association. Textural class numbers are: (1) coarse, (2) medium, (3) fine. Slope class letters are (*a*) level to undulating, (*b*) rolling to hilly, (*c*) steeply dissected to mountainous.
2. The associated soils — subdominant soils with an extension of more than 20 percent of the mapping unit.
3. Inclusions of important soils occupying less than 20 percent of the mapping unit.
4. Phases related to the presence of indurated layers, hard rock, salinity or alkalinity in the soil, or of cerrado vegetation.
5. An estimate of the area of the unit in thousands of hectares.
6. The climate symbol.[1]
7. Countries of occurrence. For Brazil, subdivisions are based on the five principal soil maps used: 1 for north, central, and west Brazil, 2 for south Brazil, 3 for coastal Baía, 4 for east Brazil, and 5 for northeast Brazil.
8. The predominant natural vegetation of the area.
9. The predominant lithology of the area.

The information on vegetation and lithology, as presented in the Table, is mainly abstracted from the vegetation and lithology sections of Chapter 4.

The soil-forming factors of vegetation and lithology should be related to the soil associations only where they have been studied and described in the field. In many soil associations they have not been identified, and the Table can present only the most probable picture. Any conclusions on soil formation drawn from the Table must, therefore, be considered provisional.

### Distribution of major soils

The South American environment is enormously varied. This applies to climate, vegetation, physiography and lithology and, as a consequence, also to soils.

To aid in understanding the soil geography, the continent has been divided into three major structural elements: lowlands, uplands, and Andes (lowlands and uplands correspond to the basins and shields described in Chapter 4). These elements have been subdivided into 27 regions, each with its own distribution of soils (Fig. 7). Most of these are also ecological regions with a characteristic climate-vegetation-soil pattern.

The lowlands (A) refer mostly to the three principal drainage systems: the Amazon, Orinoco and Paraguay basins. The drainage conditions are very important for subdivision. There are also significant differences in climate.

The uplands (B) cover the ancient Guianan, Brazilian and Patagonian shields of the eastern part of the continent. In addition to climate, these soil regions are distinguished mainly on the basis of their physiography and lithology which are closely related to their soil patterns.

[1] According to the Papadakis system. See J. Papadakis, *Climates of the World and their Agricultural Potentialities*, Buenos Aires, 1966.

TABLE 3. — SOIL ASSOCIATIONS AND RELATED INFORMATION

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Ag1-3a | Ap | | | 454 | 1.221 | Peru | Tropical evergreen forest and swamp forest. herbaceous swamp | Alluvium |
| Ao1-1a | | | | 1 339 | 1.2 | Brazil 4 | Tropical seasonal forest | Precambrian metamorphic rocks |
| Ao1-2a | | | | 304 | 1.121 | Brazil 3 | Tropical seasonal forest | Cretaceous sandstones. shales. conglomerates and sandy limestones. Precambrian metamorphic rocks |
| Ao1-2b | | | | 2 814 | 1.77, 4.11, 4.13, 4.14 | Brazil 2 | Campos limpos in the south. lowland tropical seasonal forest in the north and *Araucaria* forest in the north | Many parent materials including Precambrian metamorphic rocks, sandstone and basalt |
| Ao1-3a | | | | 1 743 | 4.13, 4.14 | Brazil 2 | Tropical seasonal forest and *Araucaria* forest | Basalt of the Trapp formation |
| Ao1-3a | | | | 377 | 1.121 | Brazil 3 | Tropical seasonal forest. restinga woodland | Shales. shaly limestones. sandstones. and Barreiras sediments |
| Ao1-3a | | | | 968 | 1.21, 1.35, 1.532 | Brazil 5 | Tropical seasonal forest. restinga woodland | Precambrian metamorphic rocks. Tertiary Barreiras beds (clastic) |
| Ao1-3b | | | | 852 | 1.121, 1.471 | Brazil 1 | Tropical evergreen forest | Cretaceous and Tertiary clastic rocks |
| Ao1-3b | | | | 487 | 1.77 | Brazil 4 | Tropical seasonal forest | Precambrian metamorphic rocks |
| Ao1-3b | | | | 453 | 1.123 | Colombia | Tropical evergreen forest and woodland savanna in North Colombia | Tertiary clastic rocks. some igneous outcrops |
| Ao1-3b | | | | 757 | 1.121, 1.471 | Peru | Tropical evergreen forest | Cretaceous and Tertiary clastic rocks |
| Ao2-2a | Ap Wd | Gh | | 1 521 | 1.121, 1.31, 1.35, 1.532 | Brazil 5 | Restinga woodland | Tertiary Barreiras series with sandstones. sands and claystones. and Precambrian metamorphic rocks |
| Ao2-2b | Ap Wd | Gh | | 2 172 | 4.11 | Brazil 2 | Tropical seasonal forest and littoral vegetation | Precambrian metamorphics. Cambrian phyllites. sandstones. shales. etc.. Permo-Carboniferous clastics. sandstone and basalt |
| Ao3-1a | Qf | | | 3 737 | 1.483, 1.484 | Venezuela | Savannas and semideciduous forest | Miocene-Pliocene-Quaternary sandstones. sands. shales. claystones. clays |
| Ao3-2a | Qf | | | 60 | 4.36 | Argentina | Grassland | Sandstones |
| Ao3-2a | Qf | | | 61 | 4.45 | Brazil 1 | Campo limpo | Cretaceous Bauru sandstone |
| Ao3-2b | Qf | | | 669 | 1.121 | Brazil 5 | Tropical seasonal forest | Cretaceous/Tertiary sandstones. claystones |
| Ao4-2b | Wh Gh | Gd | | 1 266 | 4.14 | Brazil 2 | Wet grassland | Botocatú sandstone and Permo-Carboniferous clastic rocks |
| Ao5-2a | Ag Gh | | | 67 | 4.15 | Brazil 2 | Gallery forest and tropical seasonal forest | Basalt of the Trapp formation. Quaternary unconsolidated deposits |
| Ao6-3b | Fo | I Gd | | 1 728 | 1.21, 1.221, 1.31 | Brazil 4 | Coastal tropical seasonal forest | Precambrian gneisses, schists. quartzites |
| Ao7-2b | Fo | | | 2 921 | 1.124, 1.77, 2.24 | Brazil 2 | Predominantly *Araucaria* forest with campos limpos | Permo-Carboniferous sandstones. shales. calcareous shales. tillites, and others |
| Ao7-3a | Fo | | Petric | 1 813 | 1.132, 1.482 | Brazil 1 | Tropical semievergreen forest | Precambrian granites |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Ao7-3a | Fo | | | 1 068 | 1.121 | Guyana | Tropical evergreen forest | Precambrian metamorphic rocks, granites |
| Ao7-3b | Fo | | | 4 290 | 1.77 | Brazil 4 | Tropical seasonal forest | Precambrian metamorphic rocks |
| Ao7-3b | Fo | | | 237 | 1.13 | Trinidad | Tropical seasonal forest | Tertiary clastic rocks |
| Ao8-3b | Fo I | | Stony | 1 040 | 1.483 | Brazil 1 | Campo cerrado | Precambrian metamorphic rocks and granites |
| Ao8-3b | Fo I | | | 680 | 1.121, 1.71 | Colombia | Tropical seasonal forest and montane forest | Igneous and metamorphic Paleozoic rocks, Cretaceous clastics |
| Ao8-3b | Fo I | | | 1 501 | 1.121 | Guyana | Tropical rainforest | Precambrian metamorphic rocks (from sedimentary and igneous rocks) and granites |
| Ao9-3b | Ap Fo | Lc | Petric | 2 376 | 1.132, 1.482 | Brazil 1 | Tropical semideciduous forest | Cambro-Ordovician slates, sandstones, conglomerates etc. and Cretaceous sandstone |
| Ao10-2/3b | I Af | | | 313 | 1.482 | Bolivia | Tropical deciduous forest | Precambrian metamorphic rocks covered by alluvium and colluvium |
| Ao10-3b | I Af | | Petric | 3 262 | 1.53, 1.483, 1.484 | Venezuela | Savanna | Tertiary sandstones, shales, claystones, lignites, conglomerates and limestones |
| Ao11-3c | Nd I | | | 4 164 | 1.131, 1.24, 1.483, 1.81 | Venezuela | Montane forest | Mesozoic metamorphics like phyllites, schists and marbles with acid and basic intrusives and extrusives. Cretaceous sandstones, shales and limestones |
| Ao12-2a | Ap | | | 5 147 | 1.121, 1.471, 1.48 | Surinam | Tropical evergreen forest and savanna | Precambrian metamorphic rocks and granites |
| Ao12-3a | Ap | | Petric | 1 877 | 1.483 | Venezuela | Savanna | Pleistocene mesa deposits |
| Ao13-3ab | I | | | 959 | 1.482 | Bolivia | Tropical semideciduous forest | Precambrian metamorphic rocks and alluvium |
| Ao13-3c | I | | | 298 | 1.72 | Ecuador | Tropical evergreen forest | Jurassic and Cretaceous calcareous, clastic and pyroclastic (tuffs and lavabeds) rocks |
| Ao13-3c | I | | | 114 | 1.13 | Trinidad | Tropical seasonal forest | Mesozoic schists, phyllites, slates, and marbleized limestones |
| Ao14-2b | Fo Af | | Petric | 2 848 | 1.483, 1.8 | Brazil 1 | Cerrado, gallery forest | Silurian limestones, slates, phyllites, arkoses |
| Ao15-3a | Ap Af | Gp Fp I | Petric | 2 617 | 1.36, 1.483, 1.916 | Brazil 1 | Tropical deciduous forest | Precambrian metamorphic rocks |
| Ao16-3a | Ap Gh | Bd | | 514 | 1.121, 1.123 | Colombia | Tropical deciduous forest | Alluvial terraces |
| Ao17-2/3a | Ap Fo | | | 12 646 | 1.221, 1.471, 1.482, 1.73 | Bolivia | Tropical wet evergreen forest | Mainly alluvium, Tertiary deposits along the border of the Andes |
| Ao17-2/3a | Ap Fo | | | 3 532 | 1.221, 1.471 | Peru | Tropical evergreen forest | Quaternary alluvium |
| Ao17-2/3a | Ap Fo | | | 6 806 | 1.132 | Brazil 1 | Tropical evergreen forest | Alluvium |
| Ao18-2/3b | I Lc | | | 489 | 1.482 | Bolivia | Tropical deciduous forest | Precambrian metamorphic rocks covered by alluvium and colluvium |
| Ao19-2a | We | | | 3 558 | 4.36 | Paraguay | Tropical seasonal forest with local swamps | Carboniferous, Permian and Jurassic sandstones with subordinate fine-grained rocks |
| Ao20-2ab | Nd Fo | Qf Gd | | 2 482 | 4.45 | Paraguay | Tropical seasonal forest and swamp vegetation | Jurassic sandstone |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Ao21-2a | Fo Qf | | Petric | 20 948 | 1.132, 1.482 | Brazil 1 | Tropical semievergreen forest | Alluvium, colluvium and Tertiary clastic deposits (Xingu headwater basin) overlying Precambrian metamorphic rocks |
| Ao22-3a | Fp | | | 77 | 1.13 | Trinidad | Tropical seasonal forest, swamp forest | Tertiary and Quaternary consolidated and unconsolidated deposits |
| Ao23-2a | Fx Ap | Gd Ph | | 405 | 1.34, 1.532 | Brazil 5 | Tropical seasonal forest. Along the shore mangrove swamp forest and restinga woodland | Precambrian metamorphic rocks, Cretaceous and Tertiary clastics and unconsolidated deposits |
| Ao24-3b | Fo Gh | | | 216 | 1.31, 1.131 | Brazil 5 | Tropical seasonal forest and coastal restinga vegetation | Metamorphic Precambrian rocks and along the coast Tertiary clastics |
| Ao24-3b | Fo Gh | | | 3 515 | 1.121, 1.71 | Colombia | Tropical evergreen forest and lower montane forest | Old Paleozoic metamorphics, basic and ultrabasic volcanics, Cretaceous and Tertiary clastics and alluvium |
| Ao25-3c | Bd I | | | 6 812 | 1.12, 1.121, 1.31, 1.34, 1.72 | Peru | Tropical evergreen forest and subtropical evergreen forest | Old Paleozoic slightly metamorphosed rocks, Young Paleozoic and Cretaceous clastic and calcareous rocks, outwash deposits, alluviums, terraces |
| Ao26-3c | Be I | | | 3 716 | 1.12, 1.121, 1.13, 1.72 | Peru | Tropical and subtropical evergreen forest | Permo-Carboniferous, Jurassic, Cretaceous and Tertiary calcareous and clastic rocks, fan deposits, terraces, alluvium |
| Ao27-3b | Fx Fo | | | 362 | 1.77 | Brazil 4 | Tropical seasonal forest | Precambrian slates, gneisses, schists |
| Ao28-3a | Ws I Fx | Hl E | | 2 464 | 1.121, 1.31, 1.34 | Brazil 5 | Tropical seasonal forest, dry deciduous Agreste forest, coastal restinga and mangrove swamp formations and caatinga | Precambrian metamorphic rocks, Cretaceous and Tertiary sandstones, siltstones and clays |
| Ap1-3a | Gd Gp | | | 184 | 1.482 | Bolivia | Tropical forest, swamp forest | Quaternary sediments |
| Ap1-3a | Gd Gp | | | 16 813 | 1.11, 1.121, 1.32, 1.471, 1.482, 1.483 | Brazil 1 | Varzea forest and cerrado | Young Quaternary alluvium |
| Ap1-3a | Gd Gp | | | 79 | 1.121 | Guyana | Tropical forest, swamp forest | Pleistocene sediments |
| Ap1-3a | Gd Gp | | | 125 | 1.121 | Surinam | Tropical forest, swamp forest | Pleistocene sediments |
| Ap2-3a | Gp Qf | Af Fo | | 7 305 | 1.132, 1.77, 1.482, 1.483 | Brazil 1 | Cerrado and wet savanna | Metamorphic rocks locally covered by alluvium, colluvium and Tertiary clastics |
| Ap3-3a | Fr Gp | | | 122 | 1.77 | Brazil 1 | Cerrado and wet savanna | |
| Ap6-2a | Vc | | | 83 | 1.13 | Peru | Savanna, herbaceous swamp | Tertiary sediments |
| Ap8-2a | Fx Gp | Gd | | 14 567 | 1.121, 1.132, 1.135, 1.471, 1.48 | Brazil 1 | Cerrado, campo varzea and wet savanna | A great variety of rocks and loose deposits from Precambrian to Pleistocene |
| Ap8-2a | Fx Gp | Gd | | 2 842 | 1.21 | Peru | Swamp forest and wet savanna | Pleistocene and more recent sediments |
| Ap8-3a | Fx Gp | Gd | | 1 323 | 1.11 | Peru | Swamp forest and wet savanna | Pleistocene and more recent sediments |
| Ap9-3a | O Gh | Jt | | 200 | 1.121, 1.471 | French Guiana | Swamp forest, tropical evergreen forest, savanna | Sands and clays of Pleistocene erosion surfaces |
| Ap9-3a | O Gh | Jt | | 155 | 1.121 | Guyana | Swamp forest, tropical evergreen forest, savanna | Sands and clays of the old eroded coastal plain (Pleistocene) |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Ap9-3a | O Gh | Jt | | 2 270 | 1.121, 1.471, 1.48 | Surinam | Swamp forest, tropical evergreen forest, savanna | Sands and clays of the old eroded coastal plain (Pleistocene) |
| Ap10-2a | R | | | 1 097 | 1.484 | Venezuela | Wet savanna and swamp forest | Quaternary fluvial and deltaic deposits of the Orinoco delta |
| Ap11-2a | Gh Bd | | | 1 735 | 1.46 | Colombia | Wet savanna (grassland) | Aeolian loessic deposits of late-glacial age |
| Ap11-2a | Gh Bd | | | 2 738 | 1.46 | Venezuela | Wet savanna (grassland) | Aeolian loessic deposits of late-glacial age |
| Ap12-3a | Gh Vp Ag | J | | 2 690 | 1.121, 1.131, 1.46 | Colombia | Flood and wet grassland savanna | Alluvial deposits of the alluvial overflow plain |
| Ap13-3a | Fp Fo | | | 1 178 | 1.46 | Colombia | Savanna | Old alluvium |
| Ap14-2/3a | Ah Gd | O | | 13 805 | 1.221, 1.471 | Bolivia | Swampy savannas de Mojos, and gallery forest | Alluvium |
| Bd1-3b | U Bf | Fo | | 1 725 | 1.77, 2.31 | Brazil 4 | Tropical seasonal forest and campo limpo | Precambrian gneisses, quartzites |
| Bd2-3bc | I | | | 293 | 7.31 | Chile | Temperate Valdivian evergreen rainforest | Paleozoic mica schists, gneisses, phyllites |
| Bd4-3c | Bh I U | Bf | | 1 025 | 1.77, 2.31 | Brazil 4 | Tropical seasonal forest | Precambrian gneisses, schists, quartzites |
| Bd5-c | Po U | | | 1 473 | 5.83 | Chile | Temperate deciduous Andean mountain forest | Tertiary clastic rocks, glacial and fluvial deposits |
| Bd5-3c | Po U | | | 587 | 6.21, 7.21, 7.31, 7.34, 7.82 | Chile | Temperate deciduous forest on the east and evergreen temperate forest on the west side of the Andes | Intrusive rocks of the Andean batholith, Paleozoic metamorphics, Cretaceous clastics, Tertiary ashes, glacial and fluvial deposits |
| Bd6-3b | Nd I | | | 1 370 | 6.21, 7.12, 7.14 | Chile | North of 40°S temperate deciduous, south of 40°S temperate evergreen forest | Paleozoic mica schists, gneisses, phyllites, acid intrusives |
| Bd7-3b | Rd Ao | | | 858 | 1.123 | Colombia | Tropical deciduous forest | Alluvial detrital fans of the Andes border |
| Bd9-2b | Ao I | | | 151 | 1.123 | Colombia | Tropical evergreen forest | Tertiary and Quaternary deposits such as detrital fans, Pleistocene mesa deposits, alluvial terraces and aeolian deposits (all with ash) |
| Bd9-3c | Ao I | | | 1 848 | 1.71 | Colombia | Montane evergreen forest | Precambrian gneisses, schists. phyllites, Cretaceous and Tertiary sandstones, shales |
| Bd9-3c | Ao I | | | 71 | 1.71 | Venezuela | Montane evergreen forest | Jurassic and Cretaceous clastic volcanic and Precambrian metamorphic and granodioritic rocks |
| Bd10-3c | Fh | | | 1 662 | 1.72 | Colombia | Lower montane evergreen rainforest | Jurassic-Cretaceous clastic and volcanic rocks, Paleozoic metamorphic and granodioritic rocks |
| Bd11-3a | Ap Ao | | | 3 980 | 1.22, 1.471, 1.482 | Bolivia | Tropical seasonal forest | Alluvium and Andes outwash deposits |
| Be1-2c | | | | 649 | 2.22 | Argentina | Mountain forests of the Tucuman area | Predominantly Precambrian meta-greywackes and phyllites and some intrusive igneous rocks, gneisses and migmatites |
| Be1-3c | | | | 1 140 | 5.83 | Argentina | Temperate deciduous Andean mountain forest with transition to peripampean thorn woodland | Cretaceous clastic rocks and glacio-fluvial deposits |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Be1-3c | | | | 65 | 5.83 | Chile | Temperate deciduous Andean mountain forest with transition to peripampean thorn woodland | Cretaceous clastic rocks and glacio-fluvial deposits |
| Be3-3b | I Vc | | | 374 | 2.32 | Peru | Montane humid forest | Mesozoic calcareous and clastic rocks |
| Be4-3b | I E | | | 1 009 | 1.12, 1.3, 1.53 | Venezuela | Tropical semideciduous and deciduous forest | Tertiary clastic and calcareous sediments, in the south also Mesozoic metamorphic rocks |
| Be5-3c | I | R Tv | | 2 073 | 6.66, 6.68, 7.82 | Argentina | Temperate Andean mountain forest with deciduous *Nothofagus* spp. | Quaternary unconsolidated, including glacial and fluvial deposits and pre-Mesozoic intrusives |
| Be5-3c | I | R Tv | | 56 | 6.66, 6,68, 7.82 | Chile | Temperate Andean mountain forest with deciduous *Nothofagus* spp. | Quaternary unconsolidated, including glacial and fluvial deposits |
| Be6-1b | Kh Re | | | 3 275 | 3.95, 5.76 | Argentina | Peripatagonian thorn woodland | Tertiary and Quaternary deposits with volcanic ash admixtures, including glacial and fluvial deposits |
| Bh1-3ab | Ah Bf Fh | U I | | 2 647 | 2.24 | Brazil 2 | *Araucaria* forest and campos limpos of the Planalto de Curitiba | Precambrian gneisses, schists, quartzites, some Carboniferous clastic rocks |
| Bh2-3ab | Fh Bf | Ah U | | 1 628 | 2.24 | Brazil 2 | *Araucaria* forest and campos limpos | Carboniferous and Permian clastic rocks |
| Bh3-3b | I | Th | | 1 381 | 2.41, 2.7 | Colombia | Paramo, alpine tundra | Quaternary volcanic ashes and outflows, Paleozoic metamorphic and intrusive igneous rocks, eastern Cordillera: Cretaceous clastic rocks |
| Bh3-3c | I | Th | | 1 723 | 2.41, 2.7 | Colombia | — | — |
| Bh3-3c | I | Th | | 1 444 | 2.3, 2.7 | Ecuador | Paramo, alpine tundra | Quaternary ashes and outflows Tertiary intermontane basin deposits, mostly volcanic Precambrian metamorphic rocks, glacial, periglacial deposits |
| Bh4-3b | I | | | 297 | 2.6 | Venezuela | Paramo, alpine tundra | Precambrian metamorphic rocks and acid intrusive rocks, glacial and periglacial deposits |
| Bk1-3a | Lf | | | 1 189 | 1.131, 1.3 | Ecuador | Thorn woodland, savanna and dry deciduous forest | Cretaceous and Tertiary clastic rocks, Quaternary alluvium |
| Bk2-b | I | | | 589 | 2.2, 2.38 | Bolivia | Upper montane grassland with *polylepis incana* forest | Ordovician-Silurian and Devonian clastic rocks |
| Bk2-c | I | | | 591 | 4.31, 4.32 | Bolivia | Lower montane cactus formation | Permo-Carboniferous and Tertiary clastic rocks of the Subandean ranges |
| Fa2-2a | Qf | | Cerrado | 15 441 | 1.483, 1.484, 1.8, 1.924 | Brazil 1 | Cerrado | Cretaceous sandstones with some Triassic and Carboniferous sandstone |
| Fa2-2a | Qf | | Cerrado | 4 040 | 1.77 | Brazil 4 | Cerrado and tropical seasonal forest | Jurassic Cretaceous sandstones |
| Fa2-3a | Qf | | Cerrado | 20 853 | 1.132, 1.482, 1.483, 1.77, 1.8, 1.916 | Brazil 1 | Campo cerrado | Cretaceous sandstones, Devonian and Carboniferous sandstones, Silurian and Precambrian metamorphics |
| Fa2-3a | Qf | | Cerrado | 4 880 | 1.8, 1.77 | Brazil 4 | Cerrado | Cretaceous and Jurassic sedimentary rocks |
| Fa4-3a | Fx | | Cerrado | 511 | 1.132, 1.482 | Brazil 1 | Cerrado | Precambrian metamorphic rocks |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Fa6-2a | Fo | Qf Ap | Cerrado Petric [1] | 2 002 | 1.482, 1.483 | Brazil 1 | Cerrado | Precambrian metamorphic rocks and Tertiary and Quaternary unconsolidated deposits |
| Fa6-3a | Fo | Qf Ap | Cerrado Petric [1] | 10 904 | 1.77, 1.482, 1.483 | Brazil 1 | Cerrado | Precambrian quartzites, schists gneisses and Devonian sandstones |
| Fa9-2a | Fr | Qf | Cerrado | 2 391 | 1.77, 4.45 | Brazil 1 | Cerrado | Jurassic sandstone, basalt of the Trapp formation, some Carboniferous clastic rocks |
| Fa9-2a | Fr | Qf | Cerrado | 535 | 4.45 | Paraguay | Cerrado | Cretaceous sandstones |
| Fa12-3a | Lf | | Cerrado | 4 199 | 1.48, 1.8 | Brazil 4 | Cerrado | Cretaceous sandstones, Silurian limestone and clastic rocks |
| Fa20-3c | I | | Cerrado | 943 | 1.48 | Brazil 1 | Cerrado | Acid extrusive rocks including rhyolites, quartz and feldspar porphyries and Precambrian metamorphics |
| Fa22-3a | Af | Qf | Cerrado Petric [1] | 1 734 | 1.482 | Brazil 1 | Cerrado | Precambrian metamorphic rocks, Devonian sandstones, Tertiary clastic deposits |
| Fh1-3a | | | | 1 016 | 2.24, 4.45 | Argentina | Tropical seasonal forest | Basalt of the Trapp formation |
| Fh1-3a | | | | 8 574 | 1.77, 2.24, 4.13 | Brazil 2 | Tropical seasonal forest in the lowlands, *Araucaria* forest interspersed with grasslands higher | Basalt of the Trapp formation |
| Fh2-3a | Bh Bf | U I Pg | | 5 823 | 2.24, 4.13 | Brazil 2 | *Araucaria* forest interspersed with campos limpos, tropical seasonal forest on the coast | Mostly basalts of the Trapp formation, but also Triassic sandstone, Permo-Carboniferous clastics and Precambrian metamorphics |
| Fh3-3b | I Tv | | | 390 | 1.73 | Colombia | Tropical evergreen forest to lower montane evergreen forest | Cretaceous-Tertiary sandstones, shales and pyroclastic admixtures |
| Fh3-3b | I Tv | | | 860 | 1.77 | Ecuador | Tropical evergreen forest | Jurassic clastics and pyroclastics, Cretaceous sandstones, limestones shales and marls, Tertiary sandstones and shales and outwash deposits with pyroclastics |
| Fo1-2a | | | | 1 196 | 1.53, 1.77, 1.924 | Brazil 1 | Caatinga, tropical semi-deciduous forest | Precambrian metamorphic rocks, Silurian carbonate and clastic rocks, Carboniferous sandstones |
| Fo1-2a | | | | 3 298 | 1.77, 1.8, 1.924 | Brazil 2 | Tropical seasonal forest, with some cerrado toward the north | Jurassic, Cretaceous and Triassic sandstones |
| Fo1-2a | | | | 3 925 | 1.77, 1.924 | Brazil 4 | Tropical seasonal forest | Triassic, Jurassic and Cretaceous sandstones |
| Fo1-2a | | | | 73 | 1.543, 1.73, 1.81 | Brazil 5 | Cerrado-caatinga | Mostly red and yellow Cretaceous sandstones |
| Fo1-2a | | | | 647 | 1.131, 1.46 | Colombia | Savannas (grassland) | Old alluvium of loamy texture |
| Fo1-2a | | | Petric | 467 | 1.121, 1.471, 1.48 | Guyana | Tropical evergreen forest | Precambrian metamorphic and acid igneous rocks |
| Fo1-2a | | | | 106 | 4.45 | Paraguay | Tropical seasonal forest | Tertiary sandstones |
| Fo1-3a | | | Petric [1] | 5 449 | 1.482, 1.483, 1.72, 1.77, 1.8 | Brazil 1 | Semideciduous tropical forest, mixed tropical palm forest | Precambrian metamorphic rocks, Cretaceous clastic rocks |

[1] The phase applies to only part of the association.

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Fo1-3a | | | | 913 | 1.77 | Brazil 2 | Tropical seasonal forest. campo cerrado and campo limpo | Precambrian metamorphic rocks. Devonian. Carboniferous. and Permian clastic rocks |
| Fo1-3a | | | | 1 859 | 1.11. 1.123 | Colombia | Tropical evergreen forest | Young Tertiary (Miocene) clastic rocks |
| Fo1-3a | | | Petric | 1 085 | 1.121 | French Guiana | Tropical evergreen forest | Precambrian slates. schists. quartzites. conglomerates. intruded by granodiorites |
| Fo1-3a | | | | 572 | 1.48 | Guyana | Tropical evergreen forest | Precambrian metamorphic rocks and granites |
| Fo1-3b | | | | 21 | 1.8 | Brazil 5 | Agreste forest | Precambrian metamorphic rocks |
| Fo1-3b | | | | 5 252 | 1.121. 1.132 | French Guiana | Tropical evergreen forest | Precambrian gneisses and granites |
| Fo1-3c | | | | 1 412 | 1.121. 1.34. 1.74. 1.8 | Brazil 3 | Tropical evergreen. seasonal and semideciduous forest | Precambrian metamorphic rocks |
| Fo1-3c | | | | 2 951 | 1.77 | Brazil 4 | Tropical seasonal forest | Mostly Precambrian metamorphic rocks |
| Fo2-2a | Qf | | | 1 109 | 1.11. 1.123 | Colombia | Savanna | Cretaceous clastic rocks. including sandstones |
| Fo2-2a | Qf | | | 8 501 | 1.484 | Brazil 1 | — | — |
| Fo3-3a | Bd Bf | U I | | 621 | 1.77. 2.24 | Brazil 2 | Predominantly campos limpos of the Ponta Grossa Planalto | Lower Devonian sandstones and shales |
| Fo3-3b | Bd Bf | U I | | 511 | 2.31 | Brazil 4 | Tropical seasonal forest | Precambrian metamorphic rocks and Tertiary alkalic rocks |
| Fo4-3b | Ao N | Lf I | | 18 444 | 1.23. 1.77. 1.8, 1.82, 2.31 | Brazil 4 | Tropical seasonal forest and campo limpo locally. caatinga and Agreste in the north | Precambrian gneiss. schists. phyllite. quartzite and granites |
| Fo5-2a | Lc | | Stony [1] | 1 722 | 1.53. 1.544. 1.8 | Brazil 1 | Caatinga | Precambrian metamorphic rocks |
| Fo6-3b | Bf Bd Fp | | Petric | 15 071 | 1.11. 1.121. 1.123. 1.131. 1.46 | Colombia | From tropical evergreen to semideciduous forest. and from woodland savanna to grassland savanna | Tertiary and Quaternary deposits such as detrital fans Pleistocene mesa deposits. alluvial terraces and aeolian deposits (all with ash) |
| Fo9-2a | Fr | | | 1 044 | 1.924 | Brazil 1 | Tropical seasonal forest and campo cerrado | Permo-Carboniferous clastic rocks |
| Fo9-2a | Fr | | | 310 | 1.77. 1.924 1.925 | Brazil 4 | Tropical semideciduous forest | Cretaceous sandstone (calcareous) |
| Fo9-3a | Fr | | | 180 | 1.77 | Brazil 4 | Tropical seasonal forest | Basic igneous intrusives and Permo-Carboniferous clastic rocks |
| Fo11-3a | Ne | | | 2 188 | 1.132. 1.72 | Brazil 1 | Tropical seasonal forest | Carboniferous clastic rocks |
| Fo11-3b | Ne | | | 1 363 | 1.132 | Brazil 1 | Tropical seasonal forest | Cambro-Ordovician clastic rocks |
| Fo12-3a | Lf | | | 228 | 1.483 | Brazil 1 | Tropical semideciduous mixed with palm forest | Precambrian metamorphic rocks |
| Fo12-3b | Lf | | | 1 129 | 1.23. 1.74. 1.77 | Brazil 3 | Tropical evergreen forest | Precambrian intermediate rocks. granites and gneisses |
| Fo13-2a | Ao | Nd I Rd | Petric | 208 | 1.48 | Guyana | Tropical evergreen forest and savannas | Precambrian metamorphic rocks and granites |

[1] The phase applies to only part of the association.

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Fo14-3a | Ao | | | 40 | 1.11 | Brazil 3 | Tropical evergreen forest | Gneisses |
| Fo14-3a | Ao | | Petric | 3 520 | 1.471, 1.48 | Surinam | Tropical evergreen forest | Precambrian metamorphics and granites |
| Fo14-3b | Ao | | | 894 | 1.48 | Bolivia | Tropical evergreen forest | Precambrian rocks |
| Fo14-3b | Ao | | | 102 275 | 1.121, 1.132, 1.23, 1.471, 1.482, 1.423, 1.484, 1.72 | Brazil 1 | Tropical seasonal forest (semievergreen) | Precambrian metamorphic rocks and granites |
| Fo14-3b | Ao | | | 300 | 1.121, 1.132, 1.471 | French Guiana | Tropical seasonal forest (semievergreen) | Precambrian metamorphic rocks and granites |
| Fo14-3b | Ao | | | 169 | 1.482 | Guyana | Tropical evergreen and seasonal forest | Precambrian metamorphic rocks and granites |
| Fo14-3b | Ao | | | 370 | 1.471 | Surinam | Tropical evergreen and seasonal forest | Precambrian metamorphic rocks and granites |
| Fo14-3c | Ao | | | 10 264 | 1.121, 1.123, 1.471, 1.7 | Venezuela | Tropical evergreen forest | Precambrian metamorphic rocks, acid intrusive rocks and Mesozoic sandstones |
| Fo15-2a | Ap Gd | | | 206 | 1.48 | Guyana | Tropical evergreen forest with savannas | Precambrian rocks |
| Fo16-2a | Ph Rd | | | 2 084 | 1.121, 1.471, 1.48 | Guyana | Tropical evergreen forest | Precambrian metamorphic and acid igneous rocks, overlain in the north by Mio-Pleistocene sands |
| Fo17-2b | Ao I Rd | Nd | | 9 295 | 1.121, 1.46, 1.471, 1.7 | Venezuela | Tropical seasonal forest and savanna | Precambrian metamorphics and basic and acidic intrusives, Mesozoic sandstones and Quaternary alluvium |
| Fo17-3c | Ao I Rd | Nd | | 1 248 | 1.121, 1.48 | Guyana | Tropical evergreen forest with savanna enclosures | Precambrian metamorphic rocks capped by Mio-Pleistocene sands with sandy clays, clays and lignites |
| Fo18-2a | Ap I | | Stony | 310 | 1.48 | Guyana | Tropical evergreen forest | Precambrian metamorphics and granites |
| Fo19-2a | Ap Qf | | Petric | 513 | 1.48 | Guyana | Tropical evergreen forest | Precambrian metamorphics and granites |
| Fo20-3b | I | | | 1 775 | 1.48 | Guyana | Tropical evergreen forest | Precambrian metamorphics and granites |
| Fo20-3b | I | | Petric | 203 | 1.121 | Guyana | Tropical evergreen forest | Basic igneous rocks such as gabbro, dolerite, diabase |
| Fo22-3b | Ao Af | | Petric [1] | 1 107 | 1.135, 1.42 | Brazil 1 | Tropical seasonal forest mixed with palms | Triassic-Cretaceous clastic rocks, terraces, alluvium |
| Fo23-3b | Nd I | | Petric | 885 | 1.48 | Guyana | Tropical evergreen forest and savanna | Precambrian metamorphics and granites |
| Fo24-2b | Rd Ao | Gd | | 1 928 | 1.121, 1.471, 1.483, 1.7 | Venezuela | Tropical evergreen and seasonal forests with savanna | Precambrian metamorphic and acid intrusive rocks and Mesozoic sandstones |
| Fo25-3a | Ap Ao | | | 1 625 | 1.11 | Ecuador | Tropical evergreen forest | Tertiary sandstones, shales, tuffites |
| Fo25-3b | Ap Ao | | | 256 | 1.123 | Brazil 1 | Tropical evergreen forest | Precambrian metamorphic rocks |
| Fo25-3b | Ap Ao | | | 1 493 | 1.121 | Colombia | Tropical seasonal forest and lower montane forest | Old Paleozoic metamorphic rocks, granodiorites, Triassic-Jurassic shales, sandstones, conglomerates, thin limestone intercalations and thick beds of volcanic flows and tuffs, Tertiary clastics |

[1] The phase applies to only part of the association.

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Fo25-3b | Ap Ao | | | 4 060 | 1.123 | Venezuela | Tropical evergreen forest | Precambrian metamorphic rocks, some Mesozoic sandstone outcrops |
| Fo26-3a | Nd | I | | 48 | 1.123 | Colombia | Tropical evergreen forest | Tertiary clastic rocks |
| Fo26-3c | Nd | I | | 210 | 1.123 | Venezuela | Tropical evergreen forest | Precambrian metamorphic rocks |
| Fo27-3a | Ao Gd | | | 2 756 | 1.123 | Colombia | Tropical evergreen forest | Cretaceous, Tertiary clastics, tuffs and basic outflows, and alluvium |
| Fo29-3a | Fx Qf Ap | G Ph | | 106 | 1.131, 1.35 | Brazil 5 | Tropical seasonal forest and restinga woodland | Tertiary clastics |
| Fo30-2a | Lf Ne | | | 1 287 | 1.541, 1.8 | Brazil 4 | Caatinga | Silurian (oolitic limestone, slate, phyllite, sandstone) |
| Fo31-3a | Lf Af | Fa Qf | Petric | 2 425 | 1.482, 1.483, 1.916 | Brazil 1 | Tropical semideciduous forest mixed with palm forest | Precambrian metamorphic rocks, Devonian and Carboniferous sandstones, and other clastic rocks, alluvium |
| Fr1-3a | | | | 1 612 | 1.924, 4.45 | Brazil 1 | Tropical semideciduous forest | Basalt of the Trapp formation |
| Fr1-3a | | | Cerrado | 4 549 | 1.71, 1.77, 1.924 | Brazil 1 | Cerrado | Basalt of the Trapp formation |
| Fr1-3a | | | | 3 864 | 1.77, 1.924 | Brazil 4 | Tropical seasonal forest | Basalt of the Trapp formation, with Jurassic and Triassic sandstones |
| Fr1-3b | | | | 522 | 1.121, 1.132, 1.471 | French Guiana | Tropical evergreen forest | Probably basic igneous rocks |
| Fr3-3a | Fo | | Cerrado | 3 119 | 1.77, 1.924, 4.35, 4.45 | Brazil 1 | Cerrado | Basalt of the Trapp formation with Carboniferous and Cretaceous sandstones |
| Fr3-3a | Fo | | Cerrado | 72 | 4.36 | Paraguay | Cerrado | Basalt of the Trapp formation |
| Fr4-3b | Ne | | | 7 651 | 1.77, 1.924, 4.13 | Brazil 2 | Predominantly tropical seasonal forest including campos limpos and some *Araucaria* forest | Basalt of the Trapp formation with some inclusions of Jurassic-Cretaceous sandstones |
| Fr4-3b | Ne | | | 1 108 | 4.36 | Paraguay | Tropical seasonal forest | Basalt of the Trapp formation with Jurassic sandstones |
| Fr5-3a | Qf | | | 760 | 1.77 | Brazil 4 | Tropical seasonal forest and campo cerrado | Basalt and intrusives with sandstone |
| Fx1-2a | | | | 52 | 1.77 | Brazil 4 | Tropical seasonal forest, restinga woodland along the coast | Tertiary sandstones and shales along the coast and in some places inland |
| Fx1-2ab | | | | 4 913 | 1.11, 1.121, 1.221, 1.77 | Brazil 3 | Tropical semideciduous and seasonal forest with some restinga woodland | Precambrian metamorphics, Cretaceous clastics, Tertiary sandstones, clays, claystones |
| Fx2-2a | Qf | | | 9 502 | 1.484, 1.53, 1.81 | Brazil 1 | Caatinga, tropical seasonal forest with mixed palm forest, cerrado, and tropical evergreen forest | Mostly Devonian sandstones with Precambrian metamorphic rocks and Triassic-Cretaceous sandstones |
| Fx2-2b | Qf | | | 779 | 1.484, 1.53 | Brazil 1 | Caatinga | Devonian sandstones |
| Fx3-2a | Ap Ao Fp | Gd Gp Qa | | 119 321 | 1.11, 1.121, 1.123, 1.13, 1.132, 1.471 | Brazil 1 | Tropical evergreen forest | Tertiary-Pleistocene deposits |
| Fx3-2a | Ap Ao Fp | Gd Gp Qa | | 16 238 | 1.11, 1.123 | Colombia | Tropical evergreen forest | Pleistocene terraces |
| Fx3-2a | Ap Ao Fp | Gd Gp Qa | | 227 | 1.11 | Ecuador | Tropical evergreen forest | Pleistocene terraces |
| Fx3-2a | Ap Ao Fp | Gd Gp Qa | | 17 532 | 1.11 | Peru | Tropical evergreen forest | Pleistocene terraces |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Fx3-3a | Ap Ao Fp | Gd Gp Qa | | 1 456 | 1.11 | Peru | Tropical evergreen forest | Tertiary outwash sediments of the Andes |
| Fx4-3a | Ap | Gd Gp | | 221 | 1.221, 1.471 | Bolivia | Tropical evergreen forest | Plio-Pleistocene sediments |
| Fx4-3a | Ap | Gd Gp | | 57 914 | 1.11, 1.121, 1.132, 1.471, 1.482 | Brazil 1 | Tropical evergreen forest | Plio-Pleistocene clays and Tertiary outwash sediments of the Andes |
| Fx4-3a | Ap | Gd Gp | | 4 001 | 1.11 | Colombia | Tropical evergreen forest | Plio-Pleistocene terraces |
| Fx4-3a | Ap | Gd Gp | | 4 099 | 1.11 | Ecuador | Tropical evergreen forest | Plio-Pleistocene clays and Tertiary outwash sediments of the Andes |
| Fx4-3a | Ap | Gd Gp | | 17 443 | 1.11, 1.121 | Peru | Tropical evergreen forest | Plio-Pleistocene clays and Tertiary outwash sediments of the Andes |
| Fx5-2a | Ao | Lf | | 657 | 1.121, 1.543 | Brazil 4 | Caatinga | Precambrian metamorphic rocks and Cretaceous sandstones |
| Fx6-3a | Vp Qf | I | | 4 512 | 1.121, 1.132, 1.471 | Brazil 1 | Tropical evergreen forest | Paleozoic arkosic sandstones. sandstones, shales, conglomerates, and some limestones |
| Fx7-2a | Ao Fo | Ap | | 98 | 1.123 | Colombia | Tropical evergreen forest | Precambrian rocks of the Guiana shield with colluvium and alluvium and some Mesozoic sandstones |
| Fx7-2a | Ao Fo | Ap | | 5 300 | 1.121, 1.123 | Venezuela | Tropical evergreen forest | Precambrian rocks of the Guiana shield. colluvium and alluvium and some Mesozoic sandstones |
| Fx7-3a | Ao Fo | Ap | | 12 021 | 1.121, 1.123, 1.131 | Colombia | Tropical evergreen to semi-deciduous forest | Pleistocene alluvial and fluvial deposits overlying at shallow depth Precambrian metamorphic rocks |
| Fx7-3a | Ao Fo | Ap | | 500 | 1.123 | Venezuela | Tropical evergreen and semideciduous forest | Pleistocene alluvial. fluvia deposits overlying at shallow depth Precambrian metamorphic rocks |
| Fx8-3b | Ao Nd | G Ph | | 779 | 1.121, 1.31, 1.35, 1.46 | Brazil 5 | Tropical seasonal forest and restinga woodland | Precambrian metamorphic and acid intrusive rocks. Tertiary Barreiras beds |
| Gc1-3a | Zg Wm | | | 535 | 5.13, 5.83, 7.12 | Argentina | Pampean and Patagonian grasslands | Marine clayey sediments and glacial and glacio-fluvial deposits |
| Gd1-3a | J Ge Gp | Ag Ap Fx | | 4 186 | 1.471 | Bolivia | Campo Varzea swamp forest | Young alluvium |
| Gd1-3a | J Ge Gp | Ag Ap Fx | | 22 022 | 1.132, 1.471 | Brazil 1 | Varzea and Igapo forests. Campo Varzea | Young Quaternary alluvium |
| Gd1-3a | J Ge Gp | Ag Ap Fx | | 693 | 1.21, 1.221, 1.77 | Brazil 4 | Mangrove vegetation along the coast and riverine swamps along the rivers | Quaternary coastal fluvial, deltaic deposits, overlying Precambrian metamorphic rocks |
| Gd1-3a | J Ge Gp | Ag Ap Fx | | 792 | 1.11 | Colombia | Tropical swamp forest | Quaternary sediments |
| Gd1-3a | J Ge Gp | Ag Ap Fx | | 710 | 1.11 | Ecuador | Tropical swamp forest | Young Quaternary sediments |
| Gd1-3a | J Ge Gp | Ag Ap Fx | | 6 610 | 1.11, 1.121, 1.13 | Peru | Varzea forest | Quaternary alluvium |
| Gd2-3a | | J | | 371 | 1.482 | Brazil 1 | Swamp forest | Alluvium |
| Gd2-3a | | J | | 977 | 4.36 | Paraguay | Swamps, grasslands, palm savanna | Quaternary alluvium of the Rio Paraguay and tributaries |
| Gd3-3a | Qa Fx | J Ph O | | 295 | 1.221 | Brazil 4 | Mangrove swamp, restinga woodland and xerophytic cacti woodland | Quaternary coastal deposits |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Gd10-3a | Ap O | | | 110 | 1.123 | Colombia | Swamp forest | Recent alluvium |
| Gd10-3a | Ap O | | | 2 865 | 1.123 | Venezuela | Swamp forest | Recent alluvium |
| Gd11-3a | Ap W | Ao J | | 7 631 | 1.46, 1.483, 1.484 | Venezuela | Gallery forest, palm savanna, grassland savanna, chaparrales | Pleistocene mesa deposits of fluvial and alluvial origin and recent alluvium |
| Gd13-3a | Ap | | | 175 | 1.11, 1.123 | Colombia | Tropical evergreen and swamp forest | Tertiary clastic rocks and alluvium |
| Gd13-3a | Ap | | | 98 | 1.123 | Ecuador | Tropical evergreen and swamp forest | Tertiary clastic rocks and alluvium |
| Gd15-a | Qa Gh Ph | Jt | | 228 | 1.121 | Brazil 3 | Restinga woodland, mangrove swamp forest | Quaternary coastal loose deposits |
| Ge1-3a | | | | 132 | 6.21 | Chile | Agricultural land, probably marsh forest | Alluvium including much volcanic material |
| Ge6-3a | Gm O | | | 484 | 1.121 | Surinam | Tropical swamp forest and swamp savanna | Young Holocene coastal deposits |
| Ge7-3a | Ap J | | | 1 062 | 1.471, 1.48 | Guyana | Campo limpo and cerrado | Cretaceous and Tertiary clastic rocks and Quaternary alluvium |
| Ge8-3a | Ph Rd | J | | 338 | 1.121, 1.471, 1.48 | Guyana | Wet savanna, marsh and swamp forest, herbaceous swamps | Acid extrusive rocks, Mesozoic sandstones |
| Ge9-3a | Je Gd | Jt | | 2 462 | 1.121, 1.483 | Venezuela | Swamp forest | Deltaic deposits |
| Ge12-2a | Be | | | 553 | 1.121, 1.123 | Colombia | Tropical evergreen and swamp forest | Tertiary and Quaternary clastic rocks and loose deposits |
| Ge12-2a | Be | | | 61 | 1.123 | Ecuador | Tropical evergreen and swamp forest | Tertiary and Quaternary clastic rocks and loose deposits |
| Gh1-a | | | | 628 | 7.12, 7.13, 7.21 | Chile | Agricultural land and coniferous alerce forest | Quaternary volcanic mudflows, glacio-fluvial deposits, alluvium |
| Gh2-a | J | | | 114 | 1.131 | Ecuador | Wet savanna and swamp forest | Alluvium containing volcanic material |
| Gh3-3a | Ag Ao Ph | | | 75 | 1.11 | Peru | Subtropical evergreen forest, swamp forest | Tertiary and Quaternary terrace and alluvial deposits |
| Gm1-3a | Zg O | Jt | | 380 | 4.14 | Brazil 2 | Grasslands, swamps and coastal vegetation | Quaternary unconsolidated marine, lacustrine or fluvial deposits |
| Gm1-3a | Zg O | Jt | | 436 | 4.14 | Uruguay | Swamp and coastal vegetation, grasslands | Quaternary unconsolidated marine, lacustrine or fluvial deposits |
| Gm2-3a | Lp | | | 964 | 1.121 | Colombia | Cultivated land, but originally tropical seasonal forest and savanna | Alluvium, Tertiary clastic rocks (of continental origin) |
| Gm4-3a | J Vc | | | 3 117 | 1.121, 1.131, 1.46, 1.483 | Venezuela | Semideciduous forest, savanna, and swamp forest | Alluvial terraces, outwash and detrital fans, recent alluvium |
| Gm5-3a | Lp O | | | 535 | 1.221, 1.471 | Bolivia | Swamps | Alluvium |
| Hh1-2a | | | Petrocalcic | 2 497 | 5.12, 5.13 | Argentina | Pampa | Pampean formation (loess deposits) |
| Hh1-2a | | | | 9 609 | 5.11, 5.128, 5.112 | Argentina | Pampa | Pampean formation (loess deposits) |
| Hh2-1b | Re | | | 2 434 | 5.12, 5.13 | Argentina | Pampa | Pampean formation (loess deposits) |
| Hl 1-2a | | | Petrocalcic | 1 169 | 5.122, 5.128 | Argentina | Pampa | Pampean formation (loess deposits) |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Hl 1-2a | | | | 688 | 4.14 | Brazil 2 | Grasslands | Precambrian gneisses, schists, and granites; Carboniferous sandstones, shales |
| Hl 1-2a | | | | 91 | 4.14 | Uruguay | Grasslands | Precambrian metamorphic rocks and granites, Carboniferous sandstones, shales |
| Hl 1-3a | | | | 6 262 | 5.112, 5.113, 5.33 | Argentina | Pampa and gallery forests along the Paraná with tropical species | Paraná alluvium and Upper Miocene sediments along the Rio Paraná and pampean formation away from the river |
| Hl 2-3c | I | | | 1 379 | 4.13 | Argentina | Tropical seasonal forest | Basalt of the Trapp formation |
| Hl 2-3c | I | | | 3 742 | 4.13, 4.45 | Brazil 2 | Tropical seasonal forests and some subordinate *Araucaria* forests | Basalt of the Trapp formation |
| Hl 3-3a | Ne | I E Gc | | 517 | 4.35 | Brazil 1 | Grassland | Cambro-Ordovician metamorphic limestones and dolomites |
| Hl 4-2a | We Wm | | | 1 332 | 4.14 | Uruguay | Pampa and coastal vegetation | A great variety of parent materials, including Precambrian schists, quartzites, slates, andesitic outflows, Quaternary marine deposits |
| Hl 5-3a | J So | | | 1 872 | 5.36 | Argentina | Gallery forest with tropical species | Pampean formation and alluvium (loess deposits) |
| Hl 6-3b | I Kl | | | 869 | 2.33 | Peru | Humid montane forest on the slopes, xerophytic woodland and savanna in the valleys, paramo on the high plateaus | Cretaceous clastic and calcareous rocks. Quaternary ashes |
| Hl 7-2bc | Wm | | | 198 | 5.83, 7.82 | Argentina | Patagonian prairie | Glacial and glacio-fluvial deposits overlying Tertiary clastic rocks |
| Hl 7-2bc | Wm | | | 1 130 | 5.83, 7.82 | Chile | Patagonian prairie | Glacial tills, moraines and glacio-fluvial deposits overlying Tertiary clastic rocks |
| Hl 7-3a | Wm | | | 3 597 | 5.112, 5.29, 5.34, 5.37 | Argentina | Pampean grassland northward grading into xerophytic deciduous forest | Pampean formation (loess deposits) |
| Hl 18-3a | Gm Vp | I | | 2 576 | 4.14 | Uruguay | Pampa | Precambrian gneisses, mica schists, amphibolites, quartzites, slates and some igneous rocks |
| Hl 10-2a | Lo Wm | | | 1 710 | 4.14 | Uruguay | Pampa | Permian and Cretaceous clastic rocks, sometimes calcareous, and limestone beds |
| Hl 11-3b | Kl Tm I | | | 1 202 | 2.38 | Peru | Dry forest and xerophytic woodland of the intermontane valleys | Alluvium. Quaternary ashes, Cretaceous clastic and calcareous rocks, acid igneous rocks |
| Hl 12-3b | I Tm | | | 181 | 2.37 | Ecuador | Humid montane forest on the slopes, xerophytic woodland in the valleys | Precambrian metamorphic rocks, igneous intrusive rocks, Jurassic clastic and calcareous rocks, Cretaceous basic igneous rocks and tuffs |
| Hl 12-3b | I Tm | | | 175 | 2.37 | Peru | Humid montane forest on the slopes, xerophytic woodland in the valleys | Precambrian metamorphic rocks, igneous intrusive rocks, Jurassic clastic and calcareous rocks. Cretaceous basic igneous rocks and tuffs |
| Hl 13-3b | J I | | | 115 | 2.61 | Peru | Subtropical and montane thorn woodland and montane forest | Cretaceous calcareous and clastic rocks, acid igneous rocks and alluvium |
| Hl 14-3a | I | Sm | | 1 292 | 5.128 | Argentina | Pampa | Pampean formation (loess and outwash deposits) |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Hl 16-3a | Vp | | | 146 | 4.14 | Brazil 2 | Pampa | Permian sandstones, shales, siltites and some limestones |
| Hl 16-3a | Vp | | | 642 | 4.14 | Uruguay | Pampa | Permian sandstones, shales, siltites and some limestones |
| Hl 17-3b | Bh I | | | 246 | 2.3 | Ecuador | Montane forest formation | Precambrian metamorphic rocks overlain by young volcanic ashes and outflows |
| Hl 18-a | Vp Wm | | | 307 | 4.14 | Brazil 2 | Grassland | Permo-Carboniferous glacial, interglacial and postglacial tillites, sandstones, shales |
| Hl 18-a | Vp Wm | | | 563 | 4.14 | Uruguay | Grassland | Permo-Carboniferous glacial, interglacial and postglacial tillites, sandstones, shales |
| Hl 19-3a | I E | Vp | | 1 120 | 1.8, 1.843 | Brazil 5 | Caatinga | Silurian limestone, slate, phyllite, sandstone |
| Hl 21-2a | Hh | | Lithic[1] | 1 704 | 1.121, 1.77 | Brazil 3 | Semideciduous tropical forest | Precambrian gneisses |
| Hl 21-3a | Hh | | | 814 | 4.14 | Uruguay | Gallery forest with tropical species and Pampa | Pampean formation and Uruguay alluvium covering Upper Tertiary sediments |
| I-bc[2] | | | | 479 | 1.471, 1.48 | Guyana | Tropical and montane evergreen forest | Precambrian biotite and biotite-garnet gneisses and biotite granites |
| I-c | | | | 17 908 | 3.271, 3.82, 3.83, 3.93, 3.94, 3.95, 5.612 | Argentina | — | — |
| I-c | | | | 4 050 | 2.4, 3.51 | Bolivia | Upper montane grassland and Polylepis forests in the west. Montane forests in the Subandean ranges | Ordovician-Silurian clastic rocks in the west. Carboniferous-Permian and Tertiary clasitc rocks in the Subandean ranges |
| I-c | | | | 293 | 5.96 | Chile | — | — |
| I-c | | | | 60 | 1.123 | Colombia | Tropical evergreen forest | Precambrian granites and metamorphics |
| I-c | | | | 2 899 | 3.34, 3.51, 3.52 | Peru | Montane steppe and desert | Palezoic acid intrusive rocks and Cretaceous clastic and calcareous rocks |
| I-Ao-Fo-c | | | | 8 002 | 1.11, 1.123, 1.132, 1.471, 1.474 | Brazil 1 | Tropical evergreen forest | Precambrian metamorphic rocks, granites and coarse Mesozoic sandstones |
| I-Ao-Fo-c | | | | 750 | 1.123 | Colombia | Tropical evergreen forest | Precambrian metamorphic and granitic rocks, Mesozoic sandstones |
| I-Ao-Fo-c | | | | 380 | 1.471 | Guyana | Tropical evergreen forest | Precambrian metamorphic rocks and Mesozoic sandstones |
| I-Ao-Fo-c | | | | 1 434 | 1.123, 1.132, 1.471, 1.74 | Venezuela | Tropical evergreen forest | Precambrian metamorphic rocks, granites and coarse Mesozoic sandstones |
| I-Bd-c | | | | 867 | 1.72, 2.31 | Bolivia | Montane rainforest, dry forest and xerophytic woodland of the intermontane valleys | Paleozoic, somewhat metamorphosed clastic and acid igneous rocks |
| I-Bd-c | | | | 876 | 1.72, 2.37 | Ecuador | Montane rainforest, dry forest and xerophytic woodland of the intermontane valleys | Precambrian metamorphic rocks |

[1] The phase applies to only part of the association.
[2] When lithosols are dominant the association is directly represented by the map symbols of the other soils.

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| I-Bd-c | | | | 6 639 | 1.72, 1.73, 2.32, 2.37, 2.38 | Peru | Montane rainforest, dry forest and xerophytic woodland of the intermontane valleys | Paleozoic, somewhat metamorphosed clastic rocks and acid igneous rocks, with Jurassic and Cretaceous clastic and calcareous rocks in northern Peru and Precambrian metamorphics in Ecuador |
| I-Bd-Be-c | | | | 820 | 2.2, 2.31, 3.51 | Bolivia | Lower montane rainforest | Old Paleozoic clastic rocks |
| I-Bd-Bh-c | | | | 860 | 2.38 | Bolivia | Montane forest and some paramo | Paleozoic clastic rocks |
| I-Bd-Bh-c | | | | 4 494 | 2.34, 2.41, 2.7 | Colombia | Upper montane forest, paramo, alpine tundra | Jurassic and Cretaceous clastic and volcanic rocks, Precambrian and Paleozoic metamorphics |
| I-Bd-Bh-c | | | | 2 278 | 1.74, 2.3 | Venezuela | Montane forests, paramo, alpine tundra | Precambrian and Paleozoic gneisses, schists, quartzites, phyllites and granites. Clastic Triassic-Jurassic rocks |
| I-Bd-Po-c | | | | 1 555 | 1.76, 2.31, 2.6 | Bolivia | Montane rainforest | Paleozoic clastic rocks |
| I-Bd-Rd-bc | | | | 11 105 | 1.77, 1.8 | Brazil 4 | Caatinga, cerrado, campos limpos | Precambrian resistant metamorphic rocks such as quartzites forming residual relief |
| I-Bd-Rd-bc | | | | 2 294 | 1.81 | Brazil 5 | Caatinga | Precambrian resistant rocks such as granites forming residual relief |
| I-Bd-Rd-c | | | | 4 478 | 1.72, 1.73, 1.76, 2.2, 4.35 | Bolivia | Subtropical rainforest | Paleozoic, locally somewhat metamorphosed, clastic rocks and Tertiary clastic rocks |
| I-Bd-Rd-c | | | | 1 640 | 1.72, 1.73, 2.31, 2.38 | Peru | Subtropical rainforest | Paleozoic, locally somewhat metamorphic clastic rocks and Tertiary clastic rocks |
| I-Bd-To-c | | | | 132 | 2.35 | Ecuador | Montane forest | Cretaceous volcanic rocks and intrusive igneous rocks |
| I-Bd-U-c | | | | 1 803 | 6.66 | Argentina | Montane steppe to temperate montane forest | Intrusive, volcanic and clastic rocks of varying age |
| I-Bd-U-c | | | | 822 | 6.66 | Chile | Montane steppe to temperate mountain forest in the south | Intrusive rocks, Mesozoic and Tertiary volcanic and clastic rocks |
| I-Be-c | | | | 1 789 | 2.38, 2.6, 2.62 | Bolivia | Montane and upper montane rainforest and cloudforest, paramo and alpine tundra | Old Paleozoic clastic rocks, Devonian and Silurian slates and sandstones and Quaternary glacial, preglacial and glacio-fluvial deposits |
| I-Be-c | | | | 3 709 | 6.66, 6.67, 10.5 | Chile | Temperate deciduous *Nothofagus* forests in the south and xerophytic woodland to montane steppe in the north | Paleozoic metamorphics, intrusive rocks and Tertiary and Quaternary tuffs and outflows |
| I-Be-c | | | | 559 | 1.42, 1.72, 1.77 | Peru | Lower montane humid forest | Jurassic-Cretaceous clastic and calcareous rocks |
| I-Be-Bh-c | | | | 1 092 | 1.72, 2.32 | Peru | Montane forest and humid paramo | Old Paleozoic slightly metamorphosed clastic rocks, glacial and periglacial deposits |
| I-Be-Lc-c | | | | 1 964 | 2.2, 2.38, 2.52 | Bolivia | Montane grassland, xerophytic woodland and montane dry forest | Paleozoic clastic rocks |
| I-Bh-c | | | | 305 | 2.7 | Colombia | Paramo, alpine tundra | Metamorphic and igneous intrusive rocks, volcanic and clastic rocks |
| I-Bh-c | | | | 409 | 2.62 | Bolivia | Paramo, alpine tundra | Metamorphic and igneous intrusive rocks, volcanic and clastic rocks |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| I-Bh-c | | | | 707 | 2.3 | Ecuador | Paramo. alpine tundra | Quaternary ashes and outflows, some Precambrian metamorphic rocks. glacial and periglacial deposits |
| I-Bh-c | | | | 2 609 | 2.42, 2.61, 2.62 | Peru | Subalpine paramo. alpine tundra | Old Paleozoic slightly metamorphosed rocks. Permo-Carboniferous calcareous. clastic rocks. Cretaceous clastic rocks and Quaternary glacial deposits |
| I-Bh-To-c | | | | 31 | 2.3 | Ecuador | Paramo. alpine tundra | Quaternary volcanic ashes |
| I-Bh-Tv-c | | | | 8 017 | 2.61, 2.62 | Peru | Upper montane cloud forest. Polylepis forest. paramo. alpine tundra | Quaternary ashes and lava outflows. glacial deposits. acid igneous rocks. Mesozoic clastic and calcareous rocks |
| I-Fh-Ne-To-c | | | | 4 086 | 1.71, 1.72, 1.73 | Colombia | Andean montane forest | Jurassic-Cretaceous volcanics with some intrusives and Quaternary ashes west of the Andes. Precambrian and Paleozoic metamorphics. Jurassic-Cretaceous and Tertiary clastics to the east |
| I-Fh-Ne-To-c | | | | 2 468 | 1.71, 1.72, 1.73 | Ecuador | Andean montane formations | Jurassic-Cretaceous volcanics with some intrusives and Quaternary ashes west of the Andes. Precambrian and Paleozoic metamorphics. Jurassic-Cretaceous and Tertiary clastics to the east |
| I-Fo-Lf-bc | | | Cerrado | 4 574 | 1.483, 1.77, 1.8 | Brazil 1 | Cerrado. cerradão | Precambrian metamorphic rocks such as quartzites resistant to weathering |
| I-Fo-Lf-bc | | | | 1 469 | 1.135, 1.42, 1.543 | Brazil 5 | Caatinga | Precambrian metamorphic rocks and acid igneous rocks |
| I-Fo-Nd-bc | | | | 2 369 | 1.121, 1.471, 1.48 | Guyana | Tropical evergreen forest. upland savanna and montane forest | A great variety of Precambrian and younger metamorphic. acid and basic igneous rocks. and Mesozoic sandstones |
| I-Fo-Nd-bc | | | | 1 721 | 1.121 | Venezuela | Tropical evergreen forest | Precambrian gneisses. schists. metamorphic tuffs. andesites |
| I-Fo-Q-b | | | | 356 | 1.484 | Brazil 1 | Cerrado, cerradão. caatinga | Devonian sandstones |
| I-Hl-bc | | | | 2 254 | 4.14 | Uruguay | Pampa | Precambrian quartzites. slates. phyllites. schists. crystalline limestones, dolomites |
| I-Hl-c | | | Cerrado | 700 | 1.483 | Brazil 1 | Cerrado | Cambro-Ordovician carbonate rocks |
| I-Hl-c | | | | 785 | 2.43 | Peru | Humid montane forests on the slopes. xerophytic woodland in the valleys. paramo on the plateaus | Cretaceous clastic, calcareous rocks. Quaternary ashes |
| I-Hl-Kl-bc | | | | 5 926 | 2.3, 2.37, 2.38 | Peru | Dry to humid montane forest | Acid igneous rocks. Old Paleozoic partly metamorphosed clastic rocks and Permian. Mesozoic. clastic and calcareous rocks. colluvium |
| I-Je-c | | | | 509 | 1.72, 1.74 | Peru | Xerophytic woodland and cacti scrubland | Old Paleozoic clastic rocks: Young Paleozoic. Mesozoic clastic and calcareous rocks: alluvium |
| I-Kh-c | | | | 1 287 | 1.7, 2.37 | Ecuador | Montane xerophytic woodland and montane forest | Precambrian metamorphic rocks. Cretaceous. Tertiary. Quaternary tuffs. ashes. outflows |
| I-Kh-J-c | | | | 2 149 | 2.33, 2.38 | Peru | Dry forest and xerophytic woodland of the inter-Andean valleys | Alluvium. Quaternary ashes. igneous rocks. Permian and Mesozoic clastic and calcareous rocks |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| I-Kl-c | | | | 2 129 | 2.3 | Peru | Montane xerophytic woodland and cacti shrubland | Acid igneous rocks, some Paleozoic, Cretaceous clastic and calcareous rocks and Quaternary ashes and outflows |
| I-Kl-Xl-c | | | | 28 | 1.7 | Ecuador | Montane thorn woodland | Paleozoic, Jurassic and Cretaceous clastic and calcareous rocks |
| I-Kl-Xl-c | | | | 280 | 1.7, 3.34 | Peru | Montane thorn woodland | Paleozoic, Jurassic and Cretaceous clastic and calcareous rocks |
| I-Lc-c | | | | 977 | 2.2, 2.38, 4.31 | Bolivia | Montane forests and xerophytic intermontane formations | Devonian, Permo-Carboniferous and Tertiary clastic rocks, almost no calcareous rocks |
| I-Lc-c | | | | 1 208 | 6.21, 7.14 | Chile | Sclerophyllous evergreen woodland | Paleozoic metamorphics and intrusive rocks |
| I-Lc-To-c | | | | 60 | 2.41 | Colombia | Montane forests | Jurassic-Cretaceous clastic-volcanic rocks, Quaternary ashes |
| I-Lf-c | | | Cerrado | 3 900 | 1.482, 1.483, 1.77, 1.8 | Brazil 1 | Cerrado | Cambro-Ordovician sandstones, arkoses, siltstones |
| I-O-Ph-c | | | | 535 | 7.33 | Argentina | Temperate forest, moorland, subalpine herbfield | Paleozoic metamorphic and intrusive rocks |
| I-O-Ph-c | | | | 2 641 | 7.33 | Chile | Temperate forests, moorland, subalpine herbfield | Paleozoic metamorphics and intrusives, Cretaceous clastic rocks of the Magellanes geosyncline |
| I-Ph-U-c | | | | 48 | 7.33 | Argentina | Temperate evergreen and deciduous forests (*Nothofagus* spp.) | Paleozoic greenstones, phyllites, gneisses, micaschists: intrusives, glacial and glaciofluvial deposits |
| I-Ph-U-c | | | | 5 869 | 7.31, 7.33, 7.82 | Chile | Temperate evergreen and deciduous forests (*Nothofagus* spp.) | Paleozoic greenstones, phyllites, gneisses, micaschists; intrusives, glacial and glaciofluvial deposits |
| I-Q-c | | | Cerrado | 4 701 | 1.132 | Brazil 1 | Cerrado | Cambro-Ordovician quartzites, sandstones, slates, Precambrian metamorphics, Tertiary sandstones |
| I-Q-c | | | | 718 | 1.7 | Brazil 1 | Savanna | Mesozoic sandstones and acid intrusive rocks |
| I-Q-c | | | | 353 | 1.7 | Venezuela | Savanna | Mesozoic sandstones and acid intrusive rocks |
| I-R-c | | | | 258 | 3.36 | Chile | Coastal desert and "lomas" vegetation | Igneous rocks and Jurassic volcanics and sedimentaries |
| I-Re-c | | | | 1 683 | 3.34, 3.52 | Peru | Tropical coastal desert | Acid rocks, Jurassic-Cretaceous sandstones, shales, marls tuffs, Old Paleozoic metamorphics |
| I-To-c | | | | 120 | 6.66 | Argentina | Temperate evergreen and deciduous *Nothofagus* forests | Intrusive rocks, Tertiary and Quaternary tuffs, outflows and ashes |
| I-To-c | | | | 5 631 | 6.66, 6.67, 7.21, 7.31 | Chile | Temperate evergreen and deciduous *Nothofagus* forests | Intrusive rocks, Tertiary and Quaternary tuffs, outflows and ashes |
| I-To-c | | | | 3 412 | 1.72, 2.41 | Colombia | Montane forest | Jurassic-Cretaceous volcanic and clastic rocks, Quaternary ashes, Precambrian and Paleozoic metamorphic and acid intrusive rocks |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| I-To-c | | | | 1 223 | 1.71, 2.3, 2.41 | Ecuador | Montane forest | Precambrian gneisses, schists, phyllites, quartzites and calcareous slates overlain by thin ash |
| I-To-c | | | | 207 | 2.61 | Peru | Humid upper montane forest with dry forest and xerophytic woodland in the valleys | Volcanic ashes, Triassic-Jurassic limestones, shales, glacio-fluvial deposits |
| I-Tv-c | | | | 6 617 | 2.4, 2.6, 2.62 | Bolivia | Upper montane steppe and desert | Quaternary unconsolidated deposits with much volcanic material, ashes and outflows, Ordovician-Silurian clastic rocks |
| I-Tv-c | | | | 1 336 | 2.62 | Chile | Puna and montane desertic steppe | Quaternary ashes and outflows |
| I-Tv-c | | | | 8 540 | 2.36, 2.39, 2.62, 3.51, 3.55 | Peru | Montane steppe, subalpine steppe, paramo, tundra | Quaternary volcanic ashes and outflows, some Jurassic and Cretaceous clastic and acid igneous rocks |
| I-U-c | | | | 1 241 | 7.82, 10.4 | Argentina | Temperate deciduous forest and subalpine herbfield | Paleozoic metamorphics, acid intrusives, glacio-fluvial deposits |
| I-U-c | | | | 1 878 | 5.83, 7.33, 7.82, 10.4, 10.5 | Chile | Temperate deciduous forest and subalpine herbfield | Paleozoic metamorphics and acid intrusives, some Cretaceous clastic rocks, glacial and glacio-fluvial deposits |
| I-Vc-Xk-c | | | | 133 | 1.72 | Colombia | Cacti scrubland, thorn woodland | Paleozoic metamorphic rocks |
| I-Vp-a | | | | 1 470 | 4.13 | Brazil 2 | Warm temperate grassland to tropical seasonal forest interspersed with campo limpo | Basalt of the Trapp formation |
| I-Vp-a | | | | 3 826 | 4.14, 5.32, 5.35 | Uruguay | Warm temperate grassland | Basalt of the Trapp formation |
| I-Vp-E-c | | | | 245 | 1.13 | Colombia | Thorn woodland savanna | Miocene sediments |
| I-Xh-c | | | | 190 | 1.7 | Ecuador | Thorn woodland | Paleozoic clastic rocks, Cretaceous basic volcanic rocks |
| I-Xh-c | | | | 503 | 1.34, 3.14 | Peru | Tropical coastal desert | Paleozoic and Tertiary clastic rocks, Quaternary alluvium and coastal terraces |
| I-Yh-b | | | | 892 | 3.55 | Chile | Montane desert | Quaternary ashes and outflows |
| I-Yh-b | | | | 95 | 3.55 | Peru | Coastal and montane desert | Intrusive rocks, Mesozoic clastic and volcanic rocks, Tertiary and Quaternary tuffs and ashes, Quaternary deposits, salt flats |
| I-Yh-c | | | | 901 | 3.56 | Argentina | — | — |
| I-Yh-c | | | | 6 376 | 3.44, 3.52, 3.55, 3.56 | Chile | Coastal and montane desert | Intrusives, Mesozoic clastics and volcanics, Tertiary and Quaternary tuffs and ashes, Quaternary deposits, salt flats |
| I-Yh-Re-c | | | | 3 278 | 3.83, 3.92 | Argentina | Steppe | Quaternary basalt with some Paleozoic tuffs, loose Quaternary deposits |
| I-Yh-So-b | | | | 1 579 | 3.52, 3.55 | Chile | Coastal Pacific desert | Intrusive rocks, Jurassic andesite flows, breccias, conglomerates, Quaternary pediments, alluvium |
| Jd1-3a | | | | 67 | 1.121 | Brazil 3 | Tropical seasonal forest | Alluvium |
| Jd13-3a | Ge | | | 3 991 | 1.131, 1.46 | Colombia | Gallery forest | Recent alluvium of floodplains |
| Jd13-3a | Ge | | | 480 | 1.131, 1.46 | Venezuela | Gallery forest | Recent alluvium |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Je1-2a | Jc | | | 282 | 1.13, 1.3 | Venezuela | Cultivated land | Alluvium |
| Je1-3a | Jc | | | 17 154 | 2.2, 2.3, 2.5, 3.5, 3.8, 3.9, 4.3, 5.1, 5.7 | Argentina | Alluvial meadows, mountain forests, deciduous forests with *Nothofagus* spp. | Alluvium |
| Je1-3a | Jc | | | 518 | 1.121 | Guyana | Riverine swamp forest and herbaceous swamp | Young alluvium |
| Je1-3a | Jc | | | 74 | 1.13 | Trinidad | Mangrove swamps and other swamp vegetation | Young alluvial and coastal deposits |
| Je3-3a | Gm O | | | 2 103 | 5.32, 5.33 | Argentina | Gallery forests with natural tropical species, imported species, such as willow and poplar | Deltaic sediments of the Colorado River |
| Je4-3a | Ge Wm Kl | | | 3 400 | 4.35, 4.36 | Argentina | Xerophytic deciduous forest and wet palm savanna | Loose Quaternary deposits and alluvium |
| Je4-3a | Ge Wm Kl | | | 164 | 4.35, 4.36 | Paraguay | Xerophytic deciduous forest and wet palm savanna | Loose Quaternary deposits and alluvium |
| Je5-3a | Zg Sm | Jc | | 14 459 | 3.2, 3.5, 3.8, 3.9, 4.2, 4.3, 5.1, 5.3 | Argentina | Wet palm savanna, swamps, and meadows | Alluvium and colluvium of the valleys and depressions with internal drainage |
| Je6-3a | Hh | | | 751 | 4.21, 4.31 | Argentina | Lower belts of Andean forest with transitions to xerophytic woodland | Alluvium and pediment deposits overlying Tertiary and Triassic clastic sediments |
| Je7-3a | Zg | | | 118 | 3.36 | Chile | River meadows, cultivated land | Alluvium |
| Je7-3a | Zg | | | 40 | 1.132 | Ecuador | — | Alluvial terraces |
| Je7-3a | Zg | | | 83 | 1.121 | French Guiana | Swamp forest and herbaceous swamp | Young coastal alluvium |
| Je7-3a | Zg | | | 56 | 1.121 | Guyana | Mangrove and other swamp forests | Young coastal alluvium |
| Je7-3a | Zg | | | 1 959 | 1.34, 3.14, 3.34, 3.4, 3.52 | Peru | Cultivated land | Alluvium and terraces, detrital fans, deltaic deposits |
| Je8-3a | Yh I | Re | | 259 | 3.34 | Peru | Tropical coastal desert | Detritus overlying acid igneous rocks |
| Je9-3a | Bd | | | 1 394 | 2.21, 4.33 | Argentina | Intermontane steppe and some mountain forest | Alluvium and pedimentary material overlying Tertiary clastic sediments |
| Je10-3a | R | | | 481 | 3.93, 5.92 | Argentina | Patagonian steppe, river meadows | Alluvium and coastal deposits |
| Je11-3a | Gm | | | 2 227 | 3.93, 5.92, 6.22, 6.27, 8.58 | Chile | Agricultural land, sclerophyllous evergreen woodland | Alluvium, including much volcanic material |
| Je12-2a | Ge Gm | | | 1 103 | 1.121, 1.131, 1.483 | Venezuela | Tropical seasonal forest, swamp forest, wet savanna | Alluvium |
| Je13-a | Ge | | | 784 | 4.36 | Argentina | Gallery forest, wet palm savanna, swamps | Alluvium |
| Je13-a | Ge | | | 1 322 | 4.36 | Paraguay | Gallery forest, wet palm savanna, swamps | Alluvium |
| Je13-2a | Ge | | | 492 | 1.13, 1.483 | Venezuela | Gallery forest | Alluvial and lacustrine deposits |
| Je13-3a | Ge | | | 329 | 1.221, 1.482, 1.73, 4.32, 4.35 | Bolivia | Gallery forest, wet palm savanna, swamps | Alluvium |
| Je14-3a | Gh | | | 780 | 1.131 | Ecuador | Savanna, thorn woodland, swamp forest | Alluvium |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Je15-3a | Gd W | | | 71 | 1.121, 4.31, 4.32 | Bolivia | Lower montane cactus formation, grassland | Alluvium |
| Je16-3a | Zo | | | 402 | 3.56 | Bolivia | Altiplano steppe | Quaternary lacustrine deposits |
| Je17-3a | Yk | I | | 152 | 3.34 | Peru | Tropical coastal desert | Alluvium |
| Je18-3a | Gh Gd | | | 5 621 | 1.121, 1.123, 1.13 | Colombia | Tropical evergreen and swamp forest and wet savanna | Alluvium |
| Je19-3a | Jt | | | 169 | 1.121 | French Guiana | Swamp forest and wet savanna | Young coastal deposits |
| Je20-3a | R Zg | | | 389 | 1.121 | Guyana | Mangrove and other swamp forests. herbaceous swamps and flooded savanna | Young coastal alluvium, mostly heavy blue and grey clays with sandy ridges rich in shells and peat |
| Je20-3a | R Zg | | | 324 | 1.121 | Surinam | Mangrove and other swamp forests, herbaceous swamps | Heavy textured deposits of the young Holocene coastal plain |
| Jt1-3a | Zg Rd Ph | Ao | | 183 | 1.11 | Brazil 3 | Mangrove swamp forest | Coastal fine textured sediments |
| Kh1-1a | | | | 3 903 | 4.22, 5.125, 5.611 | Argentina | Transition between pampean grassland and peripampean thorn woodland in the south, woodland and xerophytic deciduous forest in the north | Pampean formation in the south and Quaternary deposits in the north (loess deposits) |
| Kh1-1a | | | Petrocalcic | 6 610 | 4.31, 4.32, 4.35, 4.36, 5.13, 5.3, 5.71 | Argentina | Transition between pampean grassland and peripampean thorn woodland | Pampean formation (loess deposits) |
| Kh1-2a | | | | 493 | 2.22, 4.21 | Argentina | Transition between the xerophytic woodlands and mountain forest | Precambrian gneisses, migmatites and granites |
| Kh2-2a | Ws Wm | We | | 2 073 | 4.35, 4.36 | Argentina | Xerophytic deciduous forest, pampean grassland | Quaternary unconsolidated deposits |
| Kh5-1a | Kk S | | Saline | 9 699 | 4.31 | Argentina | Xerophytic deciduous forest | Quaternary deposits |
| Kh5-1a | Kk S | | Saline | 1 533 | 4.32, 4.35 | Bolivia | Xerophytic deciduous forest | Quaternary deposits |
| Kh5-1a | Kk S | | Saline | 6 967 | 4.32 | Paraguay | Xerophytic deciduous woodland | Quaternary deposits |
| Kh6-1ab | Kk S | I | | 1 696 | 4.31, 4.32 | Bolivia | Xerophytic thorn woodland | Tertiary clastic rocks of the Subandean ranges, Quaternary alluvium |
| Kk1-3a | Hl J | | | 55 | 2.61 | Peru | Lower montane dry forest and montane humid forest | Triassic-Jurassic and calcareous rocks, alluvium |
| Kl 1-2a | Re | | | 5 421 | 3.93, 5.81, 5.96, 10.5 | Argentina | Peripatagonian thorn woodland | Unconsolidated Quaternary, glacial, fluviatile, aeolian, or lacustrine deposits |
| Kl 2-2a | Ge Wm | | | 3 624 | 4.35 | Argentina | Xerophytic deciduous forest and palm savanna | Quaternary unconsolidated deposits and alluvium |
| Kl 2-2a | Ge Wm | | Saline | 128 | 4.32 | Argentina | Xerophytic deciduous forest | Unconsolidated Quaternary, fluviatile, aeolian, or lacustrine deposits |
| Kl 2-2a | Ge Wm | | Saline | 3 900 | 4.32, 4.35 | Paraguay | Xerophytic deciduous forest | Unconsolidated Quaternary, fluviatile, aeolian, or lacustrine deposits |
| Kl 3-3a | Gc Kk | Ge J | | 328 | 2.38 | Peru | Montane humid forest | Mostly Permo-Carboniferous limestones and shales |
| Kl 4-3a | | | | 132 | 2.51, 2.6 | Bolivia | Altiplano steppe | Tertiary and Quaternary fluvial and lacustrine volcanic deposits |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Kl 4-3b | | | | 130 | 1.53 | Venezuela | Thorn woodland | Triassic-Jurassic-Cretaceous and Tertiary clastic rocks |
| Kl 5-3b | Vp I | | | 546 | 1.74 | Peru | Dry forests and xerophytic woodland and cacti scrubland | Cretaceous clastic and calcareous rocks |
| Kl 7-2c | I | | | 840 | 3.55, 3.56 | Chile | Montane desert and steppe | Quaternary ashes and outflows, igneous rocks |
| Kl 7-3b | I | | | 305 | 1.71 | Colombia | Intermontane thorn woodland, cacti scrubland, savanna | Cretaceous clastic rocks, Triassic-Jurassic shales and quartzites, acid igneous rocks |
| Kl 7-3b | I | | | 187 | 2.32 | Ecuador | Intermontane thorn woodland, cacti scrubland, savanna | Cretaceous clastic rocks, Triassic-Jurassic shales and quartzites, acid igneous rocks |
| Kl 7-3b | I | | | 475 | 2.32 | Peru | Humid montane forests on the slopes, xerophytic woodland and savanna in the valleys | Precambrian metamorphic rocks, acid intrusive rocks, Cretaceous clastic and calcareous rocks |
| Kl 8-3b | I So | | | 205 | 1.53 | Venezuela | Thorn woodland, deciduous forest | Cretaceous-Tertiary clastic rocks |
| Kl 10-3b | Tv | | | 366 | 1.73 | Colombia | Intermontane thorny woodland, cacti scrubland and savanna of the intermontane dry valleys | Quaternary volcanic ashes, Cretaceous volcanic and clastic rocks, alluvium |
| Kl 11-3a | So | | | 261 | 1.53 | Ecuador | Coastal steppe and thorn woodland | Tertiary clastic rocks and Quaternary clastic loose deposits |
| Kl 13-ab | J Xh | | | 725 | 1.121 | Colombia | Intermontane thorny, woodland, cacti scrubland and savanna | Cretaceous and Tertiary clastic rocks and alluvium |
| Lc1-3a | Fo | I Ws | Stony | 1 953 | 1.53, 1.543, 1.544, 1.81 | Brazil 1 | Caatinga | Precambrian metamorphic rocks |
| Lc2-3a | Lf Ws | V So I | Stony | 508 | 1.543, 1.8 | Brazil 4 | Caatinga | Precambrian metamorphic rocks and Silurian oolitic limestone, sandstone, phyllite, slate |
| Lc2-3b | Lf Ws | V So I | | 317 | 2.2 | Bolivia | Lower montane thorn woodland and cactus scrubland | Devonian clastic rocks |
| Lc2-3b | Lf Ws | V So I | Stony | 9 237 | 1.77 | Brazil 4 | Tropical seasonal forest | Precambrian metamorphic rocks |
| Lc2-3b | Lf Ws | V So I | Stony | 15 596 | 1.31, 1.34, 1.42, 1.5, 1.543 1.8, 1.83 | Brazil 5 | Caatinga | Precambrian metamorphic rocks and granites |
| Lc3-3a | | | | 1 086 | 6.27 | Chile | Sclerophyllous evergreen woodland | Intrusive rocks, Paleozoic metamorphics, Mesozoic and Tertiary clastic and volcanic rocks |
| Lc3-3b | | | | 301 | 4.31 | Bolivia | Montane evergreen forest with transitions to Chaco woodland | Carboniferous sandstones and other clastic rocks, Tertiary slightly consolidated sandstones with intercalated tuffs and shales |
| Lc4-3a | Lf | | | 77 | 6.22 | Chile | Sclerophyllous evergreen woodland | Mainly intrusive rocks |
| Lc5-3a | Vc | | | 478 | 6.24, 6.27 | Chile | Sclerophyllous evergreen woodland | Intrusive rocks, Tertiary clastic rocks, and volcanics |
| Lc6-c | I Vc | So | | 2 219 | 2.38 | Bolivia | Montane dry forest, xerophytic woodland and grassland | Ordovician-Silurian and Devonian clastic rocks |
| Lc6-c | I Vc | So | | 30 | 2.38 | Chile | Temperate deciduous *Nothofagus* forest | Cretaceous clastic rocks and Pleistocene morainic material |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Lc6-3a | I Vc | So | | 2 660 | 6.22, 8.85 | Chile | Agricultural land and sclerophyllous evergreen woodland | Quaternary glacio-fluvial and alluvial volcanic deposits, Tertiary tuffs, Cretaceous tuffaceous and intrusive rocks |
| Lc6-3a | I Vc | So | | 1 070 | 1.121, 1.13, 1.71, 1.72, 2.34 | Colombia | Montane forests, swamp forest, wet savanna | Paleozoic igneous and metamorphic rocks, Paleozoic, Mesozoic clastic rocks, some alluvium |
| Lc6-3a | I Vc | So | | 181 | 1.13, 1.71 | Venezuela | Montane forest | Clastic rocks, some limestones, igneous rocks, metamorphic rocks |
| Lc6-3b | I Vc | So | | 1 831 | 2.34, 2.7 | Colombia | Thorn woodland, savanna, deciduous forest, now under cultivation | Tertiary clastic rocks, Cretaceous clastic, igneous and metamorphic rocks, alluvium and colluvium |
| Lc6-3b | I Vc | So | | 381 | | Ecuador (Galapagos Islands) | — | Basalt |
| Lc7-3b | Lf I | | | 617 | 1.53 | Venezuela | Thorn woodland, cacti scrubland | Mostly Quaternary deposits |
| Lc8-3b | Bk Lf | | | 522 | 1.131, 1.7 | Ecuador | Subtropical thorn woodland, savanna and tropical deciduous forest | Cretaceous and Tertiary clastic rocks |
| Lc9-3b | I Ws So | Lf Fo Hl | Stony | 6 657 | 1.31, 1.532, 1.533, 1.8 | Brazil 5 | Caatinga | Precambrian gneisses, schists, quartzites; acid intrusives, Silurian limestones, sandstones, slates, phyllites |
| Lc10-3a | J S | | | 532 | 2.31, 2.39, 4.31 | Bolivia | Montane dry forest and xerophytic woodland | Permo-Carboniferous and Tertiary clastic rocks in the south, Ordovician clastic rocks in the north |
| Lf1-1a | | | | 4 920 | 1.77, 1.924 | Brazil 4 | Tropical semideciduous seasonal forest | Cretaceous sandstones (calcareous), Silurian limestones and clastic rocks |
| Lf1-2a | | | | 2 154 | 1.42, 1.483, 1.484 | Brazil 1 | Tropical semideciduous forest with mixed palm forest | Alluvium and terrace material overlying Cretaceous clastic rocks |
| Lf1-2a | | | | 59 | 1.121 | Venezuela | Tropical seasonal forest | Tertiary clastic rocks |
| Lf1-3b | | | | 395 | 1.121, 1.8 | Brazil 3 | Tropical seasonal and semideciduous forest | Precambrian metamorphic rocks |
| Lf2-2a | Fo I | Re | Stony | 904 | 1.42, 1.81 | Brazil 5 | Caatinga | Mostly Precambrian rocks, some Cambrian and Ordovician clastic rocks |
| Lf3-3b | Fo | I | | 1 205 | 1.77 | Brazil 1 | Tropical semideciduous forest | Precambrian metamorphic rocks |
| Lf4-3b | Fa Qf | I Bd | | 4 533 | 1.8 | Brazil 4 | Tropical seasonal forest | Silurian oolitic limestone, phyllite, schists, sandstone |
| Lf5-2b | Fo Ne | | Stony | 1 956 | 1.77, 2.31 | Brazil 4 | Tropical seasonal forest | Precambrian metamorphic rocks with derived alluvium and colluvium |
| Lf5-2b | Fo Ne | | | 1 394 | 1.77, 2.31 | Brazil 4 | Tropical seasonal forest | Precambrian metamorphic rocks |
| Lf6-2b | I Ne Hl | E Gp | Lithic [1] | 1 278 | 1.132, 1.42, 1.77, 1.924, 4.35, 4.36 | Brazil 1 | Tropical semideciduous and seasonal forests | Cambro-Ordovician crystalline limestones, dolomites, marls, shales, sandstones. Precambrian metamorphic rocks and Carboniferous clastic rocks |
| Lf9-3b | Lp Af | Gd Gp | Petric [1] | 2 014 | 1.42, 1.484 | Brazil 1 | Tropical seasonal forest with mixed palm forest | Cretaceous sandstones, terraces, alluvium |

[1] The phase applies to only part of the association.

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Lf10-3b | Ne | | Lithic [1] | 566 | 1.21, 1.74 | Brazil 3 | Tropical evergreen and seasonal forests | Gneisses (charnockite gneiss) |
| Lf11-2a | Ao | | | 2 434 | 1.77, 1.916, 1.924, 4.35 | Brazil 1 | Tropical semideciduous forest | Precambrian metamorphic rocks and Carboniferous clastic rocks |
| Lf11-2a | Ao | | | 274 | 4.36 | Paraguay | Tropical deciduous forest | Precambrian metamorphic rocks |
| Lf11-2b | Ao | | | 3 073 | 1.924 | Brazil 1 | Tropical semideciduous forest | Cretaceous sandstone |
| Lf11-3b | Ao | | Petric [1] | 2 312 | 1.482 | Brazil 1 | Tropical evergreen, seasonal, and semideciduous forests and cerrado | Precambrian metamorphic rocks |
| Lf12-3c | Re I | | Stony | 417 | 1.543, 1.8 | Brazil 5 | Caatinga, Agreste | Precambrian metamorphic and acid intrusive rocks |
| Lf13-2a | Ao I Nd | | | 68 | 1.121 | Colombia | Montane forest | Precambrian and Paleozoic metamorphic and igneous outcrops, Triassic to Tertiary clastic rocks |
| Lf13-2a | Ao I Nd | | | 2 500 | 1.121, 1.123, 1.13, 1.483 | Venezuela | Montane deciduous forests | Precambrian and Paleozoic metamorphic and igneous outcrops, Triassic to Tertiary clastic rocks |
| Lf14-2/3a | Ao Wm | Gh | | 4 899 | 1.42, 1.482 | Bolivia | Tropical deciduous and semideciduous forests | Precambrian metamorphic rocks covered by alluvium and colluvium |
| Lf15-2ab | We | | | 538 | 4.36 | Paraguay | Tropical seasonal forest | Carboniferous tillites and sandstones |
| Lf16-3b | I Lc | | Stony | 581 | 1.543 | Brazil 5 | Caatinga | Precambrian metamorphic and acid igneous rocks, Cretaceous clastic rocks |
| Lf21-3b | Ao | Fa | Petric [1] | 131 | 1.77 | Brazil 1 | Semideciduous tropical forest | Precambrian metamorphic rocks |
| Lf22-3b | Fo Ne | We I | | 2 534 | 1.31, 1.532, 1.8 | Brazil 5 | Mainly dry deciduous Agreste forest, including cerrado and caatinga | Precambrian metamorphic and acid intrusive rocks |
| Lf23-2/3a | Fo Lc | I V Ws | Stony | 24 340 | 1.21, 1.31, 1.5, 1.8 | Brazil 4 | Caatinga and tropical seasonal forest | Precambrian metamorphic rocks, Silurian oolitic limestones, slates, phyllites, sandstones and arkoses, Pleistocene and Holocene terraces, alluvium |
| Lo2-2b | I | | | 1 120 | 4.14 | Brazil 2 | Grassland | Precambrian metamorphic rocks and granites |
| Lo2-2b | I | | | 58 | 4.14 | Uruguay | Grassland | Precambrian metamorphic rocks and granites |
| Lo2-2c | I | | | 439 | 4.32, 4.33 | Argentina | Montane forest | Upper Tertiary clastic rocks, mostly sandstones, shales and some tuffs |
| Lo2-2c | I | | | 215 | 4.32, 4.33 | Bolivia | Montane forest | Tertiary clastic rocks |
| Lo3-2a | Hl Lc | | | 609 | 4.14 | Uruguay | Pampa | Triassic sandstone |
| Lo4-3a | We | | | 3 475 | 1.13, 1.3 | Colombia | Deciduous forest and savanna in the south, thorn woodland and cacti scrubland along the coast | Miocene shales and sandstones, Quaternary deposits |
| Lp1-2a | Lf R | J | | 5 409 | 1.482 | Bolivia | Tropical semideciduous forest and savanna | Alluvium, in the eastern part on Precambrian metamorphic rocks |

[1] The phase applies to only part of the association.

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Nd1-3a | | | | 1 193 | 4.13, 4.15 | Brazil 2 | Grasslands (campos limpos) and *Araucaria angustifolia* forest | Basalt of the Trapp formation |
| Nd1-3a | | | | 99 | 4.36 | Paraguay | Tropical seasonal forest | Precambrian micaschists, phyllites, and other metamorphic rocks |
| Nd1-3b | | | | 208 | 4.36, 4.45 | Argentina | Tropical seasonal forest | Plateau basalts of the Trapp formation |
| Nd1-3b | | | | 739 | 4.14 | Brazil 2 | Grassland (campos limpos) | Carboniferous sandstones, shales, tillites; Precambrian metamorphic rocks |
| Nd1-3b | | | | 1 371 | 6.21, 7.13, 7.14, 7.21 | Chile | South of 40°S evergreen Valdivian rainforest, northwards temperate deciduous *Nothofagus* forest | Paleozoic metamorphics. Tertiary sandstones; Quaternary deposits in the central valley mainly volcanic |
| Nd1-3b | | | | 1 505 | 1.123, 1.131 | Ecuador | Tropical seasonal forest | Alluvium, outwash deposits, terraces, Tertiary and Quaternary clastics |
| Nd1-3b | | | | 1 250 | 1.121 | French Guiana | Tropical evergreen forest | Precambrian schists, quartzites, carbonatized rocks and basic metamorphic rocks |
| Nd1-3b | | | | 1 590 | 4.36, 4.45 | Paraguay | Tropical seasonal forest | Plateau basalts of the Trapp formation |
| Nd1-3b | | | | 58 | 1.72 | Peru | Subtropical humid evergreen forest | Old Paleozoic slightly metamorphosed rocks |
| Nd1-3b | | | | 3 212 | 1.121, 1.46, 1.483, 1.484 | Venezuela | Tropical evergreen, tropical seasonal forest | Precambrian metamorphic and acid intrusive rocks and Mesozoic sandstones |
| Nd2-3c | Ao | | | 1 248 | 4.14 | Brazil 2 | Grassland (campos limpos) | Mostly Precambrian metamorphic rocks and granites, some outcrops of conglomerates and arkoses |
| Nd3-3b | I | | | 704 | 1.471, 1.48 | Guyana | Tropical evergreen forest | Precambrian metamorphic rocks and granites: basic igneous rocks |
| Nd4-3c | Fo I | | Petric | 107 | 1.121 | Guyana | Tropical evergreen forest | Basic igneous rocks like gabbro, dolerite, diabase |
| Nd5-2b | Ao I | | | 169 | 1.123 | Colombia | Tropical evergreen forest | Old Tertiary mainly clastic rocks |
| Nd5-3a | Ao I | | | 786 | 1.13 | Colombia | Montane forest | Metamorphic and igneous rocks, Triassic-Jurassic volcanic/sedimentary rocks and Quaternary alluvium |
| Ne1-3a | | | | 808 | 4.45 | Argentina | Tropical seasonal forest | Basalt of the Trapp formation, Tertiary and Quaternary slightly consolidated deposits |
| Ne1-3b | | | | 262 | 1.924 | Brazil 2 | Tropical seasonal forest | Basalt of the Trapp formation |
| Ne1-3b | | | | 323 | 1.77, 1.924, 2.31 | Brazil 4 | Tropical seasonal forest | Basic igneous rocks (basalts and intrusives) |
| Ne1-3b | | | | 3 297 | 1.121, 1.471, 1.48 | Surinam | Tropical evergreen forest | Probably metamorphosed andesites, basalts, and ultrabasic rocks, carbonatized rocks |
| Ne2-3b | Fx Fo | | | 304 | 1.132 | Brazil 1 | Tropical evergreen forest | Probably Carboniferous limestone. calcareous sandstone, shale and gypsum beds |
| Ne3-3b | I Fo | | | 1 795 | 1.132 | Brazil 1 | Tropical evergreen forest | Probably basalt |
| Ne4-3b | Lf Fr | | | 313 | 1.483, 1.77, 1.8 | Brazil 1 | Tropical semideciduous forest | Precambrian and Silurian metamorphic rocks, the latter including limestones |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Ne5-3b | Ao I | | | 360 | 1.11 | Colombia | Tropical evergreen forest | Metamorphic and basic intrusive rocks |
| Ne5-3b | Ao I | | | 575 | 1.11 | Ecuador | Tropical evergreen forest | Tertiary clastics with pyroclastic admixtures, Quaternary detrital fans |
| Ne5-3c | Ao I | | | 248 | 1.74 | Colombia | Humid subtropical forest | Cretaceous clastic rocks, alluvium |
| Ne5-3c | Ao I | | | 2 232 | 1.12, 1.75 | Peru | Tropical evergreen and montane evergreen forests | Paleozoic partly metamorphosed clastic rocks, Triassic-Jurassic limestones and shales, Cretaceous - Tertiary sandstones, shales and some limestones |
| Ne11-3c | Lf Fo Hl | I | | 931 | 1.221, 1.77 | Brazil 4 | Tropical seasonal forest | Precambrian metamorphic rocks |
| O1-a | | | | 339 | 1.121, 1.131, 1.46 | Colombia | Swamp and moorland | Fluvial deposits on the lowest parts of the alluvial overflow plain |
| O1-a | | | | 162 | 1.121 | French Guiana | Herbaceous, aquatic swamps | Young marine and fluvio-marine alluvium |
| O1-a | | | | 113 | 1.121 | Surinam | Swamps | Young alluvium |
| O1-b | | | | 1 047 | 7.31 | Chile | Moor, bogland | Intrusive rocks, Permo-Carboniferous sandstones, shales and limestones, Quaternary glacial and glacio-fluvial deposits |
| O2-b | Ph I | | | 745 | 7.82 | Falkland Islands | Moor, bogland | Paleozoic clastic rocks |
| O3-b | Ph | | | 406 | 7.82 | Falkland Islands | Moorland | Paleozoic clastic rocks |
| O4-a | Jt Gm Ge | J | | 769 | 1.121 | Guyana | Marsh and swamp forest, including herbaceous swamp and periodically flooded savanna | Young coastal plain deposits |
| Ph1-1b | Bd | | | 333 | 7.82 | Argentina | Temperate deciduous *Nothofagus* forest | Glacial and glacio-fluvial deposits overlying Tertiary clastic rocks |
| Ph1-1b | Bd | | | 400 | 5.83, 7.82 | Chile | Temperate deciduous *Nothofagus* forest | Glacial and glacio-fluvial deposits overlying Tertiary clastic rocks |
| Ph2-1b | O Pg | | | 63 | 5.83, 7.31 | Chile mainland | Temperate deciduous *Nothofagus* forest | Glacial and glacio-fluvial deposits overlying Tertiary clastic rocks |
| Ph2-1b | O Pg | | | 60 | 7.31 | Chiloé | Temperate evergreen forest (Valdivian rainforest) | Paleozoic mica schists, gneisses, phyllites |
| Ph3-1b | O | I | | 14 | 7.14 | Chile | Temperate evergreen forest | Paleozoic metamorphics |
| Ph8-1b | | | | 505 | 7.82 | Argentina | Temperate deciduous to evergreen *Nothofagus* forest | Glacial and glacio-fluvial deposits overlying Cretaceous clastic rocks |
| Ph8-1b | | | | 161 | 7.82 | Chile | Temperate deciduous to evergreen *Nothofagus* forest | Glacial and glacio-fluvial deposits overlying Cretaceous clastic rocks |
| Qa1-1a | Ph Gh | Zg Jt | | 183 | 1.21 | Brazil 4 | Restinga, coastal formations | Quaternary coastal deposits |
| Qa1-1a | Ph Gh | Zg Jt | | 189 | 1.21, 1.35 | Brazil 5 | Restinga, woodland, and mangrove swamps | Quaternary coastal and deltaic deposits |
| Qa2-1a | Ph | Gh | | 106 | 1.121 | Brazil 3 | Restinga, woodland and mangrove swamp forest | Quaternary sandy coastal deposits |
| Qa3-1a | Ao Gd | | | 99 | 1.121 | French Guiana | Tropical evergreen forest | Sandy beach ridges |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Qa4-1a | Fo Ph | | | 73 | 1.121 | French Guiana | Tropical evergreen forest with savanna enclosures | Sands |
| Qa4-1a | Fo Ph | | | 772 | 1.121, 1.471, 1.48 | Guyana | Tropical evergreen forest with savanna enclosures | Mio-Pleistocene sands |
| Qa4-1a | Fo Ph | | | 968 | 1.121 | Surinam | Tropical evergreen forest with enclosures of savanna | Sands |
| Qf1-1a | | | | 578 | 1.77, 1.924 | Brazil 1 | Tropical seasonal forest. cerrado | Triassic and Cretaceous sandstones |
| Qf1-1a | | | Petric | 16 | 1.121 | Surinam | Upland savanna and tropical evergreen forest | Hard quartz sandstones, conglomerates and basic igneous rocks |
| Qf1-1b | | | Cerrado | 596 | 1.135, 1.42 1.73 | Brazil 4 | Cerrado | Devonian, Cretaceous. Tertiary sandstones and detritus of Precambrian metamorphic rocks |
| Qf2-1a | Ap Gd | Ph | | 253 | 1.7 | Guyana | Savanna and montane forest | Hard quartz sandstones with subordinate shales, conglomerates and arkoses |
| Qf2-1a | Ap Gd | Ph | | 593 | 1.7 | Venezuela | Upland savanna and montane forest | Hard quartz sandstones with subordinate shales, conglomerates, and arkoses |
| Qf3-1a | Fo | | | 15 185 | 1.132, 1.482, 1.72 | Brazil 1 | Transitional zone between caatinga and cerrado and tropical seasonal forest | Devonian, Carboniferous, Triassic, Cretaceous sandstones and shales |
| Qf3-1a | Fo | | Cerrado | 9 837 | 1.482, 1.483 | Brazil 1 | Cerrado | Precambrian metamorphics, Devonian, Carboniferous Triassic and Cretaceous clastic rocks, including sandstones, basic igneous rocks |
| Qf3-1a | Fo | | Petric[1] | 712 | 1.132, 1.42, 1.482, 1.484, 1.53 | Brazil 1 | Tropical seasonal forest (deciduous) | Devonian, Carboniferous and Triassic sandstones |
| Qf3-1a | Fo | | | 87 | 4.45 | Paraguay | Tropical seasonal forest | Jurassic sandstones |
| Qf5-1a | Af | Gp | Petric | 2 854 | 1.42, 1.484 | Brazil 1 | Tropical seasonal forest with palms | Carboniferous Permian and Triassic sandstones, siltstones, and shales |
| Qf6-1a | Fo | Gh | Cerrado | 2 890 | 1.8 | Brazil 1 | — | A very fine rounded quartz sandstone with argillaceous or siliceous cement |
| Qf7-1a | Fo Fr | Gh | Cerrado | 9 645 | 1.77, 1.916, 1.924 | Brazil 1 | — | Carboniferous sandstones with some fine-textured sediments, Jurassic and Cretaceous calcareous sandstones |
| Qf7-1a | Fo Fr | Gh | Cerrado | 2 611 | 1.924 | Brazil 4 | Cerrado | Carboniferous, Jurassic, and Cretaceous sandstones |
| Qf8-1a | Ao Fo | I | | 1 537 | 1.42 | Bolivia | Tropical seasonal forest (semideciduous) | Old Paleozoic and Tertiary sandstones, lutites, jaspers and conglomerate beds, quartzites |
| Qf9-1a | Fo I | | Cerrado | 8 200 | 1.482, 1.483, 1.77, 1.916 | Brazil 1 | Cerrado | Cambro-Ordovician, Devonian, Permo-Carboniferous and Cretaceous sandstones, Precambrian metamorphics |
| Qf10-1a | Fr | | Cerrado | 152 | 1.77 | Brazil 4 | Tropical seasonal forest | Sandstone |
| Qf11-1a | Fx Ap Ao | Ph G | | 739 | 1.483 | Brazil 5 | Tropical seasonal forest, some cerrado patches and restinga woodland | Tertiary clastics |

[1] The phase applies to only part of the association.

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Qf12-1a | I So | | | 3 195 | 1.31, 1.532, 1.533, 1.543, 1.83 | Brazil 4 | Caatinga and some cerrado patches | Cretaceous sandstones. siltstones. and clays. capped in places by Tertiary clays |
| Qf13-1a | Bk Lf Lp | I Zg So | Petric [1] | 728 | 1.483 | Brazil 5 | Caatinga | Cretaceous coarse calcareous sandstones. limestones and marls, Pliocene sandstones. shales. clays. gravels. Quaternary sands |
| Qf14-1a | Af Ap Lf | I | Petric | 9 012 | 1.42, 1.484 | Brazil 1 | Tropical deciduous forest | Devonian. Carboniferous. Permian. and Triassic sandstones with subordinate shales and siltstones |
| Qf14-1a | Af Ap Lf | I | | 779 | 1.42, 1.484 | Brazil 1 | Tropical deciduous forest | Devonian Carboniferous. Permian, and Triassic sandstones with subordinate shales and siltstones |
| Qf14-1a | Af Ap Lf | I | | 706 | 1.121, 1.471, 1.48 | Surinam | Savanna | Metamorphic and granitic rocks. sandy colluvium and alluvium in the depressions and valleys |
| Qf15-1b | Ao | | Cerrado | 450 | 1.42 | Brazil 1 | Cerrado | Devonian sandstones |
| Qf16-1a | Fo | I | | 21 | 1.77 | Brazil 4 | Tropical seasonal forest | Precambrian metamorphic rocks |
| Qf16-1a | Fo | I | | 319 | 1.543, 1.8 | Brazil 5 | Caatinga | Cretaceous sandstones. Precambrian metamorphic rocks |
| Rd1-1a | | | | 600 | 4.36, 5.32, 5.35, 5.36 | Argentina | Gallery forest with tropical species | Alluvium |
| Rd1-1a | | | Shifting sand | 797 | 1.534 | Brazil 5 | Caatinga | Quaternary quartz sands |
| Rd1-1a | | | | 157 | 5.32, 5.35 | Uruguay | Gallery forest with tropical species | Alluvium |
| Rd1-1b | | | | 122 | 1.135 | Brazil 1 | Restinga | Coastal Quaternary deposits |
| Rd1-1b | | | | 134 | 1.11, 1.121 | Brazil 3 | Restinga woodland | Sandy Quaternary sediments |
| Rd1-1b | | | | 130 | 1.46 | Colombia | Savanna and forest remnants | Dune sands (river dunes) |
| Rd9-1a | Ph Qa | | | 183 | 1.11, 1.123 | Brazil 1 | Tropical evergreen forest | Precambrian granites |
| Rd13-1c | I | | | 470 | 1.71 | Bolivia | Tropical evergreen forest | Tertiary and Quaternary sandy deposits |
| Rd13-1c | I | | | 92 | 1.71 | Peru | Tropical evergreen forest | Tertiary and Quaternary deposits of the Andean borderland |
| Rd14-1a | Qa Ap Ws | So I | | 864 | 1.135, 1.42 | Brazil 5 | Restinga woodland and deciduous forests of the Agreste type | Precambrian metamorphic rocks. Cretaceous and Tertiary sandstones, claystones and limestones. alluvium |
| Re1-1a | | | | 6 063 | 3.82, 5.13, 5.71, 5.72 | Argentina | Peripampean thorn woodland. low open tussock grassland with thickets of *Prosopis* spp. | Pampean formation (loess deposits) |
| Re1-1a | | | | 415 | 1.13, 1.5 | Venezuela | Xerophytic woodland and cacti scrubland | Coastal deposits. dune sands |
| Re1-1b | | | | 907 | 3.92, 5.95, 7.12 | Argentina | Coastal vegetation | Dunes on sand and sandstone of Upper Tertiary marine formations |
| Re1-1b | | | | 12 | 7.14 | Chile | — | — |

[1] The phase applies to only part of the association.

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Re2-1a | Yk Xk | I | | 553 | 1.5 | Colombia | Cacti scrubland | Quaternary deposits |
| Re3-1a | Yk J | | | 544 | 3.14, 3.34 | Peru | Montane steppe and scrubland | Paleozoic and Jurassic clastic and calcareous rocks. Quaternary detrital fans, terrace and outwash deposits |
| Re4-1a | Yk Zo | J | Petrocalcic [1] | 199 | 3.34 | Peru | Tropical coastal desert | Quaternary coastal deposits |
| Re5-1a | J Yh | | | 100 | 1.131, 1.3 | Ecuador | Tropical coastal desert | Quaternary deposits such as coastal terraces and dunes |
| Re5-1a | J Yh | | | 2 685 | 3.14, 3.34 | Peru | Tropical coastal desert | Quaternary deposits such as coastal terraces and dunes |
| Re5-1b | J Yh | | | 7 980 | 3.91, 6.66, 6.67 | Argentina | Steppe | Quaternary basalts, pre-Mesozoic intrusive rocks. Triassic and Cretaceous clastic rocks, volcanic flows and tuffs |
| Re6-1a | J W | | | 1 703 | 1.73, 4.32, 4.35 | Bolivia | Savanna with palms and shrubs | Alluvium and outwash deposits |
| Re7-1a | Ge Gm | Zg | | 1 139 | 4.11 | Brazil 2 | Dune and swamp vegetation | Quaternary unconsolidated aeolian, marine, and lacustrine deposits |
| Re8-1a | Bk Lf | I Zg | | 1 473 | 1.135, 1.42, 1.572 | Brazil 5 | Caatinga | Cretaceous hard siliceous limestone underlain by medium grained sandstone |
| Re10-1a | Po | | | 250 | 1.121 | Surinam | Tropical evergreen forest | Sandy coastal ridges |
| Re11-1a | Zo | | | 385 | 3.34 | Peru | Tropical coastal desert | Quaternary alluvium, dune sands, coastal terraces |
| Sm1-3a | Gm Ge | O Jt | | 362 | 4.11 | Brazil 2 | Swamp halomorphic vegetation | Quaternary marine and lacustrine unconsolidated deposits over Precambrian metamorphics |
| Sm2-3a | Zo Zg | | | 1 863 | 5.11, 5.12, 5.13 | Argentina | Pampa | Aeolian deposits of pampean formation |
| Sm3-3a | Gm Wm | | | 5 661 | 4.21, 4.36, 5.112, 5.128, 5.37 | Argentina | Xerophytic woodland grading southward into pampean grassland | Aeolian deposits of pampean formation |
| Sm3-3a | Gm Wm | | Petrocalcic | 1 073 | 5.112, 5.128 | Argentina | Pampa | Aeolian deposits of pampean formation |
| Sm4-3a | Wm | | | 2 205 | 4.21, 4.36, 5.37 | Argentina | Xerophytic deciduous woodland and pampean grassland | Unconsolidated Quaternary sediments |
| Sm5-3a | Ge | | | 1 016 | 5.11 | Argentina | Pampa | Marine deposits of the coastal low terrace |
| Sm6-3a | J Zg | | | 458 | 4.32, 4.35 | Bolivia | Swamps | Quaternary alluvium |
| So1-3a | Zo | | | 184 | 3.56 | Bolivia | Desertic Altiplano steppe | Lacustrine Quaternary deposits |
| So2-3a | Zg | | | 74 | 4.32, 4.35 | Bolivia | Swamps, xerophytic woodland | Chaco deposits |
| So2-3a | Zg | | | 1 894 | 4.32, 4.35 | Paraguay | Swamps, xerophytic woodland | Quaternary Chaco deposits |
| Th2-c | Tv I | | | 421 | 6.66, 6.67 | Argentina | Temperate Andean mountain forests (with *Araucaria araucana*) | Quaternary basalt and ashes |
| Th2-c | Tv I | | | 440 | 6.67, 7.82 | Chile | Temperate Andean mountain forests (with *Araucaria araucana* in the north) | Quaternary and Tertiary ashes, tuffs, and volcanic outflows, older intrusives |

[1] The phase applies to only part of the association.

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Th3-c | I | | | 82 | 6.66, 7.82 | Argentina | Temperate Andean mountain forests with deciduous *Nothofagus* spp. and *Araucaria araucana* | Volcanics of various ages overlying igneous intrusives |
| Th3-c | I | | | 2 800 | 6.66, 7.81, 7.82 | Chile | Temperate Andean mountain forests with deciduous *Nothofagus* spp. and *Araucaria araucana* forest | Volcanics, Jurassic and Tertiary in the south, elsewhere Tertiary and Quaternary, overlying igneous intrusives |
| Th3-c | I | | | 105 | 1.7 | Ecuador | — | — |
| Th4-a | | | | 2 054 | 7.12 | Chile | Agricultural land of the central valley, originally temperate deciduous *Nothofagus* forest | Quaternary volcanic mudflows and glacio-fluvial deposits |
| Th4-a | | | | 641 | 1.73, 2.41 | Colombia | Montane forests | Volcanic material over Paleozoic metamorphic rocks |
| Th4-b | | | | 851 | 6.21, 6.22, 6.66 | Chile | Agricultural land and sclerophyllous evergreen woodland | Quaternary volcanic mudflows and glacio-fluvial deposits |
| Th4-b | | | | 42 | 1.73 | Colombia | Montane forests and paramo, alpine tundra | Quaternary ashes over Paleozoic metamorphic and clastic rocks |
| Th4-c | | | | 120 | 6.66, 7.12, 7.13 | Chile | Agricultural land, originally Valdivian rainforest, temperate deciduous *Nothofagus* forest, and coniferous forest | Quaternary volcanic mudflows and glacio-fluvial deposits |
| Th4-c | | | | 148 | 2.41 | Colombia | Montane and upper montane forest | Cretaceous volcanics, Quaternary volcanic ashes, and igneous intrusives |
| Th4-c | | | | 700 | 2.41 | Ecuador | Montane and upper montane forest | Cretaceous volcanics, Quaternary volcanic ashes, and igneous intrusives |
| Th5-c | R | | | 1 007 | 7.82 | Argentina | Temperate deciduous Andean mountain forest | Tertiary, Quaternary tuffs and outflows overlying igneous and metamorphic rocks |
| Th5-c | R | | | 1 115 | 6.66, 7.82 | Chile | Temperate deciduous Andean mountain forest | Tertiary-Quaternary tuffs, ashes, and outflows overlying Meso-Cenozoic igneous rocks and Precambrian metamorphics |
| Th7-a | Tv | | | 1 038 | 1.123 | Ecuador | Tropical evergreen forest | Predominantly volcanic alluvium and Tertiary clastic and sometimes tuffaceous rocks |
| Th8-a | Gh Bh | O | | 1 188 | 2.51, 2.61, 2.62 | Peru | Lake Titicaca: Altiplano steppe and river meadows; Headwaters Rio Mantaro: upper montane forests, paramo | Lake Titicaca: Quaternary volcanic, alluvial and lacustrine deposits<br>Rio Mantaro: Quaternary ashes, glacial and glacio-fluvial deposits |
| Th10-b | Gh | | | 287 | 1.11, 1.123 | Colombia | Tropical evergreen forest | Cretaceous, Tertiary, and Quaternary ashes, tuffs, outflows and clastic rocks |
| Th10-b | Gh | | | 215 | 1.11, 1.123 | Ecuador | Tropical evergreen forest | Cretaceous, Tertiary, and Quaternary tuffs, outflows and clastic rocks |
| Tm1-a | | | | 529 | 3.56 | Bolivia | Altiplano steppe | Quaternary deposits containing much volcanic material and Quaternary ashes |
| Tm1-a | | | | 780 | 2.3, 2.41 | Ecuador | Intermontane thorn woodland, savanna (mostly cultivated) | Young Tertiary-Quaternary volcanic ashes and fluvial, lacustrine and glacio-fluvial deposits |
| Tm2-a | G Th | J | | 453 | 1.73 | Colombia | Cultivated land and thorn woodland of the dry intermontane valleys | Alluvium and Cretaceous basic volcanic rocks |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Tv1-a | R | | | 307 | 3.56 | Bolivia | Altiplano steppe | Tertiary and Quaternary deposits, containing much volcanic material |
| Tv1-c | R | | | 415 | 6.67 | Argentina | Transitional between steppe and Andean mountain forests | Upper-Cretaceous/early Tertiary andesitic tuffs and breccias with subordinate clastic and calcareous deposits |
| Tv2-a | | | | 291 | 6.21 | Chile | — | — |
| Tv2-a | | | | 334 | 2.39, 3.55, 2.62 | Peru | Altiplano steppe, river meadows | Quaternary ashes and alluvial deposits |
| Tv2-b | | | | 814 | 1.123, 1.131, 2.41 | Ecuador | Intermontane thorn woodland and savanna, tropical seasonal forest | Quaternary volcanic ashes and outflows |
| Tv2-c | | | | 60 | 7.92, 10 | Argentina | Temperate deciduous Andean mountain forest | Quaternary ashes and outflows overlying intrusive rocks |
| Tv2-c | | | | 54 | 7.92, 10 | Chile | Temperate deciduous Andean mountain forest | Quaternary ashes and outflows overlying intrusive rocks |
| Tv2-c | | | | 60 | 1.121 | Colombia | Thorn woodland and cacti scrubland of the dry intermontane valleys | Volcanic ashes |
| Tv3-a | Kl J | | | 934 | 2.51, 2.62, 3.55 | Bolivia | Altiplano steppe | Quaternary ashes and outflows, igneous rocks and Tertiary and Quaternary fluvial and lacustrine deposits |
| Tv3-a | Kl J | | | 299 | 2.62 | Chile | Montane steppe | Quaternary ashes and outflows |
| Tv3-c | Kl J | | | 89 | 2.51, 3.55 | Bolivia | Altiplano steppe, river meadows | Quaternary ashes, fluvial and lacustrine deposits, Permian calcareous and clastic rocks |
| Tv3-c | Kl J | | | 210 | 2.51, 3.55 | Peru | Altiplano steppe, river meadows | Quaternary ashes, fluvial and lacustrine deposits, Permian calcareous and clastic rocks |
| Tv4-a | I Yk | J | | 990 | 3.34, 3.52 | Peru | Coastal desert | Mostly young Tertiary and Quaternary deposits, much volcanic material |
| Tv5-b | Kh I | | | 437 | | Ecuador (Galapagos Islands) | — | Pyroclastic deposits |
| Tv5-b | Kh I | | | 256 | 2.38 | Peru | Humid montane forest and dry forest, xerophytic woodland in the valleys | Quaternary ashes and outflows |
| Tv6-b | I | Kl Hl | | 414 | 3.35 | Peru | Subalpine desert paramo, tundra | Quaternary ashes and lava outflows |
| Tv6-c | I | Kl Hl | | 344 | 2.6 | Bolivia | Montane desert, Puna steppe | Quaternary ashes |
| Tv6-c | I | Kl Hl | | 490 | 2.6 | Chile | Puna steppe and montane desert | Quaternary ashes and other deposits, pediments, alluvium, mostly volcanic |
| U2-b | Be O | | | 363 | 5.81, 5.83, 7.82 | Argentina | Patagonian prairie with acid bog and moorland in the depressions | Gravelly glacio-fluvial and glacial deposits of the Pleistocene |
| U2-b | Be O | | | 1 485 | 5.81, 5.83, 7.82 | Chile | Temperate deciduous mountain forest, Patagonian grassland | Tertiary clastic rocks and Quaternary glacial and glaciofluvial deposits |
| Vc1-3a | | | | 176 | 1.543 | Brazil 4 | Caatinga | Calcareous alluvium |
| Vc1-3a | | | | 2 034 | 1.121, 1.13, 1.483, 1.484 | Venezuela | Savanna, swamp forest | Predominantly Quaternary (also Tertiary), fluvial and deltaic sediments |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Vc2-3a | J | | | 385 | 1.13 | Peru | Semideciduous and deciduous tropical forests | Tertiary and Quaternary outwash, terrace and alluvial deposits |
| Vc3-3a | Ne Ao | Ap | | 339 | 1.12 | Peru | Tropical evergreen and semideciduous forests | Tertiary and Quaternary outwash, terrace and alluvial deposits |
| Vp1-3a | | | | 189 | 4.35 | Brazil 1 | Tropical seasonal forest | Cambro-Ordovician limestones |
| Vp1-3a | | | | 295 | 4.14 | Brazil 2 | — | Carboniferous tillites, sandstones, shales, argillites, Permian clastic rocks and oolitic limestones |
| Vp1-3a | | | | 58 | 1.121 | Brazil 3 | Restinga | Cretaceous limestone and clastic rocks |
| Vp1-3a | | | | 100 | 6.22, 6.24 | Chile | Agricultural land | Reworked volcanic material (glacio-fluvial, fluvial, alluvial) |
| Vp1-3a | | | | 45 | 1.121 | Colombia | Thorn woodland and deciduous forest, savanna | Alluvium |
| Vp1-3a | | | | 535 | 1.3 | Ecuador | Wet savanna and thorn woodland | Quaternary alluvium, Cretaceous dolerite, basalt, andesite, dacite, and their tuffs |
| Vp1-3a | | | | 224 | 4.35 | Paraguay | Tropical seasonal forest | Cambro-Ordovician limestones with frequent interbeds of marls, shales, sandstones and siltstones |
| Vp1-3a | | | | 248 | 4.14 | Uruguay | Warm temperate grassland | Permo-Carboniferous, glacial, interglacial and postglacial clastic rocks and limestone |
| Vp2-3a | Hl | | | 4 306 | 5.32, 5.33, 5.35 | Argentina | Pampean grassland grading northward into xerophytic deciduous forest | Paraná alluvium and pampean formation |
| Vp2-3a | Hl | | | 745 | 5.32, 5.35, 4.14 | Brazil 2 | Grassland | Basalt of the Trapp formation |
| Vp3-3a | Hl | I | | 1 215 | 4.14 | Uruguay | Pampa | Basalt of the Trapp formation, Cretaceous calcareous sandstones |
| Vp4-3a | Hl Wm | | | 1 706 | 4.14 | Uruguay | Pampa | Quaternary marine and loessic deposits and Cretaceous calcareous sandstones |
| Vp5-3a | I Xl | | | 246 | 1.34 | Ecuador | Thorn woodland | Paleozoic, Jurassic, Cretaceous and Quaternary calcareous clastic and volcanic deposits |
| Vp5-3a | I Xl | | | 739 | 1.34 | Peru | Thorn woodland | Paleozoic, Jurassic, Cretaceous and Quaternary calcareous, clastic and volcanic deposits |
| Vp6-3a | Wm S | E J | | 1 673 | 4.35 | Paraguay | Palm savanna, xerophytic woodland | Quaternary alluvium and some outcrops of acid and basic intrusive rocks |
| Wd7-2a | Ap Vp | Ao | | 905 | 4.36 | Paraguay | Grassland | Precambrian metamorphics, Silurian sandstones and Carboniferous clastic rocks |
| We1-3a | R | | | 1 664 | 4.36, 5.36 | Argentina | Xerophytic deciduous forest, palm savanna | Alluvium |
| We2-2a | So | | | 625 | 4.14 | Uruguay | Grassland | Permean clastic rocks |
| We2-3a | So | | | 1 088 | 4.36, 5.35 | Argentina | Xerophytic deciduous forest, palm savanna | Alluvium |
| We3-2a | Wm | | | 146 | 4.13 | Brazil 2 | Grassland, swamps | Quaternary alluvial, lacustrine and marine deposits |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| We3-3a | Wm | | | 148 | 5.36 | Argentina | Grassland | Alluvium |
| We5-2a | | | | 2 191 | 4.11, 4.13, 4.14 | Brazil 2 | Warm temperate grassland, swamps and campo limpo | Quaternary alluvial and lacustrine deposits, Precambrian metamorphic rocks and granites, Permian clastic rocks |
| We5-2a | | | | 46 | 4.11 | Uruguay | Swamp vegetation, warm temperate grassland | Quaternary lacustrine and alluvial deposits |
| We6-2/3a | S Kl | | Saline | 6 942 | 4.35 | Paraguay | Xerophytic deciduous forest and wet palm savanna | Unconsolidated Quaternary, fluviatile, aeolian and lacustrine deposits |
| We7-3a | Vp | | | 102 | | Chile | — | — |
| We14-3a | Ws Gp Qa | So Jv | | 4 324 | 1.42, 1.482 | Bolivia | Wet palm savanna, swamps, campo cerrado, tropical seasonal forest | Alluvial |
| We14-3a | Ws Gp Qa | So Jv | | 16 886 | 1.42, 1.483, 4.35, 4.36 | Brazil 1 | Wet palm savanna, swamps, campo cerrado, tropical seasonal forest | Quaternary alluvium |
| We14-3a | Ws Gp Qa | So Jv | | 690 | 4.36 | Paraguay | Swamps | Holocene sediments |
| Wm1-3a | Gm Vp | | | 1 412 | 5.35 | Argentina | Xerophytic deciduous forest, wet palm savanna | Paraná alluvium and pampean formation |
| Wm1-3a | Gm Vp | | | 1 746 | 4.13, 4.14, 4.15 | Brazil 2 | Wet grassland | Alluvium overlying basalt and sandstone with Permian clastic rocks in the headwater region |
| Wm2-2/3a | Vp | | | 292 | 4.15, 5.35 | Brazil 2 | Gallery forest and grassland | Basalt of the Trapp formation *and alluvium* |
| Wm2-3a | Vp | | | 1 604 | 5.35, 5.36 | Argentina | Xerophytic deciduous forest, palm savanna, and some pampean grassland | Paraná alluvium and pampean formation (loess deposits) |
| Wm3-3a | Sm | | | 1 196 | 5.11 | Argentina | Pampa | Pampean formation (loess deposits) |
| Wm4-2a | Ge | | | 2 106 | 4.36 | Paraguay | Grassland, wet palm savanna | Paraná alluvium |
| Wm4-3a | Ge | | | 1 394 | 4.36 | Argentina | Xerophytic deciduous forest, wet palm savanna | Paraná alluvium |
| Wm6-2/3a | S Kl | | | 436 | 4.35 | Bolivia | Swamps and tropical semideciduous forest | Paraguay alluvium |
| Wm7-3a | Hl | | | 126 | 5.11 | Argentina | Pampa | Pampean formation (loess deposits) |
| Wm7-3a | Hl | | Petrocalcic | 1 016 | 5.128 | Argentina | Pampa | Pampean formation (loess deposits) |
| Wm8-3a | J O | | | 91 | 2.34 | Colombia | Cultivated land (deciduous forest) | Quaternary alluvium of the Bogotá basin |
| Wm9-2a | Lf Kl | | | 3 565 | 1.42, 1.435, 1.482, 1.73 | Bolivia | Tropical deciduous forest, savanna | Quaternary outwash and alluvium |
| Ws1-3a | Ap | | | 237 | 1.482 | Brazil 1 | Tropical semideciduous forest | Pleistocene sediments over Carboniferous and Triassic clastic rocks |
| Xh1-3c | I | | | 163 | 1.7 | Ecuador | Thorn woodland and savanna | Precambrian metamorphic rocks, alluvium |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Continued)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Xh2-a | | | | 2 004 | 2.6, 3.56 | Bolivia | Montane and Altiplano steppe | Mostly Quaternary unconsolidated deposits, Tertiary clastic rocks with much volcanic material, Devonian clastic rocks |
| Xh3-b | Tv I | | | 2 366 | 2.6, 3.56 | Bolivia | Altiplano steppe | Quaternary and locally Tertiary Altiplano aeolian, fluvial, lacustrine, volcanic deposits |
| Xh3-b | Tv I | | | 188 | 2.6, 3.56 | Chile | Altiplano steppe | Quaternary unconsolidated deposits with much volcanic material |
| Xh4-2a | Kh S | | Saline | 9 804 | 4.21, 4.31, 4.32 | Argentina | Xerophytic deciduous forest | Unconsolidated Quaternary outwash sediments of the Andes |
| Xh4-2a | Kh S | | Saline | 3 700 | 4.32, 4.35 | Bolivia | Xerophytic deciduous forest | Unconsolidated Quaternary outwash sediments of the Andes |
| Xh4-2a | Kh S | | Saline | 2 199 | 4.21, 4.31, 4.32 | Paraguay | Xerophytic deciduous forest | Unconsolidated Quaternary outwash sediments of the Andes |
| Xh5-1a | Xk S | | Saline | 10 937 | 3.25, 3.26, 4.22, 5.62 | Argentina | Peripampean thorn woodland with tree thickets in low open tussock grassland | Unconsolidated Quaternary outwash and loess deposits |
| Xk1-2a | I | | | 296 | 6.27 | Chile | Xerophytic woodland to montane steppe | Intrusive rocks, Jurassic volcanics, Quaternary alluvium |
| Xk1-3b | I | | | 1 857 | 1.131, 1.53 | Venezuela | Xerophytic thorn woodland and cacti shrubland | Mesozoic metamorphic rocks, Tertiary sandy, shaly and calcareous sediments |
| Xk2-2a | Yk | | | 695 | 1.3, 3.12 | Colombia | Cacti scrubland | Tertiary and Quaternary clastic sediments |
| Xk2-3b | Yk | | | 902 | 1.53, 3.12 | Venezuela | Cacti scrubland | Tertiary clastic rocks, Quaternary loose deposits such as dune sands |
| Xk3-1a | Xh | | Petrocalcic | 8 867 | 3.83, 5.13, 5.71, 5.72 | Argentina | Peripampean thorn woodland, tree thickets in low open tussock grassland | Pampean formation (loess deposits) |
| Xl 1-3b | I | | | 246 | 1.3, 1.484, 1.53 | Venezuela | Tropical deciduous forest | Tertiary clastic and calcareous deposits |
| Xl 1-3c | I | | | 211 | 1.53 | Venezuela | Tropical deciduous forest and xerophytic thorn woodland | Tertiary clastic rocks and Quaternary loess deposits |
| Yh1-a | Re | | | 1 998 | 2.6, 3.56 | Bolivia | Desertic tundra and Altiplano steppe | Paleozoic clastic rocks, and Quaternary deposits with much ash admixture |
| Yh1-1a | Re | | Sodic | 857 | 3.55 | Chile | Montane desert | Quaternary unconsolidated deposits partly volcanic, igneous outcrops |
| Yh1-2a | Re | | Sodic | 346 | 3.52 | Chile | Coastal desert | Quaternary unconsolidated deposits partly volcanic, intrusive rocks |
| Yh2-1c | Zo | | | 40 | 3.5 | Bolivia | Montane desert | Quaternary pedimentary, alluvial and aeolian deposits, partly volcanic |
| Yh2-1c | Zo | | | 185 | 2.6 | Chile | Montane desert, Puna steppe | Quaternary ashes and outflows |
| Yh2-2a | Zo | | Saline | 3 140 | 3.52 | Chile | Montane desert | Quaternary pedimentary alluvial and aeolian deposits, partly volcanic |
| Yh3-2a | I | | | 2 113 | 3.36, 3.44 | Chile | — | — |

TABLE 3. – SOIL ASSOCIATIONS AND RELATED INFORMATION (Concluded)

| MAP SYMBOL | ASSOCIATED SOILS | INCLUSIONS | PHASE | EXTENSION (1 000 ha) | CLIMATE | OCCURRENCE | VEGETATION | LITHOLOGY |
|---|---|---|---|---|---|---|---|---|
| Yh3-2a | I | | Sodic | 2 421 | 3.36, 3.44 | Chile | Coastal desert and some lomas vegetation nourished by moisture condensing from sea fogs | Intrusive rocks, Paleozoic metamorphics, Jurassic volcanics, coastal terraces, and alluvium |
| Yh4-1b | Re Xh | | | 15 892 | 3.274, 3.82, 3.91 | Argentina | Montane steppe with low thorny shrubs and tussock grasses | Predominantly Quaternary deposits with volcanic ash and some outcrops of Triassic and Tertiary clastics and tuffs |
| Yh5-1c | Zo Tv | | | 1 830 | 2.6 | Argentina | Montane desert and Puna steppe | Quaternary ashes and outflows |
| Yh5-1c | Zo Tv | | | 956 | 2.6 | Chile | Montane desert and shrub-clad steppe of the Altiplano | Quaternary ashes and outflows and Paleozoic clastic rocks |
| Yl 1-2a | Yk Zo | Re | Sodic [1] | 33 091 | 3.82, 3.83, 3.91, 3.92, 3.93, 3.94, 3.95, 10.5 | Argentina | Patagonian steppe of tussock grasses and thorn shrubs (almost no trees) | Unconsolidated Quaternary deposits locally shallow over basalt and tuffs, Precambrian gneisses and migmatites south of the Rio Limay-Negro |
| Yl 2-2a | Zo | | Sodic [1] | 8 230 | 2.6, 3.56 | Argentina | Montane desert | Quaternary ash and other deposits, mainly volcanic |
| Yl 2-2a | Zo | | | 384 | 2.6, 3.56 | Bolivia | Montane desert | Quaternary ashes |
| Yl 2-2a | Zo | | | 748 | 2.52, 2.6, 3.56 | Chile | Montane desert | Quaternary ashes |
| Zg1-3a | Jt Gp | | | 4 141 | 1.121, 1.132, 1.135 | Brazil 1 | Mangrove and other swamp formations | Marine and brackish water deposits |
| Zg1-3a | Jt Gp | | | 1 240 | 1.121, 1.131 | Venezuela | Mangrove swamp | Deltaic and coastal deposits |
| Zg2-3a | Wm Sm | | | 1 905 | 5.12 | Argentina | Pampa | Pampean formation (loess deposits) |
| Zg5-3a | Je Gm | | | 907 | 1.121, 1.13, 1.3 | Colombia | Mangrove and other swamp formations | Quaternary marine and fluvio-marine deposits |
| Zg5-3a | Je Gm | | | 387 | 1.32 | Ecuador | Mangrove and other swamp formations | Quaternary marine and fluvio-marine deposits |
| Zo1-2a | Yh | | | 1 860 | 3.52 | Chile | Montane desert | Quaternary unconsolidated deposits overlying Jurassic volcanics (mainly andesitic) and intrusive rocks |
| Zo1-2a | Yh | | | 21 | 3.34 | Peru | Montane desert | Quaternary unconsolidated deposits overlying Jurassic volcanics (mainly andesitic) and intrusive rocks |

[1] The phase applies to only part of the association.

The Andean mountain ranges (C) include the whole system of mountains and foothills which dominate the western part of the continent. Here the situation is complex. Apart from physiography, there are strongly contrasting climatic conditions imposed by the great range in latitude, the rapid changes in altitude, the cold Humboldt current and the nearby hot equatorial Amazon-Orinoco basin. There are also large differences in lithology, particularly in volcanic regions, and all these affect the pattern of soil regions.

### A. Soil regions of the lowlands

#### A1. AMAZON BASIN

This huge sedimentary basin consists mainly of unconsolidated Tertiary and Pleistocene kaolinitic clays and quartz sands. Holocene deposits cover only a small part of the region.

Altitudes vary from 0 to 250 metres in the eastern part and up to 400 metres in western Amazonas. Three important sedimentation levels have been recognized.

##### 1. *Flat plateau land, the Amazon planalto*

This is of Plio-Pleistocene age. The elevation varies between 150 and 250 metres in the west and becomes less toward the east. The planalto surface consists of 10 to 20 metres of uniform, heavy "Belterra" clay originating from kaolinitic deposits eroded during the Andes uprising. Sedimentation took place in a shallow inland sea when the sea level was high.

The most common soil is the Xanthic Ferralsol under equatorial rain forest. The imperfectly drained parts have Plinthic Acrisols with a vegetation which is mostly savanna.

##### 2. *Pleistocene terraces at various levels*

Redissection of the Amazon planalto and sedimentation of reworked Tertiary and older deposits after the Amazon river began its action have resulted in a series of terraces of various levels. The topography here may be rather steep, although gentle slopes predominate. Again, the most important soils are the Xanthic Ferralsols, but the texture may vary and become more sandy toward the east. Associated soils on the lower river terraces include coarse acid sands (Dystric Regosols) of which some are now Humic Podzols. Plinthic Acrisols also occur as well as concretionary Xanthic Ferralsols. One explanation for the presence of concretions is that they are fossil plinthite and as such present the relics of Plinthic Acrisols which developed on a former land surface with poor drainage. Erosion after the poor drainage conditions ceased removed the A horizon and sometimes part of the plinthic B horizon. Subsequent weathering of the plinthite in the better drained position resulted in a new profile. Under these conditions vertical transportation of clay may take place (concretionary Orthic Acrisols). Plinthite may also be found in the lower part of the Ferralsols.

On some of the terraces "Black Indian" soil (Terra Preta de Indio) occurs. Although restricted to small patches, these man-made soils, developed by pre-Colombian Indian tribes, are most remarkable in having maintained a high content of phosphate, calcium and organic carbon. Thus, under wet tropical conditions man-made soils can apparently be most resistant to leaching of plant nutrients, with humus stabilized at a high level.

##### 3. *Holocene floodplains*

These areas, which occupy only a small percentage of the Amazon Basin but nevertheless cover millions of hectares, consist principally of Dystric Gleysols. Humic Gleysols and Plinthic Acrisols also occur. Like the Fluvisols in this region they are mostly of low base saturation. Soils on the levees of the Amazon-Solimoes river, where base-rich sediments may be found, are exceptions. This is probably because the river originates in a limestone-rich section of the Peruvian Andes.

#### A2. BOLIVIAN LOWLANDS

From the point of view of soils, this is one of the least known regions in South America. It is part of the Subandean depression and probably made up of terraces comparable to the Amazon planalto, but these have been completely eroded or buried by alluvial fans originating from the flanks of the Andes. Sediments have also been deposited from the side of the Brazilian plateau, and consequently the pattern and nature of the soils are unpredictable. Toward the north Orthic Ferralsols probably occupy a large part of the area. More poorly drained associated Xanthic soils and Albic Arenosols occur on some of the lower terraces. Plinthic Acrisols are important in the more poorly drained savanna areas. Toward the south the climate includes a dry season, and Orthic Acrisols are known to exist, some of them probably with ferruginous concretions. As associated soils Ferralsols, Dystric Gleysols and Plinthic Acrisols would be expected.

### A3. Orinoco basin

The divide between the Amazon and Orinoco basins is not pronounced enough to result in an abrupt change in soil pattern, but so far the characteristic Belterra clay of the Amazon planalto has not been reported in the Orinoco lowlands. The very heavy Xanthic Ferralsols could, therefore, be limited to the Amazon basin. Erosion surfaces in the Orinoco basin are generally of younger age than those of the Belterra. The Meta river separates relatively high Pleistocene plains (up to 150 metres higher than the river) in the south from an aeolian plain, an alluvial overflow plain and a landscape of alluvial terraces north of the river.

The high plains in the south could indicate the nature of the remaining unexplored part of the Colombian Orinoco basin. These plains are locally covered with loess, especially in the northeast. To the west, they are much dissected and have soils with concretions which probably helped to conserve the hilly landscape against further levelling. The soils have been tentatively presented on the map as concretionary Dystric Cambisols, but concretionary Orthic Acrisols can also be expected. These Cambisols are similar to Ferralsols in morphology but appear to be less weathered and of higher cation exchange capacity. It is possible that they are influenced by volcanic ash. Such soils will probably not be found at greater distances from the Andes. The nondissected parts are reported to consist of Ferralsols. The drainage ways, which occupy an increasing percentage of the area toward the east where topography becomes more level, have Gleyic and Plinthic Acrisols and Humic Gleysols as major components.

*The alluvial overflow plain*, north of the Meta river, forms a deltaic pattern of natural levees and slack water areas that extends into Venezuela. The slack water areas cover more than fifty percent of the landscape and are flooded in the wet season. The soils are mainly Plinthic Acrisols and Plinthic Ferralsols with minor extensions of Humic Gleysols and Vertisols. The levees consist of Dystric Cambisols, often with lateritic concretions in the subsoil. In Venezuela, where the climate is drier, larger areas of Vertisols occur.

*The aeolian plain* consists of a level deposit of heavily leached loess interrupted by longitudinal dunes. The predominant soils are poorly drained incipient Plinthic Acrisols and Plinthic Luvisols.

*The Venezuelan llanos* also consist of Quaternary sediments with some additions of fresh alluvium. Predominant soils are Gleysols and Plinthic Luvisols in association with quartz Regosols and Fluvisols in some of the stream valleys. In the better drained parts of the so-called llano mesas, which consist of low and flat-topped rises of Tertiary soft shales, the soils are probably Orthic Acrisols and Ferralic Arenosols, but Ferralsols could also occur.

*The Unare depression*, which drains directly to the Caribbean, includes many concretionary Orthic Acrisols associated with Ferric Luvisols and Lithosols. Vertisols have also been reported.

### A4. Atlantic coastal lowlands

Elevations in this region rarely exceed 50 metres, and the water table is high and often saline. The coastline, which in many places is bordered by marshes and mangrove forests, is still aggrading with sediments carried by coastal currents. The sediments originate from the Amazon (coast of Brazil, Guyana, Surinam and French Guiana) and from the Orinoco (Venezuelan coast). It has been observed in Surinam that these sediments, which at the beginning of their transport are mostly kaolinitic, appear to be predominantly illitic when redeposited.

In many places narrow strips of sands, transported by the rivers originating on the Guiana shield, form a series of low bars and ridges parallel to the coast or at a slight inclination to it because of the coastal current.

The soils of the ridges are quartz sand Regosols, Albic Arenosols and Humic Podzols. Between and on the inland side of these sand ridges, peaty swamps have developed particularly in Guyana and Surinam. The peaty layer is often a shallow strip on top of the mineral hydromorphic soil and makes good agricultural land when drainage can be provided.

Dominant soils of the coastal lowlands are the Gleysols. These can be found at all stages of maturity from recent deposited and anaerobic salty sediments to structured, desalinized soils, homogenized by soil biological activity. Soils occurring include Gleyic Solonchaks (often with a mangrove vegetation), Humic Gleysols and Dystric Gleysols, sometimes with saline subsoils. A very remarkable soil for this region is the acid sulfate or "cat-clay" soil (Thionic Fluvisol). These have a very high aluminum saturation. When the undrained soil becomes aerated and oxidation takes place, sulfuric acid is formed from iron sulfides and the soils become extremely acid.

In Guyana, French Guiana, and Surinam, and on Marajo Island at some distance from the present shoreline and behind the Holocene young coastal plain there is a belt of older coastal sediments with Plinthic Acrisols dominant in association with Histosols, Eutric, Humic and Mollic Gleysols and Thionic

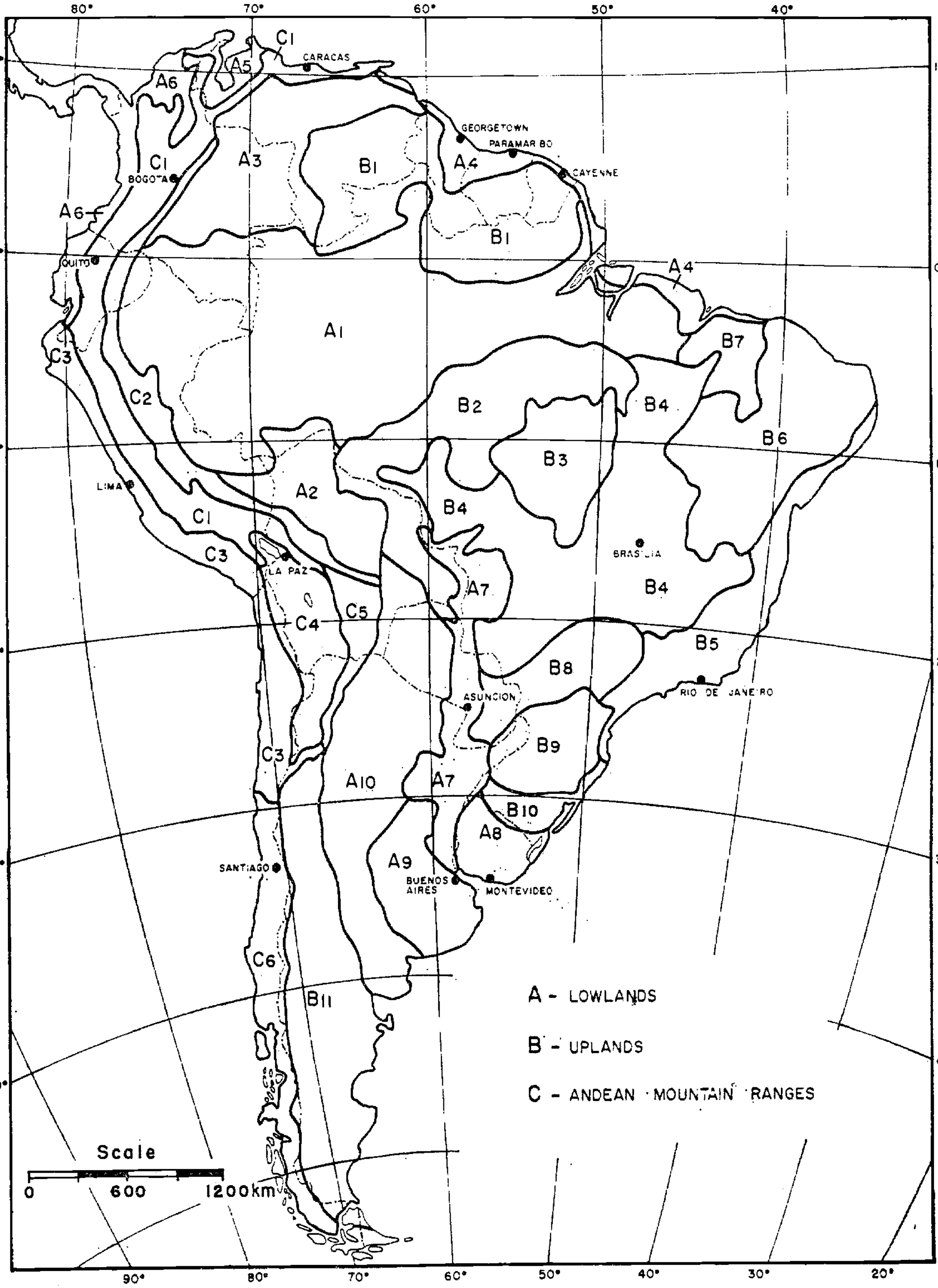


*Figure 7. – Broad soil regions of South America*

Fluvisols. In these same countries but further inland, quartz sediments have been deposited, of very coarse and mixed grain, probably laid down during the early Pleistocene by a great number of relatively short, south-north running, braided rivers. The sediments overlie an old pediplain of the Guiana shield. They are locally very thin and therefore form a transitional strip between the marine coastal formations and the crystalline uplands. In Guiana the sandy strip is extensive in places and includes both white and brown sands, the former sometimes assuming the morphology of a gigantic Podzol and the latter containing some kaolinitic claylike sandy Ferralsols. They have been mapped as Albic Arenosols in association with Orthic Ferralsols and Humic Podzols. Locally, concretionary soils occur which are probably Plinthic Acrisols eroded during a period of high sea level. They are typical of the older surface of this pediplain.

### A5. Maracaibo basin

The elevation of this level area is less than 75 metres. The vegetation varies from humid tropical forest in the southwest through semiarid formations in the plains of the central part, to shifting sand dunes, almost without plant cover, on the Goajira peninsula. Except for some Tertiary rocks along the edges, the basin is filled with Quaternary sediments. On the sides of the lake, Fluvisols, Gleysols and some Vertisols occur.

Toward the fringes, bordering the surrounding Andes, and still in a subhumid climate, Ferric Luvisols have been reported, while in the drier regions in the north there may be salt-affected soils and Xerosols.

### A6. Pacific coastal lowlands

This region includes the humid low coastal ranges and foothills of the western Andes, together with alluvial plains and terraces, marine terraces, estuarine and delta alluvial deposits, and local areas of coastal sand dunes. The natural vegetation consists principally of tropical evergreen forest with coastal fringes of mangrove forest and swamp forest where drainage is poor. North of the Isthmus of Panama the climate is drier and the soils are Orthic Luvisols associated with Planosols. Gleyic Fluvisols occur in the stream valleys.

Also in Colombia, but farther south, the upland plains are reported to consist mainly of red-yellow Ferralsols. Their relationship with the Ferralsols of Brazil is not known. The cation exchange capacity of the clay may be near the upper limit for typical Ferralsols. The influence of volcanic dusting, and subsequent weathering of volcanic glass, can be expected.

On some of the coastal terraces there are Orthic Acrisols and Podzols. Fluvisols, Gleysols and Solonchaks occur on the coastal plain. In Ecuador soils of high base status containing a high proportion of vulcanic ash occur as a narrow strip at the foot of the Andes at 400 to 600 metres altitude. Some of these may be Ochric Andosols. Ancient Dystric Nitosols, Lithosols and Fluvisols may be found near the coast. Vitric Andosols, Fluvisols and Eutric Cambisols also occur here. The soil pattern of the southern area changes toward the coast. The climate here is less humid, and Mediterranean-like soils (Chromic Luvisols) have been reported from the uplands and Vertisols from the lowlands.

### A7. Paraná/Paraguay basin

This is the third largest basin in South America after the Amazon and the Orinoco. Flattish landforms prevail, and poor drainage conditions are characteristic. The basin originated during Late Tertiary times and was subsequently filled with sediments.

In the Brazilian Pantanal, the northern part of the basin, the sediments are kaolinitic because they originate from the ancient strongly weathered Brazilian plateau. Toward the south calcium-rich sediments predominate. The Pantanal soils are mainly Dystric Gleysols, Plinthic Acrisols, Vertisols and Solonetz. Planosols have also been reported. On the better drained cerrado uplands Orthic Ferralsols and Ferralic Arenosols occur.

In Paraguay very flat areas with Planosols occur in association with saline soils. The climate here is considerably drier than in the Pantanal.

In the Argentinian part of the basin many Planosols are also found, but Vertisols dominate the soil pattern in the south. Luvic Phaeozems and Humic Gleysols are common with extensive areas of Fluvisols, Eutric Gleysols and Regosols near the border between Paraguay and Argentina and north of Buenos Aires.

### A8. South Brazilian and Uruguayan lowlands

This region is far from uniform and compares only locally with the Argentinian pampa although it is a natural grassland region.

Flattish land occupies perhaps half of the region, lying between the outcrops of the crystalline basement in the east, the Permian and other old sediments in the middle and basalt in the west.

In southwestern Uruguay loess deposits occur which give rise to Phaeozems with argillic B horizons. In places where the loess has been cemented with carbonates, Rendzinas occur. The lowland associates here are Solonetz and Mollic Gleysols. Pellic Vertisols also occupy important areas.

In eastern Uruguay the parent material consists of erosion products of the crystalline metamorphic and acid igneous rocks. Here associated soils include Phaeozems, the argillic B horizons of which may have reddish hues. Formerly the soils have also been named reddish prairie soils. Associated soils are Lithosols and Mollic Gleysols. In comparison to the pampean Phaeozems, the majority of Uruguayan Phaeozems are darker in colour, shallower and heavier textured and are not as well drained. Manganese and iron concretions are common in the subsoil.

In the coastal Laguna Merim zone of Uruguay and Brazil, the landscape is composed of a broad lowland plain bordering the lake with valleys extending inland. Ancient alluvial fans and lacustrine sediments are the chief parent materials. Dominant soils are Mollic Gleysols and Mollic Planosols.

In northern Uruguay on the border with Brazil, the landscape consists of hills and broad basins. The upland soils are derived from partly calcareous Permian sandstones and shales. Phaeozems of various textures are dominant and include what have been called sandy reddish prairie soils. The lowland soils are chiefly Vertisols, Mollic Gleysols, Mollic Planosols and some Eutric Gleysols. Also the association of Orthic Luvisols, Chromic Luvisols and Luvic Phaeozems occurs here, derived from Tacuarembo sandstone.

Northwestern Uruguay is the most elevated (300 m) and most dissected part of the country and is characterized mainly by very shallow soils. The parent material is basalt comprising horizontal diaclases which impede weathering and root penetration. Dominant soils are Lithosols, associated with Vertisols, Phaeozems and Mollic Gleysols.

Orthic Luvisols occur in association with the outcropping granites and metamorphic Precambrian rocks in S. Rio Grande do Sul and northern Uruguay. They are mostly rather shallow. Lithosols are also rather frequent.

### A9. Argentinian pampa

The pampa with its 500 000 sq km is the largest area of fertile soils in South America. It is a uniform region, covered with Quaternary sediments. The predominant parent material is the pampean loess, the texture of which becomes finer from west to east. Finer textured postpampean deposits occur in lacustrine depressions and streambeds. The sediments are calcareous and rich in plagioclase, hornblende, pyroxenes and volcanic glass.

The composition of these materials suggests a volcanic origin, probably from the southern Andes. There is evidence of fresh ash having been added in recent times.

Although remarkably uniform as a whole, certain differences can be observed between the northern, the eastern, and the southeastern and western pampean regions.

The northern pampa is more humid, and its relief is not as flat as in the other regions. The texture of the soils is finer, and Phaeozems with an argillic B horizon are dominant. Sometimes they intergrade toward Vertisols if the texture becomes heavy in the topsoil.

The western pampa has a drier climate, and the sediments are coarser. Phaeozems without an argillic B horizon occur in association with Regosols. Locally, sand dunes can be observed which are still actively moving. Gleyic Solonchaks, in association with Planosols, are common in the depressions.

The eastern pampa or depressed pampa has poor drainage as can be seen from the chain of lakes existing there. Dominant soils are Mollic Solonetz, Mollic Planosols and Mollic Gleysols.

Soils in the southeastern pampa are underlain at varying depths by a cemented calcareous layer, tosca. The tosca is probably a result of soil evolution and subsequent erosion during an earlier geological period. Deposition of the aeolian sediments in which the present-day soil developed took place later. Tosca is generally related to the undulations in the landscape and occurs under Phaeozems, Planosols and Solonetz.

### A10. Chaco and peripampa

This region consists of two parts which have very different climates: the hot semiarid Chaco in the north and the subtropical temperate peripampa in the south.

The Chaco is a huge outwash plain built up of sediments derived mainly from the eastern Andes. At least locally, sedimentation took place under lacustrine conditions. Because of the arid climate, primary minerals and soluble salts are abundant. During the dry season, strong winds redistribute salt crystals accumulated at the surface of salt spots. The formation of argillic B horizons through argilluviation, one of the predominant soil-forming processes in the region, is attributed to the easy dispersion of clay under the influence of salt. The heavy-textured subsoils make the area susceptible to inundation during the west season in the summer.

In this region reddish Kastanozems with argillic B horizons are dominant and are associated with Planosols and Solonetz. In the driest parts soils seem similar to the Haplic Xerosols. The Chaco soils have been shown on the map with a salic phase.

The peripampean region is a wide flat sedimentary plain dissected by wide valleys. Sediments are coarse-textured and show a volcanic influence similar to the pampean sediments. Soils are better drained than in the Chaco, while saline and alkali soils are less frequent. Nevertheless, there are large salt flats in the northern area. Kastanozems without argillic B horizons are dominant throughout the region and occur in association with Regosols.

Southwestward, toward the Patagonian Desert, the organic matter content of topsoils is less, and free calcium carbonate is frequent in the subsoil, mostly in the form of concretions. Xerosols occur here together with Regosols. Fluvisols associated with Solonetz, and Gleyic Solonchaks occur in the valleys.

## B. Soil regions of the uplands

The upland soil regions comprise old and stable landscapes of the ancient Brazilian and Guiana shields separated by the Amazon lowlands. The predominant feature of these landscapes is the occurrence of old erosion surfaces of various ages. These levels were created by prolonged past cycles of erosion and occupy characteristic positions in the landscape. Recognition of these surfaces is important for the understanding of the closely related soil patterns. Due to their ancient nature, correlation with the geological time scale is difficult.

The oldest erosion surfaces dating from the Mesozoic era are rare. Only in east Brazil do they form a meaningful element of the landscape. Northward and westward they decline and ultimately pass beneath an extensive cover of Upper Cretaceous sandstones deposited under continental conditions. Dominant soils are Lithosols and Ferralic Arenosols.

The Tertiary erosion surfaces are much more important. They are related to the early Tertiary Sul-Americana planation. The mantles of soil material that subsequently developed are extremely weathered and can be as old as 30 million years, dating back to the Mid-Tertiary. Such erosion surfaces have their greatest extent on the Central Brazilian Plateau, at a general altitude of 750 metres. Here the waste mantle can be up to thirty metres deep. The typical soils of such surfaces are Acric Ferralsols that are probably among the oldest soils of the world.

More recent erosion cycles have removed much of the early Tertiary surfaces, especially in the semiarid northeast and in coastal Brazil. This destruction has been particularly active during and after the Plio-Pleistocene cymatogeny which produced huge archings, coastal monoclines, basins and rift valleys. The topography is usually highly dissected, and the mantle of weathering products is much thinner than on the early Tertiary surfaces. Thick sediments may be found, however, in places where strong colluvial or alluvial deposition took place, as in the Paraíba rift valley.

Soils related to the young erosion surfaces have either cambic or argillic B horizons. Further profile development depends on the nature of the parent rock and on the prevailing climate. The most common soils are the Orthic Acrisols, but Ferric Luvisols, Eutric Nitosols, Chromic Luvisols and Dystric Cambisols also occur. Where the younger surfaces are transitional to older erosion surfaces in which they are carved, soils are sometimes intergrades between Orthic Acrisols and Ferralsols.

The landforms of central Brazil are older and better preserved than those of coastal Brazil. They are only slightly affected by the coastal upheaval. Moreover, the erosive force or the relief energy in central Brazil, including the Paraná, Paraguay and the Amazon drainage systems, is much reduced by the enormous distances to their coastal outlets. Large parts of central Brazil also consist of sedimentary formations which, when they are deep, are generally more permeable and therefore more resistant to geological erosion than most igneous and metamorphic rocks.

Rather young erosion surfaces may be present above the older Tertiary ones, where erosion has destroyed the oldest and highest planation surfaces. Certain resistant geological formations, often of Precambrian or Paleozoic age, rising above the level of the Tertiary surface, may also have given rise to more recent soil patterns. The layer of weathered soil material is mostly thin, especially over steep slopes and hard rock, like quartzite, and here Lithosols may become dominant. Common among the more developed soils are the Orthic Acrisols and Dystric Cambisols. Often the lower part of these soils has been formed in situ while subsequent colluviation or drift has been responsible for the deposition of a more recent top layer. Such a discontinuity can be recognized from prominent stonelines formed of the most resistant rock fragments. These stonelines, however, because of secondary influences, do not necessarily present themselves exactly at the divide between the two layers.

### B1. Guyana uplands

Various erosion cycles have modelled the Guiana shield (Guyana, Surinam and French Guiana) into a complex of extensive rolling to hilly crystalline uplands, level pediplains and mountainous highlands.

In the hilly crystalline uplands there are a number of erosion surfaces at various levels, which together have been described as the Guiana peneplain.

After the elevation of the Guiana shield during the Plio-Pleistocene cymatogeny, the older high-standing planation surfaces were attacked by intensive erosion, creating a young, highly dissected relief with initial pediplanation. In some places the ancient, strongly weathered mantle of soil material was only partly removed. In south Guyana for instance, where the old Kwitaro surface (300 to 360 metres) has been progressively dissected, shallow Ferralsols are common on steep slopes, sometimes with a high content of iron concretions. The concretions may have contributed to the conservation of the soils against erosion. Many hilltops are still covered by concretionary soils. Nearer to the coast of Guyana, dissection of the Plio-Pleistocene Rupununi surface has created an assembly of Ferralsols and Orthic Acrisols, the former in the better preserved mantle of sedimentary and residual materials, and the latter where erosion has exposed the underlying acidic rocks. The soils are often sandy and show an extremely low activity of the clay fraction and a very low sum of bases, remarkable for soils occurring in rugged topography. However, these polycyclic soil materials have been repeatedly weathered, transported and redeposited.

At a lower level a less dissected gradational surface can be recognized, further degraded by recent erosion. Here, deep clay-textured Ferralsols are the principal soils, but their occurrence is not widespread.

Hilly surfaces, representing the residual relief of tropical weathering of Precambrian rocks, mostly granites, are common especially in French Guiana and Surinam. The soils often show a marked increase in clay with depth. The climate here is typically subhumid and comprises two short dry seasons. In French Guiana the soils have been described as slightly leached Ferralitic; on the map they are included in the Orthic Ferralsols.

Where intrusions of basic rock occur, the related soils are more deeply weathered and often consist of Dystric and Eutric Nitosols. They are generally of low base status in the three countries.

The level pediplains of old age have only locally resisted erosion. Remnants of an old surface known as the Kopinang surface are present in the Pacaraima mountains on both sides of the upper Ireng river. Soils related to these very old plateaus are Ferralic Arenosols, which are sometimes gravelly. The poverty of the vegetation, an open grass cover, is probably due to the extremely low amount of plant nutrients.

Remains of the younger Kwitaro planation can be found in southern Guyana. The soils are truncated Plinthic Acrisols and Ferralsols.

In general both the crystalline uplands and the level pediplains have a natural vegetation cover of tropical forest.

The mountainous highlands cover a considerable part of the interior of the Guiana shield. Rising abruptly from the Guiana peneplain the Pacaraima mountains represent the most important part of these highlands with a sequence of plateaus separated by escarpments forming a series of levels from 300 to 2700 metres. The relief has resulted from uplifting, block-faulting and erosion of the flat-lying sedimentary rocks of the Roraima formation, which are dominantly Mesozoic sandstones and conglomerates. Acid sandy, sometimes gravelly, Ferralic Arenosols are predominant in this formation. However, where basic rocks have intruded Dystric Nitosols and some Eutric Nitosols may be found. In the Rupununi region the Kanuku mountains are another highland area, probably formed by block-faulting. Lithosols are the most common soils. Between these two highland complexes there is a graben filled in with Tertiary clastic sediments. This depressed area forms an undefined divide between the Essequibo and Amazon drainage systems. Predominant soils are Dystric Gleysols, Plinthic Acrisols and Fluvisols.

On the southern frontiers of the three former Guianas stands a low mountain range (Serra Acarai, Serra Tumachuma) representing a relic relief of an old pediplanation process which has formed the Kwitaro surface. As in the Kanuku mountains, Lithosols are the predominant soils.

### B2. Forested Amazon uplands of the Brazilian shield

This region is covered by seasonal tropical forest, and the climate is predominantly subhumid tropical. The soils are not well known. Topography is more subdued than on the Guiana shield except for a few mountain ranges forming water divides in the south. Generally these divides are flat-topped (mesas) and represent the remnants of the early Tertiary pediplanation surface. Very often they carry sandy deposits which have become extremely leached, resulting in Ferralic Arenosols as on the Serra do Cachimbo.

The greater part of the landscape, however, has been modelled by the action of a younger erosion cycle dating from the Upper Tertiary which has destroyed much of the Lower Tertiary surface. The dominant soils are Acric Ferralsols of very low cation exchange capacity and of very low base status. Heavy textured, dark red Ferralsols derived from shales and phyllites also occur, with Orthic Acrisols on some hill slopes.

Important intrusions of diabase and other volcanic rocks appear near the middle course of the Xingu river. In this remote and largely unexplored part of Brazil, extensive areas of Nitosols, at least partly of medium to high base status, probably exist in association with Lithosols and Orthic Ferralsols.

### B3. Central Brazilian depression

From the geomorphological viewpoint the name for this region is misleading, because extensive uplands (200 to 300 metres) are included. Again little is known of this distant and inhospitable area of huge marshes and dense forests.

The region probably originated as a depressed area in the Brazilian plateau during the late Tertiary, due to the orogenic movements which in the same period gave rise to the Andes. The sediments subsequently deposited originated from the surface of the Brazilian plateau and form a rather shallow layer over the Precambrian crystalline rock. They contain much coarse material, suggesting a relatively dry climate during the deposition, perhaps an interpluvial of the Pleistocene. The heavier materials are kaolinitic and are similar to the sediments deposited in the Amazon basin. Soil formation during the Pleistocene probably took place under extreme weathering conditions, similar to those of the Guiana shield, as soils with ferruginous concretions are widespread. Fluctuating water tables and seasonally water-saturated soils can be expected in sedimentary basins like this with a hot humid climate. With the gradual uplift, the soils later reached a better drained position in the landscape. In the soil regions in the cooler and less humid area in the south of Brazil, iron concretions become rarer, and they are virtually absent in the state of São Paulo.

The concretionary soils of the higher terraces often show podzolization in the topsoil and can be classified as Orthic Acrisols (petric phase). They occur in association with Ferralic Arenosols and Dystric Gleysols.

### B4. Central Brazilian cerrado uplands

The cerrado vegetation is a characteristic open formation consisting of low shrubs and trees and a patchy grass cover. It dominates central Brazil, extending on the fringes into Maranhão, Baía and São Paulo states. Locally the monotony of the vegetation is broken by occurrences of grass savanna or "campo limpo" or by seasonal tropical forest. The climate is subhumid tropical with a dry season of five to seven months during the summer. By far the greatest part of the region consists of ancient, level to gently undulating planation surfaces, most of which belong to the early Tertiary erosion surface. In association with these, younger erosion forms have penetrated to the heads of all the hydrographic systems.

The soils related to the well-preserved ancient erosion surfaces are Ferralsols which have been included in the legend as Acric Ferralsols, cerrado phase. Among themselves they may differ, but it can be expected that a high proportion can be correlated with the so-called Acrorthox of the United States classification. They are Ferralsols with extremely low cation exchange capacities and are very low in bases, particularly calcium. They are mostly deficient in phosphorus, sulfur, zinc and boron.

On the fringes in south Maranhão and in São Paulo, Ferralsols with cerrado vegetation are not as low in bases and exchange capacity as they are in central Brazil.

Associated with the cerrado Ferralsols, extensive areas of Ferralic Arenosols are present over Cretaceous continental sandstones, as on the Serra dos Parecis, Serra do Roncador and the tablelands of West Baía. The vegetation on these reddish-yellow quartz sands is sometimes even sparser than on the heavier-textured Ferralsols, becoming locally entirely devoid of shrubs and trees.

The areas covered with forest are less extensive but important for human settlement. They occur on younger landscapes such as the elevated crystalline formations or erosion-susceptible scarps of tablelands. Considerable areas of forest occur in the Mato Grosso region of the state of Goiás. The forests grow on the more elevated dark red Ferralsols developed over crystalline rock. These soils have a medium base saturation in the topsoil, decreasing with depth. Here Acric Ferralsols, cerrado phase, occur at a lower level and as usual are related to a more stable ancient erosion surface. Other soils which may be found in more dissected topography and often derived from acidic crystalline rocks are Orthic Acrisols, which become more frequent toward the south, and Ferric Luvisols, reported to occur in the Alto Paranaíba region, the Alto Araguaya region, and the south of Mato Grosso. The latter may include Ferric Acrisols, but in the absence of data on their base saturation they are all called Luvisols. Also in the south of the cerrado region the Mesozoic Trapp formation, consisting of basalt, has been brought to the surface by the dissective action of the Paraná river system. There the soils are for the greater part highly weathered Rhodic Ferralsols with cerrado vegetation. Where these soils are related to old erosion surfaces they appear to be similar in chemical and physical characteristics to the Acric Ferralsols, cerrado phase, except for the high iron content (including magnetite) and the typical dusky red colours. Near the river courses some Eutric Nitosols appear on the steep banks of the river valleys. Finally, Lithosols associated with Ferralic Arenosols and sometimes Dystric Cambisols occur in residual mountain formations consisting of very hard rocks like quartzites and sericite quartzites. These complexes are common in the eastern extensions of the cerrado region and in the surroundings of the Federal District.

### B5. Atlantic uplands of Brazil

This region is of predominantly rolling to hilly topography with some high mountain ranges such as the Serra da Mantiqueira and Serra do Mar rising over it. The climate is subhumid tropical with the exception of some places along the coast which have an ever-humid moisture regime. The predominant vegetation is a seasonal tropical to wet evergreen forest near the coast. Much of the original vegetation has been removed by farmers and is now replaced by grassland.

Strong degradation of the Tertiary erosion surfaces has taken place during and after the Plio-Pleistocene uplift of the eastern part of the Brazilian shield. This has resulted in today's young hilly topography, with most of the drainage ways running toward the west where they join the Rio São Francisco and Paraná systems. Only on the coastal edge of the region do the rivers run directly toward the sea. Here dissection has been strongest. Along the coast there is a natural barrier of uplifted Tertiary marine sediments, known as taboleiros.

The extensive landscapes of rolling to hilly topography are sometimes referred to in the Brazilian literature as "seas of hills." They are by far the most widespread feature in this soil region and represent a rejuvenated landscape carved in the older pediplains. The predominant soils, relatively young, are related to the sloping land and belong mostly to the Orthic Acrisols. At a higher level, partly on remnants of the older erosion surface but mostly on a somewhat renewed mantle of polycyclic soil material, Orthic Ferralsols can be found. It is not uncommon to find intergrades between the Ferralsols and the Orthic Acrisols, similar in morphology to the Dystric Nitosols, except for their colour. Their position in the landscape is also transitional between these soils, being in places where mixing of somewhat weathered soil materials could take place.

On the youngest erosion surfaces, Ferric Luvisols and Eutric Nitosols can be expected. Such soils support much of the cocoa production in coastal Baía where the topography is hilly and erosion has removed most of the old waste mantle.

For humid tropical conditions Cambisols, exceptionally high in bases and phosphates, are the best cocoa soils of the region. West of this area, and under drier conditions, Luvic Phaeozemlike soils derived from acid igneous and metamorphic rocks occur. These show a remarkably intensive homogenization by earthworms.

Near the boundary with the central southern region (B8) there are gravelly Ferric Luvisols, derived from granite, with an argillic B horizon and sometimes a high base saturation.

The forested mountain ranges include many Lithosols and Dystric Cambisols. At altitudes above 2300 metres in Campos do Jordão in the Serra do Mantiqueira, the natural vegetation changes from the different types of montane forest to grassland and the soils are Humic Cambisols, apparently similar to those found above the treeline in the high humid Andes. Associated soils may include Podzols and Lithosols.

The fringe of coastal formations draining directly eastward to the Atlantic becomes wide in São Paulo and Paraná states. Here the major soils are Orthic Acrisols with Orthic Podzols, some of which, after removal of the iron pan by groundwater, now appear to be Gleyic Podzols.

The taboleiros near the coast carry on their flat tops Xanthic Ferralsols, similar to those described for the Amazon region, which become heavier textured toward the north. In coastal northeast Brazil most taboleiro soils are Orthic Acrisols.

Finally there are the usual low-lying coastal areas with high water tables. Soils occurring here include Humic Gleysols, Dystric Gleysols and Gleyic Acrisols. Fluvisols are also found. The occurrence of coastal blocks, isolated hills and mountains contributes to the spectacular setting of the coastal scenery.

Dystric Regosols and limited areas of Podzols have developed on the sands of coastal dunes and bars.

### B6. Northeastern Brazilian uplands

This region is dominated by the semiarid caatinga vegetation formation, consisting of a complex of cacti scrubland and thorny woodland. However, seasonal forest occurs in the mountains, in the escarpments separating the plateaus, and in the river valleys and humid depressions with high water table. Cerrado vegetation is also present, especially on tablelands composed of Tertiary and Cretaceous rocks as, for example, near Tucano, Baía.

In general, the relief is gently undulating, broken only by escarpments, isolated mountains and hills with steep slopes (inselbergs). In this region, upstream from Juazeiro, the Rio São Francisco valley, with a general width exceeding 50 km, is a remarkable element in the landscape. It was formed by rifting in the crest of the Plio-Pleistocene cymatogen. In general, however, the landscape is only slightly dissected by fluviatile action, so that alluvial deposits occupy only narrow strips of land. The relief is mainly the result of long-lasting pediplanation processes under semiarid conditions. These processes are still active.

In some elevated parts like the Planalto da Borborema and the Serra do Araripe, different erosion surfaces stand at distinct levels. The undulating plateau, 600 to 800 metres high, between Teixeira in the west and Campina Grande in the east in the Borborema massif, was probably levelled by the early Tertiary erosion cycle. This surface has a weathering mantle of about 20 metres of kaolinitic clays capped by a sandy ferruginous crust. In the Serra do Araripe the flat tops have Xanthic Ferralsols of low base status developed over Cretaceous ferruginous sandstones. The rainfall is higher, and the vegetation resembles the tall cerrado or cerradão.

In southern Piaui, Ferralsols occur on the chapadas over Paleozoic and Triassic sedimentary rocks, reportedly with a caatinga vegetation. They have been shown as Orthic Ferralsols on the map. Their base status is unknown but if it is medium to high, both in the surface and subsoil, a general correlation seems justified between the caatinga vegetation and soils with a strong seasonal water deficiency and at least a medium supply of bases.

The levelled elevated country in other parts of the region consists of Cretaceous or older sandy sedimentary rocks. A huge sandstone plateau occurs east of the town of Floresta and extends southward far into Baía state. The soils are mainly Regosols, associated with Vertisols (derived from the heaviest sediments), Solonetz and Lithosols.

The Quaternary pediplains in the west of the region still carry a considerable amount of siliceous sediments, while stonelines and hard ferruginous concretions are also common. Here the soils resemble the Ferric Luvisols. Where the sedimentary layer is deep, Orthic Ferralsols with base saturations above 50 percent in the B horizon have been described locally as caatinga Latosols. Regosols are found in association.

Where the sedimentary cover has been eroded the ancient Precambrian metamorphic rocks become exposed, and Chromic Luvisols and Lithosols occur. Toward the east and north these soils are probably predominant. They intermingle with their eroded phases and with moderately deep alkaline soils, mostly Solodic Planosols.

Quartzitic stones can often be found on the surface, while quartzitic Lithosols are associated rather frequently with Precambrian siliceous outcrops.

Locally, Silurian limestone formations come to the surface as in the area south of the town Juazeiro in northern Baía. The related soils include Vertisols and Rendzinas.

There is a narrow transitional strip called "Agreste" on the boundary with the more humid coastal uplands. Here the rainfall averages 800 to 1000 mm, and the vegetation is deciduous forest with many leguminous trees. The soils have high base status and generally argillic B horizons. Textural changes are less abrupt than in the Chromic Luvisols, and topsoils do not become so hard when dry. The occurrence of Terra Preta soil, which has a thick, black, extremely acid A horizon, over a finer textured, acid B horizon, is interesting. One wonders if a special type of vegetation or prolonged previous cultivation could be a factor in the formation of this exceptional soil.

### B7. Transitional tablelands of northeast Brazil

This region has a transitional position between the humid forested lowlands of Amazonia, the thorny woodlands and cactus scrublands of semiarid northeastern Brazil and the savannas of central Brazil. Yet it is characterized by the frequent occurrence of palm forests, which are mainly composed of the important Babaçu (*Orbignya martiana*) and Carnaúba (*Copernicia cerifera*) palms. Mixed seasonal forests, varying from semievergreen in the northwest to deciduous in the southeast, are also common.

The typical landscape of somewhat dissected tablelands and mesas of gentle relief extends into the adjacent soil regions. It has been developed from sediments of Paleozoic and Mesozoic age which were deposited in a huge basin in the Brazilian shield (Maranhão basin). Subsequent pediplanation under semiarid conditions produced an erosion surface which can still be recognized from the flat tops. Later fluvial dissection produced a variety of valleys which become deeper and steeper toward the south.

The soils related to the higher tablelands are mostly Ferralic Arenosols associated with sandy yellowish Ferralsols. The latter resemble the caatinga Ferralsols, but the base saturation is lower. Toward the coast and related to the slopes in more strongly expressed relief, concretionary soils are common, mostly associated with Arenosols and locally with Lithosols. The dissected hilly topography between the Parnaíba and Itapiouri rivers contains extensive Ferric Luvisols, some of which are concretionary. Here the lowest positions are occupied by sandy Eutric Gleysols of medium to high base saturation.

The broad valley of the Itapiouri river consists of Gleysols and Fluvisols. Nearer to the coast Plinthic Acrisols and Plinthic Luvisols are widespread, while fringing the coastline Gleyic Solonchaks occur.

### B8. Central southern Brazilian uplands

The climate of this region is tropical subhumid with a dry period of 3 to 5 months during the winter. Frosts may occur, especially toward the south.

Most of this region, forming a part of the Paraná drainage basin, was originally a huge depression in the Brazilian shield which was filled up during the Mesozoic with clastic sediments and basic volcanic rocks.

The region consists mainly of gently undulating uplands, broken by cuestas in the more elevated eastern part. The old erosion surfaces, formed after the general uplift in the late Cretaceous, consist mainly of sandy sediments belonging to the Cretaceous continental Bauru formation. However, the underlying basalt has been exposed again over extensive areas by the action of a subsequent erosion cycle which created broad valley systems, incised by 100 metres or more, in the Paraná drainage basin.

The Bauru sandstone is often cemented by calcium carbonate, a feature which is more common toward the east. Sandy Ferric Luvisols on the calcium-rich sandstones are common. Where the Bauru sandstone has no calcareous cement, soils are mostly sandy, dark-red Orthic Ferralsols which grade into the landscape of the cerrado region toward the west, where the Ferralsols are less "acric" than those of central Brazil.

The soils developed over the old basalt surfaces are Rhodic Ferralsols, dusky red with a high iron content. Although the base status is low, it is higher than that of the Orthic Ferralsols developed from sediments and acid or intermediate rocks. The Rhodic Ferralsols have played an important part in the development of the states of São Paulo and Paraná. Where erosion has washed away most of the old sedimentary mantle, soils developed on basalt are much younger. They have been named Terra Roxa Estruturada soils in Brazil and belong to the Eutric Nitosols. Their nutrient supply is high. They are usually associated with rather steep slopes where erosion is a serious problem. Their greatest extent is in northern Paraná where they occur in association with Rhodic Ferralsols. Here the aeolian Caiuá sandstone, deposited over the basalt and sloping down toward the Paraná river, increases its influence toward the southwest ("norte novissimo") where it gives rise to Eutric Nitosols mixed with sand, sandy dark red Orthic Ferralsols, and sandy Orthic Acrisols and Ferralic Arenosols.

In eastern São Paulo, in the highest parts of the region near the boundary with the crystalline coastal uplands, the usual combination of levelled ridge crests and incised broad valley systems rises from 550 metres in the north to 700 metres in the south. Here it merges into the Ponta Grossa planalto of the planalto region in south Brazil. The parent material here consists of sediments of Paleozoic age which arch around the eastern limit of the Mesozoic basin. Soils in the most northern part are sandy Acric Ferralsols with a cerrado vegetation. Toward the south, in the Medio Tietê, the old surfaces have been dissected. The soils of the sloping country consist mainly of sandy Orthic Acrisols with Rhodic Ferralsols in the level and older parts of the landscape. In the south where the vegetation is grass savanna (campo limpo), clay-textured dark red Orthic Ferralsols developed over shales are predominant. They differ from the Acric Ferralsols of central Brazil in having higher cation exchange capacities.

### B9. Southern Brazilian planaltos

This region also consists of a series of neo-Mesozoic and Tertiary planation surfaces, subdivided by rivers running east-west. The surfaces have been carved in a Jurassic basalt formation. Unlike the São Paulo region, the more recent overlying sediments here have been entirely removed. The basalt formation has a total thickness of 600 to more than 1000 metres and represents the widest area of basalt outflow in the world.

From the Paraná basin to the high plateaus in the east the elevation of the country rises gradually, but locally there are more abrupt steps. The descent to the Atlantic coast is often abrupt and precipitous (Serra Geral escarpment). The climate is semitropical with hot summers and cool winters, frosts being common. Humidity ranges from humid in the east to subhumid toward the west.

The characteristic vegetation for most of the region is the coniferous *Araucaria angustifolia* forest. This is generally separated sharply from the other vegetation types (including tropical forests and grasslands) and is closely related to the temperature regime, which in turn can be related to the altitude.

With regard to soils, the following broad plateau levels are important: above 900 metres, 900-400 metres, 400-200 metres. The strongly dissected river valleys and scarps are also important landscapes, as are the peripheral areas. Some of these, like the Curitiba planalto and the Ponta planalto in Paraná, are not related to the basalt outflow.

1. *Plateau land above 900 metres: the grassland plains of high altitude*

These gently rolling plains contain soils which are on the borderline for classification as Ferralsols. On the map they have been indicated as Humic Ferralsols. The prevailing cool, wet and cloudy weather is reflected in the strongly developed acid A horizons. The subsoil is different from Ferralsols of the tropical environment in presenting some cracking, while irreversible drying is also indicated by laboratory analyses. The soil colours are yellowish rather than red even though there is a high percentage of iron oxides. The clay of the subsoil does not disperse in distilled water. Cation exchange capacity may be greater than the Brazilian limit for Latosols of 12.5 me/100g clay, but is less than the 16 me percent limit for the Oxisols (U.S. Department of Agriculture Soil Survey staff, 1960). The percent base saturation is low, and there is a relatively high content of free aluminum (4 to 6 me/100g soil). These Ferralsols may intergrade into Humic Cambisols. Locally, at the highest level, Podzols with thin iron pans occur, a most uncommon phenomenon on basaltic rock. These Podzols also have free aluminum and show a certain smeariness which may indicate the presence of allophane clays and a relationship to Andosols.

2. *Plateau land of 900 to 400 metres: the* Araucaria *forest planalto*

This area is the most characteristic and the most extensive of the soil region. The topography varies from gently undulating to rolling and appears locally to be hilly. The occurrence of *Araucaria*, although restricted to specific climatic conditions, is related to its rather demanding soil fertility requirements which include at least a medium content of calcium. This may explain its absence in certain areas, mostly grasslands, where the climatic conditions seem to be suitable for its growth.

The predominant soils of this part of the planalto region are again Ferralsols belonging to the Humic Ferralsol unit. They differ from the Humic Ferralsols described earlier for the higher plateaus in having slightly lower cation exchange capacities (6.5 to 12.5 me/100g clay) and in having reddish colours in the topsoil. The subsoil becomes hard when dry and may show some structure and pressure faces when clay-textured. These Ferralsols may also have a high free aluminum content. Locally, Triassic aeolian sandstone which underlies the basalt comes near the surface and the soils are more sandy than usual. In the more hilly country Dystric Nitosols have developed in more recent waste mantles.

3. *Plateau land of 400 to 200 metres with grasslands and tropical forests*

Here the *Araucaria* forest disappears and gives way to tropical forest and grassland. Soils are rather similar to the Rhodic Ferralsols described for the more tropical soil regions of Brazil, but the organic matter content is higher. Other soils which may occur are Eutric Nitosols, Dystric Nitosols, and sandy Orthic Acrisols where sandstone dominates in the composition of the parent material.

4. *Strongly dissected planalto and scarps*

This area is mainly made up of the mountainous areas along the major Uruguay and Igaçau Rivers, the steep descents on the southern limits of the planalto, and the Misiones region of northern Argentina.

In the wind-protected river valleys temperatures are relatively high and the vegetation is tropical forest. This is the youngest landscape of the region, and the soils are mostly developed on steep slopes. They are high in bases, have high cation exchange capacities, and strongly developed $A_1$ horizons. Where deep enough, argillic B horizons are common with reddish colours. The latter have also been called reddish prairie soils and on the map have been included in the Phaeozem unit.

The associated shallower soils vary from Eutric Cambisols to Lithosols.

5. *Peripheral areas*

In the south, near the Paraná river, and related to the basaltic Trapp formation, Dystric Nitosols occur in association with Humic Gleysols, Vertisols and Plinthic Gleysols. In Argentina these soils are Eutric Nitosols.

In the north the planaltos of Curitiba and Ponta Grossa have been included in this soil region because of their similarity in altitude, climate, vegetation and topography.

The Curitiba planalto, standing at more than 900 metres altitude and gradually dipping toward the west, is a complex of old erosion surfaces cut across the Precambrian crystalline rocks. Locally, the planalto carries a layer of fluvic-lacustrine Tertiary sediments. Where these sediments consist of shales, so called Rubrozem soils occur which can be correlated with the Humic Acrisols. These are not the dominant soils of the Curitiba planalto, but they have some remarkable characteristics. They have strongly developed black $A_1$ horizons, reddish brown to red argillic B horizons and extreme acidity due to their almost complete saturation with free aluminum. Dystric Cambisols are more common and occur in association with Rankers and in some places with Humic Cambisols.

The Ponta Grossa planalto, standing between 700 and 900 metres, is formed over Paleozoic sediments, of which the karstic Furnas sandstone is the most widespread. Steep scarps form a characteristic divide between the Curitiba planalto in the east and the basaltic planaltos of northern Paraná. Toward São Paulo the descent of the Paleozoic sediments which here reach their highest point is gradual.

Associated soils in general have a high free aluminum saturation. They include shallow Humic Cambisols, red Humic Ferralsols and Podzols.

## B 10. Southern Brazilian and Uruguayan Prairies

This region is far from uniform and compares locally with the Argentinian pampa in being a natural grassland region. Flattish land occupies less than half the region, lying between the outcrops of crystalline basement in the east, Permian and other old sediments in the middle and basalt in the west.

In southwestern Uruguay loess deposits occur, giving rise to Phaeozems with argillic B horizons. In places where the loess has been cemented with carbonates, Rendzinas occur. The lowland associates here are Solonetz and Mollic Gleysols. Pellic Vertisols also occupy important areas.

In eastern Uruguay the parent material consists of erosion products of the crystalline metamorphic and acid igneous rocks. The associated soils include Phaeozems, the argillic B horizons of which may have reddish hues and which have also been named reddish prairie soils. Associated soils are Lithosols and Mollic Gleysols. In comparison to the pampean Phaeozems, the majority of Uruguayan Phaeozems are darker in colour, shallower and heavier textured, and are not as well drained. Manganese and iron concretions are common in the subsoils.

In the coastal Laguna Merim zone of Uruguay and Brazil, the landscape is composed of a broad lowland plain bordering the lake with valleys extending inland. Ancient alluvial fans and lacustrine sediments are the chief parent materials. Dominant soils are Mollic Gleysols and Mollic Planosols.

In northern Uruguay on the border with Brazil, the landscape consists of hills and broad basins. The upland soils are derived from partly calcareous Permian sandstones and shales. Phaeozems of various textures are dominant and include what have been called sandy reddish prairie soils. The lowland soils are chiefly Vertisols, Eutric and Mollic Planosols and Mollic Gleysols. Also the association of Orthic Luvisols, Chromic Luvisols and Luvic Phaeozems occurs here, derived from Tacuarembo sandstone.

Northwestern Uruguay is the most elevated (300 metres) and most dissected part of the country and is characterized mainly by very shallow soils. The parent material is basalt comprising horizontal diaclases which impede weathering and root penetration. Dominant soils are Lithosols, associated with Vertisols, Phaeozems and Mollic Gleysols.

Orthic Luvisols occur in association with outcropping granites and metamorphic Precambrian rocks in Rio Grande do Sul State and Northern Uruguay. They are mostly rather shallow and are frequently accompanied by Lithosols.

## B 11. West and south Argentinian uplands

Three different zones can be distinguished in this heterogeneous region:

### 1. *Central Argentina and Patagonian steppe*

This vast area consists of tablelands, basins and plains incised by wide valleys. Where a cover of more recent material occurs, this is mostly the result of volcanic dusting. The climate is desertic, rainfall varying between 100 and 200 mm/year. In the south strong winds are typical. The vegetation consists of bushy steppe with scattered grass tufts and low thorny shrubs.

The soils are weakly developed due to the dry climate. In the north they are formed mostly from more recent accumulations of sediment, and barren sand dunes are common. Noncalcareous sandy Regosols occur together with calcareous greyish Yermosols without argillic B horizons. In the depressions Solonchak and Solonetz soils are common. Lithosols are frequent near the Argentine Andes.

In the south, tablelands have been formed over the Precambrian Patagonian shield. Unlike the landscapes of the Brazilian and Guiana shields, the landscape of the Patagonian shield developed during the Tertiary and Quaternary under a depositional rather than under a denudational regime. Extensive flows of Pliocene and Quaternary basalts and the deposition of Tertiary and Quaternary sediments of marine, aeolian and fluviatile facies also occurred. Although old erosion surfaces appear to be present, their history is much obscured by volcanic emissions.

Soils of the tablelands are often covered by a desert pavement. Here the older soils are mainly reddish Yermosols with finer textured subsoils which show little evidence of clay movement. These soils are only weakly calcareous at most, but they may overlie a layer cemented with calcium carbonates and salts. They occur in association with Regosols. Lithosols occur on steep slopes. The broad valleys include Fluvisols, known locally as "Mallinsoils," and Gleysols and Histosols may also be found in some of the southern valleys.

2. *Southeast Andean foothills*

This landscape is transitional between the Patagonian Desert and the Andes. Toward the west the vegetation changes gradually from thorny woodland to temperate *Nothofagus* forest. Annual rainfall increases to 500 mm in the west, and topography becomes hilly to mountainous. Soils are derived mainly from colluvial materials. They are not well known but seem to include Eutric Cambisols, Humic Cambisols, Andosols, Regosols, and Lithosols.

3. *Southern Patagonia and Tierra del Fuego*

In the coldest lowlands of Argentina, also known as the Patagonian prairie, vegetation consists of tall tuft grasses. Annual rainfall is between 250 and 350 mm. Parent material for the soils are Eocene and Oligocene marine deposits and glacial Quaternary materials. They give rise mainly to shallow soils which resemble Rankers and which contain high amounts of nondecayed roots. Histosols occur in depressed positions. Other soils mentioned for this region include Phaeozemlike soils, shallow dark clay soils similar to Rendzinas, and Vertisols, Gleysols and Planosols.

## C. Soil regions of the Andean mountain ranges

The Andean mountain ranges are composed of a western range of marine Mesozoic and more recent volcanic rocks with an elongated batholitic core and an eastern chain of folded sedimentary, often Paleozoic rocks with scattered older granite and schist outcrops.

Both the eastern and western flanks are steep, but between the extensive plateaus (mostly of volcanic origin) intermontane basins with internal drainage and inter-Andean valleys running parallel to the ranges represent areas with more gentle relief.

The formation of the modern Andes began during the early Pleistocene and is the result of a forceful uplift of the whole region accompanied by blockfaulting. Before this uplifting and during the late Tertiary, all preexisting mountain ranges formed during earlier sets of movements were reduced to a rather level surface (the Puna surface). Remnants of this initial surface of the uplift appear on the western and eastern front ranges of the central Andes, regularly rising toward the central Puna de Altiplano. Moreover, at least two marked pauses in the uplift of the Peruvian and Bolivian Andes have left their imprints in the form of partial plains and terraces along the rivers.

The moisture regime varies widely from superhumid on the slopes facing the Amazon basin, humid on the Pacific coast and in most of the Patagonian Andes, to desertic in the central and western part.

Soil-forming processes in these youthful unstable landscapes are dominated by intensive erosion and sedimentation, interrupted locally by seismic adjustments and volcanic activity. Thus, most soils show weak profile development. Truncation and accumulation of colluvial materials are common. Horizontal banding in the soil profiles is often an inheritance of stratified parent materials. Classification, therefore, is extremely difficult. Local systems of soils classification are based largely on parent materials, dominant type of clay, texture and base status.

### C1. Northern Andes

This region has a humid climate, but many inter-Andean valleys have local climates that are subhumid to semiarid. Temperatures may vary considerably over short distances. Most of the region is covered with forests arranged in a number of altitudinal belts. Volcanic rocks form the principal parent materials in the west, but in the eastern section soils are commonly derived from sedimentary rocks, including limestone. In the north the eastward branching Venezuelan Andes, ending in northern Trinidad, include large areas of Mesozoic metamorphic rocks.

At the highest level, between 3500 and 4500 metres, equatorial subalpine shrub and grassland plains are common. The soils derived from volcanic material are Ochric Andosols mostly of low base status. Soils may also be derived from glacial deposits with some mixture of volcanic ash in the upper part of the profile. They have strongly developed, dark, acid topsoils and have been placed in the Humic Cambisols.

The steepland soils comprise many Lithosols and shallow Dystric Cambisols. The somewhat drier inter-Andean valleys consist mainly of stony Kastanozems, Phaeozems and Lithosols. In addition, Chromic Luvisols, Vertisols and Solonetz soils are present in the driest valleys. North of Quito an important dry area with Vitric Andosols occurs. The southeastern ranges of the region are highly dissected and have a cloudy, superhumid cool climate. They belong to the so-called Yungas of Bolivia. Parent materials consist mainly of sandstones and claystones. Apart from Lithosols, which are dominant, Dystric and Eutric Cambisols, Podzols and Histosols occur.

### C2. Eastern ranges and foothills

The eastern wall of the Andes which faces the Amazon and Orinoco drainage basins is quite precipitous. Valley systems are few and mountain ranges steep. In Ecuador part of the region is thickly mantled with recent volcanic ash, while elsewhere sedimentary and igneous rocks of different ages prevail. The climate is humid, and the natural vegetation consists of definite altitudinal belts of forest, varying from montane temperate at the highest, to equatorial at the lowest level.

At high altitude Lithosols are predominant in association with Dystric Cambisols and, in Ecuador, with Andosols. Below approximately 200 metres soils are mainly Orthic Acrisols, Eutric Nitosols and perhaps Humic Ferralsols, similar to those of southern Brazil. In the Madre de Dios region extensive areas consisting of Dystric Regosols associated with Lithosols occur between 450 and 1200 metres.

### C3. Western ranges and foothills

This region covers the arid and semiarid western part of the Andean Cordillera, together with the extremely arid and saline desert of the Pacific coastal lowlands. Its altitude ranges from sea level to about 3500 metres. Aridity is directly associated with the dehydrating effect of the cool Humboldt current flowing northward along the Pacific coast which intersects and condenses most of the moisture in the airstream flowing from the west.

Vegetation is almost absent near the Pacific coast. However, west-facing slopes between 150 and 1000 metres have a sparse vegetation supported by moisture condensing from sea fogs. Further inland the rainfall is scanty and irregular (0 to 250 mm), and the resulting xerophytic vegetation ranges from sparse cacti in the north to thorny woodlands in the south.

The region can be subdivided into: the Chilean desert, the Peruvian lowlands, and the western desertic mountain ranges.

1. *The Chilean lowland desert* is the most arid part of South America. The greater part is devoid of vegetation, and salt plains are common. This landscape, which has a general elevation of more than 1000 metres, is composed of valleys filled by gravel beds, low hills of indurated sedimentary rocks and granites, and some fragments of old erosion surfaces littered with boulders.

The soils are mainly regosolic and lithosolic Yermosols. Solonchaks occur in the lowest parts, where saline water tables stand near the surface.

2. *The Peruvian lowland desert* includes broad pedimentary dry plains, interrupted by alluvial valleys, coastal hills and elevated marine terraces. In south Peru soils are derived from volcanic ash (Vitric Andosols). In the far north a large area of desertic dune sands occurs (Eutric Regosols). A remarkable feature in this region is the presence of real xerophitic "Lomas" forest in favourable sites at elevations between 500 and 700 metres. At this altitude persistent fogs frequently occur, so that the trees can condense a considerable quantity of moisture from the air. Most of this forest has now been consumed as domestic fuel.

Soils are mainly Regosols and Lithosols, with minor occurrences of Yermosols, Fluvisols and Solonchaks.

3. *The western desertic mountain ranges* extend from northern Peru to central Chile and range in elevation from over 1000 to 5500 metres. The climate is arid to semiarid, and the vegetation ranges from scattered cactus formations to a more dense xerophytic scrubland at the higher elevations.

Most soils are Lithosols and Regosols, but on the more stable landforms Yermosols with lime-enriched subsoils are common (Calcic Yermosols). Toward the east, soils with thin subsurfaces showing an increased clay content may be found (Luvic Yermosols). In southern Peru, where the parent material is volcanic, Lithosols and Vitric Andosols occur in close association.

### C4. Andean altiplano

The Andean altiplano is a huge high-level intermontane basin at elevations above 3500 metres. Nowadays this basin, which is possibly produced by block-faulting during the uprise of the Andean ranges, is floored with the sediments of shrunken or extinct lakes (Titicaca and Poopó Lakes and the great relict salars).

The altiplano can be subdivided into a subhumid, a semiarid and an arid part.

The subhumid altiplano is located in the vicinity of the fresh water Lake Titicaca. Rainfall is spread over three or four summer months. The landscape around the lake is mainly flat with Mollic Gleysols and, in the depressions, Solonetz and Solonchak soils. Beyond the flats the general surface is at a mean elevation of 3800 metres and has an undulating to rolling topography. North of the lake volcanic parent materials are common, and the dominant soils are Mollic Andosols associated with Gleysols, Histosols and Humic Cambisols.

Many of the soils are of moderate to heavy texture. At the southern border of Lake Titicaca Kastanozems are common in association with shallow Rendzinas and Lithosols.

The semiarid altiplano comprises broad salt flats, where crystalline deposits of soluble salt are distributed over the area. The landscape is mainly undulating to rolling with a mean elevation of 3750 metres. Many isolated volcanic peaks rise far above this, some of them reaching more than 6000 metres. The most widespread soils are perhaps the soils formed from volcanic ash, with distinct dark sandy topsoils (Vitric Andosols). Their colour is probably due to the prevailing grass vegetation. Lithosols and Xerosols occur more to the west, where parent materials include nonvolcanic materials such as lacustrine, aeolian and fluvial sediments.

The arid altiplano is found in the southwestern extent of the altiplano. Much of the landscape is without vegetation. Dunes and long narrow salt flats are common.

Volcanic ash of various ages and mineralogical composition has a strong influence on the soil pattern, and there are large areas of Vitric Andosols. However, other soils, sometimes with argillic B horizons, occur (Luvic Yermosols). In Chile most soils are said not to have the dark brown topsoils and to be calcareous only in the pale yellowish brown subsoils. Textures are seldom heavier than light clay loams.

The Vitric Andosols are derived usually from coarse pumiceous sand, which gives rise to rather uniform soils over wide areas. Sometimes andesitic ash and basaltic sands form the parent material. Allophane content is low, except in some of the oldest buried andesitic ash layers, and in general there is no sharp distinction between the soils derived from volcanic ash (Vitric Andosols) and those which have other parent materials (Yermosols, Regosols).

### C5. Central eastern Andes

This highly dissected mountainous region which faces the Gran Chaco lowlands shows a marked increase in rainfall from the eastern foothills, which are semiarid, to the west, which is humid. The natural vegetation is mainly composed of montane forest formations which form the southern extension of the tropical Andean mountain forests. There are some important intermontane valleys and relatively extensive alluvial plains. In the eastern part, which has light summer rains, soils show an increased clay content in the subsoil. These are classified as Orthic Luvisols and Chromic Luvisols with a predominance of Lithosols. Toward the west there are Eutric and Dystric Cambisols, also associated with Lithosols.

The valley soils are mainly heavy-textured Fluvisols with local areas of Solonetz and Vertisols. Many are calcareous throughout the profile, but in the extreme north some soils formed from acid sandy sediments show distinct evidence of leaching and resemble Orthic Acrisols. Dystric Regosols are also probably more extensive here.

### C6. Southern Andes

South of the 30°S parallel the altitude of the Andean ranges declines gradually from 4000 metres in the north to 2000 metres in the south, becoming increasingly dissected by sea fjords and transverse valleys. In the central part there are a number of isolated high mountainous areas with ice caps, alpine snow fields and glaciers.

Much of the northern sector is thickly mantled by layers of volcanic ash originating from a long chain of intermittently active volcanoes. Even on the steepest slopes the ash may be as deep as 4 metres. The annual rainfall rises from about 500 mm in the north to more than 2000 mm in the wet temperate areas of Valdivia, Aysen and Magellanes. On the east side of the Andes the precipitation decreases rapidly to 500 mm at the border of the Patagonian steppe. The vegetation comprises diverse types of temperate forests including sclerophyllous evergreen woodlands and *Araucaria araucana* forests in the north and *Nothofagus* forests in the south.

The central range has a rough, strongly dissected topography. In the extreme north the volcanic ash mantle is discontinuous and thin. Lithosols and Eutric Cambisols prevail. In the central area the mantle becomes much thicker and Humic Andosols dominate, most of them dystrophic. In Chile they are known as Trumao soils. In the southern sector the distribution of ash is again limited, and the soils are mainly Lithosols, Rankers and Podzols.

The coastal fjord land consists dominantly of steep slopes with Lithosols, Rankers and Podzols. At the foot of the mountains Gleysols and Regosols are present on alluvial and marine terrace deposits and coastal sands.

Histosols are common in some of the offshore islands, but they are often salty.

The coastal lowlands of central Chile are composed of the hilly to rolling lower foothills of the Andes, the level low terraces and alluvial plains of the central longitudinal valley and the low hills of the coastal ranges. The climate has a Mediterranean-like temperature and moisture regime.

The Andean foothills are thickly covered with volcanic ash, and the soils are predominantly Humic Andosols. Those of the low terraces and plains of the central valley include Vertisols, Mollic Gleysols and Fluvisols on recent, postglacial volcanic drift.

In the low coastal hills, crystalline rocks including granite and mica schist together with Tertiary sediments occur. The soils are Chromic Luvisols, Eutric and Dystric Cambisols. Dystric Nitosols developed over ancient basaltic andesitic rocks have also been reported. These soils are much older than the surrounding Andosols. Kaolin, gibbsite and halloysite are the chief clay minerals in all horizons with a dominance of kaolin in the lowest horizon.

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# 6. LAND USE AND SOIL SUITABILITY

Land use in South America is concentrated in a small portion of the continent, leaving huge areas covered by their natural vegetation and not used for agricultural production.

More densely populated areas include the Atlantic coast from the Amazon to the pampa region of Argentina, the Caribbean coast, some of the inter-Andean valleys and the northern altiplano. Among the thinly populated areas are the tropical forest zone of the Amazon, Orinoco and Upper Paraguay basins, the cerrado region of central Brazil and the Patagonian desert in south Argentina (see Fig. 8).

The population of the continent was estimated at 180 million in 1968, compared to 165 million in 1965, showing a rapid increase. About 38 percent of the economically active population is employed in agriculture, cultivating not more than 5 percent of the total surface and using about 20 percent more as grazing land (FAO, 1969).

Except for the areas planted with important export crops, cultivated lands generally yield little. Long-term trends show some increases including some in important food crops like wheat, oats and potatoes.

The general picture of production, especially for foodstuffs, is one of small farms, individually owned or rented and yielding only slightly over subsistence. It is difficult on such farms to introduce fertilizers, insecticides, better varieties of plants and equipment to increase the productivity of both soil and crop. Brazil and Venezuela have increased their food production per inhabitant during the last fifteen years, but in the other countries the figure remained the same or decreased slightly. Yields of the major crops are under the world average, higher than in Africa but lower than in Asia for certain crops like rye, oats and potatoes. Therefore, a substantial increase in production by making better use of the soil already under cultivation is feasible as a complementary possibility to the cultivation of new areas.

Consumption of fertilizers has increased substantially in South America, but they are mainly used for cash crops like sugarcane, cotton and coffee. Nevertheless the number of farmers with progressive farming methods is increasing, as can be seen from the fourfold increase in the number of tractors between 1950 and 1965.

Between the traditional and the modern type of agriculture, as defined in this chapter, a series of intermediate levels can be recognized, related to the range and intensity of management practices introduced by the farmers to improve and maintain soil productivity. These will vary from place to place and depend on technical and social factors as well as on economic factors like prices of such agricultural inputs as fertilizer, machinery, irrigation and drainage.

Traditional agriculture can be described as a farm management in which none or negligible amounts of capital are used for soil management owing to the low level of technical knowledge. The set of agricultural implements includes only the most simple hand tools and, locally, animal traction. Farming practices depend on traditional knowledge, which may include simple drainage works. Clearing of the vegetation is mostly done by burning; the roots are not removed. No fertilizers are applied, and only in specific cases (paddy) is irrigation used. Erosion control measures are taken only in exceptional cases. Since farming depends on the natural fertility the land will be abandoned when production stops or when yields become too low.

In improved farming systems intensive use is made of capital, and there is a high level of technical knowledge. Management practices are carried out with the help of power-operated machinery. These practices include intensive drainage, elaborate anti-erosion measures and intensive fertilization when necessary. Irrigation is not common practice but is being considered, at least from the soil and topographic angle.

For easy reference the discussion of land use and soil suitabilities of the dominant soils is given here in alphabetical order of symbols. Some soils that are similar from the point of view of agricultural production have been discussed together.

More specialized data on properties of the various soils appear in the appendix to this volume.

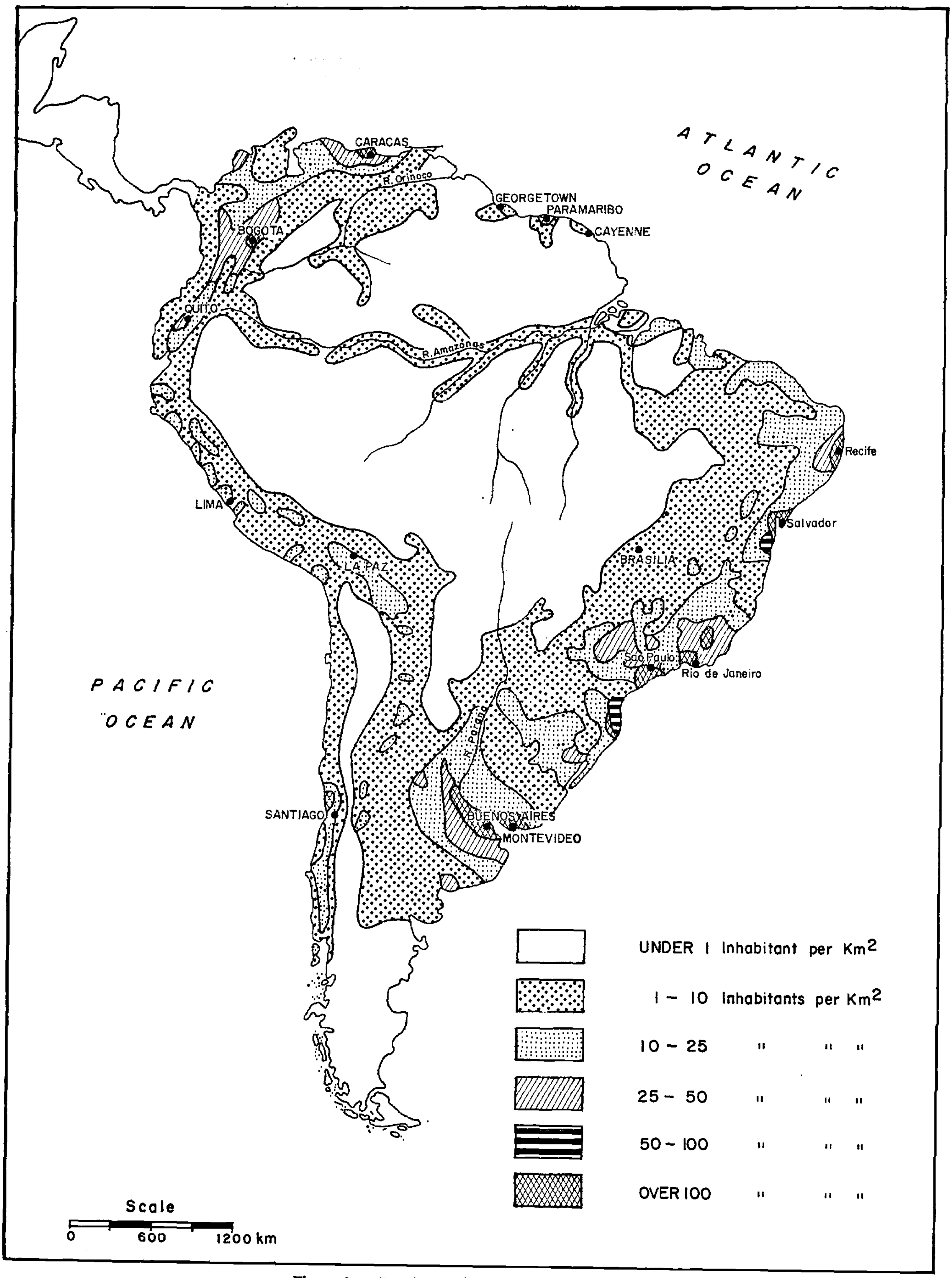


*Figure 8. – Population distribution, South America*

## A. Acrisols

### Ah. Humic Acrisols

*Use.* These soils have not been indicated on the soil map of South America but do occur in south Brazil in association with Humic Cambisols on the planalto of Curitiba. Because of their extreme acidity they are not used by farmers except for extensive grazing of their natural grassland vegetation.

*Suitability.* For traditional farming these soils are not suited for crop production because of the low content of available nutrients especially phosphorus. Pastures are also poor.

For improved farming the high cost of liming to transform these soils, which are reported to be almost saturated with free aluminum, into fertile land may not be economic at the present time. The topography allows for mechanization and erosion does not seem to be a serious problem, but strong horizonation of the soil profile will reduce the water intake rate. There is no water deficiency in the area where the soils occur.

### Ao. Orthic Acrisols

*Use.* The percentage of these soils used for agriculture varies in different regions. On the eastern slopes of the Andes they occur in dissected landscapes and are mostly covered by tropical forest. On the Guiana shield also (Venezuela, north Brazil, Guyana, Surinam and French Guiana), where they occur in virtually uninhabited areas, they are not used for agriculture. In coastal Brazil, São Paulo and Paraguay, 20 to 30 percent are used for agriculture and 40 to 50 percent for pasture. Principal crops are coffee, sugarcane, citrus and maize, with a smaller acreage in pineapple, tea and rice. In Rio Grande do Sul these soils are devoted mainly to grazing. In northeastern Brazil, in the subhumid littoral, age-old monocultivation of sugarcane has taken place, and these soils are still considered here as among the best for agriculture. Waste from sugar factories is regularly applied to the fields, as well as fertilizer, but the dissected topography makes introduction of rational production methods very difficult.

*Suitability.* Under traditional management, these soils have only restricted suitability for agriculture because of the rather low soil fertility.

Under improved management the fertility problem can be solved, but other problems remain, such as the predominantly rolling to hilly topography which limits the use of tractor-driven implements. Crops susceptible to an excess of water in the soil will meet difficulties during the rainy season because of the rather dense subsoil. Erosion susceptibility is a serious problem because of the strong horizonation which impedes infiltration, promotes sliding and sheet erosion, and leads easily to gully erosion.

### Ap and Lp. Plinthic Acrisols and Plinthic Luvisols.

*Use.* These soils have their greatest extent in the less inhabited parts of South America, the Amazon and Orinoco basins, Bananal Island in central Brazil and the Pantanal in southwest Brazil. Most of them are not used for farming and are covered either by forests, savannas (cerrado) or grassland. Parts are used for extensive grazing, as on Marajo Island at the mouth of the Amazon, in the Pantanal and on the llanos of Colombia and Venezuela.

*Suitability.* Under traditional management the suitability of these soils depends mainly on their fertility status and their risk of inundation. The Plinthic Acrisols (low base status) occur to a greater extent in Brazil, while in Colombia and Venezuela the Plinthic Luvisols (high base status) are more common. Plinthic Luvisols are, however, found in Maranhão (Brazil). The Plinthic Acrisols in the Amazon do not suffer much from inundation as they usually occupy the higher terraces. Here the cerrado vegetation makes seasonal grasslands with mineral imbalances the most serious limitation for cattle raising. Deficiencies in phosphorus, sodium, potassium, copper and cobalt are probably widespread. Sometimes during the dry season cattle are grazed on the seasonally inundated Fluvisols, Dystric Gleysols or Vertisols which occur as lower-lying associates in the same landscape. The higher nutrient status of these soils compensates to some extent for the deficiencies of the Plinthic Acrisols during the humid season.

For improved management drainage is the greatest problem. Much depends on the depth of the plinthite which may harden on drying out after the lowering of the water table. This can create a hardened layer which will restrict root development and enhance the water shortage during the dry season. In the wet season increased waterlogging may result. However, a partial improvement of the drainage conditions is generally feasible. Suitabilities are more related to grassland, but adapted crops such as rice and jute can be grown. Rubber is also known to grow well.

## B. Cambisols

### Bd. Dystric Cambisols

*Use.* These soils are rarely used for agriculture. Their occurrence is widespread in mountainous areas with a humid climate such as the eastern slopes of the Andes, and in coastal Brazil.

In the eastern Andes of Peru, between 2800 and 3600 metres altitude, shallow and very steep Dystric Cambisols occur extensively in association with Lithosols. Settlement here has never been successful. Among the crops tried was coffee, but the low soil fertility and the excessive rainfall which may reach as high as 8000 mm made it impossible. In the Llanos Orientales region of Colombia Dystric Cambisols are seldom used for agriculture. Here on the rolling high plains these soils frequently have indurated lateritic crusts (petric phase on the soil map) which considerably reduces root penetration, rooting volume, workability and drainage. These soils have a restricted suitability for extensive grazing, but forest can be better maintained. On the old and subrecent alluvial fans of the Piedmont in the same region, soils are deeper and occur on smoother topography. Although locally stony surfaces occur, soils do not have the ferruginous crusts, and possibilities for agricultural development are better. Low fertility is the primary problem, especially the lack of phosphate, but a full fertilizer treatment will be needed. Drainage possibilities are good and mechanical equipment can be used. Excellent pastures could be developed; among the recommended grasses are puntero, gordura, pangola and guinea. In coastal southern Chile Dystric Cambisols are covered by forest. In coastal Brazil these soils are used for grazing and forestry, but immediately after forest clearing, subsistence crops and coffee were grown.

*Suitability.* The Dystric Cambisols are poor soils for improved management because of slope, depth and stoniness or the occurrence of impeding ferruginous concretionary (petric) layers. Also because of the often excessive rainfall they are generally more suitable for pasture and forestry than for crop cultivation.

### Be. Eutric Cambisols

*Use.* In South America the widest extension of Eutric Cambisols seems to be in the subhumid to semiarid transitional zones, as on the fringes of Patagonia and in northern Venezuela. Here the principal use of these soils is grazing.

Only if derived from rocks rich in ferro-magnesium minerals in dissected topography may Eutric Cambisols be found in humid tropical climates. As such they occur in coastal Baía where they are mainly cultivated for cocoa, in the eastern Andes of Peru where some coffee is grown and in the southern lowlands of Chile.

*Suitability.* For traditional management these are good soils because of the high levels of plant nutrients. In humid climates excellent crop cultivation is possible, but for annual crops the land may be too steep. With high rainfall, erosion will be severe because of shallow depth and consequent rapid saturation with water. In the dry zones extensive grazing seems to be the only suitable use.

Improved management will sometimes find adequate water supplies for irrigation, but topography is mostly too steep for this. In humid climates Eutric Cambisols are often less suitable for modern management because of steepness and stoniness, but tree crops, pastures and forestry will do well.

### Bh. Humic Cambisols

*Use.* These soils occur in the highest parts of the humid Andes, mostly above 4000 metres. They are acid soils and are used mainly for grazing of llama, alpacas, goats, sheep and cows. Locally potatoes are grown but yields are low. As they contain small amounts of allophane, it can be expected that phosphate fixation is a problem, as it is with the Andosols. In southern Brazil above 900 metres and where they are derived from basalt, Humic Cambisols are very acid due to high levels of free aluminum. Where the natural vegetation is grassland and where the mixed (*Araucaria angustifolia*) pine forest has been cleared, grazing is the main occupation. The steepest parts have often kept their forest vegetation.

*Suitability.* These are only medium class soils for traditional farming because of their rather low fertility level. Improvement calls for liming. Climatic conditions in the high Andes restrict the choice in crops which can be grown, grazing is probably the best use for these soils.

## F. Ferralsols

### Fa. Acric Ferralsols

*Use.* These are soils of low natural fertility, and the population density on them is low. Most of them are still under natural vegetation. In some of the more densely populated areas clearing of the natural vegetation has been started and attempts made to use the soils for the cultivation of crops. Rapidly, however, they lose any natural fertility they had and revert to pasture.

*Suitability*. The main limitation of these soils is their low nutrient content. They occur under savanna (cerrado) vegetation where, unlike a forest, there is little reserve of nutrients. On the soil map soils under cerrado vegetation have been separated as a cerrado phase, shown by an overprint.

Under traditional management burning of the vegetation is a common practice to increase the nutrient status of the soil with the ashes. However, in the cerrado savanna even after burning, the soils can only be used for extensive grazing. In fact, many of the Acric Ferralsols are known for their extremely low fertility which includes deficiencies in less important elements and the almost complete absence of available calcium in the subsoil. This makes the growth of roots in this layer almost impossible. Such phenomena have been observed for instance in some of the savanna areas of the central plateau in Brazil, where Brasilia is situated.

Under improved management emphasis lies in increasing the fertility status of the soils, but a great deal more experimental work will have to be done, particularly on trace elements, before their fertility problems are completely overcome. Brazilian soil scientists are making good progress with complete fertilizer treatments and, in particular, have had remarkable responses to zinc. The most economic returns from fertilizers can be expected from the clay-textured Ferralsols which have higher cation exchange capacities and higher organic matter contents. In the sandier Ferralsols added fertilizer may be rapidly leached from the soil.

The favourable physical properties of these soils minimize the risk of erosion. The topography is predominantly smooth so that all kinds of machinery can be used, although sometimes termite mounds may cause problems for cultivation.

The Acric Ferralsols usually occur in areas with a pronounced dry season with three to five months of water shortage. This causes great stress in most perennial plants.

### Fh. Humic Ferralsols

*Use*. Less than 20 percent of these soils are used for intensive agriculture. Most of them are used as pasture in an extensive way. Winter crops cultivated in southern Brazil are wheat, oats, potatoes; summer crops are maize, soya, also some cassava and beans. In northern Argentina (Missiones) tea is cultivated. An important native tree which is harvested to make a local beverage is the "herva mate" (*Ilex paraguayensis*). The native *Araucaria angustifolia* pine is an important supplier of long fibre for the pulp and paper industry.

*Suitability*. Under traditional management these soils are commonly used for agriculture, depending on the level of fertility, which is usually moderate. The long slopes, seldom steeper than five percent, may provide a slight to moderate susceptibility to erosion. Both sheet and gully erosion have been observed.

Under improved management these are good soils for agriculture, but improvement of soil fertility is essential. Treatments need to include lime to neutralize the free aluminum commonly present. At least one ton of limestone per milliequivalent percent Al is needed to free the upper 30 centimetres of aluminum. If the amount of lime applied is not sufficient, serious fixation of phosphate fertilizers will continue.

These soils are being actively examined for the production of wheat, of which Brazil is a major importer. The topography permits mechanized farming, except for some parts where the basaltic rock frequently surfaces. Erosion can easily be controlled, but the humid climate encourages rust disease and presents a serious limitation for economic production. Plant breeders so far have not been able to overcome this problem by creating resistant varieties, so the best use of these soils is perhaps intensive meat production on improved pastures.

Forestry, particularly planting of the climatically adapted Paraná pine (*Araucaria angustifolia*), may not be profitable on these soils because of rather high nutrient requirements. In Brazil, so far, the use of fertilizer is uncommon in forestry.

### Fo. Orthic Ferralsols

*Use*. Because of the low natural fertility and the low population density in Brazil, most of these soils, which are extensive in South America, are still covered by their natural vegetation. Only in the more densely populated areas has clearing of the natural vegetation recently started. The soils are first used for the cultivation of crops such as coffee, citrus, cotton, banana, mulberry, pineapple, cassava and sometimes eucalyptus. Later they are converted into pasture, as even under shifting cultivation they lose their natural fertility within a few years.

*Suitability*. The principal limitation of these soils is their low nutrient content. However, because they support a forest vegetation they have rather higher nutrient reserves than similar soils under savanna (Acric Ferralsols) and have been separated from them.

Under traditional management burning of the forest is a common practice, to increase with the ashes the low nutrient status of the soil. This makes possible a shifting cultivation system for a few years.

Under improved management emphasis is placed on increasing fertility levels. Experimentation has not developed far enough yet to state that the low fertility of these soils is no longer a problem for modern farming. However, research and experimentation indicate that with fertilizers many of them could reach high to very high productivity levels.

There is much practical experience in the farming of Orthic Ferralsols using fertilizers in São Paulo with sugarcane, wheat, citrus, corn and cotton. Phosphate is usually the first deficiency, then calcium and magnesium, and after some time of cultivation, potassium and sulfur. Nitrogen will always be required for prolonged intensive cultivation. The most economic returns from fertilizers can be expected from the clay-textured Ferralsols, which have higher cation exchange capacities and higher organic matter contents. The sandier Ferralsols have the problem of severe leaching of fertilizer.

Favourable physical properties and high structural stability reduce the risk of erosion to a minimum. A favourable factor for the modern management of Ferralsols is their predominantly smooth topography enabling the use of all kinds of machinery, although sometimes sizeable termite mounds may cause problems for cultivation when they occur in a rather dense pattern. However, Orthic Ferralsols are also known to occur on much steeper land, as for instance in the states of São Paulo and in northeastern Brazil. Here, forestry and pastures are more suitable than cropping.

### Fr. Rhodic Ferralsols

*Use.* Due to their medium fertility, which is rare in the regions of predominantly poor soils where the Rhodic Ferralsols occur, these soils are much used for agriculture, probably 60 to 80 percent of their total surface being cultivated in agricultural regions. Principal crops are coffee, sugarcane, cotton, peanuts (São Paulo, Paraná), upland rice, potatoes, corn, beans, alfalfa and cassava. In the subtropical environment of Rio Grande do Sul crops include oats, wheat, soya, maize and flax. Some 20 to 30 percent is used for pasture.

*Suitability.* Under traditional management these are good soils, due to their medium to high natural fertility and the absence of other serious limitations. Minor regions with moderate or strongly limited fertility are included. The latter are mostly used for pasture or extensive grazing as is the case with the Rhodic Ferralsols, cerrado phase, in Mato Grosso and western São Paulo. A serious limitation which occurs irregularly, peaking in cycles of 10 to 12 years, is frost; this causes special problems for coffee cultivation in southwest São Paulo and northern Paraná.

Under improved management these are very good soils due to favourable physical properties and excellent responses to fertilizers. These are good possibilities for the use of mechanical equipment. The frost problem is being approached now with various practices like careful planning of plantation sites, the opening of channels through the plantations and forests for the rapid removal of cold air masses, or direct action by atmospheric dispersion of emulsions (fog-making) during frosty nights.

### Fx. Xanthic Ferralsols

It is necessary to distinguish between the Xanthic Ferralsols of the Amazon basin, of coastal Brazil and of northeastern Brazil.

#### 1. *Amazon basin*

*Use.* In the Amazon only small areas of Xanthic Ferralsols are in use for shifting cultivation. Crops include rice, beans, cassava, cotton and malva. Yields are very low. An important permanent crop, which is dominantly cultivated by Japanese settlers, is pepper. Historically important enterprises which are still active are the extraction of rubber, Brazil nuts and timber from the forests which these soils carry.

*Suitability.* Under the present shifting cultivation system, various annual crops can be grown for a short period, but because of the low fertility yields they decrease rapidly and a long fallow period is necessary for restoration.

Under improved management a high percentage of the Xanthic Latosols in the Amazon will prove to be good soils. Good response to fertilizer has been shown already for black pepper, a crop which consumes about half the total amount of fertilizer applied in the Amazon region.

A gradual change from shifting cultivation to permanent cultivation might be promoted through the introduction of NPK fertilizers in moderate amounts to maintain yields for a longer time between the fallow periods. A short fallow period remains necessary, expecially for the lighter textured soils, because of the very low cation exchange capacity which needs to be increased by the organic matter accumulated during the fallow. Other cultural practices should also be directed toward returning as much crop residue as possible to the soil. In the explored part of the Amazon considerable areas of Xanthic Ferralsols have been observed with largely undulating and more accentuated relief. Here the soils have little value for modern agriculture, but in the other parts there is no limitation to the use of mechanical equipment.

Sometimes the Xanthic Ferralsols are extremely high in clay content (more than 70 percent). This may cause rather poor workability as the soil gets hard in the dry season and sticky during the rains. Also root penetration can be difficult, probably because of oxygen deficiency in the dense soil mass.

The inaccessibility of the regions where these soils occur is probably the most important problem for the establishment of agriculture. Tropical grasslands have been established successfully in some areas and water buffalo have been introduced together with various kinds of zebu. Mechanized agriculture will face the problem of having to remove the roots and vegetation remaining after clearing.

2. *Coastal Brazil*

*Use.* Here only 10 to 20 percent of the soils are occupied because of the low to medium fertility levels. Principal crops are sugarcane, citrus, pineapple, tobacco, maize and cassava. In Baía there are recent plantations of rubber and oil palm. In São Paulo and Rio de Janeiro states 70 to 80 percent of these soils are used for pasture.

*Suitability.* Under traditional management these are soils of restricted suitability because of their low natural fertility. In large areas water deficiency also imposes serious problems.

Under improved management these are good soils for agriculture. At the beginning they need intensive fertilizing, especially with phosphate, and irrigation is recommended in large parts of coastal Brazil. Availability of water on the elevated taboleiras may be restricted. Mechanization has good possibilities on the Tertiary surfaces, except in some dissected areas like that south of Salvador in Baía.

3. *Northeastern Brazil*

*Use.* In northeastern Brazil, where the climate is semiarid, land use is restricted to areas where water can be collected and stored in ponds or depressions. The rainy season is highly irregular, which makes dry farming risky. In general, land use consists of extensive grazing of goats, cattle and horses. The vegetation growth in the wet season is remarkable.

*Suitability.* The soils are unsuitable for traditional farming, because of the strong water deficiency and the fact that what water there is cannot be easily reached for irrigation. These soils usually occupy elevated parts in the landscape, the remnants of old dissected plateaus, especially in southern Piauí.

For modern farming these are good soils for irrigation, both in terms of slope and permeability. Natural fertility is medium and this can easily be improved with fertilizers. The texture is somewhat sandy, which might cause rather heavy water losses, but the natural drainage is such that there is no risk of salinization of irrigated lands.

Sometimes these soils occur only in relatively small areas in association with other soils which have little adequacy for modern agriculture, because of stoniness, concretions or for other reasons. This problem is known in the San Francisco basin in western Pernambuco.

### G. Gleysols

*Use.* Although the Gleysols vary enormously they are discussed together because poor drainage gives them a common dominating limitation. The land use pattern in most of South America indicates that capital for the usually costly improvement of these soils is rarely available. Therefore, their use is extensive, being mainly grazing during the season when the soils are not inundated and, locally, rice cultivation. In Guyana, Surinam and French Guiana, where the soils occur at or near sea level, intensive drainage works have been carried out, and crops include sugarcane, rice, bananas, cocoa and Liberica coffee. The natural fertility of these young marine sediments is usually high. They are heavy clay soils and, therefore, less suitable for crops with small seeds. In river valleys near urban centres all over the continent the soils are intensively used for the cultivation of horticultural crops, particularly the Eutric Gleysols and Mollic Gleysols. Coastal Gleysols may have a high sodium content (Sodic Gleysols).

*Suitability.* Often traditional management is able to carry out simple drainage work, which makes the Gleysols suitable for crops adapted to seasonal wetness, like rice, jute and sugarcane. Good pastures can also be established. The value of such improvements depends especially on the natural status. The coastal Gleysols and also the Gleysols of subhumid temperate regions usually have a high base status (Argentina, Chile, Uruguay).

The Gleysols of the Orinoco basin in Venezuela and Colombia also have a medium to high base status, but most of the Gleysols of the Amazon are acid, as are those of the Central Brazilian depression and the Pantanal area, and of equatorial Bolivia.

Improved management can make good use of these soils, although the range of crops to be cultivated will be restricted by characteristics like texture, clay mineralogy and depth of ground water.

### H. Phaeozems

*Use.* The widest occurrence of Phaeozems is in the humid and subhumid pampa region of Argentina, Uruguay and adjacent southern Brazil. These soils have developed mostly on Quaternary sediments and partly over older sediments or rock types. In Argentina Phaeozems are found almost exclusively on pampean loess or on silt loam and loam derived from loess, in an essentially flat topography. Pampean loess occupies a singular position among the loess deposits of the world, insofar as it consists mainly of wind-blown volcanic ash. These deposits have accumulated since the end of the Tertiary and during the whole of the Quaternary until the present time, as a consequence of the intensive volcanic activity of the southern part of the Cordillera de los Andes. These deposits wedge out from the southern Cordillera to the northeast of the Continent, covering the whole pampas area and wedging out over older rocks including granites and basalts of Uruguay and southern Brazil.

Phaeozems have developed under natural prairie-like grass lands or under open savanna-type vegetation, in a climate that ranges from semiarid in the west over subhumid to humid in the east and northeast. The Haplic character of the Phaeozems is clear in the western part, but toward the east Luvic characters appear and in the eastern part only Luvic Phaeozems are found.

During the last 100 years the area has been converted to a great extent from range land to extensive mixed farming, but it still is one of the world's major beef-producing regions.

In any case, the Luvic and Haplic Phaeozems form excellent cropland. With the advent of European colonization to this area, many lands have been ploughed up and sown in wheat and other small grains, preponderantly those areas in humid to semihumid climatic regimes (Luvic Phaeozems), where crop security is greatest. During the first five decades of this century the Argentine pampas were one of the world's major wheat-producing areas. Present agricultural production from Phaeozems areas is more diversified and includes besides beef, mutton and wheat, crops like corn, oil seeds (sunflower, linseed), oats, barley, rye, potatoes and sweet potatoes. There is also extensive growing of forage crops (alfalfa) and seeded pastures (fescue-rye grass-clover mixtures). According to recent figures, about half of the Phaeozem area in Argentina is under pasture, the other half under various crops. Natural fertility of well drained Haplic and Luvic Phaeozems is high, since these soils are little leached and since physical and chemical conditions are optimal for crop growth. Productivity is limited in certain years through a lack of available moisture during the growth season. On the average, rainfall balances out against evapotranspiration, with a slight net moisture deficit during summer and a slight excess in winter. In years of low rainfall crop production falls. In such years supplemental irrigation may work miracles, and all practices aimed at a conservation of winter soil moisture help increase summer crop production.

In years of drought Haplic Phaeozems, with a relatively low soil moisture storage capacity, have to be protected against overgrazing and wind erosion. Luvic Phaeozems suffer to a lesser extent from drought, since the argillic B horizon adds to its moisture storage capacity. These soils have to be protected against water erosion in years of excessive or erratic rainfall.

In southern Brazil Phaeozems occur under subtropical conditions in strongly dissected topography over basalt. Because of their high fertility, a rare feature in this region, these soils have become intensively colonized by European settlers. Principal crops are beans, maize, cassava, potatoes and soya. Phaeozems are also extensively used in some of the inter-Andean valleys and in the cool humid highlands of the Andes. Settlement here goes back to pre-Inca times. Cultivated crops include potatoes, maize, wheat, oats, quinua (*Chenopodium quinua*), alfalfa and legumes, with grazing on the steeper parts. Severe erosion can often be observed and planting of forest trees such as *Eucalyptus globulus* and pines is recommended.

The occurrence of Phaeozems in the tropical climate of Baía, where they are mapped in a transitional position between the humid coast and the semiarid inland, is exceptional. Grazing is the main agricultural activity.

*Suitability.* The Phaeozems of Argentina are excellent soils for both traditional and modern management. Well drained types are adapted to a wide variety of crops, pastures and forages, and no major limitations have to be coped with. Luvic Phaeozems, with a heavy textured argillic horizon, may show a somewhat impeded internal drainage, slightly undesirable for optimal growth of corn but not depressing the yield of wheat. Well drained Luvic Phaeozems on deep pampean loess, with a moderately developed argillic B horizon, are among the best croplands of the world. Haplic Phaeozems, without an argillic B horizon, may show susceptibility to drought, especially if soils are coarse textured as in the western zone of the pampean region.

Phaeozems in the pampean region in general show little response to fertilizers. Some response to nitrogen and phosphorus is noted on intensively cropped soils, but under management systems of mixed farming, where two to three years of grain and oilseed cropping is alternated with a few years of pastures and alfalfa, no economic response to fertilizers is noted. Seasonally deficient soil moisture seems to be the main limiting factor in crop production.

On the more leached Luvic Phaeozems some response to N and P is noted, and these soils may benefit from an occasional liming if the pH falls below 5.5.

Generally speaking the high natural fertility, easy workability, and the excellent climatic conditions have favoured a rapid expansion of livestock farming and cropping of cereals in the whole area. The highly dissected subtropical Phaeozems of southern Brazil are good soils for traditional management with its use of animal-drawn implements. Modern farming meets problems because of steepness and stoniness preventing the use of tractors.

### I. Lithosols

*Use.* These soils are rarely used for agriculture. Their predominantly steep and highly dissected topography, combined with the usual rockiness and stoniness, makes them unsuitable for cultivation. Only on rare occasions may they be used for some crops. For instance, in ever-humid coastal Baía, some cocoa is grown on Lithosols developed on steep slopes. Here roots grow into the cracks of weathered rocks, which consist of ferromagnesium-rich gneisses and diorites. Good pastures occur on gently undulating Lithosols, developed over basalt in southern Brazil and northern Uruguay. In the Mediterranean climate, grapes and olives sometimes can be found on stony eroded slopes of calcareous formations, but generally speaking, Lithosols are either left idle or used for extensive grazing. Sometimes, if climatic conditions permit, they are used for reforestation.

*Suitability.* Lithosols are not suitable for traditional or modern farming. However, in certain areas Lithosols are being cultivated because they have a high fertility status in comparison to the other much older soils in the same environment. Such a misuse of the land could be disastrous for the environmental equilibrium, heavy soil erosion could prevail and reforestation become virtually impossible. The best use of Lithosols is for forestry, wild life and recreation.

### J. Fluvisols

*Use.* The Fluvisols occur in close association with various kinds of Gleysols. The latter are usually predominant in South America. This discussion restricts itself to the Fluvisols, which occupy the better drained parts of river basins. When they have been mapped as dominant soils, in Argentina, Paraguay, Venezuela, Colombia and along the Pacific Coast, their land use is most varied and closely related to climate and population density. In many parts of the world, such as Europe and southeast Asia, they are probably the most intensively farmed soils of the region. This is not necessarily so in South America. In Argentina, for instance, they occur in the dry region of Patagonia, but farmers concentrate in other parts of the country like the pampa and in northern Argentina where good soils are abundant under more favourable climatic conditions. But in Patagonia Fluvisols are the better soils, with more water available due to their depressed position and to seepage water from the shallow higher terraces. Often these valleys also include Humic Gleysols and are the best areas for sheep grazing. In coastal Peru many of the Fluvisols are irrigated, with sugarcane and cotton the principal crops. In southern Ecuador rice and sugarcane are grown, in northwest Colombia rice and tobacco, and in Venezuela in the Maracaibo basin there is mainly grassland.

*Suitability.* Under traditional management the Fluvisols are good soils, especially since their fertility is generally higher than that of the older surrounding soils. In the Amazon region of Peru, calcareous alluvial soils are important, and along the Amazon and Solimoes rivers in Brazil Eutric Fluvisols of high potential can be found. Crops which can be grown include coconut, rubber, sugarcane, fruits, rice, maize, tobacco, cotton, jute and kenaf. Depending on the drainage conditions, various crop rotations can be used. The soils are less suitable for upland crops like coffee and tea.

Under modern management these are excellent soils, but drainage and irrigation may be needed to guarantee permanent good yields. Usually some fertilizer will be needed too.

### K. Kastanozems

*Use.* These soils, which occur normally under drier conditions than the Phaeozems but which are closely related to them, are very extensive on the eastern and southern fringes of the pampean region, in semiarid northern Argentina and Paraguay, in the dry inter-Andean valleys of Peru and Colombia, and on the northern part of the Andean altiplano, near Lake Titicaca. In the semiarid Chaco region of Paraguay and northern Argentina, Kastanozems often have a high salt content (saline phase on the soil map) and are rarely used for agriculture. The main occupation here is extensive grazing, but in the other regions they are popular soils, much in use, even though the pronounced seasonal dryness is a strong limitation to crop choice. Irrigation is being applied but has led in some places, as in the lower valley of the Rio Colorado, to an increased salt content of the soils. These soils do not always have free drainage. They may occur with an argillic B horizon (Luvic Kastanozems) or with a subhorizon of secondary carbonate enrichment. In the southern pampa it is also rather common to find a layer of hard limestone (tosca) at varying depths which may impede drainage and promote salinization of the soils.

Grazing on planted pastures is the most important use of Kastanozems in the pampean region. Among the irrigated crops are alfalfa, vegetables (tomatoes, peppers, onions), fruit trees (mainly apples and pears), grapes and poplars. Rainfall in this region is 500 to 600 mm/year, and suitabilities without irrigation are limited. Kastanozems are also being irrigated in the subhumid to arid inter-Andean valleys (rainfall 250 to 1000 mm), because without irrigation their use is restricted to extensive grazing and some short season small grain cereals. Among the irrigated crops are wheat, oats, maize, legumes and fruit trees (hueso), while under warmer conditions sugarcane, citrus and fibre crops are grown. The unirrigated parts are overgrazed and often severely eroded. In the northern altiplano, between 3800 and 4200 metres, rainfall varies between 500 and 700 mm. Water deficiency is still strong here but less severe than in some of the inter-Andean valleys. Low temperature is the principal limitation for vegetative growth, and frost may cause great damage to the crops. There is, nevertheless, an intensive cultivation pattern, mainly of subsistence crops like potatoes, wheat, barley, bran, vegetables, oats and quinua (*Chenopodium quinua*). Livestock are numerous on the uncultivated stony and shallow soils. Supplementary fodder is obtained by harvesting the reeds and rushes growing in the shallow waters of the margin of Lake Titicaca.

Much of the Chaco plain in Paraguay and northern Argentina is without permanent agriculture or is used only for extensive seasonal grazing. Few crops can withstand the soil conditions with extreme dryness and salinity problems in the dry season and saturation with water in the short wet season. Drainage is difficult because of the general low inclination of the plain. Water supplies for cattle are seasonally inadequate and often saline.

*Suitability.* For traditional management most Kastanozems are of only restricted suitability because of the strong seasonal water deficiency. Marginal yields can be obtained by dry farming with crops adapted to the climatic conditions, and extensive grazing is feasible, although the possible cattle density is restricted.

Improved farming can be successful if irrigation can be provided but often (Luvic) Kastanozems have impeded drainage, while irrigation water can be highly saline (Chaco region). As these soils occur in the high Andes, climatic limitations related to low daily temperatures present the chief restriction to high productivity. Fertility is usually high, and there is a considerable amount of organic matter in the topsoil if the texture is not too sandy. Trace elements, especially zinc, may become deficient because of the relatively high calcium carbonate content. For fruit trees iron is frequently needed.

## L. Luvisols

### Lc. Chromic Luvisols

*Use.* In northeastern Brazil where these soils are most extensive, the semiarid climate restricts land use to extensive grazing and local activities related to short season crops like cotton, peanuts and sisal. The chief subsistence crops are cassava, maize and beans. The next most extensive area is in central Chile west of Santiago. Here the climate is similar to the climate of the Mediterranean region in Europe and the crops also correspond — wheat, oats, grapes, apricots, peaches, fibre crops and oil seed crops including olives, with dairy production and livestock fattening on irrigated pastures.

In the drier Andean valleys in Colombia and Bolivia, crops include potatoes, maize, wheat, vegetables, oats, fruits, alfalfa and grass for milk and meat cattle. In coastal Ecuador, which is for a great part covered by tropical forests, crops include coffee, cotton, rice, sugarcane, cocoa, bananas and grass.

*Suitability.* Under traditional management these soils are moderately good for agriculture. Fertility levels are usually medium to high. The most important limitation is water, as a long dry summer season is characteristic of the climate where they occur. Another important factor is the strong erosion susceptibility which requires careful management including terrace-building for the cultivation of crops. The remarkable hardening of these soils upon drying may present tillage problems for the use of manual implements.

Under improved management fertilizers, especially in combination with irrigation, will increase crop yields substantially. Phosphorus is often the element most needed, besides nitrogen. The great variety of depth and frequently the strong slopes of these soils complicate irrigation and make careful erosion control desirable. Mechanization is often restricted by stoniness and slopes. Small machinery can frequently be used, but stone removal and terracing will be required in many places.

Lf. Ferric Luvisols

*Use.* In South America these soils occur mainly in subhumid and semiarid climates. They are used principally for annual crops (Brazil) and grazing (northeast and southwest Brazil and Bolivia). Only in Baía are there Ferric Luvisol-like soils in a tropical humid climate. Here they are among the best cocoa soils of the region. In the states of São Paulo and Minas Gerais about 70 percent of these soils are under cultivation. Principal crops are cotton, peanuts, sugarcane, corn, upland rice and coffee. Castor beans, potatoes, beans, tobacco and bananas are also grown.

*Suitability.* Under traditional management these are good soils because of the medium to high fertility. The strong and steep varieties which are known to occur in Minas Gerais (these are perhaps intergrades to the Eutric Nitosols) give problems in the use of equipment and present a serious risk of erosion.

Under improved management the use of fertilizer is necessary. In São Paulo great responses to phosphorus have occurred, and nitrogen is also commonly deficient. Generally speaking the Ferric Luvisols present no particular problems for the use of fertilizers. Sometimes erosion problems may be serious, however. Topsoils are often of sandy to medium texture overlying a rather dense and impermeable subsoil at varying depth. The conservation practices needed depend on the slope gradient and length of slope. The heavy subsoil may impede drainage during the rainy season. The water deficiency problem varies from moderate in southern Brazil to strong in northeast Brazil, where dry farming has only restricted possibilities.

## N. Nitosols

Nd. Dystric Nitosols

*Use.* When these soils occur in populated areas they are used rather extensively. In Rio Grande do Sul, for instance, 60 to 70 percent are used for pasture. The pasture is mostly natural, providing food for one head of cattle per three hectares. Some 20 to 30 percent is used for agriculture, the main crops being wheat, oats and soya beans. In other parts of South America, such as Guyana, Surinam, French Guiana and Venezuela, these soils are mainly covered by tropical forest.

*Suitability.* These soils occur mostly in association with the Rhodic Ferralsols, with which they compare in suitability for agriculture. They may be somewhat less leached of nutrients, but their base saturation is less than 35 percent and their cation exchange capacities are low. Under traditional management these soils are no more than moderately suitable for agriculture and grazing. In Brazil, where they occur in Rio Grande do Sul, high exchangeable aluminum is common, and they therefore require heavy liming.

Under improved management, erosion susceptibility may become the principal limiting factor, since fertility can be adequately controlled. These soils may occur in rather dissected topography with slopes of 5 to 15 percent or even steeper, and here the use of mechanical equipment will be limited. As the clay of these soils is less flocculated than in the Ferralsols and their porosity is lower, erosion susceptibility is more severe under similar conditions of slope and rainfall. Where the Dystric Nitosols occur, rainfall is usually high all through the year. These can be excellent soils for agriculture provided that the various limitations are properly managed.

Ne. Eutric Nitosols

*Use.* These soils are much used in agricultural areas. Due to their high natural fertility they are among the best soils in tropical South America and have contributed largely to the development of southern Brazil. In São Paulo and Paraná they are mainly used for coffee but sugarcane, alfalfa, castor beans, corn, bananas, watermelons and rice are also grown. They also occur on the eastern slopes of the Andes in steep topography where they are locally used for crop cultivation including coffee. In coastal central Chile, steep Eutric Nitosols are used for cereals, potatoes and pasture.

*Suitability.* Under traditional management these are good soils but soil losses by erosion are likely to occur.

Under improved management erosion presents the most important limitation. A moderate limitation for the use of mechanical implements (slopes steeper than 15 percent) often occurs. Applications of fertilizer will usually be necessary to maintain the fertility of the soil under intensive management.

## O. Histosols

*Use.* These soils are rather extensive in the coastal Guianas, in southern Chile and on the Falkland Islands. As they are poorly drained, low in fertility, with deficiencies of minor elements such as copper and molybdenum, and often with toxic salts, they are rarely used. In Guyana, Surinam and French Guiana, if artificially drained, some shallow rooting crops are grown with liming and fertilizing. Bananas and sometimes Liberica coffee can also be grown, but most of these soils are still marshes, used as fresh water reserves for peat production and for fish breeding. On the offshore islands of southern Chile extensive areas of peaty organic soils occur, which are constantly swept by salt-laden winds of gale force and have little agricultural potential. They are part of the "Magellanic moorland" consisting of low shrubs, grasses and bog plants.

Histosols are spread all over the continent in major river beds and are locally intensively cultivated with horticultural crops to supply the cities. The Paraiba valley in coastal Brazil is an example. In some undulating landscapes, where Histosols occupy the lowest position in the landscape and drainage is virtually impossible, they are used for grazing.

*Suitability.* Under traditional management the soils are poor. Under improved management they are expensive to reclaim properly and therefore suitable only for the cultivation of high-value market crops like horticultural crops, including flowers and ornamental trees. The peat eventually becomes irreversibly dry, causing sinking of the land surface with additional problems for drainage and destruction of soil structure as it is converted into hard aggregates. The cakes can easily catch fire during the dry season.

## P. Podzols

*Use.* These soils have been mapped as dominant soils only in southern Chile and Tierra del Fuego, but they are known to occur rather extensively throughout the continent, especially in coastal Brazil (mainly Gleyic Podzols) and in the Amazon in association with Plinthic Luvisols (Humic Podzols). Because of the very thick E horizons consisting of bleached quartz sand and the very thin $A_1$ horizons, these soils compare with the Dystric Regosols in their suitability for agriculture. Except for some cashew and pine plantations they are used only for extensive grazing or left under their original forest vegetation.

*Suitability.* Podzols are poor soils under traditional management and also unattractive for modern management because of a high leaching rate and restricted response to fertilizer. Severe water deficiency problems may occur during the dry season. In some of the low-lying Podzols water stagnates on the hard and impervious spodic B horizon during the wet season (Gleyic Podzols) or when the water table rises.

The deep Podzols are sometimes suitable for pine planting, and under heavy manuring coconuts and pineapples could be grown.

In southern Chile and Tierra del Fuego grazing is the only feasible use for these soils. Fairly good pastures can be established on the low-lying Podzols (Gleyic Podzols) if the dry season is short.

## Q. Arenosols

### Qf. Ferralic Arenosols

*Use.* In Brazil, where these soils mainly occur, the vegetation is mostly a low open cerrado with a poor grass cover. If forest is present it is rather low. Because of their extremely low fertility, the Ferralic Arenosols are used only for extensive grazing.

*Suitability.* Under traditional management these soils are unsuitable for agriculture, as they are extremely poor in nutrients and their organic matter content is low. The predominant sandy texture provides easy workability for hand labour, but even in shifting cultivation these soils are among the least desirable. Once the forest is cleared it is likely that a poor secondary growth of shrubs and grasses will be the final result.

Under improved management these soils develop only very slowly into productive soils for most crops. The extremely low cation exchange capacity, due to the low content and low activity of the clay (kaolinite and oxides of aluminum and iron) allows a high leaching rate of fertilizers. Increasing the organic matter content is a difficult and probably uneconomic task, perhaps only possible in relation to the cultivation of certain tree crops, but in central Brazil, where these soils are most frequent, tree crop cultivation is limited by low moisture retention and seasonal dryness. The use of coated fertilizers may become successful on a small scale. A few adapted crops could perhaps be successfully grown like cashew, pineapple, tobacco (with intensive management) and certain less demanding pine varieties like *Pinus elliottii.*

Locally the topography of these soils can be rolling or hilly. Once the natural vegetation has been cleared erosion will be severe and difficult to control. Mechanization is generally possible on these soils, although machinery adapted to the sandy soil texture may be expensive.

## R. Regosols

*Use.* As dune formations along the coast, Regosols often contain fair amounts of free calcium carbonate. In the humid tropical belt they are much used for coconut cultivation. Away from the coast, the Regosols of humid tropical climates are usually extremely acid, and the only crops observed are cashew and pineapple and certain pine trees like *Pinus hondurensis*, *Pinus carribea* and *Pinus elliottii*. In drier climates Regosols may contain high contents of weatherable minerals, but they are in little use for agriculture because of the very low water retention.

Such Regosols as are found in ridges in northeast Argentina make excellent soils for citrus and tobacco under conditions of sufficient rainfall. Since most Regosols are poor in supplying plant nutrients, they have to be fertilized adequately, including the addition of minor element frits in the fertilizer mixture.

*Suitability.* Sandy Regosols have a rather low suitability for agriculture except for some adapted crops under favourable environmental conditions. Coconuts can often be grown successfully if the groundwater table is not too deep. Pine varieties can be grown if the climate is not too dry or the content of weatherable minerals in the soil too low. Traditional management sometimes prefers these soils because of their easy workability, but great care has to be taken to avoid erosion of the noncoherent soil material. Intensive soil conservation practices, like tie-ridging, may be needed for the cultivation of annual crops. Peanuts and cassava are among the suitable crops for dry farming.

Improved farming meets the serious problem of low water retention of irrigation water and very low retention of fertilizers. Once these problems can be solved, various crops (tobacco, for example) can be grown. In some humid temperate countries these are excellent soils for the production of flower bulbs. It can be expected that building, recreation and forestry in densely populated countries will be directed more and more toward these soils, at least toward the Dystric Regosols.

## S. Solonetz

*Use.* Mollic and Orthic Solonetz soils are widespread in Argentina, in some areas as dominant soils, in others in association with nonalkaline soils like Planosols, Phaeozems or Kastanozems. They also occur over relatively large areas in Uruguay and in southern Brazil.

Mollic Solonetz is dominant in the Rio Salado basin of the province of Buenos Aires, an extensive range land area in the depressed part of the Argentine pampa. Soils are imperfectly to very poorly drained, and land use appears to be closely related to natural drainage conditions as well as to the intensity of the alkalinity problem. Exchangeable Na percentage ranges from 5 to 60 at the surface, increasing with depth in the profile and normally showing a maximum in the argillic B horizon. Range land of extremely low productive capacity prevails on the poorly drained soils or on Solonetz with a high exchangeable Na percentage at the surface, as in many parts of the coastal area of the depressed pampa. Native pastures are of better quality on the somewhat better drained Solonetz soils, but the carrying capacity of the range land is still low, averaging one head of cattle to two to three hectares.

*Suitability.* Under traditional agriculture these soils are rather unsuitable for the cultivation of crops. The impermeability of the subsurface horizons impedes root development and causes an unfavourable soil moisture regime. These soils may support grassland of fair quality but are difficult to use for nonirrigated crops.

Improved agriculture on Solonetz depends essentially on the possibility of replacing sodium by calcium in the exchange complex. The improvement of Solonetz has been extensively dealt with in soils literature and is not elaborated upon here. Specifically for South America, pasture improvement has been obtained in Argentina through sod-seeding of alkali-tolerant grasses (*Agropyron* species) and legumes and the application of phosphate fertilizer to start the growth of legumes. Reclamation and drainage of Solonetz under range land has not been tried in Argentina, since it is considered to be uneconomical under prevailing conditions. The poor drinking quality of groundwater in Solonetz areas is an additional problem where a more intensive range utilization is envisaged. It should be noted that Mollic Solonetz, thanks to thick topsoil and a relatively lower alkalinity, is more responsive to improvement techniques than Orthic and Gleyic Solonetz.

## T. Andosols

*Use.* Andosols are common in the volcanic Andes, especially in southern Chile, in western Ecuador and in south-central Colombia. They also occur in southwestern Peru. Most common are the Humic Andosols which are dystrophic. The "Trumao" soils of southern Chile are Humic Andosols, acid soils with a high rate of phosphate fixation, therefore not intensively farmed. The topography also is often too steep to develop agriculture. Where agriculture has begun, erosion has immediately become active. In the Chilean coastal lowland, including Chiloé Island and the bordering Andean foothills, Andosols are being farmed for potatoes, wheat, oats, cloves, pastures and forests on the steeper slopes. Low-lying Andosols are only used for summer pastures and forests on the steeper slopes. The presence of an iron pan in the underlying fluvic glacial gravels and a common tendency to overdrain the soil material above the pan restricts farming on these soils. They also shrink in volume and settle unevenly if drainage is rapidly and intensively applied. Mollic Andosols occur in central Ecuador where excellent grasslands support many cattle, and cereals, maize and potatoes are also grown. At a lower level in the Santo Domingo area, strongly weathered Andosols are used for bananas, cacao, coffee, sugarcane and citrus. The Vitric Andosols are extensive in the semiarid western part of the Peruvian Andes. These soils, because of their stoniness and acidity, are not used for agriculture.

*Suitability.* For traditional management the Andosols are difficult to farm, as they are usually very acid and need heavy liming to reduce the phosphate fixation. Under suitable climatic conditions tea and pyrethrum could be grown, as they are adapted to acidity. However, topography is often steep and this excludes the use of machinery. The soils are also susceptible to erosion. In level areas ploughs will not scour in these volcanic ash materials. The Vitric Andosols usually occur under dry climatic conditions. Where they are deep and topography is smooth, irrigation can be applied to these soils if water is available.

## V. Vertisols

*Use.* Where the Vertisols are most extensive, in the llanos of Venezuela and Colombia, in the Pantanal of southwest Brazil, and in the lowland areas of Uruguay and eastern Argentina, Entre Rios province, they are mainly used for grazing. Their natural vegetation is often grassland.

Locally, as in the Reconcavo area of coastal Baía (Brazil), sugarcane has been planted on these soils for centuries. Irrigated Vertisols in Chile produce wheat, barley and sunflower. Other crops are flax and sugar beet (Uruguay), rice (Venezuela), cotton, peas and beans. In Argentina Vertisols carry wheat, maize, linseed and sunflower, but a great part of the area is still under native savanna-like vegetation of low productive capacity. Thorny bush species, like many *Prosopis*, overshadow an undergrowth of hard grasses. Range land has to be cleared and managed carefully to avoid overgrazing and subsequent erosion. Also in northwest Peru extraction of wood from the natural forest vegetation has been intensive, while the soils were also used for extensive grazing. Nowadays irrigation is important, producing a great variety of annual and perennial crops (45 000 ha are irrigated in the San Lorenzo area).

*Suitability.* Under both traditional and improved management these are difficult soils because of their high content of swelling clay minerals, mainly montmorillonite. They usually occur in regions with a well expressed to strong dry season when they become extremely hard; then during the wet season they are sticky and virtually impossible to work. Fortunately a great many of them are self-mulching, meaning that they expand and shrink in such a way that certain parts of the topsoil, varying from 5 to 30 cm in thickness, become crumbled and make tillage less important. When they occur in a depressed position, low infiltration rate becomes an additional problem, also related to the typical physical characteristics. This makes irrigation difficult because of poor drainage and the subsequent risk of salinization. However, it was found in the Sudan that Vertisols have a natural reaction against the surface accumulation of salts. Salts, under normal irrigation, are washed to the subsoil through cracks and fissures leaving at least 30 cm (the rooting zone) where salt does not accumulate to dangerous levels. Management practices therefore should be directed toward maximum infiltration and storage of moisture during the dry season, while in the wet season drainage is essential.

Their topographic position may often be so unfavourable that the soils have to be used for grazing rather than crops. Subsurface irrigation is practically impossible. However, successful surface drainage has been provided by ridge or furrow cultivation, hilling with furrows and, in Argentina, bedding. These methods are mainly directed at increasing the infiltration rate.

Another serious problem in Vertisols is their high susceptibility to erosion if the surface is not entirely flat. Rainfall is often concentrated during short periods, intake rate is low, and the crumbly surface soil may move, even on gentle slopes. Standard conservation practices do not suffice, as they tend to interfere with the necessary surface drainage. Slopes above 5 percent should not be used at all for new crops, while on lesser slopes various rotations of new crops planted on the contour and ground cover crops should be used. Fertility is not a serious problem. This has been attributed to the self-mulching, which adds fresh material to the surface. Vertisols can be deficient in available phosphorus and nitrogen, and sulfur, iron and molybdenum are often lacking. Calcium, magnesium and sodium are usually very high. Response to fertilizer has not been marked because of the poor physical properties, comparing unfavourably with the response of other widespread tropical soils like the Ferralsols.

In summary, the Vertisols are rather unsuitable soils for traditional management because of their difficult workability.

For improved management the Vertisols are rather good soils because practices have been found to partly overcome the limitations related to the poor physical characteristics. The Vertisols on slopes are better than those on low-lying sites because drainage is less troublesome. However, a stronger susceptibility to erosion of these soils will impose other problems.

## W. Planosols

*Use.* Because of their level and low-lying position in the landscape, and the presence of a heavy-textured, impermeable B horizon, usually at shallow depth, most of these soils are inundated for part of the year. They make excellent rice soils and as such contribute greatly to the production of this crop in Brazil (Rio Grande do Sul) and northern Argentina. During the dry season and during the wet season if not used for rice or sugarcane cultivation, they are mostly used for grazing. The Mollic and Solodic Planosols, as found in flat relief in parts of the Argentine pampa, are among the best grasslands of the area. The natural sod on these soils, which consists mainly of an association of *Stipa* species, may be replaced by artificial pasture-legume mixtures to ensure a higher productive capacity in terms of more head of cattle per hectare.

*Suitability.* Because of their impervious subsoil, which can be quite deep and difficult to break, Planosols can be used only for adapted crops. Drainage can remove the risk of inundation in many areas, but internal drainage would remain poor. In dry years grassland will suffer seriously because the roots cannot penetrate deeply enough into the resistant subsoil material. Moreover, this becomes extremely hard when dry so that water stagnation starts at the beginning of the rainy season. They are good soils for irrigated rice cultivation, both for traditional management and modern management. The natural fertility is usually medium to high. The Mollic Planosols are better than the Eutric Planosols because of the better water storage and greater water availability during the dry season and also because of their easier workability. Sometimes the subsoil of Planosols may contain a medium content of sodium, to which rice and many grass species are, however, sufficiently resistant, but irrigation water should have a low salt content.

## X. Xerosols

*Use.* Both in characteristics and land use Xerosols are transitional between the Yermosols of the arid regions and the Kastanozems which occur in a somewhat moister environment. Therefore, their occurrence on the fringes of the Patagonian desert, in the central part of the Andean altiplano, in the driest parts of the semiarid Chaco region of Paraguay, Bolivia and northern Argentina, and in semiarid northern Venezuela and northern Colombia can be expected. Everywhere these soils are used for extensive grazing although locally irrigation schemes have been developed.

In the central altiplano of Bolivia where the mean annual rainfall is between 200 and 400 mm, cropping is restricted to the steeper slopes of rolling land and the lower slopes of mountains because of the very strong and cold winds and frosts which occur during much of the year. Grazing with llamas is more common than with alpaca, and sheep outnumber cattle. In Argentina the temperatures are high and grazing finds greater possibilities. In Paraguay and Bolivia Xerosols are mostly salty (saline phase on the soil map) and grazing is very restricted. In northern Venezuela and northern Colombia the annual rainfall is about 500 mm and although desert soils have been reported, extensive areas are probably Xerosols perhaps with rather thin and light coloured A horizons. They are used sometimes for the production of sisal and pineapples. The most extensive area is used for grazing goats. This has resulted in the loss of much ground cover, which gives the impression of a drier climate than really exists.

*Suitability.* Xerosols have a restricted suitability for the cultivation of a few adapted short-season crops, but production is risky because of the irregularity of the rainy season. Extensive grazing is feasible only to a limited extent to enable the recuperation of the sparse natural vegetation. Irrigation often meets serious problems because of common drainage-impeding layers in the subsoil (argillic, calcic horizons) and in many places of shallowness. The supply of plant nutrients is usually high, but excesses of soluble salt may complicate the use of fertilizer on irrigated plots. Deficiencies of minor elements like iron and zinc seem to be common, and the need for nitrogen fertilizer is great.

## Y. Yermosols

*Use.* In Patagonia where these soils occur on old terraces and tablelands, they are mainly used for extensive sheep grazing. Because of shallowness, often stoniness, and frequently the presence of an ancient and strongly developed argillic B horizon (Yl: Luvic Yermosols), they are seldom irrigated.

The desert soils of northern Chile and the desertic altiplano are mostly saline or alkali. Both primitive and modern agricultural operations in the alkali desert soils have always been restricted to areas which can be irrigated. These include some carefully planned modern schemes applied to the older, stable desert soils of the nearly level terraces. However, agricultural operations are still confined to younger soils of the valley bottom lands and to the nearby gently sloping alluvial fans where simple traditional irrigation schemes are easy to apply. The main crops grown are market garden crops (tomatoes, peppers, melons, string beans, lettuce), cereals (wheat, barley, corn), forage crops (alfalfa, Sudan grass), but some fibre crops (flax, cotton) and fruits (papaya, citrus, avocado, chirimoya, grapes) can also be grown in areas with good air drainage where there is less likelihood of frost damage. Irrigation systems range from free flooding to modern contour canals. In some valleys subsurface drainage has not had enough attention, resulting in the formation of saline and alkali soils. The chief fertilizer response is to nitrogen. Sulfate of ammonia can usually be expected to give better results than the national saltpetre. Economic responses to phosphate (guano mixture) have been observed in leguminous crops. The coastal desert soils are predominantly hilly with only local areas of more subdued relief. No indigenous agriculture has ever been practised on these soils, as irrigation water has generally to be brought from high in the cordillera by pipelines. Water for the experimental vegetable growing station at Areas Vendes near Antofagasta is obtained in this way. Near Arica city, water for a similar station will, however, be obtained from shallow wells and bores. The desertic altiplano of Bolivia receives less than 100 mm of rainfall per year, and in some years no rain is recorded. Severe frosts may occur any time of the year; therefore crop production is restricted to particularly warm slopes and sheltered locations. Broad, barren salt plains are common. Elsewhere on the Yermosols plant cover is scarce and restricted to open patchy grassland. Agriculture is mainly pastoral; llama and sheep flocks are herded across the plains.

*Suitability.* These soils are not suitable for either traditional or improved agriculture because of the predominant water deficiency. Their suitability for irrigation depends on many features, the assessment of which is not within the scope of this study.

## Z. Solonchaks

*Use.* Orthic Solonchaks are extensive in the arid parts of northern Chile where they are rarely used by farmers. Primitive agriculture in this region concentrated upon the use of parts of the Solonchak areas, employing wide pits dug down to within 50 cm of the level of the water table so that capillary rise in fine sandy and silty soils permitted the growth of moderately salt-tolerant crops. The salt which accumulated at the surface was repeatedly removed. When salinity became too high, a new series of pits was excavated. Modern reclamation practices directed to the removal of salts through irrigation in combination with drainage are not yet common in South America since such practices are expensive.

*Suitability.* These soils are rather unsuitable for traditional agriculture. In the subhumid and humid environments, where salinity is related to specific topographic positions, like drainage basins without outlet, e.g. in the Argentinian pampa, they may still support a fair grass growth but should not be used for nonirrigated crop growing.

Improved agriculture, especially in dry areas, depends entirely on successful leaching of salts through physical, biological and hydrotechnical reclamation methods and combinations of these practices. Such soil improvements have been discussed in various handbooks dealing with arid lands and are not elaborated upon here. It should be recalled, however, that problems of irrigation are closely connected to drainage possibilities since the physiography of saline plains is often such that leaching of salts in large areas is almost impossible without pumping. In humid environments, drainage to a depth of a few decimetres from the surface can be a great improvement, while in arid regions deep drainage (2 to 3 metres) is often necessary. In general the desired result of the irrigation, drainage and other practices is always to arrive at a well drained, nonsaline soil with a deep ground water table. Soil fertility soon becomes a problem after soil leaching has started. It is not essential at the first stage of reclamation to remove all the salt. There are quite a few plant varieties, even some legumes, with a reasonable salt tolerance which can be grown at an early stage of desalinization.

## Conclusions

An outstanding feature of South American soils is their low natural fertility. Soil regions A1, B1, B2, B3, B4, B5 and B9, which make up approximately 50 percent of the continent, consist predominantly of various kinds of Ferralsols, Orthic Acrisols and Ferralic Arenosols, all low in cation exchange capacity and in exchangeable bases.

Another limitation which severely affects the agricultural use of the soils is deficiency of water. Broadly speaking, 20 percent of South America, including soil regions A9, B6, B11, C3 and C4 have semiarid climates, making agriculture without irrigation hazardous or impossible. The soils are mainly Yermosols, Regosols, Lithosols, salt-affected soils like Solonchak and Solonetz, Ferric Luvisols and Chromic Luvisols.

One of the principal characteristics of the soils of the regions A2, A3, A4, A5 and A7 is poor drainage. These regions make up about 10 percent of the continent. Here the soils are mainly Gleysols, Plinthic Acrisols, Vertisols and Planosols.

The Andes have large areas of steeplands where Lithosols are dominant and where more developed soils are relatively scarce. Soil regions with predominantly steep slopes are C1, C2, C5 and C6, which make up about 10 percent of the continent. Apart from Lithosols, other important soils are Dystric Cambisols, Andosols and Orthic Acrisols, whose occurrence is clearly related to altitude and parent material. These are acid soils, but relatively large areas of eutrophic soils can also be found in the inter-Andean valleys and on some foothills, including Kastanozems, Phaeozems, Chromic Luvisols and Eutric Cambisols.

The areas where soils do not have serious limitations extend over less than 10 percent of the continent. The soil regions A8, B7, B8 and B10, which belong to this category, consist of Phaeozems, Kastanozems, Ferric Luvisols, some of the Rhodic Ferralsols with medium to high base status, Eutric Nitosols and Chromic Luvisols.

## Reference

FAO. *Production yearbook, 1969.* Rome. 1969

# APPENDIX

## Morphological, Chemical and Physical Properties of South American Soils : Data from Selected Profiles [1]

In this appendix data are presented on typical profiles representing several of the major soil units that occur as dominant or as associated soils on the Soil Map of South America.

The profiles were selected from published and unpublished material available to the project. Whenever possible acknowledgement is made to the sources of the data that have been used.

The purpose of including these descriptions and tables is to help define more clearly the nature of the soil units used in the map. Naturally, the description and analyses of one or two profiles will not show the range of characteristics within such broad units but, combined with the definitions in Volume I and with the descriptions and analyses in the other volumes, they should help at least to establish the concepts on which the legend is based.

For most of the soil units only one profile is described. However, for some of the more extensive units two profiles are presented to give some impression of the range that can be expected. For instance, soils of high or low base status or of fine or coarse texture may occur within a unit, and examples of these have been included. Again a unit may occur in areas with different climates, and examples of these are also given.

The data have been set out systematically to include most of the items generally available in survey reports. With such a variety of sources (information from eight countries) there is of course considerable diversity in the information supplied. However, an attempt has been made to present it as uniformly as possible so that valid comparisons can be made. Where established standards such as the U.S.D.A. *Soil Survey Manual* (Soil Survey Staff, 1951) have been used, there is no difficulty. In other places there may be some uncertainty in the definition of terms, and care in interpretation is needed.

[1] By R.B. Miller.

### Analytical methods

It is important when considering analyses to know the methods that have been used. In most reports these are described or, at least, outlined, and a reference given. Where this is not done it is often possible to find the information in other publications.

The following publications contain details of most of the methods used:

| | |
|---|---|
| Argentina | - Cappannini and Lores, 1966, p. 47. |
| Brazil | - Comissão do Solos, 1962, pp. 67-71. |
| Chile | - Soil Survey Staff, 1960, pp. 30-32. |
| Guyana | - FAO, 1965-66, Vol. 2, pp. 1-2, 11-13. |
| Peru | - Zamora, Carucci and Echenique, 1967, Appendix B. |
| Uruguay | - Kaplan and Duran, 1968. |
| Venezuela | - Westin, 1962, pp. 155-161. |

A preliminary survey of the methods indicates that there is, in fact, considerable uniformity. Similar methods for pH, carbon and nitrogen, particle size and, to some extent, cation exchange are used in most laboratories, and these results can be compared with some confidence. The actual methods are discussed in more detail below.

### Presentation of data

Whenever possible the data have been taken from the original documents without alteration. However, some changes have been made for the sake of brevity or uniformity of presentation.

#### SITE DESCRIPTION

The information used to describe the site is as follows:

Location: An attempt was made to locate the site of each profile by the distance and direction from a main town, and by latitude and longitude. In many reports insufficient information was given to determine accurate siting.

Altitude: The altitude is given in metres above mean sea level.

Physiography: Where possible, the nature of the landscape as well as the slope at the profile site are given. Because of differences in definition of terms like undulating, moderately steep, etc., figures are used if they are available.

Drainage: The drainage description is usually given, as in the U.S. Soil Survey Manual, as a synthesis of run-off, permeability and internal soil drainage.

Parent material: Sometimes parent rock is given under this heading.

Vegetation: There is normally insufficient information and insufficient space to describe the site vegetation, so only general terms to describe the kind of vegetation cover are given, e.g. grassland, deciduous forest.

Climate: The climate is given as an index figure according to the system of Papadakis (1966), outlined in Chapter 4. As a general description the name of the subgroup is also included, e.g. for the climate index 1.121, the description of 1.1 (humid semihot equatorial) is given.

## Profile description

The profile descriptions have been rewritten in the pattern outlined in "Guidelines for Soil Profile Description" (FAO). The information is given in the order: colour, mottling, texture, structure, consistency, other items. Horizon designations have been altered to conform with the definitions given in Volume I. Where they were not included in the original description, they have been added on the basis of the descriptive and analytical information available.

## Analyses

Figures have sometimes been rounded or recalculated on a different basis, for the sake of uniformity.

pH is usually measured at a 1:1 soil/water ratio but paste and 1:2.5 are also used. Measurements in N KCl are given where they are available.

Cation exchange. Percent base saturation (% BS) is given as a whole number, the cation exchange capacity, total exchangeable bases, and exchangeable Ca, Mg and Na are given to one place of decimals, and exchangeable K to one place, or when low to 0.05 me %.

As pointed out by Bennema (1966, Appendix 4), the method used in determining cation exchange capacity (CEC) is important, as CEC and % BS are both used as differentiating characteristics in soil classification. In South America most countries use CEC found at pH 7 either by distillation of absorbed ammonia as in Peru or by summation of Ca, Mg, K and Na plus exchange acidity found by titrating an N calcium acetate leachate back to pH 7 (Brazil). Three countries, however (Argentina, Guyana and Venezuela), use a leaching with barium chloride-triethanolamine at pH 8.1 or 8.2, which gives an appreciably higher value for CEC. Bennema presents graphs comparing the methods, and these should be consulted before comparisons involving different methods are made.

Organic matter. The Walkley-Black and Kjeldahl methods, or variations of them, are used by all laboratories. The figures for carbon and nitrogen are given to one and two decimal places respectively. Values for organic matter (OM) are given where they are separately determined.

Particle size analysis. The pipette method is usually used and the following particle size ranges are separated:

| | |
|---|---|
| coarse sand | 2 000 – 500 μ |
| fine sand | 500 – 50 μ |
| silt | 50 – 2 μ |
| clay | below 2 μ |

Textures are found by use of the triangular texture diagram in the U.S. *Soil Survey Manual.* Where different methods or different size ranges are used this is shown in a footnote. The results are given as whole numbers, recalculated if necessary to percentages of organic matter-free soil with fractions coarser than 2 mm removed. The fractions above 2 mm are combined under the heading "stones." The flocculation index is the percentage of the clay that remains flocculated, i.e. that is not dispersed when the soil is shaken in distilled water.

Available phosphorus. A variety of methods have been used, and all the results have been recalculated to give mg of P/100 g soil.

Soluble salts are quoted as electrical conductivity (E.C.) in mmhos/cm at 25°C of a soil paste. In Guyana a 1:5 soil/water extract is used and the percentage of salts calculated from conductivity figures by Piper's formula.

Mineralogy. If information is available it is summarized in a note under the profile description.

Other analyses are explained in the tables where necessary.

## Discussion

Because of the limited number of profiles presented it is not possible to discuss the properties of the soil units in any detail. Furthermore, profiles were not sampled specifically to characterize the particular soil units, rather they were selected as satisfactory representatives of the various units within the limits of the data available. The information is best used to illustrate typical properties of various units and to make comparisons.

The variations may be looked at in two ways. First, there are the variations in properties from unit to unit, and second there are the variations within units.

Despite the few samples, it is possible to follow a general development pattern in a sequence such as Fluvisols – Cambisols – Luvisols – Acrisols – Ferralsols. The falling pH, falling bases and phosphorus, increasing clay and increasing flocculation index are example of the trends present. Some of the differences, of course, follow from the use of such factors as cation exchange capacity, percent base saturation and percent clay in the definitions, but the overall pattern is consistent with our concepts of these soils. The very low levels of potassium and phosphorus in the more developed soils is a notable feature that will be of particular importance in their agricultural development and use.

Differences within the major divisions and the subdivisions may also be considered. The differences within major divisions are of particular interest as illustrations of the application of the criteria developed for the definitions of the units. These criteria are numerous and diverse, including morphological, physical, and chemical properties. The data provide many examples; many more may be found in the analyses of soils from other continents.

Soil profiles, of course, are the result of the operation of a complex array of factors. Changes in any given factor do not necessarily show up in clear differences in properties. However, the site information and the morphological, physical and chemical data do give a useful overall picture of each unit. They also help us to understand how the soils were formed, how they are related, how they may be classified and how they may be used.

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TABLE 4. – SOIL PROFILES

| Symbol and Unit | | | Country | Climate | Page |
|---|---|---|---|---|---|
| Ao | ACRISOL | Orthic | Brazil | 1.77 | 128 |
| Ao | | Orthic | Venezuela | 1.484 | 130 |
| Bh | CAMBISOL | Humic | Brazil | 2.31 | 132 |
| Fa | FERRALSOL | Acric | Brazil | 1.132 | 134 |
| Fh | | Humic | Brazil | 2.24 | 136 |
| Fo | | Orthic | Brazil | 1.77 | 138 |
| Fo | | Orthic | Brazil | 1.72 | 140 |
| Fr | | Rhodic | Brazil | 1.77 | 142 |
| Fx | | Xanthic | Brazil | 1.482 | 144 |
| Gd | GLEYSOL | Dystric | Brazil | 1.121 | 146 |
| Ge | | Eutric | Guyana | 1.121 | 148 |
| Gh | | Humic | Brazil | 1.77 | 150 |
| Hh | PHAEOZEM | Haplic | Argentina | 5.113 | 152 |
| Hl | | Luvic | Uruguay | 4.14 | 154 |
| Jt | FLUVISOL | Thionic | Guyana | 1.121 | 156 |
| Kh | KASTANOZEM | Haplic | Peru | 2.62 | 158 |
| Lf | LUVISOL | Ferric | Brazil | 1.77 | 160 |
| Nd | NITOSOL | Dystric | Brazil | 4.13 | 162 |
| Ne | | Eutric | Brazil | 1.77 | 164 |
| Od | HISTOSOL | Dystric | Guyana | 1.121 | 166 |
| Ph | PODZOL | Humic | Brazil | 1.61 | 168 |
| Qa | ARENOSOL | Albic | Guyana | 1.121 | 170 |
| Qf | | Ferralic | Brazil | 1.77 | 172 |
| Re | REGOSOL | Eutric | Argentina | 5.13 | 174 |
| Sm | SOLONETZ | Mollic | Argentina | 5.112 | 176 |
| Th | ANDOSOL | Humic | Chile | 6.21 | 178 |
| Tv | | Vitric | Peru | 2.51 | 180 |
| Vc | VERTISOL | Chromic | Brazil | 1.543 | 182 |
| Vp | | Pellic | Peru | 1.72 | 184 |
| We | PLANOSOL | Eutric | Argentina | 4.36 | 186 |
| Wm | | Mollic | Argentina | 5.35 | 188 |
| Ws | | Solodic | Argentina | 5.111 | 190 |
| Xh | XEROSOL | Haplic | Argentina | 5.71 | 192 |

| | |
|---|---|
| **ORTHIC ACRISOL** | **Ao** |
| **Red-yellow podzolic** | Brazil |
| **Comissão de Solos, 1958** | Profile 13, p. 131 |
| **Location** | 49 km W Rio de Janeiro, old road to São Paulo, 22° 44′S, 43° 44′W |
| **Altitude** | 40 m |
| **Physiography** | Undulating |
| **Parent material** | Granitic gneiss |
| **Vegetation** | Grassland with trees, *Hyparrhenia rufa*, *Imperata brasiliensis* |
| **Climate** | 1.77, humid tierra templada |

**Profile description** [1]

| | | |
|---|---|---|
| A | **0-10 cm** | Dark greyish brown (10YR 4/2) sandy loam; moderately developed medium granular structure; slightly hard, friable, plastic, nonsticky; clear boundary. |
| E | **10-30 cm** | Yellowish brown (10YR 5/4) sandy clay loam; strongly developed fine granular structure; hard, friable, plastic, nonsticky; weakly cemented; gradual boundary. |
| EB | **30-45 cm** | Yellowish brown (10YR 5/6) sandy clay loam; weakly developed fine subangular structure; hard, firm, slightly plastic, slightly sticky; weakly cemented; gradual boundary. |
| $B_1$ | **45-75 cm** | Yellowish red (5YR 5/6) clay; moderately developed fine subangular structure; slightly hard, firm to friable, plastic, sticky; thin clayskins; clear boundary. |
| $B_2$ | **75-155 cm** | Red (2.5YR 4/8) clay loam; strongly developed medium subangular structure; slightly hard, friable, plastic, sticky; thick clayskins; clear boundary. |
| BC | **155-195 cm** | Red (2.5YR 5/8) clay loam; moderately developed large subangular structure; slightly hard, friable, slightly plastic, sticky; thin clayskins; clear boundary. |
| C | **195 + cm** | Sandy loam with distinct mottling. |

Coarse sand is 96% quartz in the $A_1$ horizon, and 98-99% in the other horizons.

[1] See Volume I for definition of horizons.

## ORTHIC ACRISOL

**Brazil**

| Horizon | Depth cm | pH H$_2$O | pH KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | CaCO$_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0—10 | 4.8 | | 4.5 | 2.2 | 49 | 1.4 | 0.4 | 0.1 | 0.3 | | 2.3 | |
| E | —30 | 4.6 | | 3.7 | 1.3 | 35 | 0.8 | 0.2 | 0.05 | 0.3 | | 2.4 | |
| EB | —45 | 4.6 | | 4.2 | 1.0 | 24 | 0.5 | 0.2 | 0.05 | 0.2 | | 3.2 | |
| B$_1$ | —75 | 4.4 | | 6.0 | 0.5 | 8 | 0.3 | 0.1 | 0.05 | 0.2 | | 5.5 | |
| B$_2$ | —155 | 4.6 | | 4.6 | 1.3 | 28 | 0.4 | 0.7 | 0.05 | 0.2 | | 3.3 | |
| BC | —195 | 4.6 | | 3.9 | 0.9 | 23 | 0.2 | 0.6 | 0.1 | 0.1 | | 3.0 | |
| C | 195+ | 4.7 | | 8.0 | 1.2 | 15 | 0.1 | 0.8 | 0.2 | 0.2 | | 6.8 | |

Cation exchange me %

| Horizon | Sol. salts | | Organic matter % C | % N | C/N | % OM | Particle size analysis %[1] stones | c. sand | f. sand | silt | clay | texture | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | 1.3 | 0.13 | 10 | | | 49 | 23 | 13 | 75 | sandy loam | 70 |
| E | | | 0.7 | 0.10 | | | | 48 | 16 | 12 | 24 | sandy clay loam | 59 |
| EB | | | 0.5 | 0.07 | | | | 43 | 13 | 12 | 32 | sandy clay loam | 62 |
| B$_1$ | | | 0.5 | 0.08 | | | | 30 | 4 | 7 | 59 | clay | 99 |
| B$_2$ | | | 0.2 | 0.06 | | | | 22 | 10 | 30 | 38 | clay loam | 100 |
| BC | | | 0.1 | 0.04 | | | | 32 | 15 | 25 | 28 | clay loam | 100 |
| C | | | | 0.04 | | | | 39 | 19 | 22 | 20 | sandy loam | 100 |

| Horizon | Solution by H$_2$SO$_4$, d = 1.47 % SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | TiO$_2$ | MnO | P$_2$O$_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % Truog | | | Quartz in c. sand % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 11.0 | 7.1 | 1.1 | | | | 2.6 | 2.4 | | 0.4 | | | 96 |
| E | 13.7 | 10.3 | 1.7 | | | | 2.2 | 2.0 | | 0 | | | 99 |
| EB | 16.1 | 12.8 | 2.0 | | | | 2.2 | 2.0 | | 0.6 | | | |
| B$_1$ | 27.8 | 23.4 | 4.1 | | | | 2.0 | 1.8 | | 0.2 | | | 99 |
| B$_2$ | 24.0 | 24.1 | 6.0 | | | | 1.7 | 1.5 | | 0.5 | | | 99 |
| BC | 26.6 | 20.5 | 5.2 | | | | 2.2 | 1.9 | | 0.7 | | | 98 |
| C | 24.0 | 20.4 | 3.5 | | | | 2.0 | 1.8 | | 2.4 | | | 98 |

| Horizon | | | | | | | | | | Moist. equiv. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | 16 | | | |
| E | | | | | | | | | | 16 | | | |
| EB | | | | | | | | | | 19 | | | |
| B$_1$ | | | | | | | | | | 28 | | | |
| B$_2$ | | | | | | | | | | 27 | | | |
| BC | | | | | | | | | | 23 | | | |
| C | | | | | | | | | | 23 | | | |

[1] International size grades.

| | |
|---|---|
| **ORTHIC ACRISOL** | **Ao** |
| **San Felix** | Venezuela |
| **Westin, 1962** | Profile 40, p. 87 and p. 139 |
| **Location** | Between San Felix and Caroni Camp, Guyana area. San Felix is 8° 23′N, 62° 38′W |
| **Physiography** | Level to undulating |
| **Drainage** | Well drained |
| **Parent material** | Old alluvium |
| **Vegetation** | Grassland, scattered trees |
| **Climate** | 1.484, hot tropical |

**Profile description**

| | | |
|---|---|---|
| A | **0-12 cm** | Dark brown (10YR 3/3) moist, brown (10YR 4/3) dry, sand; weak very coarse and fine granular structure; soft, very friable, nonsticky and nonplastic; contains many uncoated quartz grains; clear smooth boundary. |
| $E_1$ | **12-30 cm** | Dark brown (7.5YR 3/2) moist, brown (7.5YR 4/4) dry, loamy sand; weak coarse angular blocky structure; slightly hard, very friable, nonsticky and nonplastic; contains many uncoated quartz grains; gradual smooth boundary. |
| $E_2$ | **30-44 cm** | Dark reddish brown (5YR 3/4) moist, reddish brown (5YR 4/4) dry, light sandy clay loam; weak coarse and medium angular blocky structure; hard, very friable, nonsticky, slightly plastic; contains many uncoated quartz grains; clear smooth boundary. |
| BE | **44-67 cm** | Dark red (2.5YR 3/6) moist, yellowish red (5YR 3/8) dry, sandy clay loam; weak medium and fine angular blocky structure; slightly hard, friable, nonsticky, slightly plastic; clear smooth boundary. |
| $B_1$ | **67-140 cm** | Red (2.5YR 4/6) moist, red (2.5YR 5/8) dry, sandy clay loam; weak medium and fine angular blocky structure; slightly hard, friable, nonsticky, plastic to slightly plastic; gradual smooth boundary. |
| $B_2$ | **140-200 cm** | Red (2.5YR 4/6) moist, light red (2.5YR 6/8) dry, sandy clay loam; weak medium and fine angular blocky structure; hard friable, nonsticky, slightly plastic; clear smooth boundary. |
| BC(?) | **200-250 cm** | Red (10R 4/6) moist, red (10R 4-5/8) dry, sandy clay loam; very weak medium and fine angular blocky structure; soft to slightly hard, very friable, nonsticky to slightly sticky, slightly plastic. |

## ORTHIC ACRISOL

### Venezuela

| Horizon | Depth cm | pH H₂O | pH KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | $CaCO_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0—12 | 4.8 | 4.8 | 3.2 | 0.8 | 25 | 0.4 | 0.4 | 0.05 | 0 | | 2.4 | |
| $E_1$ | —30 | 4.7 | 4.3 | 3.7 | 0.7 | 19 | 0.4 | 0.2 | 0.05 | 0.1 | | 3.1 | |
| $E_2$ | —44 | 4.7 | 4.3 | 4.0 | 0.6 | 15 | 0.4 | 0.2 | 0.05 | 0 | | 3.5 | |
| BE | —67 | 5.0 | 4.7 | 3.5 | 0.8 | 23 | 0.4 | 0.4 | 0.05 | 0 | | 2.8 | |
| $B_1$ | —90 | 5.4 | 4.7 | 3.2 | 0.7 | 22 | 0.3 | 0.4 | 0.05 | 0 | | 2.5 | |
| — | —140 | 5.6 | 4.7 | 2.8 | 0.7 | 25 | 0.2 | 0.5 | 0.05 | 0 | | 2.1 | |
| $B_2$ | —200 | 5.3 | 4.6 | 2.2 | 0.9 | 41 | 0.2 | 0.6 | 0.05 | 0.1 | | 1.3 | |
| BC | —235 | 5.4 | 4.6 | 2.1 | 0.9 | 43 | 0.3 | 0.5 | 0.05 | 0.1 | | 1.2 | |
| — | 235+ | 5.5 | 4.6 | 2.1 | 0.9 | 43 | 0.3 | 0.3 | 0.05 | 0.3 | | 1.1 | |

| Horizon | Sol. salts | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | 0 | 9 | 80 | 4 | 7 | sand | |
| $E_1$ | | | | | | | 1 | 6 | 75 | 6 | 13 | sandy loam | |
| $E_2$ | | | | | | | 1 | 9 | 61 | 8? | 20? | sandy clay loam | |
| BE | | | | | | | 1 | 7 | 55 | 8 | 30 | sandy clay loam | |
| $B_1$ | | | | | | | 1 | 7 | 52 | 8 | 33 | sandy clay loam | |
| — | | | | | | | 1 | 9 | 52 | 8 | 31 | sandy clay loam | |
| $B_2$ | | | | | | | 1 | 8 | 58 | 8 | 26 | sandy clay loam | |
| BC | | | | | | | 1 | 8 | 59 | 8 | 25 | sandy clay loam | |
| — | | | | | | | 1 | 8 | 60 | 8 | 24 | sandy clay loam | |

| Horizon | Clay analysis % $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ |
|---|---|---|---|---|---|---|---|---|---|
| A | 37.6 | 27.8 | 11.5 | | | | | 1.9 | |
| $E_1$ | 40.8 | 26.4 | 13.2 | | | | | 2.0 | |
| $E_2$ | 39.3 | 24.5 | 14.4 | | | | | 2.0 | |
| BE | 39.9 | 27.2 | 14.4 | | | | | 1.9 | |
| $B_1$ | 38.1 | 29.4 | 10.8 | | | | | 1.8 | |
| — | 38.3 | 31.4 | 16.0 | | | | | 1.6 | |
| $B_2$ | 38.7 | 34.4 | 12.5 | | | | | 1.5 | |
| BC | 38.6 | 32.9 | 12.6 | | | | | 1.6 | |
| — | 39.4 | 35.2 | 8.4 | | | | | 1.6 | |

| | |
|---|---|
| **HUMIC CAMBISOL** | **Bh** |
| **Campos do Jordão soils** | Brazil |
| **Comissão do Solos, 1960** | Profile 69, p. 455 |
| **Location** | 1 km from Pico de Itapeva on road to Campos do Jordão, São Paulo State. 22° 44'S, 45° 35'W. |
| ***Altitude*** | *1780 m* |
| **Physiography** | Mountainous, 50% slope |
| **Drainage** | Moderately well drained |
| **Parent material** | Granite |
| **Vegetation** | High altitude subtropical forest |
| **Climate** | 2.31, medium terra fria |

**Profile description**

| | | |
|---|---|---|
| A | **0-17 cm** | Black (N 1/) sandy loam; weakly developed medium granular structure; soft, friable, nonplastic, nonsticky; abundant roots; gradual smooth boundary. |
| AB | **17-80 cm** | Dark brown (10YR 3/3) sandy clay loam; weakly developed small subangular blocky structure; soft, friable, slightly plastic, slightly sticky; fewer roots; diffuse smooth boundary. |
| $B_1$ | **80-130 cm** | Strong brown (8YR 5/8) moist, yellow (10YR 8/6) dry, clay loam; prismatic structure breaking to weak small subangular blocks; hard, friable, slightly plastic, slightly sticky; slightly porous; few roots; diffuse smooth boundary. |
| $B_2$ | **130-180 cm** | Brownish yellow (10YR 6/6) moist, very pale brown (10YR 7/4) dry, sandy clay loam; prismatic structure breaking to weak small subangular blocks; hard, friable, plastic, sticky; slightly porous; diffuse smooth boundary. |
| $C_1$ | **180-240 cm** | Light reddish brown (1.5YR 6/4), with mixed colours from decomposition of parent material, loam; massive. |
| $C_2$ | **240-300 cm** | Light reddish brown (2.5YR 6/4), with mixed colours from decomposition of parent material, loam. |

NOTE: No clayskins were observed. Coarse sand was 95% quartz in A, AB and $B_1$ horizons. The $B_2$, $C_1$ and $C_2$ had 58%-67% quartz, 29-36% biotite and small amounts of clay concretions and other minerals, including 5% of microcline in the $C_2$.

## HUMIC CAMBISOL

**Brazil**

| Horizon | Depth cm | pH |  | Cation exchange me % |  |  |  |  |  |  |  |  | $CaCO_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H |  |
| A | 0—17 | 3.6 | 3.1 | 58.7 | 0.6 | 1 | 0.2 | 0.2 | 0.2 | 0.1 |  |  |  |
| AB | —80 | 4.8 | 4.2 | 21.5 | 0.4 | 2 | 0.1 | 0.2 | 0.05 | 0.1 |  |  |  |
| $B_1$ | —130 | 5.1 | 4.3 | 6.1 | 0.3 | 5 | 0.1 | 0.1 | 0.05 | 0 |  |  |  |
| $B_2$ | —180 | 5.1 | 4.0 | 5.0 | 0.4 | 7 | 0.1 | 0.2 | 0.05 | 0 |  |  |  |
| $C_1$ | —240 | 5.1 | 4.0 | 5.0 | 0.4 | 8 | 0.1 | 0.2 | 0 | 0 |  |  |  |
| $C_2$ | —300 | 5.2 | 4.0 | 3.6 | 0.3 | 9 | 0.1 | 0.1 | 0 | 0 |  |  |  |

| Horizon | Sol. salts |  | Organic matter |  |  |  | Particle size analysis %[1] |  |  |  |  |  | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture |  |
| A |  |  | 12.6 | 1.15 | 11 |  | 0 | 29 | 46 | 9 | 16 | sandy loam | 93 |
| AB |  |  | 5.2 | 0.37 | 14 |  | 2 | 29 | 43 | 5 | 23 | sandy loam | 93 |
| $B_1$ |  |  | 1.0 | 0.08 | 12 |  | 1 | 25 | 34 | 14 | 27 | sandy clay loam | 80 |
| $B_2$ |  |  | 0.6 | 0.05 |  |  | 0 | 21 | 39 | 16 | 24 | sandy clay loam | 56 |
| $C_1$ |  |  | 0.5 | 0.04 |  |  | 0 | 26 | 34 | 20 | 20 | sandy loam | 60 |
| $C_2$ |  |  | 0.3 | 0.02 |  |  | 2 | 24 | 35 | 17 | 24 | sandy clay loam | 99 |

| Horizon | Solution by $H_2SO_4$, d = 1.47 % |  |  |  |  |  | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ |  |  |  |  |  |  |
| A | 4.9 | 4.2 | 6.7 | 0.4 |  | 0.13 | 2.0 | 1.0 | 1.0 | <0.4 |  |  |
| AB | 4.8 | 9.1 | 8.9 | 0.3 |  | 0.12 | 0.9 | 0.5 | 1.6 | <0.4 |  |  |
| $B_1$ | 8.1 | 17.5 | 10.4 | 1.6 |  | 0.03 | 0.8 | 0.6 | 2.6 | <0.4 |  |  |
| $B_2$ | 12.0 | 25.0 | 9.0 | 1.4 |  | 0.02 | 0.8 | 0.7 | 4.4 | <0.4 |  |  |
| $C_1$ | 13.7 | 21.1 | 9.6 | 1.5 |  | 0.02 | 1.1 | 0.9 | 3.5 | <0.4 |  |  |
| $C_2$ | 13.5 | 26.1 | 6.9 | 1.2 |  | 0.02 | 0.9 | 0.8 | 5.9 | 1.0 |  |  |

| Horizon |  |  |  |  |  |  |  |  |  | Moist. equiv. |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A |  |  |  |  |  |  |  |  |  | 40 |  |  |  |
| AB |  |  |  |  |  |  |  |  |  | 27 |  |  |  |
| $B_1$ |  |  |  |  |  |  |  |  |  | 25 |  |  |  |
| $B_2$ |  |  |  |  |  |  |  |  |  | 34 |  |  |  |
| $C_1$ |  |  |  |  |  |  |  |  |  | 32 |  |  |  |
| $C_2$ |  |  |  |  |  |  |  |  |  | 35 |  |  |  |

[1] International size grades.

| | |
|---|---|
| **ACRIC FERRALSOL** | **Fa** |
| **Clayey pale yellow latosol** | Brazil |
| **R.B. Cate Jr., T.H. Day** | FAO manuscript, 1962 |
| **Location** | Curuá Una, Pará state 2° 40'S, 54° 05'W |
| **Altitude** | 100 m |
| **Physiography** | Flat |
| **Drainage** | Well drained |
| **Parent material** | Tertiary lacustrine sediments |
| **Vegetation** | Heavy forest |
| **Climate** | 1.132, humid semihot equatorial |

**Profile description**

| | | |
|---|---|---|
| **A** | **0-28 cm** | Dark brown (10YR 4/3) clay; strongly developed fine to very fine subangular blocky structure; friable to firm; a few carbon fragments; many roots. |
| **AB** | **28-41 cm** | Brown (7.5YR 4/4) clay; weakly developed coarse blocky to strongly developed very fine subangular blocky structure; friable. |
| **BA** | **41-84 cm** | Reddish yellow (7.5YR 6/8) and brown (7.5YR 4/4) variegated clay; strongly developed very fine subangular blocky structure; friable. |
| **$B_1$** | **84-130 cm** | Reddish yellow (7.5YR 6/8) clay; structureless to weakly developed very coarse and moderately developed very fine subangular blocky structure; occasional very fine textured cemented fragments yellowish red outside, dark grey inside. |
| **$B_2$** | **130-280 cm** | Reddish yellow (7.5YR 6/8) clay; friable, plastic, sticky; no roots below 180 cm. |
| **$B_3$** | **280-460 cm** | Reddish yellow (5YR 6/8) clay; friable, plastic, sticky; very compact; quite dry, probably at wilting point. |

NOTE: Much macrobiological activity making the soil loose and porous down to about 130 cm. The activity decreases with depth. A termite hive was uncovered in the soil pit.

## ACRIC FERRALSOL

**Brazil**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | | CaCO₃ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC[1] | TEB[2] | % BS | Ca | Mg | K | Na | Al[1] | H[1] | | |
| A | 0—28 | 4.4 | 3.8 | 4.1 | 0.8 | | | | | | 2.3 | 2.6 | | |
| AB | —41 | 4.6 | 3.8 | 2.8 | 0.2 | | | | | | 1.5 | 0.9 | | |
| BA | —84 | 4.7 | 3.8 | 2.2 | 0.3 | | | | | | 1.2 | 0.5 | | |
| $B_1$ | —130 | 4.0 | 3.9 | 0.6 | 0.4 | | | | | | 0.2 | 0.1 | | |
| $B_2$ | —280 | 5.4 | 4.9 | 0.3 | 0.4 | | | | | | 0.1 | 0.0 | | |
| $B_3$ | —460 | 5.8 | 5.2 | 0.2 | 0.2 | | | | | | 0.1 | 0.0 | | |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | | | | | | | | | 13 | 14 | 73 | clay | |
| AB | | | | | | | | | 9 | 7 | 84 | clay | |
| BA | | | | | | | | | 8 | 4 | 88 | clay | |
| $B_1$ | | | | | | | | | 10 | 6 | 84 | clay | |
| $B_2$ | | | | | | | | | — | — | — | — | |
| $B_3$ | | | | | | | | | 2 | 31 | 67 | clay | |

| Horizon | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | Kaolinite % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | 52 | | |
| AB | | | | | | | | | | 70 | | |
| BA | | | | | | | | | | 58 | | |
| $B_1$ | | | | | | | | | | 70 | | |
| $B_2$ | | | | | | | | | | 74 | | |
| $B_3$ | | | | | | | | | | 78 | | |

[1] Melich (1960). — [2] By $NH_4OAc$, 1N, pH 7.

| | |
|---|---|
| **HUMIC FERRALSOL** | **Fh** |
| **Durox soil** | Brazil |
| **WSRR 25** | FAO, 1966a, profile 11, p. 25 |
| **Location** | 4 km SW Vacaria, Rio Grande do Sul, 28° 31′S, 51° 02′W |
| **Altitude** | 920 m |
| **Physiography** | Strongly rolling, elevated |
| **Drainage** | Well drained |
| **Parent material** | Basalt |
| **Vegetation** | Grassland, *Artistida pallens* abundant |
| **Climate** | 2.24, low tierra fria |

**Profile description**

| | | |
|---|---|---|
| **A** | **0-19 cm** | Dark reddish brown (5YR 3/3) moist, heavy clay; moderately developed medium and coarse granular structure; very hard, firm to friable, plastic, sticky; abundant roots but main growth is horizontal and roots do not greatly penetrate into lower horizons; root channels lined with "coatings"; diffuse smooth boundary. |
| **AB** | **19-40 cm** | Dark reddish brown (5YR 3/4) moist, heavy clay; moderately developed medium and coarse granular structure; very hard, friable, plastic, slightly sticky, porous; few roots, with coatings along root channels; diffuse smooth boundary. |
| **BA** | **40-56 cm** | Dark reddish brown (2.5YR 3/4) moist, heavy clay; moderately developed fine and medium subangular blocky structure; very hard, friable, plastic, slightly sticky, porous; weak and scarce clayskins on peds; no roots; gradual smooth boundary. |
| **$B_1$** | **56-117 cm** | Dark red (2.5YR 3/6) moist, heavy clay; weakly developed, fine and medium subangular blocky structure; friable, slightly plastic, slightly sticky; few weakly developed clayskins on peds; gradual smooth boundary. |
| **$B_2$** | **117-176 cm** | Red (2.5YR 4/6) moist, heavy clay; weakly developed fine and medium subangular blocky structure; friable, slightly plastic, slightly sticky, porous; few weak clayskins; gradual smooth boundary. |
| **BC** | **176-200 cm** | Red (10R 4/6) moist, heavy clay; weakly developed medium and coarse subangular blocky structure; friable, slightly sticky, slightly plastic, porous; few weak clayskins. |

## HUMIC FERRALSOL

**Brazil**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | | CaCO₃ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | | |
| A | 0—19 | 4.7 | 3.7 | 18.4 | 3.1 | 17 | 1.7 | 1.2 | 0.1 | 0.1 | | | | |
| AB | —40 | 4.7 | 3.7 | 15.7 | 1.6 | 10 | 1.0 | 0.5 | 0.05 | 0.1 | | | | |
| BA | —56 | 4.8 | 3.7 | 13.8 | 1.3 | 9 | 0.9 | 0.4 | 0.05 | 0 | | | | |
| $B_1$ | —117 | 5.6 | 4.0 | 7.9 | 1.1 | 14 | 0.7 | 0.4 | 0.05 | 0 | | | | |
| $B_2$ | —176 | 5.6 | 4.0 | 7.6 | 0.9 | 12 | 0.6 | 0.3 | 0 | 0 | | | | |
| BC | —200 | 5.6 | 4.0 | 8.0 | 1.1 | 14 | 0.6 | 0.4 | 0.05 | 0.1 | | | | |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | | | 3.1 | 0.22 | 14 | | | | | | 22 | | |
| AB | | | 2.1 | 0.14 | 15 | | | | | | 31 | | |
| BA | | | 1.5 | 0.12 | 13 | | | | | | 15 | | |
| $B_1$ | | | 0.6 | 0.08 | | | | | | | 0 | | |
| $B_2$ | | | 0.6 | 0.06 | | | | | | | 0 | | |
| BC | | | 1.1 | 0.05 | | | | | | | 0 | | |

| Horizon | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | 2.0 | 1.2 | 1.6 | | | |
| AB | | | | | | | 1.8 | 1.2 | 2.0 | | | |
| BA | | | | | | | 1.9 | 1.3 | 2.2 | | | |
| $B_1$ | | | | | | | 1.8 | 1.2 | 2.0 | | | |
| $B_2$ | | | | | | | 1.8 | 1.2 | 2.0 | | | |
| BC | | | | | | | 1.9 | 1.3 | 2.2 | | | |

| | |
|---|---|
| **ORTHIC FERRALSOL** | **Fo** |
| **Orthic dark red latosol** | Brazil |
| **Rep. FAO-EPTA 2197** | Bennema, 1966, p. 49. Comissão do Solos, 1960, profile 42, p. 310. |
| **Location** | 14 km SE Rio Claro, São Paulo State, 22° 28′S, 47° 29′W |
| **Altitude** | 700 m |
| **Physiography** | Gently undulating, 5-10% slope |
| **Drainage** | Well drained |
| **Parent material** | Shales and argillites |
| **Vegetation** | Former tropical forest, now grassland with some small trees |
| **Climate** | 1.77, humid tierra templada |

**Profile description**

| | | |
|---|---|---|
| **A** | **0-30 cm** | Reddish brown (5YR 4/3) dry, dark reddish (2.5YR 3/4) moist, dark brown (7.5YR 4/6) crushed dry, clay; strong medium granular structure; hard, firm, very plastic, very sticky; weak coatings; roots abundant; gradual smooth boundary. |
| **BA** | **30-60 cm** | Yellowish red (5YR 4/6) dry, dark red (2.5YR 3/6) moist, strong brown (7.5YR 5/6) crushed dry, clay; weak compound prismatic structure which breaks down into moderate medium subangular blocks; hard, slightly firm, plastic, sticky; few weak coatings; roots abundant; gradual boundary. |
| **$B_1$** | **60-150 cm** | Yellowish red (5YR 4/6) dry, dark red (2.5YR 3/6) moist, strong brown (7.5YR 5/6) crushed dry, clay; weak compound prismatic structure which breaks easily into weak very fine and fine granules; slightly hard, friable, slightly plastic, slightly sticky; few weak coatings; few roots; diffuse smooth boundary. |
| **$B_2$** | **150-210 cm** | Reddish brown to red (2.5YR 4/5) dry, dark red (10YR 3/6) moist, strong brown (7.5YR 5/7) crushed dry, with common, medium, prominent, dark grey (5YR 4/1) mottles, clay; massive, porous soil mass which breaks easily to weak medium subangular blocky and weak fine granular structure; slightly hard, firm, slightly plastic, slightly sticky; few strong coatings; abrupt boundary. |
| **BC** | **210-260 cm** | Reddish brown (2.5YR 4/4) dry, dark red (10YR 3/6) moist, with common, medium, prominent, dark grey (5YR 4/1) mottles, clay; massive, porous soil mass which breaks easily to weak medium subangular blocky and weak fine granular structure; slightly hard, firm, slightly plastic, slightly sticky; few strong coatings; abrupt boundary. |
| **C** | **260-280 cm** | White (2.5YR 8/0) and dark grey (5YR 4/1) clay. |

NOTE: Fine black "buckshot" concretions are present in the BC and C horizons.

# ORTHIC FERRALSOL

## Brazil

| Horizon | Depth cm | pH H$_2$O | pH KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | CaCO$_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | *Total* | | |
| A | 0—30 | 4.7 | 3.9 | 11.5 | 4.1 | 35 | 2.1 | 1.1 | 0.8 | 0.1 | 7.4 | | |
| BA | —60 | 4.8 | 4.0 | 8.2 | 2.5 | 30 | 1.4 | 0.7 | 0.4 | 0.1 | 5.6 | | |
| B$_1$ | —150 | 5.2 | 4.2 | 5.1 | 1.1 | 22 | 0.5 | 0.3 | 0.2 | 0.1 | 4.0 | | |
| B$_2$ | —210 | 5.3 | 4.1 | 5.3 | 1.3 | 25 | 0.6 | 0.4 | 0.2 | 0.1 | 4.0 | | |
| BC | —260 | 4.8 | 4.0 | 5.6 | 0.9 | 16 | 0.4 | 0.2 | 0.2 | 0.1 | 4.7 | | |
| C | —280+ | 4.6 | 3.7 | 6.7 | 1.1 | 16 | 0.4 | 0.5 | 0.1 | 0.1 | 5.6 | | |

| Horizon | Sol. salts | | Organic matter % C | % N | C/N | % OM | Particle size analysis %[1] stones | c. sand | f. sand | silt | clay | texture | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | 1.6 | 0.14 | 11 | | 0 | 3 | 13 | 8 | 76 | clay | 60 |
| BA | | | 1.0 | 0.09 | 11 | | 0 | 2 | 10 | 11 | 77 | clay | 68 |
| B$_1$ | | | 0.5 | 0.05 | | | 0 | 4 | 9 | 10 | 77 | clay | 100 |
| B$_2$ | | | 0.2 | 0.03 | | | 0 | 2 | 8 | 11 | 79 | clay | 100 |
| BC | | | 0.2 | 0.03 | | | 0 | 2 | 10 | 14 | 74 | clay | 100 |
| C | | | 0.1 | 0.05 | | | 0 | 11 | 9 | 25 | 55 | clay | 100 |

| Horizon | Solution by H$_2$SO$_4$, d = 1.47, % SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | TiO$_2$ | MnO | P$_2$O$_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P Truog mg % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 24.3 | 24.3 | 13.0 | 1.2 | 0.02 | 0.11 | 1.7 | 1.3 | 3.0 | <0.4 | | |
| BA | 25.6 | 26.7 | 13.1 | 1.1 | 0.02 | 0.10 | 1.6 | 1.3 | 3.4 | <0.4 | | |
| B$_1$ | 25.2 | 27.5 | 13.4 | 1.2 | 0.02 | 0.09 | 1.6 | 1.2 | 3.2 | <0.4 | | |
| B$_2$ | 27.2 | 27.4 | 13.2 | 1.2 | 0.02 | 0.08 | 1.7 | 1.3 | 3.0 | <0.4 | | |
| BC | 27.4 | 26.7 | 13.4 | 1.1 | 0.02 | 0.08 | 1.8 | 1.3 | 3.3 | <0.4 | | |
| C | 27.5 | 19.9 | 6.5 | 0.4 | 0.02 | 0.07 | 2.4 | 2.0 | 4.7 | <0.4 | | |

| Horizon | | | | | | | | | | Moist. equiv. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | 32 | | |
| BA | | | | | | | | | | 33 | | |
| B$_1$ | | | | | | | | | | 32 | | |
| B$_2$ | | | | | | | | | | 35 | | |
| BC | | | | | | | | | | 35 | | |
| C | | | | | | | | | | 36 | | |

[1] International size grades.

| | |
|---|---|
| **ORTHIC FERRALSOL** | **Fo** |
| **Red-yellow latosol** | Brazil |
| **WSRR 22** | Beek and Bennema, profile 7, p. 65, Analyses by DPFS, Rio de Janeiro |
| **Location** | 10 km NW Vilhena, Rondônia Territory, 12° 30'S, 60° 10'W |
| **Altitude** | 620 m |
| **Physiography** | Undulating, sample from upper slope of 3-5% |
| **Drainage** | Very well drained |
| **Vegetation** | Tropical semideciduous forest |
| **Climate** | 1.72, humid tierra templada |

**Profile description**

| | | |
|---|---|---|
| **O** | **1-0 cm** | |
| **A** | **0-4 cm** | Dark brown (7.5YR 4/4) clay; weakly developed very fine to fine granular structure; friable, slightly plastic; abrupt smooth boundary. |
| **AB** | **4-12 cm** | Strong brown (7.5YR 5/6) heavy clay; weakly developed very fine to medium granular structure; friable, plastic, sticky; clear smooth boundary. |
| **BA** | **12-25 cm** | Yellowish red (5YR 5/6) clay; moderately developed very fine to fine subangular blocky structure; friable, plastic, sticky; gradual smooth boundary. |
| **$B_1$** | **25-80 cm** | Yellowish red (5YR 5/8) heavy clay; very friable, plastic, very sticky. |
| **$B_2$** | **80-200 cm** | Yellowish red (4YR 5/8) heavy clay; very friable, plastic, very sticky. |
| **$B_3$** | **200-270 cm** | Reddish yellow (5YR 5.5/8) clay; friable, very plastic, very sticky. |

NOTES: Many roots in A and AB with a predominant diameter of 1 to 2 mm: A, AB and BA are very porous.

## ORTHIC FERRALSOL

**Brazil**

| Horizon | Depth cm | pH $H_2O$ | pH KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | $CaCO_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O | 1—0 | 4.3 | 3.4 | 59.6 | 5.3 | 9 | 3.2 | 1.4 | 0.6 | 0.1 | 4.0 | 50.3 | |
| A | —4 | 3.9 | 3.4 | 35.3 | 1.4 | 4 | 1.2 | | 0.1 | 0 | 4.6 | 29.4 | |
| AB | —12 | 4.1 | 4.0 | 14.5 | 0.7 | 5 | 0.6 | | 0.05 | 0 | 2.0 | 4.8 | |
| BA | —25 | 4.4 | 4.2 | 9.4 | 0.6 | 6 | 0.5 | | 0.05 | 0 | 1.2 | 7.6 | |
| $B_1$ | —80 | 5.2 | 4.5 | 5.9 | 0.5 | 8 | 0.4 | | 0.05 | 0 | 0.5 | 4.9 | |
| $B_2$ | —200 | 5.3 | 5.0 | 3.5 | 0.5 | 14 | 0.5 | | 0 | 0 | 0 | 3.0 | |
| $B_3$ | —270+ | 5.8 | 6.2 | 1.7 | 0.4 | 24 | 0.4 | | 0 | 0 | 0 | 1.3 | |

| Horizon | Sol. salts | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O | | | 23.1 | 1.25 | 19 | | 0 | | | | | | |
| A | | | 7.8 | 0.69 | 11 | | 0 | 8 | 3 | 25 | 64 | clay | 86 |
| AB | | | 2.7 | 0.20 | 13 | | 0 | 10 | 4 | 22 | 64 | clay | 67 |
| BA | | | 1.7 | 0.15 | 11 | | 0 | 10 | 5 | 17 | 68 | clay | 78 |
| $B_1$ | | | 1.0 | 0.08 | 12 | | 0 | 9 | 5 | 11 | 75 | clay | 65 |
| $B_2$ | | | 0.6 | 0.06 | | | 0 | 9 | 6 | 9 | 76 | clay | 100 |
| $B_3$ | | | 0.3 | 0.06 | | | 0 | 6 | 5 | 11 | 78 | clay | 51 |

| Horizon | Solution by $H_2SO_4$, d = 1.47 % $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O | 13.2 | 20.4 | 6.3 | 0.5 | | 0.02 | 1.1 | 0.9 | 5.1 | 1.0 | | |
| A | 15.7 | 27.3 | 8.1 | 0.8 | | 0.01 | 1.0 | 0.8 | 5.3 | 0.3 | | |
| AB | 17.6 | 32.6 | 9.6 | 0.0 | | 0.01 | 0.9 | 0.8 | 5.3 | 0.2 | | |
| BA | 18.3 | 35.6 | 10.0 | 0.0 | | | 0.9 | 0.7 | 5.5 | 0.2 | | |
| $B_1$ | 18.8 | 36.7 | 10.1 | 1.0 | | | 0.9 | 0.7 | 5.7 | 0.1 | | |
| $B_2$ | 18.8 | 37.3 | 10.2 | 1.1 | | | 0.9 | 0.7 | 5.7 | 0 | | |
| $B_3$ | 18.2 | 38.6 | 10.7 | 1.2 | | | 0.8 | 0.7 | 5.6 | 0 | | |

| Horizon | | | | | | | | | | Moist. equiv. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O | | | | | | | | | | — | | |
| A | | | | | | | | | | 74 | | |
| AB | | | | | | | | | | 34 | | |
| BA | | | | | | | | | | 32 | | |
| $B_1$ | | | | | | | | | | 30 | | |
| $B_2$ | | | | | | | | | | 28 | | |
| $B_3$ | | | | | | | | | | 29 | | |

| | |
|---|---|
| **RHODIC FERRALSOL** | **Fr** |
| **Latosol roxo** | Brazil |
| **Rep. FAO-EPTA 2197** | Bennema, 1966, p. 39, Comissão de Solos, 1960, profile 37, p. 287 |
| **Location** | 15 km N Ituverava, São Paulo State. 20° 09'S, 47° 47'W |
| **Altitude** | 560 m |
| **Physiography** | Undulating |
| **Drainage** | Well drained |
| **Parent material** | Basalt |
| **Vegetation** | Second growth forest |
| **Climate** | 1.77, humid tierra templada |

**Profile description**

| | | |
|---|---|---|
| **A** | **0-20 cm** | Dark greyish brown (2.5YR 3/3) clay; moderate medium granular structure; slightly hard, friable, slightly plastic, sticky; roots abundant; gradual smooth boundary. |
| **BA** | **20-40 cm** | Dark reddish brown (2.5YR 3/4) clay; weak medium granular structure; soft, friable, slightly plastic, sticky; roots abundant; diffuse smooth boundary. |
| **$B_1$** | **40-60 cm** | Dark reddish brown (2.5YR 3/4) clay; weak medium subangular breaking down into weak fine granular structure; friable, slightly plastic, slightly sticky; few roots; gradual smooth boundary. |
| **$B_2$** | **60-120 cm** | Dark red (2.5YR 3/5) clay; massive porous breaking down into weak fine granular structure; soft, very friable, slightly plastic, slightly sticky; few roots; clear wavy boundary. |
| **CB** | **120-130 cm** | Clay loam; horizon comprising rotten rock and B material. |

## RHODIC FERRALSOL

**Brazil**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO₃ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| | | | | | | | | | | | *Total* | | |
| A | 0—20 | 5.2 | 5.0 | 14.2 | 8.6 | 61 | 5.9 | 2.1 | 0.6 | 0.1 | 5.6 | | |
| BA | —40 | 5.7 | 5.6 | 10.0 | 7.6 | 76 | 4.7 | 2.1 | 0.7 | 0.1 | 2.4 | | |
| $B_1$ | —60 | 6.0 | 5.9 | 8.9 | 7.2 | 81 | 4.2 | 2.6 | 0.3 | 0.1 | 1.7 | | |
| $B_2$ | —120 | 6.1 | 6.3 | 7.4 | 6.5 | 88 | 3.8 | 2.3 | 0.2 | 0.1 | 0.9 | | |
| CB | —130+ | 6.4 | 6.5 | 8.2 | 8.0 | 98 | 3.6 | 3.5 | 0.8 | 0.1 | 0.2 | | |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis %[1] | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | | | 1.7 | 0.15 | 11 | | 1 | 3 | 25 | 16 | 56 | clay | 57 |
| BA | | | 1.0 | 0.08 | 12 | | 0 | 2 | 18 | 20 | 60 | clay | 48 |
| $B_1$ | | | 0.8 | 0.06 | | | 0 | 2 | 16 | 17 | 65 | clay | 96 |
| $B_2$ | | | 0.6 | 0.05 | | | 2 | 3 | 20 | 19 | 58 | clay | 100 |
| CB | | | 0.4 | 0.03 | | | 0 | 9 | 35 | 21 | 35 | clay loam | 99 |

| Horizon | Solution by $H_2SO_4$, d = 1.47 % | | | | | | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % Truog | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | | | | | | | |
| A | 18.6 | 18.9 | 25.4 | 5.0 | 0.2 | 0.49 | 1.7 | 0.9 | 1.2 | 1.1 | | | |
| BA | 21.5 | 24.6 | 23.6 | 4.4 | 0.2 | 0.35 | 1.5 | 0.9 | 1.6 | 0.7 | | | |
| $B_1$ | 21.9 | 26.0 | 23.2 | 4.4 | 0.1 | 0.33 | 1.4 | 0.9 | 1.8 | 0.8 | | | |
| $B_2$ | 20.0 | 25.3 | 24.9 | 5.0 | 0.1 | 0.28 | 1.3 | 0.8 | 1.6 | 0.7 | | | |
| CB | 20.6 | 24.7 | 24.4 | 4.5 | 0.2 | 0.33 | 1.4 | 0.9 | 1.6 | 0.7 | | | |

| Horizon | | | | | | | | | | Moist. equiv. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | 29 | | | |
| BA | | | | | | | | | | 33 | | | |
| $B_1$ | | | | | | | | | | 35 | | | |
| $B_2$ | | | | | | | | | | 34 | | | |
| CB | | | | | | | | | | 36 | | | |

[1] International size grades.

| | |
|---|---|
| **XANTHIC FERRALSOL** | **Fx** |
| **Kaolinitic yellow latosol, very heavy texture** | Brazil |
| **Rep. FAO-EPTA 2197** | Bennema, 1966, p. 55, Sombroek, 1966, profile 24, p. 129 |
| **Location** | 247 km S San Miguel do Guamá, Pará State, 3° 45'S, 47° 45'W |
| **Altitude** | 200 m |
| **Physiography** | Flat top of high terrace |
| **Drainage** | Well drained |
| **Parent material** | Pliocene lacustrine sediments |
| **Vegetation** | Primeval tropical forest, dense undergrowth |
| **Climate** | 1.482, hot tropical |

**Profile description**

| | | |
|---|---|---|
| **$O_1$** | **8-5 cm** | Undecomposed plant residues. |
| **$O_2$** | **5-0 cm** | Partly decomposed plant residues with many fine roots. |
| **A** | **0-2 cm** | Dark yellowish brown (10YR 4/4) heavy clay; moderate medium to fine subangular and weak fine granular structure; friable, plastic, sticky; many pores; locally the horizon is crusty due to the intense activity of insects, especially termites; abundant roots, mostly fine; clear boundary. |
| **AB** | **2-20 cm** | Yellowish brown (10YR 5/6) heavy clay; moderate fine subangular blocky and very fine granular structure; soft, friable, plastic, sticky; many pores; abundant roots; gradual boundary. |
| **$B_1$** | **20-60 cm** | Strong brown (7.5YR 5/6) heavy clay; weak to moderate, fine to medium subangular and weak very fine granular structure; slightly hard, friable, plastic, sticky; pores; faint clayskins; many roots; diffuse boundary. |
| **$B_2$** | **60-150 cm** | Strong brown (7.5YR 5/6) heavy clay; weak medium subangular and weak very fine granular structure; slightly hard, friable to firm, plastic, sticky; pores common; few very weak clayskins; many roots; diffuse boundary. |
| **BC(?)** | **150-250 cm** | Yellowish red (5YR 5/8) heavy clay; massive to weak medium subangular structure; few pores; very few roots. |

## XANTHIC FERRALSOL

### Brazil

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO$_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| A | 0—2 | 4.0 | 3.5 | 14.9 | 2.2 | 15 | 0.9 | 1.0 | 0.3 | 0.1 | 2.2 | 10.4 | |
| AB | —20 | 4.2 | 3.8 | 6.9 | 0.7 | 11 | *Total* 0.6 | | 0.1 | 0 | 1.6 | 4.6 | |
| $B_1$ | —60 | 4.7 | 4.1 | 4.6 | 0.6 | 14 | 0.5 | | 0.1 | 0 | 1.1 | 2.9 | |
| $B_2$ | —150 | 5.2 | 4.7 | 2.7 | 0.6 | 22 | 0.5 | | 0.1 | 0 | 0.2 | 1.9 | |
| BC | —250 | 5.5 | 4.9 | 2.0 | 0.6 | 28 | 0.5 | | 0.1 | 0 | 0.2 | 1.2 | |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | | | 3.6 | 0.33 | 11 | | 0 | 4 | 11 | 10 | 75 | clay | 69 |
| AB | | | 1.3 | 0.13 | 10 | | 0 | 2 | 8 | 7 | 83 | clay | 60 |
| $B_1$ | | | 0.7 | 0.08 | | | 0 | 1 | 6 | 5 | 88 | clay | 100 |
| $B_2$ | | | 0.4 | 0.05 | | | 0 | 1 | 13 | 12 | 74 | clay | 100 |
| BC | | | 0.3 | 0.03 | | | 0 | 1 | 10 | 14 | 75 | clay | 100 |

| Horizon | Solution by $H_2SO_4$. d = 1.47 % | | | | | | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | | | | Truog | Bray-1 | |
| A | 28.8 | 25.5 | 8.3 | 1.0 | | 0.05 | 1.9 | 1.6 | 5.3 | 0.2 | 0.5 | |
| AB | 30.8 | 29.6 | 8.7 | 0.9 | | 0.03 | 1.8 | 1.5 | 5.0 | 0.2 | 0.2 | |
| $B_1$ | 33.7 | 32.4 | 10.0 | 0.8 | | 0.03 | 1.8 | 1.5 | 5.0 | | 0.1 | |
| $B_2$ | 33.9 | 32.9 | 10.4 | 0.8 | | 0.03 | 1.8 | 1.5 | 5.0 | | 0 | |
| BC | 32.5 | 33.4 | 9.5 | 1.0 | | 0.03 | 1.7 | 1.4 | 4.7 | | 0 | |

| Horizon | | | | | | | | | | Moist. equiv. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | 35 | | |
| AB | | | | | | | | | | 32 | | |
| $B_1$ | | | | | | | | | | 34 | | |
| $B_2$ | | | | | | | | | | 34 | | |
| BC | | | | | | | | | | 34 | | |

| | |
|---|---|
| **DYSTRIC GLEYSOL** | **Gd** |
| **Gley pouco húmico** | Brazil |
| **Falesi (1964)** | pp. 45-50 |
| **Location** | Santana - Serra do Navio railway at km 150. 0° 37'N, 51° 44'W |
| **Physiography** | Flat flood plain of Rio Cupixi |
| **Drainage** | Imperfect |
| **Parent material** | Alluvial clays and silts |
| **Vegetation** | Secondary shrub vegetation |
| **Climate** | 1.121, humid semihot equatorial |

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**Profile description**

| | | |
|---|---|---|
| **Ag** | **0-20 cm** | Light grey (10YR 7/1) with common medium prominent yellow (10YR 7/6) mottles, clay; moderately developed small subangular blocky and granular structures; compact, slightly plastic, nonsticky; clear smooth boundary. |
| **$Cg_1$** | **20-50 cm** | Light grey (10YR 7/1) with many medium prominent yellow (10YR 7/6) mottles, clay loam; moderately developed small to medium subangular blocky structure; compact, slightly plastic, nonsticky. |
| **$Cg_2$** | **50-100 cm** | Light grey (10YR 7/1) with small and medium prominent brownish-yellow moist, and yellow mottles, clay; massive; plastic, nonsticky. |

## DYSTRIC GLEYSOL

**Brazil**

| Horizon | Depth cm | pH H₂O | pH KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | CaCO % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | pH | | Cation exchange me % | | | | | | | | | |
| Ag | 0—20 | 4.8 | | 5.9 | 2.1 | 36 | 0.7 | 0.9 | 0.2 | 0.3 | 1.5 | 2.3 | |
| $Cg_1$ | —70 | 4.9 | | 4.5 | 1.6 | 35 | 0.6 | 0.7 | 0.1 | 0.2 | 0.9 | 2.1 | |
| $Cg_2$ | —130 | 5.1 | | 6.7 | 4.5 | 67 | 1.0 | 1.4 | 0.3 | 1.9 | 0.2 | 2.0 | |

| Horizon | Sol. salts | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Organic matter | | | | Particle size analysis % | | | | | | |
| Ag | | | 1.1 | 0.13 | 9 | 2.0 | | 0 | 30 | 29 | 41 | clay | |
| $Cg_1$ | | | 0.5 | 0.06 | 8 | 0.8 | | 0 | 38 | 24 | 38 | clay loam | |
| $Cg_2$ | | | 0.5 | 0.04 | 12 | 0.8 | | 0 | 31 | 3 | 66 | clay | |

| | |
|---|---|
| **EUTRIC GLEYSOL (saline phase)** | **Ge** |
| **De Velde clay saline phase** | Guyana |
| **FAO, 1965-66** | Vol. V, pp. 37, 94 |
| **Location** | 10 km W Providence, Berbice River, 6° 11'N, 57° 35'W |
| **Physiography** | Flat, subject to flooding with brackish water at highest tides |
| **Drainage** | Poorly to somewhat poorly drained |
| **Parent material** | Moderately fine to fine textured alluvium |
| **Vegetation** | Salt-tolerant plants |
| **Climate** | 1.121, humid semihot equatorial |

**Profile description**

| | | |
|---|---|---|
| A | **0-10 cm** | Grey (10YR 5/1) with few, fine, distinct dark brown mottles around root channels, clay; weak, medium granular structure; slightly sticky, slightly plastic; numerous fine roots; clear smooth boundary. |
| $Cg_1$ | **10-38 cm** | Grey (5Y 6/1) with common, medium prominent yellowish brown mottles, clay; massive to weak, medium subangular blocky structure; sticky, plastic; fine roots; gradual wavy boundary. |
| $Cg_2$ | **38-85 cm** | Grey (5Y 6/1) with many, medium, prominent yellowish brown and brownish yellow mottles, clay; massive structure; sticky, plastic; few fine roots; clear smooth boundary. |
| $Cg_3$ | **85-110 cm** | Greenish grey (5GY 6/1) with few medium prominent strong brown mottles, clay; massive structure; soft, sticky, plastic; gradual wavy boundary. |
| $Cg_4$ | **110-150 +** | Greenish grey (5GY 5/1) clay; massive structure; abundant organic specks and decaying plant material; sticky, plastic. |

## EUTRIC GLEYSOL
### Guyana
### (Saline phase)

| Horizon | Depth cm | pH $H_2O$ | pH KCl | Cation exchange me % CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | $CaCO_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0—10 | 5.2 | | 39.0 | 25.1 | 64 | 3.5 | 17.0 | 0.9 | 3.7 | 0.2 | 13.7 | |
| $Cg_1$ | —38 | 7.1 | | 29.7 | 26.1 | 88 | 3.5 | 16.8 | 0.7 | 5.1 | 0.0 | 3.6 | |
| $Cg_2$ | —60 | 6.6 | | 28.9 | 25.3 | 88 | 3.0 | 16.8 | 1.0 | 4.5 | 0.0 | 3.6 | |
| $Cg_3$ | —112 | 6.2 | | 30.7 | 25.7 | 84 | 3.1 | 17.0 | 1.1 | 4.5 | 0.0 | 5.0 | |
| $Cg_4$ | —150 | 4.7 | | 34.0 | 23.1 | 68 | 3.3 | 15.6 | 1.0 | 3.2 | 1.1 | 9.8 | |

| Horizon | Sol. salts Total % | | Organic matter % C | % N | C/N | % OM | Particle size analysis % stones | c. sand | f. sand | silt | clay | texture | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0.18 | | 4.1 | 0.34 | 12 | | | | 5 | 60 | 35 | silty clay loam | |
| $Cg_1$ | 0.27 | | 1.0 | 0.21 | 5 | | | | 2 | 55 | 43 | silty clay | |
| $Cg_2$ | 0.23 | | 0.7 | 0.04 | 17 | | | | 1 | 48 | 51 | silty clay | |
| $Cg_3$ | 0.21 | | 1.6 | 0.13 | 12 | | | | 1 | 57 | 42 | silty clay | |
| $Cg_4$ | 0.42 | | 2.7 | 0.15 | 18 | | | | 3 | 83 | 14 | silt loam | |

| Horizon | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % Truog | | | Silt[1] % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | 0.1 | | | 55 |
| $Cg_1$ | | | | | | | | | | 1.2 | | | 48 |
| $Cg_2$ | | | | | | | | | | 1.6 | | | 40 |
| $Cg_3$ | | | | | | | | | | 1.5 | | | 50 |
| $Cg_4$ | | | | | | | | | | 3.0 | | | 68 |

| Horizon | Soluble salts me % $SO_4^{--}$ | $Cl^-$ | acids | bases | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0.3 | 2.2 | 0.1 | 4.0 | | | | | | | | |
| $Cg_1$ | 0.9 | 3.8 | 0.0 | 5.8 | | | | | | | | |
| $Cg_2$ | 1.2 | 3.3 | 0.0 | 5.1 | | | | | | | | |
| $Cg_3$ | 2.0 | 2.5 | 0.0 | 4.3 | | | | | | | | |
| $Cg_4$ | 4.4 | 3.0 | 0.0 | 8.3 | | | | | | | | |

[1] International size grades.

| | |
|---|---|
| **HUMIC GLEYSOL** | **Gh** |
| **Humic Gley** | Brazil |
| **Comissão de Solos, 1962** | Profile 21, p. 321 |
| **Location** | 20 km S Pimenta, Formiga-Passos road, Minas Gerais State 20° 39′S, 45° 49′W |
| **Altitude** | 690 m |
| **Physiography** | Flat |
| **Drainage** | Very poorly drained |
| **Parent material** | Holocene deposits |
| **Vegetation** | Hydrophilic grass species with some shrubs |
| **Climate** | 1.77, humid tierra templada |

**Profile description**

| | | |
|---|---|---|
| $A_1$ | **0-20 cm** | Black (10 YR 2/1) clay; moderately developed very small to large granular structure; firm, plastic, sticky; diffuse smooth boundary. |
| $A_2$ | **20-55 cm** | Black (N 2/-) clay; moderately developed very small to large granular structure; firm, plastic, very sticky; clear smooth boundary. |
| ACg | **55-65 cm** | Dark grey (10YR 4/1) and light grey (10YR 6/1) with common medium to large prominent strong brown (7.5YR 5/7) mottles, clay; moderately developed medium prismatic structure breaking to moderately developed very small to small subangular blocks; firm, plastic, very sticky; clear smooth boundary. |
| $Cg_1$ | **65-85 cm** | Light grey (10YR 6/1) with very many large prominent strong brown (7.5YR 5/7) and common, medium prominent greyish white (N 8/ ) mottles, heavy clay; moderately developed medium prismatic structure breaking to very small to medium subangular blocks; firm, very plastic, very sticky; diffuse smooth boundary. |
| $Cg_2$ | **85-125 cm** | Greyish white (N 8/-) with common, large, prominent yellowish brown (10YR 4.5/6) and common, medium to large prominent strong brown (7.5YR 5/7) mottles, heavy clay; plastic, very sticky. |

NOTES: Roots end at $Cg_1$. Small concretions up to 2 mm diameter occur at the top of the ACg. The coarse sand minerals are quartzite and quartz.

## HUMIC GLEYSOL

**Brazil**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO$_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H$_2$O | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| A$_1$ | 0—20 | 5.0 | 4.1 | 20.5 | 0.7 | 3 | 0.5 | | 0.1 | 0.1 | 3.1 | 16.7 | |
| A$_2$ | —55 | 4.8 | 4.0 | 17.9 | 0.5 | 3 | 0.4 | | 0.05 | 0.1 | 3.9 | 13.5 | |
| ACg | —65 | 5.0 | 3.8 | 13.1 | 1.2 | 9 | 0.9 | 0.2 | 0.05 | 0 | 4.4 | 7.5 | |
| Cg$_1$ | —85 | 4.9 | 3.8 | 9.5 | 2.2 | 23 | 1.6 | 0.1 | 0.05 | 0.1 | 3.6 | 3.6 | |
| Cg$_2$ | —125+ | 5.3 | 3.9 | 10.3 | 6.5 | 64 | 5.4 | 1.0 | 0.05 | 0.1 | 1.9 | 1.8 | |

| Horizon | Sol. salts | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A$_1$ | | 6.4 | 0.51 | 13 | | 1 | 4 | 24 | 24 | 48 | clay | 90 |
| A$_2$ | | 3.0 | 0.16 | 19 | | 1 | 5 | 16 | 23 | 56 | clay | 63 |
| ACg | | 1.3 | 0.07 | 18 | | 1 | 5 | 12 | 19 | 64 | clay | 5 |
| Cg$_1$ | | 0.5 | 0.04 | | | 1 | 4 | 4 | 16 | 76 | clay | 5 |
| Cg$_2$ | | 0.1 | 0.02 | | | 0 | 1 | 3 | 25 | 71 | clay | 10 |

| Horizon | Solution by H$_2$SO$_4$ d = 1.47 % | | | | | | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | TiO$_2$ | MnO | P$_2$O$_5$ | | | | Truog | Bray-1 | |
| A$_1$ | 19.1 | 18.8 | 2.6 | 0.5 | | 0.11 | 1.7 | 1.6 | 11.3 | 0.8 | 0.5 | |
| A$_2$ | 20.6 | 22.3 | 1.4 | 0.6 | | 0.06 | 1.6 | 1.5 | 25.2 | 0.8 | 0.4 | |
| ACg | 25.2 | 24.7 | 1.6 | 0.6 | | 0.04 | 1.7 | 1.7 | 24.7 | <0.4 | 0.3 | |
| Cg$_1$ | 31.4 | 29.2 | 2.0 | 0.7 | | 0.03 | 1.8 | 1.8 | 23.1 | <0.4 | 0.3 | |
| Cg$_2$ | 34.2 | 28.8 | 2.2 | 0.6 | | 0.03 | 2.0 | 1.9 | 20.7 | 0.5 | 0.2 | |

| Horizon | | | | | | | | | | Moist. equiv. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A$_1$ | | | | | | | | | | 42 | | |
| A$_2$ | | | | | | | | | | 34 | | |
| ACg | | | | | | | | | | 34 | | |
| Cg$_1$ | | | | | | | | | | 35 | | |
| Cg$_2$ | | | | | | | | | | 35 | | |

| | |
|---|---|
| **HAPLIC PHAEOZEM** | **Hh** |
| **Teodelina** | Argentina |
| **FAO, 1967** | Site 4b, pp. 42-3 |
| **Location** | 14 km SE Junin, Buenos Aires Province, 34° 39'S, 60° 50'W |
| **Altitude** | 76 m |
| **Physiography** | Gently undulating western sandy pampa |
| **Parent material** | Fine loamy sand, generally loess with $CaCO_3$ |
| **Climate** | 5.113, typical pampean |

**Profile description**

| | | |
|---|---|---|
| **A** | **0-26 cm** | Black (10YR 2/1) moist, loam; weak subangular blocky structure breaking to granular; friable, nonplastic, nonsticky; many roots, worms; crotovines; gradual smooth boundary. |
| **AB** | **26-38 cm** | Very dark greyish brown to very dark brown (10YR 2.5/2) moist, loam to clay loam; medium subangular blocky structure; friable, slightly plastic, slightly sticky; few clay skins; many roots; crotovines; clear smooth boundary. |
| **BA** | **38-63 cm** | Very dark brown (10YR 2/2) moist, clay loam; medium, prismatic structure breaking to blocky structure; friable, plastic, slightly sticky; many clayskins; common roots; gradual smooth boundary. |
| **B** | **63-90 cm** | Very dark greyish brown (10YR 3/2) moist, clay loam; coarse and medium prismatic structure; friable, plastic, slightly sticky; common clay skins; few patches of organic matter; common roots; gradual wavy boundary. |
| **$BC_1$** | **90-150 cm** | Dark brown (10YR 3/3) moist with prominent medium common iron mottles (5YR 4/4), sandy clay loam; medium, subangular blocky structure; friable, slightly plastic, nonsticky; common roots; gradual smooth boundary. |
| **$BC_2$** | **150-180 cm** | Dark yellowish brown (7.5YR 4/4) moist with prominent medium common iron mottles (5YR 4/4), sandy loam; very weak subangular blocky to massive structure; friable, nonplastic, nonsticky; few roots; diffuse smooth boundary. |
| **C** | **180 +** | Dark yellowish brown (7.5YR 4/4) moist, loamy sand; structureless; loose, nonplastic, nonsticky; few roots. |

**HAPLIC PHAEOZEM**

**Argentina**

| Horizon | Depth cm | pH H₂O | pH KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | $CaCO_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | pH | | Cation exchange me % | | | | | | | | | |
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| A | 0—26 | 6.1 | | 24.9 | 21.5 | 86 | 16.5 | 2.9 | 1.6 | 0.5 | | | 0 |
| AB | —38 | 6.2 | | 20.0 | 16.9 | 85 | 12.2 | 2.9 | 1.4 | 0.4 | | | 0 |
| BA | —63 | 6.4 | | 20.0 | 17.0 | 85 | 12.4 | 2.7 | 1.5 | 0.4 | | | 0 |
| B | —90 | 6.5 | | 19.6 | 16.1 | 82 | 10.2 | 3.6 | 1.9 | 0.4 | | | 0 |
| $BC_1$ | —150 | 6.6 | | 19.4 | 16.7 | 86 | 10.0 | 4.5 | 1.8 | 0.4 | | | 0 |
| $BC_2$ | —180 | 6.9 | | 18.2 | 16.2 | 89 | 9.6 | 4.1 | 2.1 | 0.4 | | | 0 |
| C | 180+ | 7.1 | | 16.9 | 16.1 | 96 | 9.4 | 4.0 | 2.3 | 0.4 | | | 0 |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | | | 1.9 | 0.18 | 11 | | | 0 | 38 | 38 | 24 | loam | |
| AB | | | 0.9 | 0.10 | 9 | | | 0 | 42 | 32 | 26 | loam | |
| BA | | | 0.7 | 0.10 | | | | 0 | 41 | 30 | 29 | clay loam | |
| B | | | 0.4 | 0.06 | | | | 0 | 39 | 34 | 27 | clay loam | |
| $BC_1$ | | | 0.3 | 0.05 | | | | 0 | 46 | 32 | 22 | loam | |
| $BC_2$ | | | 0.2 | 0.03 | | | | 0 | 50 | 39 | 11 | loam | |
| C | | | 0.1 | | | | | 0 | 57 | 33 | 10 | sandy loam | |

| | |
|---|---|
| **LUVIC PHAEOZEM** | **Hl** |
| **Assoc. Bt8-3b** | Uruguay |
| **Kaplan and Duran, 1968** | |
| **Location** | S.W. Uruguay |
| **Physiography** | Convex medium slopes, 4-5% |
| **Parent material** | Pre-Devonian metamorphic rock |
| **Climate** | 4.14, humid subtropical |

**Profile description**

| | | |
|---|---|---|
| **A** | **0-13 cm** | Very dark grey brown to very dark brown (10YR 2.5/2) clay loam; weak fine subangular blocky structure; friable, slightly sticky, slightly plastic; abundant 2-5 mm pores; clear boundary. |
| **AE** | **13-23 cm** | Black to very dark brown (10YR 2/1.5) clay loam; moderately developed fine subangular blocky structure; friable, sticky, slightly plastic; abundant 2-5 mm pores; clear boundary. |
| **$B_1$** | **23-42 cm** | Very dark grey brown to very dark grey (10YR 3/1.5) clay; small red mottles with clear limits; strongly developed large subangular blocky structure; very firm, very sticky, very plastic; thin continuous very dark grey brown (10YR 3/2) clayskins on all aggregates; few pores larger than 1 mm; gradual boundary. |
| **$B_2$** | **42-56 cm** | Very dark grey brown (10YR 3/2) with occasional small yellowish red (5YR 4/2) mottles with clear limits, clay; strongly developed large subangular blocky structure; very firm, very sticky, very plastic; continuous dark grey brown (10YR 4/2) clayskins of medium thickness on all aggregates, few pores larger than 1 mm; clear boundary. |
| **BC** | **56-68 cm** | Very dark grey brown (10YR 3/2) with common yellowish red (5YR 4/6) 5-15 mm mottles with clear limits and clear contrast, heavy silty clay loam to clay loam; strongly developed large subangular blocky structure; firm, very sticky, very plastic; thick very dark grey brown (10YR 3/2) clayskins on all aggregates; few pores larger than 1 mm; clear boundary. |
| **C** | **68 +** | Altered material from crystalline schist. |

## LUVIC PHAEOZEM

**Uruguay**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | $CaCO_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| A | 0—13 | 5.3 | 4.8 | 30.0 | 22.7 | 76 | 17.2 | 4.5 | 0.5 | 0.5 | 2.4 | 4.9 | — |
| AE | —23 | 5.6 | 4.9 | 31.1 | 23.3 | 75 | 18.3 | 4.2 | 0.5 | 0.3 | 3.0 | 4.8 | — |
| $B_1$ | —42 | 5.7 | 4.9 | 35.7 | 30.3 | 85 | 22.9 | 6.6 | 0.5 | 0.3 | 2.3 | 3.1 | — |
| $B_2$ | —56 | 5.9 | 5.0 | 35.5 | 30.4 | 86 | 23.9 | 5.2 | 0.5 | 0.8 | 2.2 | 2.9 | — |
| BC | —68 | 6.3 | 5.3 | 30.8 | 29.1 | 94 | 24.3 | 4.5 | 0 | 0.3 | 0 | 1.7 | — |
| C | 68+ | 7.4 | 6.5 | 26.4 | 26.5 | 100 | 22.4 | 3.8 | 0 | 0.3 | 0 | 0 | + |

| Horizon | Sol. salts | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | | 5.4 | 0.38 | 14 | 9.3 | | 25 | | 48 | 27 | loam | |
| AE | | 4.0 | 0.28 | 14 | 6.9 | | 27 | | 42 | 31 | clay loam | |
| $B_1$ | | 1.5 | 0.14 | 11 | 2.6 | | 24 | | 27 | 49 | clay | |
| $B_2$ | | 1.6 | 0.16 | 10 | 2.8 | | 19 | | 31 | 50 | clay | |
| BC | | 1.1 | 0.11 | 10 | 1.9 | | 16 | | 46 | 38 | silty clay loam | |
| C | | 0.5 | 0.06 | | 0.8 | | 43 | | 34 | 23 | loam | |

| Horizon | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % Bray-1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | 0.22 | | |
| AE | | | | | | | | | | 0.17 | | |
| $B_1$ | | | | | | | | | | 0.04 | | |
| $B_2$ | | | | | | | | | | 0.02 | | |
| BC | | | | | | | | | | 0.02 | | |
| C | | | | | | | | | | 0.05 | | |

| | |
|---|---|
| **THIONIC FLUVISOL** | **Jt** |
| **Mara clay** | Guyana |
| **FAO, 1965-66** | Vol. V, pp. 50, 97 |
| **Location** | 5 km E Mara, Berbice River, 6° 01'N, 57° 35'W |
| **Physiography** | Flat |
| **Parent material** | Fine textured fluvio-marine sediments |
| **Vegetation** | Includes blechnum fern, moco moco, grasses, wild cherry, white cedar |
| **Climate** | 1.121, humid semihot equatorial |

**Profile description**

| | | |
|---|---|---|
| $O_1$ | 30-8 cm | Dark reddish brown (5YR 2/2 to 3/2) peat; slightly decomposed, darkening in air, black muck common around roots of trees; numerous roots. |
| $O_2$ | 8-0 cm | Black (10YR 2/1) muck mixed with yellowish brown (10YR 5/6) ashes, charcoal, and baked clay; strong fine subangular blocky structure; slightly brittle breaking to a black mass; distinct odour of $H_2S$; abrupt wavy boundary. |
| A | 0-3 cm | Very dark grey (10YR 3/1) clay; weak medium granular structure; plastic, slightly sticky; some penetration of muck from above; numerous roots; clear wavy boundary. |
| $AC_1$ | 3-10 cm | Grey (5Y 6/1) some dark grey in upper part with yellowish red mottles in root channels, clay; plastic, sticky; faint odour of $H_2S$; clear smooth boundary. |
| $AC_2$ | 10-30 cm | Grey (5Y 6/1) with many medium prominent yellowish red mottles usually in old root channels, clay; massive structure; plastic, sticky; distinct odour of $H_2S$; clear smooth boundary. |
| $Cg_1$ | 30-80 cm | Greenish grey (5GY 6/1) with common medium prominent yellow and yellowish brown mottles, clay; plastic, sticky; few dark brown concretions especially around root channels; distinct odour of $H_2S$; numerous medium and some fine roots; gradual boundary. |
| $Cg_2$ | 80-100 cm | Grey (10YR 6/1) with few fine distinct yellowish brown mottles, clay; massive; plastic, sticky; distinct odour of $H_2S$; common fine roots with some brown staining around root channels; abrupt smooth boundary. |
| $Cg_3$ | 100-150 cm | Greenish grey (5GY 5/1) clay; plastic, sticky; distinct odour of $H_2S$; few fine and medium roots. |

## THIONIC FLUVISOL

**Guyana**

| Horizon | Depth cm | pH $H_2O$ | pH KCl | Cation exchange me % CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | $CaCO_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $O_2$ | 8—0 | 4.4 | | 47.2 | 2.0 | 4 | 0.4 | 1.1 | 0.3 | 0.2 | 9.6 | 35.6 | |
| A | —3 | 4.4 | | 29.2 | 3.2 | 11 | 0.5 | 2.4 | 0.2 | 0.1 | 13.8 | 22.2 | |
| $AC_1$ | —10 | 4.0 | | 28.4 | 4.2 | 15 | 0.5 | 3.4 | 0.2 | 0.1 | 14.5 | 9.7 | |
| $AC_2$ | —30 | 4.2 | | 27.0 | 5.0 | 18 | 0.5 | 4.0 | 0.3 | 0.2 | 14.6 | 7.4 | |
| $Cg_1$ | —84 | 3.4 | | 26.5 | 4.3 | 16 | 0.5 | 3.2 | 0.2 | 0.4 | 13.1 | 9.1 | |
| $Cg_2$ | —100 | 4.1 | | 30.5 | 4.7 | 15 | 0.5 | 3.6 | 0.2 | 0.4 | 15.1 | 10.5 | |
| $Cg_3$ | —150 | 3.5 | | 31.1 | 3.3 | 11 | 0.3 | 2.3 | 0.4 | 0.3 | 17.3 | 10.5 | |

| Horizon | Sol. salts Total % | | Organic matter % C | % N | C/N | % OM | Particle size analysis %[1] stones | c. sand | f. sand | silt | clay | texture | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $O_2$ | 0.07 | | 9.8 | 0.58 | 17 | | | | — | — | | | |
| A | 0.06 | | 7.2 | 0.29 | 25 | | | | — | — | | | |
| $AC_1$ | 0.06 | | 2.1 | 0.03 | | | | | 2 | 45 | 53 | silty clay | |
| $AC_2$ | 0.04 | | 0.8 | 0.24 | | | | | 1 | 46 | 53 | silty clay | |
| $Cg_1$ | 0.05 | | 0.5 | 0.05 | | | | | 10 | 40 | 50 | silty clay | |
| $Cg_2$ | 0.10 | | 1.4 | 0.09 | | | | | 1 | 46 | 53 | silty clay | |
| $Cg_3$ | 0.24 | | 2.5 | 0.06 | | | | | 1 | 45 | 51 | silty clay | |

| Horizon | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % Truog | | exch. Fe me % | Silt % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $O_2$ | | | | | | | | | | 3.9 | | | |
| A | | | | | | | | | | 1.6 | | | |
| $AC_1$ | | | | | | | | | | 1.0 | | | 34 |
| $AC_2$ | | | | | | | | | | 0.8 | | | 37 |
| $Cg_1$ | | | | | | | | | | 0.7 | | 4.6 | 32 |
| $Cg_2$ | | | | | | | | | | 1.9 | | 8.4 | 34 |
| $Cg_3$ | | | | | | | | | | 0.5 | | 10.0 | 39 |

| Horizon | Soluble salts me % $SO_4^{--}$ | $Cl^-$ | acids | bases | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Cg_3$ | 6.0 | 0.1 | 1.6 | 3.4 | | | | | | | | | |

[1] International size grades.

| | |
|---|---|
| **HAPLIC KASTANOZEM** | **Kh** |
| **Calacala** | Peru |
| **ONERN Department of Soils** | |
| **Location** | 118 km NNW Puno. 14° 56'S, 70° 28'W |
| **Altitude** | 3925 m |
| **Physiography** | Nearly flat altiplano, 0-1% slope |
| **Parent material** | Clay and calcareous material |
| **Vegetation** | Grasses |
| **Climate** | 2.62, high Andine |

**Profile description**

| | | |
|---|---|---|
| **A** | **0-10 cm** | Very dark brown (7.5YR 2/2) when moist, loam; fine angular blocky structure; friable, slightly plastic, nonsticky; clear wavy boundary. |
| **AB** | **10-25 cm** | Black (7.5YR 2/0) when moist, loam; medium angular to fine subangular blocky structure; firm, very plastic, very sticky; gradual boundary. |
| **BCk** | **25-60 cm** | Dark reddish brown (5YR 3/2) when moist, silt loam; medium subangular blocky structure; firm, plastic, sticky; laminar stratification of calcareous material; abrupt wavy boundary. |
| **Ck** | **60-80 cm** | Dark reddish brown (5YR 3/3) when moist, loamy sand; soft; small calcareous inclusions; some soft iron and manganese concretions. |

## HAPLIC KASTANOZEM

**Peru**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO₃ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| A | 0—10 | 7.0 | | 20.4 | 12.9 | 63 | 8.0 | 2.4 | 0.7 | 1.8 | | | trace |
| AB | —25 | 7.9 | | 19.7 | 19.7 | 100 | 7.9 | 8.0 | 0.5 | 3.3 | | | trace |
| BCk | —60 | 8.5 | | 16.1 | 16.1 | 100 | 3.8 | 8.4 | 0.5 | 3.4 | | | 1.3 |
| Ck | —80 | 8.8 | | 4.5 | 4.6 | 100 | 2.3 | 0.8 | 0.1 | 1.4 | | | 3.6 |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | | | 5.1 | 0.24 | 21 | 8.8 | | | 47 | 38 | 15 | loam | |
| AB | | | 2.7 | 0.15 | 18 | 4.7 | | | 39 | 50 | 11 | loam | |
| BCk | | | 0.7 | 0.07 | | 1.2 | | | 35 | 54 | 11 | silt loam | |
| Ck | | | 0.1 | 0.03 | | 0.2 | | | 81 | 12 | 7 | sandy loam | |

| Horizon | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | Available, kg/ha | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | P | K | |
| A | | | | | | | | | | 0 | 370 | |
| AB | | | | | | | | | | 6 | 120 | |
| BCk | | | | | | | | | | 7 | 120 | |
| Ck | | | | | | | | | | 7 | 120 | |

| FERRIC LUVISOL | Lf |
|---|---|
| Marilia | Brazil |
| Rep. FAO-EPTA 2197 | Bennema 1966, p. 74 from Comissão do Solos, 1960, profile 22, p. 209. |
| Location | 9 km SW Marilia, São Paulo state, 22° 19'S, 50° 00'W |
| Altitude | 620 m |
| Physiography | Undulating, 6-10% slope |
| Drainage | Moderately well drained |
| Parent material | Sandstone with calcareous cementation |
| Vegetation | Coffee after semievergreen tropical forest |
| Climate | 1.77, humid tierra templada |

**Profile description**

| | | |
|---|---|---|
| Ap | 0-20 cm | Dark reddish brown (5YR 3/3) loamy sand; single grain structure; soft, friable, nonplastic, nonsticky; roots abundant; smooth boundary. |
| E | 20-42 cm | Yellowish brown (5YR 4/3) sand; single grain structure; soft, friable, nonplastic, nonsticky; roots abundant; abrupt smooth boundary. |
| $B_1$ | 42-77 cm | Reddish brown (2.5YR 4/4) with common prominent medium dark reddish brown (5YR 2/2) mottles, sandy clay loam; weak fine subangular structure; very hard, friable, very plastic, sticky; few weak clayskins; very porous; roots abundant; gradual smooth boundary. |
| $B_2$ | 77-97 cm | Dark red (2.5YR 3/6) with few medium prominent dark reddish brown (5YR 2/4) mottles, sandy clay loam; massive, porous, breaking to weak fine granular structure; very hard, friable, plastic and sticky; few roots; gradual smooth boundary. |
| BC | 97-209 cm | Yellowish red (5YR 4/6) sandy loam; massive, porous, breaking down into weak very fine granular structure; slightly hard, very friable, plastic, sticky; few roots. |

NOTE: The fine sand is 98 to 100% quartz with traces of mica in the Ap, $B_2$ and BC horizons. The clay is predominantly kaolinitic.

## FERRIC LUVISOL

**Brazil**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO$_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| | | | | | | | | | | | *Total* | | |
| Ap | 0—20 | 6.3 | 5.5 | 4.0 | 3.3 | 83 | 3.0 | 0.2 | 0.1 | 0 | 0.7 | | |
| E | —42 | 6.6 | 5.6 | 2.5 | 2.0 | 80 | 1.8 | 0.2 | 0 | 0 | 0.5 | | |
| $B_1$ | —77 | 6.4 | 5.3 | 6.0 | 5.4 | 90 | 4.3 | 1.0 | 0.1 | 0 | 0.6 | | |
| $B_2$ | —97 | 6.2 | 5.2 | 5.4 | 4.5 | 83 | 3.5 | 0.9 | 0.1 | 0 | 0.9 | | |
| BC | —209 | 6.4 | 5.8 | 4.4 | 3.5 | 80 | 2.6 | 0.7 | 0.1 | 0 | 0.8 | | |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis %[1] | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| Ap | | | 0.4 | 0.05 | 8 | | 0 | 24 | 67 | 3 | 6 | sand | 53 |
| E | | | 0.1 | 0.02 | | | 0 | 21 | 73 | 2 | 4 | sand | 34 |
| $B_1$ | | | 0.2 | 0.06 | | | 0 | 16 | 57 | 2 | 25 | sandy clay loam | 50 |
| $B_2$ | | | 0.2 | 0.02 | | | 0 | 14 | 60 | 2 | 24 | sandy clay loam | 55 |
| BC | | | 0.1 | 0.02 | | | 0 | 19 | 61 | 2 | 18 | sandy loam | 61 |

| Horizon | Solution by $H_2SO_4$, d = 1.47% | | | | | | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % Truog | | | Moist. equiv. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | | | | | | | |
| Ap | 3.5 | 3.1 | 1.4 | 0.5 | | 0.2 | 1.9 | 1.5 | 3.4 | 0.9 | | | 4 |
| E | 2.5 | 2.4 | 1.2 | 0.5 | | 0.2 | 1.8 | 1.4 | 3.2 | 0.9 | | | 4 |
| $B_1$ | 10.5 | 9.1 | 2.9 | 1.2 | | 0.2 | 2.0 | 1.6 | 4.9 | 0.7 | | | 14 |
| $B_2$ | 10.0 | 8.7 | 2.7 | 1.7 | | 0.2 | 2.0 | 1.6 | 5.0 | 0.7 | | | 14 |
| BC | 8.1 | 7.2 | 2.5 | 0.6 | | 0.2 | 1.9 | 1.6 | 4.5 | 0.7 | | | 12 |

[1] International size grades.

## DYSTRIC NITOSOL Nd

| | |
|---|---|
| **Estação soil** | Brazil |
| **Rep. FAO-EPTA 2197** | Bennema 1966, p. 64 |
| **WSRR 25** | FAO, 1966a, profile 49, p. 73 |
| **Location** | Passo Fundo Experimental Station, Passo Fundo, Rio Grande do Sul 28° 18'S, 52° 25'W |
| **Altitude** | 680 m |
| **Physiography** | Undulating, 8% slope |
| **Drainage** | Well drained |
| **Parent material** | Basalts of the Trapp formation |
| **Vegetation** | Subtropical mixed forest with *Ilex paraquariensis* and *Araucaria angustifolia* |
| **Climate** | 4.13, humid subtropical |

**Profile description**

| | | |
|---|---|---|
| A | **0-15 cm** | Dark reddish brown (2.5YR 3/4) moist, clay; moderately developed medium and coarse granular structure; very hard, firm, plastic, sticky, few pores; abundant roots, with coatings along channels; diffuse smooth boundary. |
| BA | **15-40 cm** | Dark red (2.5YR 3/5) moist, clay; weakly developed medium subangular blocky structure; very hard, firm to friable, plastic, sticky, porous; few weakly developed clayskins on peds; roots common, with coatings along channels; gradual smooth boundary. |
| $B_1$ | **40-70 cm** | Dark red (2.5YR 3/5) moist, heavy clay; moderately developed medium and fine subangular blocky structure; hard, firm, plastic, sticky, few pores; weakly developed and few clayskins on peds; few roots; soil in the mass shows increased cohesion due to clayskins which are visible at about 60 magnification; diffuse smooth boundary. |
| $B_2$ | **70-160 cm** | Dark red (2.5YR 3/6) moist, heavy clay; moderately developed fine subangular blocky structure; hard, firm; few pores; weakly developed and few clayskins, although their presence is confirmed at 60 magnifications; gradual smooth boundary. |
| $B_3$ | **160-190 cm** | Dark red (2.5YR 3/6) moist, clay; no visible structure in the relatively poorly coherent mass, which breaks readily to angular blocks; hard, firm; slightly sticky, slightly plastic; few pores; occasional fragments of weathering rock. |

## DYSTRIC NITOSOL

**Brazil**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO₃ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| A | 0—15 | 5.9 | 5.2 | 18.3 | 10.5 | 57 | 6.4 | 3.0 | 1.1 | 0 | 0.2 | 7.6 | |
| BA | —40 | 5.0 | 4.2 | 14.0 | 6.1 | 44 | 2.7 | 3.3 | 0.1 | 0 | 1.1 | 6.8 | |
| $B_1$ | —70 | 5.1 | 4.0 | 11.3 | 2.7 | 24 | 1.7 | 0.9 | 0.1 | 0 | 2.3 | 6.3 | |
| $B_2$ | —160 | 5.6 | 4.0 | 9.8 | 1.8 | 18 | 1.0 | 0.7 | 0.1 | 0 | 2.5 | 5.5 | |
| $B_3$ | —190 | 5.6 | 4.0 | 9.8 | 1.7 | 17 | 0.9 | 0.8 | 0 | 0 | 2.7 | 5.4 | |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | | | 3.2 | 0.28 | 12 | | 0 | 7 | 9 | 39 | 45 | clay | 51 |
| BA | | | 1.1 | 0.12 | 9 | | 0 | 4 | 7 | 32 | 57 | clay | 86 |
| $B_1$ | | | 0.7 | 0.10 | | | 0 | 3 | 4 | 22 | 71 | clay | 100 |
| $B_2$ | | | 0.5 | 0.07 | | | 0 | 3 | 6 | 27 | 64 | clay | 100 |
| $B_3$ | | | 0.2 | 0.04 | | | 0 | 2 | 12 | 41 | 45 | clay | 100 |

| Horizon | Solution by $H_2SO_4$, d = 1.47 % | | | | | | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % Truog | | MnO Total % | Moist. equiv. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | | | | | | | |
| A | 19.8 | 16.8 | 25.9 | 3.7 | 0.4 | 0.22 | 2.0 | 1.0 | 1.0 | 0.2 | | 0.44 | 31 |
| BA | 20.9 | 18.8 | 25.9 | 4.0 | 0.3 | 0.17 | 1.9 | 1.0 | 1.1 | 0 | | 0.28 | 30 |
| $B_1$ | 26.8 | 23.2 | 21.8 | 3.0 | 0.2 | 0.16 | 2.0 | 1.2 | 1.7 | 0 | | 0.17 | 36 |
| $B_2$ | 28.8 | 24.7 | 21.1 | 2.7 | 0.2 | 0.18 | 2.0 | 1.3 | 1.8 | 0 | | 0.15 | 38 |
| $B_3$ | 29.9 | 24.9 | 24.3 | 3.0 | 0.2 | 0.19 | 2.0 | 1.3 | 1.6 | 0 | | 0.22 | 38 |

| | |
|---|---|
| **EUTRIC NITOSOL** | **Ne** |
| **Terra Roxa Estruturada** | Brazil |
| **Rep. FAO-EPTA 2197** | Bennema, 1966, p. 76, Comissão do Solos, 1960, profile 29, p. 250. |
| **Location** | 8 km E Ourinhos, São Paulo state, 23° 03′S, 49° 45′W |
| **Altitude** | 580 m |
| **Physiography** | Undulating, hilltop, 5% slope |
| **Drainage** | Well drained |
| **Parent material** | Basalt |
| **Vegetation** | Coffee after semievergreen tropical forest |
| **Climate** | 1.77, humid tierra templada |

**Profile description**

| | | |
|---|---|---|
| Ap | **0-19 cm** | Dark reddish brown (2.5YR 3/4) moist, dark red (2.5YR 3/6) dry, yellowish red (5YR 4/7) rubbed dry, clay; strong fine and medium subangular blocky structure; very hard, very firm, plastic, slightly sticky; abundant roots; clear smooth boundary. |
| $B_1$ | **19-80 cm** | Dark reddish brown (2.5YR 3/4) moist, dark red (2.5YR 3/6) dry, yellowish red (5YR 4/7) rubbed dry, clay; strong fine and medium subangular blocky structure; slightly hard, firm, plastic, slightly sticky; abundant strong clayskins; clear smooth boundary. |
| $B_2$ | **80-134 cm** | Dark reddish brown (2.5YR 3/4) moist, dark red (2.5YR 3/7) dry, yellowish red (5YR 4/8) rubbed dry, clay; moderately developed fine subangular blocky structure; soft, friable, slightly plastic, nonsticky; strong clayskins; few roots; gradual smooth boundary. |
| $B_3$ | **134-224 cm** | Dark reddish brown (2.5YR 3/4) moist, dark red (2.5YR 3/7) dry, yellowish red (5YR 4/8) rubbed dry, clay; massive, very porous, breaking easily into weak fine granular structure; soft, very friable, slightly plastic, nonsticky; roots absent; gradual wavy boundary. |
| C | **224-250 cm** | Dark brown (7.5YR 5/6) clay; soft, very friable, slightly plastic, nonsticky. |

NOTE: The clay in the Ap horizon contains quartz and 1 : 1 lattice clays. In the $B_2$ and $B_3$ horizons 1 : 1 minerals and iron oxides are codominant, with some gibbsite also present. The sand fractions have a high percentage of magnetite and iron concretions with smaller amounts of quartz.

**EUTRIC NITOSOL**

**Brazil**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | $CaCO_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| Ap | 0—19 | 6.2 | 5.6 | 16.9 | 14.5 | 86 | 9.7 | 3.7 | 1.1 | 0.1 | 0 | 2.3 | |
| $B_1$ | —80 | 5.8 | 5.3 | 11.3 | 8.9 | 79 | 4.8 | 3.4 | 0.6 | 0.1 | 0 | 2.4 | |
| $B_2$ | —134 | 4.8 | 4.5 | 9.4 | 6.0 | 64 | 2.0 | 3.9 | 0.1 | 0.1 | 0.5 | 2.0 | |
| $B_3$ | —224 | 5.0 | 4.4 | 8.6 | 4.5 | 52 | 1.0 | 3.4 | 0.1 | 0.1 | 0.8 | 3.2 | |
| C | —250 | 4.9 | 3.9 | 9.5 | 3.8 | 40 | 0.8 | 2.8 | 0.1 | 0.1 | 2.1 | 3.6 | |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % [1] | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| Ap | | | 1.5 | 0.18 | 8 | | 0 | 1 | 20 | 15 | 64 | clay | 56 |
| $B_1$ | | | 0.6 | 0.07 | | | 0 | 1 | 5 | 12 | 82 | clay | 71 |
| $B_2$ | | | 0.4 | 0.05 | | | 0 | 1 | 12 | 14 | 73 | clay | 100 |
| $B_3$ | | | 0.2 | 0.03 | | | 0 | 1 | 18 | 20 | 61 | clay | 100 |
| C | | | 0.2 | 0.05 | | | 0 | 6 | 26 | 25 | 43 | clay | 100 |

| Horizon | Solution by $H_2SO_4$, d = 1.47 % | | | | | | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % Truog | | | Moist. equiv. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | | | | | | | |
| Ap | 22.0 | 17.1 | 27.9 | 7.2 | 0.4 | 0.26 | 2.2 | 1.1 | 1.0 | 0.8 | | | 27 |
| $B_1$ | 29.7 | 23.9 | 22.7 | 4.3 | 0.1 | 0.22 | 2.1 | 1.3 | 1.6 | 0.9 | | | 35 |
| $B_2$ | 28.4 | 23.3 | 24.0 | 5.2 | 0.2 | 0.19 | 2.1 | 1.3 | 1.5 | 0.7 | | | 33 |
| $B_3$ | 28.3 | 22.7 | 24.7 | 5.6 | 0.1 | 0.19 | 2.1 | 1.3 | 1.4 | 0.8 | | | 32 |
| C | 29.7 | 22.7 | 23.8 | 5.1 | 0.1 | 0.28 | 2.2 | 1.4 | 1.5 | 0.8 | | | 36 |

| | |
|---|---|
| **DYSTRIC HISTOSOL** | **Od** |
| **Anira peat** | Guyana |
| **FAO, 1965-66** | Vol. VI, pp. 37, 75 |
| **Location** | 5 km NW Wiruni river mouth, 5° 43′N, 57° 53′W |
| **Physiography** | Flat, lowest part of landscape |
| **Drainage** | Very poorly drained |
| **Parent material** | Plant remains |
| **Vegetation** | Grasses, some fern and white cedar |
| **Climate** | 1.121, humid semihot equatorial |

**Profile description**

| | | |
|---|---|---|
| $O_1$ | **0-15 cm** | Dark brown (7.5YR 4/2) peat; structureless; many medium and fine roots; gradual smooth boundary. |
| $O_2$ | **15-50 cm** | Dark reddish brown (5YR 3/2) peat; structureless; many fine roots; there is not much decomposition of the organic matter in this horizon; gradual smooth boundary. |
| $O_3$ | **50-100 cm** | Very dark greyish brown (10YR 3/2) peat; structureless; much decomposition of organic material but undecomposed leaves, roots and twigs still visible; gradual smooth boundary. |
| $O_4$ | **100-150 cm** | Very dark brown (10YR 2/2) peat; structureless; more decomposition of organic matter than in horizons above, but plant parts can be recognized. |

## DYSTRIC HISTOSOL

### Guyana

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO₃ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| $O_1$ | 0—15 | 4.0 | | 78 | 2.6 | 3 | 0.9 | 1.0 | 0.3 | 0.4 | 5.5 | 70 | |
| $O_2$ | —50 | 4.0 | | 76 | 1.8 | 2 | 0.4 | 0.6 | 0.1 | 0.7 | 6.8 | 68 | |
| $O_3$ | —100 | 3.9 | | 79 | 2.4 | 3 | 0.4 | 0.8 | 0.1 | 1.1 | 7.6 | 70 | |
| $O_4$ | —150 | 4.1 | | 71 | 1.8 | 2 | 0.4 | 0.6 | 0.1 | 0.7 | 6.7 | 63 | |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total % | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| $O_1$ | 0.03 | | 27.6 | 0.89 | 31 | | | | | | | | |
| $O_2$ | 0.03 | | 50.7 | 0.98 | 52 | | | | | | | | |
| $O_3$ | 0.06 | | | 0.90 | | | | | | | | | |
| $O_4$ | 0.04 | | 46.8 | 0.91 | 52 | | | | | | | | |

| Horizon | | | | | | | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % Truog | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | | | | | | |
| $O_3$ | | | | | | | | | | 1.3 | | |
| $O_2$ | | | | | | | | | | 0.4 | | |
| $O_3$ | | | | | | | | | | | | |
| $O_4$ | | | | | | | | | | 0.4 | | |

| | |
|---|---|
| **HUMIC PODZOL** | **Ph** |
| **Hydromorphic podzol** | Brazil |
| **Comissão do Solos, 1960** | Profile 73, p. 482 |
| **Location** | 2 km N Canareia, São Paulo state, 25° 03′S, 47° 56′W |
| **Altitude** | 10 m |
| **Physiography** | Flat |
| **Drainage** | Imperfectly drained |
| **Parent material** | Holocene marine sediments |
| **Vegetation** | Secondary coastal scrub |
| **Climate** | 1.61, cool tropical |

**Profile description**

| | | |
|---|---|---|
| **A** | **0-10 cm** | Very dark brown (10YR 2/2) sand; weak fine granular structure; soft, friable, nonplastic, nonsticky; abundant roots; clear wavy boundary. |
| **E** | **10-30 cm** | Light grey (N/7) sand; single grain structure; soft, nonplastic, nonsticky; roots decreasing; abrupt irregular boundary. |
| **$B_1$** | **30-45 cm** | Very dark brown (10YR 2/2) sand; soft, friable, nonplastic, nonsticky; weakly cemented with organic material; few roots; abrupt irregular boundary. |
| **$B_2$** | **45-75 cm** | Dark reddish brown (5YR 3/3) sand; strongly cemented; no roots; abrupt irregular boundary. |
| **BC** | **75-95 cm** | Dark brown (7.5YR 3/2) and strong brown (7.5YR 5/6) sand in layers 2 mm to 1 cm thick; strongly cemented; no roots; gradual boundary. |
| **C** | **95-195 cm** | White (2.5Y 8/2) with layers 2 to 5 mm thick of strong brown (7.5YR 5/6) sand; single grain structure; soft, nonplastic, nonsticky. |
| | | Below this horizon is a light grey Cg horizon. |

NOTE: The fine sand is 99% quartz

# HUMIC PODZOL

## Brazil

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO₃ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| A | 0—10 | 3.8 | 2.9 | 8.6 | 1.9 | 22 | 1.0 | 0.8 | 0.1 | 0.1 | 2.1 | 4.6 | |
| E | —30 | 4.6 | 3.5 | 0.5 | 0.3 | 60 | 0.2 | 0.1 | 0 | 0 | 0 | 0.2 | |
| $B_1$ | —45 | 3.8 | 3.2 | 30.6 | 0.4 | 1 | 0.2 | 0.1 | 0 | 0.1 | 5.8 | 21.5 | |
| $B_2$ | —75 | 4.4 | 3.8 | 13.3 | 0.3 | 2 | 0.2 | 0.1 | 0 | 0 | 2.2 | 10.8 | |
| BC | —95 | 4.9 | 4.2 | 12.1 | 0.4 | 4 | 0.3 | 0.1 | 0 | 0 | 1.8 | 9.8 | |
| C | —195 | 4.9 | 4.5 | 1.5 | 0.3 | 21 | 0.1 | 0.1 | 0 | 0 | 0.4 | 0.8 | |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % [1] | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | | | 3.3 | 0.23 | 14 | | 0 | 3 | 92 | 2 | 3 | sand | 93 |
| E | | | 0.1 | 0.01 | | | 0 | 1 | 98 | 1 | 0 | sand | 100 |
| $B_1$ | | | 3.6 | 0.09 | 40 | | 0 | 2 | 92 | 2 | 4 | sand | 86 |
| $B_2$ | | | 1.3 | 0.03 | 45 | | 0 | 1 | 98 | 0 | 1 | sand | 33 |
| BC | | | 1.4 | 0.04 | 36 | | 0 | 1 | 96 | 1 | 2 | sand | 18 |
| C | | | 0.2 | 0.01 | | | 0 | 16 | 83 | 1 | 0 | sand | 78 |

| Horizon | Solution in $H_2SO_4$, d = 1.47 % | | | | | | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % Truog | | | Moist equiv. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | | | | | | | |
| A | 0.7 | 0.2 | 0.4 | 0.4 | | 0.02 | 5.3 | 2.5 | 0.8 | 1.0 | | | 12 |
| E | 0.2 | 0.2 | 0.4 | 0.4 | | 0.02 | 2.2 | 0.9 | 0.7 | 0.6 | | | 2 |
| $B_1$ | 0.9 | 0.9 | 0.4 | 0.6 | | 0.02 | 1.8 | 1.4 | 3.3 | 0.7 | | | 12 |
| $B_2$ | 0.5 | 1.0 | 0.7 | 0.8 | | 0.02 | 0.9 | 0.6 | 2.4 | 1.0 | | | 5 |
| BC | 1.4 | 2.1 | 0.5 | 0.2 | | 0.02 | 1.2 | 1.0 | 6.1 | 0.7 | | | 11 |
| C | 1.1 | 1.0 | 0.5 | 0.1 | | 0.02 | 1.9 | 1.5 | 3.1 | 0.7 | | | 2 |

[1] International size grades.

| | |
|---|---|
| **ALBIC ARENOSOL** | **Qa** |
| **Tiwiwid sand** | Guyana |
| **FAO, 1965-66** | Vol. V, pp. 81, 105 |
| **Location** | 5 km SE Tarani West Lock, Tarani Canal-Berbice river, 5° 45′N, 57° 37′W |
| **Physiography** | Flat or gently undulating uplands |
| **Drainage** | Excessively drained |
| **Parent material** | Coarse-textured sediments |
| **Vegetation** | Forest or scrub |
| **Climate** | 1.121, humid semihot equatorial |

**Profile description**

| | | |
|---|---|---|
| $A_1$ | **0-10 cm** | Very dark grey (10YR 3/1) sand containing numerous white sand grains which give the surface a salt and pepper appearance, sand grains are medium to coarse in size; weak, fine granular structure; very friable; common fine roots; gradual smooth boundary. |
| $A_2$ | **10-18 cm** | Dark grey (10YR 4/1) grading to grey (10YR 5/1) sand with numerous white sand grains; single grain structure; loose, very friable; common fine roots; clear smooth boundary. |
| $C_1$ | **18-60 cm** | Grey grading to light grey (10YR 5/1 to 6/1) medium sand; single grain structure; loose, very friable; few fine roots and occasional medium roots; gradual smooth boundary. |
| $C_2$ | **60-120 +** | Light grey to white (10YR 7/1 to 8/2) medium sand; single grain structure; loose, very friable; occasional fine roots. |

**ALBIC ARENOSOL**

**Guyana**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO₃ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| $A_1$ | 0—10 | 4.6 | | 2.0 | 0 | | 0 | 0 | 0 | 0 | 0.1 | 1.9 | |
| $A_2$ | —18 | 4.5 | | 2.4 | 0.1 | | 0 | 0 | 0 | 0.1 | 0.2 | 2.1 | |
| $C_1$ | —60 | 5.4 | | 0.2 | 0 | | 0 | 0 | 0 | 0 | 0 | 0.2 | |
| $C_2$ | —120 | 5.8 | | 0.3 | 0.1 | | 0 | 0 | 0 | 0.1 | 0 | 0.2 | |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| | | | | | | | | | *Total* | | | | |
| $A_1$ | | | 2.5 | 0.04 | | | | | 98 | 2 | 0 | sand | |
| $A_2$ | | | 1.7 | 0.02 | | | | | 98 | 2 | 0 | sand | |
| $C_1$ | | | 0.1 | 0.01 | | | | | 98 | 2 | 0 | sand | |
| $C_2$ | | | 0 | | | | | | 97 | 3 | 0 | sand | |

| Horizon | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % Truog | | silt [1] % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $A_1$ | | | | | | | | | | 0.6 | | 2 |
| $A_2$ | | | | | | | | | | 0.6 | | 1 |
| $C_1$ | | | | | | | | | | 0.7 | | 0 |
| $C_2$ | | | | | | | | | | 0.9 | | 0 |

NOTE: These analyses are from a profile similar to the one described on the facing page.
[1] International size grades.

| | |
|---|---|
| **FERRALIC ARENOSOL** | **Qf** |
| **Regosol intergrade to Latosol** | Brazil |
| **Comissão do Solos 1960** | Profile 85, p. 552 |
| **Location** | Campinas, São Paulo state, 22° 55′S, 47°03′W |
| **Altitude** | 650 m |
| **Physiography** | Gently undulating, slope 2-3% |
| **Drainage** | Very well drained |
| **Parent material** | Sand |
| **Vegetation** | Cerrado (savanna) grasses |
| **Climate** | 1.77, humid tierra templada |

**Profile description**

| | | |
|---|---|---|
| A | **0-15 cm** | Dark reddish brown (5YR 3/4) mottled with zones of leached sand, loamy sand; weak fine granular structure; soft, friable, nonplastic, nonsticky; roots abundant; clear smooth boundary. |
| $BC_1$ | **15-49 cm** | Reddish brown (5YR 4/4) sandy loam; weak fine granular structure; soft, very friable, nonplastic, nonsticky; roots abundant, clear smooth boundary. |
| $BC_2$ | **49-112 cm** | Yellowish red (5YR 4/6) sandy loam; weak fine granular structure; soft, friable, nonplastic, nonsticky; roots abundant; diffuse smooth boundary. |
| $BC_3$ | **112-148 cm** | Yellowish red (5YR 4/7) sandy loam; massive and porous breaking to weak fine granular and single grain structure; slightly hard, friable, nonplastic, slightly sticky; roots abundant; diffuse smooth boundary. |
| $BC_4$ | **148-328 cm** | Yellowish red (5YR 4/8) sandy loam; massive and porous breaking to weak fine granular and single grain structure; slightly hard to hard, friable, slightly plastic, slightly sticky; roots abundant; diffuse smooth boundary. |
| $BC_5$ | **328-528 cm** | Yellowish red (5YR 5/8) to red (2.5YR 5/8) sandy loam; massive and porous breaking to weak fine granular and single grain structure; firm to friable, slightly plastic, slightly sticky; few roots; diffuse smooth boundary. |
| C (?) | **528-600 +** | Red (10R 5/6) with few small prominent light brown (7.5YR 6/4) mottles, sandy loam; massive; slightly hard, friable, slightly plastic, slightly sticky; no roots. |

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NOTE: The sand fraction is almost entirely quartz. Clay in the $BC_4$, $BC_5$ and C horizons is also quartz dominant with 1 : 1 minerals minor in the $BC_4$ and C and codominant in the $BC_5$. Gibbsite is also a minor constituent of the $BC_4$.

## FERRALIC ARENOSOL

**Brazil**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO$_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| A | 0—15 | 4.5 | 3.9 | 2.5 | 0.7 | 28 | | | | | 0.5 | 1.3 | |
| BC$_1$ | —49 | 4.6 | 3.9 | 2.4 | 0.7 | 28 | | | | | 0.6 | 1.1 | |
| BC$_2$ | —112 | 4.7 | 4.0 | 1.9 | 0.5 | 27 | | | | | 0.5 | 0.9 | |
| BC$_3$ | —148 | 4.9 | 4.2 | 1.8 | 0.7 | 37 | | | | | 0.4 | 0.8 | |
| BC$_4$ | —328 | 5.4 | 4.5 | 1.6 | 0.7 | 42 | | | | | 0.2 | 0.7 | |
| BC$_5$ | —528 | 5.7 | 4.6 | 1.5 | 0.6 | 37 | | | | | 0 | 0.9 | |
| C | —600 | 5.0 | 3.9 | 2.2 | 0.6 | 29 | | | | | 1.2 | 0.3 | |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis %[1] | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | | | 0.5 | 0.04 | 11 | | 0 | 21 | 66 | 4 | 9 | sandy loam | 75 |
| BC$_1$ | | | 0.3 | 0.03 | | | 0 | 9 | 75 | 3 | 13 | sandy loam | 74 |
| BC$_2$ | | | 0.2 | 0.02 | | | 0 | 20 | 63 | 2 | 15 | sandy loam | 72 |
| BC$_3$ | | | 0.2 | 0.02 | | | 0 | 18 | 65 | 3 | 14 | sandy loam | 90 |
| BC$_4$ | | | 0.1 | 0.01 | | | 0 | 18 | 65 | 2 | 15 | sandy loam | 99 |
| BC$_5$ | | | 0.1 | 0.01 | | | 0 | 14 | 66 | 3 | 17 | sandy loam | 99 |
| C | | | 0.1 | 0.01 | | | 0 | 11 | 63 | 12 | 14 | sandy loam | 98 |

| Horizon | Solution by $H_2SO_4$, d = 1.47% | | | | | | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | P mg % Truog | | | Moist. equiv. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | | | | | | | |
| A | 4.2 | 5.1 | 1.6 | 0.3 | | 0.02 | 1.4 | 1.2 | 5.0 | <0.4 | | | 8 |
| BC$_1$ | 5.1 | 6.1 | 1.6 | 0.3 | | 0.02 | 1.4 | 1.2 | 5.8 | 0.7 | | | 8 |
| BC$_2$ | 4.9 | 6.4 | 1.6 | 0.3 | | 0.02 | 1.3 | 1.1 | 6.2 | <0.4 | | | 8 |
| BC$_3$ | 5.5 | 6.9 | 2.0 | 0.3 | | 0.02 | 1.4 | 1.1 | 5.5 | <0.4 | | | 9 |
| BC$_4$ | 5.2 | 6.7 | 1.8 | 0.3 | | 0.02 | 1.3 | 1.1 | 6.0 | <0.4 | | | 10 |
| BC$_5$ | 6.4 | 7.8 | 1.9 | 0.3 | | 0.02 | 1.4 | 1.2 | 6.3 | <0.4 | | | 10 |
| C | 10.1 | 9.2 | 1.8 | 0.2 | | 0.02 | 1.9 | 1.7 | 8.2 | <0.4 | | | 16 |

[1] International size grades.

| | |
|---|---|
| **EUTRIC REGOSOL** | **Re** |
| **Huinca Renancó** | Argentina |
| **Etchevehere and Musto** | 1966, site 11 |
| **Location** | 32 km N Huinca Renancó, Córdoba Province, 34° 33′S, 64°23′W |
| **Altitude** | 200 m |
| **Physiography** | Internal drainage basin |
| **Drainage** | Well drained |
| **Parent material** | Sand |
| **Vegetation** | Western pampa xerophilous forest |
| **Climate** | 5.13, typical pampean |

**Profile description**

| | | |
|---|---|---|
| $A_1$ | **0-20 cm** | Very dark grey brown (10YR 3/2) moist, sandy loam; weak fine subangular blocky structure breaking to single grain; very friable; diffuse, smooth boundary. |
| AC | **20-45 cm** | Very dark grey brown to dark brown (10YR 3/2.5) moist, sand; massive; loose; diffuse wavy boundary. |
| $C_1$ | **45-200 cm** | Dark yellowing brown (10YR 3/4) moist, sand; massive to single grain structure; loose; abrupt wavy boundary. |
| $C_2$ | **200 +** | Dark yellowish brown (10YR 3/4) moist, sand; massive to single grain structure; loose; abundant free carbonates. |

## EUTRIC REGOSOL

### Argentina

| Horizon | Depth cm | pH H₂O | pH KCl | Cation exchange me % CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | $CaCO_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $A_1$ | 0—20 | 6.4 | | 11.2 | 10.9 | 97 | 6.2 | 2.8 | 1.7 | 0.2 | | | 0 |
| AC | —45 | 6.7 | | 10.7 | 10.4 | 97 | 6.0 | 2.9 | 1.4 | 0.1 | | | 0 |
| $C_1$ | —200 | 7.3 | | 9.4 | 9.9 | 100 | 6.0 | 3.1 | 0.6 | 0.2 | | | 0 |
| $C_2$ | 200+ | 8.2 | | 4.8 | | | | | 0.9 | 0.4 | | | 1.6 |

| Horizon | Sol. salts E.C. | | Organic matter % C | % N | C/N | % OM | Particle size analysis % stones | c. sand | f. sand | silt | clay | texture | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $A_1$ | 0.1 | | 0.7 | 0.07 | 0 | | | 2 | 72 | 16 | 10 | sandy loam | |
| AC | 0.1 | | 0.4 | 0.04 | | | | 2 | 75 | 14 | 9 | sandy loam | |
| $C_1$ | 0.1 | | 0.2 | 0.03 | | | | 2 | 76 | 14 | 8 | sandy loam | |
| $C_2$ | 0.1 | | 0.1 | | | | | 2 | 82 | 11 | 5 | loamy sand | |

| | |
|---|---|
| **MOLLIC SOLONETZ** | **Sm** |
| **Las Flores** | Argentina |
| **FAO, 1967** | Site 21, pp. 54-55 |
| **Location** | 8 km NE Las Flores, Buenos Aires Province, 35° 58′S, 59°01′W |
| **Altitude** | 28 m |
| **Physiography** | Depressed pampa |
| **Drainage** | Imperfectly drained |
| **Vegetation** | Eastern pampa, grassland |
| **Climate** | 5.112, typical pampean |

**Profile description**

| | | |
|---|---|---|
| **Ap** | **0-15 cm** | Very dark grey (10YR 3/1) moist, sandy loam; weak medium subangular blocky structure breaking to granular; very friable; abrupt smooth boundary. |
| **$A_2$** | **15-20 cm** | Very dark grey (10YR 3/1) moist, sandy loam; weak medium subangular blocky structure breaking to granular; very friable, nonsticky, nonplastic; crotovines; gradual wavy boundary. |
| **E** | **20-40 cm** | Dark brown (10YR 3/3) moist, sand; weak medium and coarse platy structure, breaking to single grain; loose; crotovines; abrupt smooth boundary. |
| **$Bt_1$** | **40-52 cm** | Brown to dark brown (10YR 4/3) moist with abundant, prominent medium brown (7.5YR 4.5/4) mottles, heavy clay; strong, coarse prismatic and columnar structure; hard, firm, very sticky, very plastic; abundant very dark grey brown (10YR 3/2) clayskins; many iron-manganese concretions; gradual wavy boundary. |
| **$Bt_2$** | **52-85 cm** | Dark yellowish brown (10YR 4/4) moist with many prominent iron mottles, clay loam; coarse prismatic structure breaking to subangular blocky; friable, very plastic, slightly sticky; moderate calcareous concretions; gradual wavy boundary. |
| **BC** | **85-150 cm** | Dark yellowish brown (10YR 4/4) moist with common mottles, sandy clay loam; weak, coarse subangular blocky structure breaking to single grain; very hard, friable, plastic, slightly sticky; few clayskins; many iron-manganese and calcareous concretions; weakly developed fragipan. |
| **Cp** | **150 +** | Water level. |

## MOLLIC SOLONETZ

### Argentina

| Horizon | Depth cm | pH H₂O | pH KCl | Cation exchange me % CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | $CaCO_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0—15 | 8.0 | | 19.6 | 18.8 | 96 | 9.7 | 4.7 | 1.5 | 2.9 | | 0.4 | 0 |
| $A_2$ | —20 | | | | | | | | | | | | |
| E | —40 | 8.9 | | 7.6 | 7.1 | 93 | 2.6 | 1.4 | 1.1 | 2.0 | | | 0 |
| $Bt_1$ | —52 | 8.7 | | 23.0 | 21.9 | 95 | 8.1 | 5.0 | 2.3 | 6.5 | | | 0 |
| $Bt_2$ | —85 | 9.1 | | 21.6 | 21.6 | 100 | 7.5 | 6.5 | 2.2 | 5.4 | | | 0.8 |
| BC | —150 | 8.9 | | 15.4 | 14.0 | 100 | 6.2 | 4.3 | 2.1 | 3.4 | | | 0.7 |

| Horizon | Sol. salts E.C. | | Organic matter % C | % N | C/N | % OM | Particle size analysis % stones | c. sand | f. sand | silt | clay | texture | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ap | | | | | | | | | | | | | |
| $A_2$ | | | 1.9 | 0.25 | 8 | | | 0 | 53 | 36 | 11 | sandy loam | |
| E | | | 0.2 | 0.03 | 7 | | | 0 | 71 | 22 | 7 | sandy loam | |
| $Bt_1$ | | | 0.3 | 0.06 | | | | 0 | 48 | 25 | 27 | sandy clay loam | |
| $Bt_2$ | 0.7 | | 0.2 | 0.05 | | | | 0 | 48 | 41 | 11 | loam | |
| BC | 1.4 | | 0.1 | | | | | 0 | 58 | 38 | 4 | sandy loam | |

| | |
|---|---|
| **HUMIC ANDOSOL** | **Th** |
| **Cautín silt loam** | Chile |
| **A.C.S. Wright, FAO, Chile** | Soil and site description |
| **Department of Agricultural Research, Royal Tropical Institute, Amsterdam** | Soil analyses |
| **Location** | 55 km NE Temuco, Cautín Province, 38° 11'S, 72° 10'W |
| **Altitude** | 525 m |
| **Physiography** | Very gently undulating surface of old piedmont terrace |
| **Drainage** | Well drained |
| **Parent material** | Fine andesitic volcanic ash |
| **Vegetation** | Forest, dominantly *Nothofagus obliqua* and *N. dombeyi* with olivillo, laurel |
| **Climate** | 6.21, marine Mediterranean |

**Profile description**

| | | |
|---|---|---|
| **$A_1$** | **0-15 cm** | Dark brown (7.5YR 3/2) dry, dark reddish brown (5YR 2/2) moist, humic silt loam; very fine granular structure; soft, very friable, very slightly sticky and very slightly plastic; diffuse boundary. |
| **$A_2$** | **15-45 cm** | Very dark grey (7.5YR 3/1) dry, dark reddish brown (5YR 3/2) moist, rather heavy silt loam; strongly developed medium subangular blocky structure, breaking readily to fine and very fine angular blocks and coarse granules; slightly hard, friable, slightly sticky, very slightly plastic; gradual boundary. |
| **AB** | **45-60 cm** | Brown (7.5YR 4/2) dry, reddish brown (5YR 4/3) moist, loam; very weakly developed coarse subangular blocky structure, breaking very readily to very fine blocks and granules under very slight pressure; soft and powdery when dry, very friable, very slightly sticky and slightly plastic; clear boundary. |
| **BC (?)** | **60-100 cm** | Yellowish brown (10YR 5/8) dry, strong brown (7.5YR 5/6) moist, loam; no recognizable structure in the mass, but breaks readily to coarse irregular blocks and granules under slight pressure; not appreciably hard when dry, slightly to moderately sticky, moderately plastic; diffuse boundary. |
| **C (?)** | **100 +** | Similar material, rather more yellowish and markedly more plastic. |

The clay minerals are mainly amorphous with allophanic characteristics. The light sand minerals are predominantly intermediate and basic plagioclase and volcanic glass. The heavy sand minerals belong to the hypersthene/augite association.

## HUMIC ANDOSOL

**Chile**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO$_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| | | | | | | | | | | | *Total* | | |
| $A_1$ | 0—15 | 5.6 | 4.9 | 64 | 5.9 | 9 | 3.0 | 2.2 | 0.6 | 0.2 | 36 | | |
| $A_2$ | —45 | 5.6 | 5.2 | 46 | 0.4 | 1 | 0 | 0.1 | 0.2 | 0.1 | 30 | | |
| AB | —60 | 5.6 | 5.4 | 51 | 0.2 | 1 | 0 | 0 | 0.2 | 0.1 | 29 | | |
| BC (?) | —100 | 5.6 | 5.5 | 40 | 0.4 | 1 | 0.1 | 0.1 | 0.2 | 0.1 | 25 | | |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis %[1] | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| $A_1$ | | | 10.4 | 1.02 | 10 | | | 2 | 6 | 75 | 17 | silt loam | |
| $A_2$ | | | 3.2 | 0.48 | 7 | | | 2 | 7 | 72 | 19 | silt loam | |
| AB | | | 3.2 | 0.41 | 8 | | | 3 | 8 | 71 | 18 | silt loam | |
| BC (?) | | | 2.2 | 0.23 | 10 | | | 6 | 10 | 64 | 20 | silt loam | |

| Horizon | Total analysis of clay, $Na_2CO_3$ fusion, % | | | | | | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | CaO | MgO | $K_2O$ | Loss on Ign. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | | | | | | | |
| $A_1$ | 20.9 | 20.7 | 13.8 | 0.2 | | | 1.7 | 1.2 | 2.5 | 0.5 | 0.2 | 0.1 | 25.9 |
| $A_2$ | 20.3 | 27.2 | 13.8 | 0.2 | | | 1.3 | 1.0 | 3.3 | 0.6 | 0 | 0.1 | 23.8 |
| AB | 17.7 | 28.9 | 12.7 | 0.3 | | | 1.0 | 1.0 | 3.3 | 0.3 | 0 | 0.1 | 24.0 |
| BC (?) | 19.3 | 31.3 | 13.4 | 0.4 | | | 1.0 | 1.0 | 3.3 | 0.6 | 0.2 | 0.1 | 21.6 |

[1] International method, obtaining dispersion by reducing the pH to 3.5 with HCl without pretreatment.

| | |
|---|---|
| **VITRIC ANDOSOL** | Tv |
| **Yunguyo** | Peru |
| **ONERN Department of Soils** | |
| **Location** | 100 km ESE Puno. 16° 15'S, 69° 04'W |
| **Altitude** | 3870 m |
| **Physiography** | *Almost flat altiplano* |
| **Parent material** | Volcanic ash |
| **Vegetation** | Cultivated, potatoes, barley |
| **Climate** | 2.51, low Andine |

**Profile description**

| | | |
|---|---|---|
| **Ap** | **0-25 cm** | Grey brown (2.5Y 5/2) dry, sandy loam; granular; soft; clear boundary. |
| $C_1$ | **25-40 cm** | Grey (5Y 5/1) dry, sand; single grain; soft; clear boundary. |
| $C_2$ | **40-95 cm** | Very dark grey brown (2.5Y 3/2) moist, sandy loam; massive; friable; clear boundary. |
| $C_3$ | **95 +** | Dark brown (7.5YR 3/2) moist, sand; single grain; loose. |

**VITRIC ANDOSOL**

**Peru**

| Horizon | Depth cm | pH H$_2$O | pH KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | CaCO$_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Cation exchange me % | | | | | | | | | |
| Ap | 0—25 | 5.3 | | 9.1 | 2.4 | 26 | 1.6 | 0.2 | 0.5 | 0.1 | | | 0 |
| C$_1$ | —40 | 5.6 | | 1.6 | 1.4 | 88 | 0.9 | 0.2 | 0.2 | 0.1 | | | 0 |
| C$_2$ | —95 | 5.3 | | 9.2 | 4.3 | 47 | 3.2 | 0.6 | 0.4 | 0.1 | | | 0 |
| C$_3$ | 95+ | 5.2 | | 5.8 | 2.1 | 36 | 1.6 | 0.1 | 0.2 | 0.1 | | | 0 |

| Horizon | Sol. salts | | Organic matter % C | % N | C/N | % OM | Particle size analysis % stones | c. sand | f. sand | silt | clay | texture | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ap | | | 0.9 | 0.06 | 15 | 1.6 | | | 74 | 20 | 6 | sandy loam | |
| C$_1$ | | | 0.2 | 0.01 | | 0.3 | | | 94 | 4 | 2 | sand | |
| C$_2$ | | | 0.7 | 0.04 | | 1.3 | | | 60 | 28 | 12 | sandy loam | |
| C$_3$ | | | 0.6 | 0.04 | | 1.0 | | | 90 | 6 | 4 | sand | |

| Horizon | SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | TiO$_2$ | MnO | P$_2$O$_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | Available, kg/ha P | K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ap | | | | | | | | | | 11 | 340 | | |
| C$_1$ | | | | | | | | | | 9 | 340 | | |
| C$_2$ | | | | | | | | | | 9 | 340 | | |
| C$_3$ | | | | | | | | | | 7 | 310 | | |

| | |
|---|---|
| **CHROMIC VERTISOL** | **Vc** |
| **Profile F14 unit 1A** | Brazil |
| **Rep. FAO/SF: BRA 22** | FAO, 1966b, p. 66. |
| **Location** | 20 km SSE Juazeiro, Baía State, 9° 30′S, 40° 24′W |
| **Altitude** | > 415 m |
| **Physiography** | Flat with slight depressions (gilgai) |
| **Drainage** | Imperfectly drained |
| **Parent material** | Calcareous clays over marble or quartzite outcrops |
| **Vegetation** | Very scattered xerophytic shrubs with annual grasses |
| **Climate** | 1.543, semiarid tropical |

**Profile description**

| | | |
|---|---|---|
| **A** | **0-20 cm** | Olive brown (2.5Y 4/4) dry and moist, clay; coarse granular mulch on surface grading to medium coarse subangular blocky structure; hard, firm; calcareous. |
| **$BC_1$** | **20-70 cm** | Olive brown (2.5Y 4/4) dry and moist, clay; mainly massive with some slickensides on horizontal planes; very hard, very firm; calcareous. |
| **$BC_2$** | **70-132 cm** | Olive brown (2.5Y 4/4) dry and moist, clay; massive, with slickensides; very hard, very firm; calcareous. |
| **C** | **132-142 cm** | Olive brown (2.5Y 4/4) dry and moist, clay; grading into pale yellowish brown and whitish decayed rock; calcareous. |

## CHROMIC VERTISOL

**Brazil**

| Horizon | Depth cm | pH $H_2O$ | pH KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | $CaCO_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Cation exchange me % | | | | | | | | | |
| A | 0—20 | 8.1 | 7.0 | 39.8 | 39.8 | 100 | 36.4 | 2.8 | 0.2 | 0.4 | | | 5.4 |
| $BC_1$ | —70 | 7.9 | 6.9 | 34.3 | 34.3 | 100 | 32.8 | 0.8 | 0.1 | 0.6 | | | 6.1 |
| $BC_2$ | —132 | 8.1 | 7.0 | 38.9 | 38.9 | 100 | 36.0 | 1.6 | 0.1 | 1.2 | | | 6.2 |
| C | —142 | 7.8 | 6.8 | 33.4 | 33.4 | 100 | 30.8 | 1.0 | 0.1 | 1.5 | | | 8.6 |

| Horizon | Sol. salts E.C. | | Organic matter % C | % N | C/N | % OM | Particle size analysis % stones | c. sand | f. sand | silt | clay | texture | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0.2 | | 0.4 | 0.06 | 7 | | 4 | 13 | 25 | 11 | 51 | clay | 80 |
| $BC_1$ | 0.2 | | 0.3 | 0.05 | | | 4 | 18 | 19 | 13 | 50 | clay | 91 |
| $BC_2$ | 0.5 | | 0.3 | 0.05 | | | 3 | 12 | 24 | 12 | 52 | clay | 39 |
| C | 1.5 | | 0.2 | 0.06 | | | 3 | 9 | 27 | 12 | 52 | clay | 40 |

| Horizon | Solution in $H_2SO_4$, d = 1.47 % $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $P_2O_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | | | Moist. equiv. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 23.1 | 13.3 | 4.7 | | | | 3.0 | 2.4 | 4.4 | | | 25 |
| $BC_1$ | 23.4 | 13.7 | 4.7 | | | | 2.9 | 2.4 | 4.6 | | | 26 |
| $BC_2$ | 23.6 | 14.0 | 4.8 | | | | 2.9 | 2.4 | 4.6 | | | 29 |
| C | 24.3 | 13.7 | 5.1 | | | | 3.0 | 2.4 | 4.2 | | | 29 |

| | |
|---|---|
| **PELLIC VERTISOL** | **Vp** |
| **Laguna Vieja** | Peru |
| **ONERN Department of Soils** | |
| **Location** | 67 km SE Moyobamba. 6° 22'S, 76° 31'W |
| **Altitude** | 356 m |
| **Physiography** | Intermontane basin, flat, with depressions |
| **Parent material** | Plastic clay |
| **Vegetation** | Forest |
| **Climate** | 1.72, humid tierra templada |

**Profile description**

| | | |
|---|---|---|
| A | **0-15 cm** | Black (5YR 2/1) moist, clay loam; slightly hard, friable, plastic, sticky; slickensides; diffuse boundary. |
| B | **15-100 cm** | Black (5YR 2/1) moist, clay; blocky structure; very hard, firm; slickensides; diffuse boundary. |
| CB | **100-140 cm** | Brown (7.5YR 5/2) clay; massive; very hard; calcium carbonate concretions; clear boundary. |
| C | **140-170 cm** | Grey brown (2.5Y 5/2) moist, clay loam; extremely hard; calcium carbonate concretions. |

## PELLIC VERTISOL

**Peru**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO₃ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| A | 0—15 | 7.3 | | 34.7 | 34.7 | 100 | 32.5 | 1.0 | 0.9 | 0.4 | | | 0.2 |
| B | —100 | 7.8 | | 31.9 | 31.9 | 100 | 30.2 | 1.0 | 0.3 | 0.4 | | | 3.2 |
| CB | —140 | 7.8 | | 29.6 | 29.6 | 100 | 28.0 | 1.0 | 0.3 | 0.4 | | | 2.2 |
| C | —170 | 7.8 | | 18.4 | 18.4 | 100 | 17.1 | 0.9 | 0.3 | 0.1 | | | 2.0 |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E.C. | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | 0.8 | | 5.4 | 0.39 | 14 | 9.2 | | | 30 | 32 | 38 | clay loam | |
| B | 0.1 | | 1.1 | 0.07 | 16 | 1.9 | | | 26 | 28 | 46 | clay | |
| CB | 2.4 | | 0.46 | 0.04 | | 0.8 | | | 32 | 26 | 42 | clay | |
| C | 2.8 | | 0.19 | 0.02 | | 0.34 | | | 44 | 26 | 30 | clay loam | |

| | |
|---|---|
| **EUTRIC PLANOSOL** | **We** |
| **Profile 4** | Argentina |
| **Cappannini and Lores** | Undated, profile 4, p. 12 |
| **Location** | 32 km S Corrientes, near El Sombrero, 27° 45'S, 58° 47'W |
| **Physiography** | Flat plain |
| **Parent material** | Tertiary clays |
| **Vegetation** | Range land |
| **Climate** | 4.36, hot semitropical |

**Profile description**

| | | |
|---|---|---|
| **A** | **0-10 cm** | Very dark grey to very dark greyish brown (10YR 3/1.5), sandy loam to loam; granular to weak fine subangular blocky structure; firm, slightly sticky, slightly plastic, diffuse boundary. |
| **$E_1$** | **10-18 cm** | Dark grey (10YR 4/1) with common fine distinct dark reddish brown (5YR 3/4) mottles, loam; granular to subangular blocky structure; firm, slightly plastic, sticky; common iron-manganese concretions; diffuse boundary. |
| **$E_2$** | **18-25 cm** | Dark grey to grey (10YR 4.5/1) with few fine prominent dark reddish brown mottles, sandy loam; weak fine subangular blocky and weak medium secondary structure; firm, slightly plastic, slightly sticky; common iron-manganese concretions in the upper part; abrupt boundary. |
| **BE** | **25-27 cm** | Very dark grey (10YR 3/1) with few fine distinct dark reddish brown (5YR 3/4) mottles, silty clay; moderate fine subangular blocky structure; very firm, sticky, plastic; clear boundary. |
| **$Bt_1$** | **27-50 cm** | Black to very dark grey (10YR 2.5/1) clay; strong medium subangular blocky structure; very firm, very plastic, sticky; many clayskins; gradual boundary. |
| **$Bt_2$** | **50-65/75cm** | Dark grey (10YR 4/1) with many fine black (10YR 2/1) mottles, clay; strong fine subangular blocky structure; same consistency as $Bt_1$; many clayskins; few iion-manganese concretions; some small quartz pebbles; gradual wavy boundary. |
| **Bck** | **65-85 cm** | Greyish brown (2.5Y 5/2) with fine faint common yellowish brown (10YR 5/8) and common prominent black (10YR 2/1) mottles, clay loam; strong medium angular blocky structure; same consistency as $Bt_1$ ; many hard $CaCO_3$ concretions, few small iron-manganese concretions; gradual boundary. |
| **C** | **85-150 cm** | Greyish brown to light greyish brown (2.5Y 5.5/2) with common fine distinct black (10YR 2/1) mottles, clay loam; moderate medium subangular blocky structure; common thin patches of clay on ped faces; few iron-manganese concretions. |

## EUTRIC PLANOSOL

### Argentina

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO₃ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H₂O | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| A/E₁ | 0—18 | 5.4 | 4.7 | 8.0 | 5.9 | 74 | 3.7 | 1.2 | 0.5 | 0.5 | | | 0 |
| E₂ | —25 | 6.5 | 4.9 | 5.8 | 3.9 | 67 | 2.4 | 0.8 | 0.2 | 0.5 | | | 0 |
| BE/Bt₁ | —50 | 6.8 | 5.1 | 29.4 | 26.5 | 90 | 20.7 | 4.2 | 0.5 | 1.1 | | | 0 |
| Bt₂ | —65 | 7.5 | 5.8 | 28.2 | 26.2 | 93 | 20.7 | 3.8 | 0.5 | 1.2 | | | 0 |
| Bck | —85 | 8.5 | 6.7 | 23.8 | 25.3 | 100 | 17.3 | 6.8 | 0.4 | 0.8 | | | 3.4 |
| C | —150+ | 7.5 | 5.1 | 18.7 | 17.0 | 91 | 13.0 | 2.8 | 0.3 | 0.9 | | | 0 |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A/E₁ | | | 1.0 | 0.10 | 10 | | | 2 | 53 | 31 | 14 | sandy loam | |
| E₂ | | | 0.3 | 0.03 | | | | 1 | 56 | 30 | 13 | sandy loam | |
| BE/Bt₁ | | | 0.7 | 0.06 | | | | 1 | 36 | 18 | 45 | clay | |
| Bt₂ | | | 0.4 | 0.04 | | | | 1 | 39 | 20 | 40 | clay | |
| Bck | | | 0.1 | 0.02 | | | | 1 | 41 | 22 | 36 | clay loam | |
| C | | | 0 | | | | | 1 | 43 | 24 | 32 | clay loam | |

| Horizon | SiO₂ | Al₂O₃ | Fe₂O₃ | TiO₂ | MnO | P₂O₅ | SiO₂/Al₂O₃ | SiO₂/R₂O₃ | Al₂O₃/Fe₂O₃ | Moist. equiv. | | | Resistance paste 1000 Ω |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A/E₁ | | | | | | | | | | 18 | | | 9 |
| E₂ | | | | | | | | | | 15 | | | 15 |
| BE/Bt₁ | | | | | | | | | | 43 | | | 2 |
| Bt₂ | | | | | | | | | | 37 | | | 2 |
| Bck | | | | | | | | | | 31 | | | 2 |
| C | | | | | | | | | | 32 | | | 2 |

| | |
|---|---|
| **MOLLIC PLANOSOL** | **Wm** |
| **Seres Dd 3.12** | Argentina |
| **M.F. Purnell** | UNDP:SF/FAO Entre Rios Project, unpublished data |
| **Location** | 32 km SW Concordia, 58° 10'W, 31° 30'S |
| **Altitude** | 41 m |
| **Physiography** | Undulating, 1% slope |
| **Drainage** | Imperfectly drained |
| **Parent material** | Pampean silt |
| **Vegetation** | Setaria, Eragrostis lujens, Ciperáceas |
| **Climate** | 5.35, subtropical pampean |

**Profile description**

| | | |
|---|---|---|
| A | **0-8 cm** | Dark greyish brown (10YR 4/2) dry, black (10YR 2/1) moist, loam; moderately developed fine crumb and strongly developed very fine subangular blocky structures; soft, very friable, plastic, slightly sticky; abundant roots; clear smooth boundary. |
| AE | **8-30 cm** | Dark grey to very dark grey (10YR 3.5/1) dry, black (10YR 2/1) moist, loam; weakly developed medium prismatic breaking to strongly developed medium subangular blocky structure; hard, friable, plastic, slightly sticky; roots common; abrupt smooth boundary. |
| $B_1$ | **30-45 cm** | Black (10YR 2/05) dry and moist, silty clay; strongly developed large columnar structure; extremely hard, very firm, very plastic, sticky; abundant slickensides; few roots; gradual smooth boundary. |
| $B_2$ | **45-75 cm** | Very dark grey (10YR 3/1) moist, silty clay; strongly developed medium angular blocky structure; very firm, very plastic, sticky; few roots; clear smooth boundary. |
| BC | **75-95 cm** | Brown (10YR 5/3) and very dark grey (10YR 3/1) moist, silty clay; strongly developed medium and fine subangular blocky structure; firm, plastic, sticky; calcium carbonate concretions, but noncalcareous; few roots; gradual smooth boundary. |
| C | **95-125 cm** | Brown (7.5YR 5/4) moist with black mottles, heavy silty clay loam; strongly developed fine to very fine subangular blocky structure; firm to friable, plastic, sticky; calcium carbonate concretions in the upper part of the horizon, noncalcareous; few roots. |

## MOLLIC PLANOSOL

**Argentina**

| Horizon | Depth cm | Hp | | Cation exchange me % | | | | | | | | | CaCO$_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H$_2$O | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| A | 0—8 | 6.0 | 4.9 | 22.8 | 20.0 | 88 | 13.4 | 5.6 | 0.7 | 0.3 | | 6.6 | 0 |
| AE | —30 | 6.2 | 4.9 | 20.8 | 17.6 | 85 | 14.2 | 2.7 | 0.4 | 0.3 | | 6.6 | 0 |
| B$_1$ | —45 | 6.4 | 5.5 | 32.8 | 31.6 | 97 | 27.3 | 3.1 | 0.8 | 0.4 | | 6.3 | 0 |
| B$_2$ | —75 | 7.2 | 6.1 | 34.2 | — | | | | 1.0 | 0.4 | | — | trace |
| BC | —95 | 8.0 | 6.8 | 30.4 | — | | | | 1.1 | 0.5 | | — | 1.3 |
| C | —125 | 7.8 | 6.3 | 25.3 | 27.3 | 100 | 23.7 | 2.3 | 0.9 | 0.4 | | 2.6 | 0 |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | | | 2.0 | 0.20 | 10 | | | 0 | 40 | 37 | 23 | loam | |
| AE | | | 1.7 | 0.17 | 10 | | | 0 | 41 | 35 | 24 | loam | |
| B$_1$ | | | 1.0 | 0.10 | 10 | | | 2 | 29 | 25 | 44 | clay | |
| B$_2$ | | | 0.6 | 0.06 | | | | 0 | 30 | 26 | 44 | clay | |
| BC | | | 0.5 | 0.05 | | | | 1 | 30 | 28 | 41 | clay | |
| C | | | 0.1 | | | | | 2 | 29 | 32 | 37 | clay loam | |

| Horizon | SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | TiO$_2$ | MnO | P$_2$O$_5$ | $\frac{SiO_2}{Al_2O_3}$ | $\frac{SiO_2}{R_2O_3}$ | $\frac{Al_2O_3}{Fe_2O_3}$ | | | | silt [1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | | | | 25 |
| AE | | | | | | | | | | | | | 24 |
| B$_1$ | | | | | | | | | | | | | 17 |
| B$_2$ | | | | | | | | | | | | | 19 |
| BC | | | | | | | | | | | | | 20 |
| C | | | | | | | | | | | | | 22 |

| Horizon | | | | | | | | | | Moist. equiv. % | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | 21 | | | |
| AE | | | | | | | | | | 23 | | | |
| B$_1$ | | | | | | | | | | 32 | | | |
| B$_2$ | | | | | | | | | | 34 | | | |
| BC | | | | | | | | | | 32 | | | |
| C | | | | | | | | | | 29 | | | |

[1]International size grades.

| | |
|---|---|
| **SOLODIC PLANOSOL** | **Ws** |
| **Series 35.11.u** | Argentina |
| **Culot, J. Ph., and Godz, P.** | Manuscript date, 1965 |
| **Location** | Reserve 6, Balcarce, Buenos Aires Province, Balcarce is 37° 51'S, 58° 15'W |
| **Physiography** | Flat flood plain, eastern pampa |
| **Drainage** | Slow to impeded |
| **Parent material** | Silt loess |
| **Vegetation** | Grassland |
| **Climate** | 5.111, typical pampean |

**Profile description**

| | | |
|---|---|---|
| **Ap** | **0-15 cm** | Black (10YR 2/1) moist, very dark grey (10YR 3/1) dry, sandy loam; moderately developed medium granular structure, slightly hard, friable, slightly plastic, sticky; abundant fine to very fine pores; abundant roots; gradual boundary. |
| **AE** | **5-40 cm** | Black (10YR 2/1) moist, very dark grey (10YR 3/1) dry, sandy loam; moderately developed medium granular structure with a tendency to massive; slightly hard, friable, slightly plastic, sticky; moderately abundant pores; moderately abundant medium to fine roots; gradual boundary. |
| **E** | **40-55 cm** | Very dark greyish brown (10YR 3/2) moist, dark grey to dark greyish brown (10YR 4/1-4/2) dry, silty sand; massive structure, slightly hard, very friable, nonplastic, nonsticky; roots rare; abrupt undulating boundary. |
| **$Bt_1$** | **55-80 cm** | Black (10YR 2/1) moist, very dark brown (10YR 2/2) dry, with abundant black (10YR 2/1) mottles on the surface when dry, strong contrast, variegated, medium to small, clear limits, clay loam; strongly developed medium to large columnar structure, with the tops of column somewhat paler in colour and leached (sands clearly visible and slightly rounded); very hard, firm, very plastic, sticky; moderately developed discontinuous clay-humus coatings; abundant fine pores; clear boundary. |
| **$Bt_2$** | **80-95 cm** | Very dark brown (10YR 2/2) when moist, brownish black (10YR 2/3) dry, mottled as in $Bt_1$, clay loam to loam; moderately developed medium subangular blocky structure with a tendency to massive, hard, firm, plastic, sticky; isolated medium developed clay-humus coatings; abundant pores; gradual boundary. |
| **C** | **95-135 cm** | Yellowish brown (10YR 5/4) moist, brown (10YR 5/3) dry, with abundant iron mottles, medium and variegated, sandy loam; massive structure; slightly hard, friable, slightly plastic, sticky; abundant pores, clear boundary. |

## SOLODIC PLANOSOL

**Argentina**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | $CaCO_3$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| Ap | 0—15 | 5.8 | | 33.0 | 20.2 | 61 | 13.6 | 3.1 | 3.1 | 0.3 | | | |
| AE | —40 | 6.0 | | 26.7 | 16.6 | 62 | 12.5 | 2.3 | 1.5 | 0.3 | | | |
| E | —55 | 6.8 | | 8.1 | 6.2 | 76 | 3.7 | 1.2 | 1.0 | 0.3 | | | |
| $Bt_1$ | —80 | 7.5 | | 23.0 | 20.8 | 89 | 9.9 | 7.2 | 2.1 | 1.6 | | | |
| $Bt_2$ | —95 | 8.6 | | 23.0 | 29.3 | 100 | 13.3 | 10.8 | 2.6 | 2.6 | | | 2.1 |
| C | —135 | 9.0 | | 14.3 | | | | | 2.1 | 2.8 | | | 0 |
| — | 135+ | 9.0 | | 10.2 | | | | | 1.5 | 2.8 | | | 0 |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis %[1] | | | | | | Flocc. index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E.C. | Total | % C | % N | C/N | % OM | stones | sand | c. silt | f. silt | clay | texture | |
| Ap | | | | | 12 | 8.8 | | 45 | 16 | 1 | 20 | loam | |
| AE | | | | | 13 | 5.4 | | 49 | 16 | 1 | 18 | loam | |
| E | | | | | 12 | 0.9 | | (62) | 20 | 1 | 8 | sandy loam | |
| $Bt_1$ | 0.5 | 0.03 | | | 9 | 0.9 | | 41 | 16 | | 35 | clay loam | |
| $Bt_2$ | 1.3 | 0.08 | | | | 0.6 | | 48 | 14 | 1 | 22 | loam | |
| C | 1.1 | 0.07 | | | | | | 59 | 18 | 9 | 14 | sandy loam | |
| — | 1.3 | 0.08 | | | | | | 61 | 20 | 8 | 11 | sandy loam | |

[1] Size grades not defined.

| | |
|---|---|
| **HAPLIC XEROSOL** | **Xh** |
| **Puento Chico** | Argentina |
| **Cappannini and Lores** | 1966, pp. 59-61, 120. |
| **Location** | Near Lot 83, junction of Buratovich and D canals, around 39° 25'S, 62° 45'W |
| **Physiography** | High terraces of Colorado River 0-3% slopes |
| **Drainage** | Well drained |
| **Parent material** | Sandy alluvium capped with aeolian sand |
| **Vegetation** | Grass, shrubs |
| **Climate** | 5.71, semiarid peripampean |

**Profile description**

| | | |
|---|---|---|
| **A** | **0-10 cm** | Dark brown (10YR 3/3) moist, greyish brown (10YR 5/2) dry, sandy loam; large subangular blocky with a tendency to laminar structure; soft, friable, somewhat plastic, nonsticky; roots; clear wavy boundary. |
| **$AC_1$** | **10-20 cm** | Very dark greyish (10YR 3/2) moist, greyish brown to dark greyish brown (10YR 4.5/2) dry, sandy loam; weak large subangular blocky structure; soft, friable, slightly plastic, nonsticky; some 1-2 cm gravels; few roots; gradual wavy boundary. |
| **$AC_2$** | **20-47 cm** | Dark brown (10YR 3/3) moist, greyish brown (10YR 5/2) dry, sandy loam; massive, with a tendency to weak medium to large subangular blocky structure; soft, friable, somewhat plastic, nonsticky; some 1-2 cm pebbles; some lenses of calcareous material from the horizon below; rodent burrows; many roots; gradual wavy boundary. |
| **$C_1$** | **47-80 cm** | Brown (10YR 4/3) moist, greyish brown (10YR 5/2) dry, fine sandy loam; massive, breaking to weak large subangular blocky structure; soft, friable; roots; gradual wavy boundary. |
| **$C_2$** | **80-110 cm** | Dark greyish brown (10YR 4/2) moist, light brownish grey (10YR 6/2) dry, sandy loam; massive, compact; some calcareous concretions (3-4 cm); abundant roots; diffuse boundary. |
| **$C_3$** | **110-130 cm** | Dark greyish brown (10YR 4/2) moist, light brownish grey (10YR 6/2) dry, sandy loam to loamy sand; massive with concretions of tosca and 6-7 cm stones; the limit of roots; transitional horizon between $C_2$ and tosca below; clear boundary. |
| **Ck** | **130-180 cm** | Very pale brown (10YR 8/4) moist, very pale brown (10YR 8/3) dry, sandy loam; massive; plastic, sticky; large irregular angular pieces of tosca. |

**HAPLIC XEROSOL**

**Argentina**

| Horizon | Depth cm | pH | | Cation exchange me % | | | | | | | | | CaCO₃ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | CEC | TEB | % BS | Ca | Mg | K | Na | Al | H | |
| A | 0—10 | 7.2 | | 31.4 | 31.4 | 100 | 18.0 | 8.6 | 2.5 | 2.3 | | | 0 |
| $AC_1$ | —20 | 8.1 | | 30.6 | 30.6 | 100 | 18.0 | 7.9 | 2.9 | 1.8 | | | 0 |
| $AC_2$ | —47 | 8.8 | | 35.1 | 35.1 | 100 | 22.5 | 7.4 | 3.1 | 2.1 | | | 0 |
| $C_1$ | —80 | 8.8 | | 19.7 | 19.7 | 100 | 10.9 | 5.7 | 1.8 | 1.3 | | | 1.2 |
| $C_2$ | —110 | 8.8 | | | | | | | | | | | 2.2 |
| $C_3$ | —130 | 9.0 | | | | | | | | | | | 2.4 |
| Ck | —180 | 9.2 | | | | | | | | | | | 22.3 |

| Horizon | Sol. salts | | Organic matter | | | | Particle size analysis % | | | | | | Moist. equiv. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E.C. | | % C | % N | C/N | % OM | stones | c. sand | f. sand | silt | clay | texture | |
| A | 0.5 | | 1.0 | 0.10 | 10 | | | 6 | 66 | 18 | 10 | sandy loam | 11 |
| $AC_1$ | 0.5 | | 0.6 | 0.10 | | | | 7 | 67 | 17 | 9 | sandy loam | 11 |
| $AC_2$ | 1.0 | | 0.4 | 0.06 | | | | 6 | 66 | 16 | 12 | sandy loam | 11 |
| $C_1$ | 2.5 | | 0.2 | 0.05 | | | | 6 | 66 | 17 | 11 | sandy loam | 11 |
| $C_2$ | 2.8 | | | | | | | 7 | 67 | 16 | 10 | sandy loam | 11 |
| $C_3$ | 2.8 | | | | | | | 5 | 70 | 16 | 9 | sandy loam | 11 |
| Ck | 3.3 | | | | | | | 3 | 70 | 13 | 14 | sandy loam | 23 |

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