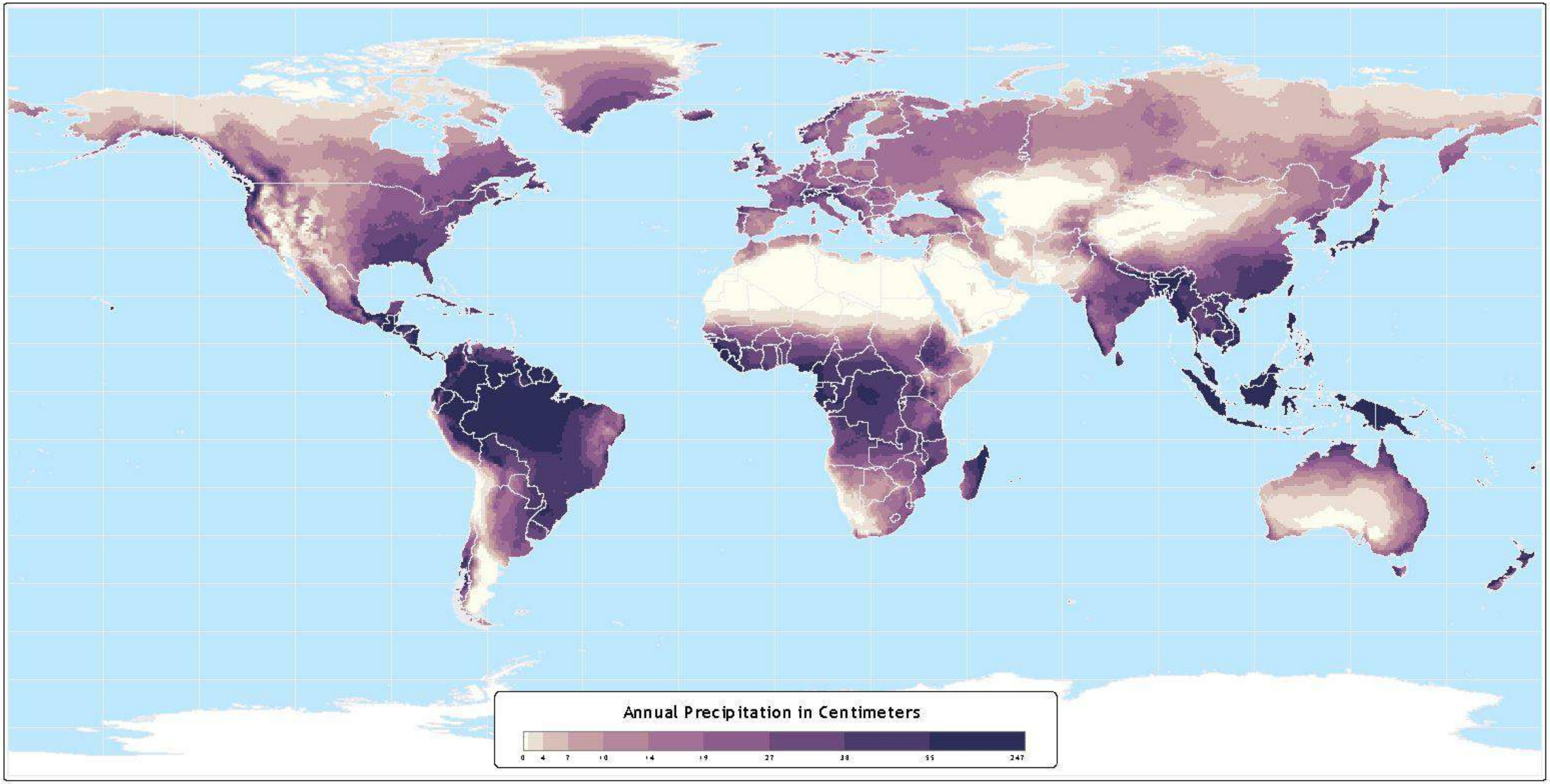

USGS
science for a changing world
Ciclo da Água
Armazenamento de água no gelo
Armazenamento de água na atmosfera
Condensação
Sublimação
Precipitação
Evapotranspiração
Evaporação
Escoamento superficial proveniente do degelo
Escoamento superficial
Caudal no rio
Evaporação
Infiltração
Nascente
Armazenamento de água doce
Descarga do aquífero
Armazenamento da água nos oceanos
Armazenamento de água subterrânea
U.S. Department of the Interior
U.S. Geological Survey
Illustration by John M. Evans, USGS
http://ga.water.usgs.gov/edu/watercycle.html

Evapotranspiração

Depois do regime de temperaturas resultante do balanço de radiação e a pluviosidade, a evapotranspiração é o processo mais relevante na definição do clima local que influencia a biota.

Annual Total Precipitation

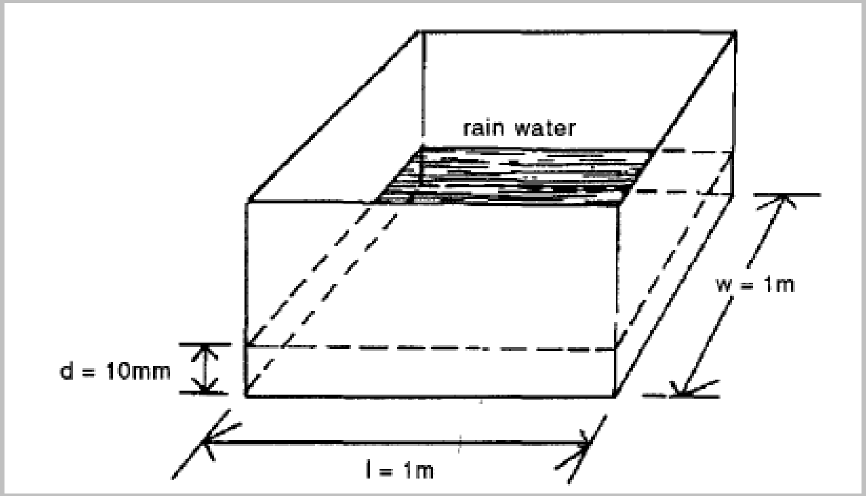


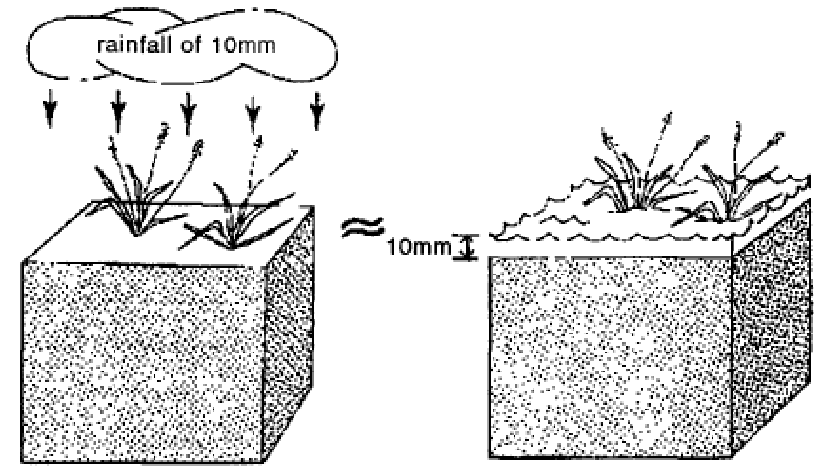
Data taken from: CRU 0.5 Degree Dataset (New et al)

Atlas of the Biosphere
Center for Sustainability and the Global Environment
University of Wisconsin - Madison

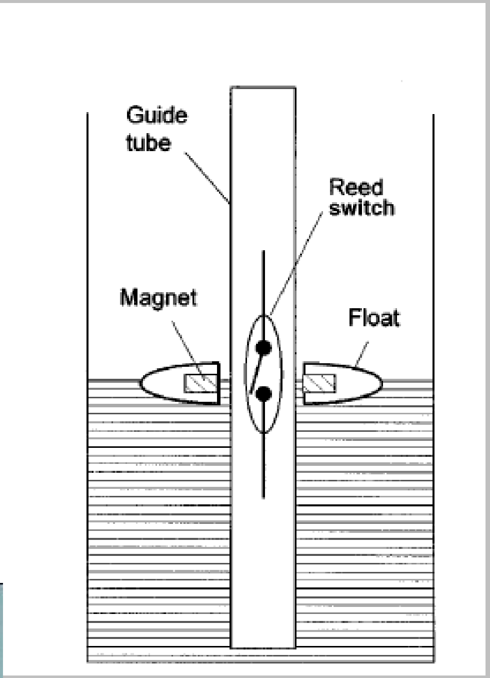
Medição da precipitação

- O que representa mm de chuva?

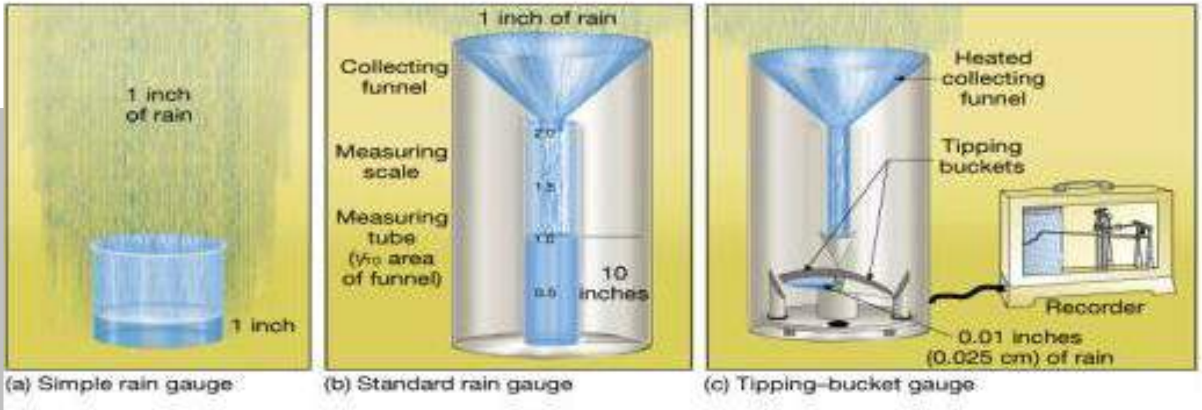


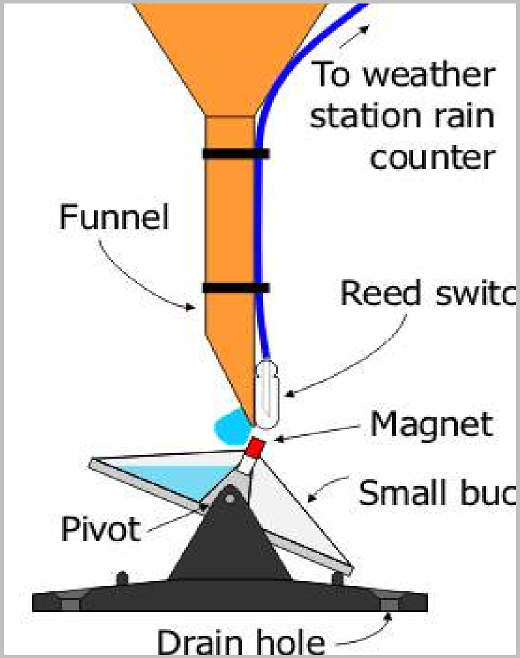


PLUVIÔMETROS



PLUVIÓGRAFO





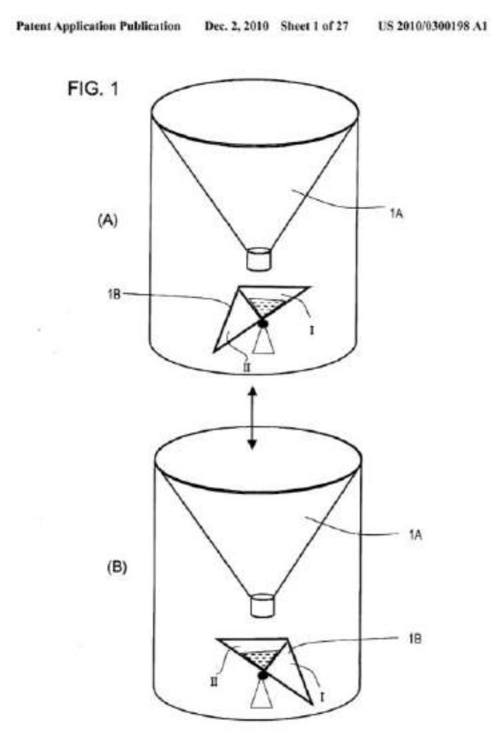
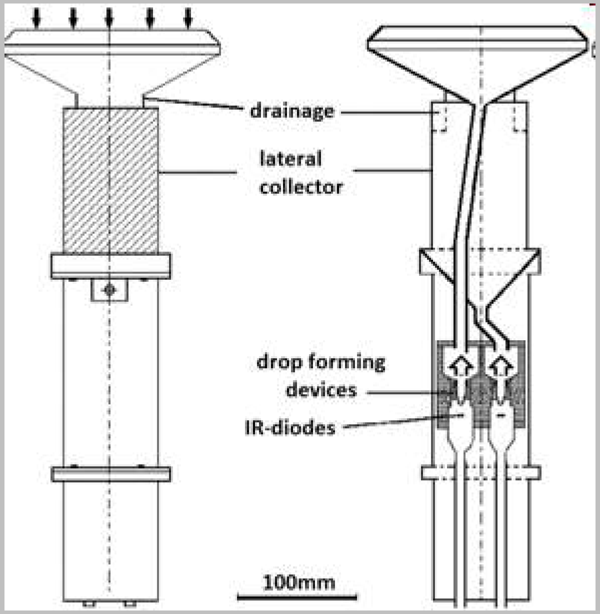
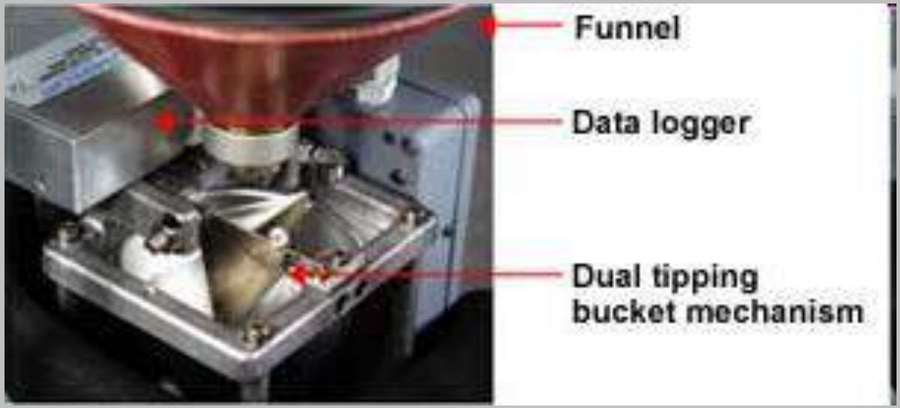
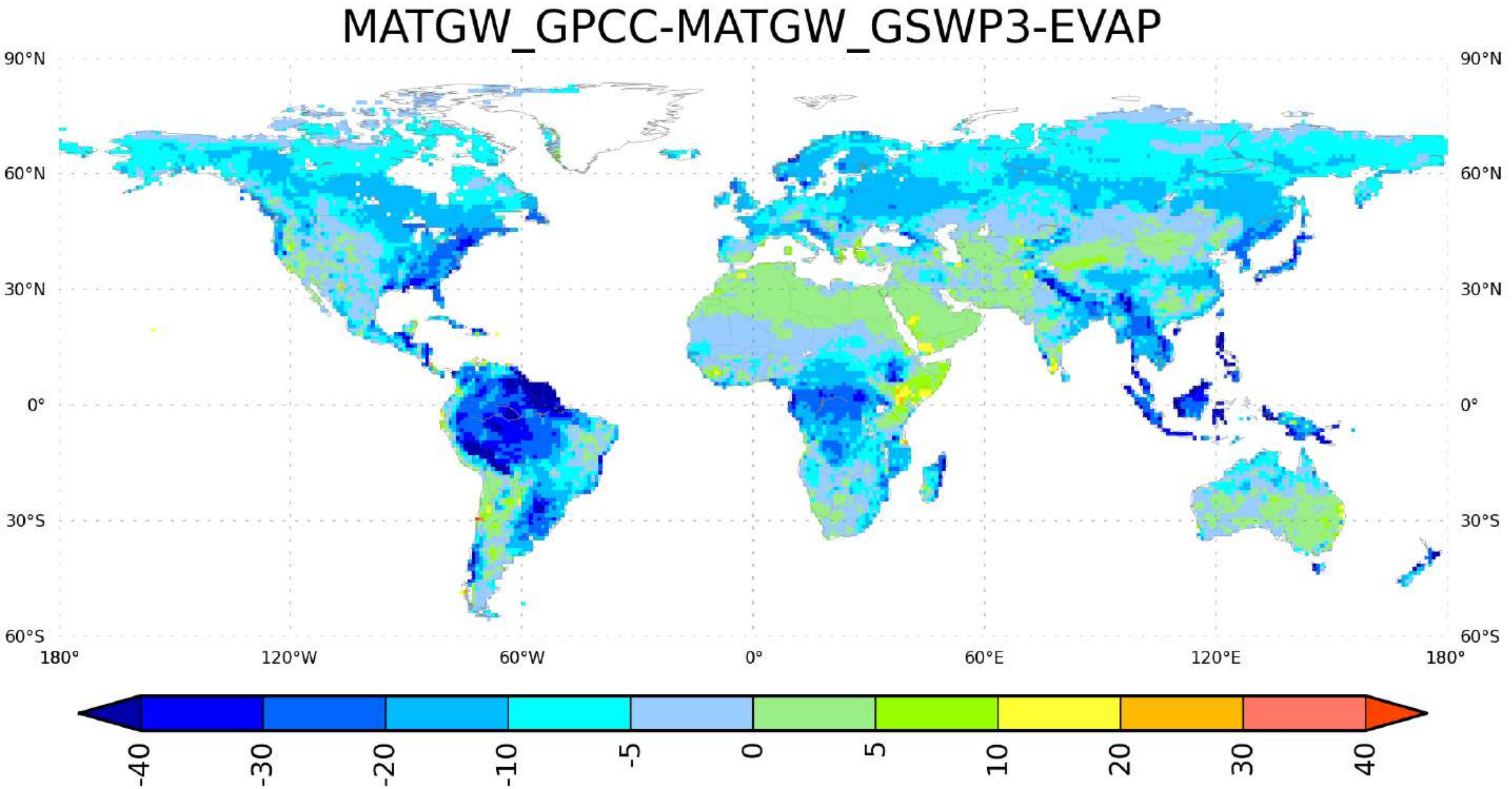

Patent Application Publication Dec. 2, 2010 Sheet 1 of 27 US 2010/0300198 A1

FIG. 1

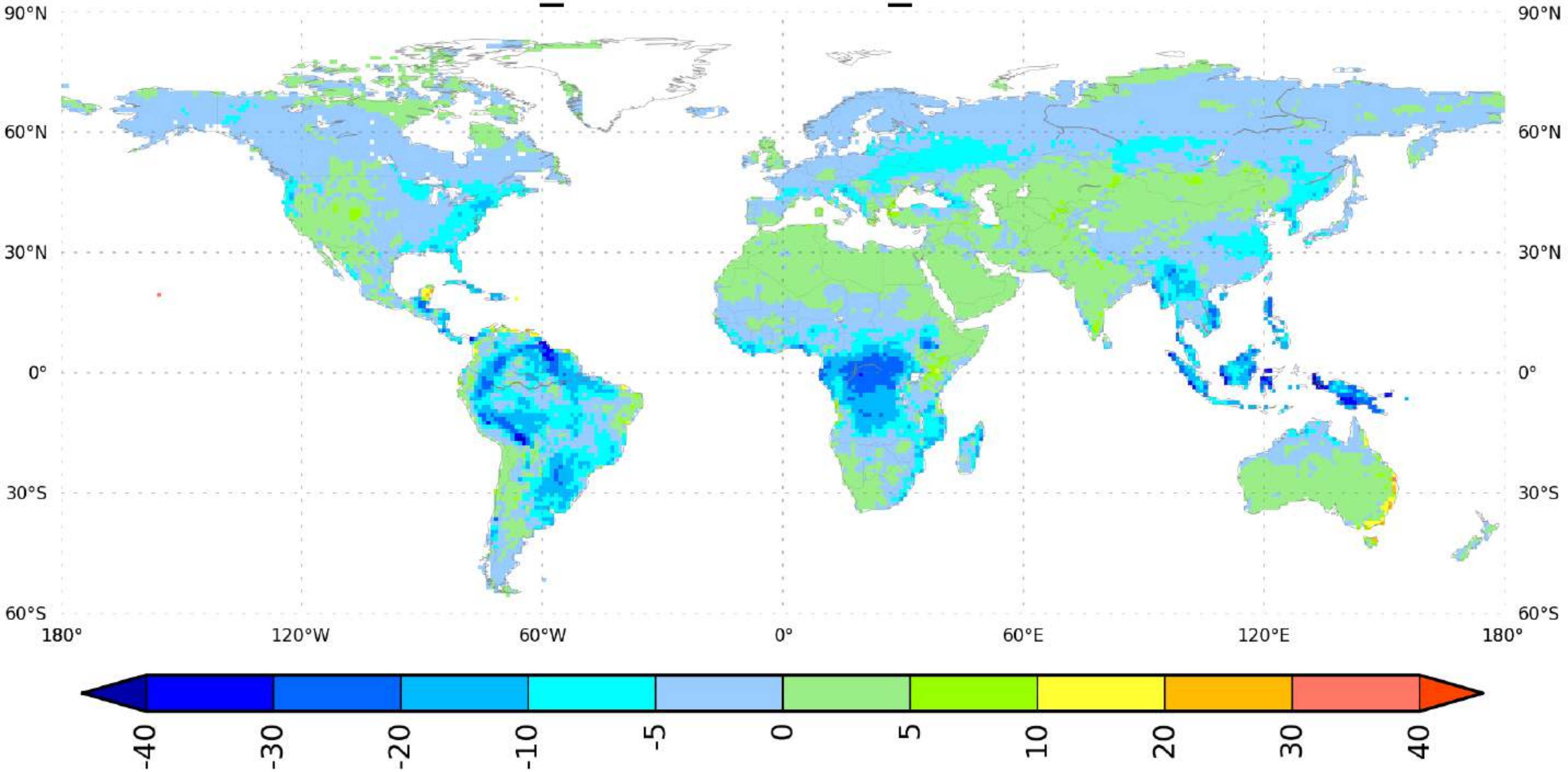




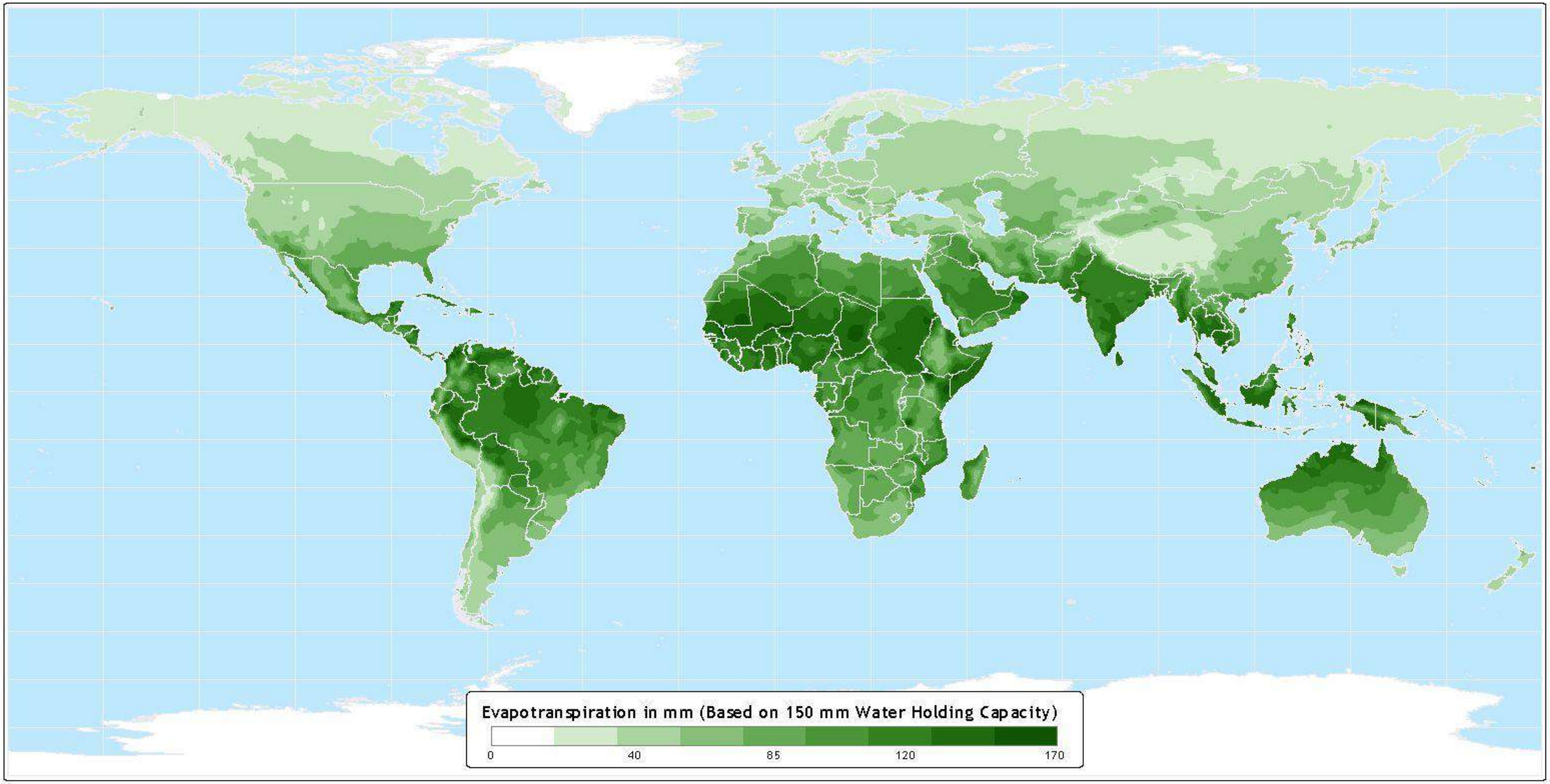


MATGW_GPCC-MATGW_GSWP3-EVAP
90°N
60°N
30°N
0°
30°S
60°S
180°
120°W
60°W
0°
60°E
120°E
180°
-40
-30
-20
-10
-5
0
5
10
20
30
40

MATGW_GPCC-MATGW_GSWP3-etflx



Potential Evapotranspiration



Data taken from: Willmott and Matsuura (2001)

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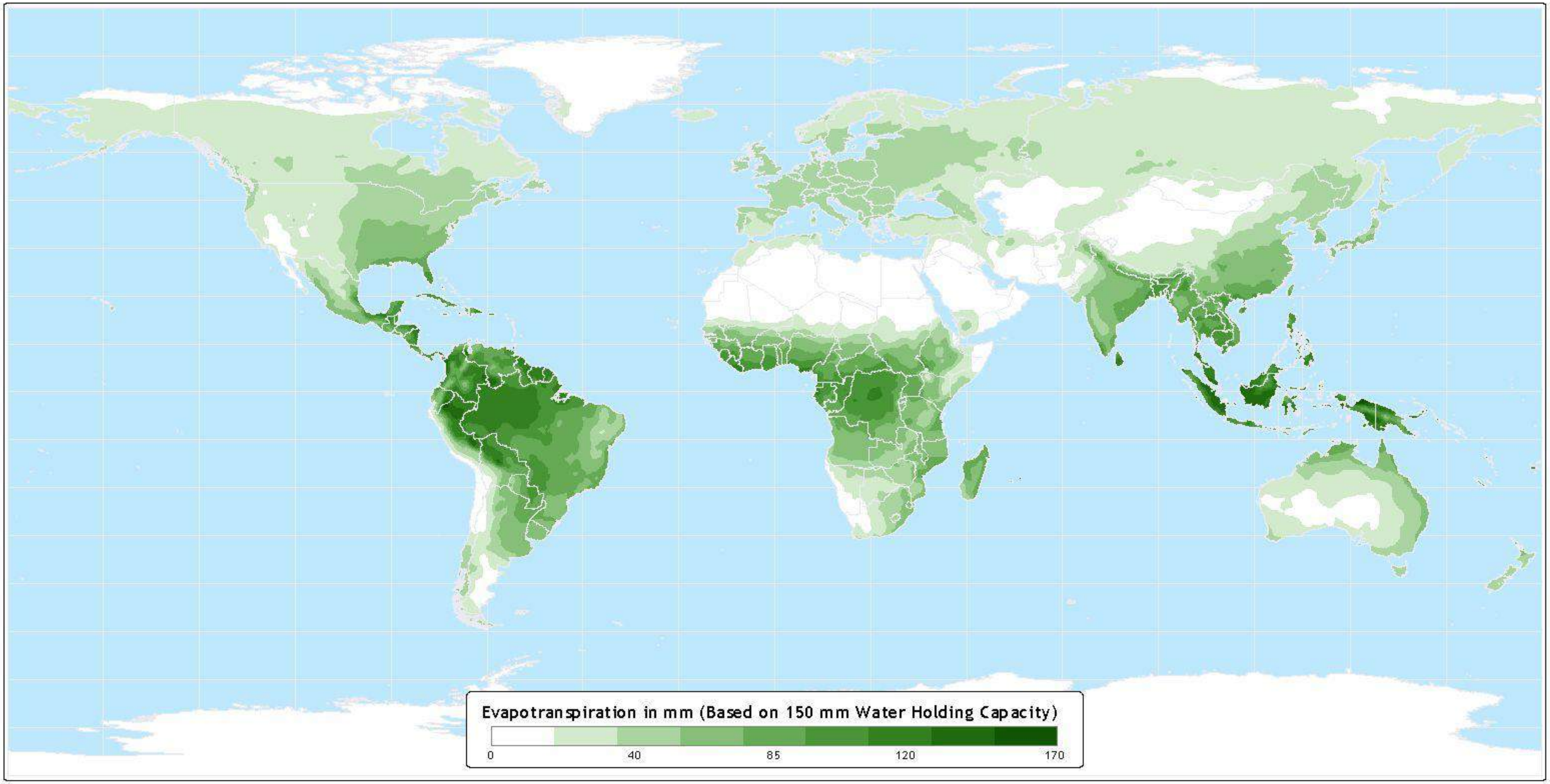
Evapotranspiration



Data taken from: Willmott and Matsuura (2001)

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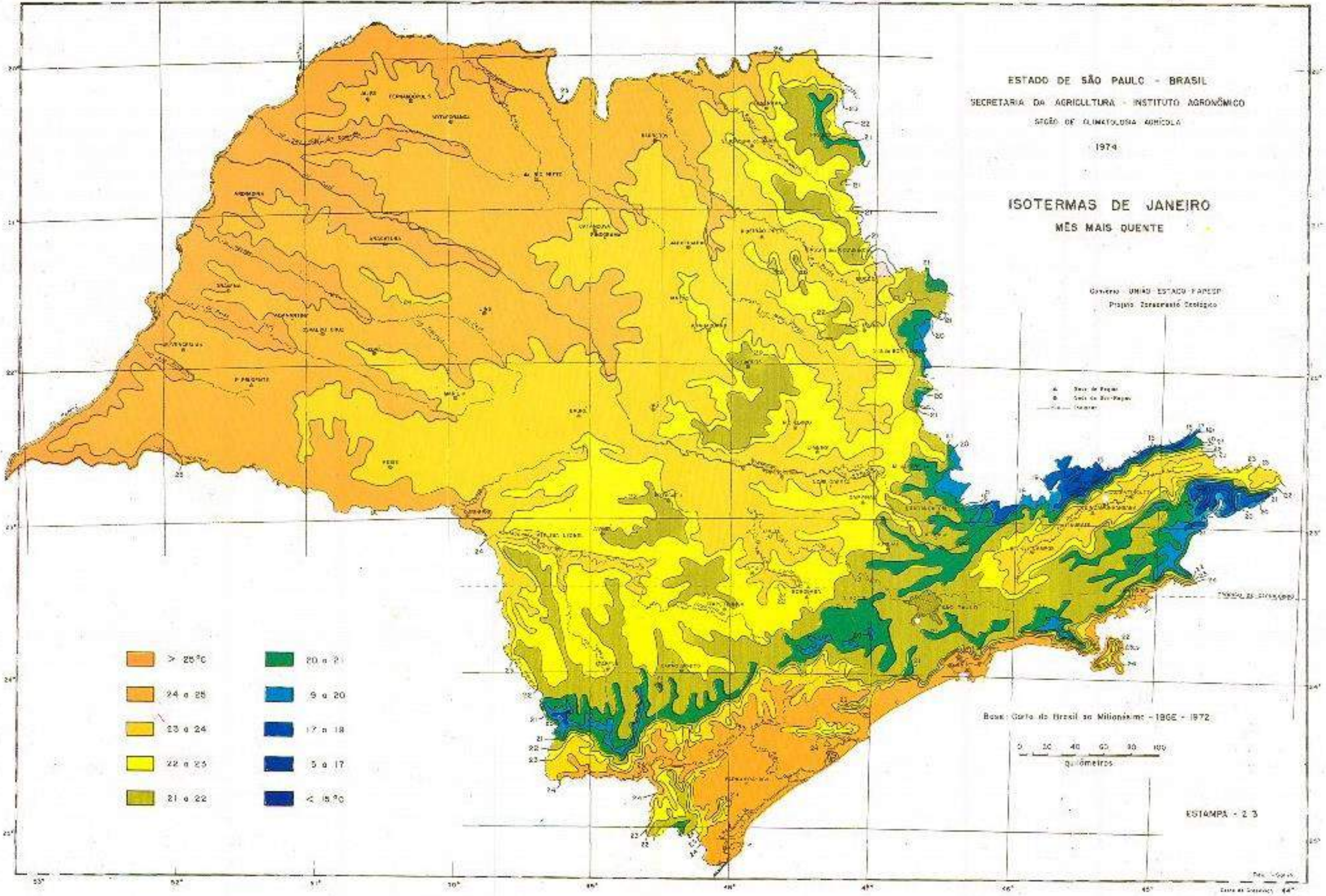


ESTADO DE SÃO PAULO - BRASIL

SECRETARIA DA AGRICULTURA - INSTITUTO AGRONÔMICO

SEÇÃO DE CLIMATOLOGIA AGRÍCOLA

1974

ISOTERMAS DE JANEIRO

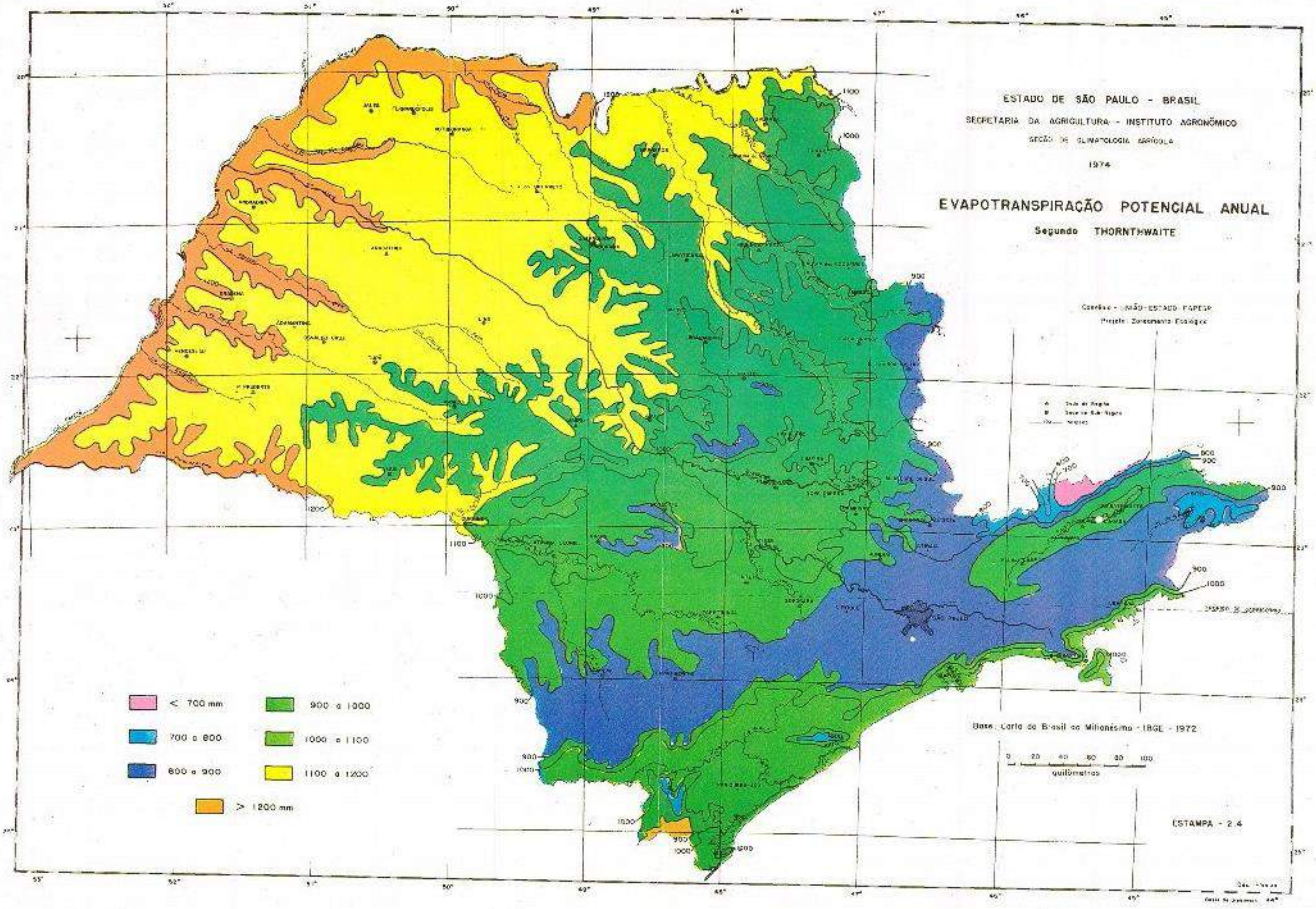
MÊS MAIS QUENTE

Convênio UNIÃO - ESTADO - FAPESP

Projeto Zoneamento Ecológico

Base: Carta do Brasil ao Milionésimo - IBGE - 1972

ESTAMPA - 2.3



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SECRETARIA DA AGRICULTURA - INSTITUTO AGRONÔMICO
SEÇÃO DE CLIMATOLOGIA AGRÍCOLA
1974

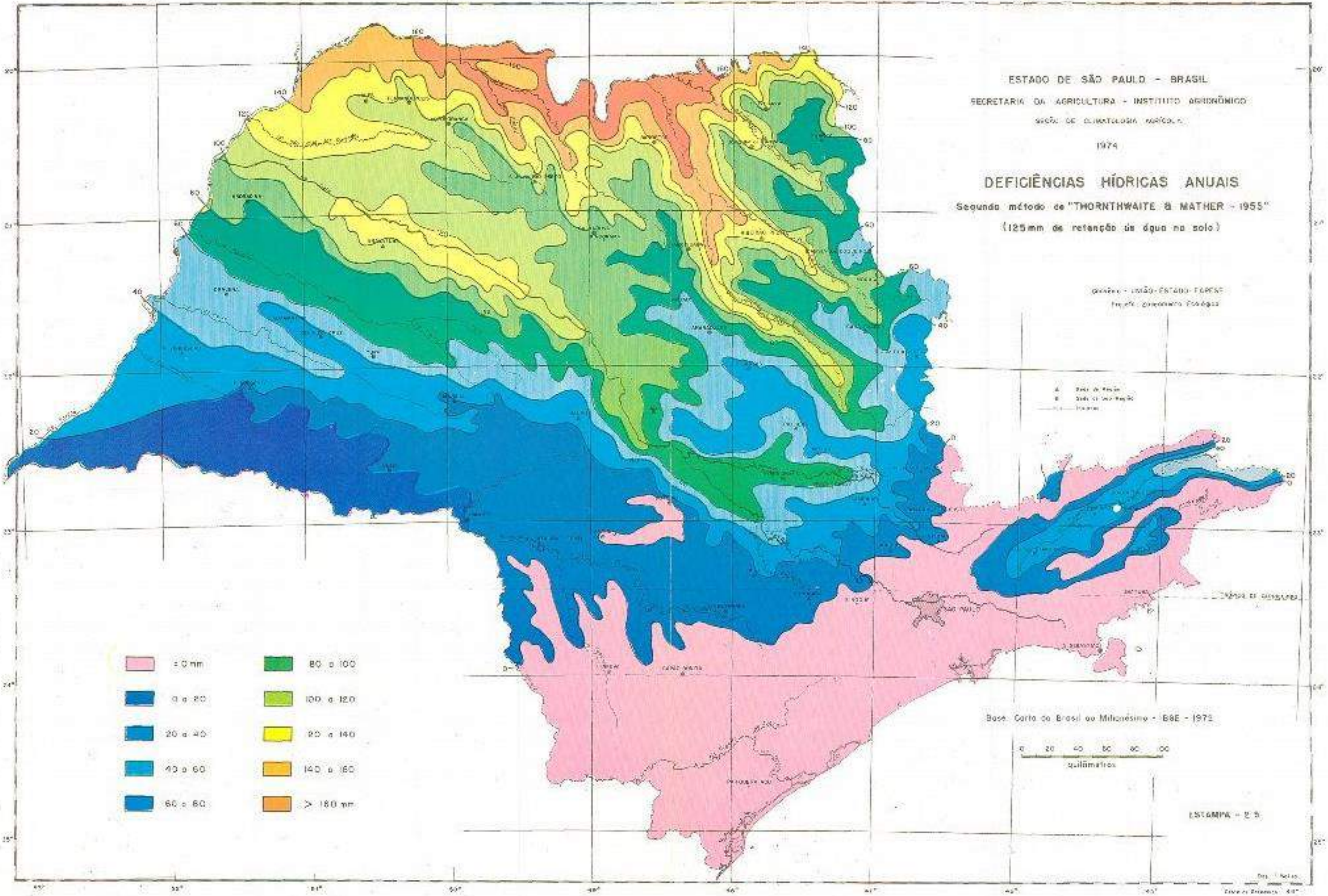
EVAPOTRANSPIRAÇÃO POTENCIAL ANUAL

Segundo THORNTHWAITE

Convênio - UNIÃO-ESTADO-FAPESP
Projeto: Zoneamento Ecológico

Base: Carta do Brasil ao Milionésimo - IBGE - 1972

ESTAMPA - 2.4



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SECRETARIA DA AGRICULTURA - INSTITUTO AGRONÔMICO

SEÇÃO DE CLIMATOLOGIA AGRÍCOLA

1974

DEFICIÊNCIAS HÍDRICAS ANUAIS

Segundo método de "THORNTHWAITE & MATHER - 1955"

(125mm de retenção de água no solo)

CONVÊNIO - UNIÃO-ESTADO-FAPESP
Projeto Zoneamento Ecológico

Base: Carta do Brasil ao Milionésimo - IBGE - 1972

ESTAMPA - 2.5

TANQUE DE EVAPORAÇÃO CLASSE A

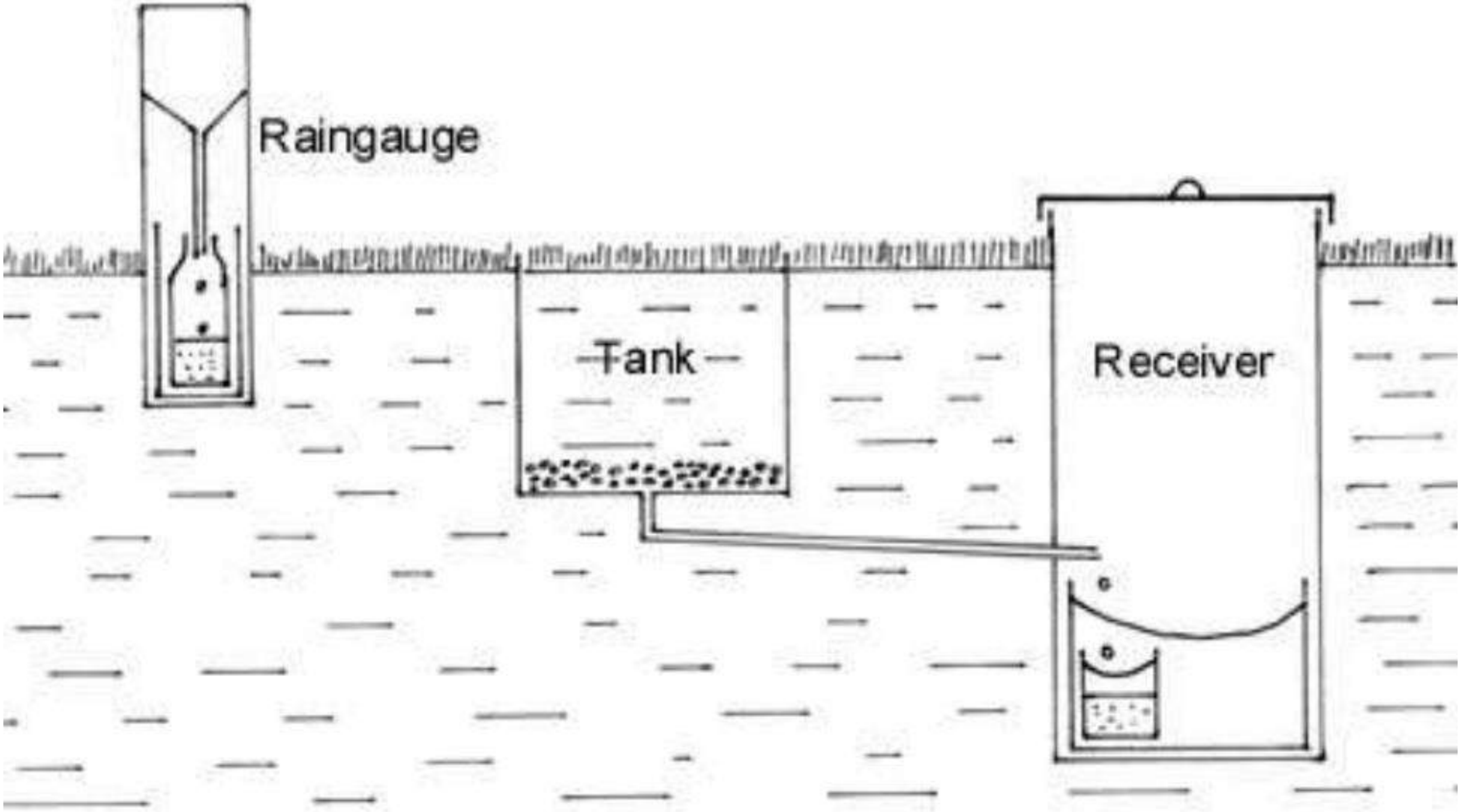
Estimativa da evapotranspiração potencial

$$PET = 16\left(\frac{L}{12}\right)\left(\frac{N}{30}\right)\left(\frac{10\,T_a}{I}\right)^{\alpha}$$

PET – evapotranspiração potencial mm/mês;
Ta – temperatura média do mês para o qual esta sendo calculado;
N – número de dias do mês;
L – número médio de horas de insolação do mês;

$$\alpha = (6.75 \times 10^{-7})I^3 - (7.71 \times 10^{-5})I^2 + (1.792 \times 10^{-2})I + 0.49239$$

$$I = \sum_{i=1}^{12}\left(\frac{T_{ai}}{5}\right)^{1.514}$$


Raingauge
Tank
Receiver

Mean water balance of the earth in 10^3 km^3 a^{-1} (Houghton 1997)

surface	precipitation	evaporation	runoff
land surface	111	71	40
ocean surface	385	425	40*

* water vapor transport in the atmosphere from the ocean to the land, for instance as cloud water

Mean annual data of the water cycle of Germany (Source: German Meteorological Service, Hydrometeorology) in mm (1 mm = 1 L m^{-2})

precipitation		evaporation	
779 mm		463 mm	
into evaporation	463 mm	from transpiration	328 mm
into ground water	194 mm	from interception	72 mm
into runoff	122 mm	from soil evaporation	42 mm
		from surface water evaporation	11 mm
		from service water evaporation	11 mm

Coeficiente de Bowen (razão de Bowen)

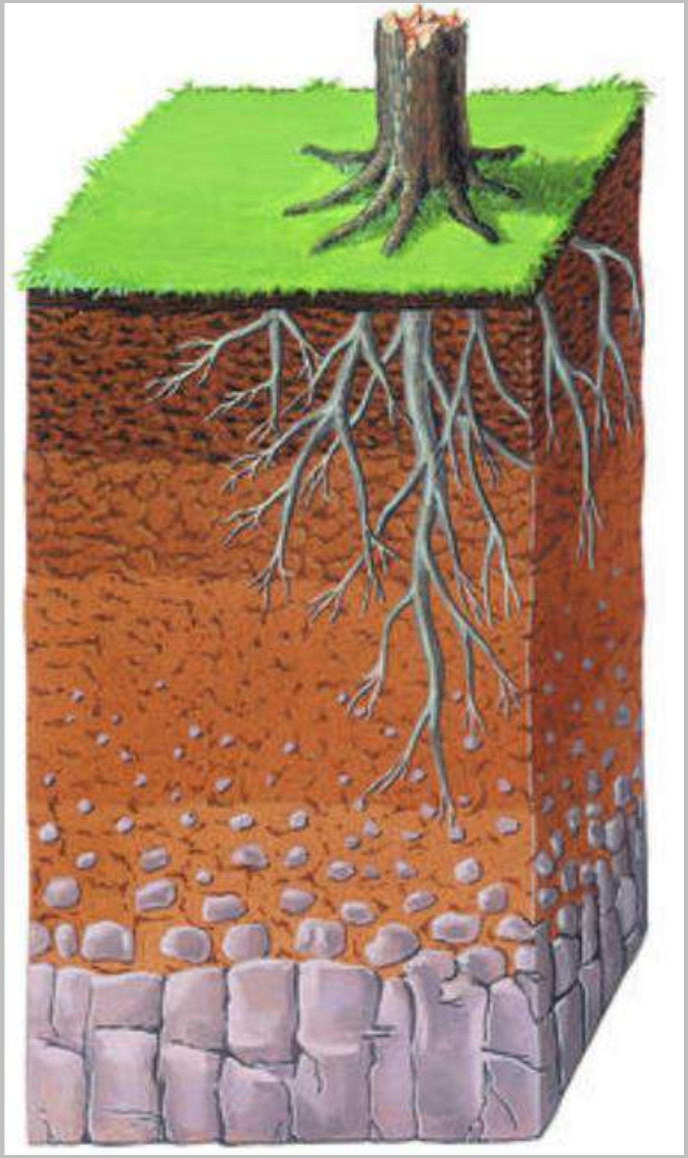
A razão de Bowen pode definir a dinâmica do calor armazenado pela relação entre a perda de calor sensível por convecção livre e a perda por calor latente.

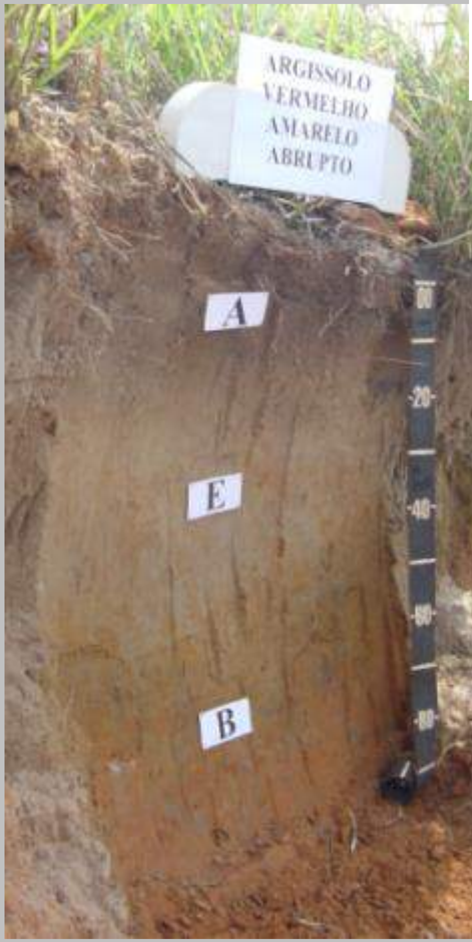
$$Q = R_n - X = \lambda E + C$$

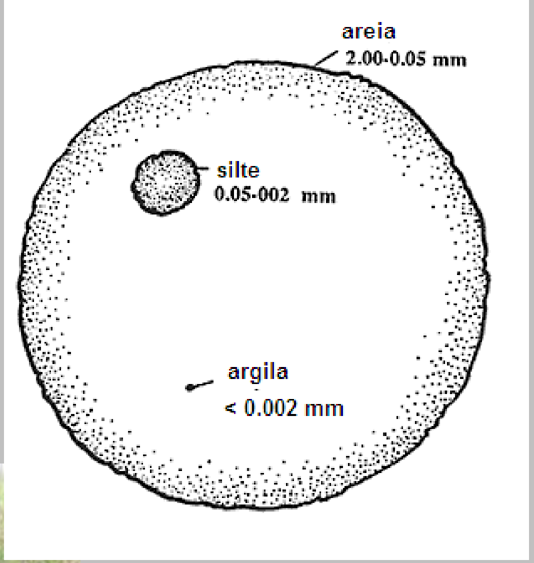
A partir do balanço de energia podemos supor que uma quantidade de calor X é armazenada no ambiente considerando as perdas por calor latente e calor sensível. A razão entre esses fluxos é a razão de Bowen. Uma das utilidades do emprego desse parâmetro é a avaliação do impacto da atividade humana no balanço de energia. O aumento no valor é associado com atividade antrópica.

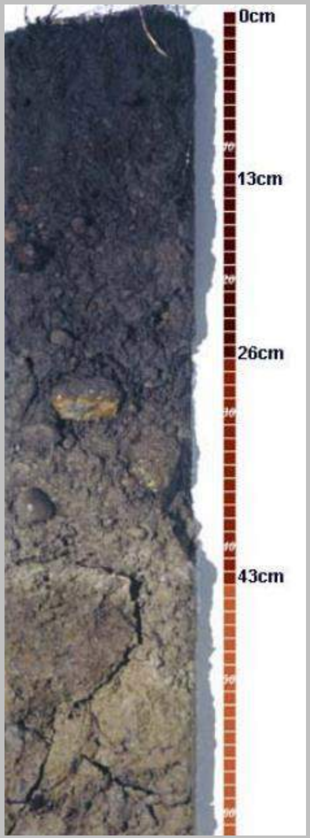
$$C/\lambda E = \beta = \gamma \frac{r}{r_h} \frac{T_s - T_a}{e_s - e_a} = \gamma^* \frac{T_s - T_a}{e_s - e_a}$$

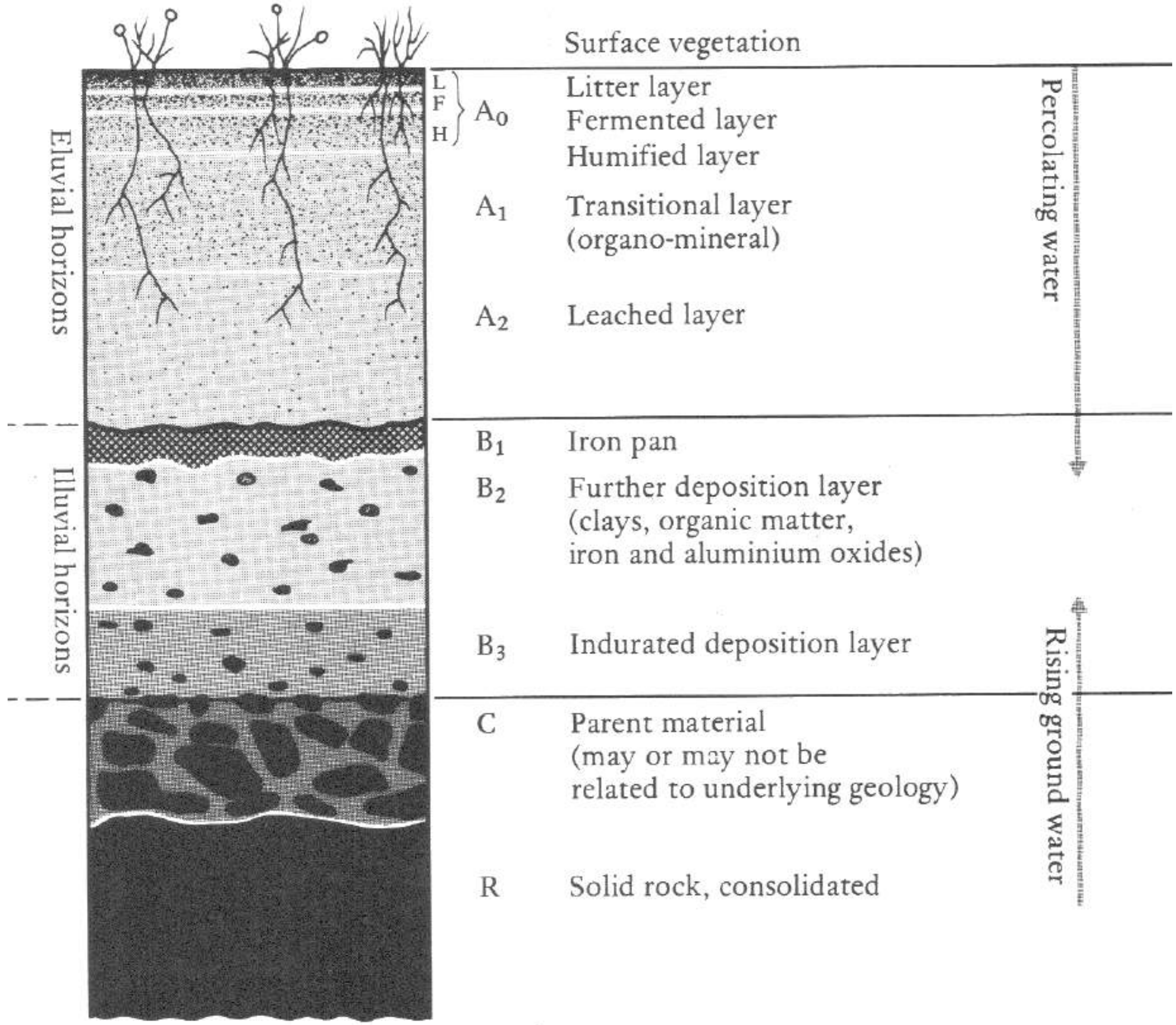
Solo

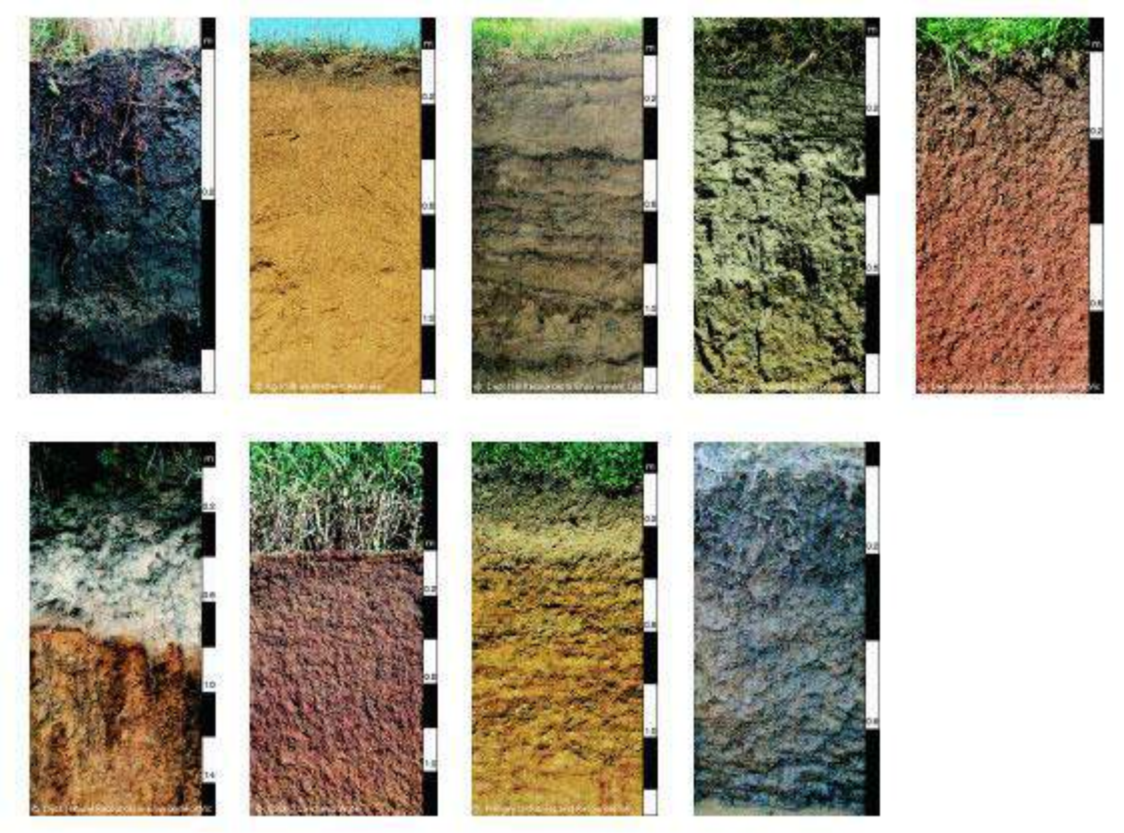


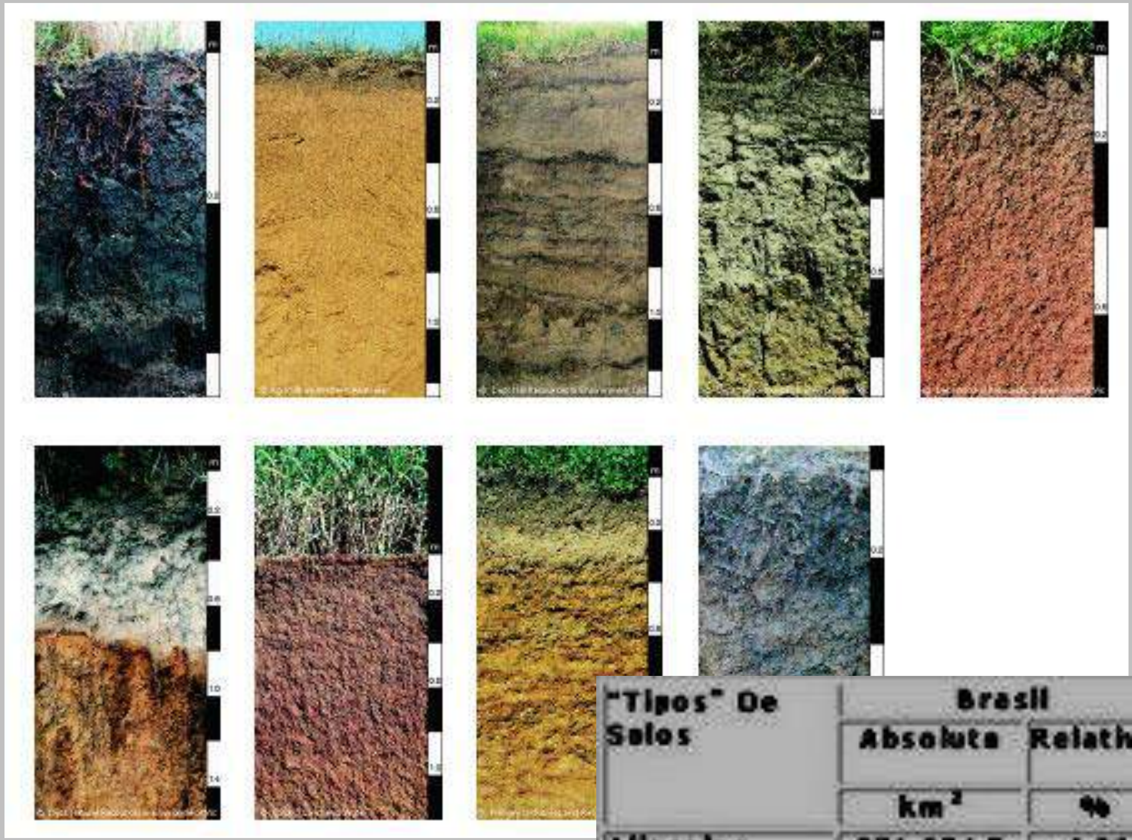

ARGISSOLO
VERMELHO
AMARELO
ABRUPTO
A
E
B
00
20
40
60
80


areia
2.00-0.05 mm
silte
0.05-002 mm
argila
< 0.002 mm

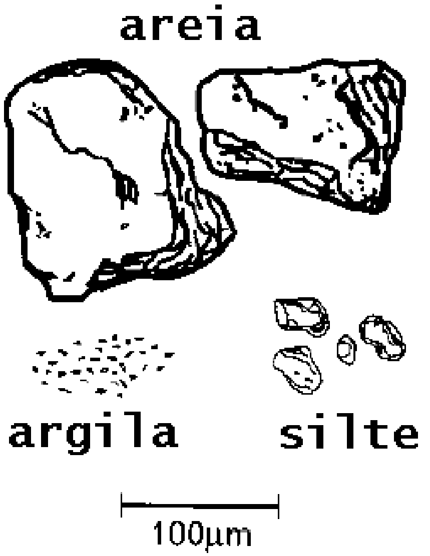

0cm
13cm
26cm
43cm


Surface vegetation
L
F
H
A_0
Litter layer
Fermented layer
Humified layer
A_1
Transitional layer
(organo-mineral)
A_2
Leached layer
B_1
Iron pan
B_2
Further deposition layer
(clays, organic matter,
iron and aluminium oxides)
B_3
Indurated deposition layer
C
Parent material
(may or may not be
related to underlying geology)
R
Solid rock, consolidated
Eluvial horizons
Illuvial horizons
Percolating water
Rising ground water





"Tipos" De Solos	Brasil		Relativa por regiões				
	Absoluta	Relativo	Norte	Nordeste	Centro-Oeste	Sudeste	Sul
	km²	%			%		
Alissolos	371.874,5	4,36	8,67	0,00	0,00	0,00	6,34
Argissolos	1.713.853,5	19,98	24,40	17,20	13,77	20,68	14,77
Cambissolos	232.139,2	2,73	1,06	2,09	1,59	8,64	9,28
Chernossolos	42.363,9	0,53	0,00	1,05	0,27	0,21	3,94
Espodossolos	133.204,9	1,56	3,12	0,39	0,26	0,37	0,00
Gleissolos	311445,3	3,66	6,41	0,78	2,85	0,5	0,4
Latossolos	3.317.590,3	38,73	33,86	31,01	52,81	56,30	24,96
Luvissolos	225.594,9	2,65	2,75	7,60	0,00	0,00	0,00
Neossolos	1.246.898,9	14,57	8,49	27,55	16,36	9,38	23,23
Nitossolos	119.731,3	1,41	0,28	0,05	1,22	2,56	11,48
Planossolos	155.152,1	1,84	0,16	6,61	1,73	0,16	3,00
Plintossolos	508.539,4	5,95	7,60	4,68	8,78	0,00	0,00
Vertissolos	169.015,3	2,01	3,20	0,99	0,36	1,20	2,60

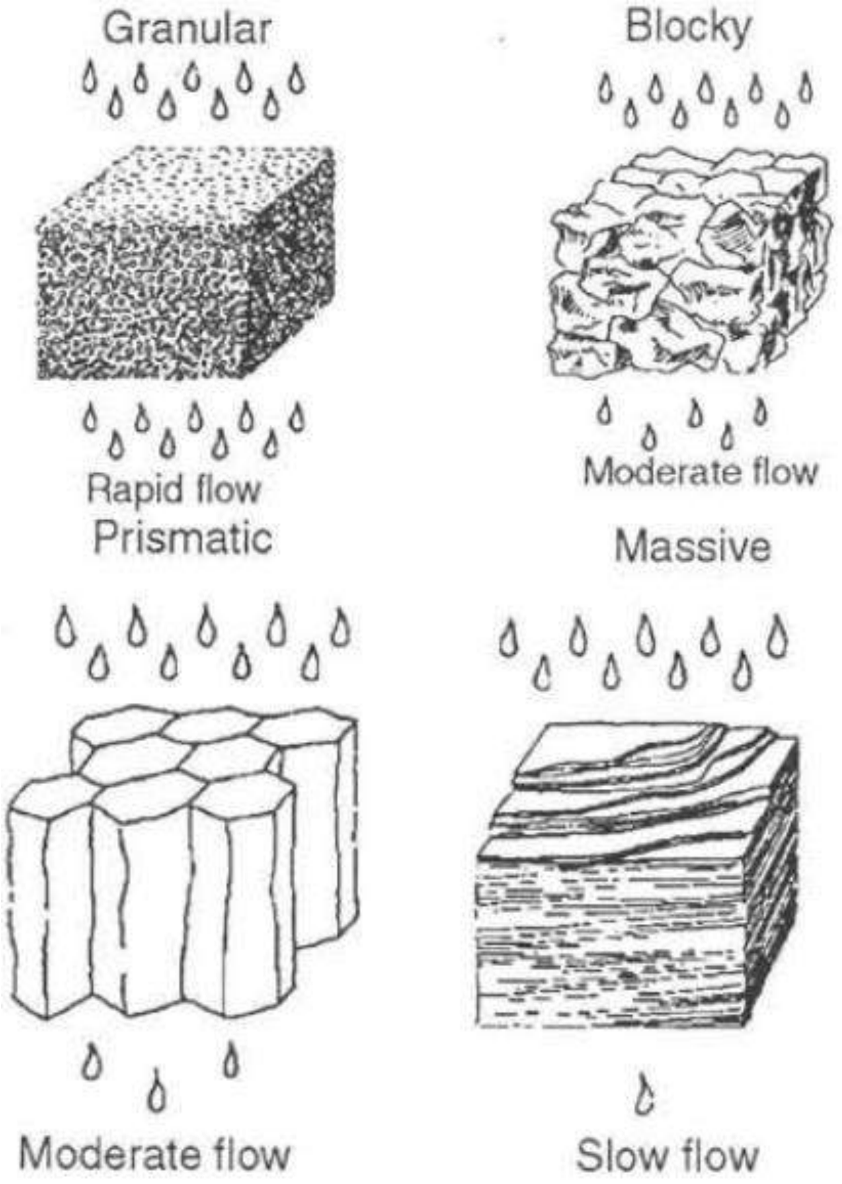


Designação dos lotes	*Diâmetro das partículas em mm*
Areia grossa	2 — 0,2
Areia fina	0,2 — 0,02
Limo	0,02 — 0,002
Argila	$< 0{,}002$

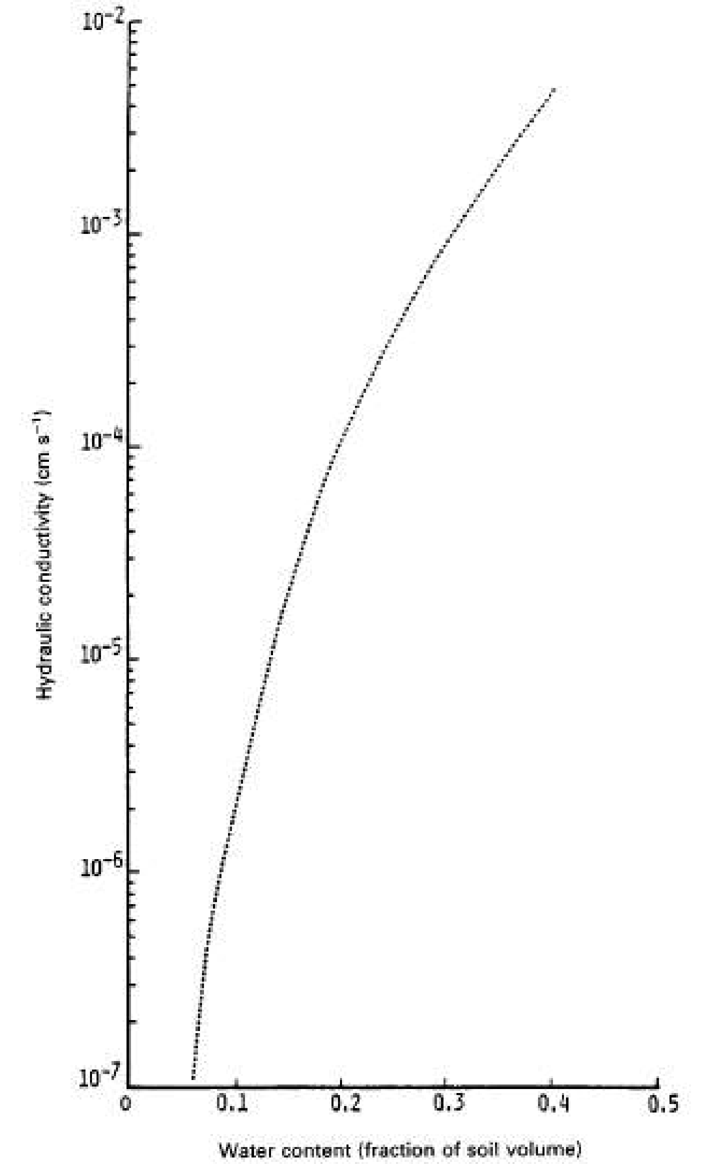
Quanto a elementos grosseiros

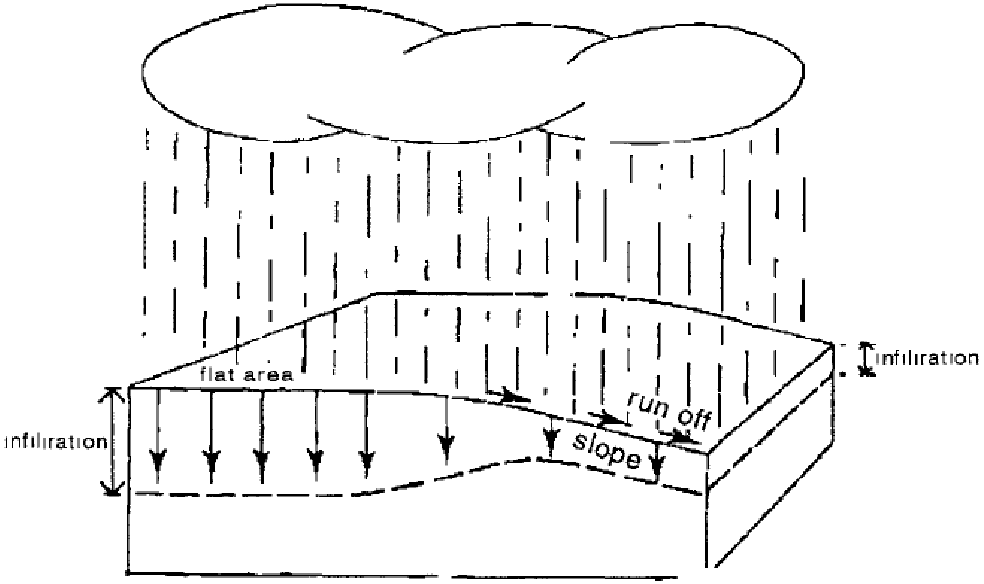
Designação	*Diâmetro em mm*
Blocos	> 200
Calhaus	200 — 100
Pedras	100 — 50
Pedras miúdas	50 — 20
Cascalho	20 — 5
Saibro	5 — 2

A estrutura do solo afeta a condutividade hidráulica. A composição granulométrica permite prever a interação com a precipitação e com a forma de irrigação.



Quanto mais molhado o solo, maior é a condutividade hidráulica. O solo seco reduz a perda de água a partir das camadas mais profundas.





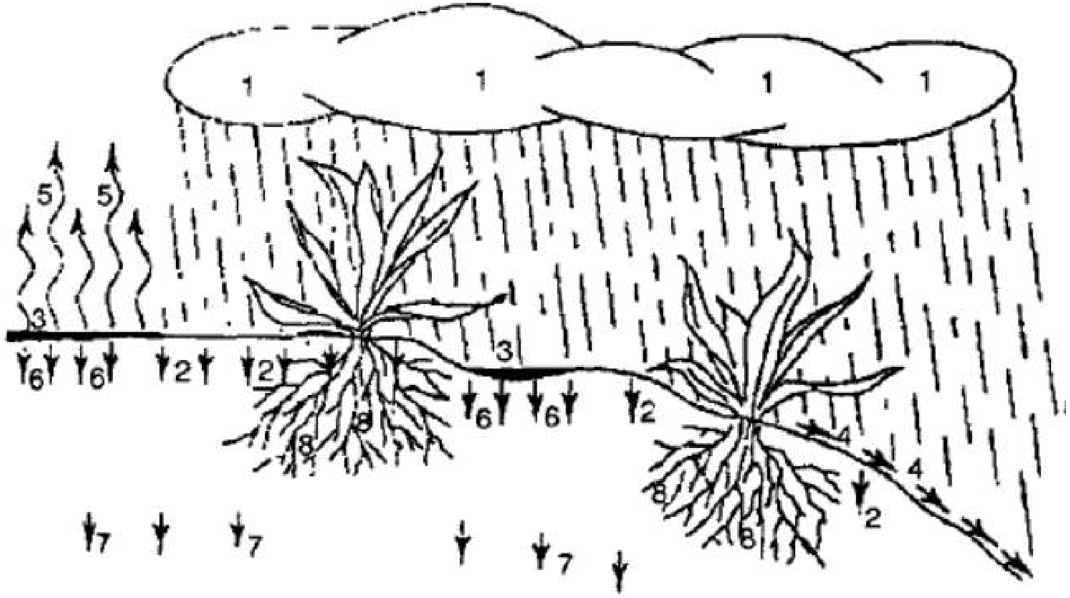
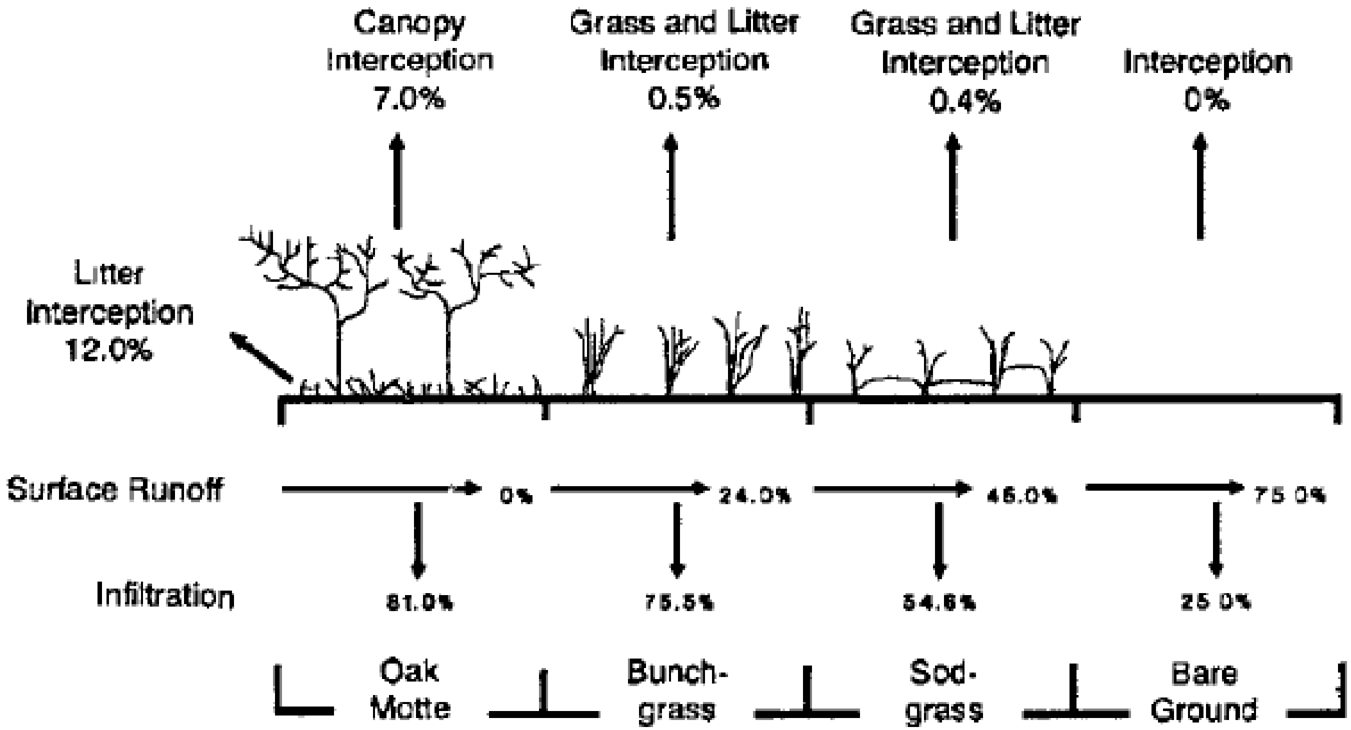
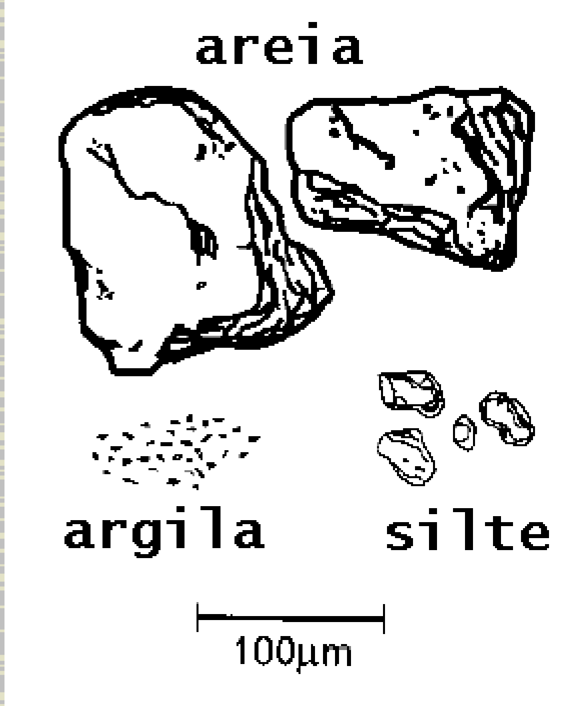
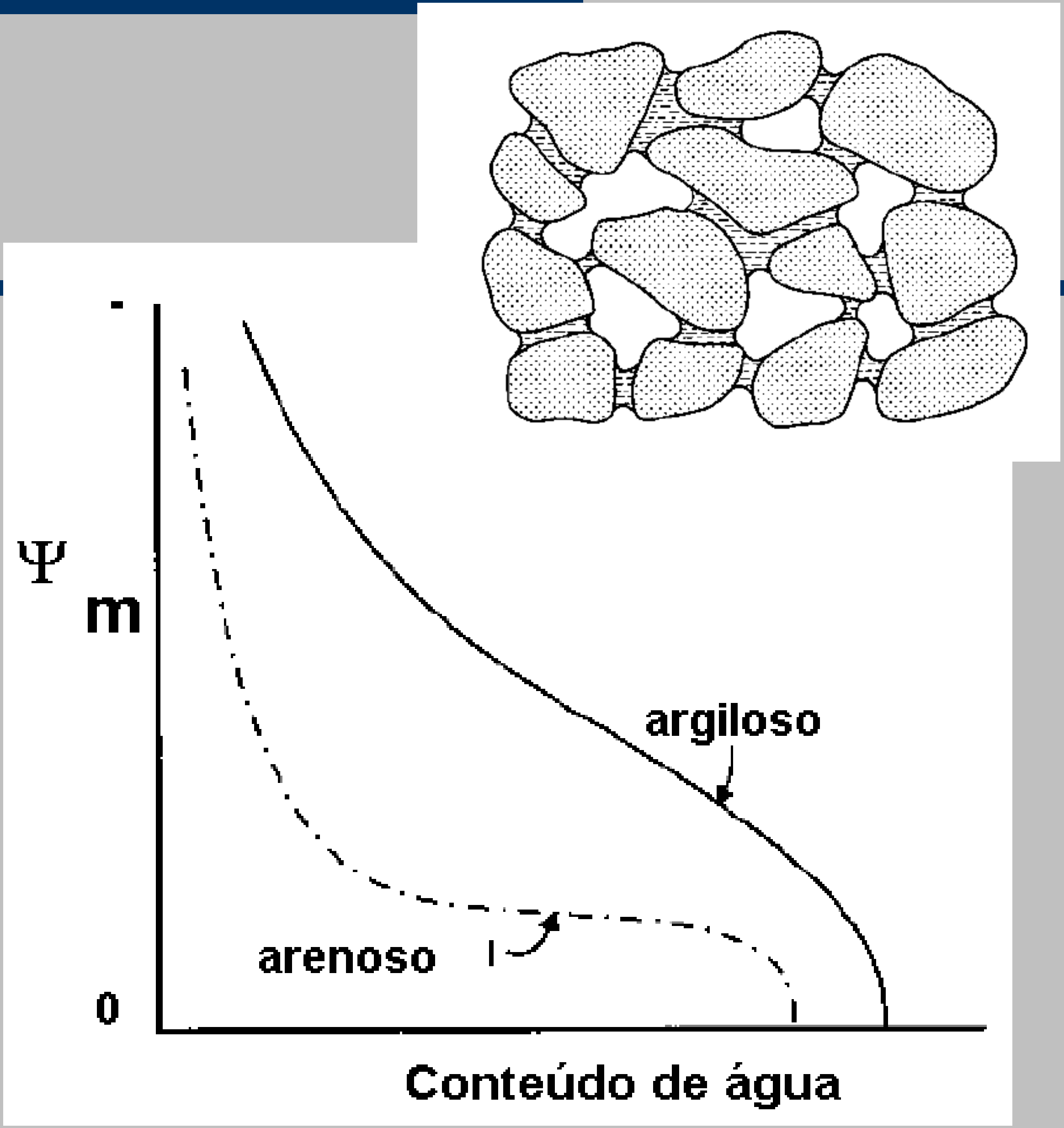


Fig:32. Effective Rainfall (8) = (1) – (4) – (5) – (7)

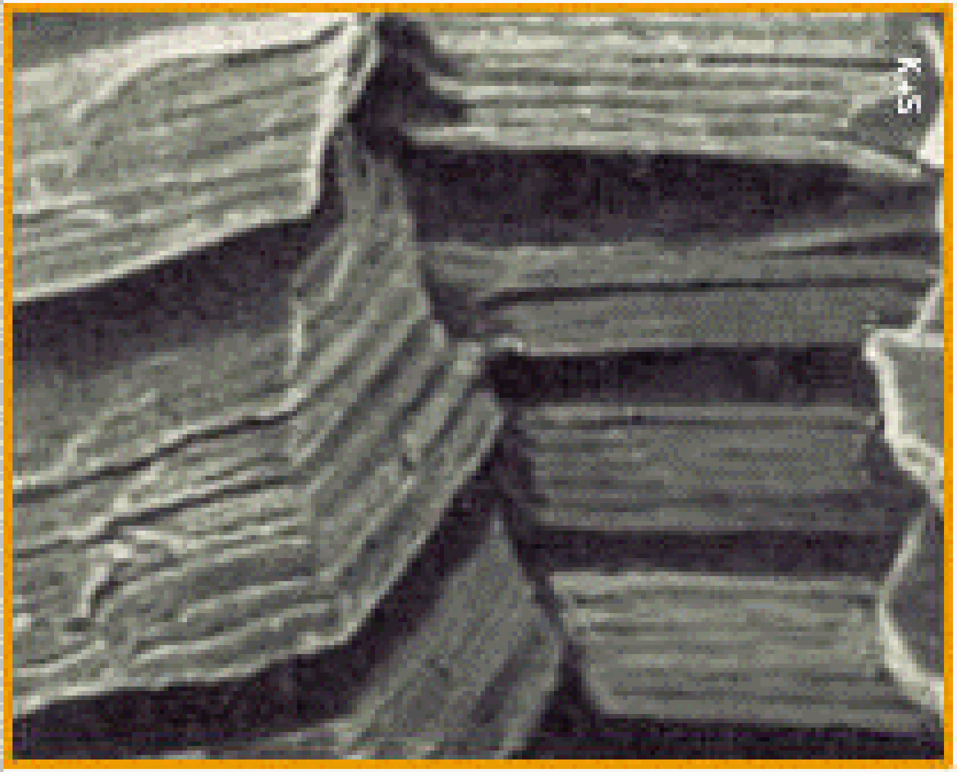
A cobertura vegetal modula o balanço hídrico da superfície.

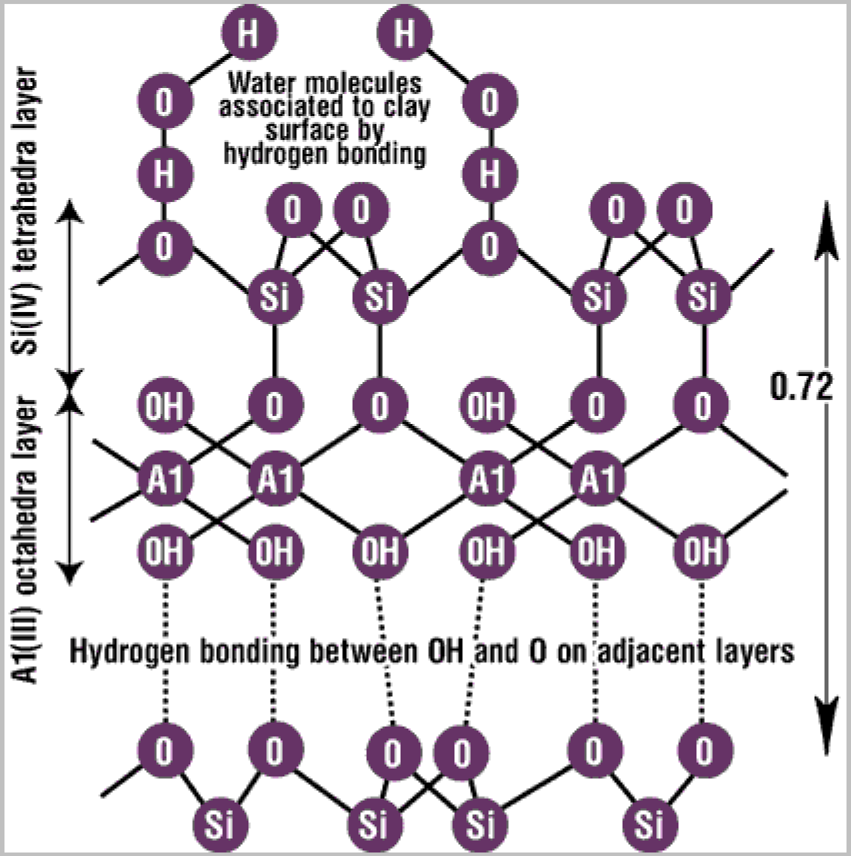



areia
argila
silte
100µm


Ψ
m
0
argiloso
arenoso
Conteúdo de água

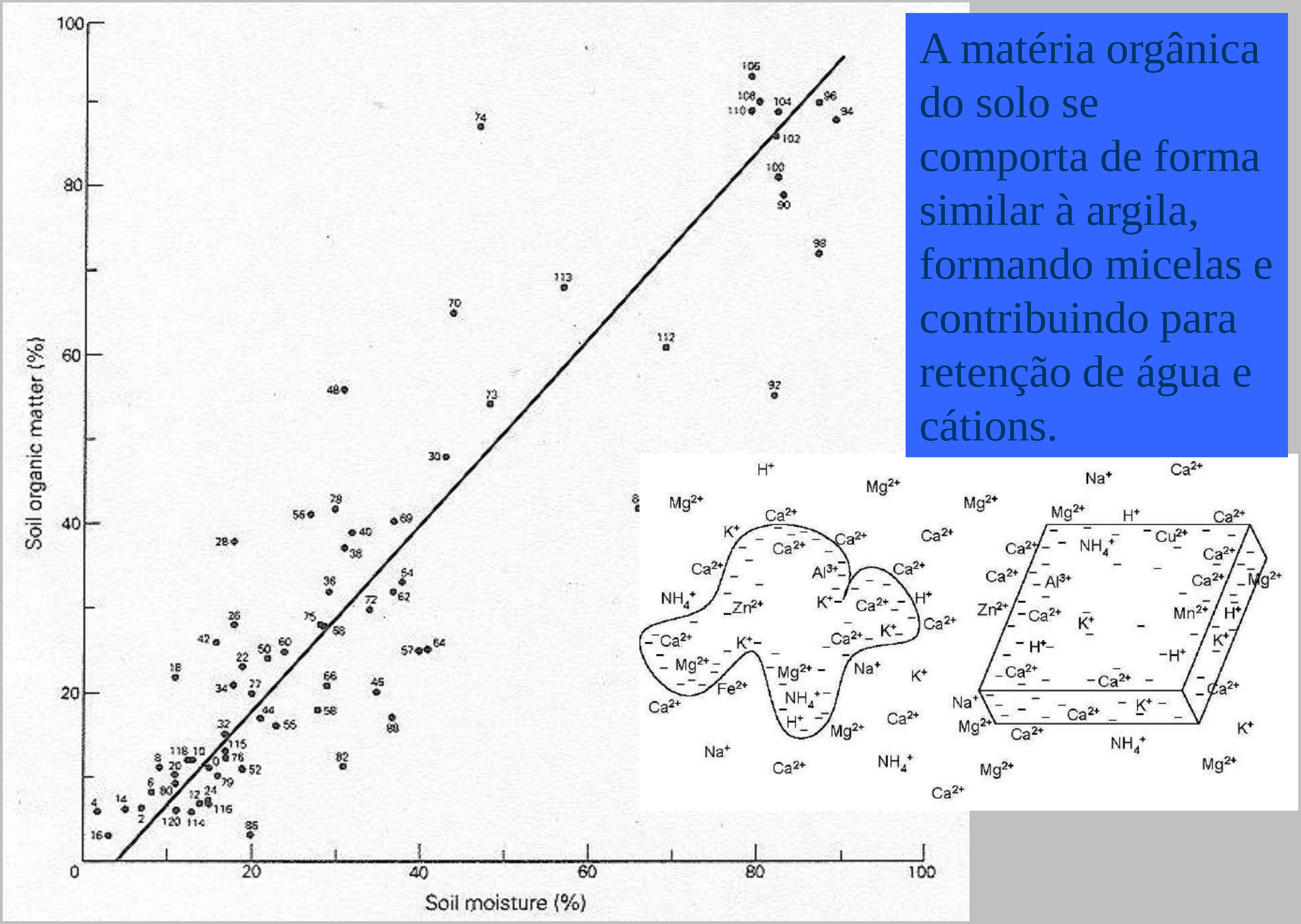
Partícula de argila





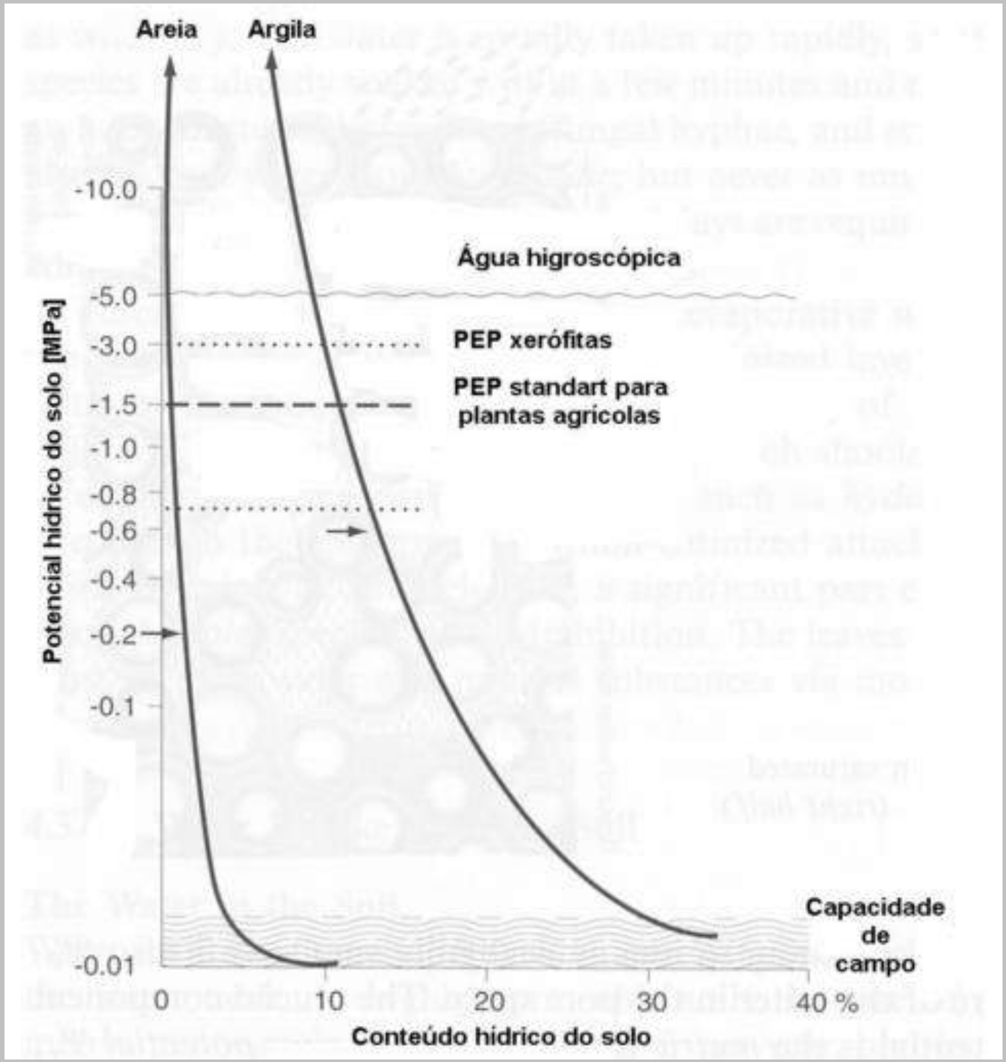
Disposição da água em relação aos silicatos da partícula de argila

A matéria orgânica do solo se comporta de forma similar à argila, formando micelas e contribuindo para retenção de água e cátions.

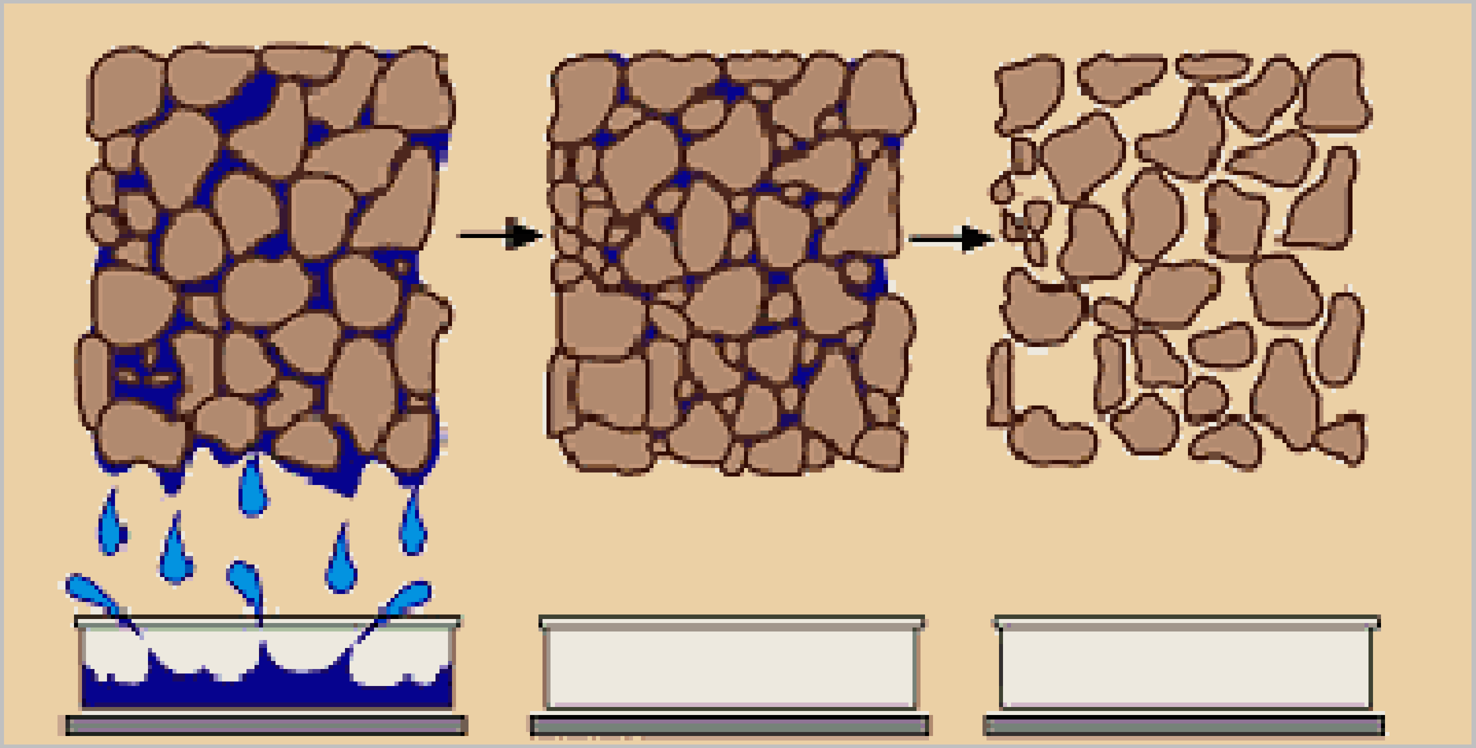


Capacidade de campo : capacidade máxima de retenção de água após a drenagem gravitacional

Ponto de murchamento permanente:
Potencial mátrico que não pode ser vencido pela força de sucção da planta.



Água disponível: conteúdo de água no solo verificado entre o ponto de murchamento permanente e a capacidade de campo.



Solo saturado

Capacidade de campo

Ponto de Murchamento Permanente

Água disponível para as plantas = profundidade de enraizamento (m) X capacidade de campo (m^3 / m^3)

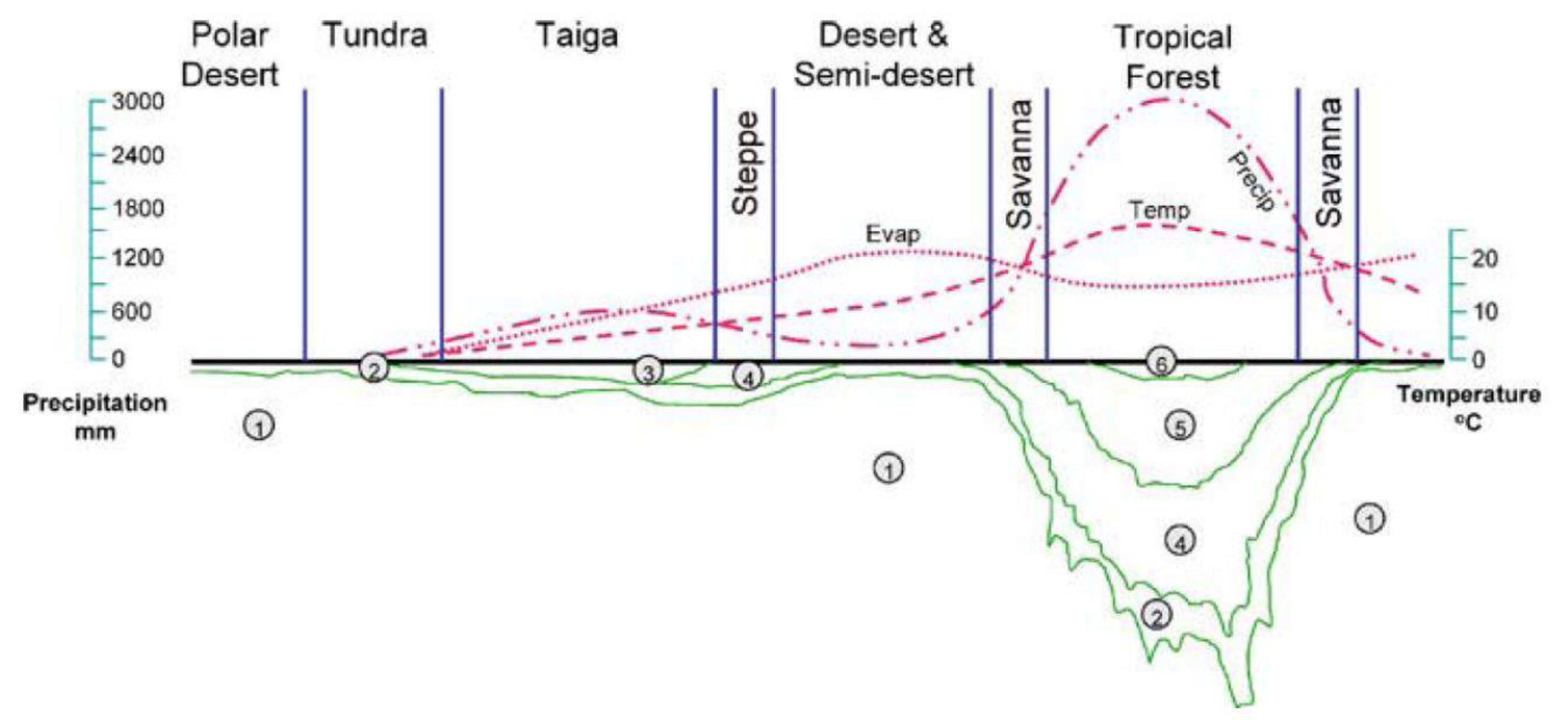


Figure G6 Polar-Equatorial transect, correlating the land ecosystems with variation in temperature and moisture conditions, and with a generalized, qualitative assessment of the related geography of the soil-forming environment under well-drained conditions: *1:* Bedrock. *2:* Incipient chemical alteration limited by cold in tundra, and lack of water in desert and semi-desert. Alkaline conditions and salt deposition under semi-desert conditions. *3:* Acidic conditions favoring podzolization. *4:* Near neutral conditions with respect to pH, bisiallitization. Calcite deposition possible under steppic vegetation. *5:* Acidic conditions favoring monosiallitisation. *6:* Acidic conditions favoring allitisation.

A CONDUTIVIDADE TERMICA DO SOLO VARIA COM O CONTEÚDO DE ÁGUA, ESTRUTURA E GRANULOMETRIA

O solo atua como um compartimento do balanço de energia e massa da biosfera, servindo de dreno e de fonte de energia. A atividade metabólica de raízes e organismos do solo é proporcional à temperatura quando o conteúdo de umidade é adequado.

A condutividade térmica do solo é um elemento importante no balanço de energia e atividade metabólica na biosfera, especialmente quando a variação na temperatura da atmosfera é alta.

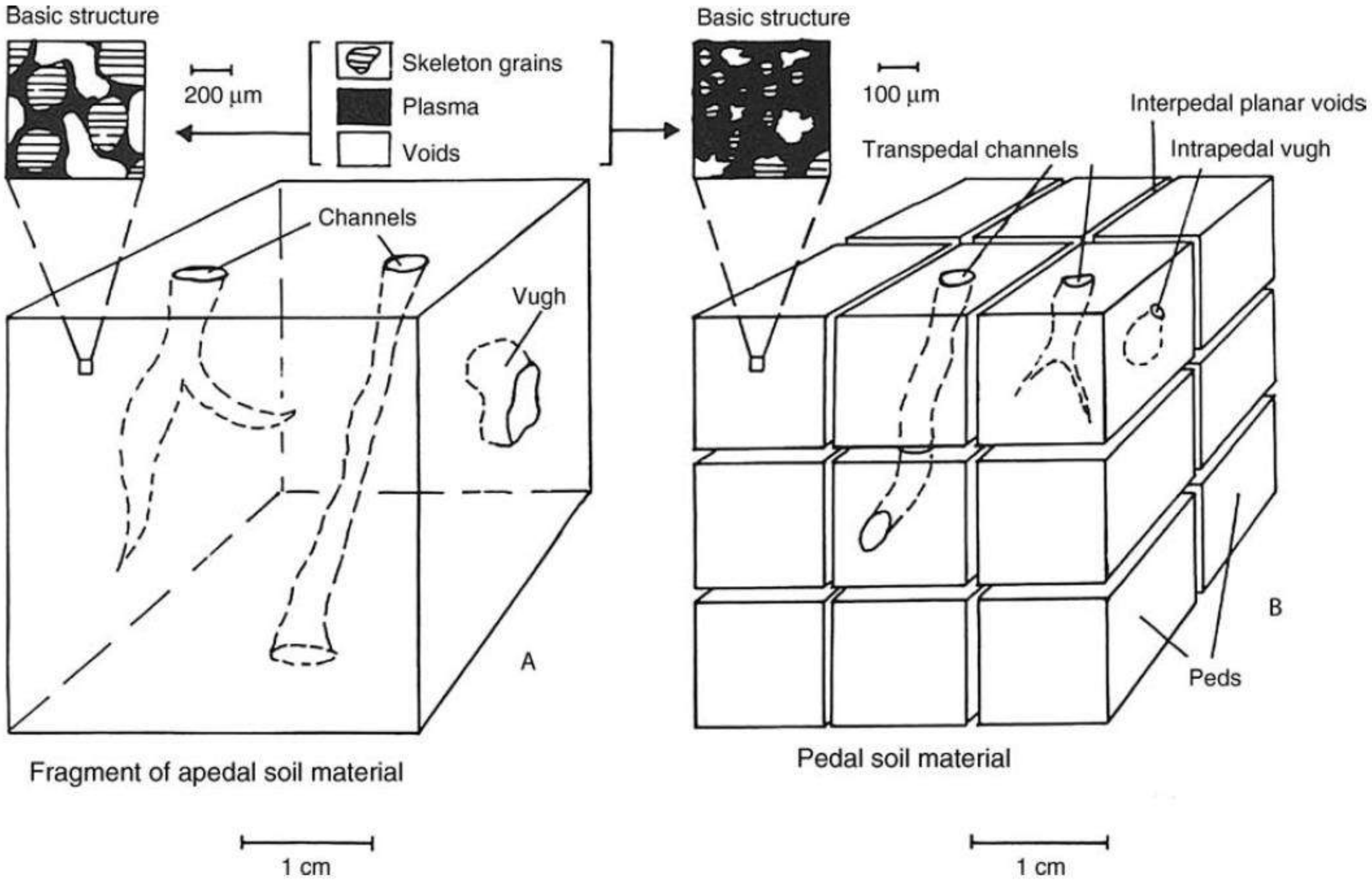
SOLO OU COMPONENTE	SECO W/m.K	UMIDO W/m.K
AREIA	0,25 a 0,32	1,77 a 2,84
AREIA GROSSA	0,13	0,52
SOLO ARGILOSO	0,25	1,59
SOLO LODOSO	0,4	1,0
TURFA	0,06	0,37
LITTER FLORESTAL	0,1	0,4

Propriedades térmicas do solo e materiais de origem

SUPERFÍCIE/solo	CONDUTIVIDADE TÉRMICA $W \cdot m^{-1} \cdot K^{-1}$	CAPACITÂNCIA TÉRMICA $10^{6}\ W \cdot s^{-1}\ m^{-3} \cdot K^{-1}$	DIFUSIVIDADE TÉRMICA $10^{-6} \cdot m^{2} \cdot s^{-1}$
GRANITO	2,73	2,13	1,28
AREIA ÚMIDA (40%)	2,51	2,76	0,91
AREIA SECA	0,30	1,24	0,24
SOLO ARENO-ARGILOSO	0,92	2,42	0,38
SOLO LODOSO (90% DE ÁGUA)	0,89	3,89	0,23

Albedo de algumas superfícies naturais

SUPERFÍCIE	ALBEDO
SOLO SECO	0,25 a 0,30
SOLO ÚMIDO	0,10 a 0,12
AREIA BRANCA	0,34 a 0,40
GRAMA	0,18 a 0,20
PINHEIRAL	0,14
ÁGUA – SOL A PINO	0,13
ÁGUA – SOL A 30 GRAUS	0,024
NEVE	0,75-0,98


Basic structure
200 µm
Skeleton grains
Plasma
Voids
Basic structure
100 µm
Interpedal planar voids
Transpedal channels
Intrapedal vugh
Channels
Vugh
A
Fragment of apedal soil material
1 cm
B
Peds
Pedal soil material
1 cm

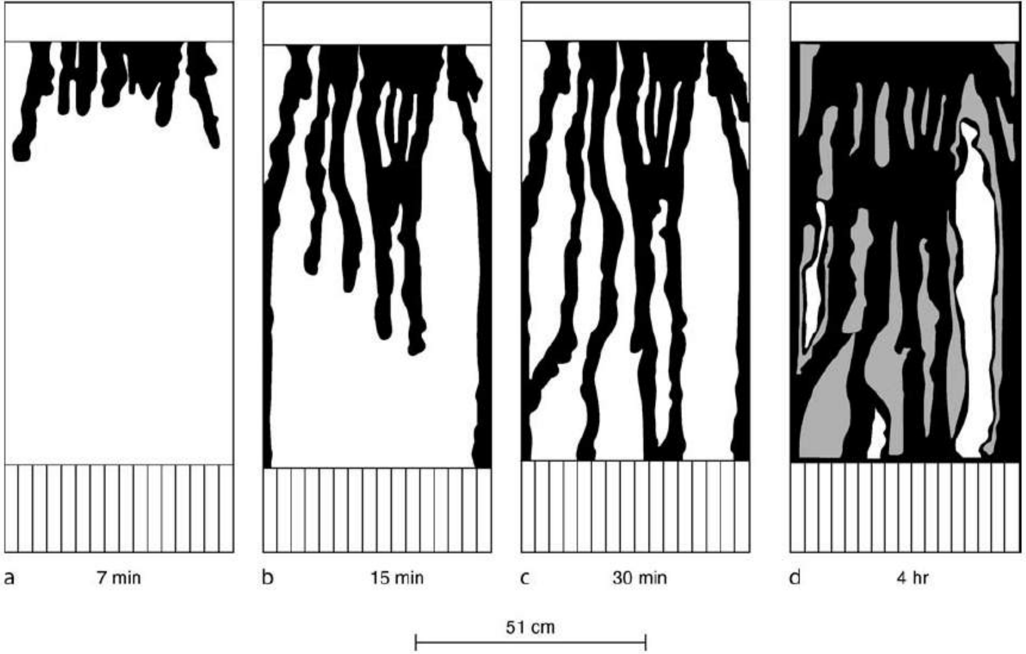
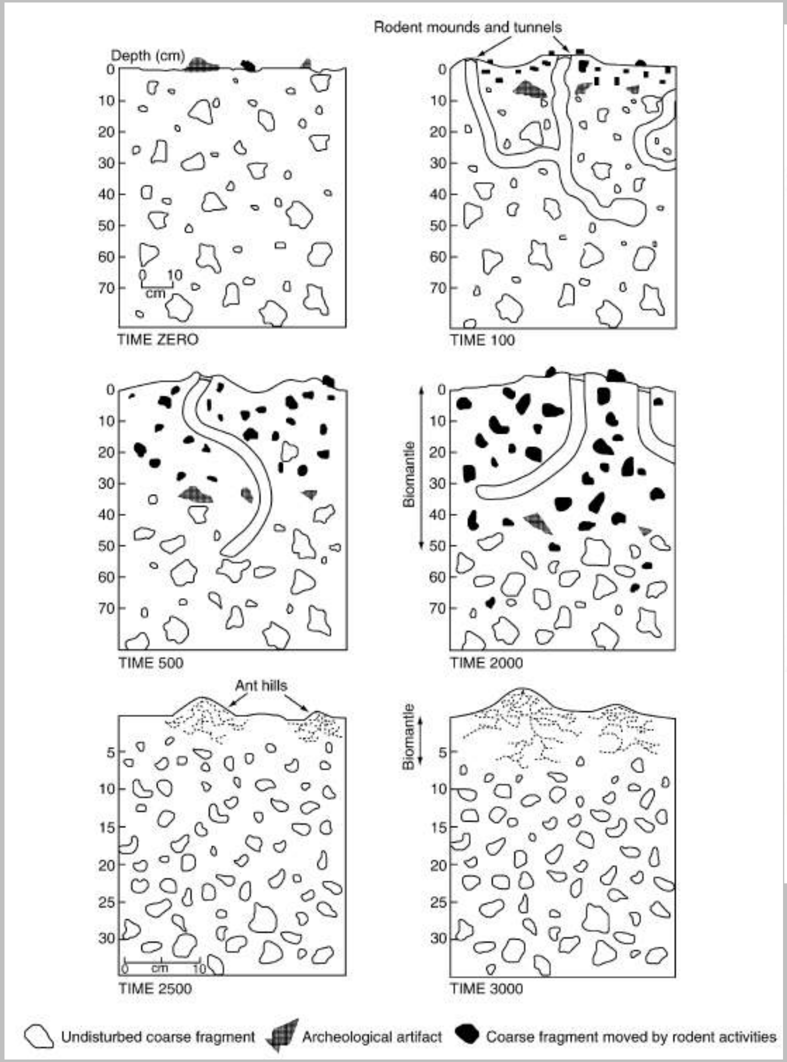


Figure P8 Development of the finger core area-fringe area in time. Core areas grow from the textural interface downward to the bottom of the chamber within the first 30 min (**a**, **b**, **c**). Finger fringe areas are formed as wetting fronts leave the fingers and move laterally into the dry sand on either side of the finger core areas (**d**) (reproduced from Glass et al., 1989).

PEDOTURBAÇÃO



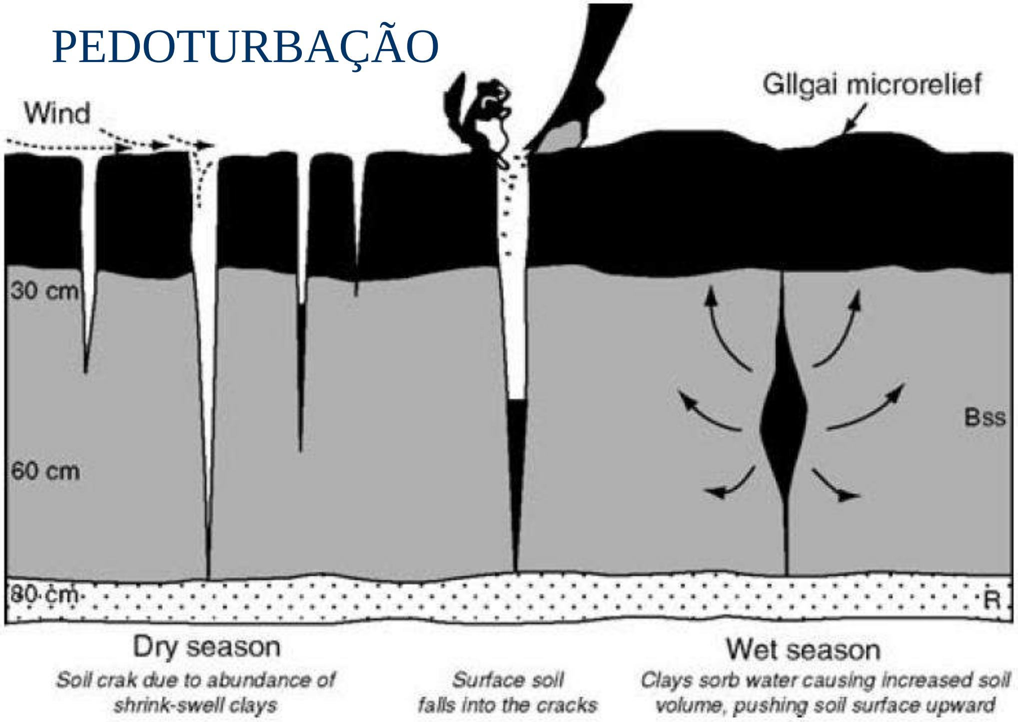
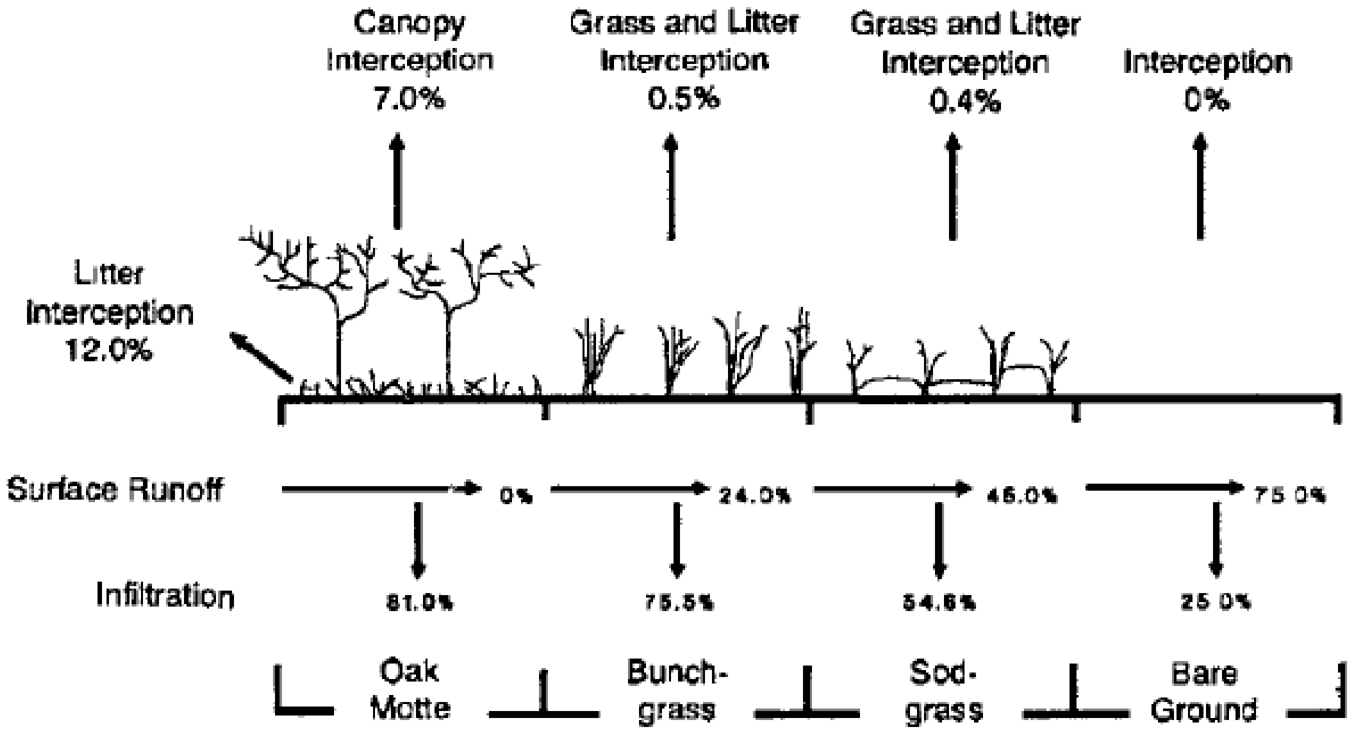


Figure P7 Vertisol horizonation and genesis (after Buol et al., 2003).

A cobertura vegetal modula o balanço hídrico da superfície.



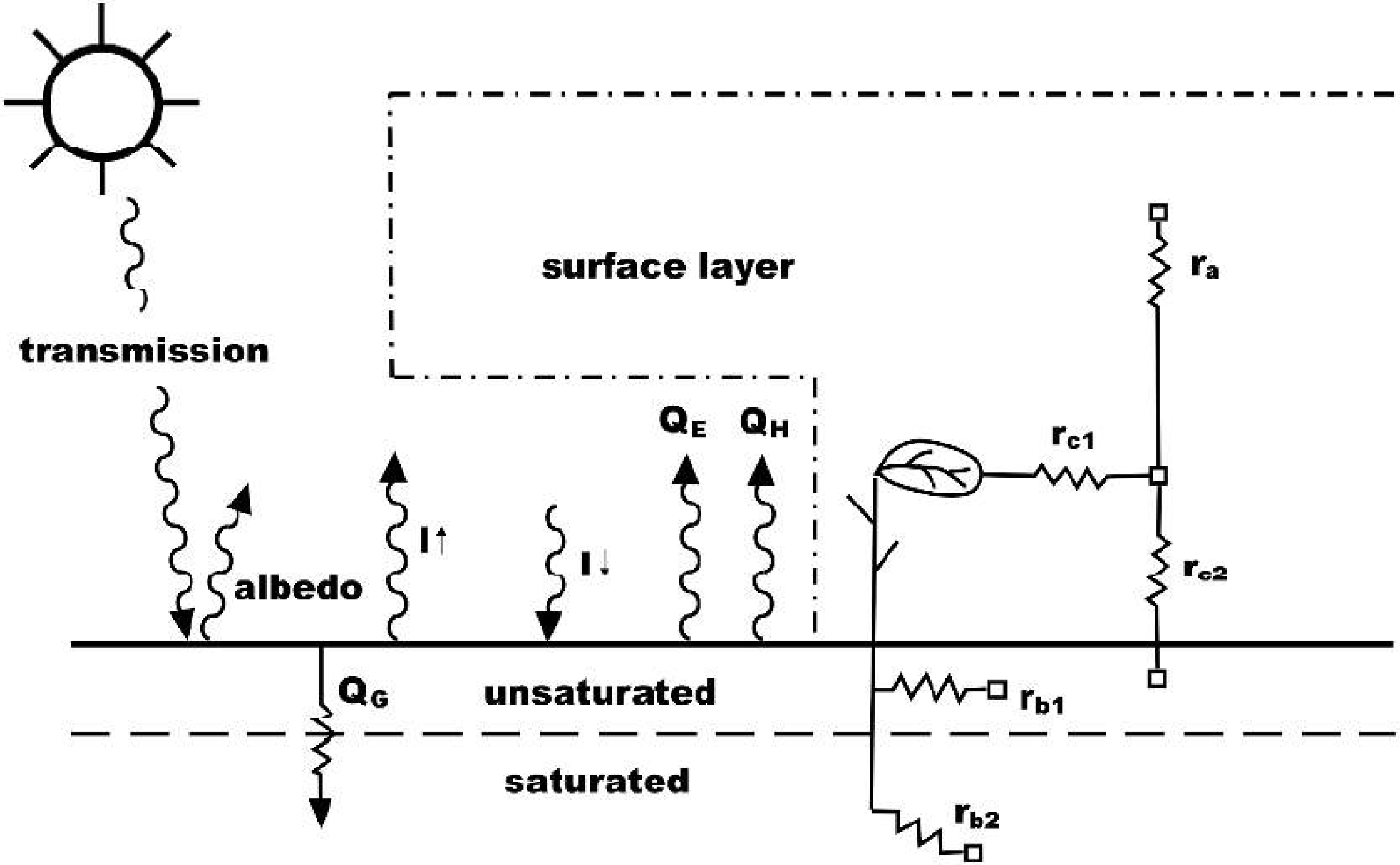


Fig. 5.2. Schematic representation of the modeling of the atmospheric surface layer including plants and soil (Blackadar 1997)

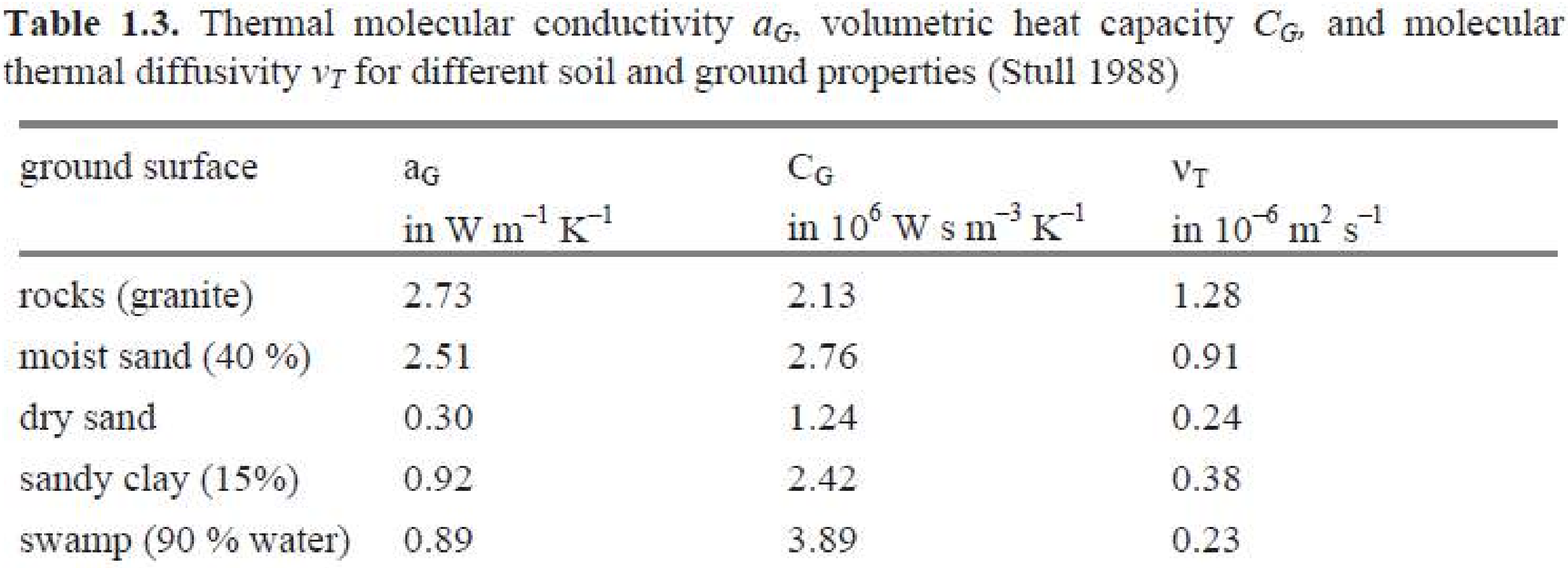


Table 1.3. Thermal molecular conductivity a_G, volumetric heat capacity C_G, and molecular thermal diffusivity ν_T for different soil and ground properties (Stull 1988)

ground surface	a_G in $\mathrm{W\,m^{-1}\,K^{-1}}$	C_G in $10^6\ \mathrm{W\,s\,m^{-3}\,K^{-1}}$	ν_T in $10^{-6}\ \mathrm{m^2\,s^{-1}}$
rocks (granite)	2.73	2.13	1.28
moist sand (40 %)	2.51	2.76	0.91
dry sand	0.30	1.24	0.24
sandy clay (15%)	0.92	2.42	0.38
swamp (90 % water)	0.89	3.89	0.23

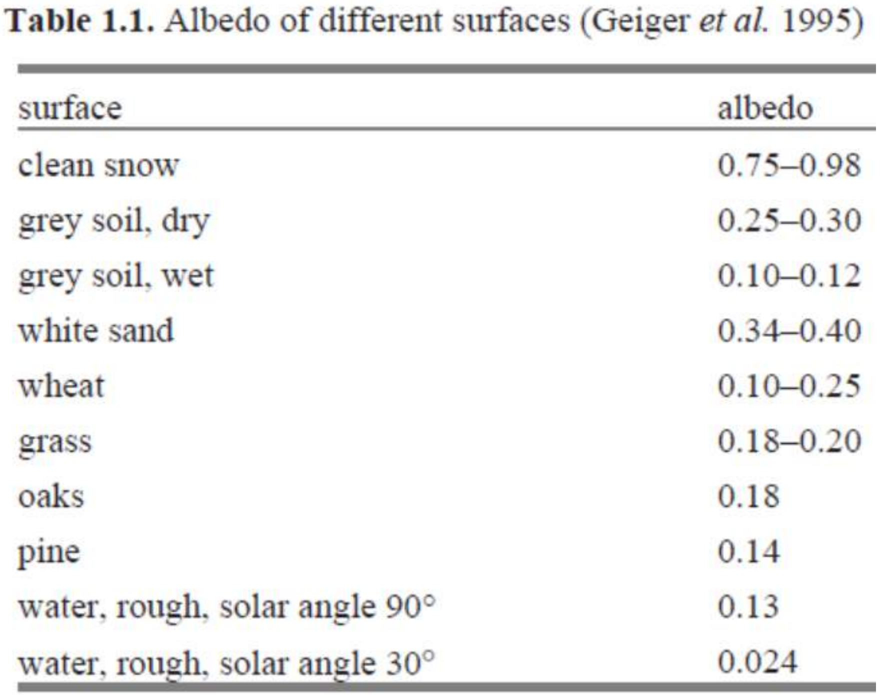


Table 1.1. Albedo of different surfaces (Geiger *et al.* 1995)

surface	albedo
clean snow	0.75–0.98
grey soil, dry	0.25–0.30
grey soil, wet	0.10–0.12
white sand	0.34–0.40
wheat	0.10–0.25
grass	0.18–0.20
oaks	0.18
pine	0.14
water, rough, solar angle 90°	0.13
water, rough, solar angle 30°	0.024

Thermal conductivity (λ) of some soil materials.

Soil	Dry θ_v	λ W m^{-1} K^{-1}	Wet θ_v	λ W m^{-1} K^{-1}
Fairbanks sand	0.003	0.33	0.18	2.08
quartz sand	0.00	0.25	0.40	2.51
sand	0.02	0.9	0.38	2.25
sand	0.00	0.27	0.38	1.77
sand	0.003	0.32	0.38	2.84
gravelly coarse sand (pumice)	0.02	0.13	0.40	0.52
medium and coarse gravel (pumice)	0.01	0.09	0.43	0.39
loamy sand	0.01	0.25	0.40	1.59
loam	0.01	0.20	0.60	1.05
Avondale loam	0.08	0.46	0.23	0.88
Avondale loam	0.03	0.31	0.30	1.20
silt loam	0.09	0.40	0.50	1.0
Yolo silt loam	0.14	0.49	0.34	1.13
Muir silty clay loam	0.03	0.30	0.30	0.90
silty clay loam	0.01	0.20	0.59	1.09
Pullman silty clay loam	0.07	0.16	0.29	0.89
Healy clay	0.04	0.30	0.30	0.91
Fairbanks peat	0.03	0.06	0.61	0.37
forest litter	0.02	0.10	0.55	0.40

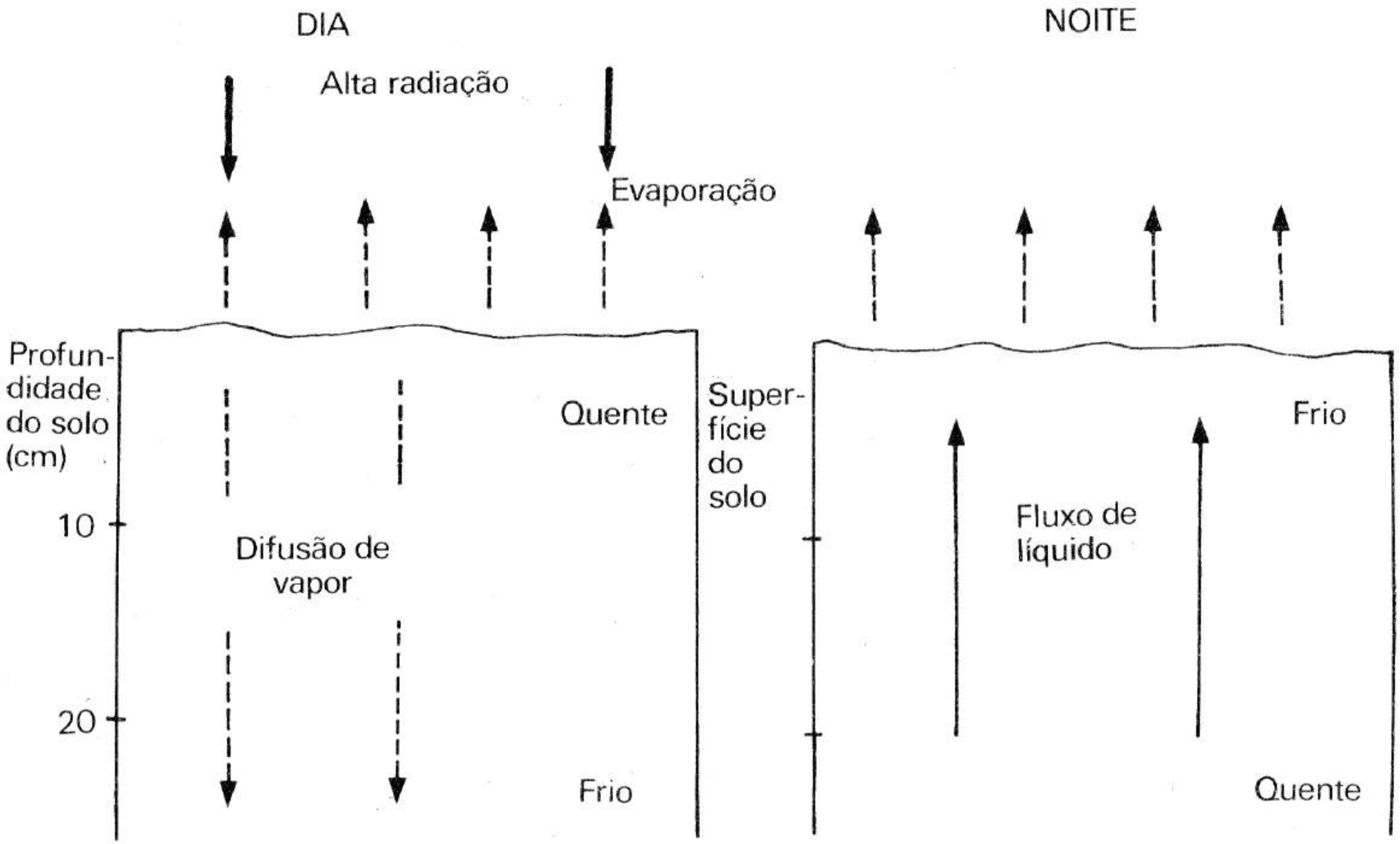
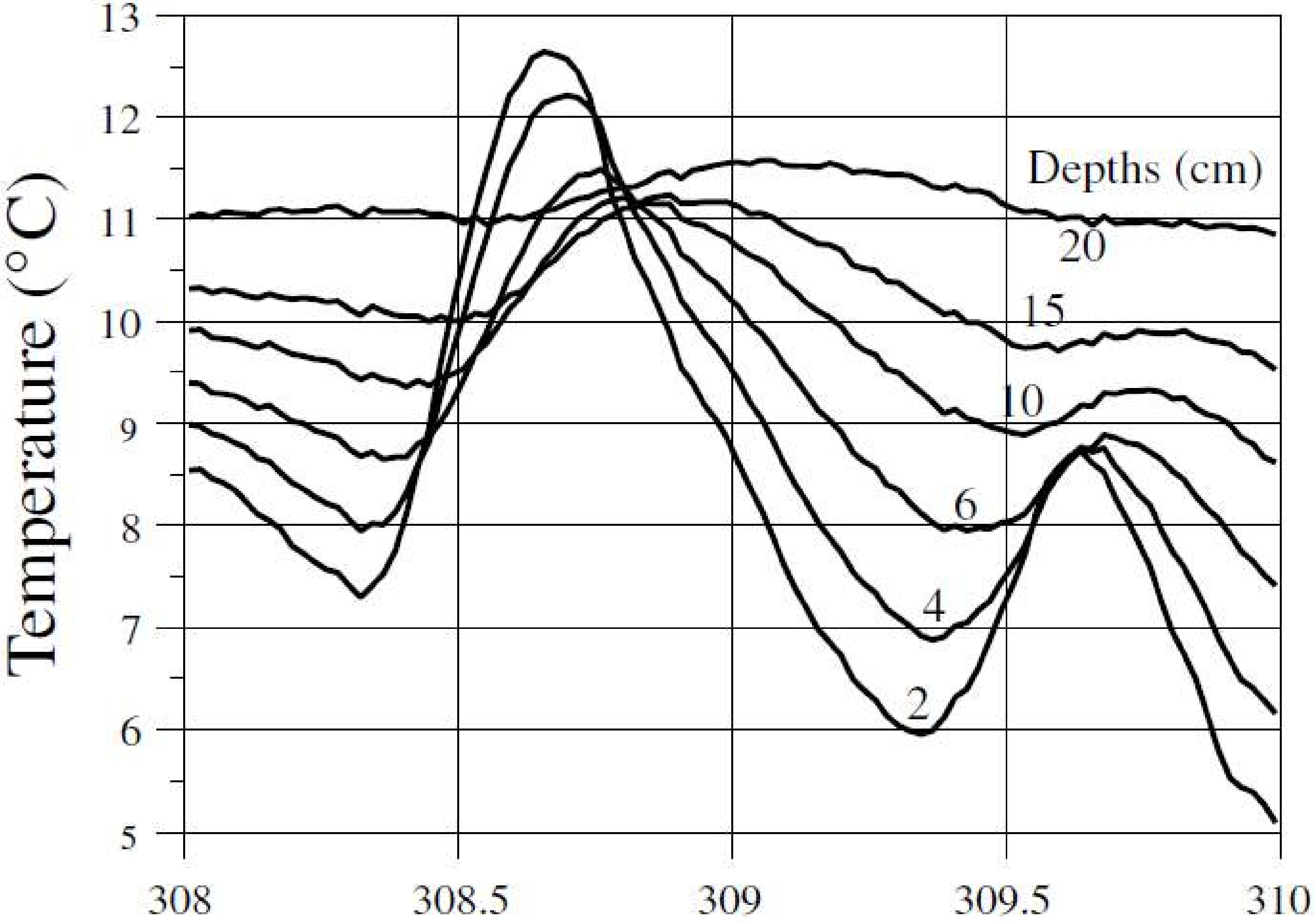


Fig. 1.2.19. — Variação diurna do movimento do vapor de água e da água líquida nas superfícies do solos secos.


Temperature (°C)
13
12
11
10
9
8
7
6
5
308
308.5
309
309.5
310
Depths (cm)
20
15
10
6
4
2

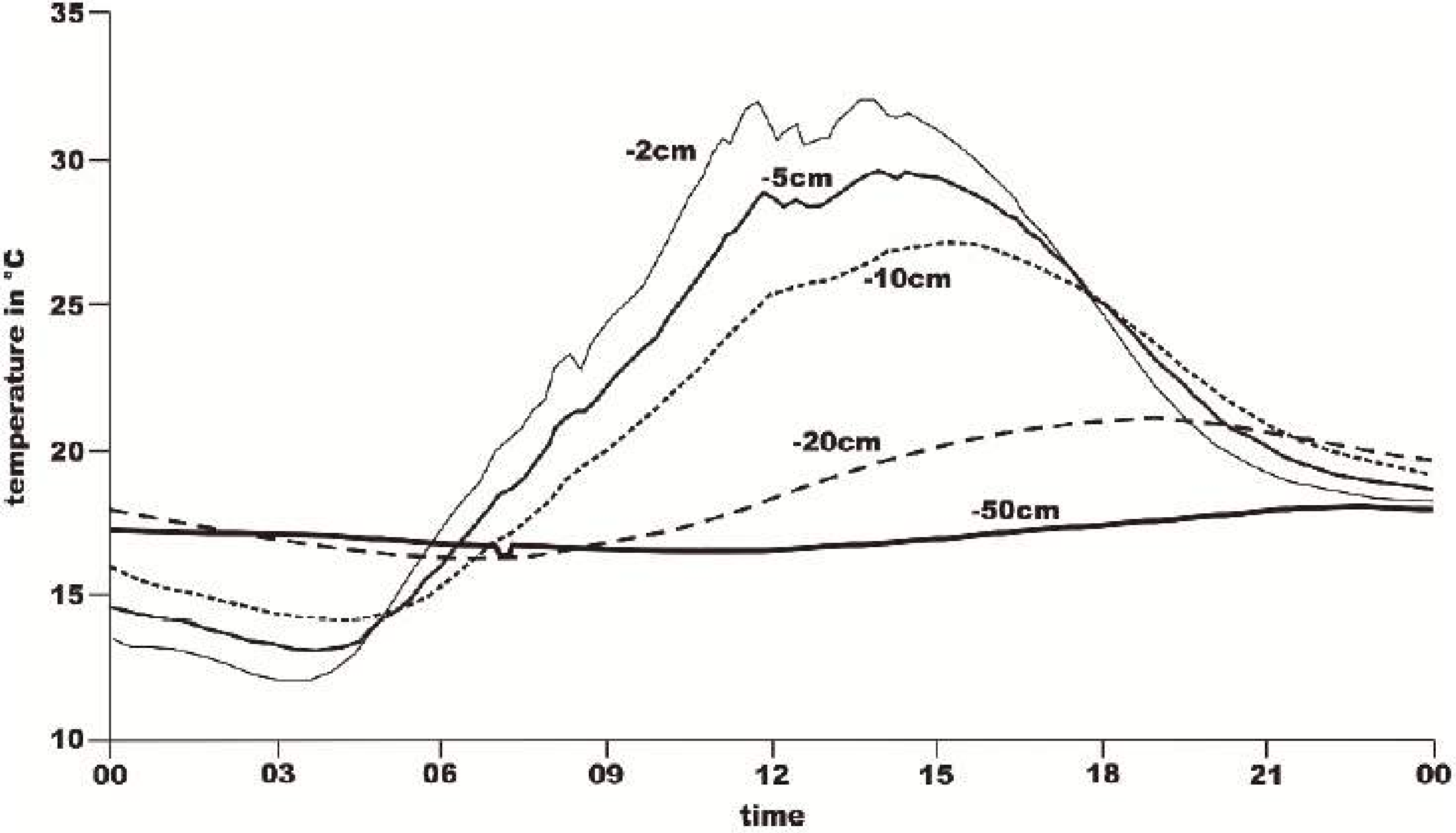


Fig. 1.10. Daily cycle of soil temperatures at different depth, measured by the University of Bayreuth during the LITFASS-98 experiment (*bare soil*) at the boundary layer measuring field site of the Meteorological Observatory Lindenberg (high clouds from 12:00 to 14:00)

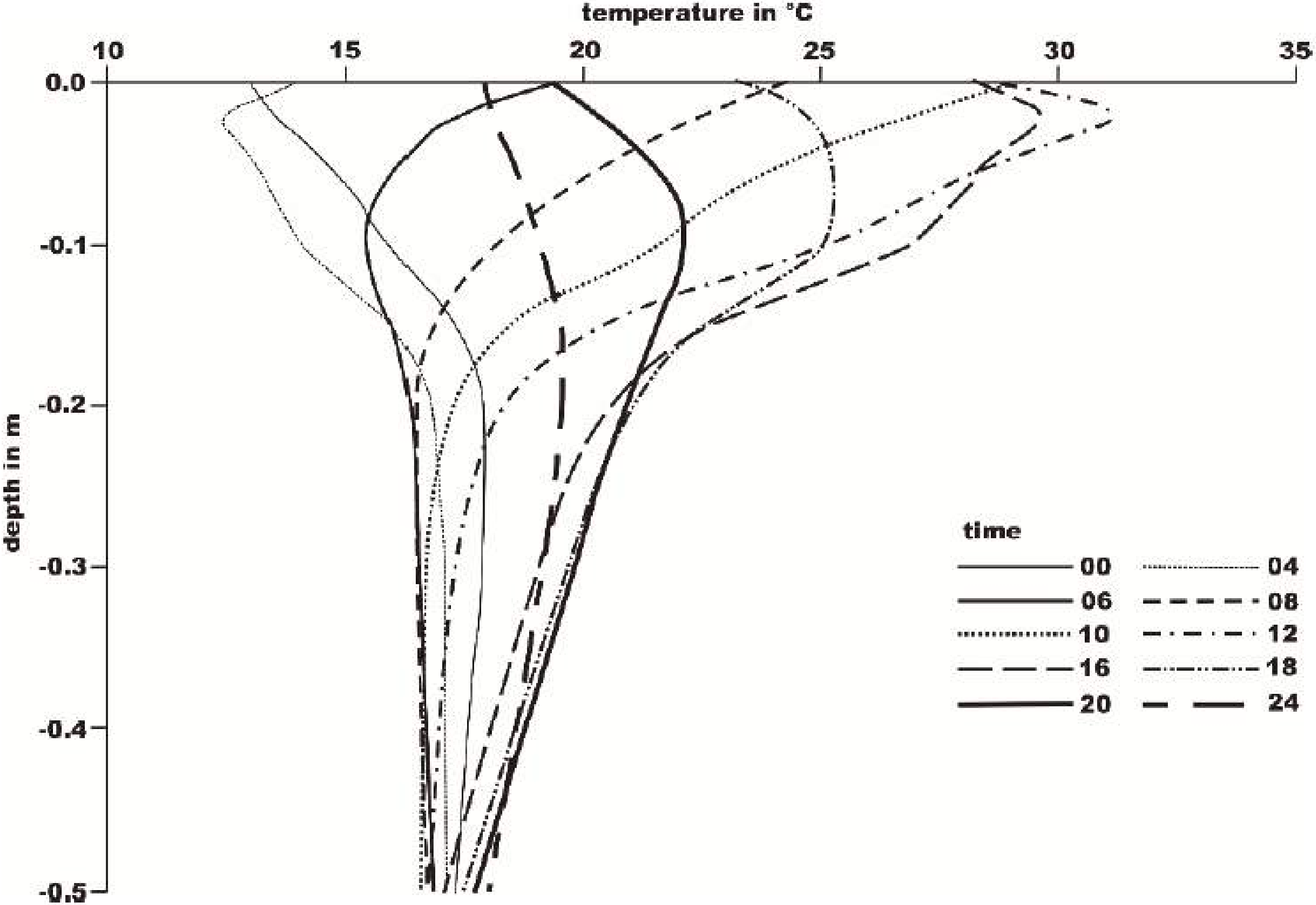
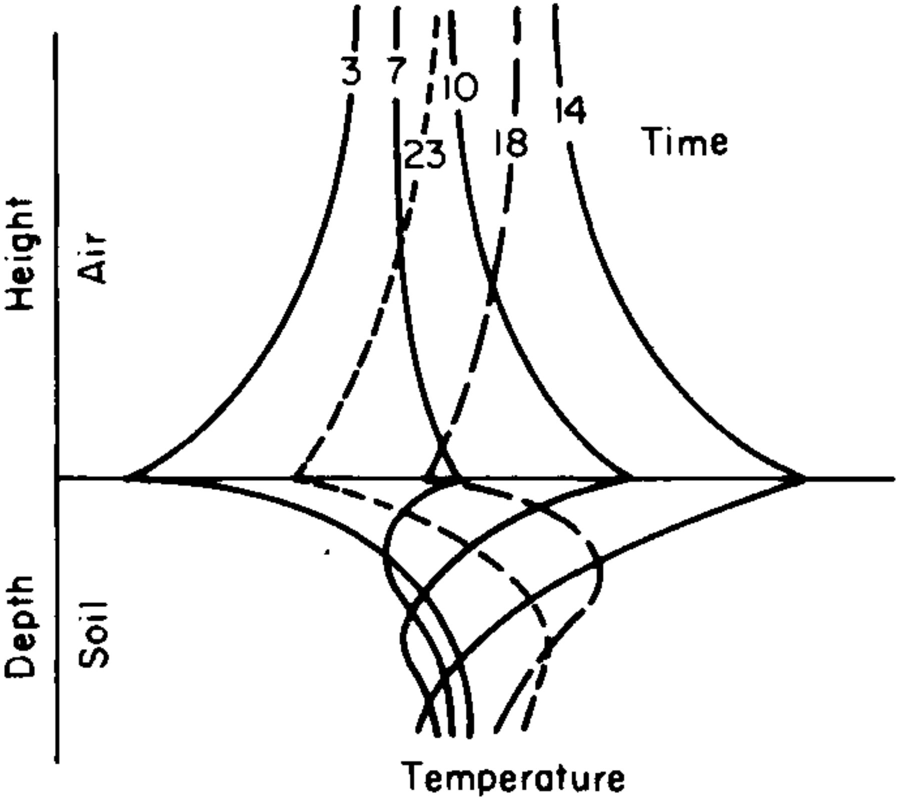
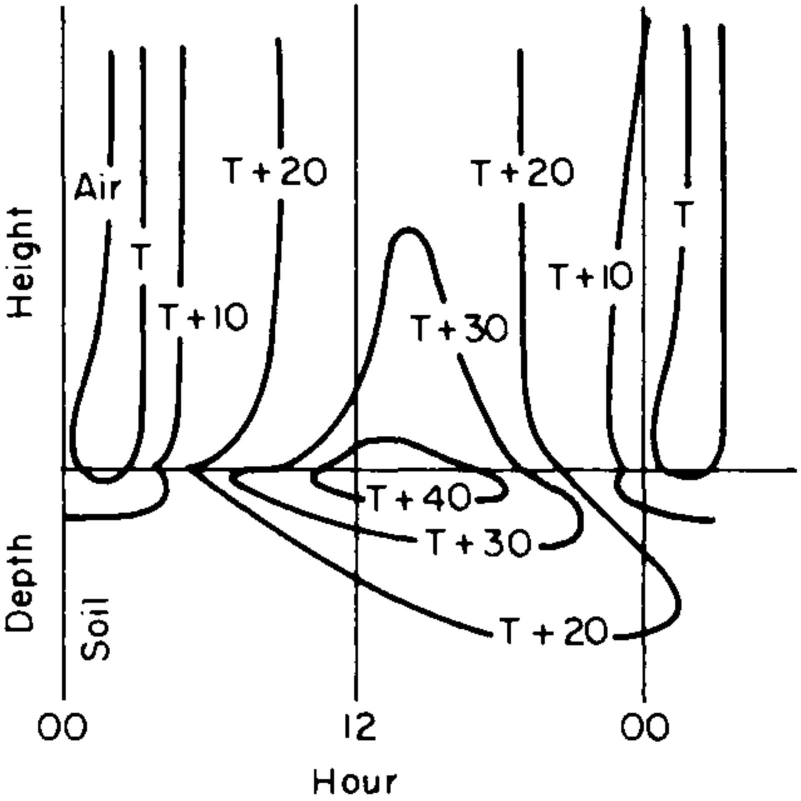


Fig. 1.9. Temperature profile in the upper soil layer on June 05, 1998, measured by the University of Bayreuth during the LITFASS-98 experiment (*bare soil*) at the boundary layer measuring field site of the Meteorological Observatory Lindenberg (high clouds from 12:00 to 14:00)


3
7
10
14
23
18
Time
Height
Air
Depth
Soil
Temperature

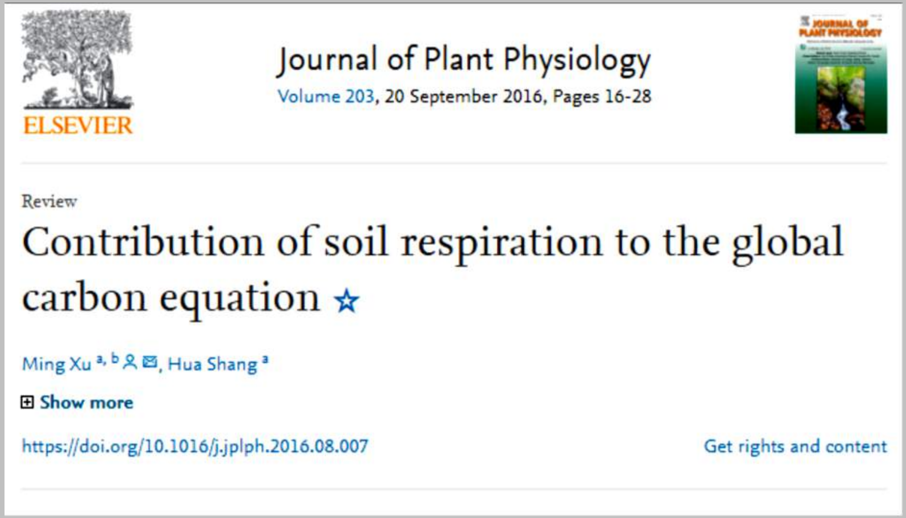

Air
T
T + 10
T + 20
T + 20
T + 30
T + 10
T
T + 40
T + 30
T + 20
Height
Depth
Soil
00
12
00
Hour

Medidores de potencial hídrico do solo:

<-Blocos de gesso

Tensiômetros

https://youtu.be/fZ2Mv2ffiaM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Journal of Plant Physiology
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Review

Contribution of soil respiration to the global carbon equation ☆

Ming Xu [a, b], Hua Shang [a]

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Plant Soil (2012) 359:183–195
DOI 10.1007/s11104-012-1195-6

REGULAR ARTICLE

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Ieda de Carvalho Mendes ·
Marcelo Ferreira Fernandes ·
Guilherme Montandon Chaer ·
Fábio Bueno dos Reis Junior

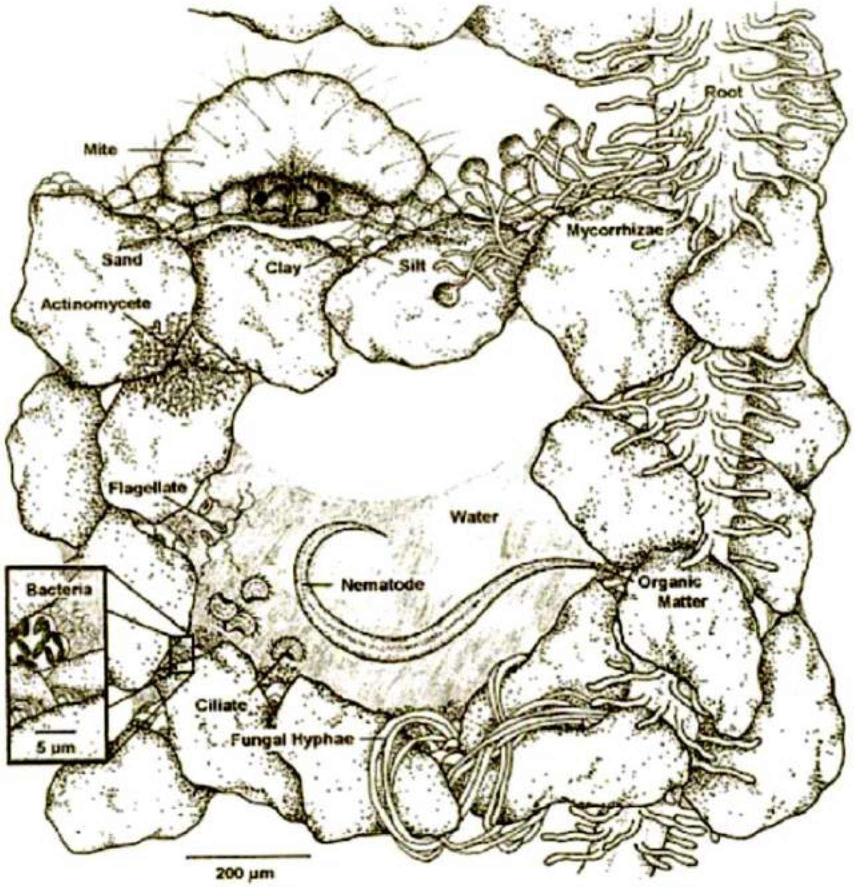
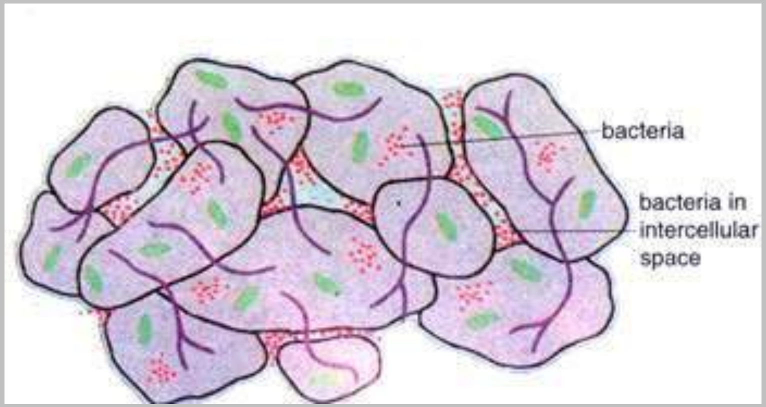
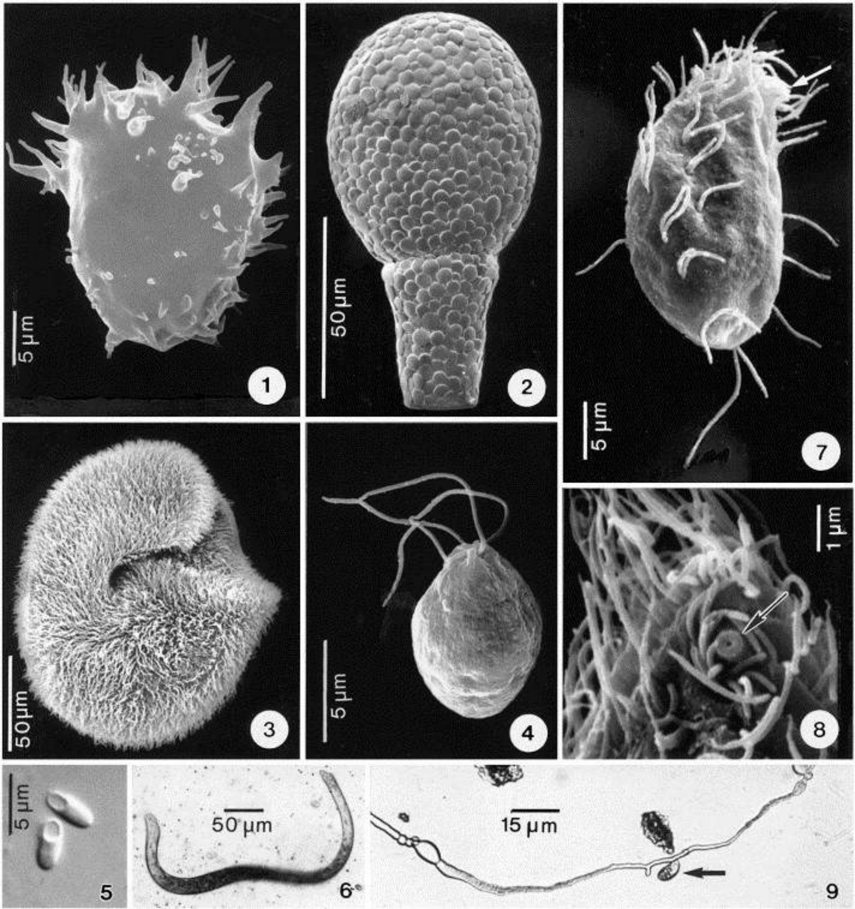


Figure S49 A soil habitat containing mineral soil particles, organic matter, water, plant root with root hairs, and soil organisms. The actual size of the soil in this drawing is slightly greatly than 1 mm^2 (original drawing by Kim Luoma. Courtesy of Peter G. Hartel).

MICROHABITATS NO SOLO

A quantidade de organismos nos microhabitats do solo varia com a estrutura dos agregados e a textura. A composição granulométrica que reflete no espaço entre os poros pode oferecer afeta a composição da biota edáfica. A mobilidade dos organismos afeta a composição da atividade microbiana nas raízes das plantas podendo interferir em processos importantes no uso dos nutrientes. Enquanto bactérias podem ter acesso a solos com maior compactação, colônias de bactérias e protozoários menores necessitam de poros de 2um pelo menos enquanto poros menores que 30um reduzem drasticamente a maior parte da biota decompositora do solo.





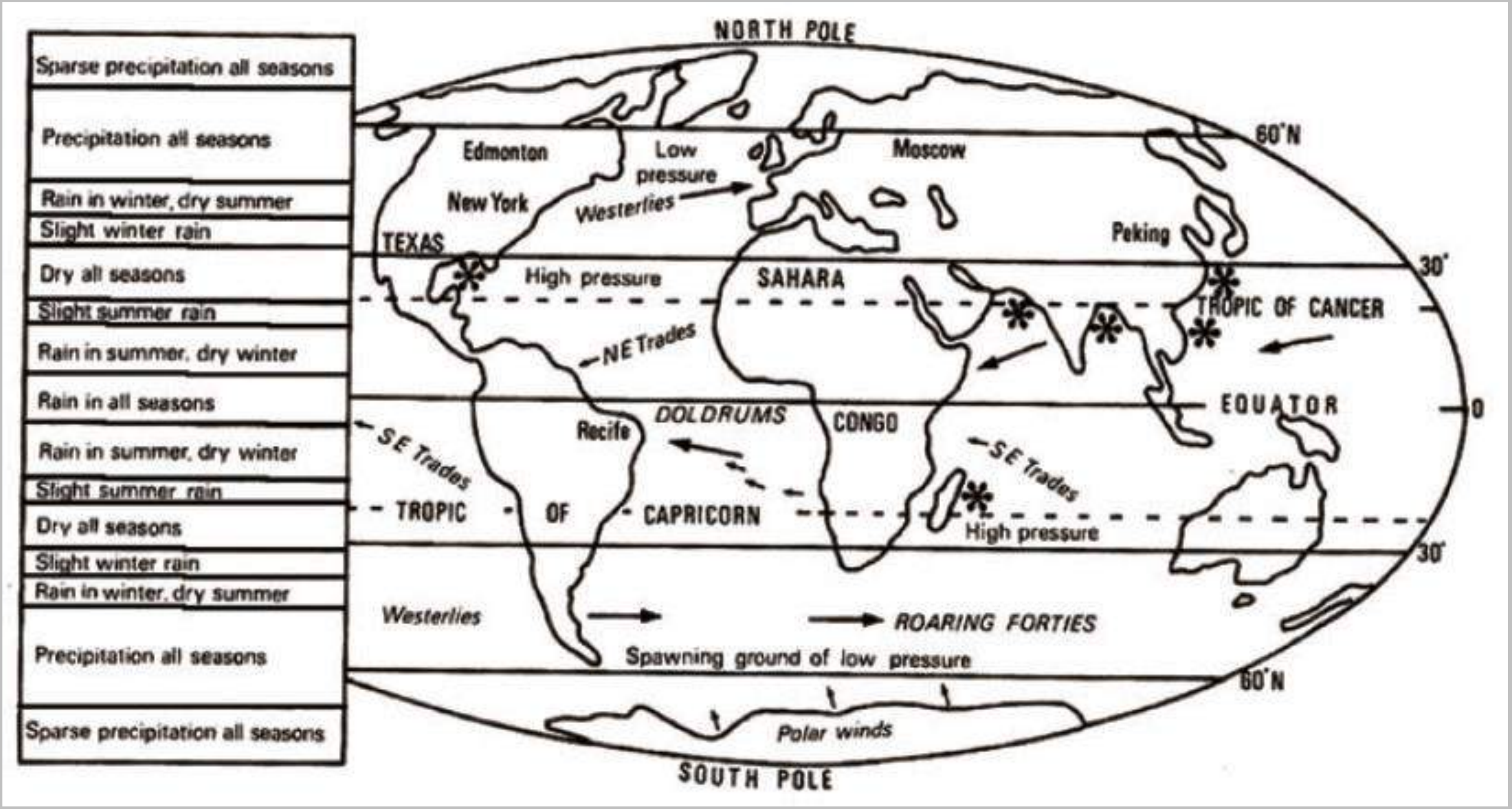
Desertificação

- O que é um “deserto”:

Região com precipitação media anual menor do que 100mm (definição nem sempre eficaz para explicar a aridez);

Região definida por um déficit hídrico pela razão entre precipitação e demanda evaporativa;

Cinturões climáticos



Razão de Budyko-Lettau

$$D = R / (L \times P)$$

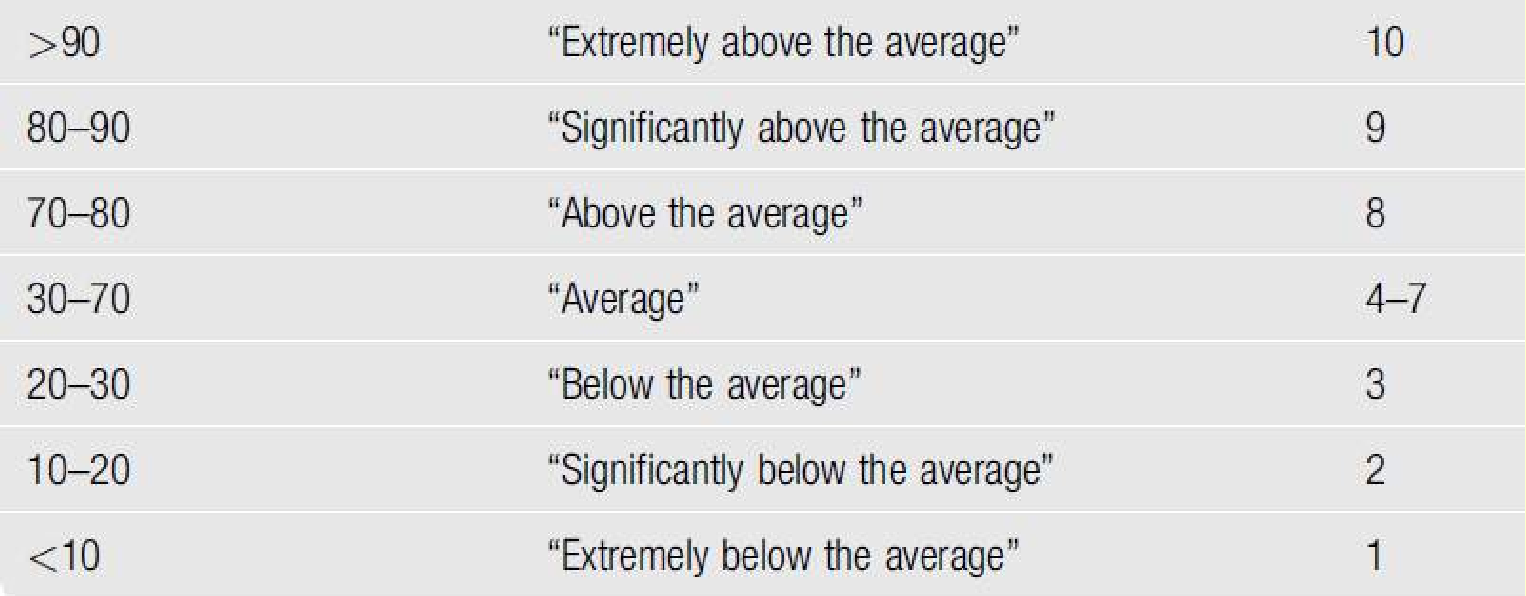
D = índice de secura;
R = ganho líquido anual de radiação;
P = precipitação média anual;
L = calor latente de evaporação da água

Concepção original:

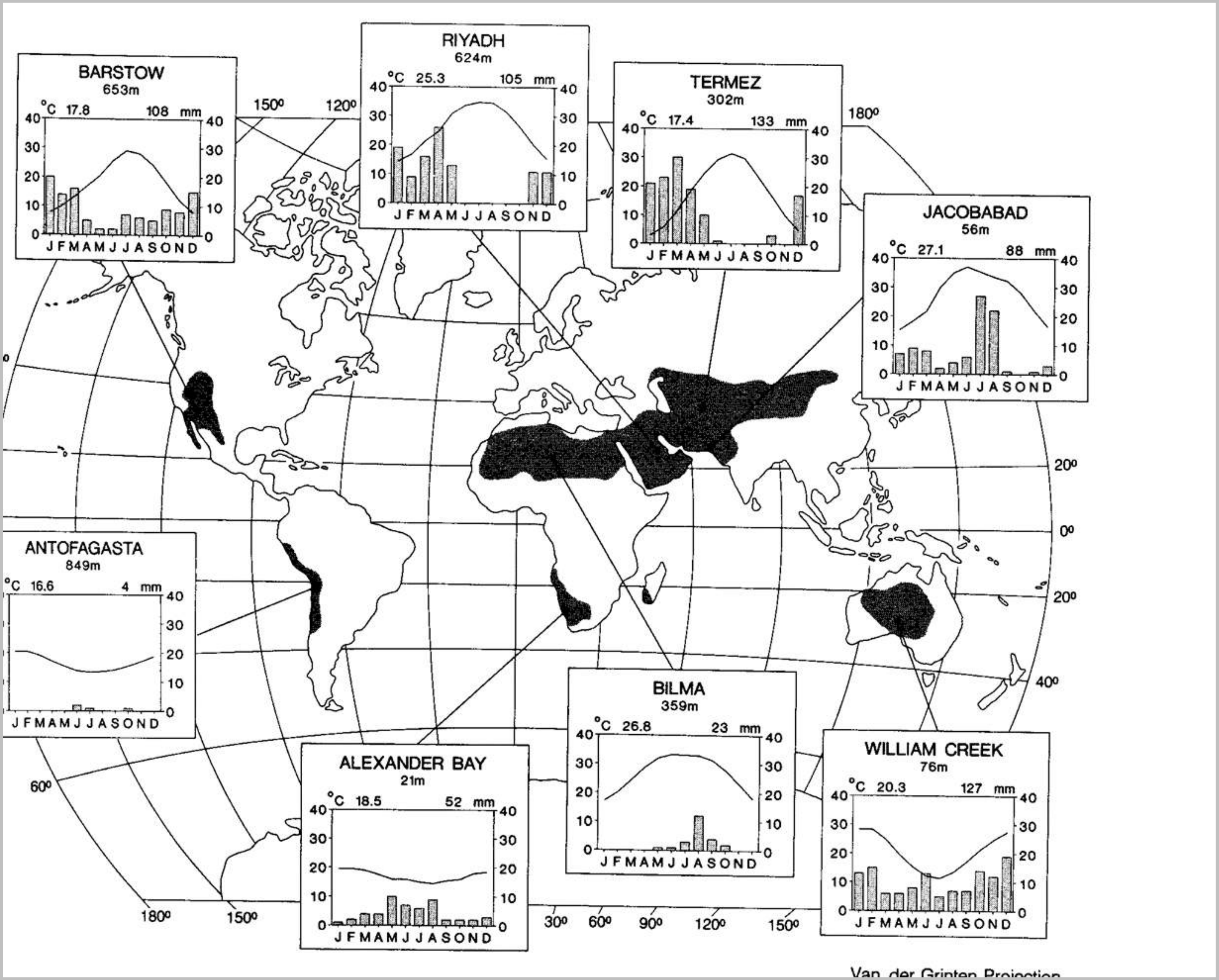
$D > 2.3$ = semi-deserto; $D \geq 3.4$ = deserto

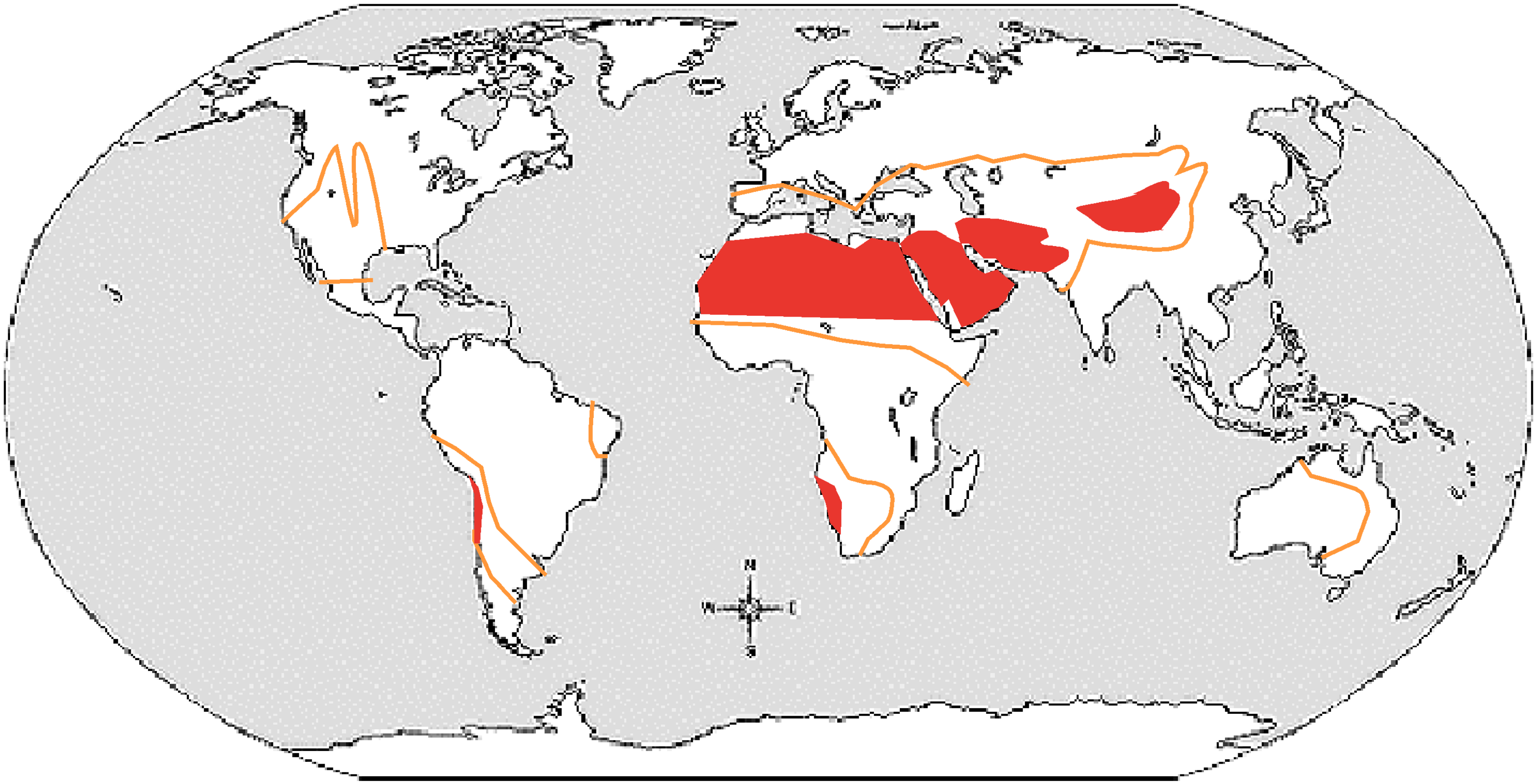
UNESCO: $D \geq 10$ = deserto extremo

INTERPRETAÇÃO DO ÍNDICE DE BUDYKO



>90	“Extremely above the average”	10
80–90	“Significantly above the average”	9
70–80	“Above the average”	8
30–70	“Average”	4–7
20–30	“Below the average”	3
10–20	“Significantly below the average”	2
<10	“Extremely below the average”	1

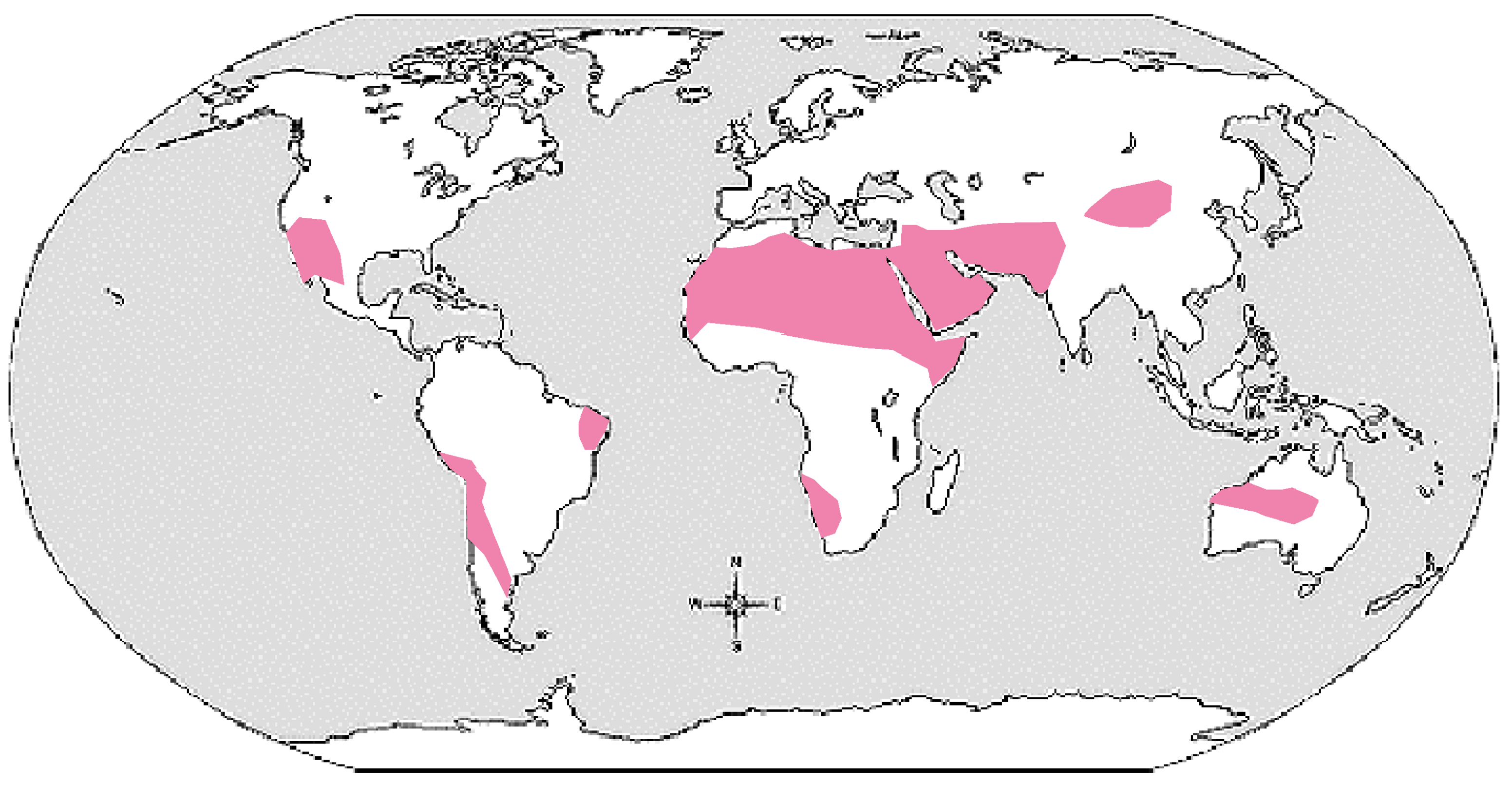

BARSTOW
653m
°C 17.8
108 mm
RIYADH
624m
°C 25.3
105 mm
TERMEZ
302m
°C 17.4
133 mm
JACOBABAD
56m
°C 27.1
88 mm
ANTOFAGASTA
849m
°C 16.6
4 mm
ALEXANDER BAY
21m
°C 18.5
52 mm
BILMA
359m
°C 26.8
23 mm
WILLIAM CREEK
76m
°C 20.3
127 mm
0
10
20
30
40
J F M A M J J A S O N D
150°
120°
180°
20°
0°
20°
40°
60°
180°
150°
30°
60°
90°
120°
150°
Van der Grinten Projection



Linha -semiárido (D≥2.3)

Área vermelha- deserto (D≥10)

Imprevisibilidade:
areas com variações maiores do que 30% na precipitação

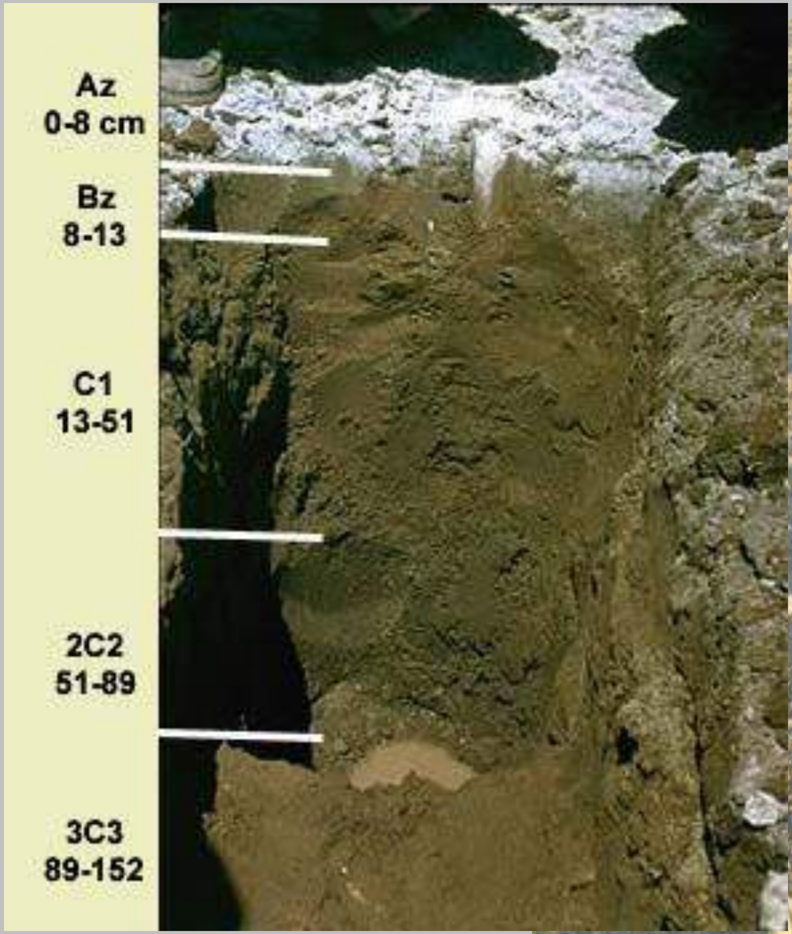


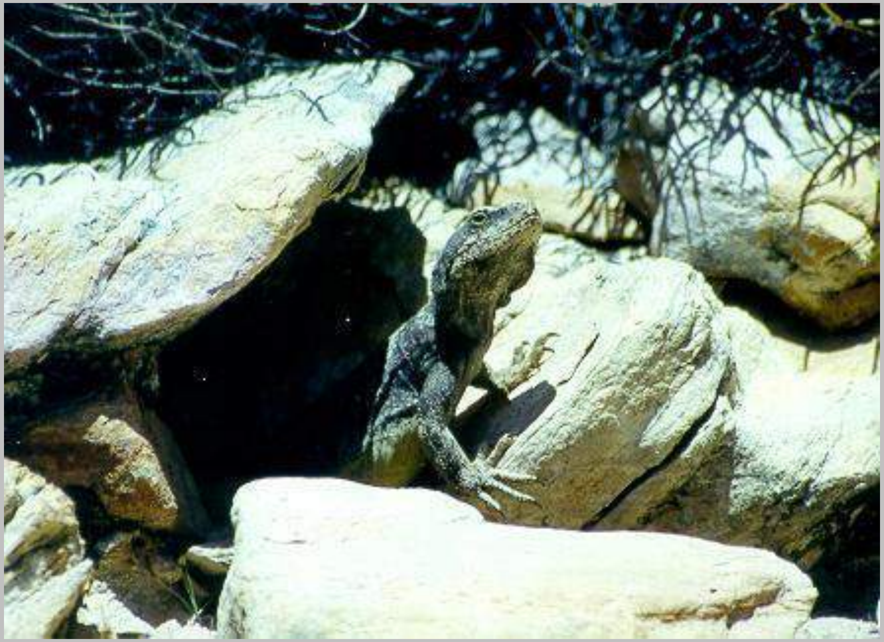
Desertos de mar frio

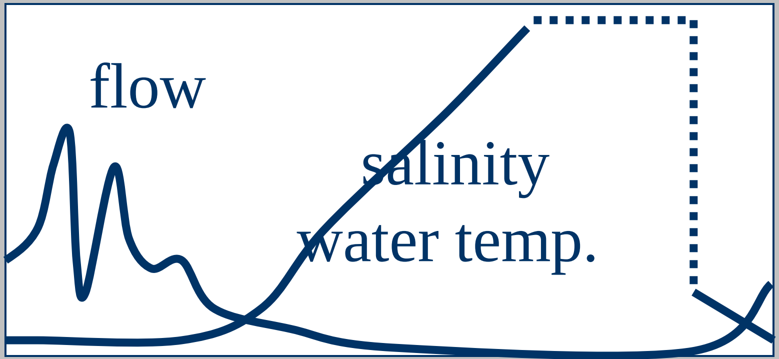
Atacama

Namib desert

Desertos salinos






flow
salinity
water temp.

Temperaturas