2444-25

College on Soil Physics - 30th Anniversary (1983-2013)

25 February - 1 March, 2013

Modeling the Soil Moisture regime for Evaluation and Prediction of Soil Hydrological and Soil Degradetion: Model "SOMORE"

PLA SENTIS Ildefonso
Universidad Central de Venezuela
Instituto de Edafologia, Facultad de Agronomia
Apartado 1131, Av.El Limon, Maracay
VENEZUELA

XII COLLEGE ON SOIL PHYSICS 2013

(30TH Aniversary)

ICTP, Trieste (Italy)

Modeling the Soil Moisture Regime for Evaluation and Prediction of Soil Hydrological and Soil Degradation Processes: Model "SOMORE"

Prof. Ildefonso Pla Sentís

Universitat de Lleida

Lleida, Spain

ipla@macs.udl.es

Water, that is often the main limiting factor of plant growth, is also the main factor directly or indirectly responsible for soil and land degradation processes

The soil moisture regime, determined by the changes in soil water content with time, is the main single factor conditioning plant growth and crop production

The processes of soil and water degradation, leading to desertification, are strongly linked to unfavorable changes in the hydrological processes responsible for the soil water balance and for the soil moisture regime

These are affected by the climate conditions and variations, and by the changes in the use and management of soil and water resources

Soil quality paradigm?

<u>Soil quality assessments of degradation</u> have been using in many cases mostly <u>subjective perceptions and soil quality indices</u>, scored from empirical judgements, generally <u>narrow in scope and with a taxonomic bias</u>, which do not allow to relate the evaluation to the overall sustainability of alternate land use systems (production, control of environmental impacts, etc).

This would be only possible if they were based on <u>clear and objective hydrological principles</u> and <u>quantitative measurements or estimations of hydrological parameters</u>, aimed at problem solving.

The evaluation of soil and water degradation processes must allow to:

-design sustainable and productive land use and management strategies, which guarantee protection of the environment,

-previewing the effects of different combinations of climate, slope and management, including extraordinary events with low return period.

That requires to change the present mostly empirical subjective and qualitative evaluations, by quantitative evaluations based on hydrological processes

The evaluations must take into consideration that soil degradation not only causes problems in-site, but it may cause serious probles off-site.

AN HYDROLOGICAL APPROACH DOES FACILITATE A MORE INTEGRAL EVALUATION AT BOTH LEVELS

The main objective must be to evaluate such hydrological processes, and to select and develop methodologies and techniques to correct or to control them under different conditions of soils, topography and climate.

This is required for suppressing or alleviating the negative effects of soil and water degradation on sustainable agricultural production, on the supply of water in adequate quantity and quality for the different potential uses, and on catastrophic events such as flooding, sedimentation, landslides, etc

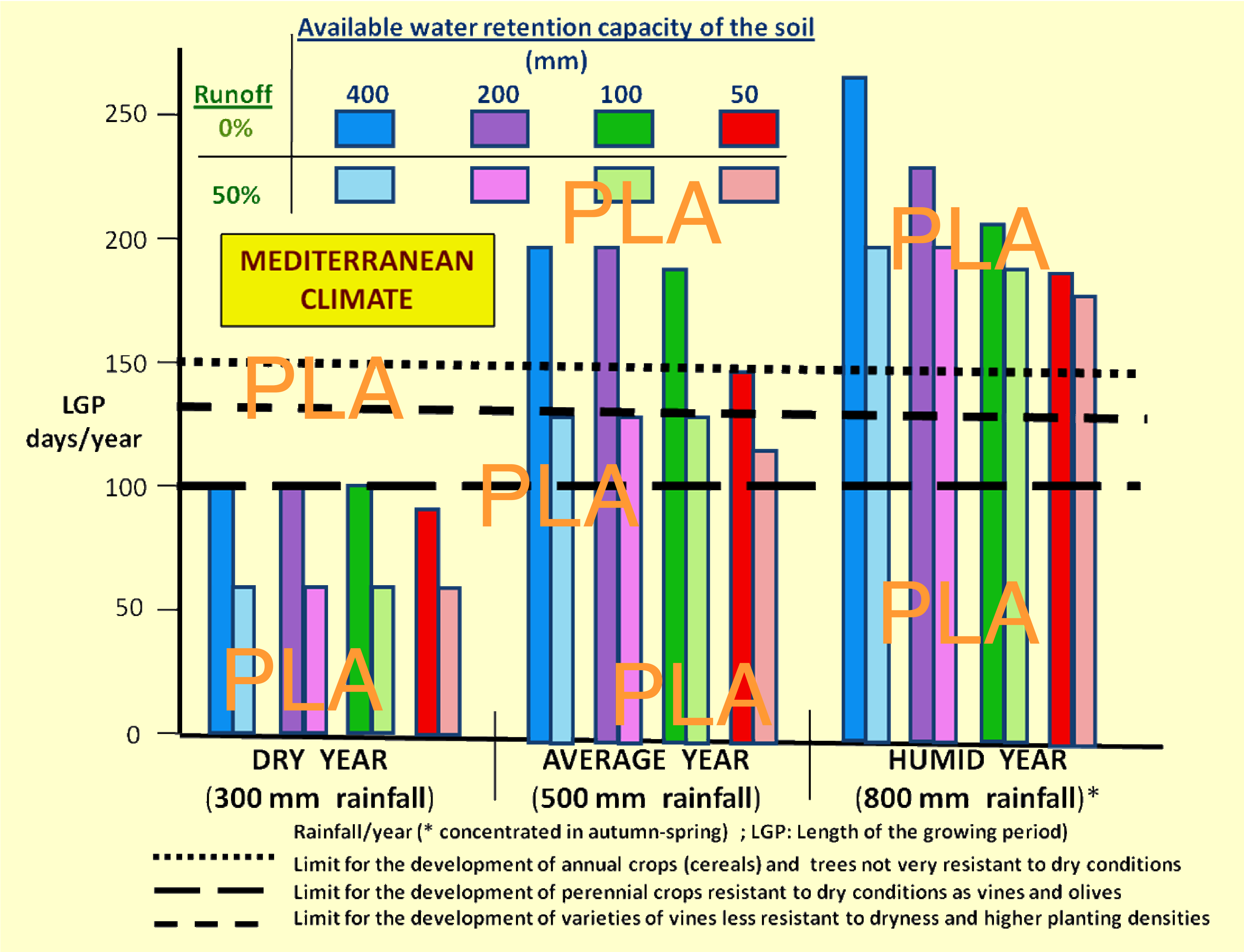
Although the close interaction between the conservation of the soil and water resources is increasingly being accepted, still in most of the cases they are evaluated separately, and consequently the prediction and prevention of the effects derived from their degradation are inadequate in many situations.

This will become more important under the previewed effects of global climatic changes, which would mainly affect hydrological processes in the land surface.

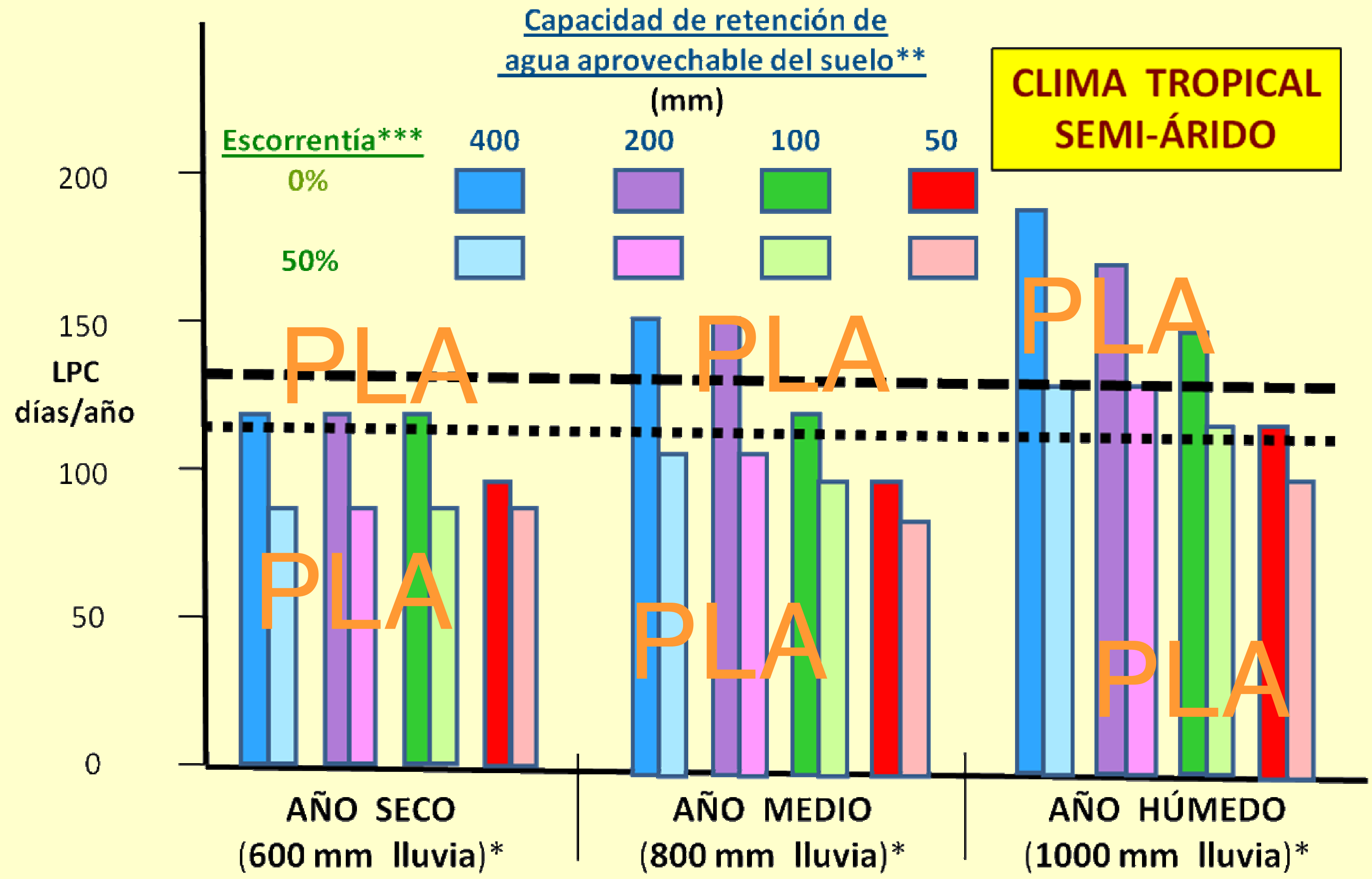
Global climate change prediction, although still rather uncertain, will increase rainfall in some regions, while others might become drier, in a rather uneven spatial and time distribution.

This may contribute to accelerate some land degradation processes leading to larger runoff and erosion, and to increased risks of floodings, landslides, mass movements and mud-flows in tropical regions, and to higher risks of crop production in subtropical and temperate regions.

But in any case, land use changes, including deforestations, and other human activities leading to soil degradation processes may affect more the soil hydrological processes and their effects on land degradation, than the previewed global climatic changes, or may increase the influence of these changes.



Available water retention capacity of the soil
(mm)
Runoff
0%
50%
400
200
100
50
MEDITERRANEAN
CLIMATE
250
200
150
100
50
0
LGP
days/year
DRY YEAR
(300 mm rainfall)
AVERAGE YEAR
(500 mm rainfall)
HUMID YEAR
(800 mm rainfall)*
Rainfall/year (* concentrated in autumn-spring) ; LGP: Length of the growing period)
Limit for the development of annual crops (cereals) and trees not very resistant to dry conditions
Limit for the development of perennial crops resistant to dry conditions as vines and olives
Limit for the development of varieties of vines less resistant to dryness and higher planting densities



* Lluvia/año : Concentrada en 6 meses

LPC: Longitud de Periodo de Crecimiento (LPC = dias con P ≥ ½ ETP) (P. Lluvia; ETP: Evapo-transpiración potencial)

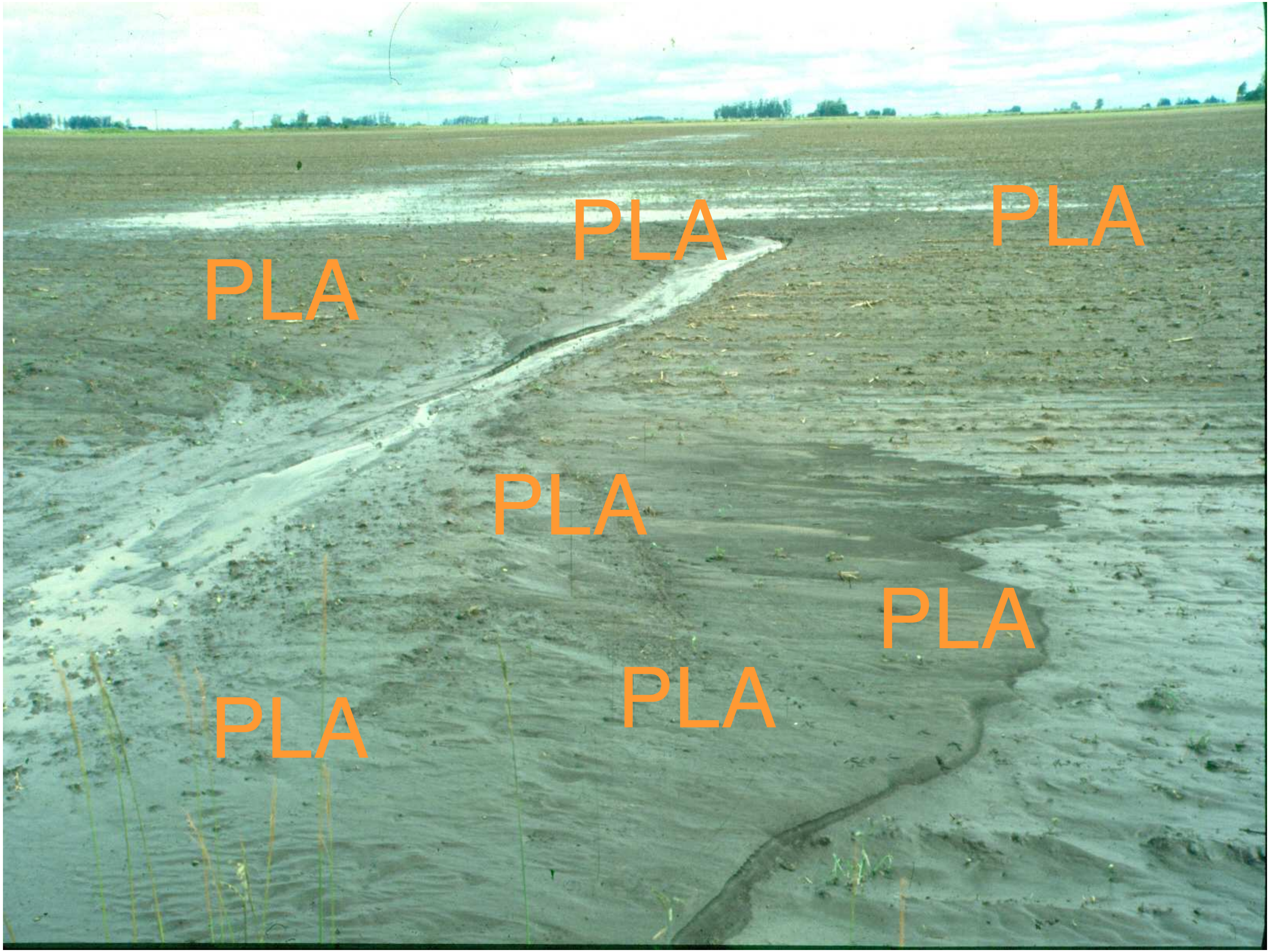
▪ ▪ ▪ ▪ Minima LPC para el desarrollo productivo de cereales de secano (sorgo)

▬ ▬ Minima LPC para el desarrollo productivo de cereales de secano (maiz)

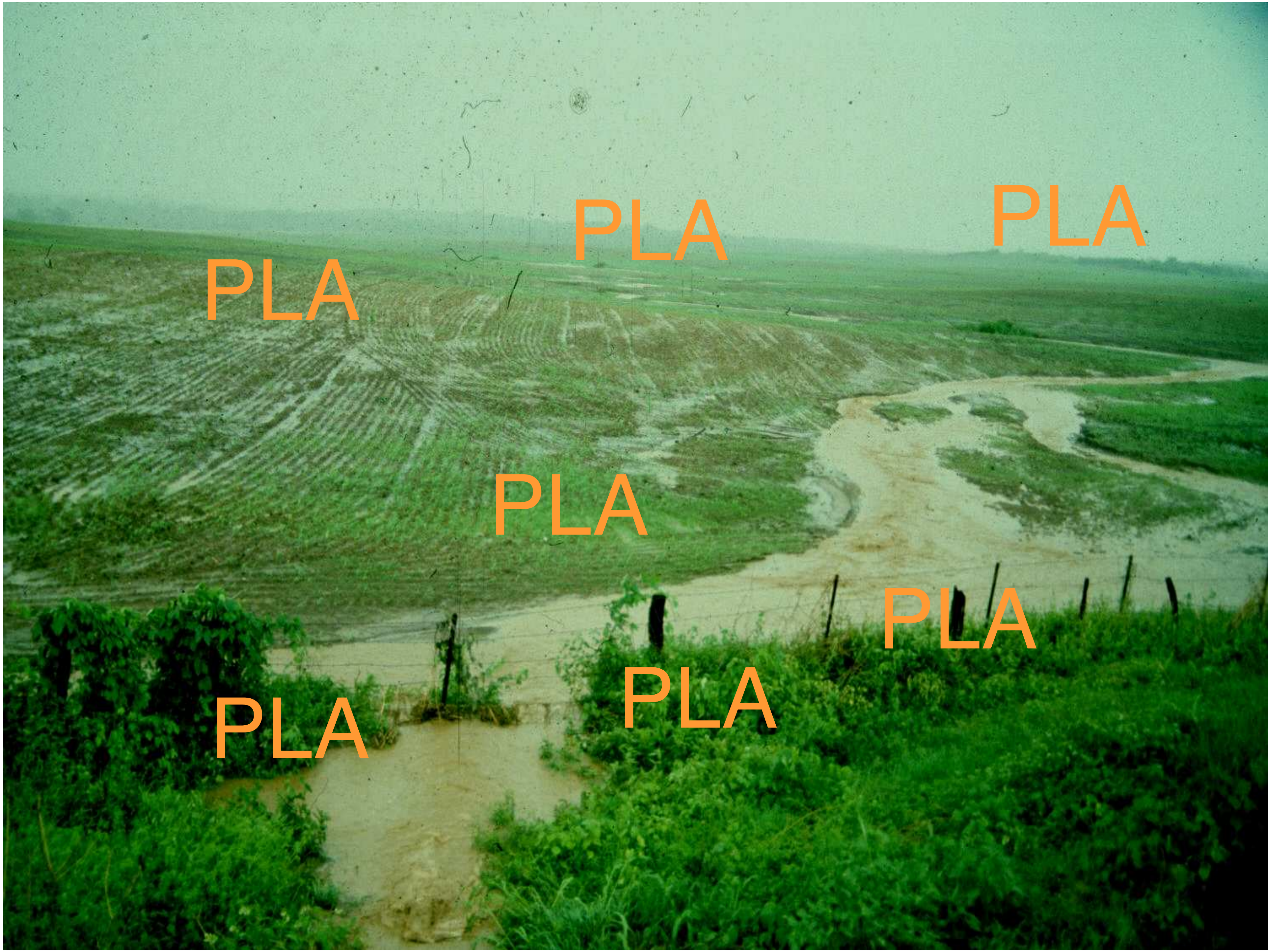
** Determinado por la capacidad de campo y por la profundidad efectiva de raíces

*** En terrenos con pendiente determinada por la velocidad de infiltración del agua en el suelo en relación a la intensidad de las lluvias

(Los valores de LPC estarán tambien afectados por variaciones en la distribución de las lluvias)


PLA
PLA
PLA
PLA
PLA
PLA
PLA

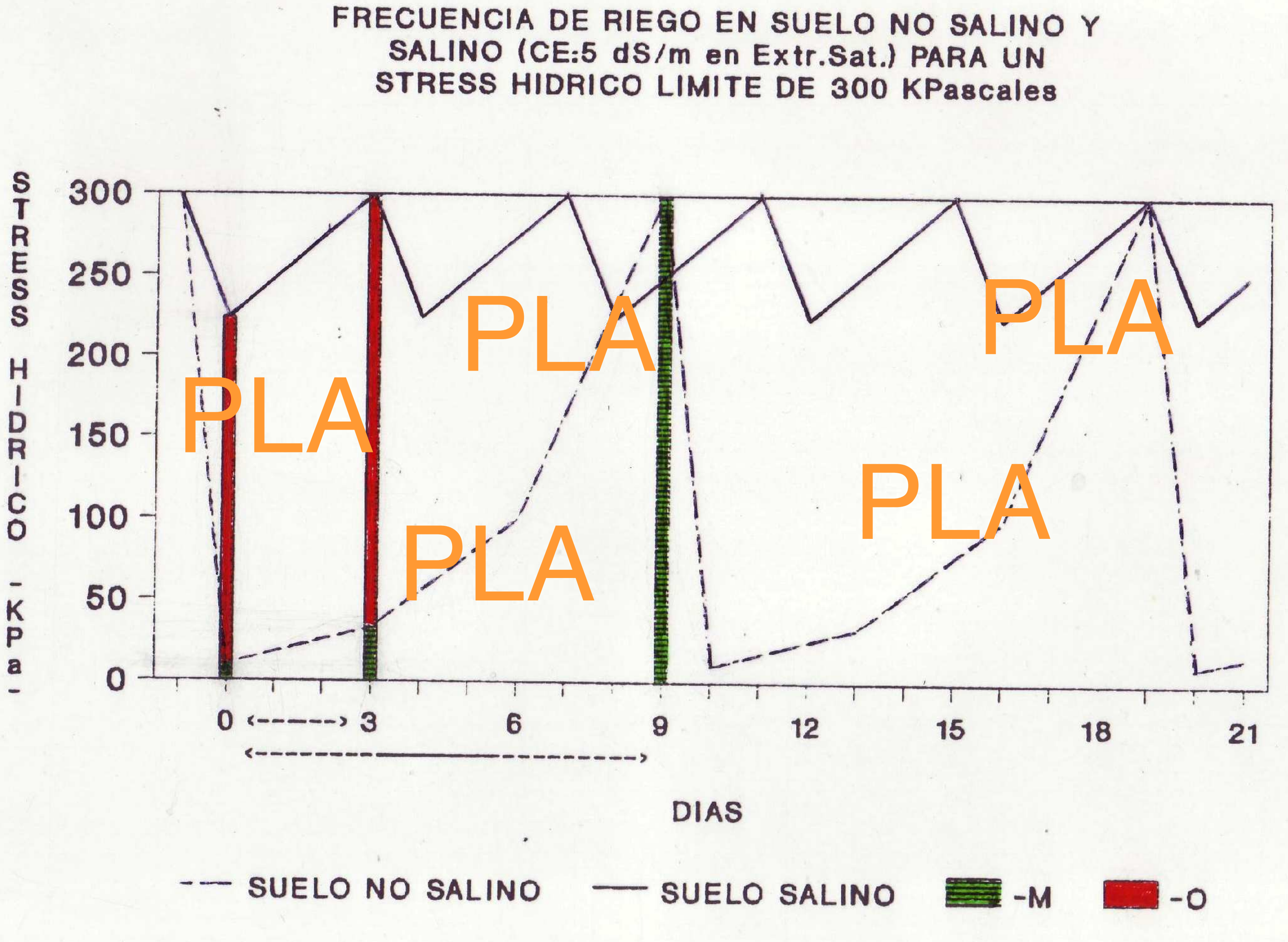

PLA
PLA
PLA
PLA
PLA
PLA
PLA




PLA
PLA
PLA
PLA
PLA
PLA
PLA

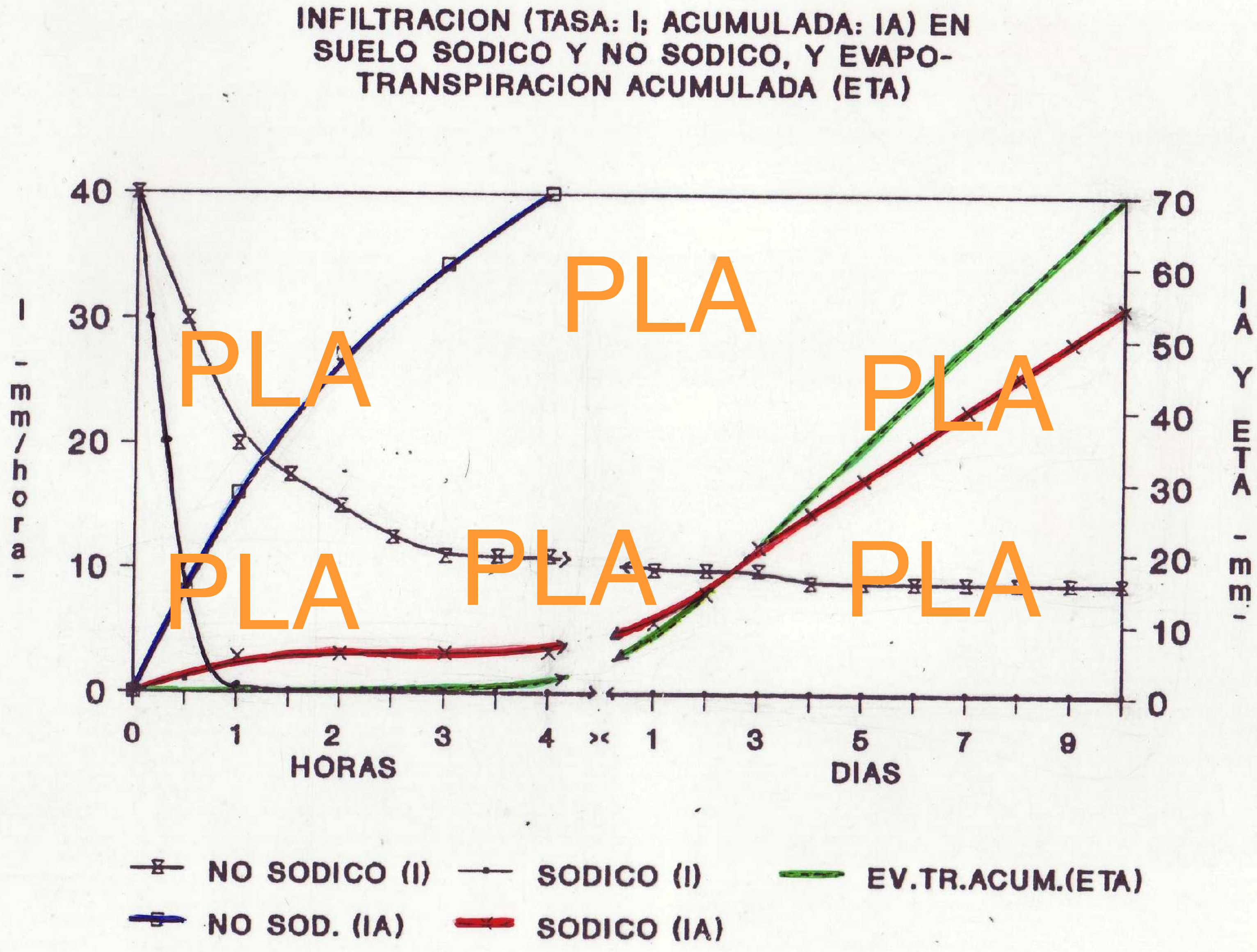

© H. KRAUSE, 2000


PLA
PLA
PLA
PLA
PLA
PLA
PLA



(STRESS HIDRICO:-(M+O); M:Potencial Mátrico; O:Potencial Osmótico)

Figura 1

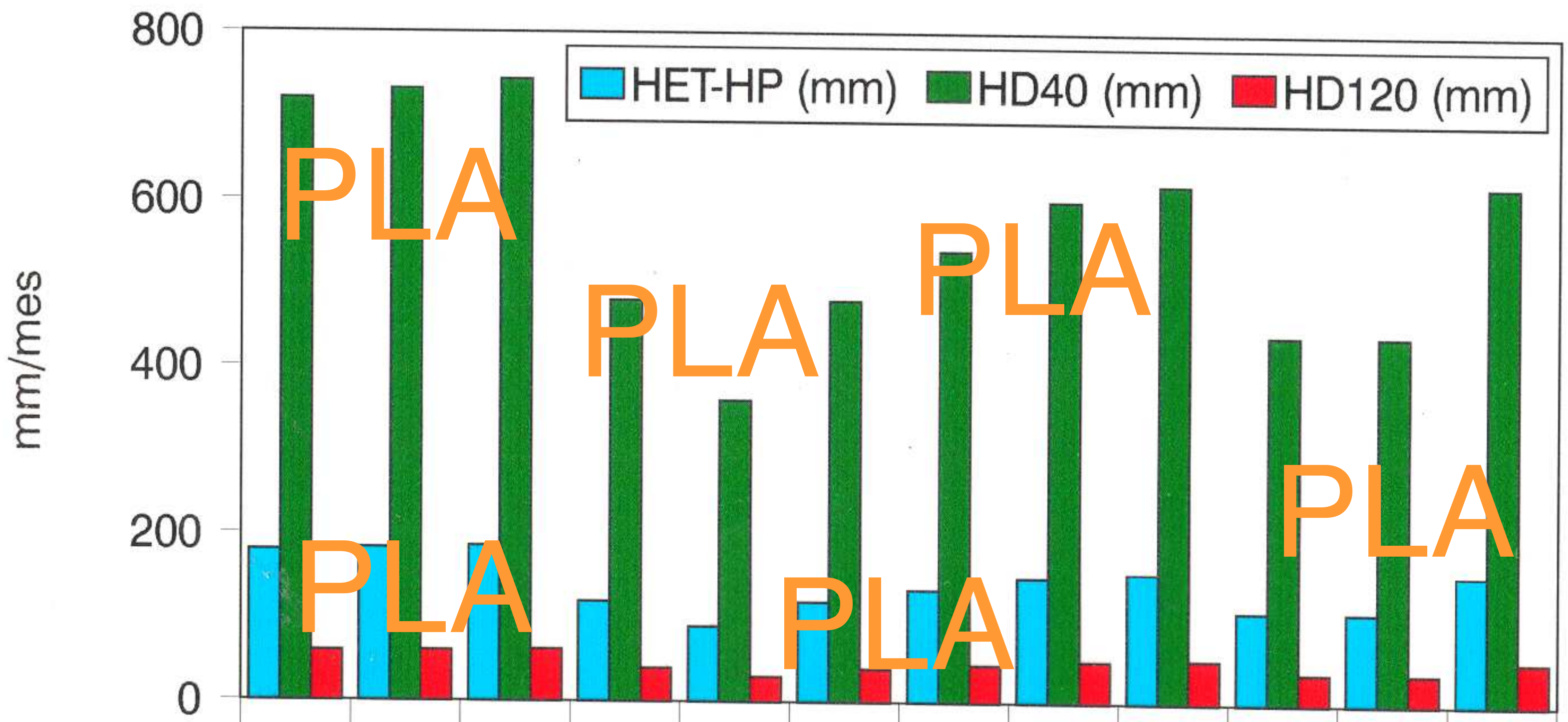


INFILTRACION (TASA: I; ACUMULADA: IA) EN SUELO SODICO Y NO SODICO, Y EVAPO-TRANSPIRACION ACUMULADA (ETA)
I - mm/hora -
IA Y ETA - mm -
HORAS
DIAS
NO SODICO (I)
SODICO (I)
EV.TR.ACUM.(ETA)
NO SOD. (IA)
SODICO (IA)
PLA

Figura 2

Figura 6. Requerimientos de riego (HR = HET-P+HD) y de drenaje (HD) para cultivos sensibles (STES: 40 meq/l) (HD40) y tolerantes (STES: 120 meq/l) (HD120) en un clima árido tropical

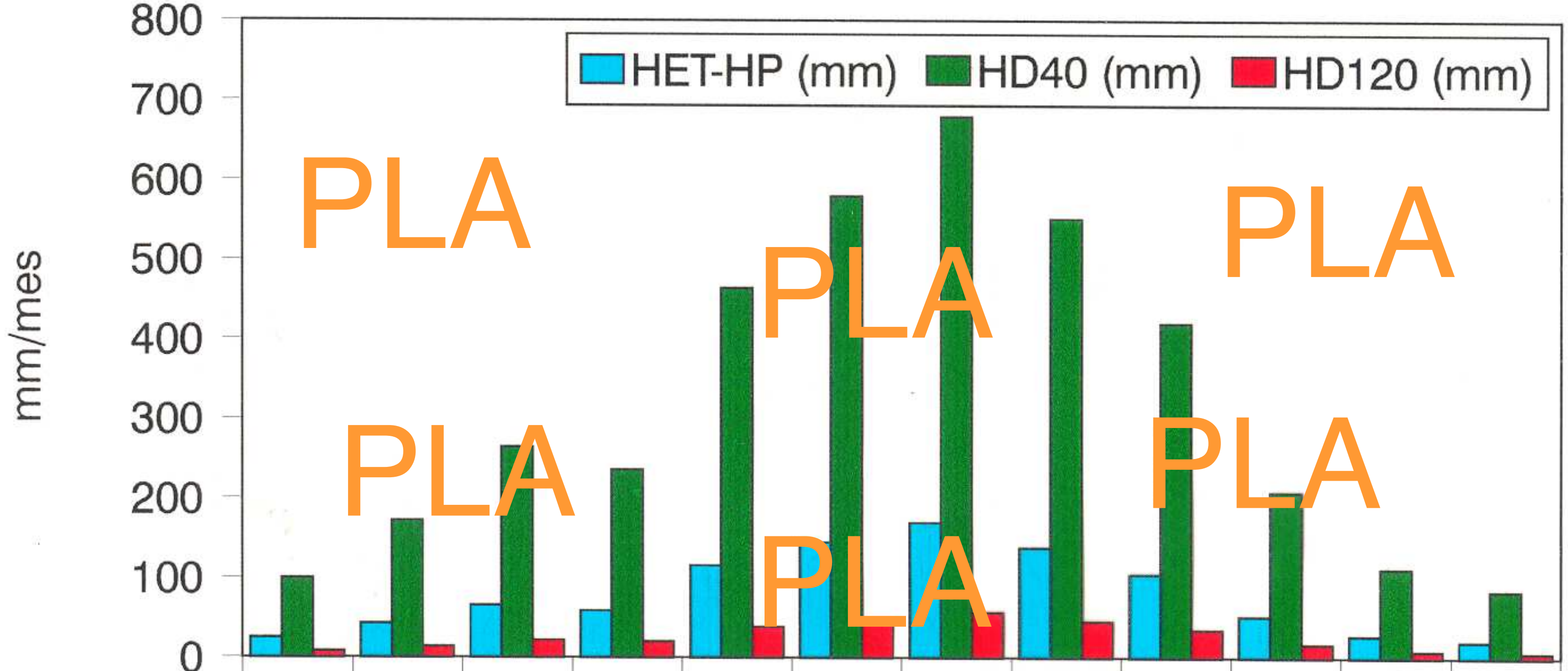
AGUA I (LFST40 = 0,48; LFST120 = 0,13; F = 0,6)



	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC
HET-HP (mm)	180	183	186	120	90	120	135	150	155	110	110	155
HD40 (mm)	720	732	744	480	360	480	540	600	620	440	440	620
HD120 (mm)	60	61	62	40	30	40	45	50	52	37	37	52

Figura 6. Requerimientos de riego (HR = HET-P+HD) y de drenaje (HD) para cultivos sensibles (STES: 40 meq/l) (HD40) y tolerantes (STES: 120 meq/l) (HD120) en un clima mediterráneo semiárido

AGUA I (LFST40 = 0,48; LFST120 = 0,13; F = 0,6)



	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC
HET-HP (mm)	25	43	66	59	116	145	170	138	105	52	28	21
HD40 (mm)	100	172	264	236	464	580	680	552	420	208	112	84
HD120 (mm)	8	14	22	20	39	48	57	46	35	17	9	7

Promoting the sustainability of irrigated agriculture in semi-arid regions by:

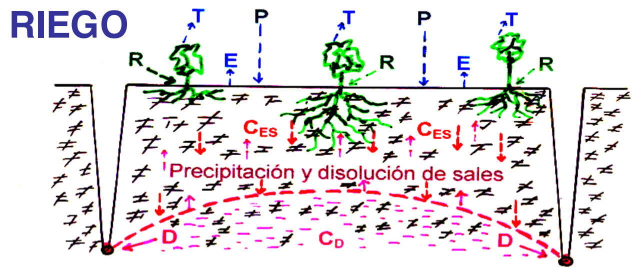
-Conducting research to develop methods for evaluating, predicting, and managing the movement of water, salts and nutrients in the root and vadose zones

-Developing new soil-water management strategies to make effective use of limited water resources available to agriculture

La adición de agua de riego, junto con las sales disueltas, residuos y otros contaminantes al suelo puede causar cambios drásticos en el régimen y balance de agua y solutos en el perfil del suelo. Estos cambios y efectos también se presentan en condiciones de secano cuando ocurren alteraciones en la profundidad y composición de las aguas freáticas.

El diagnóstico de los procesos y problemas de salinización y sodificación de los suelos es indispensable para precisar las alternativas más adecuadas y sostenibles de manejo de las tierras, tanto en condiciones de regadío como de secano.

Para dicho diagnóstico se requiere integrar a través de modelos los factores de clima, cultivo, cobertura, calidad de agua de riego y de agua freática; procesos químicos, físicos y biológicos involucrados; y prácticas de manejo del riego y del drenaje.



$H_R = (H_{ET} - H_P) + H_D$ $\quad H_R C_R = H_D C_D \quad (C_{ET} = 0;\ C_P \approx 0)$

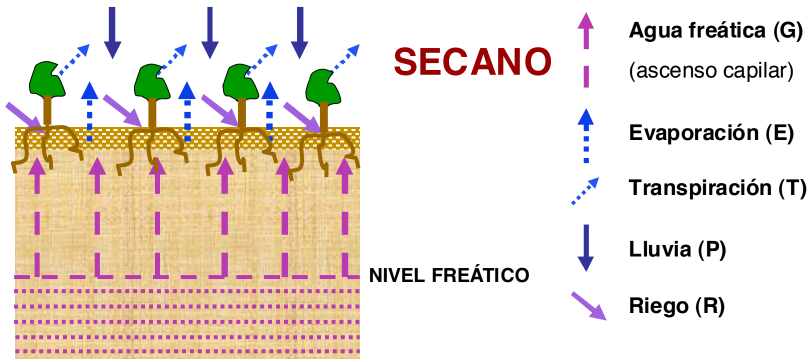
$H_D/H_R = C_R/C_D = L$ $\quad C_D/C_{ES} = F\ (\leq 1)$

$C_D = C_{ES} \times F$ $\quad C_R/(C_{ES} \times F) = L$

$LF = C_R/C_{ES}$

Sales de posible precipitación: $CaCO_3$, $MgCO_3$, $CaSO_4$

Sales de posible disolución: " " "



$L_G = (H_P + H_R) . F / H_G$

L : Fracción de lavado; H : Lámina de agua; F : Eficiencia de lavado

ES: Extracto de saturación

(meq / litro)	Ca	Mg	Na	B	S	CL	RAS	
G:	2	2	8	6	2	4	5,6	(H_R : 0)
Suelo (ES):	2	2	32	12	8	16	22,4	(H_G : 160 mm; H_P : 50 mm)
Suelo (ES):	2	2	128	36	32	64	89,6	(H_G : 160 mm; H_P : 10 mm)

Figura 1. Factores comunes en el desarrollo de suelos afectados por sales en condiciones de riego o de secano.

The increased requirements of <u>more quantitative results in probabilities and risks of soil degradation and its influence on crop production and environmental damage</u>, may be partially satisfied with the <u>use of modeling</u>, where the large number of important variables involved in the degradation processes, and their interactions, may be <u>integrated.</u>

<u>Direct measurements of runoff and soil loss in the traditional erosion field plots</u>, is a <u>slow and costly process</u>, due to the high variability of climate and soils in time and space, which makes it <u>not practical in places where the resources are scarce and there are required short term solutions.</u>

The <u>simple field techniques</u> must be preferred, because of <u>operational considerations</u>, and because they are more <u>able to be adapted to the required sample volume and spatial variation</u> - there are possible more replicate measurements- of soil hydraulic properties <u>under field conditions</u>.

Although <u>modern indirect techniques</u> like <u>remote sensing, computerized data processing, GIS and simulation models</u> may help in the required evaluations, they will always <u>require of actualized and accurate direct measurements or estimations of soil hydraulic parameters</u> .

The presently used <u>empirical models must be replaced with process based event models</u>, which require a <u>better understanding of changing hydrological properties</u> as influenced by soil management, cropping sequences, vegetation, and climate.

<u>Simulation models based on hydrological processes</u> may be very helpful to <u>integrate and to convert the measured or estimated soil, climate, plant and management parameters into predicted soil water balances and soil moisture regimes</u> for each particular combination of them, actual or previewed.

These models may be <u>very simple</u>, or they can be <u>extremely complex</u>.

<u>Simulation errors</u> derived from estimation errors in soil properties and <u>the sampling costs</u> are generally <u>lower when simple models are used</u> for predicting water balance in space.

Additionally, <u>simpler models require fewer input data</u>, and therefore they <u>allow larger samples and sampling densities</u> for a given field measurement.

ELSEVIER

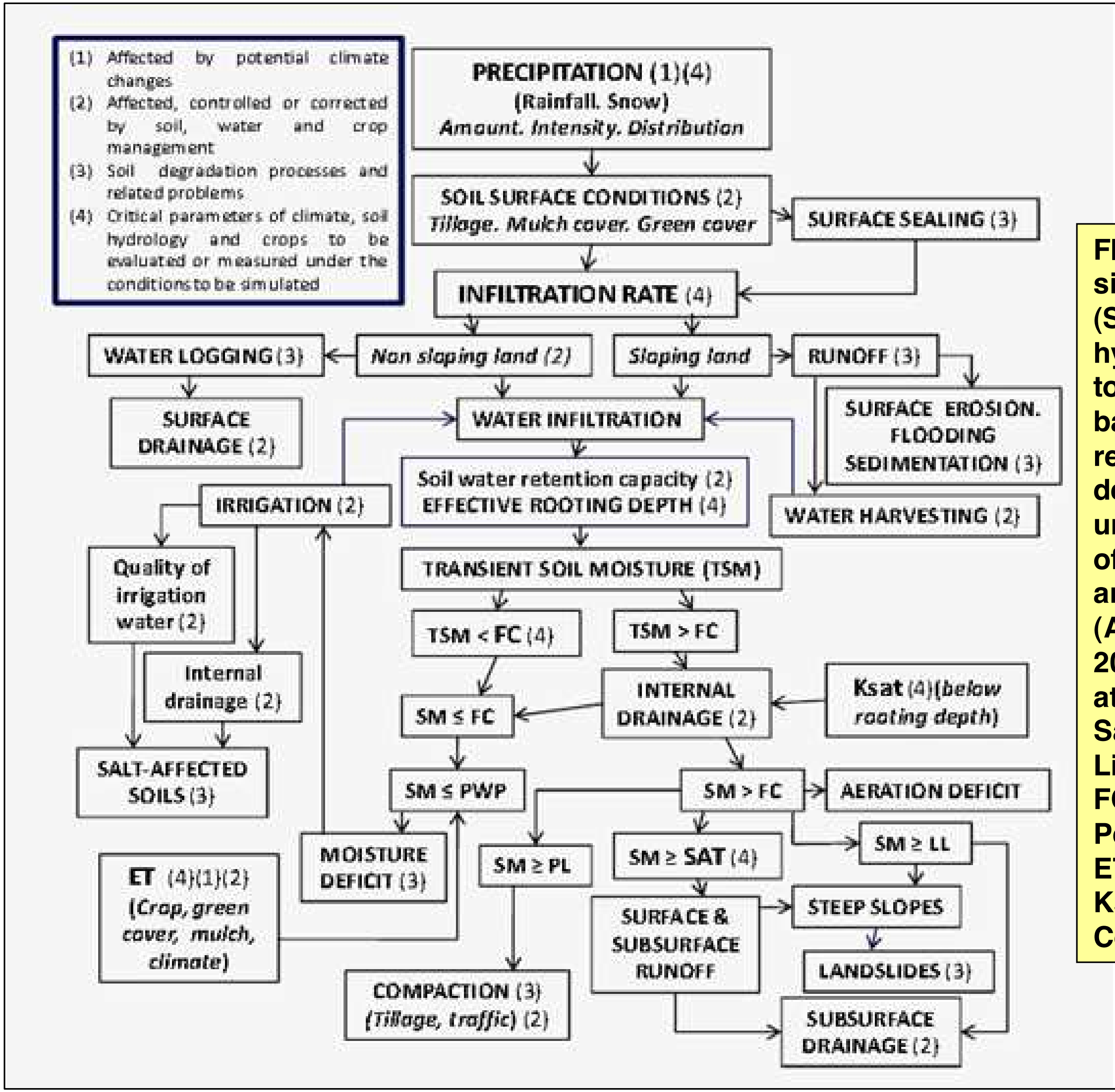
Soil Technology 11 (1997) 17–30

SOIL
TECHNOLOGY

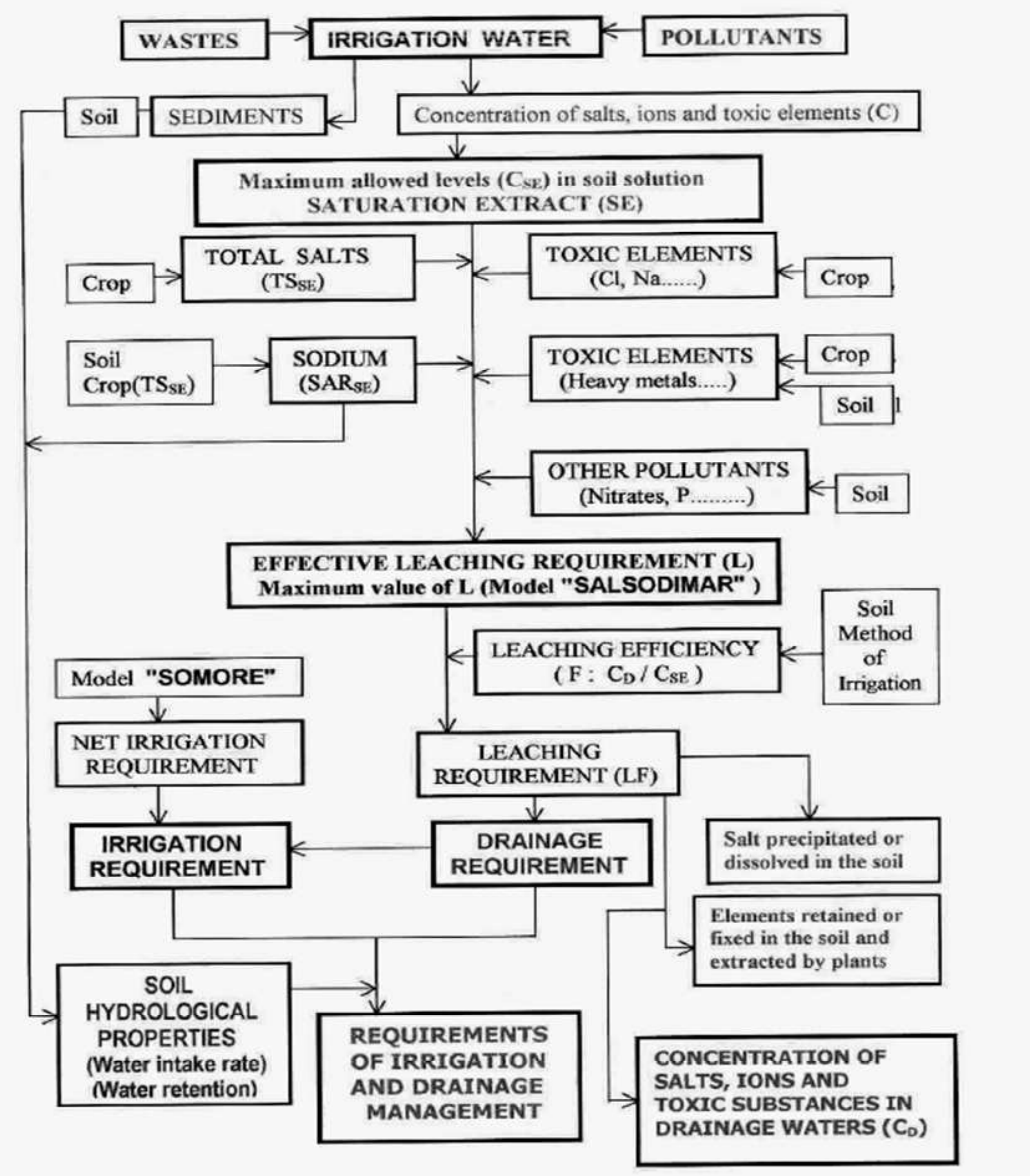
A soil water balance model for monitoring soil erosion processes and effects on steep lands in the tropics

Ildefonso Pla Sentís *

Facultad de Agronomía, Universidad Central de Venezuela, Apartado 1131 (Las Acacias), Maracay, Venezuela



Flow diagram of a simulation model (SOMORE) based on hydrological processes to predict soil water balance, soil moisture regime and derived soil degradation processes under different scenarios of climate, soil and soil and water management (Adapted from Pla, 1997, 2006) (SM: Soil moisture at root depth; SAT: Saturation; LL: Liquid Limit;PL:Plastic Limit; FC:Field Capacity; PWP: Permanent wilting point; ET:Evapo-Transpiration; Ksat: Saturated Hydraulic Conductivity)



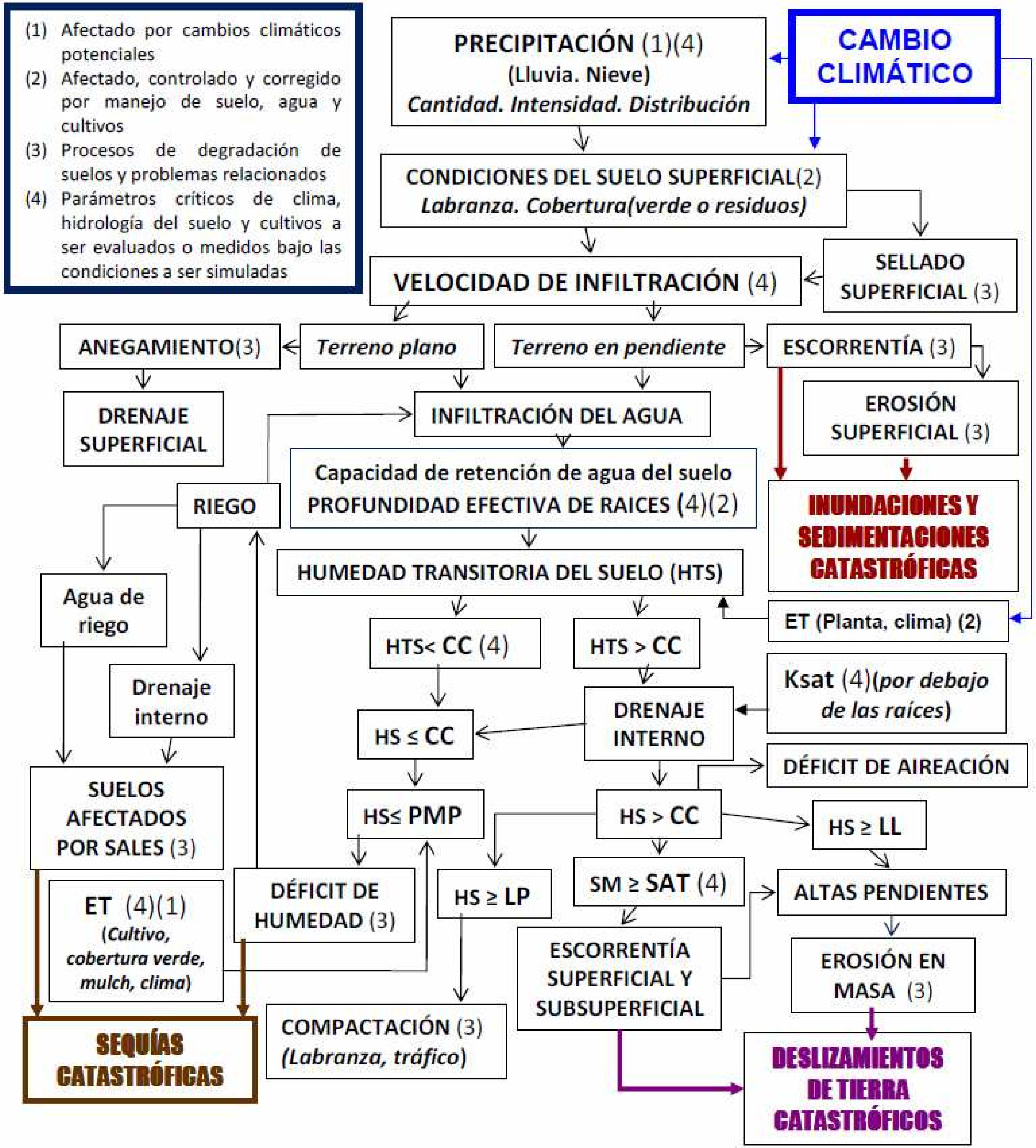
Flow diagram of the model "SALSODIMAR" (I. Pla, 1997)

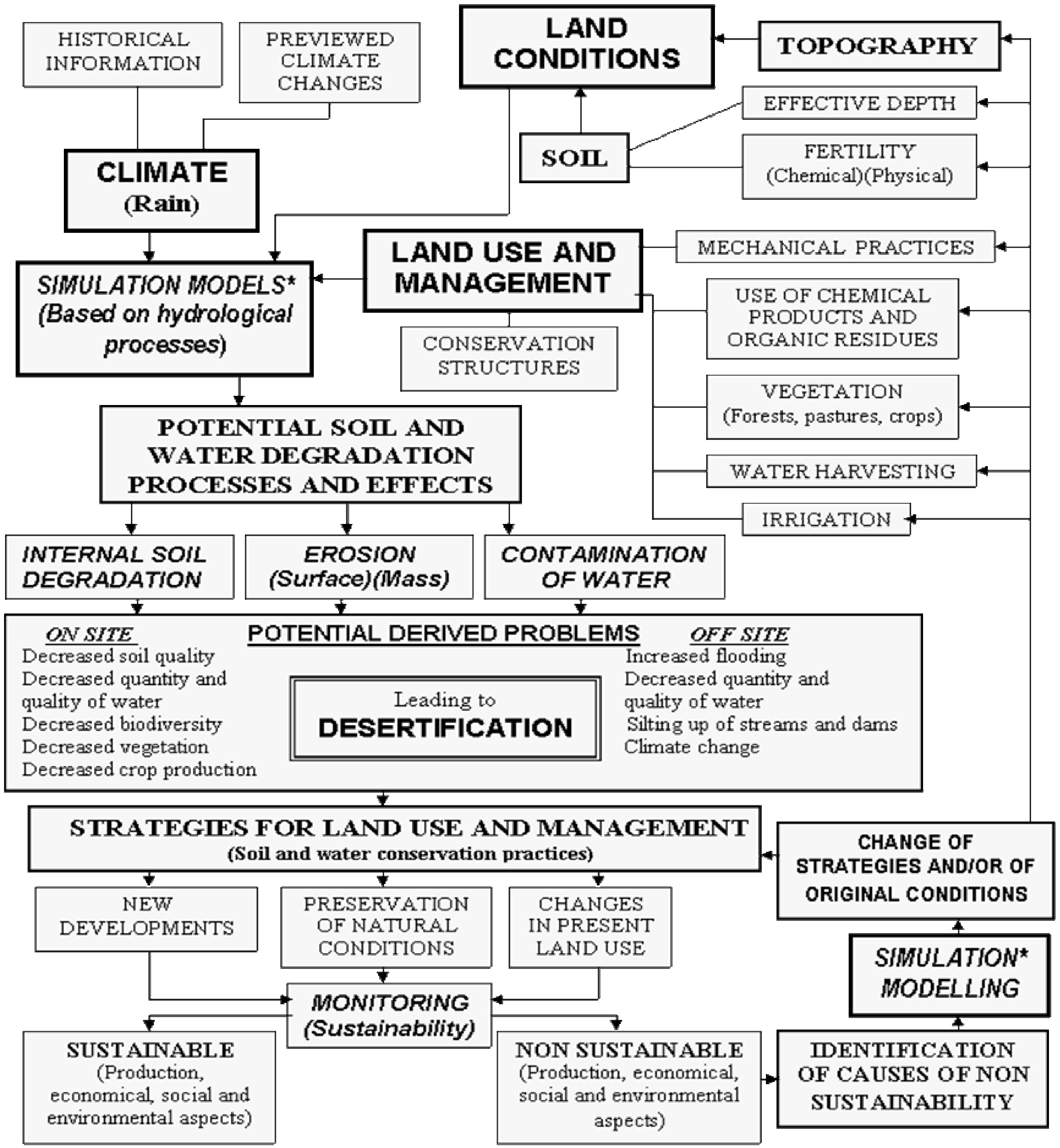
The simulation model SOMORE simulates the evolution of the soil water balance and regime in the soil

The predictions may be used to identify the more probable soil degradation processes, and for the selection of the best alternatives of soil and water conservation practices for each combination of soils, climate and topography

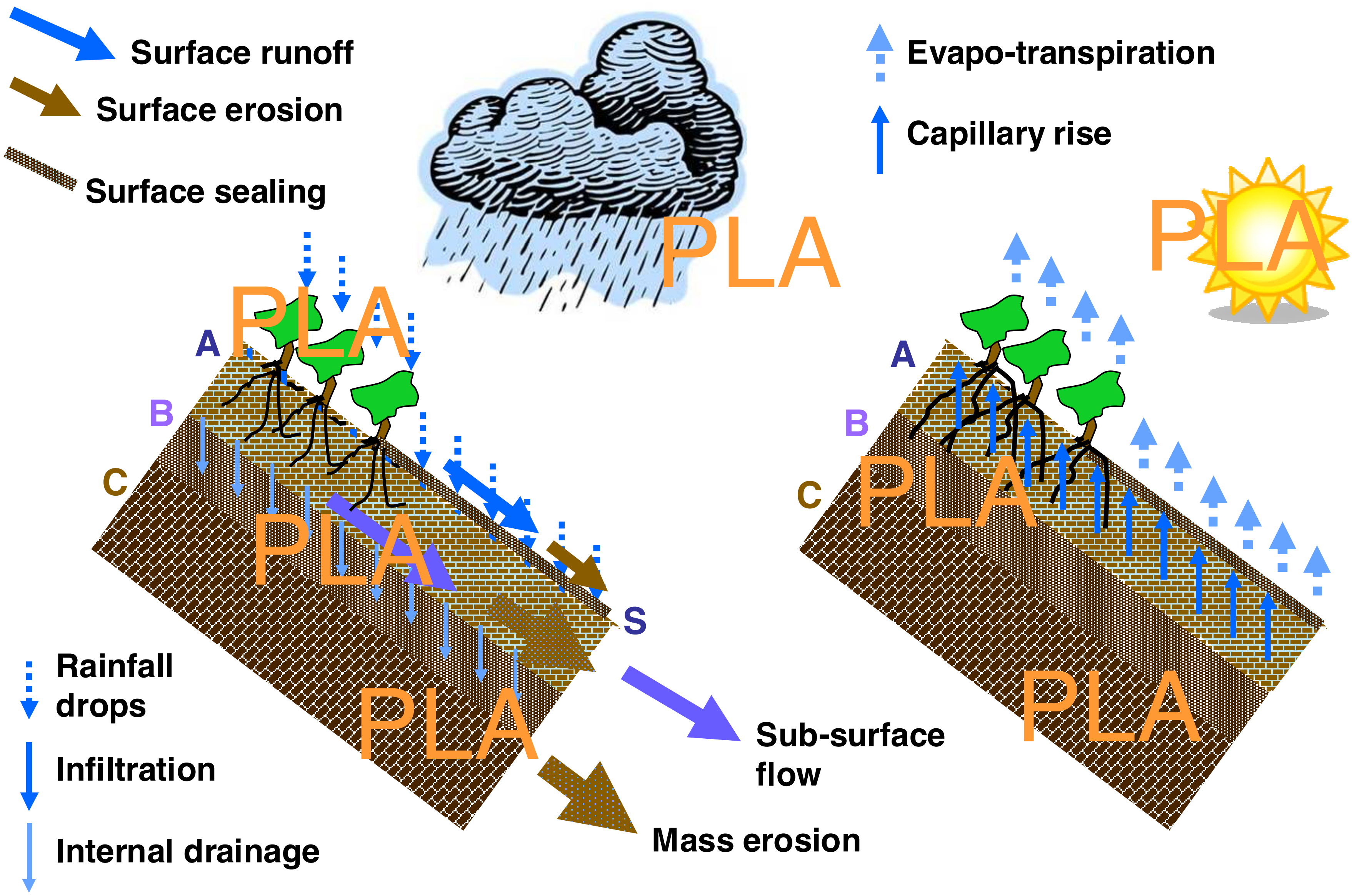
The main output of the model is the soil moisture regime at root depth, and the water losses by runoff and internal drainage

The predicted soil moisture regime may be interpreted in relation to problems of drought, at different times and growth stages of natural vegetation and crops

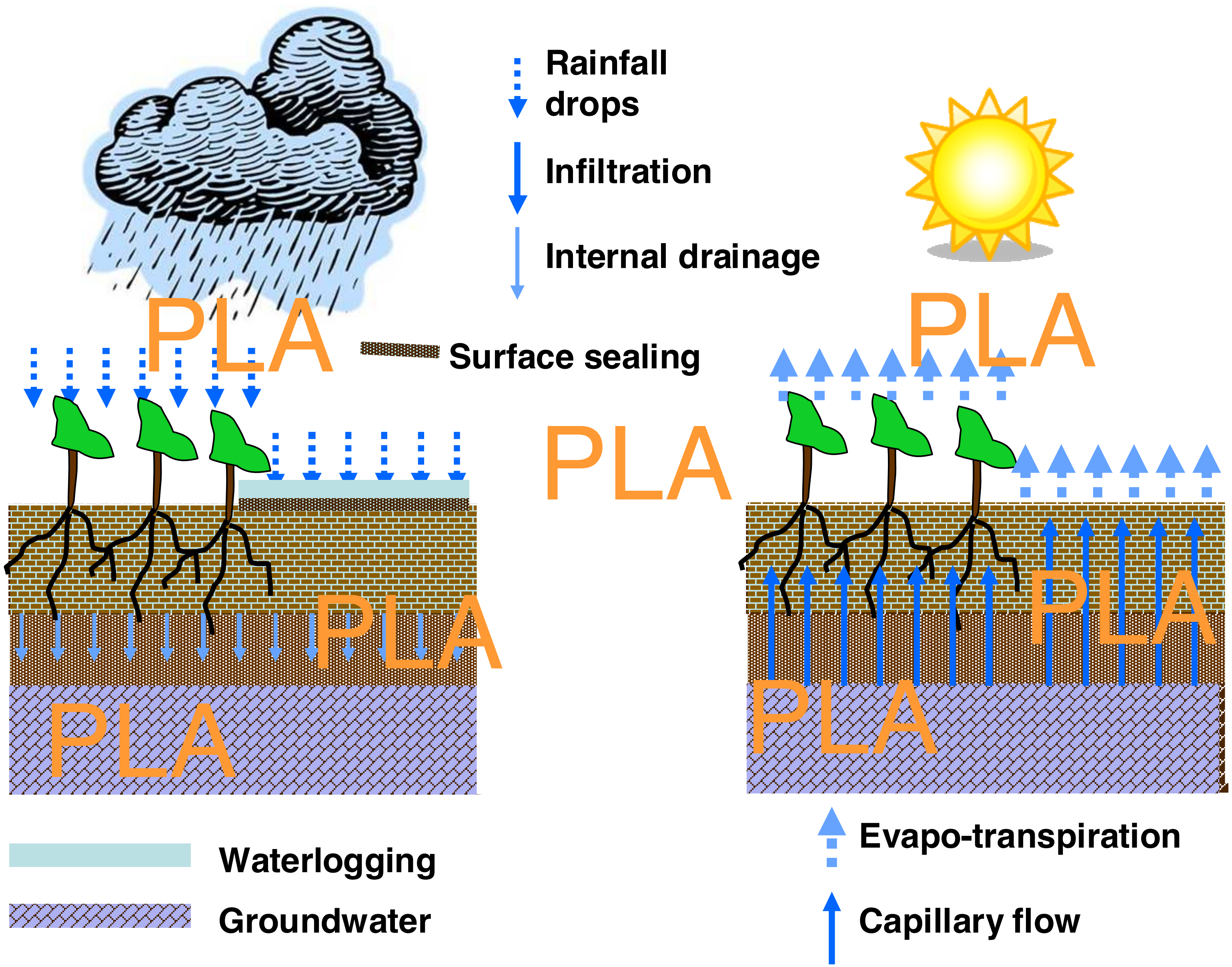

(1) Afectado por cambios climáticos potenciales
(2) Afectado, controlado y corregido por manejo de suelo, agua y cultivos
(3) Procesos de degradación de suelos y problemas relacionados
(4) Parámetros críticos de clima, hidrología del suelo y cultivos a ser evaluados o medidos bajo las condiciones a ser simuladas
PRECIPITACIÓN (1)(4)
(Lluvia. Nieve)
Cantidad. Intensidad. Distribución
CAMBIO CLIMÁTICO
CONDICIONES DEL SUELO SUPERFICIAL(2)
Labranza. Cobertura(verde o residuos)
SELLADO SUPERFICIAL (3)
VELOCIDAD DE INFILTRACIÓN (4)
ANEGAMIENTO(3)
Terreno plano
Terreno en pendiente
ESCORRENTÍA (3)
DRENAJE SUPERFICIAL
INFILTRACIÓN DEL AGUA
EROSIÓN SUPERFICIAL (3)
Capacidad de retención de agua del suelo
PROFUNDIDAD EFECTIVA DE RAICES (4)(2)
RIEGO
INUNDACIONES Y SEDIMENTACIONES CATASTRÓFICAS
HUMEDAD TRANSITORIA DEL SUELO (HTS)
Agua de riego
ET (Planta, clima) (2)
HTS< CC (4)
HTS > CC
Drenaje interno
Ksat (4)(por debajo de las raíces)
DRENAJE INTERNO
HS ≤ CC
DÉFICIT DE AIREACIÓN
SUELOS AFECTADOS POR SALES (3)
HS≤ PMP
HS > CC
HS ≥ LL
ET (4)(1)
(Cultivo, cobertura verde, mulch, clima)
DÉFICIT DE HUMEDAD (3)
HS ≥ LP
SM ≥ SAT (4)
ALTAS PENDIENTES
ESCORRENTÍA SUPERFICIAL Y SUBSUPERFICIAL
EROSIÓN EN MASA (3)
COMPACTACIÓN (3)
(Labranza, tráfico)
SEQUÍAS CATASTRÓFICAS
DESLIZAMIENTOS DE TIERRA CATASTRÓFICOS



Role of simulation modelling based on hydrological processes for evaluating potential soil and land degradation and desertification, and for planning land use, management



HYDROLOGICAL FACTORS AND PROCESSES INCLUDED IN THE HYDROLOGICALLY BASED SIMULATION MODEL, SOMORE (FOR SLOPING LANDS)



HYDROLOGICAL FACTORS AND PROCESSES INCLUDED IN THE HYDROLOGICALLY BASED SIMULATION MODEL, SOMORE (FOR FLAT LANDS)

Model "SOMORE" (I. Pla 1997)

REQUIRED INFORMATION (DAY BY DAY)

R: Total rainfall **(mm)**

V_R : Rainfall intensity **(mm/hour)**

V_I : Infiltration rate **(mm/hour)**

ET: Evapo-transpiration **(mm/day)**

P: Effective depth of the soil **(mm)** (depth with the 90% of the root development if the main interest is the soil water regime in relaltion to plant development; depth to the limiting layer for internal drainage in case of studies related with groundwater level or with processes of mass erosion)

K_{Ss} : Saturated hydraulic conductivity of the soil at depth P **(mm/hour)**

Θ_{SAT} : Volumetric moisture of the soil P at saturation **(m^3 / m^3)**

L_{SAT} (mm): Θ_{SAT} . P (L : Water depth)

Θ_{LL} : Volumetric moisture of the soil P at liquid limit **(m^3 / m^3)**

L_{LL} (mm): Θ_{LL} . P

Θ_{CC}: Volumetric moisture of the soil P at field capacity **(m^3 / m^3)**

L_{CC} (mm): Θ_{CC} . P

Θ_{PMP} : Volumetric moisture of the soil P at wilting point **(m^3 / m^3)**

L_{PMP} (mm): Θ_{PMP} . P

Θ_{Si} : Volumetric moisture of the soil P at the beginning of the day **(m^3 / m^3)**

L_{Si} (mm): Θ_{Si} . P

INFORMATION TO BE CALCULATED (DAY BY DAY)

$\mathbf{E_I}$: Surface runoff due to reduced infiltration **(mm/day)**

$\mathbf{E_{SAT}}$: Surface runoff due to soil saturation by water **(mm/day)**

$\mathbf{D_I}$: Internal drainage **(mm/day)**

$\mathbf{T_{DI}}$: Time with soil moisture above Θ_{CC}: **(hours/day)**

$\mathbf{D_{ss}}$: Sub-surface runoff **(mm/day)**

$\mathbf{L_{Ai}}$: Surface waterlogging due to reduced infiltration at the beginning of the day **(mm)**

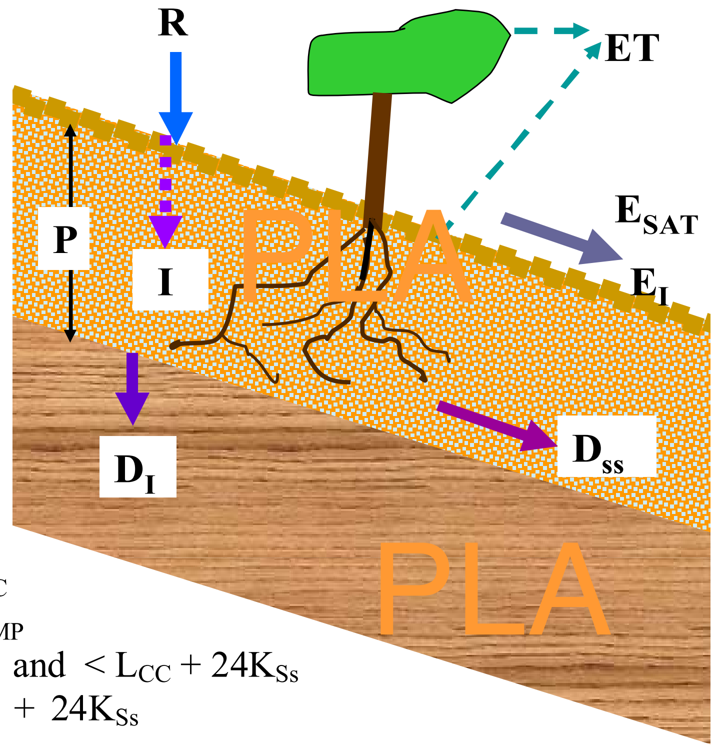
$\mathbf{L_{Af}}$: Surface waterlogging due to reduced infiltration at the end of the day **(mm)**

$\mathbf{L_{Af\ (SAT)}}$: Surface waterlogging due to soil saturation at the end of the day **(mm)**

$\mathbf{T_A}$: Time with waterlogging due to reduced infiltration **(hours/day)**

$\mathbf{T_{A\ (SAT)}}$: Time with waterlogging due to soil saturation **(hours / day)**

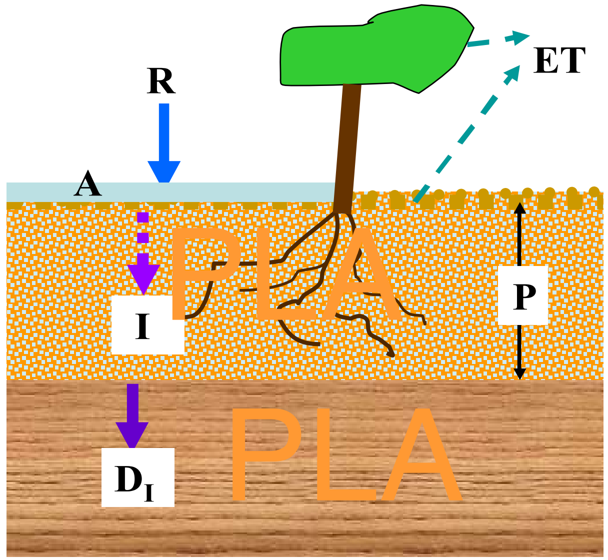
$\mathbf{L_{Sf}}$: Soil moisture (depth) in P at the end of the day **(mm)**



CALCULATIONS (SLOPING LAND)

$E_I = (R - 10) - ((R . V_I) / V_R)$ (mm)	if E_I (calculated) > 0
$E_I = 0$ (mm)	if E_I (calculated) ≤ 0
$L_{Sf} = L_{Si} + (R - E_I) - ET$ (mm)	if L_{Sf} (calculated) $\leq L_{CC}$
$L_{Sf} = L_{PMP}$ (mm)	if L_{Sf} (calculated) $\leq L_{PMP}$
$L_{Sf} = L_{CC}$ (mm)	if L_{Sf} (calculated) $> L_{CC}$ and $< L_{CC} + 24K_{Ss}$
$L_{Sf} = L_{Si} + (R - E_I) - 24\,K_{Ss} - ET$ (mm)	if L_{Sf} (calculated) $\geq L_{CC} + 24K_{Ss}$
$L_{Sf} = L_{SAT}$ (mm)	if L_{Sf} (calculated) $\geq L_{SAT}$
$E_{SAT} + D_{ss} = L_{Sf}$(calculated) $- L_{SAT}$ (mm)	if L_{Sf} (calculated) $\geq L_{SAT}$
$E_{SAT} + D_{ss} = 0$ (mm)	if L_{Sf} (calculated) $< L_{SAT}$
$D_I = L_{Sf}$(calculated) $- L_{CC}$ (mm)	if D_I (calculated) > 0 and $< 24K_{Ss}$
$D_I = 24K_{Ss}$ (mm)	if D_I (calculated) $\geq 24K_{Ss}$
$D_I = 0$ (mm)	if D_I (calculated) ≤ 0

$T_{DI} = D_I / K_{Ss}$ (hours / day)



CALCULATIONS (FLAT LAND)

$L_{Af} = L_{Ai} + R - 24V_I - ET$ (mm)	if L_{Af} (calculated) ≥ 0
$L_{Af} = 0$ (mm)	if L_{Af} (calculated) < 0
$L_{Ai} = L_{Af}$ (from the previous day) (mm)	
$T_A = (L_{Ai} + R - ET) / V_I$ (hours/day)	if T_A (calculated) > 0 y ≤ 24
$T_A = 24$ (hours/day)	if T_A (calculated) > 24
$T_A = 0$ (hours/day)	if T_A (calculated) ≤ 0
$L_{Sf} = L_{Si} + ((R + L_{Ai}).(V_I / V_R))$ - ET (mm)	if L_{Sf} (calculated) $< L_{CC}$
$L_{Sf} = L_{CC}$ (mm)	if L_{Sf} (calculated) $\geq L_{CC}$ and $< L_{CC} + 24K_{Ss}$
$L_{Sf} = L_{Si} + ((R + L_{Ai}).(V_I / V_R)) - 24K_{Ss}$ - ET (mm)	if L_{Sf} (calculated) $\geq L_{CC} + 24K_{Ss}$
$L_{Sf} = L_{SAT}$ (mm)	if L_{Sf} (calculated) $\geq L_{SAT}$
$L_{Sf} = L_{PMP}$ (mm)	if L_{Sf} (calculated) $\leq L_{PMP}$
$L_{Af\,(SAT)} = L_{Sf}$ (calculated) $- L_{SAT}$ (mm)	if $L_{Af(SAT)}$ (calculated) > 0
$T_{A\,(SAT)} = (L_{Sf}$ (calculated) $- L_{SAT}) / K_{Ss}$ (hours)	if $T_{A(SAT)}$ (calculated) > 0
$T_{A\,(SAT)} = 0$ (hours)	if $T_{A(SAT)}$ (calculated) ≤ 0
$D_I = (L_{Sf} - L_{CC}) / K_{Ss}$ (mm)	if D_I (calculated) > 0
$D_I = 0$ (mm)	if D_I (calculated) ≤ 0
$T_{DI} = D_I / K_{Ss}$ (hours/day)	if T_{DI} (calculated) < 24
$T_{DI} = 24$ (hours/day)	if T_{DI} (calculated) ≥ 24

SOMORE (SOIL MOISTURE REGIME MODEL)
Version 3,0 (August 1991)

A computer simulation model and program for predicting the moisture regime of agricultural soils in relation to crops, tillage, irrigation and drainage practices, under specific (average, extreme or probable) climatic conditions, various management systems, and different processes and degrees of soil physical degradation.

Developed by:
Prof. Dr. ILDEFONSO PLA SENTÍS*

Programmed by:
Carlos A. Pla Burgos

***Facultad de Agronomía, Universidad Central de Venezuela**
Maracay, Venezuela

This program and model calculates the daily soil moisture regime, including the degree and duration of water-logging, and the amounts of water losses by runoff or internal drainage, or stored in the soil, making a classification of the days with different levels of soil moisture deficits or excesses for each growing period of the crop, giving the irrigation water requirements. It incorporates easily measured physical properties and rooting depths, for different climates and soil physical conditions, representative or product of various soil management practices and degradation processes.

EXAMPLE OF INPUT OF THE MODEL

Water regime in dryland vineyards
NON-LEVELED, WITHOUT COVER, SLOPING LAND IN ALT PENEDÉS (SPAIN)

Location, Climate and Crop:

Location: **Masquefa** Latitude: **41º 29´ N** Longitude: **1º 48´ E** Altitude : **260 m. asl**
Annual rainfall : **400-700 mm/year**
Rainy season (period) : **September-February** Rainfall: **250-500 mm**
Dry season (period) : **March-August** Rainfall: **150-200 mm**
Type of year: **Humid** Return period: **5 years**
Slope: **20 %** Crop: **Vineyards for wine and cava production (Chardonay)**
Interval: **October 1996 – September 1997**

Given Conditions and Values

Possibilities of runoff or surface drainage: **Yes**
Effective rooting depth of the soil: **800 mm**
Average of predominant rainfall intensities: **40 mm/hour**
Average infiltration rate: **20 mm/hour**
Saturated hydraulic conductivity of the subsoil: **3 mm/hour**
Soil moisture (vol/vol) of soil DS at saturation: **0.40**
Soil moisture (vol/vol) of soil DS at liquid limit: **0.38**
Soil moisture (vol/vol) of soil DS at plastic limit: **0.30**
Soil moisture (vol/vol) of soil DS at field capacity: **0.28**
Soil moisture (vol/vol) of soil DS at a tension of 0.15 Mpa: **0.12**
Soil moisture (vol/vol) of soil DS at a tension of 1.5 Mpa: **0.08**
Soil moisture (vol/vol) of soil DS the first day: **0.12**

EXAMPLE OF DAILY OUTPUT OF THE MODEL

- 1 -

Day	HR (mm)	HET (mm)	HSD (mm)	HWL-TWL (mm)	(h)	HID-TID (mm)	(h)	TLI (h)	HAS (mm)	HDS (mm)	HIR (mm)	Class.	
1	0	1.0	0	0	0	0	0	0	0	53	0	DT	
2	60	2.0	0	48	6	0	0	0	0	111	0	DA	
3	10	2.0	0	8	1	0	0	0	0	119	0	DA	
4	0	2.0	0	0	0	0	0	0	0	117	0	DA	
5	0	1.0	0	0	0	0	0	0	0	116	0	DA	
6	0	1.0	0	0	0	0	0	0	0	115	0	DA	
7	0	1.0	0	0	0	0	0	0	0	114	0	DA	
8	0	1.0	0	0	0	0	0	0	0	113	0	DA	
9	0	1.0	0	0	0	0	0	0	0	112	0	DA	
10	0	1.0	0	0	0	0	0	0	0	111	0	DA	
11	0	1.0	0	0	0	0	0	0	0	110	0	DA	
12	0	1.0	0	0	0	0	0	0	0	109	0	DA	
13	0	1.0	0	0	0	0	0	0	0	108	0	DA	
14	0	1.0	0	0	0	0	0	0	0	107	0	DA	
15	0	1.0	0	0	0	0	0	0	0	106	0	DA	
16	0	1.0	0	0	0	0	0	0	0	105	0	DA	
17	0	1.0	0	0	0	0	0	0	0	104	0	DA	
18	0	1.0	0	0	0	0	0	0	0	103	0	DA	
19	0	1.0	0	0	0	0	0	0	0	102	0	DA	
20	0	1.0	0	0	0	0	0	0	0	101	0	DA	
21	0	1.0	0	0	0	0	0	0	0	100	0	DA	
22	0	1.0	0	0	0	0	0	0	0	99	0	DA	
23	0	1.0	0	0	0	0	0	0	0	98	0	DA	
24	0	1.0	0	0	0	0	0	0	0	97	0	DA	
25	0	1.0	0	0	0	0	0	0	0	96	0	DA	
26	0	1.0	0	0	0	0	0	0	0	95	0	DA	
27	0	1.0	0	0	0	0	0	0	0	94	0	DA	
28	0	1.0	0	0	0	0	0	0	0	93	0	DA	
29	0	1.0	0	0	0	0	0	0	0	92	0	DA	
30	0	1.0	0	0	0	0	0	0	0	91	0	DA	
31	0	1.0	0	0	0	0	0	0	0	90	0	DA	
32	0	1.0	0	0	0	0	0	0	0	89	0	DA	
33	50	2.0	0	40	5	11	5	0	0	126	0	DA	
34	30	2.0	0	24	3	28	14	0	0	126	0	DA	
35	0	1.0	0	0	0	0	0	0	0	125	0	DA	
36	0	1.0	0	0	0	0	0	0	0	124	0	DA	
37	0	1.0	0	0	0	0	0	0	0	123	0	DA	
38	0	0.0	0	0	0	0	0	0	0	123	0	DA	
39	0	0.0	0	0	0	0	0	0	0	123	0	DA	
40	0	0.0	0	0	0	0	0	0	0	123	0	DA	
41	0	0.0	0	0	0	0	0	0	0	123	0	DA	
42	0	0.0	0	0	0	0	0	0	0	123	0	DA	
43	0	0.0	0	0	0	0	0	0	0	123	0	DA	
44	30	2.0	0	24	3	25	13	0	0	126	0	DA	
45	10	2.0	0	8	1	8	4	0	0	126	0	DA	
46	0	1.0	0	0	0	0	0	0	0	125	0	DA	
47	100	2.0	0	80	10	48	24	9	0	175	0	DA	DL
48	60	2.0	0	48	6	48	24	14	0	185	0	DE	DL
49	10	2.0	0	8	1	48	24	0	0	145	0	DA	DL
50	0	1.0	0	0	0	18	9	0	0	126	0	DA	

Identification of Variables

HR : Rainfall in mm

HET : Evapo-transpiration in mm

HSD: Water losses by runoff ort surface drainage in mm

HWL: Water-logging in mm

TWL: Duration of water-logging in hours

HID: Water losses by internal drainage in mm

TID: Duration of water losses by internal drainage in hours

TLI: Duration of viscous fluid consistence in hours

HAS: Runoff after saturation in mm

HDS : Soil moisture at rooting depth interval (DS) in mm

HDS/DS: Soil moisture (vol/vol) at rooting depth

HIR : Irrigation water requirement (net) in mm.

Clasification of days

DW: Day with water-logging > 12 hours

DS : Day with soil saturated with water > 12 hours

DL : Day with soil at viscous fluid consistence > 12 hours

DA: Day with adequate soil moisture (CC – 0,15 MPa)

DT: Day with moisture stress (0,15 MPa – 1,5 MPa)

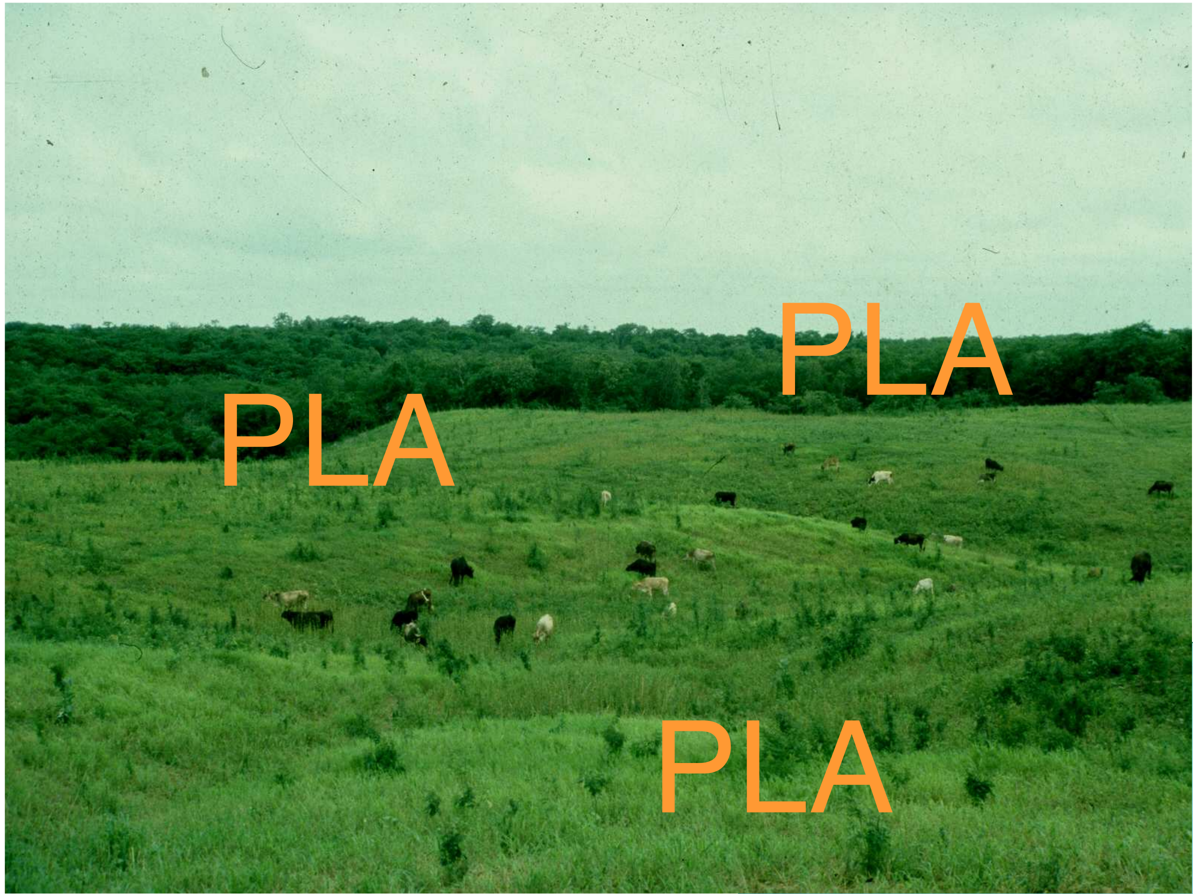
DP: Day with defficit of soil moisture (< 1,5 MPa)

DI: Day with irrigation requirement

EXAMPLE OF DAILY OUTPUT OF THE MODEL

Day	HR (mm)	HET (mm)	HSD (mm)	HWL-TWL (mm)	(h)	HID-TID (mm)	(h)	TLI (h)	HAS (mm)	HDS (mm)	HIR (mm)	Class.	
276	0	4.0	0	0	0	0	0	0	0	44	0	DT	
277	0	4.0	0	0	0	0	0	0	0	40	0	DT	
278	0	4.0	0	0	0	0	0	0	0	36	0	DT	
279	0	4.0	0	0	0	0	0	0	0	36	4	DP	DI
280	0	4.0	0	0	0	0	0	0	0	36	4	DP	DI
281	16	4.0	3	0	0	0	0	0	0	45	0	DT	
282	12	4.0	0	0	0	0	0	0	0	53	0	DT	
283	0	4.0	0	0	0	0	0	0	0	49	0	DT	
284	0	4.0	0	0	0	0	0	0	0	45	0	DT	
285	0	4.0	0	0	0	0	0	0	0	41	0	DT	
286	0	4.0	0	0	0	0	0	0	0	37	0	DT	
287	0	4.0	0	0	0	0	0	0	0	36	3	DP	DI
288	20	4.0	6	0	0	0	0	0	0	46	0	DT	
289	8	4.0	0	0	0	0	0	0	0	50	0	DT	
290	0	4.0	0	0	0	0	0	0	0	46	0	DT	
291	0	4.0	0	0	0	0	0	0	0	42	0	DT	
292	0	4.0	0	0	0	0	0	0	0	38	0	DT	
293	0	4.0	0	0	0	0	0	0	0	36	2	DP	DI
294	0	4.0	0	0	0	0	0	0	0	36	4	DP	DI
295	0	4.0	0	0	0	0	0	0	0	36	4	DP	DI
296	0	5.0	0	0	0	0	0	0	0	36	5	DP	DI
297	0	5.0	0	0	0	0	0	0	0	36	5	DP	DI
298	0	5.0	0	0	0	0	0	0	0	36	5	DP	DI
299	0	5.0	0	0	0	0	0	0	0	36	5	DP	DI
300	0	5.0	0	0	0	0	0	0	0	36	5	DP	DI
301	0	5.0	0	0	0	0	0	0	0	36	5	DP	DI
302	2	5.0	0	0	0	0	0	0	0	36	3	DP	DI
303	0	5.0	0	0	0	0	0	0	0	36	5	DP	DI
304	0	5.0	0	0	0	0	0	0	0	36	5	DP	DI
305	0	5.0	0	0	0	0	0	0	0	36	5	DP	DI
306	10	5.0	0	0	0	0	0	0	0	41	0	DT	
307	0	4.0	0	0	0	0	0	0	0	37	0	DT	
308	4	4.0	0	0	0	0	0	0	0	37	0	DT	
309	10	4.0	0	0	0	0	0	0	0	43	0	DT	
310	10	3.0	0	0	0	0	0	0	0	50	0	DT	
311	0	3.0	0	0	0	0	0	0	0	47	0	DT	
312	10	3.0	0	0	0	0	0	0	0	54	0	DA	
313	0	2.0	0	0	0	0	0	0	0	52	0	DT	
314	0	2.0	0	0	0	0	0	0	0	50	0	DT	
315	0	2.0	0	0	0	0	0	0	0	48	0	DT	
316	0	2.0	0	0	0	0	0	0	0	46	0	DT	
317	0	1.0	0	0	0	0	0	0	0	45	0	DT	
318	0	1.0	0	0	0	0	0	0	0	44	0	DT	
319	0	1.0	0	0	0	0	0	0	0	43	0	DT	
320	0	1.0	0	0	0	0	0	0	0	42	0	DT	
321	0	1.0	0	0	0	0	0	0	0	41	0	DT	
322	0	1.0	0	0	0	0	0	0	0	40	0	DT	
323	0	1.0	0	0	0	0	0	0	0	39	0	DT	
324	0	1.0	0	0	0	0	0	0	0	38	0	DT	
325	0	1.0	0	0	0	0	0	0	0	37	0	DT	
326	0	1.0	0	0	0	0	0	0	0	36	0	DP	
327	0	1.0	0	0	0	0	0	0	0	36	1	DP	DI
328	0	1.0	0	0	0	0	0	0	0	36	1	DP	DI
329	0	1.0	0	0	0	0	0	0	0	36	1	DP	DI

SOME APPLICATIONS OF "SOMORE"

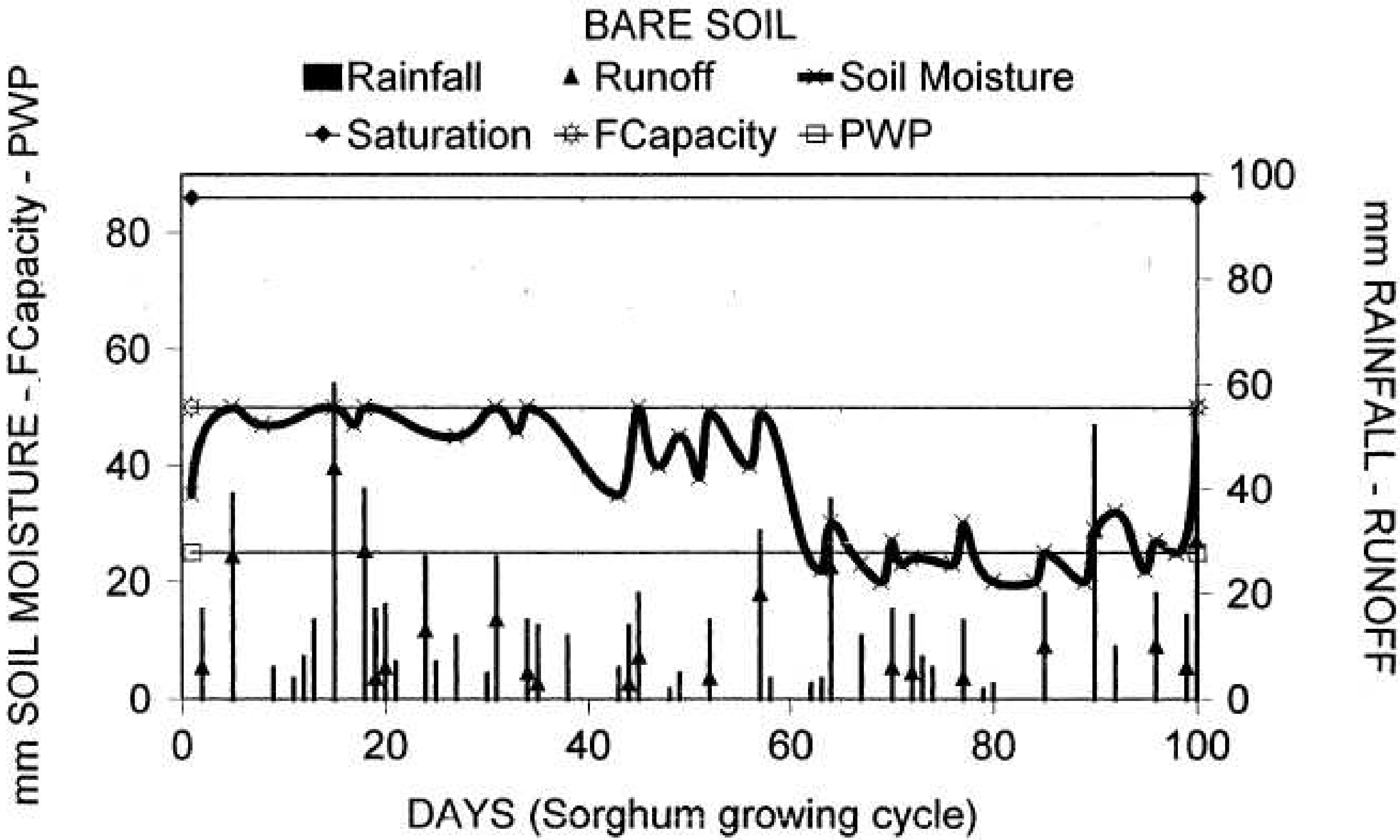



PLA


PLA
PLA
PLA

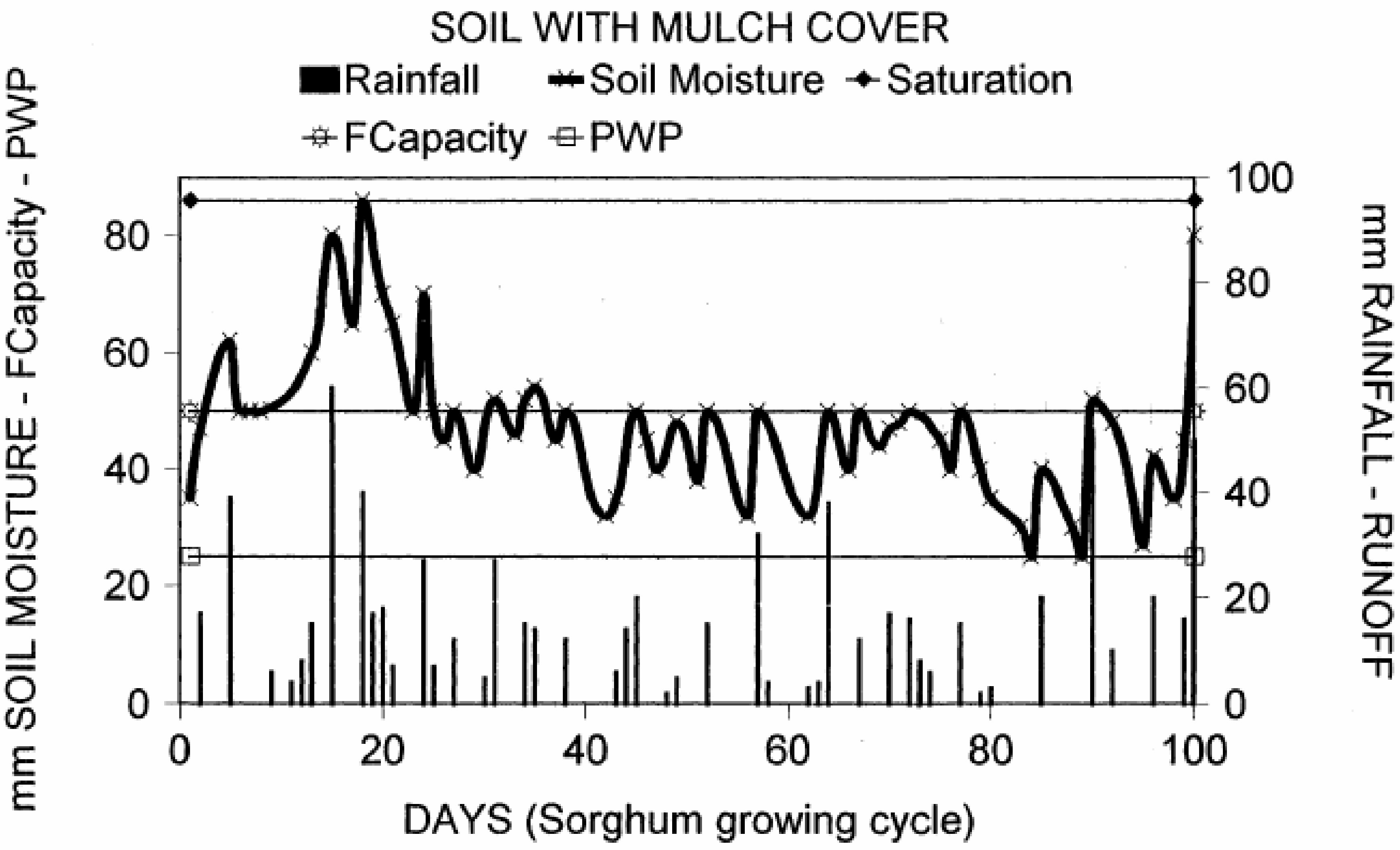

PLA
PLA


PLA

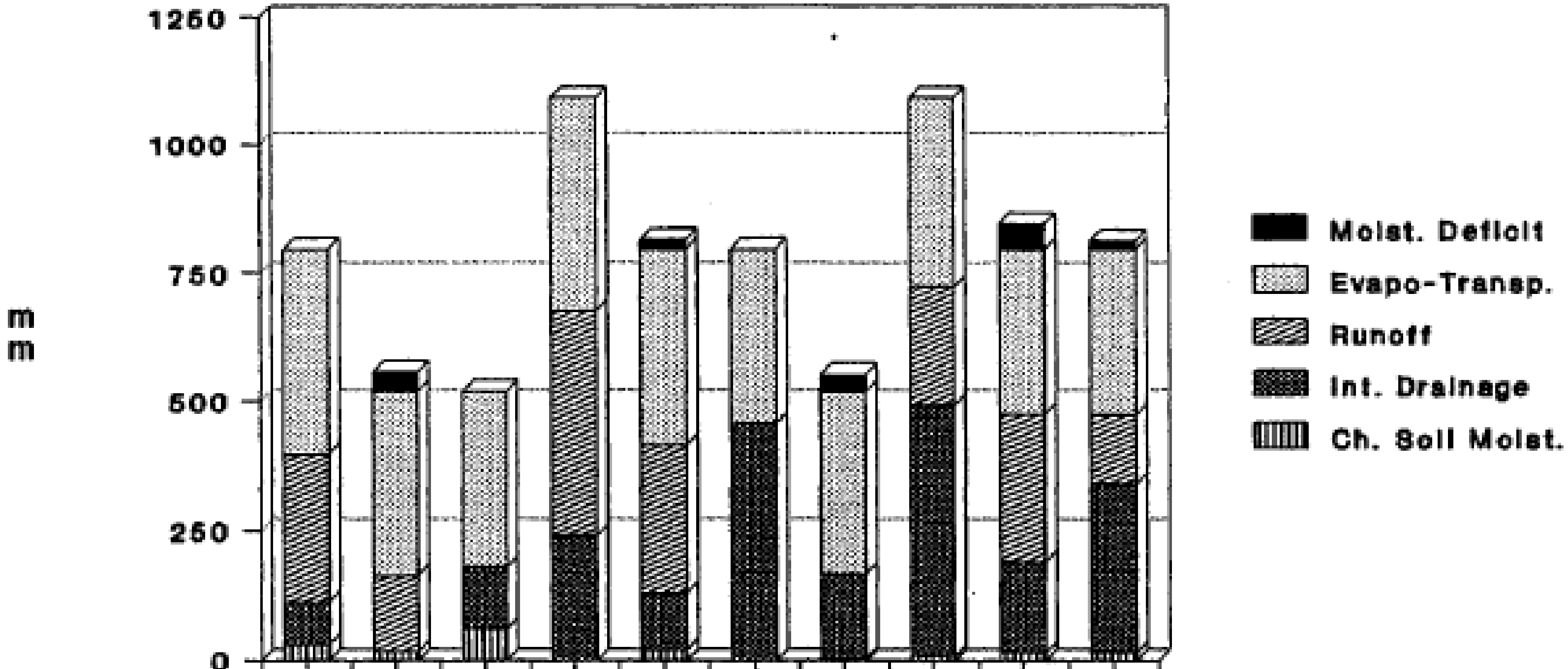


BARE SOIL
Rainfall
Runoff
Soil Moisture
Saturation
FCapacity
PWP
mm SOIL MOISTURE - FCapacity - PWP
mm RAINFALL - RUNOFF
DAYS (Sorghum growing cycle)
0
20
40
60
80
100

FIGURE 7

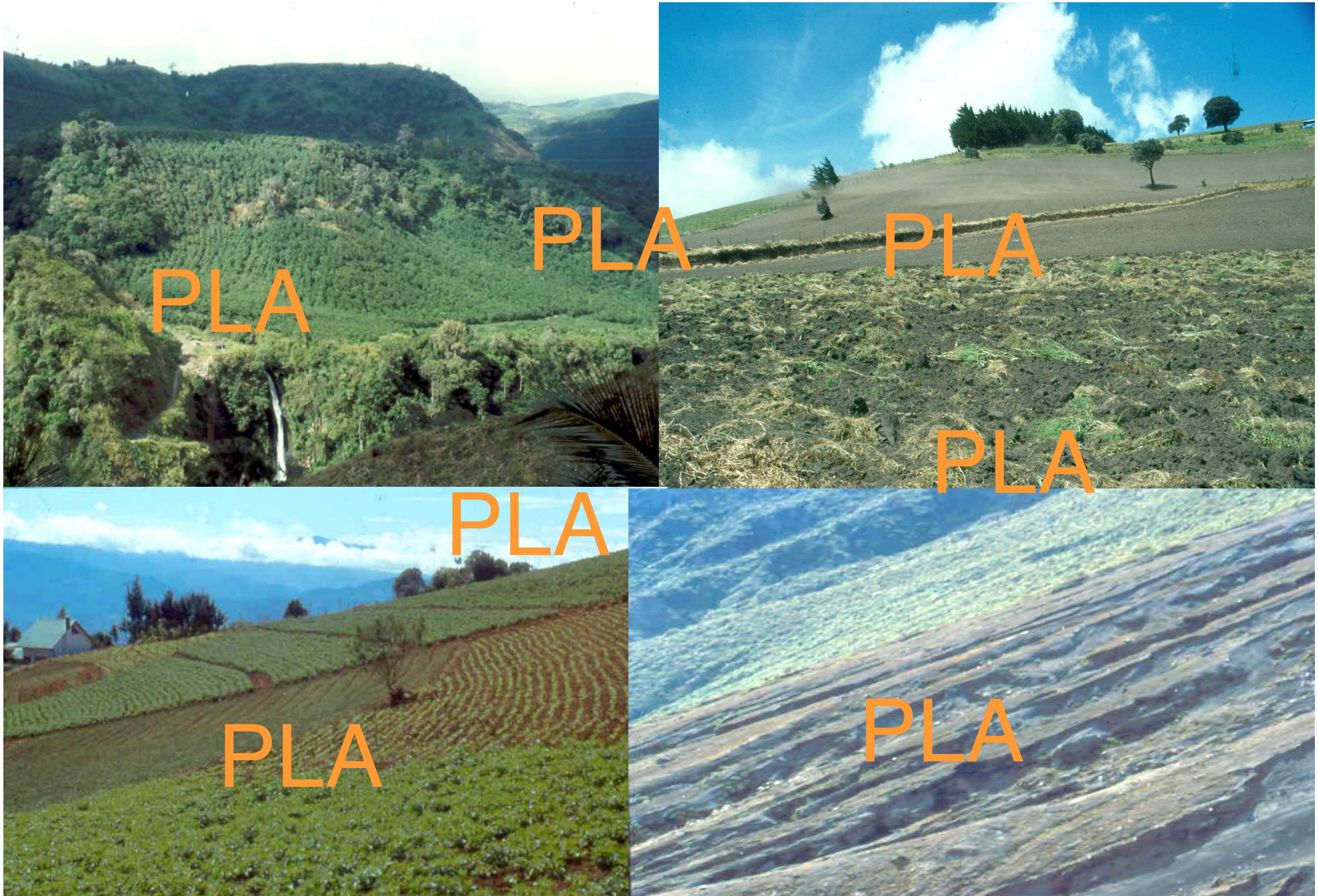


SOIL WITH MULCH COVER
Rainfall
Soil Moisture
Saturation
FCapacity
PWP
mm SOIL MOISTURE - FCapacity - PWP
mm RAINFALL - RUNOFF
0
20
40
60
80
100
DAYS (Sorghum growing cycle)

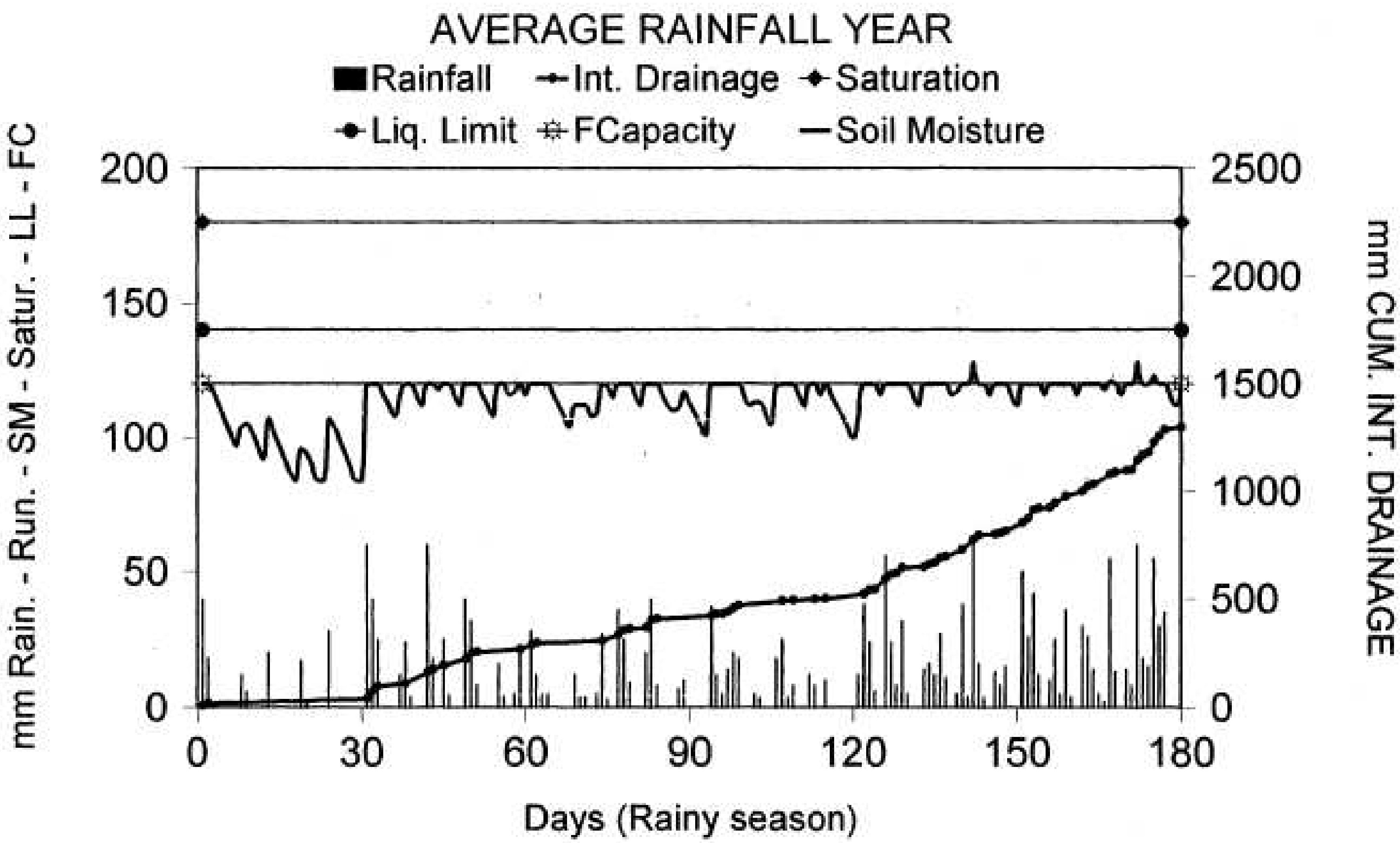


	40cm B A	40cm B L	40cm C L	20cm B H	20cm B A	20cm C A	20cm C L	10cm C H	10cm B A	10cm C A
Moist. Deficit	0	38	0	0	19	0	34	0	49	17
Evapo-Transp.	399	355	340	416	381	340	352	367	321	323
Runoff	285	147	0	436	285	0	0	233	285	133
Int. Drainage	82	0	118	240	109	454	162	482	174	324
Ch. Soil Moist.	30	17	61	0	21	2	5	10	16	16

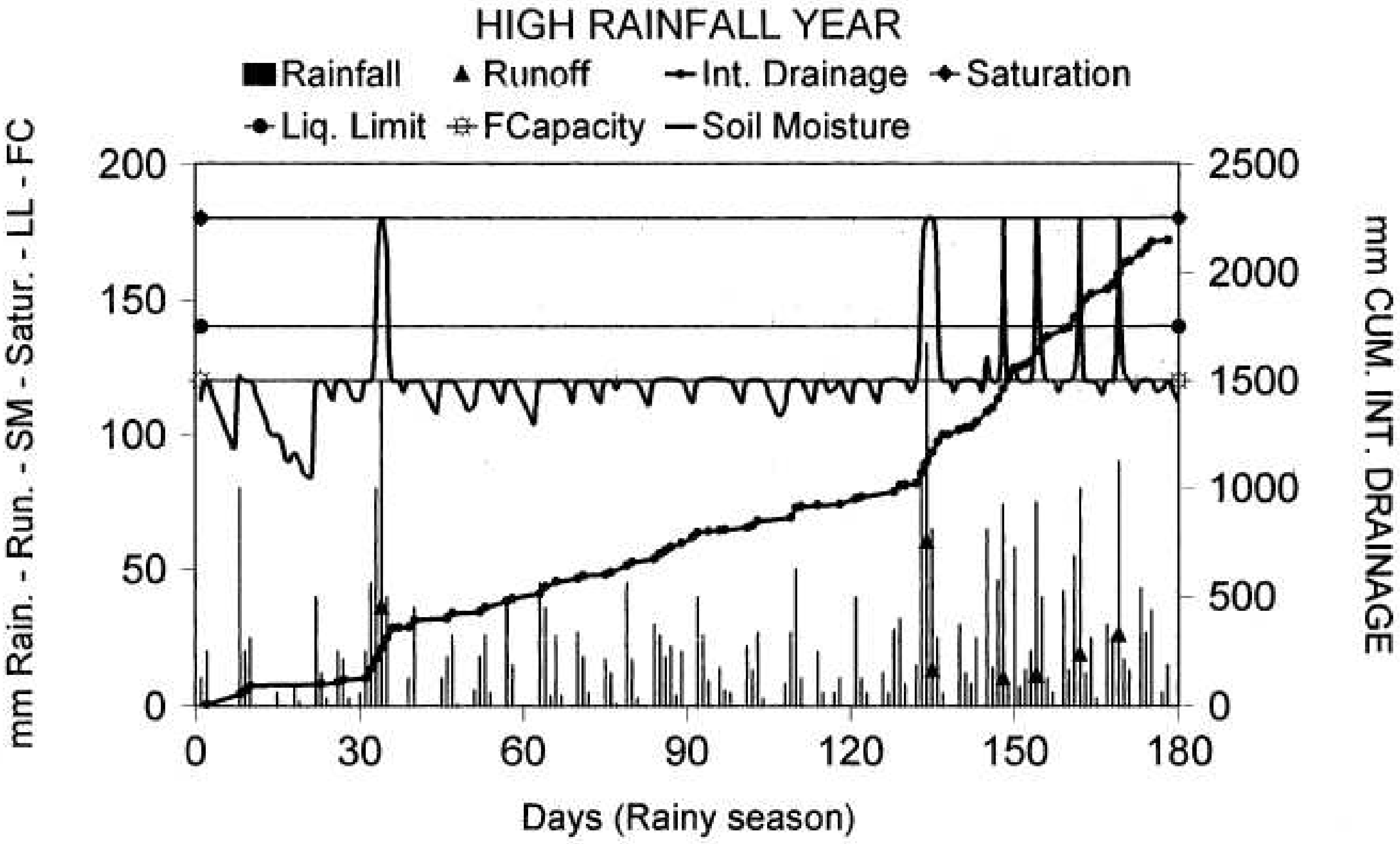
Fig. 3. Water balance in the rooting zone during the growing period of sorghum, in a sandy-loam Alfisol, bare (B) or covered with plant residues (C), under high (H), average (A) and low (L) annual rainfall, and effective rooting depths of 10, 20 and 40 cm. There are shown, for each combination, the total volume in mm of the moisture deficit (Moist. Deficit), evapotranspiration (Evapo-Transp.), surface runoff (Runoff), internal drainage (Int. Drainage) and change in soil moisture (Ch. Soil Moist.).



Soil erosion; Landslides: Forest, Coffee > Annual crops
Costa Rica (volcanic soils)

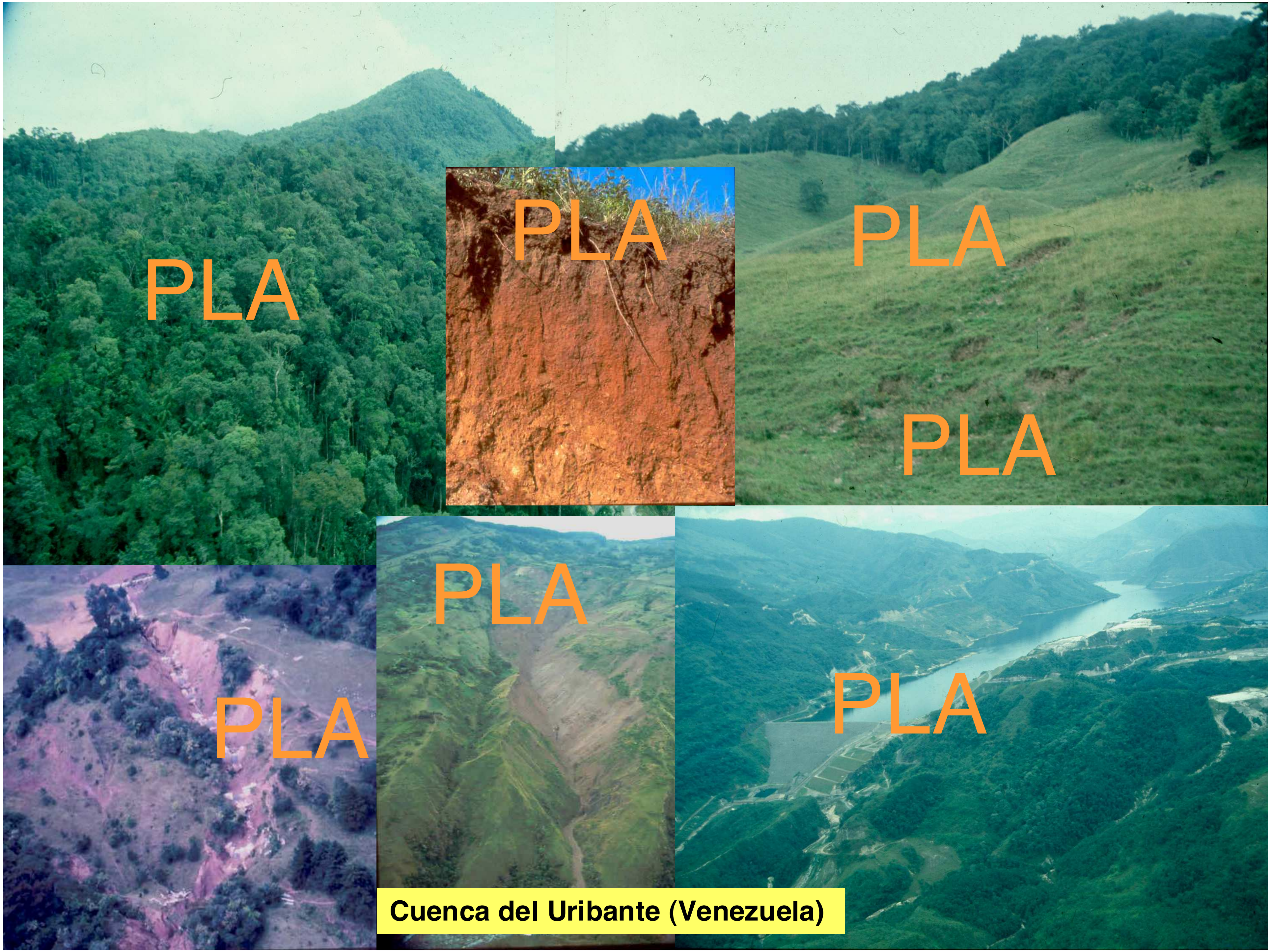


AVERAGE RAINFALL YEAR
Rainfall
Int. Drainage
Saturation
Liq. Limit
FCapacity
Soil Moisture
mm Rain. - Run. - SM - Satur. - LL - FC
mm CUM. INT. DRAINAGE
200
150
100
50
0
2500
2000
1500
1000
500
0
0
30
60
90
120
150
180
Days (Rainy season)



HIGH RAINFALL YEAR
Rainfall
Runoff
Int. Drainage
Saturation
Liq. Limit
FCapacity
Soil Moisture
mm Rain. - Run. - SM - Satur. - LL - FC
mm CUM. INT. DRAINAGE
200
150
100
50
0
2500
2000
1500
1000
500
0
0
30
60
90
120
150
180
Days (Rainy season)

FIGURE 10



Cuenca del Uribante (Venezuela)

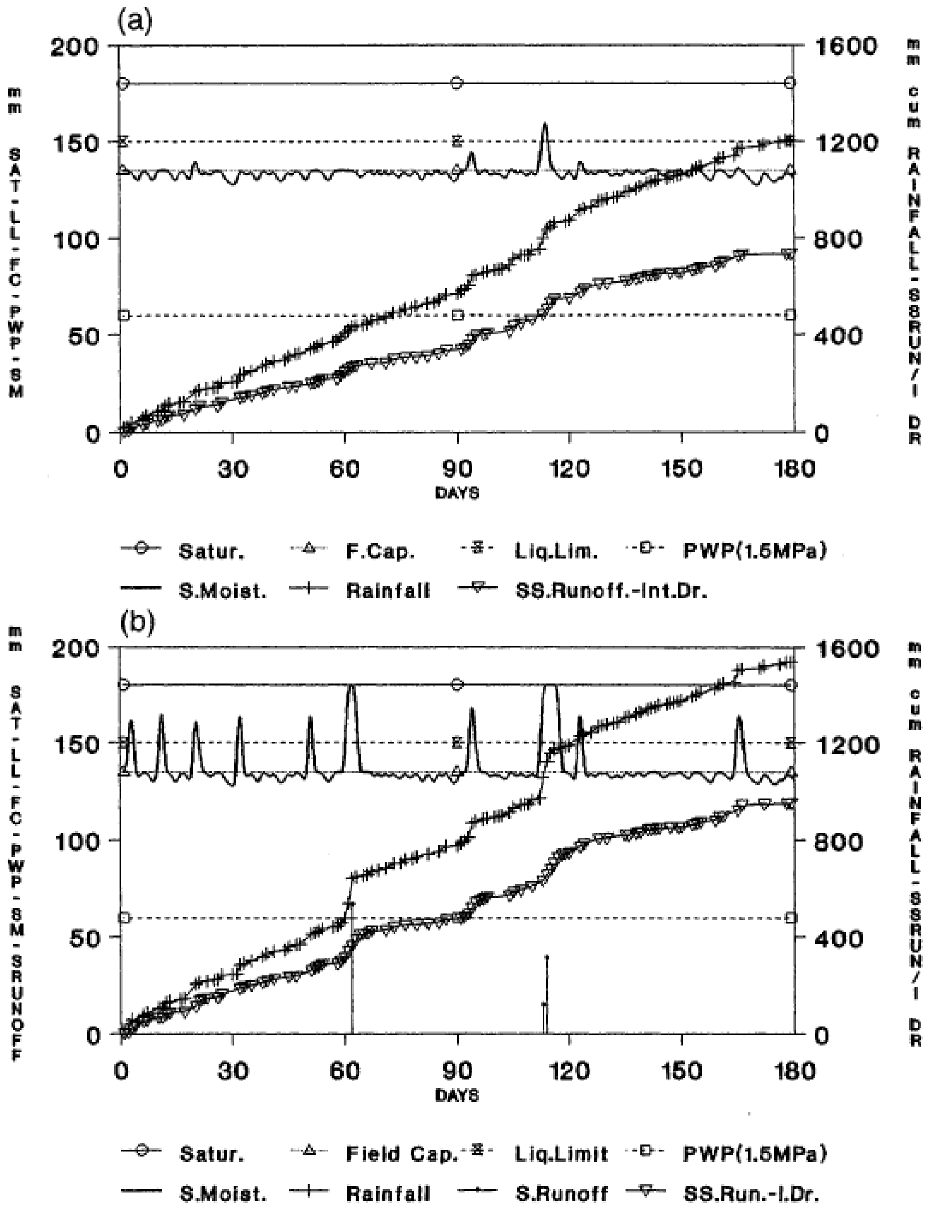


Fig. 5. Soil moisture regime in the surface 30 cm of a clay–loam Ultisol with 30–100% slope gradient, covered with overgrazed pasture, during the rainy season of a year with average total rainfall (return period (RP): 2 years) (a), and of a year with exceptionally high total rainfall (RP: 10 years) (b). There are shown the changes with time in mm of the soil moisture at 0–30 cm depth as related to saturation (SAT), liquid limit (LL), field capacity (FC) and permanent wiltting point (PWP); of cumulative rainfall (cum. RAINFALL); of cumulative subsurface runoff + internal drainage (SSRUN-IDR); and of daily surface runoff (S. RUNOFF).

Application of the model SOMORE:

-to study the effects on the soil moisture regime of the soils of the changes in land and crop management in three of the main regions

Alt Penedés (Barcelona)

Priorat (Tarragona)

Costers del Segre (Lleida)

with vineyards dedicated to the production of high quality wines and cava in Catalonia

The main changes in land management in those two regions include:

-levelling and use of green cover in rainfed vineyards of the Alt Penedés

-terracing and tillage in rainfed vineyards (ocassionally with a limited complementary irrigation) of the Priorat

The soils in Alt Penedés and Costers del Segre:

-mainly silty-loam textures

-derived of calcareous lutites

The soils in the Priorat:

-very stony (>50% coarse fraction)

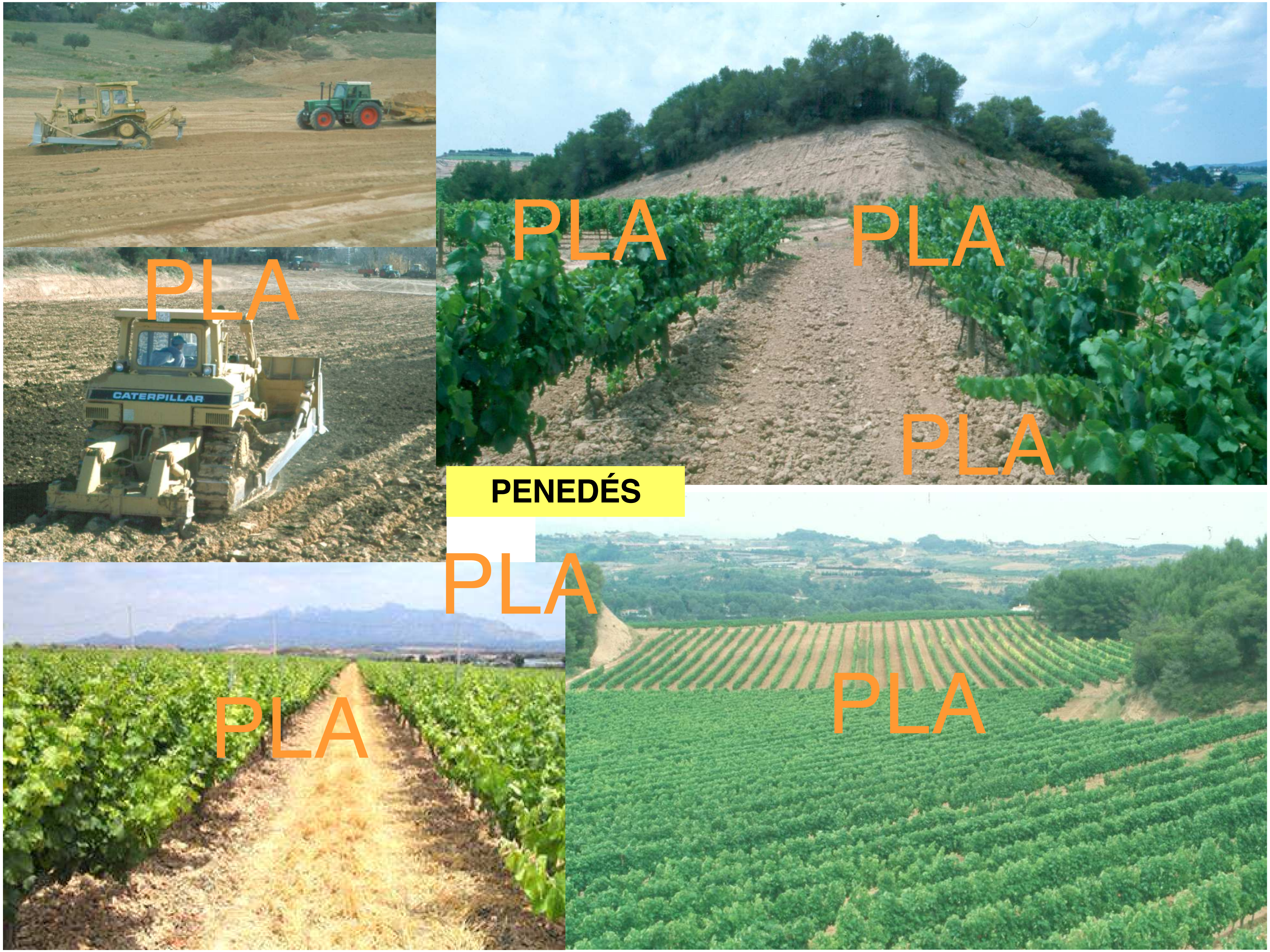
-derived of slates

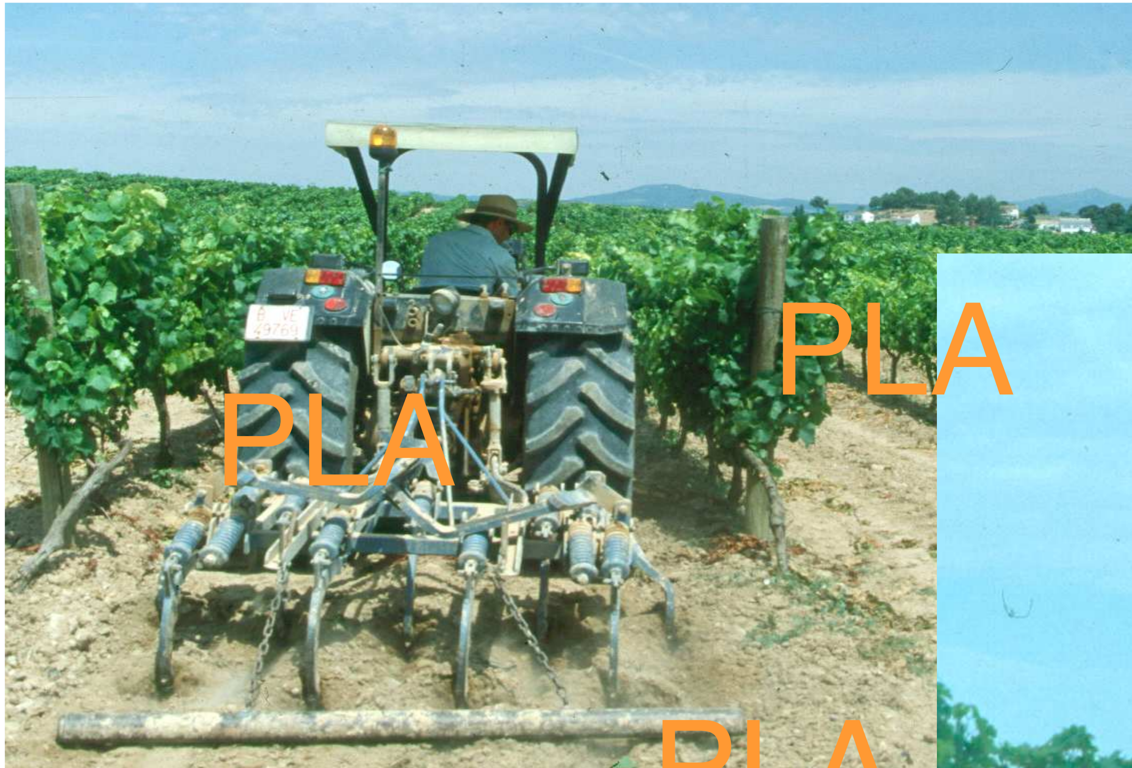
-calcareous only in the deeper soil where the clay (smectites) content slightly increases

	Slope %	Coarse fraction %	Effective rooting depth cm	AWC mm	Rainfall Infiltration mm/hour		K sat (subsoil) mm/hour
					No cover	Cover	
PENEDÉS							
NON LEVELED	*10*	*<5*	*20 → 80*	*200*	*20*	*50*	*3*
LEVELED	*6*	*5-10*	*15 → 60*	*120*	*5*	*20*	*0,4*
PRIORAT							
SLOPES	*50*	*50-60*	*0 → 40*	*61*	*>200*	*>200*	*>200*
TERRACES	*0*	*30-60*	*10 → 70*	*110*	*>100*	*>100*	*>100*

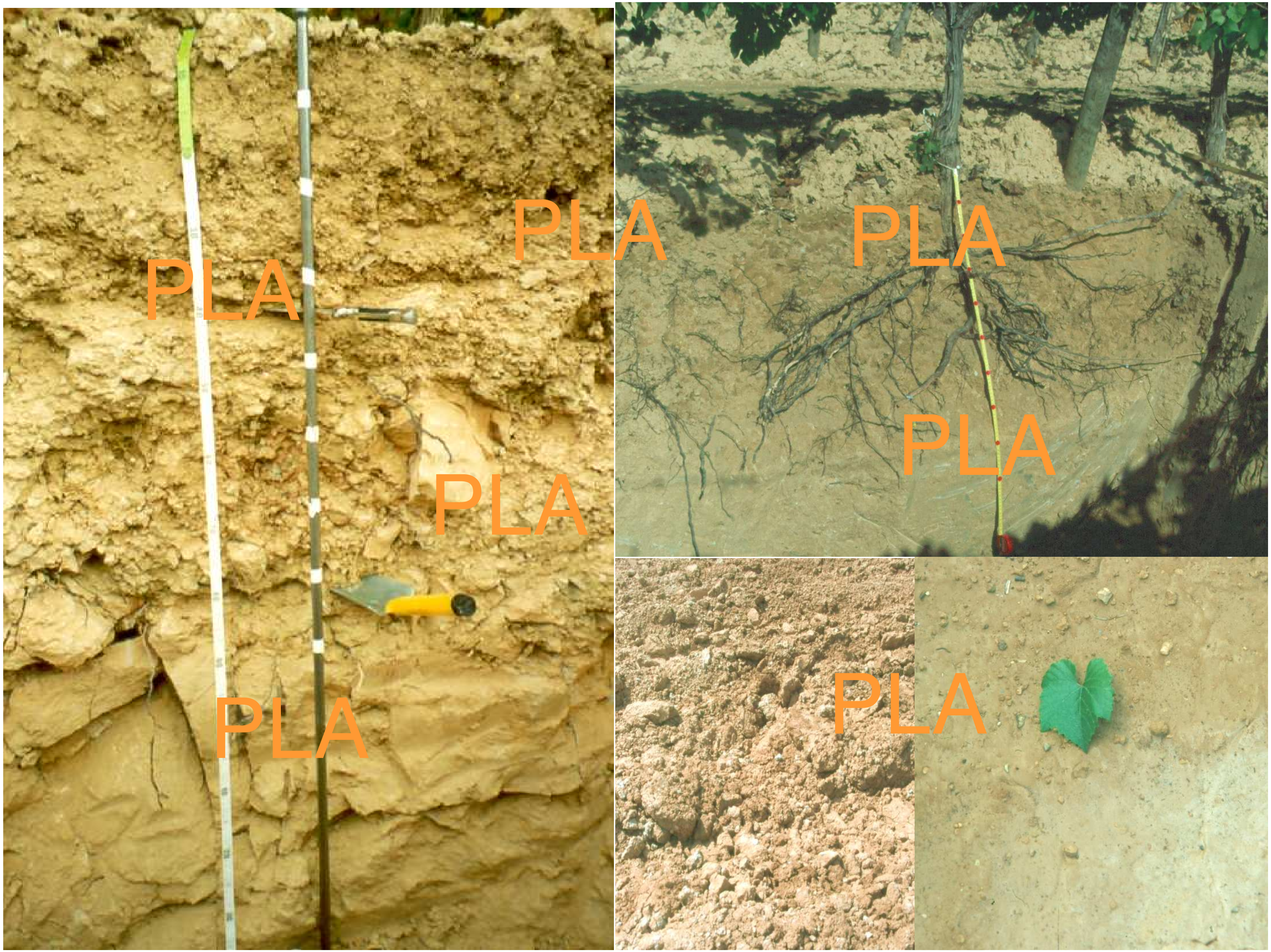
(AWC: Available water capacity)

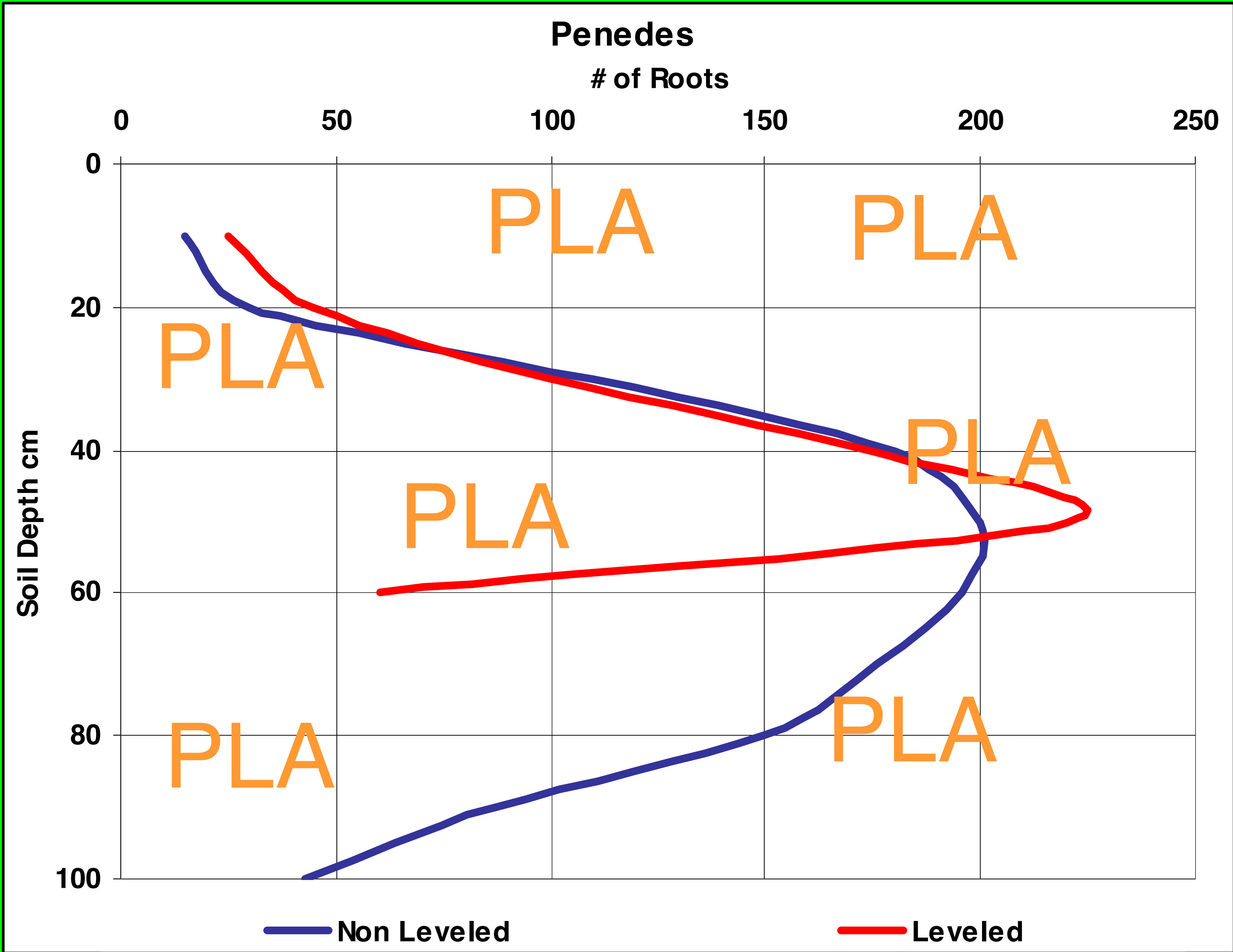
PENEDÉS


PENEDÉS
PLA
PLA
PLA
PLA
PLA
PLA
PLA
CATERPILLAR

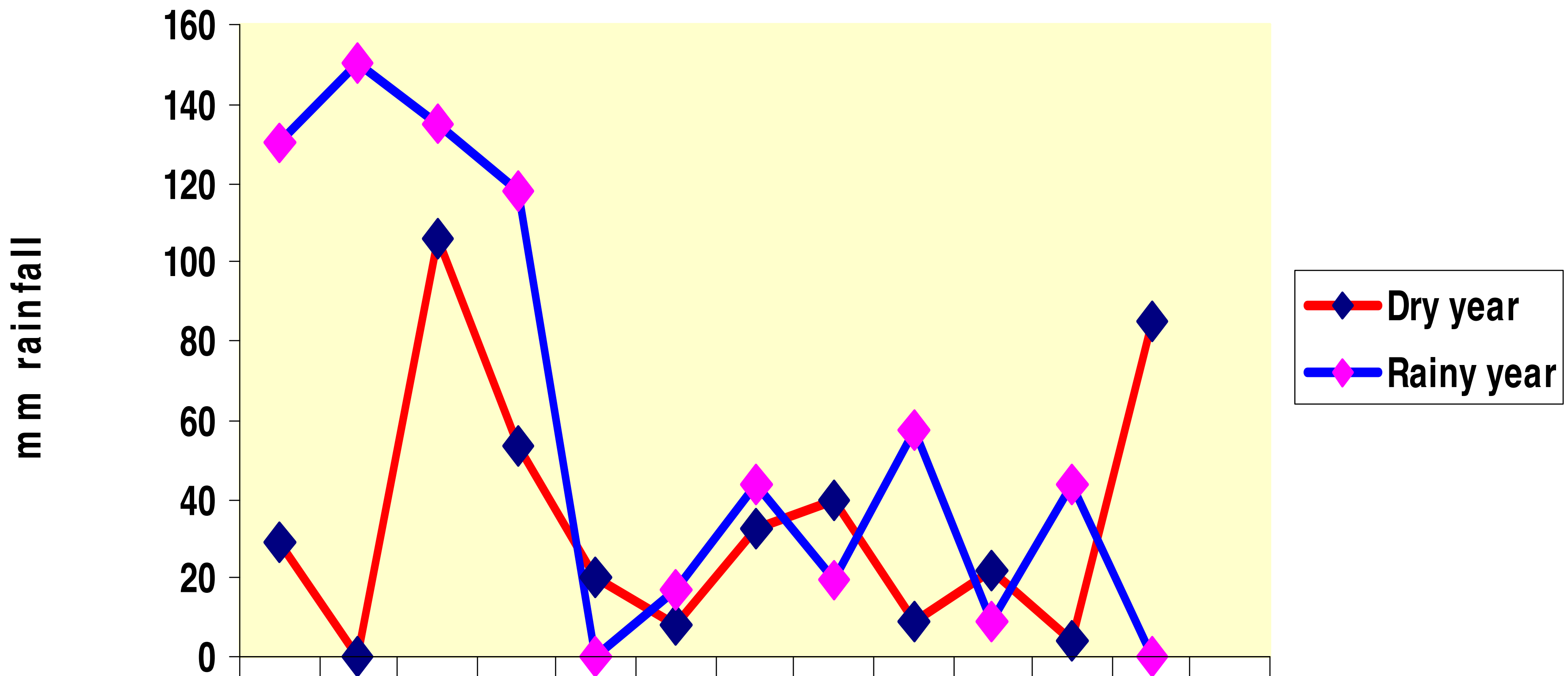


PENEDÉS


PLA
PLA
PLA
PLA
PLA
PLA


Penedes
# of Roots
0
50
100
150
200
250
0
20
40
60
80
100
Soil Depth cm
PLA
PLA
PLA
PLA
PLA
PLA
PLA
Non Leveled
Leveled

Rain Alt Penedes



	Oct.	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Dry year	29	0	106	53	20	8	32	40	9	22	4	85
Rainy year	130	150	135	118	0	17	44	19	57	9	44	0

month

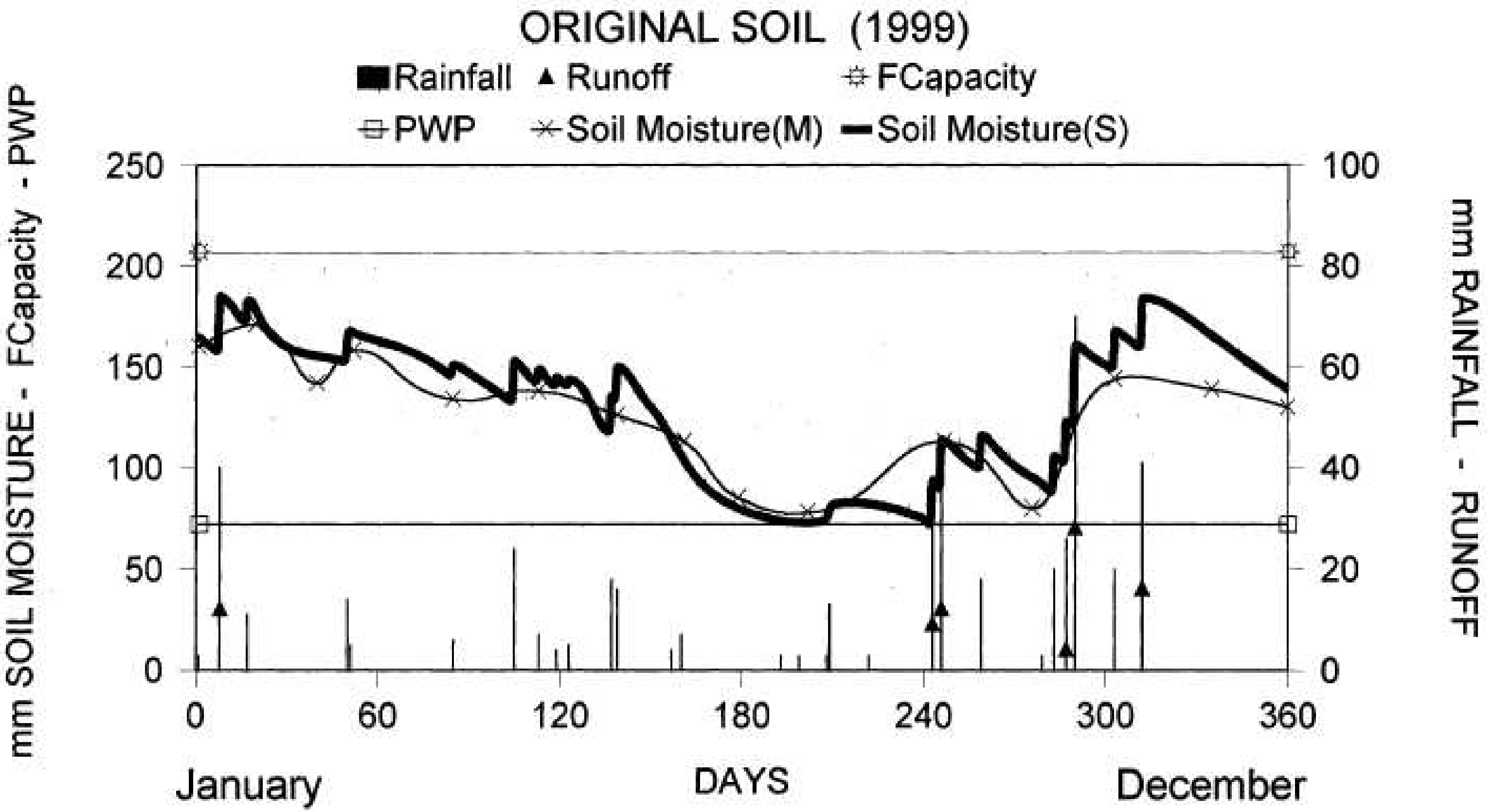
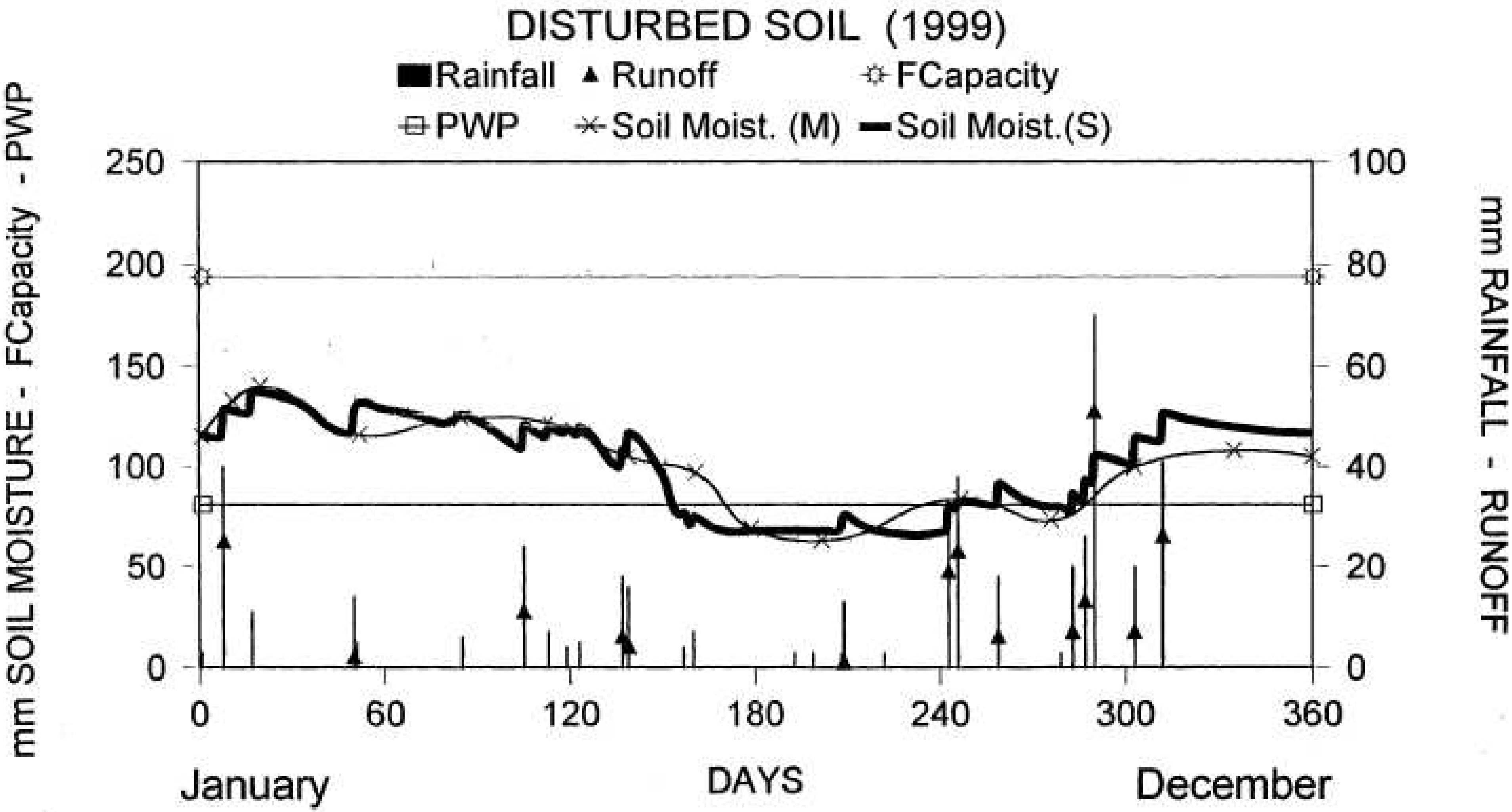
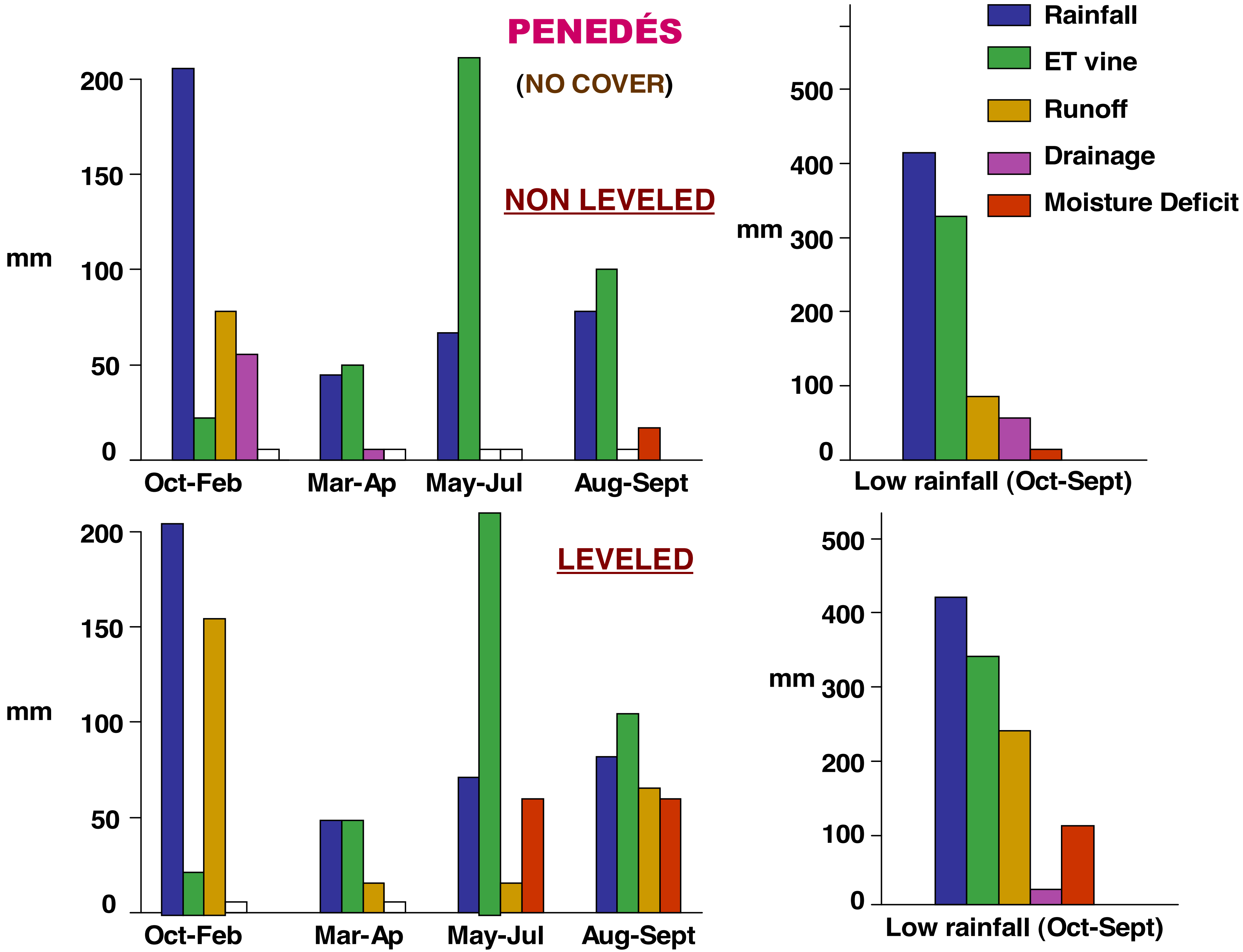

ORIGINAL SOIL (1999)
Rainfall
Runoff
FCapacity
PWP
Soil Moisture(M)
Soil Moisture(S)
mm SOIL MOISTURE - FCapacity - PWP
mm RAINFALL - RUNOFF
250
200
150
100
50
0
100
80
60
40
20
0
0
60
120
180
240
300
360
January
DAYS
December

FIGURE 5



DISTURBED SOIL (1999)
Rainfall
Runoff
FCapacity
PWP
Soil Moist. (M)
Soil Moist.(S)
mm SOIL MOISTURE - FCapacity - PWP
mm RAINFALL - RUNOFF
250
200
150
100
50
0
100
80
60
40
20
0
0
60
120
180
240
300
360
January
DAYS
December

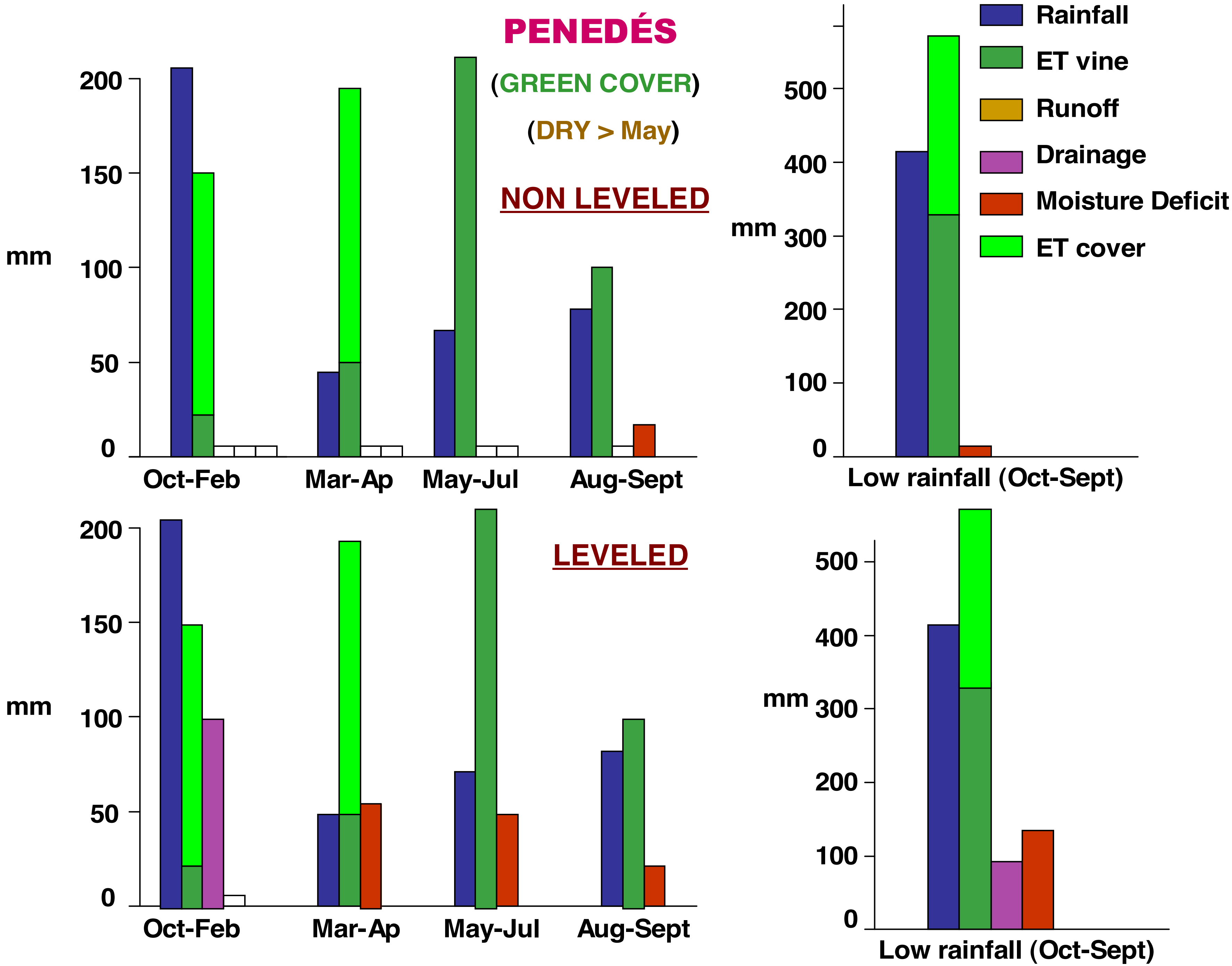
FIGURE 6



PENEDÉS
(NO COVER)
NON LEVELED
LEVELED
mm
200
150
100
50
0
Oct-Feb
Mar-Ap
May-Jul
Aug-Sept
500
400
300
200
100
Low rainfall (Oct-Sept)
Rainfall
ET vine
Runoff
Drainage
Moisture Deficit

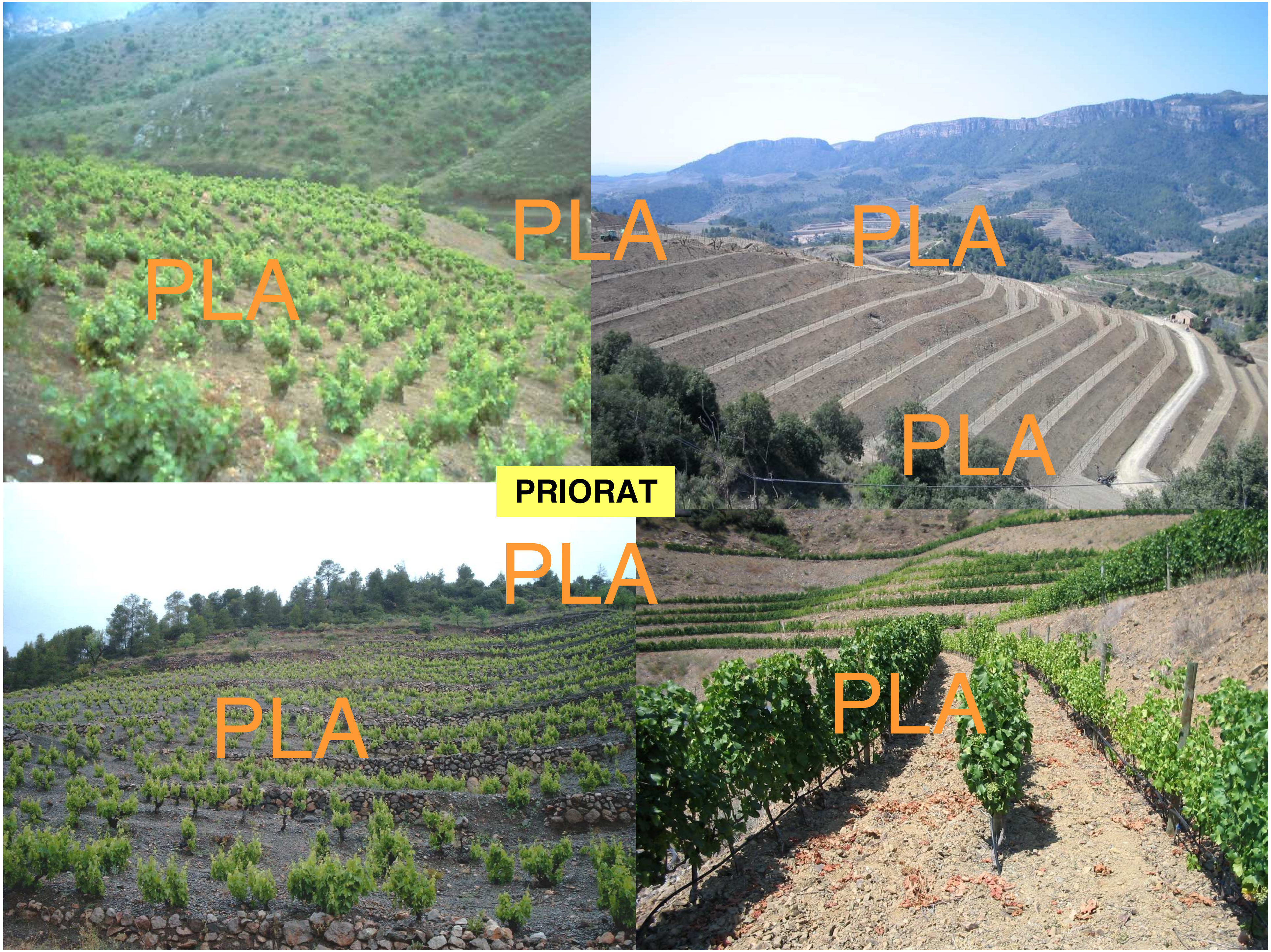

PLA
PLA
PLA
PLA
PLA
PLA
PLA

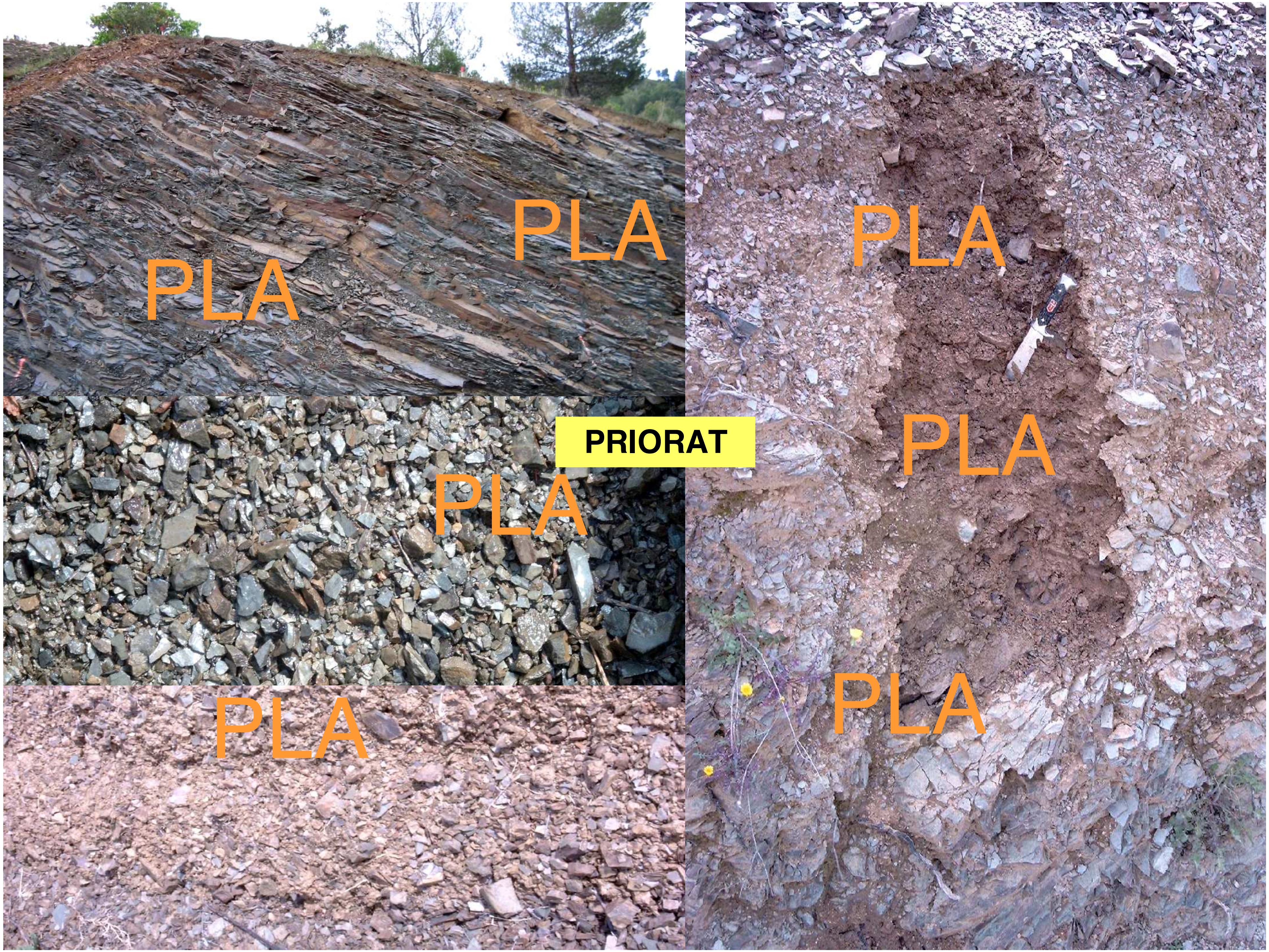

PLA
PLA
PLA
PLA
PLA
PLA
PLA

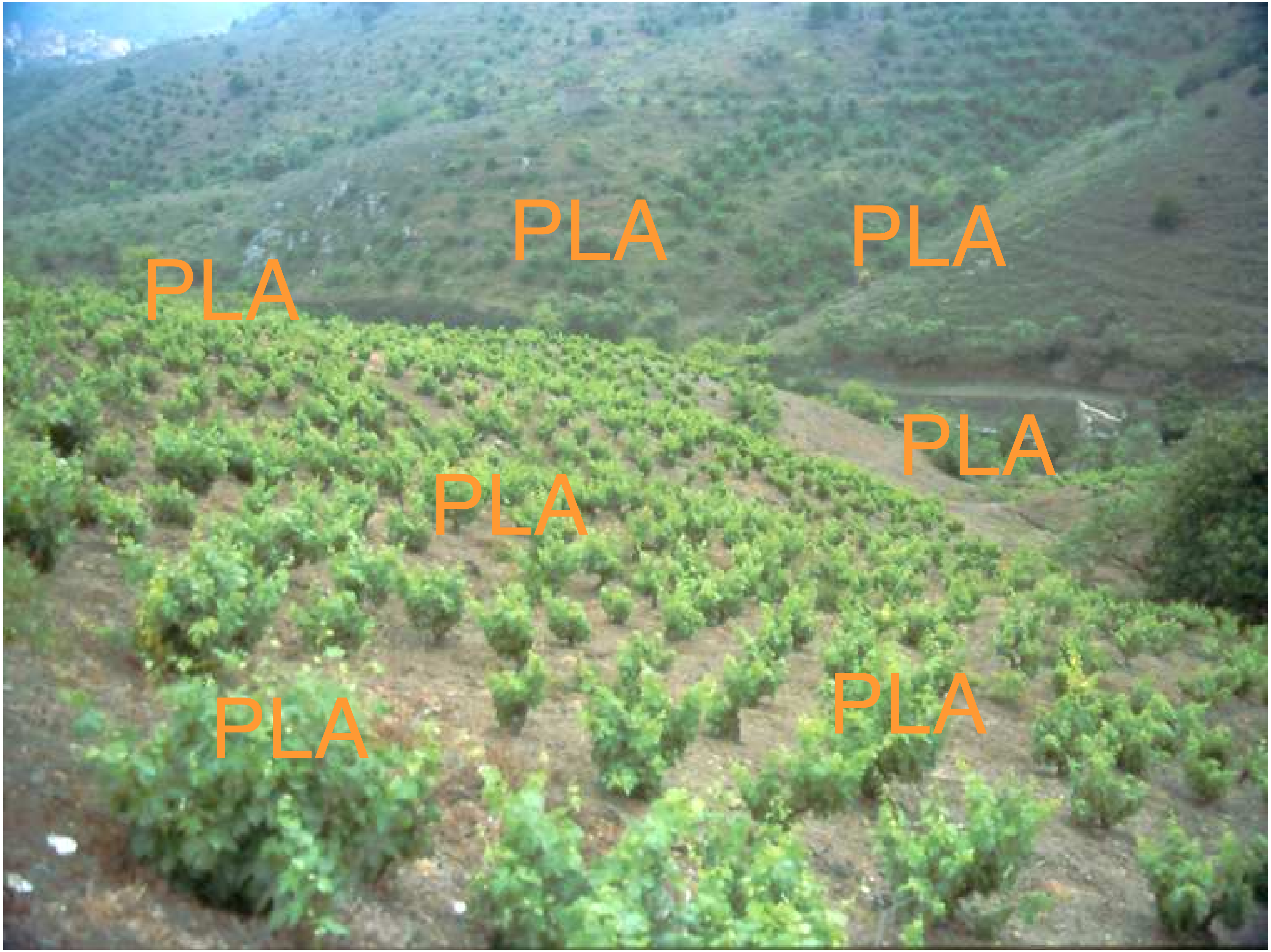


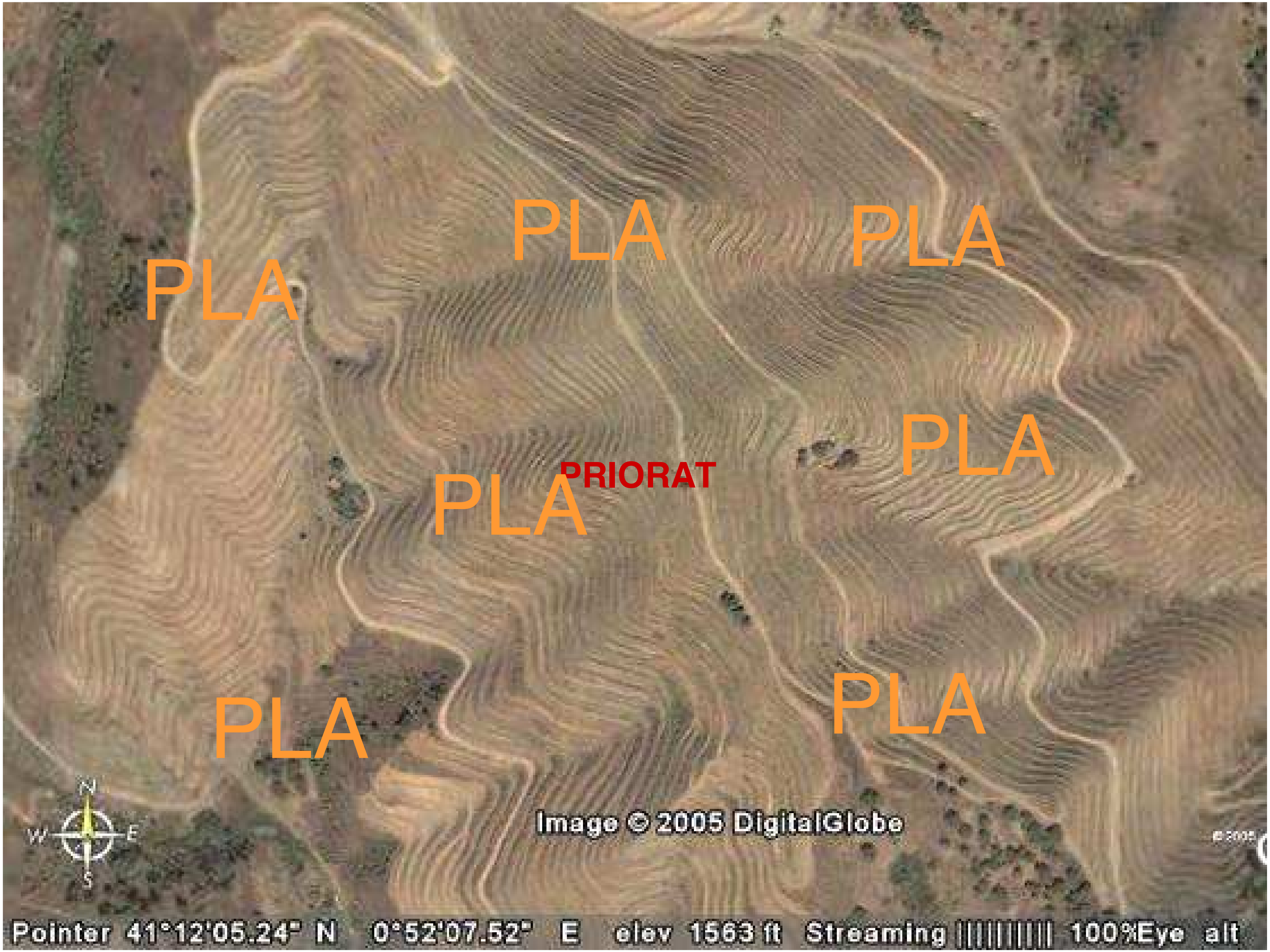
PENEDÉS
(GREEN COVER)
(DRY > May)
NON LEVELED
LEVELED
mm
0
50
100
150
200
Oct-Feb
Mar-Ap
May-Jul
Aug-Sept
Low rainfall (Oct-Sept)
300
400
500
Rainfall
ET vine
Runoff
Drainage
Moisture Deficit
ET cover

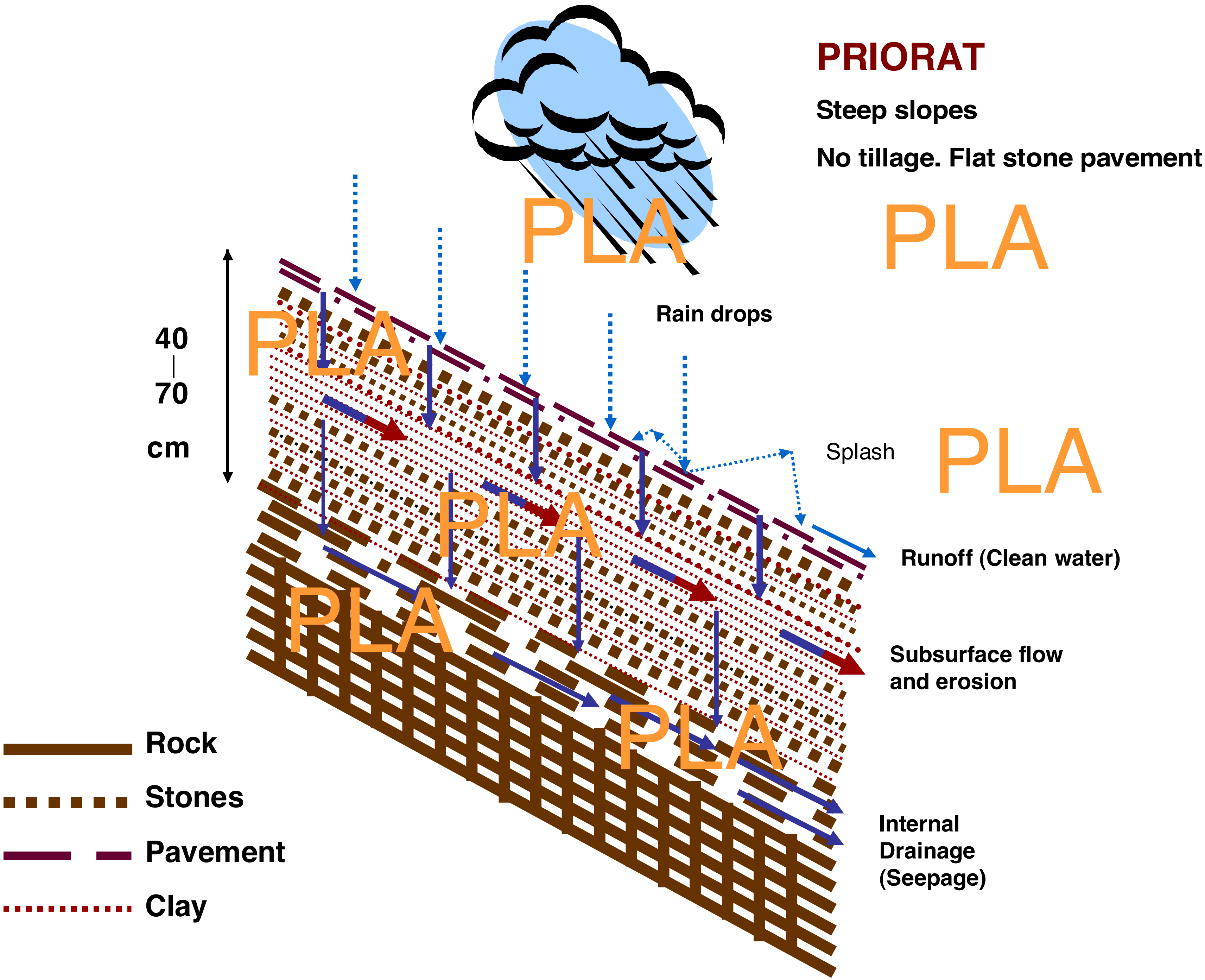
PRIORAT


PLA
PLA
PLA
PLA
PRIORAT
PLA
PLA


PLA
PLA
PLA
PRIORAT
PLA
PLA
PLA
PLA


PLA
PLA
PLA
PLA
PLA
PLA
PLA

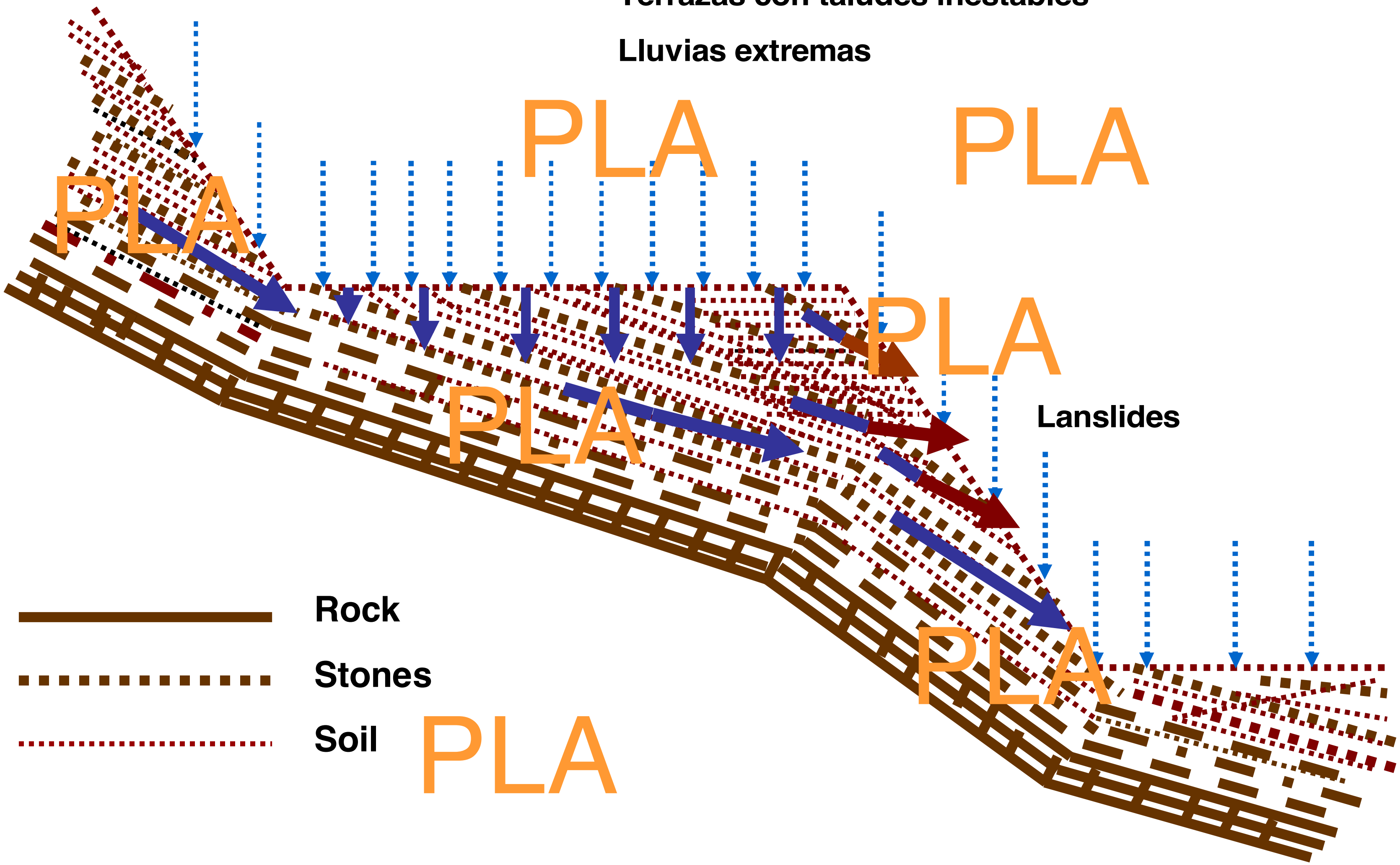

PLA
PLA
PLA
PRIORAT
PLA
PLA
PLA
PLA
N
W
E
S
Image © 2005 DigitalGlobe
Pointer 41°12'05.24" N 0°52'07.52" E elev 1563 ft Streaming |||||||||| 100%Eye alt

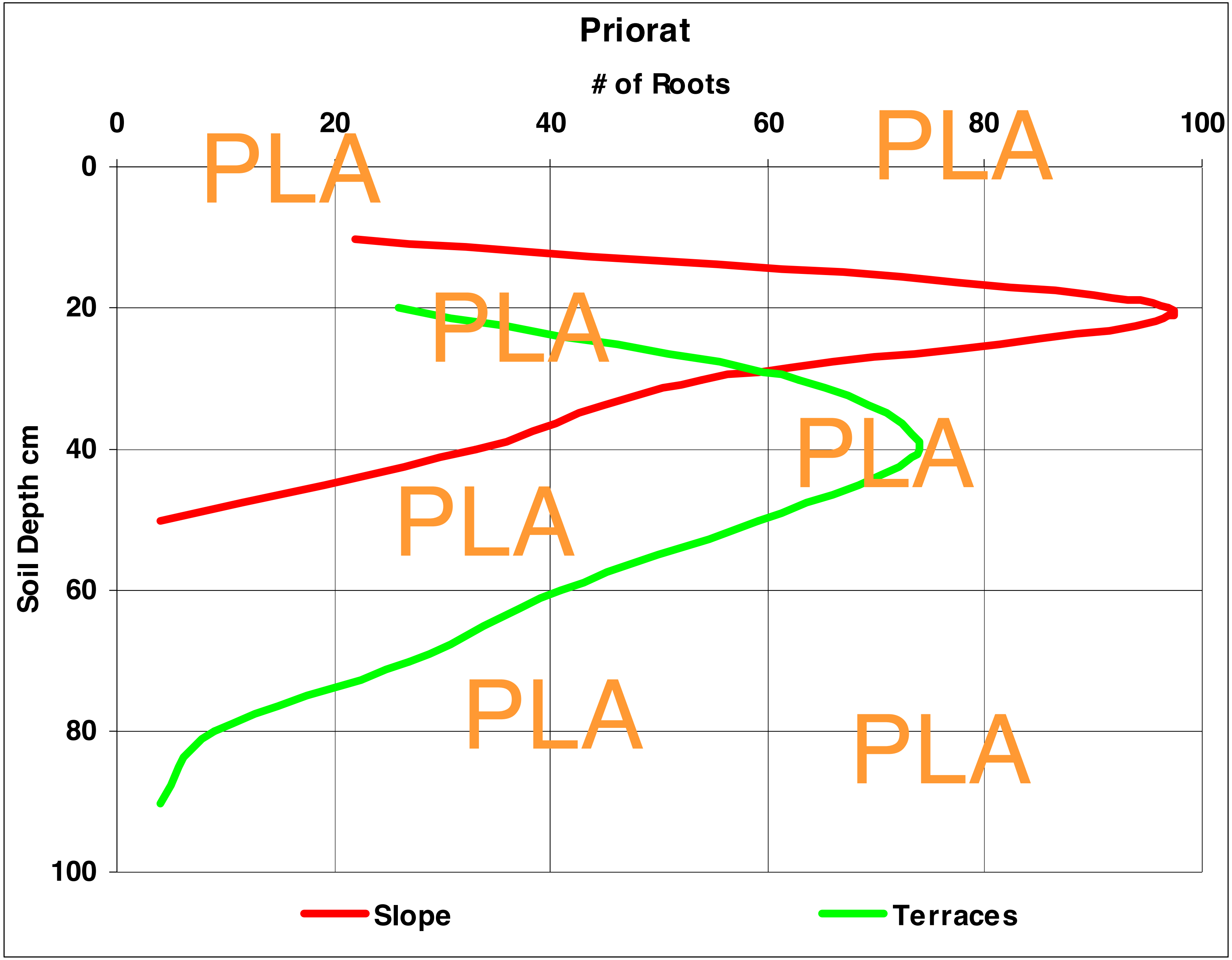

PRIORAT
Steep slopes
No tillage. Flat stone pavement
Rain drops
Splash
Runoff (Clean water)
Subsurface flow
and erosion
Internal
Drainage
(Seepage)
40
70
cm
Rock
Stones
Pavement
Clay

PRIORAT

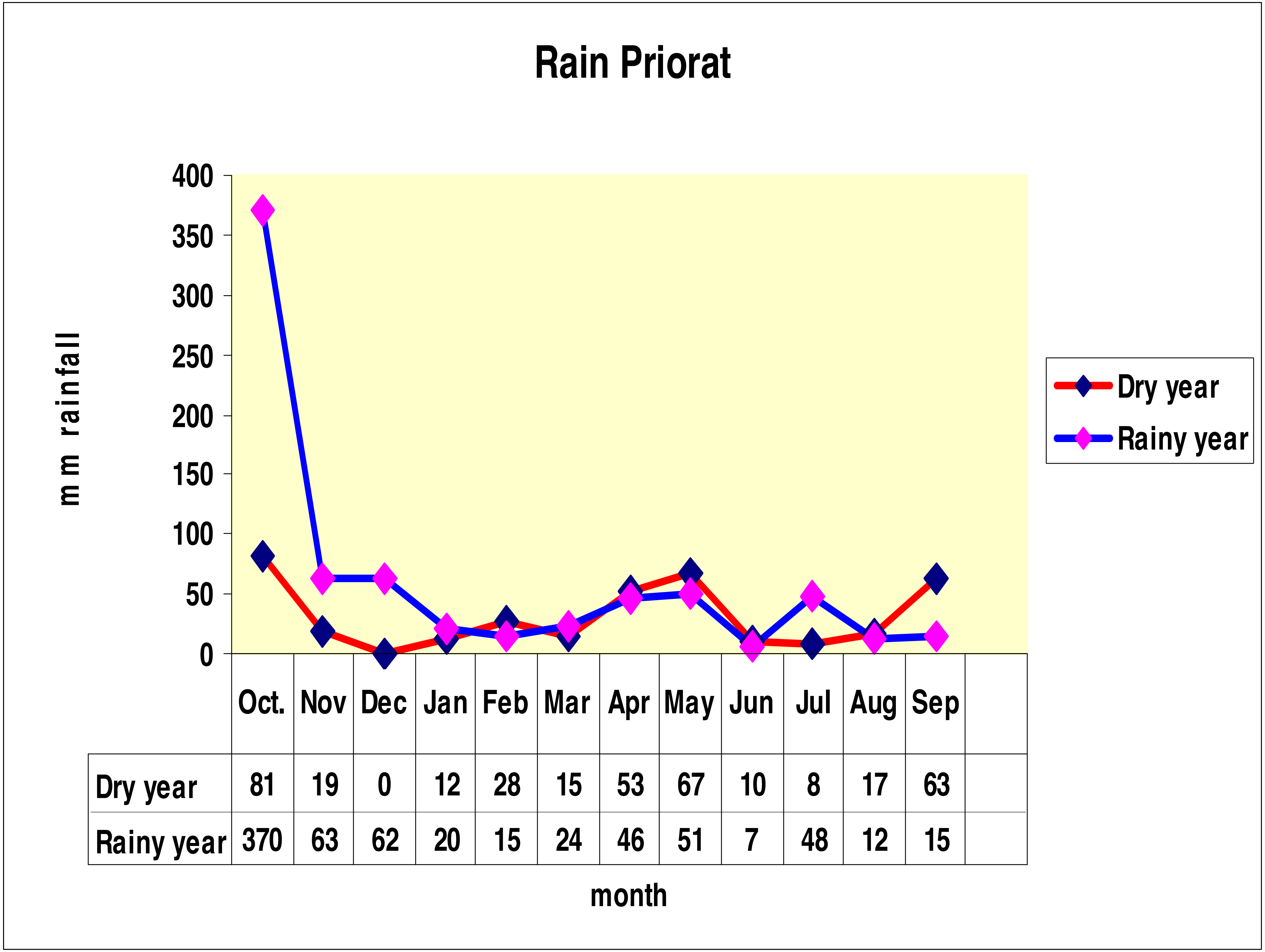
Terrazas con taludes inestables

Lluvias extremas





Priorat
# of Roots
0
20
40
60
80
100
Soil Depth cm
0
20
40
60
80
100
Slope
Terraces
PLA



	Oct.	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Dry year	81	19	0	12	28	15	53	67	10	8	17	63
Rainy year	370	63	62	20	15	24	46	51	7	48	12	15

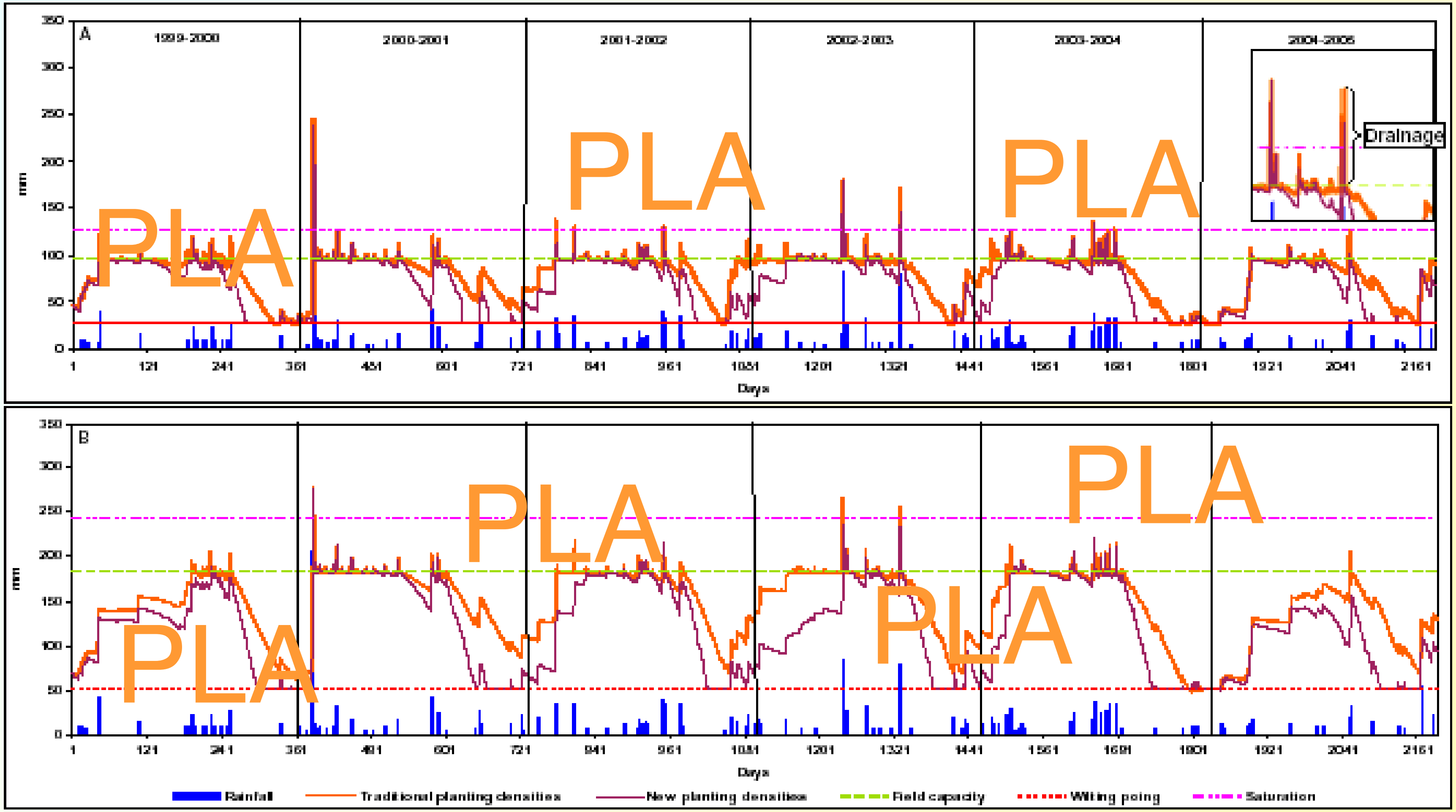
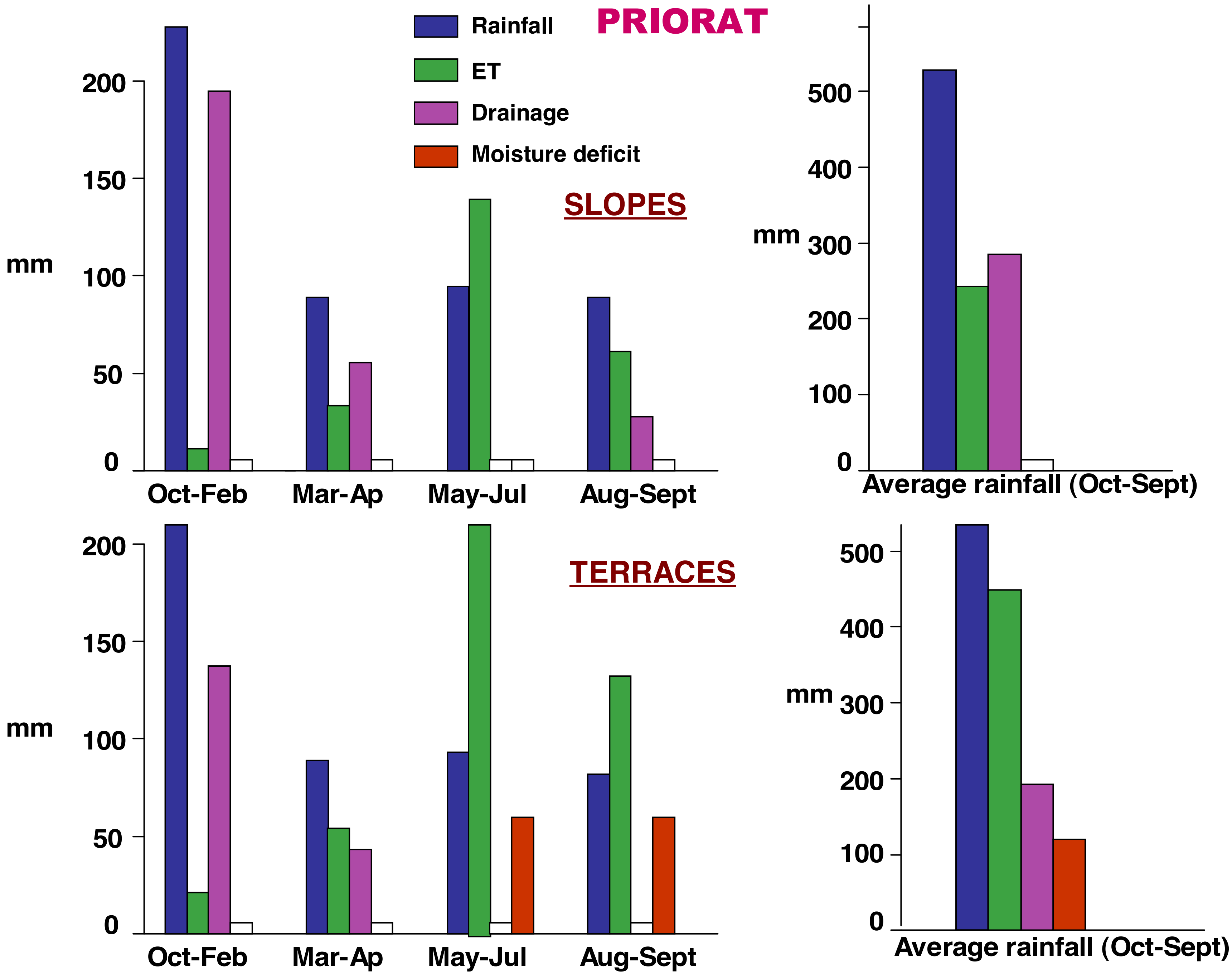
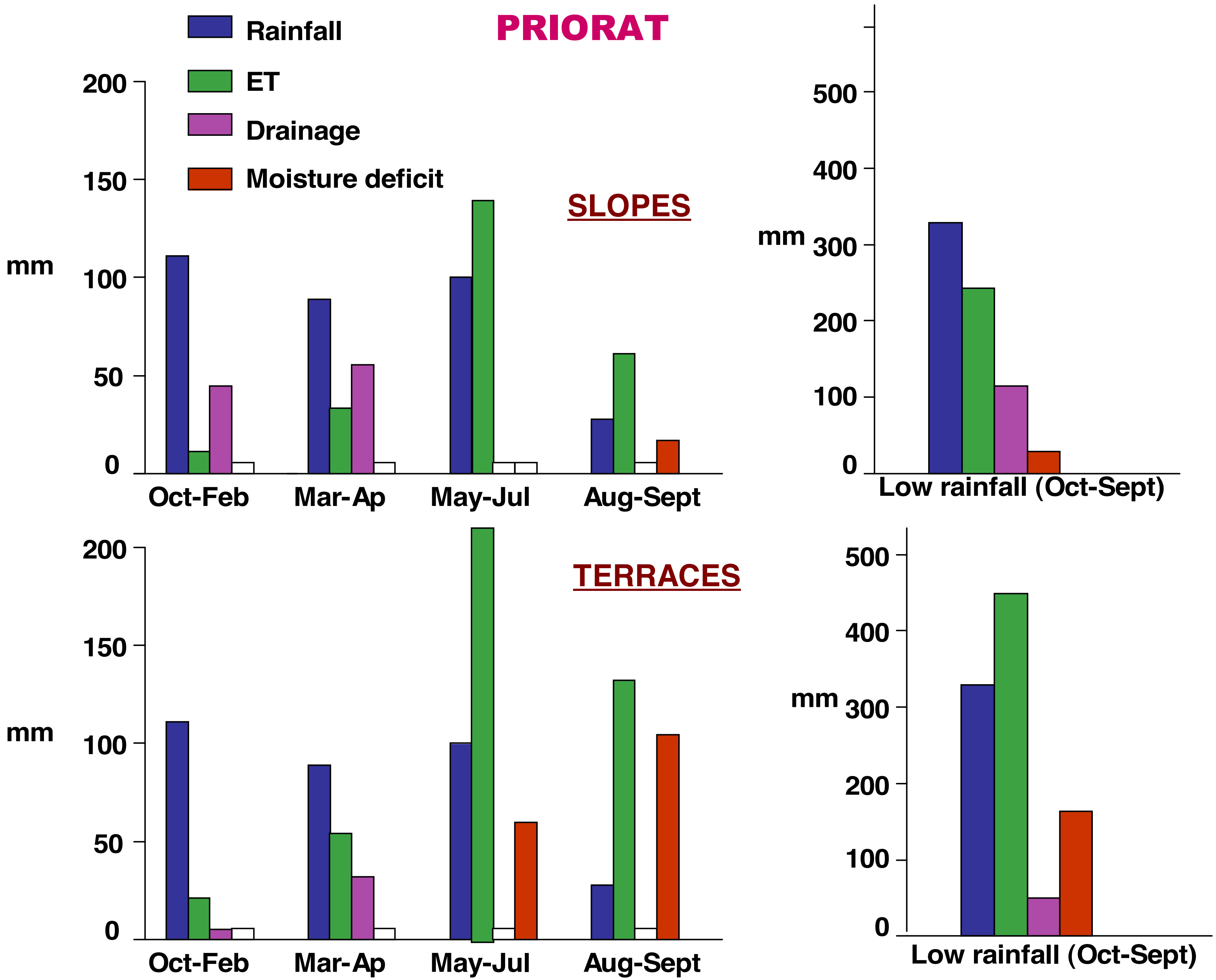
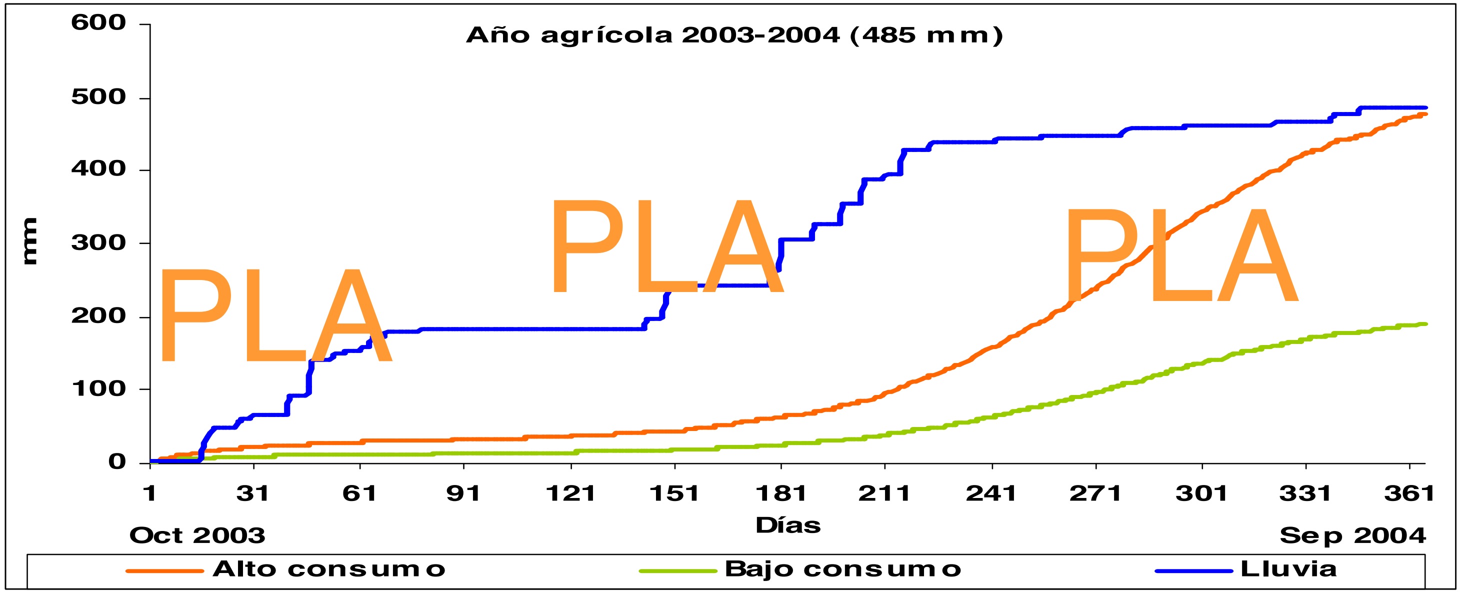
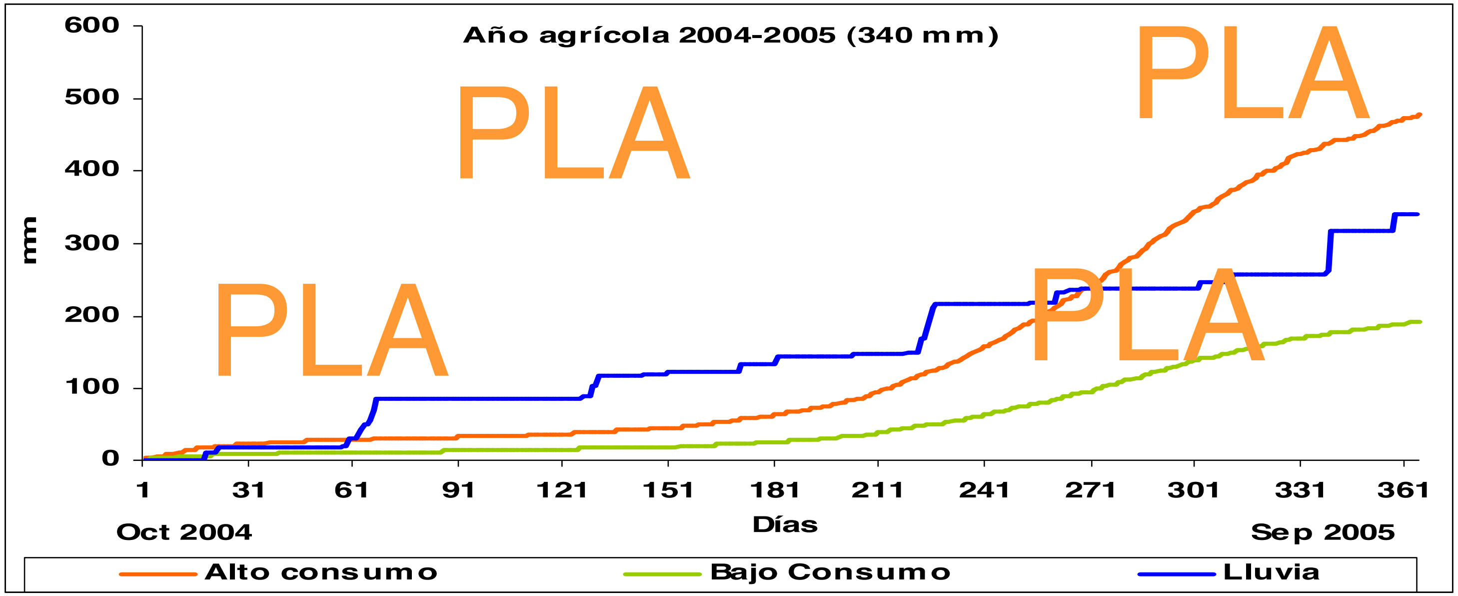


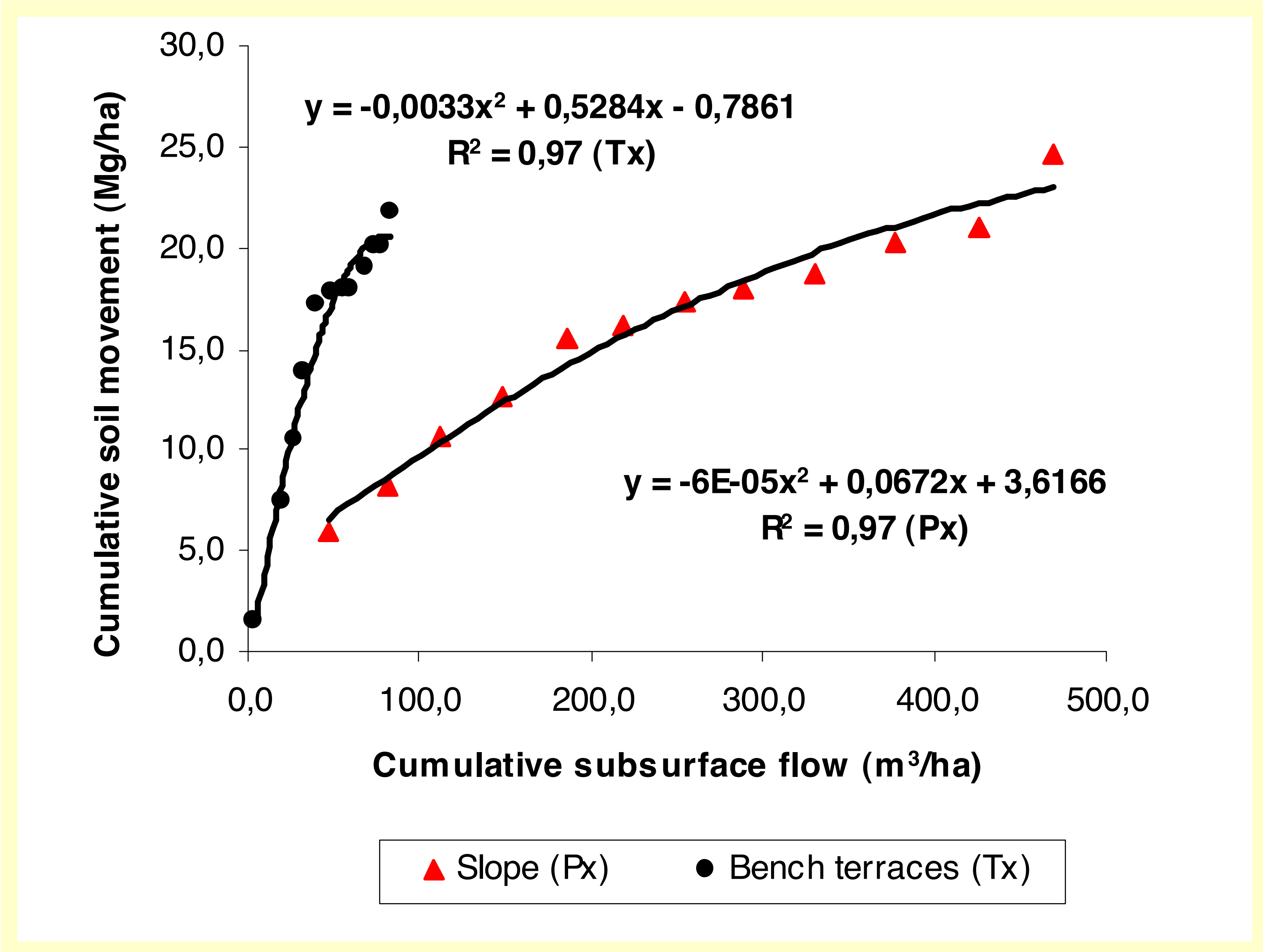
Figure 3. Simulated soil moisture regime in six (1999-2005) consecutive agricultural years (starting in October and finishing in September) with different plantation densities and different effective rooting depths. (A: 60 cm rooting depth; B: 80 cm rooting depth).


PRIORAT
Rainfall
ET
Drainage
Moisture deficit
SLOPES
TERRACES
mm
200
150
100
50
0
Oct-Feb
Mar-Ap
May-Jul
Aug-Sept
500
400
300
200
100
Average rainfall (Oct-Sept)

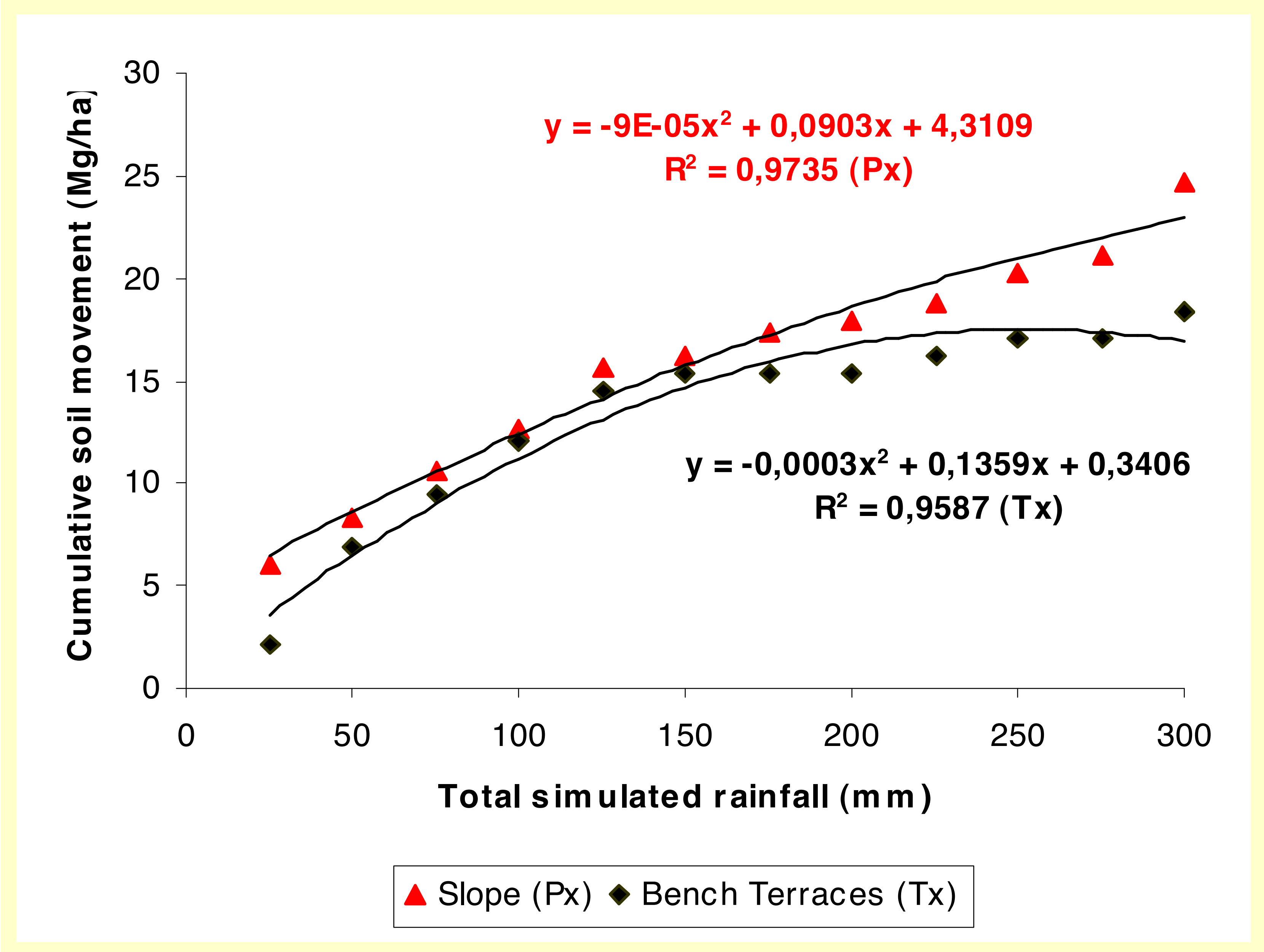

PRIORAT
Rainfall
ET
Drainage
Moisture deficit
SLOPES
mm
200
150
100
50
0
Oct-Feb
Mar-Ap
May-Jul
Aug-Sept
mm
500
400
300
200
100
0
Low rainfall (Oct-Sept)
TERRACES
mm
200
150
100
50
0
Oct-Feb
Mar-Ap
May-Jul
Aug-Sept
mm
500
400
300
200
100
0
Low rainfall (Oct-Sept)


Año agrícola 2003-2004 (485 mm)
mm
600
500
400
300
200
100
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Días
Oct 2003
Sep 2004
Alto consumo
Bajo consumo
Lluvia

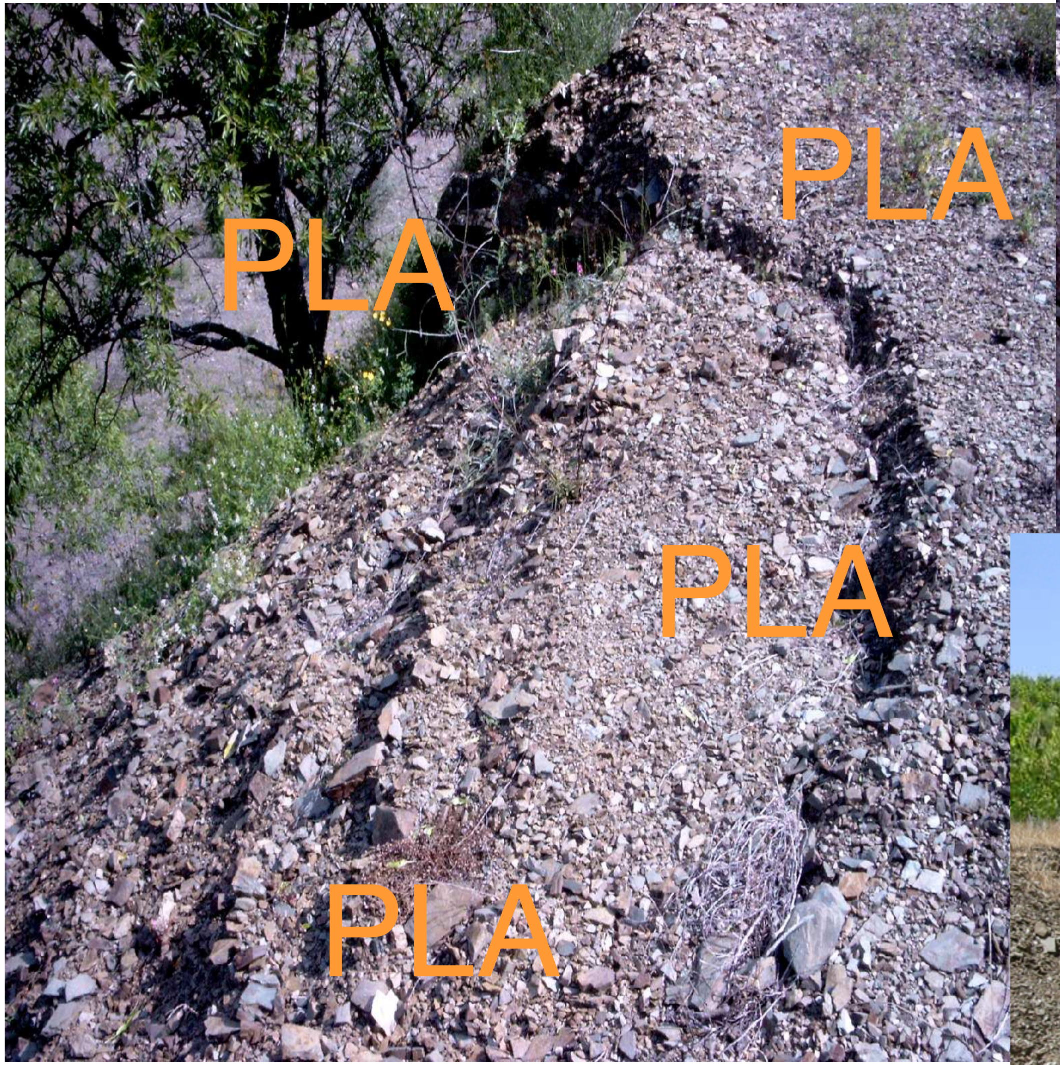

Año agrícola 2004-2005 (340 mm)
mm
600
500
400
300
200
100
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Días
Oct 2004
Sep 2005
Alto consumo
Bajo Consumo
Lluvia

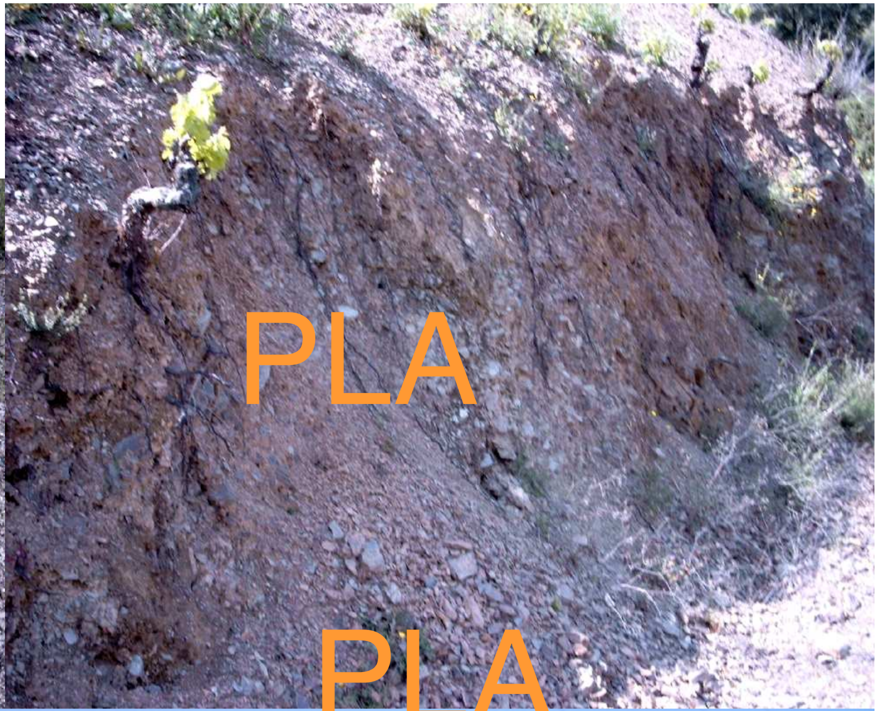


y = -0,0033x² + 0,5284x - 0,7861
R² = 0,97 (Tx)
y = -6E-05x² + 0,0672x + 3,6166
R² = 0,97 (Px)
Cumulative soil movement (Mg/ha)
Cumulative subsurface flow (m³/ha)
30,0
25,0
20,0
15,0
10,0
5,0
0,0
0,0
100,0
200,0
300,0
400,0
500,0
Slope (Px)
Bench terraces (Tx)

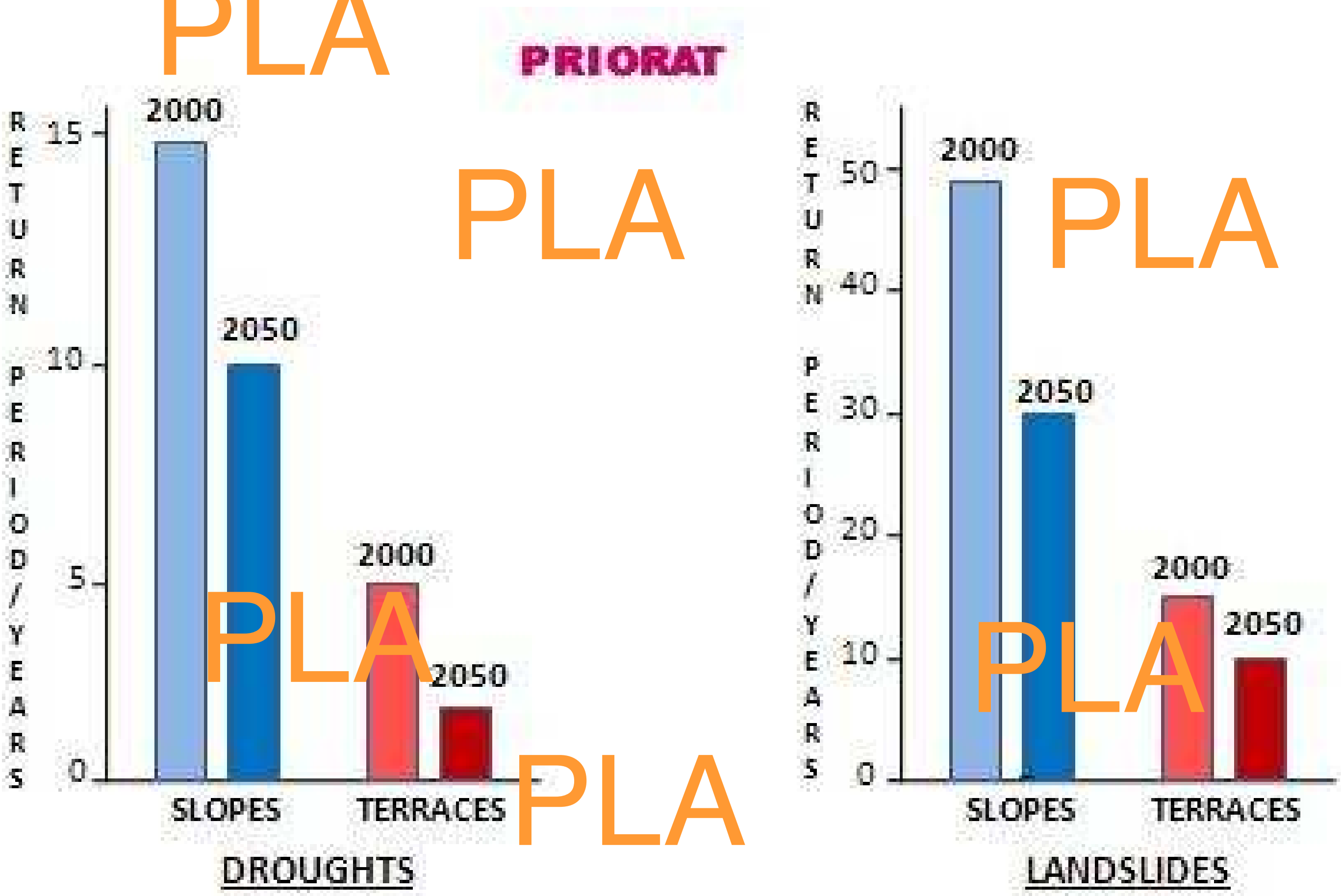


y = -9E-05x2 + 0,0903x + 4,3109
R2 = 0,9735 (Px)
y = -0,0003x2 + 0,1359x + 0,3406
R2 = 0,9587 (Tx)
Cumulative soil movement (Mg/ha)
0
5
10
15
20
25
30
0
50
100
150
200
250
300
Total simulated rainfall (mm)
Slope (Px)
Bench Terraces (Tx)


PLA
PLA
PLA
PLA


PLA
PLA


PLA



Changes in probabilities (return periods) of droughts and landslides due to terracing in dryland vineyards of the Priorat region (NE Spain) as affected by the previewed climate changes from year 2000 to 2050 (IS92e Scenario. IPCC)

It may be concluded that :

The processes of soil and water degradation are closely linked through unfavorable alterations in the hydrological processes determining the soil water balance and the soil water regime.

They are also conditioned by the climatic conditions and by the use and management of the soil and water resources.

Therefore, an hydrological approach to the evaluation and prediction of the conservation of soil and water against degradation processes would be essential for an adequate development, selection, and application of sustainable and effective use and management practices.

New research approaches based on the evaluation of the hydrological processes, under different scenarios on changing climate, soil properties, and soil and crop management,

with the use of practical and flexible models and computer based programs like SOMORE,

would help to select or develop more adequate packages of technologies to reduce soil and water degradation,

and to control their growing negative effects on crop productivity, degradation of ecosystems, and on derived catastrophic events in the whole World