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I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

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COLLEGE ON SOIL PHYSICS
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"College on soil physics and problems of food production and environmental effects affecting the world population"

Ildefonso PLA SENTIS
Universitat de Lleida
Department de Medi Ambient i Ciencies del Sol
Av. Alcalde Rovira Roure 177
25198 Lleida
SPAIN

These are preliminary lecture notes, intended only for distribution to participants

MAIN BUILDING STRADA COSTIERA, 11 TEL. 2240111 TELEFAX 224163 TELEX 460392 ADRIATICO GUEST HOUSE VIA GRIGNANO, 9 TEL. 224241 TELEFAX 224531 TELEX 460449
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SOIL CONSISTS OF PARTICLES OF DIFFERENT SIZES AND SHAPES, ARRANGED IN DIFFERENT WAYS, WITH VOIDS OR PORE SPACE BETWEEN THE PARTICLES

THE SOIL HAS BEEN DESCRIBED AS A THREE PHASE (SOLID, LIQUID, GAS) SYSTEM IN DYNAMIC EQUILIBRIUM, WITH CONTINUOUS CHANGES.

PHYSICALLY, THE SOIL IS MADE UP OF MINERALS OF VARIOUS SIZES WITH SOME ORGANIC MOLECULES STRONGLY BONDED TO THE MINERALS AND SOME ORGANIC MATTER PHYSICALLY MIXED IN.

THE SOLID PARTICLES EXIST IN A CERTAIN ARRANGEMENT AND THE VOIDS OR PORE SPACES BETWEEN THESE ARE PARTLY FILLED WITH DILUTE SOLUTIONS AND PARTLY WITH GASES

THE MOST COMMON PHYSICAL PROPERTIES OF A SOIL ARE PROBABLY THOSE OF DENSITY AND DEGREE OF WETNESS

SOILS AND WATER ARE THE MOST IMPORTANT RESOURCES FOR ENSURING SUSTAINABILITY OF FOOD PRODUCTION

POOR SOIL AND WATER MANAGEMENT MAY CAUSE SEVERE LAND AND SOIL DEGRADATION.
SOIL DEGRADATION HAS BEEN DEFINED AS A DECREASE ON THE ABILITY OF THE SOIL TO PERFORM ITS FUNCTION AS MEDIUM FOR PLANT GROWTH, REGULATOR OF THE WATER REGIME, AND AS ENVIRONMENTAL FILTER, DUE TO NATURAL AND MAN-INDUCED CAUSES.

UNFAVOURABLE ALTERATIONS OF THE SOIL PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES HAVE A NEGATIVE EFFECT ON PLANT PRODUCTIVITY AND ENVIRONMENTAL QUALITY

THE PROCESS OF SOIL DEGRADATION GENERALLY STARTS WITH THE DEGRADATION OF THE SOIL STRUCTURE, SPECIALLY THE FUNCTIONAL ATTRIBUTES OF SOIL PORES TO TRANSMIT AND RETAIN WATER, AND TO FACILITATE ROOT GROWTH.
THE DETERIORATION OF THOSE ATTRIBUTES IS MANIFESTED THROUGH INTERRELATED PROBLEMS OF SURFACE SEALING, SOIL COMPACTION, IMPEDED ROOT GROWTH, POOR DRAINAGE, FREQUENT DROUGHT, EXCESIVE RUNOFF, AND ACCELERATED EROSION

IN SPITE OF SOME TECHNOLOGICAL ADVANCES IN AGRICULTURAL PRODUCTION, STILL MILLIONS OF PEOPLE IN DEVELOPING COUNTRIES OF THE WORLD DO NOT HAVE ENOUGH TO EAT.

THERE ARE A NUMBER OF CAUSES, BUT THE MAIN ONE IS THE FAST REDUCTION IN THE PRODUCTIVE CAPACITY OF LAND AND IN THE QUANTITY AND QUALITY OF WATER RESOURCES, BY INCREASING RATES OF SOIL EROSION AND LAND DEGRADATION IN GENERAL. LAND DEGRADATION DIRECTLY AFFECTS FOOD SUPPLIES, DIMINISHING CROP YIELDS AND INCREASING RISKS OF PRODUCTION

IN ADDITION TO EFFECTS ON CROP PRODUCTIVITY AND PRODUCTION RISKS, SOIL DEGRADATION ALSO AFFECTS NEGATIVELLY HYDROGRAPHIC CATCHEMENTS, AND THE WATER SUPPLY TO THE POPULATION AND FOR IRRIGATION AND PRODUCTION OF HYDROELECTRIC POWER. NATURAL DESASTERS BY FLOODINGS, LANSLIDES, SEDIMENTATION..... AFFECTING WITH GROWING INCIDENCE THE DEVELOPING COUNTRIES ARE ALSO ROOTED IN SOIL DEGRADATION

Table 8a. Physical soil constraints by region in the developing world.

Region		Total Land Area	No Inherent Constraints	Physical constraints: Steep Slopes	Shallow Soils	Poor Drainage	Tillage Problems
Africa	(million ha)	3011	443	261	398	198	112
	%	-	14.7	8.7	13.2	6.6	3.7
C. America	(million ha)	274	58	69	44	15	19
	%	-	21.2	25.2	16.1	5.5	6.9
S. America	(million ha)	1898	208	329	193	213	27
	%	-	11.0	17.3	10.2	11.2	1.4
S.E. Asia	(million ha)	897	33	261	91	109	76
	%	-	3.7	29.1	10.1	12.2	8.5
S.W. Asia	(million ha)	678	46	161	174	6	6
	%	-	6.8	23.7	25.7	0.9	0.9

Source: World Resources Institute 1990.

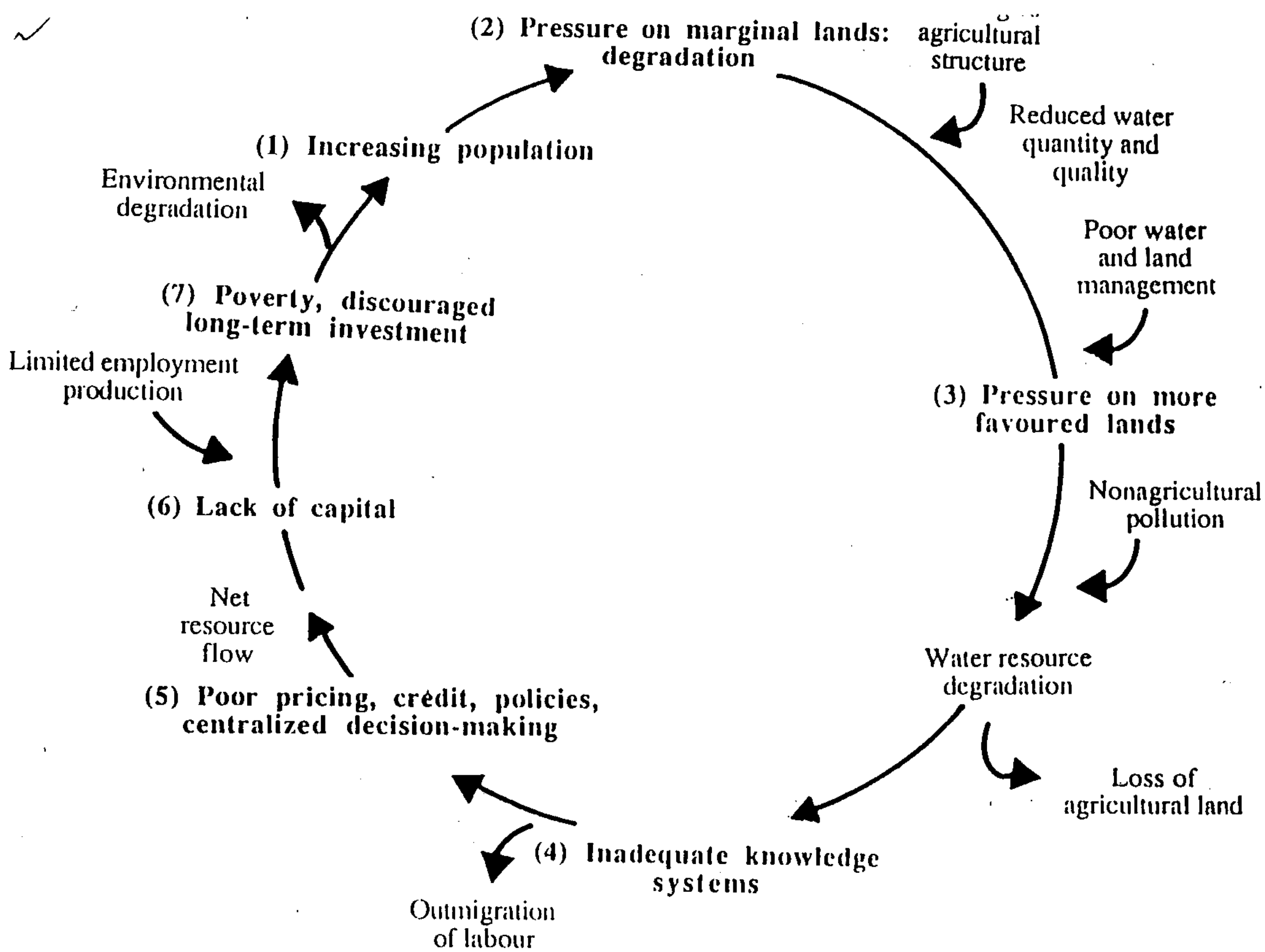


Figure II.1 The cycle of unsustainability (Rhoades and Harwood, 1992).

Table 1. Human-induced soil degradation: 1945-1990 (After World Resources Institute 1992).

	Degraded area (hectares x 10^6)		Degraded areas as percentage of vegetated land	
Region	Total	Moderate, Severe, Extreme	Total	Moderate, Severe, Extreme
World	1964	1215	17.0	10.5
Europe	219	158	23.1	16.7
Africa	492	321	22.1	14.4
Asia	747	453	19.8	12.0
Oceania	103	6	13.1	0.8
North America	96	79	5.3	4.4
Central America, Mexica	63	61	24.8	24.1
South America	243	139	14.0	8.0

Date Source: Oldeman, L.R., V.W.P. van Engelen, and J.H.M. Pulles 1990. The extent of human-induced soil degradation. Ann 5 of L.R. Oldeman, R.T.A. Hakkeling, and W.G. Sombrock. World map of the status of human-induced soil degradation: exploratory note. rev. 2nd ed. (International Soil Reference and Information Centre, Wageningen, The Netherlands 1990), Tables 1

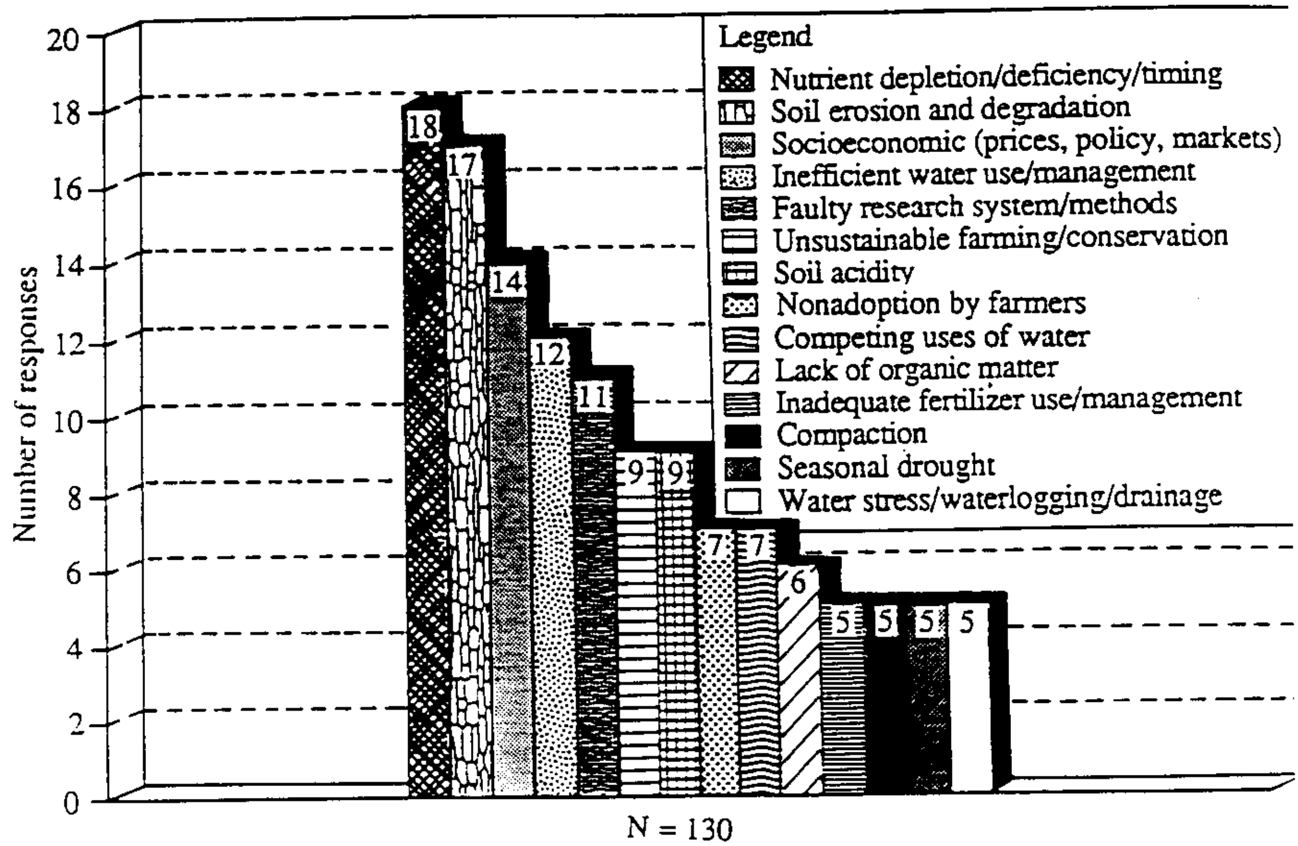


Figure III.3 Perception of major SWNM problems.

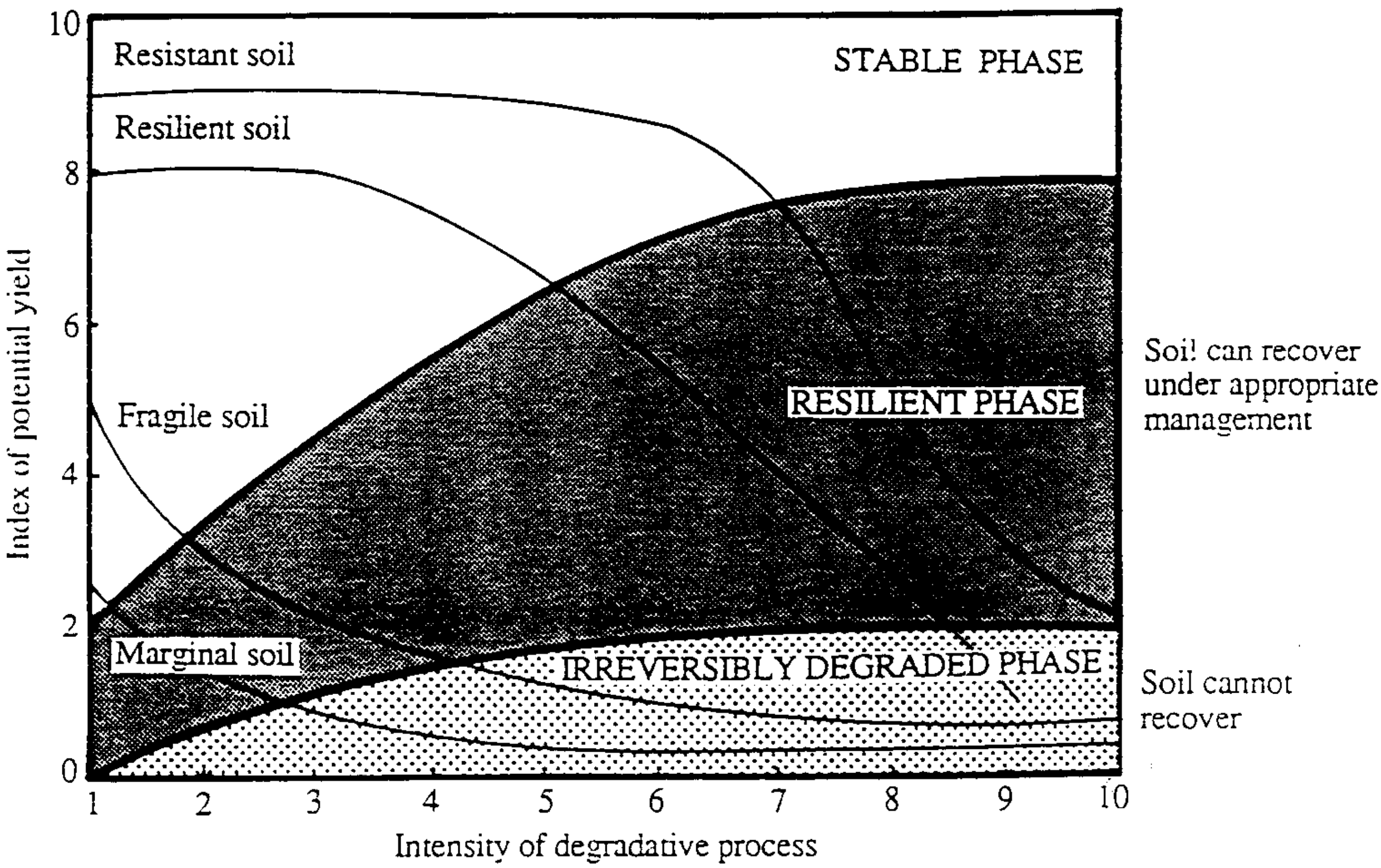


Figure III.2 Response of resistant, resilient, fragile, and marginal soils to stress (adapted from Lal, Hall, and Miller, 1989).

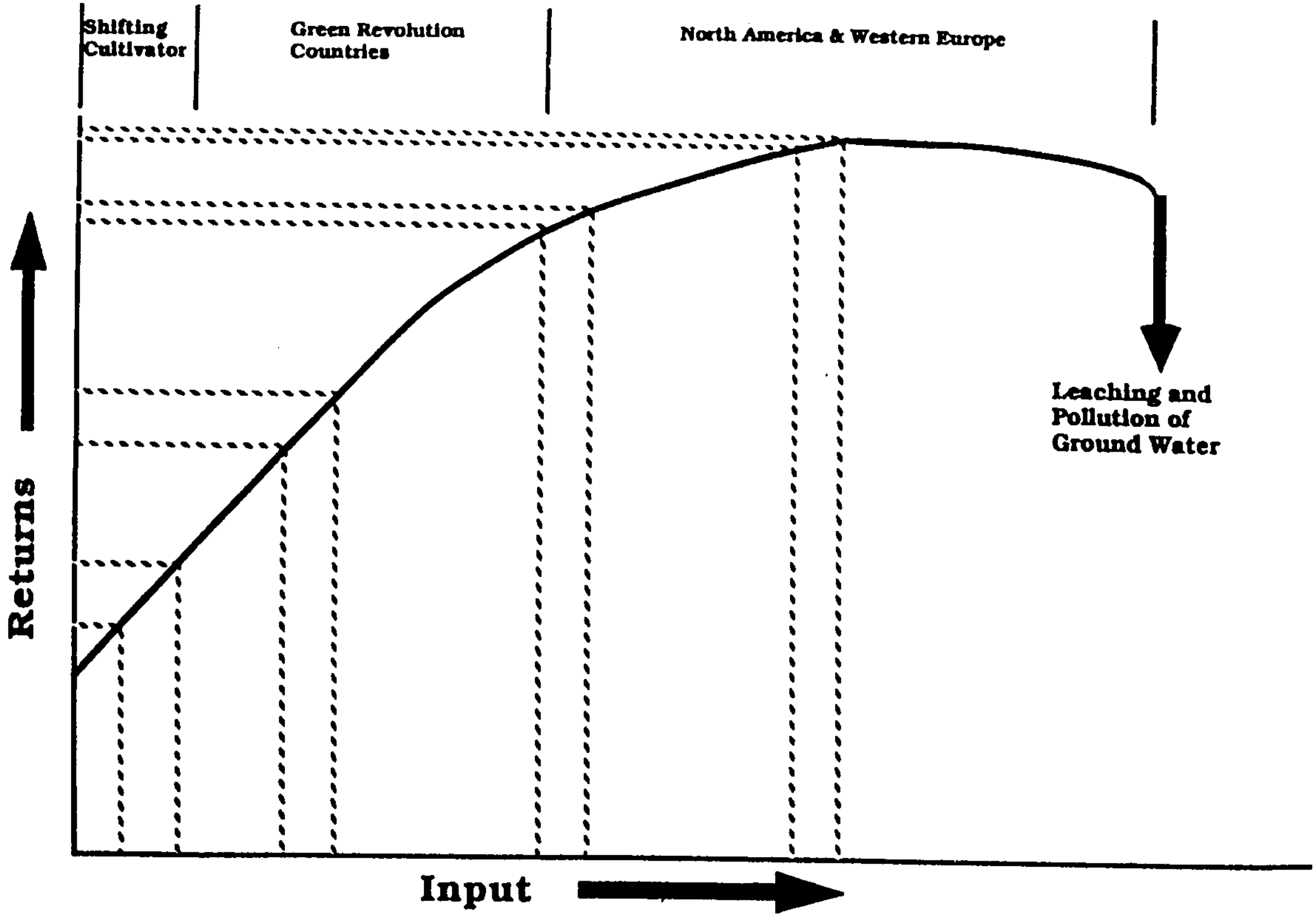


Figure 1. A generalized response curve depicting output-input ratio for farming systems ranging from subsistence shifting cultivator to large-scale commercial agriculture.

Table 1. Energy efficiency (outinput ratio) for crop production in different production systems.

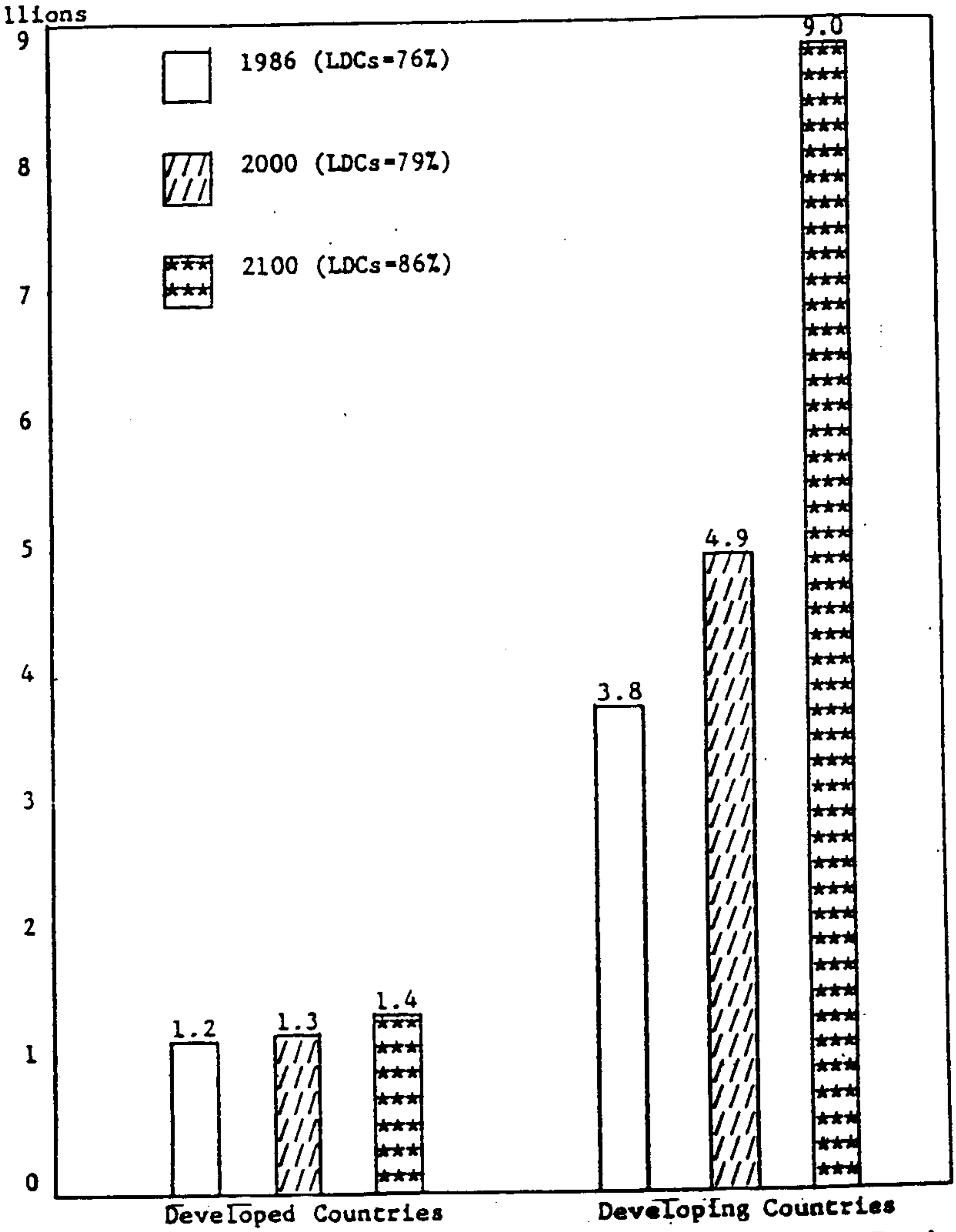
Crop	Energy Efficiency: Less Developed Countries	Energy Efficiency: Developed Countries
Wheat	6.25 (India)	2.0 (United States)
Rice	7.7 (Philippines)	1.35 (United States)
Corn	16.7 (Mexico)	2.7 (United States)
Sorghum	20.0 (Sudan)	3.1 (France)

Source: Le Pape and Merica (1983)

Table 2. Food energy output per man-hour of farm labor.

System	Crops	Output (MJ/Man-Hour)
Subsistence tropics	Rice	11-19
	Maize, millet, sweet potato	25-30
Semi-industrial (Green Revolution)	Rice	40
	Maize	23-48
Industrial crops	Rice (United States)	2,800
	Cereals (United Kingdom)	3,040
	Maize (United States)	3,800

Source: Leach (1976)



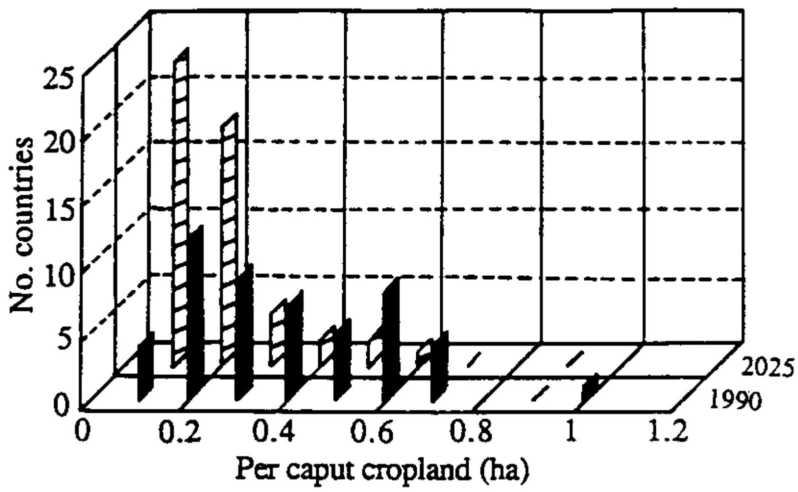
gure 1. World population distribution—1986, 2000, and 2100 (ODC, 1982; Popula-
n Reference Bureau, 1986).

Table 5. Projected population demand pressure on cropland, pasture and forest/woodland ir developing world.

Region	Total cropland, pasture and forest/woodland (million ha)	Population density (per 1000 ha)			
		1950	1990	1995	202
Africa	1763	126	364	423	90
Asia	1688	816	1844	2022	291
C. America	197	276	768	850	133
S. America	1516	74	196	215	32
Pacific Rim	43	47	115	129	21

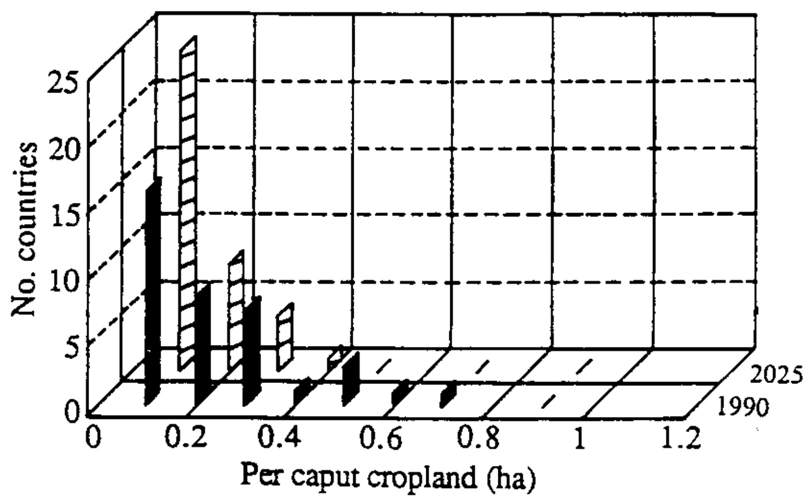
Source: Hanson, Bathrick, and Weber 1993.

(a) Per caput cropland in year 1990 and 2025
AFRICA



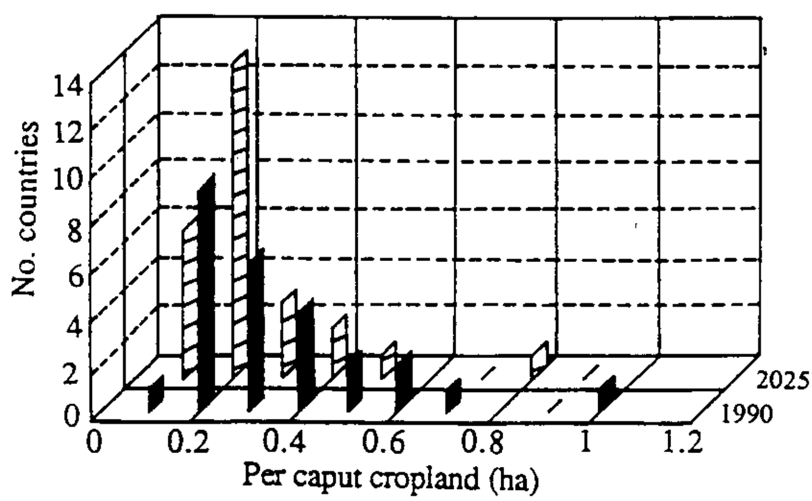
Source: WRI (1992)

(b) Per caput cropland in year 1990 and 2025
ASIA



Source: WRI (1992)

(c) Per caput cropland in year 1990 and 2025
CENTRAL AND SOUTH AMERICA



Source: WRI (1992)

<u>SOIL PHYSICS</u> IS THE APPLICATION OF THE PRICIPLES OF PHYSICS TO THE CHARACTERIZATION OF SOIL PROPERTIES AND THE UNDERSTANDING OF SOIL PROCESSES INVOLVING THE TRANSPORT OF MATTER OR ENERGY. **THEREFORE SOIL PHYSICS IS A SUBDISCIPLINE OF BOTH PHYSICS AND SOIL SCIENCE**

EARLIER STUDIES IN SOIL PHYSICS HAVE INVOLVED ISSUES AS SOIL STRUCTURE, FIELD SOIL WATER RETENTION AND MOVEMENT, SOIL MECHANICS, SOIL SALINITY, MOST OF THEM FOCUSED ON THE PHYSICAL PROPERTIES OF SOILS AS **A MEDIUM FOR CROP PRODUCTION, INCLUDING THOSE AFFECTING ROOT GROWTH AND PLANT WATER UPTAKE**

THE RESEARCH ON SOIL PHYSICS HAVE BEEN GOING FROM THE EARLY MOSTLY THEORETICAL STUDIES ON WATER, HEAT AND SOLUTE MOVEMENTS IN SOILS TO LABORATORY EXPERIMENTS INVOLVING MOSTLY DISTURBED, HOMOGENEOUS SOIL SYSTEMS, AND LASTLY TO FIELD-SCALE TESTING OF FLOW/TRANSPORT THEORIES AND MODELS.

AT PRESENT THE DEVELOPMENT OF PROCESS-BASED SIMULATION MODELS HAS ALLOWED THE INTEGRATION OF AVAILABLE KNOWLEDGE FOR FORMULATING AND EVALUATING ALTERNATIVE AGRICULTURAL SOIL, CROP, AND WATER MANAGEMENT PRACTICES, FOCUSED PRIMARILY ON WATER QUANTITY ISSUES (IRRIGATION, DRAINAGE, RUNOFF).

THE SOIL-WATER COMPLEX DOES NOT [illegible] CONSTANT PROPERTIES OR CONDITIONS OF STABLE EQUILIBRIUM, SPECIALLY DUE TO THE COLOIDAL COMPONENTS (CLAY AND HUMUS)

WATER ITSELF IS A SUBSTANCE OF UNIQUE AND COMPLEX BEHAVIOR, WITH CHANGES OF STATE AND OF PROPERTIES AFFECTED BY TEMPERATURE, PRESSURE AND SOLUTES

DUE TO THE NON POSSIBILITY TO DEFINE THE EXACT PHYSICAL STATE OF THE SOIL AT ANY TIME, WE ARE OBLIGED TO SIMPLIFY OUR SYSTEM, CONCENTRATING UPON THE FACTORS WHICH APPEAR TO HAVE THE GREATEST AND MOST DIRECT INFLUENCE ON THE PROBLEM AT HAND.

IN MANY CASES, THE THEORIES AND EQUATIONS EMPLOYED IN SOIL PHYSICS DO NOT DESCRIBE THE SOIL ITSELF, BUT AN IDEAL AND WELL-DEFINED MODEL BY WHICH WE SIMULATE THE SOIL. WE ALSO TEND TO DESCRIBE THE SYSTEM MACROSCOPICALLY RATHER THAN MICROSCOPICALLY.

BEFORE APPLYING THEORIES AND MODELS BASED ON OVERSIMPLIFICATIONS OF THE SOIL PHYSICAL STATE, THEY HAVE TO BE CHECKED AND PROVED BY EXPERIMENTATION,

OUR ACTUAL PRESENT-DAY KNOWLEDGE OF THE PHYSICAL BEHAVIOR OF THE SOIL-WATER SYSTEM IS STILL BOTH EMPIRICAL AND THEORETICAL, WITH SOME CONTRADICTIONS OR LACK OF COORDINATION AMONG THEM.

ALTHOUGH SOIL PHYSICISTS STILL MUST REMAIN CONCERNED ABOUT THE PHYSICAL ENVIRONMENT OF PLANTS, BECAUSE AGRICULTURAL PRODUCTION WILL REMAIN A CRITICAL ISSUE FOR FEEDING THE INCREASING POPULATION IN A WORLD WITH LIMITED SOIL AND WATER RESOURCES, **THE CONSERVATION OF THOSE RESOURCES AGAINTS DEGRADATION AND POLLUTION PROBLEMS BY AGRICULTURAL AND NON AGRICULTURAL AGENTS AT LOCAL, REGIONAL AND GLOBAL SCALES HAS BECOME ONE OF THE MAIN PRESENT AND FUTURE RESPONSABILITIES OF SOIL PHYSICISTS**.

THE ENVIRONMENTAL PROBLEMS HAVE TO BE ADDRESSED WITH A BROAD MULTIDISCIPLINARY PERSPECTIVE IN VIEW OF THE MANY PHYSICAL, CHEMICAL AND BIOLOGICAL PROCESSES AFFECTING THE BEHAVIOR AND TRANSPORT OF WATER AND DISSOLVED CONSTITUENTS IN THE SOIL

SOIL PHYSICISTS MUST BE CONCERNED WITH FLOW AND TRANSPORT PROCESSES IN THE ZONE BETWEEN THE SOIL SURFACE AND THE GROWNDWATER TABLE. WITH SHALLOW GROUNDWATER TABLES WE MUST BE CONCERNED NOT ONLY WITH DOWNWARD FLOW AND TRANSPORT, BUT ALSO WITH POSSIBLE UPWARD FLOW OF WATER AND DISSOLVED CONSTITUENTS.

FOR THOSE APPROACHES THERE IS REQUIRED AN INTERACTION WITH HYDROLOGISTS AND GEOLOGISTS

ALTHOUGH THE ACTUAL SCIENCE OF SOIL PHYSICS IS A VERY YOUNG ONE, IT IS NOW RECOGNIZED AS A VITAL FIELD OF INTEREST IN CONNECTION WITH HYDROLOBY, ECOLOGY, ENGINEERING AND AGRICULTURE, BUT THE PROGRESS IN APPLICATIONS TO SOLVE REAL PROBLEMS IN THOSE AREAS HAS BEEN DIFFICULT AND SLOW.

THE EARLY DEVELOPMENT OF WATER SCIENCE AND HYDROLOGY DID NOT ALLOW A PROPER STUDY OF SOIL-WATER INTERACTIONS, ESSENTIAL IN LINKING PROCESSES OF THE HYDROLOGICAL CYCLE.

THE SURFACE PHYSICAL PROPERTIES OF SOILS (VERY VARIABLE IN TIME AND SPACE) DETERMINE THE RATIO BETWEEN INFILTRATION OF RAINFALL AND RUNOFF. SEALING EFFECTS MAY REDUCE THIS RATIO TO LESS THAN 50%.

THE SUB-SURFACE PHYSICAL PROPERTIES OF SOILS DETERMINE THE EFFECTIVE SOIL ROOTING DEPTH AND STORAGE CAPACITY OF WATER, THE DRAINAGE OF EXCESS RAINWATER, AND THE GROUNDWATER RECHARGE AND FLOW.

WITH THE INCREASED USE OF SOIL FOR DISPOSAL OF ORGANIC WASTES, AND THE INTENSIFICATION OF AGRICULTURAL USE OF SOILS AND WATERS (FERTILIZERS, HERBICIDES, INSECTICIDES) PROBLEMS OF CONTAMINATION OF SURFACE WATERS, SOILS AND GROUNDWATERS HAVE BECOME IMPORTANT

THERE HAS BEEN A TREMENDOUS INCREASE IN THE DEVELOPMENT AND USE OF COMPUTER MODELS SIMULATING VARIOUS ASPECTS OF WATER AND SOLUTE MOVEMENT IN THE SOIL, BUT UNFORTUNATELY THE SIMULATION OF FIELD-SCALE PROCESSES REQUIRES CONSIDERABLE EFFORT IN QUANTIFYING A LARGE NUMBER OF SPATIALLY AND TEMPORALLY VARIABLE SOIL HYDRAULIC AND SOLUTE TRANSPORT PARAMETERS

NEW METHODS AND TECHNOLOGIES TO COST-EFFECTIVELLY MEASURE PERTINENT PHYSICAL PROPERTIES ARE CRITICALLY NEEDED FOR SIMULATING INCREASINGLY COMPLEX FIELD SYSTEMS, AND TO IMPROVE CURRENT METHODS FOR SOIL AND WATER DESIGN SAMPLING

AMONG THE POTENTIALLY AVAILABLE NEW APPROACHES FOR RAPID NON-INVASIVE IN-SITU MEASUREMENTS OF SOIL PHYSICAL PROPERTIES ARE:

- ELECTROMAGNETIC METHODS FOR CHARACTERIZING SALINITY AND WATER CONTENT
- GROUNG PENETRATING RADAR METHODS FOR DETECTING SUBSOIL LAYERS
- NUCLEAR MAGNETIC RESONANCE TECHNIQUES FOR STUDYING SOIL POROSITY AND PERMEABILITY
- X-RAY COMPUTED TOMOGRAPHY FOR STUDYING THE THREE DIMENSIONAL GEOMETRY AND CONTINUITY OF MACROPORES
- TIME-DOMAIN REFLECTOMETRY METHODS FOR IN-SITU MEASUREMENT OF WATER CONTENT AND SALINITY DISTRIBUTION BOTH IN THE LABORATORY AS WELL IN THE FIELD
- REMOTE SENSING TECHNIQUES TO OBTAIN SPATIAL AND TEMPORAL DISTRIBUTIONS OF SOIL MOISTURE

SOIL PHYSICISTS ARE INCREASINGLY BECOMING PARTICIPANTS IN GLOBAL-SCALE HYDROLOGIC RESEARCH, BEING SPECIALLY INTERESTED IN THE LAND SURFACE COMPONENT OF GLOBAL HYDROLOGICAL PROCESSES, COOPERATING WITH HYDROLOGISTS, CLIMATOLOGISTS AND GLOBAL CLIMATE MODELERS

MODELS ARE USED

- FOR DESIGNING OR ANALYZING SPECIFIC EXPERIMENTS ON WATER AND SOLUTE MOVEMENT;

- FOR EXTRAPOLATING INFORMATION GAINED FROM A LIMITED NUMBER OF FIELD STUDIES TO DIFFERENT TILLAGE AND WATER MANAGEMENT SCHEMES;

- FOR EVALUATING THE COMPARATIVE EFFECTS OF ALTERNATIVE SOIL AND WATER MANAGEMENT PRACTICES AND CHEMICAL APPLICATION TECHNOLOGIES ON CROP PRODUCTION AND GROWNDWATER POLLUTION;

- FOR REMEDIATION PURPOSES;

- FOR RISK ASSESMENT STUDIES INVOLVING SPECIFIC SOIL AND WATER DEGRADATION OR POLLUTION CASES

THE LARGE NUMBER OF MODELS DEVELOPED FOR PREDICTING WATER AND CONTAMINANT TRANSPORT, AND FOR GEOESTATISTICALY ANALYZING SPATIALLY VARIABLE SOIL PHYSICAL PROPERTIES MUST BE DOCUMENTED AND MADE AVAILABLE MORE EFFECTIVELY TO THE USERS

CONDUCTING FIELD EXPERIMENTS ON WATER FLOW AND SOLUTE TRANSPORT IN NATURALLY HETEROGENEOUS FIELD SOILS CAN BE EXTREMELY COSTLY AND TIME CONSUMING IN TERMS OF MANPOWER, EQUIPMENT, AND ANALYTICAL EXPENSES

THIS COLLEGE ON SOIL PHYSICS AIMS:

- TO PROVIDE PARTICIPANTS WITH A KNOWLEDGE OF SOIL PHYSICAL PROPERTIES AND PROCESSES SO THAT THEY MAY UNDERSTAND AND SOLVE AGRONOMIC, ENGINEERING AND ENVIRONMENTAL PROBLEMS AND ACTIVITIES SUCH AS DRAINAGE, IRRIGATION, EROSION, FERTILIZATION, SOIL POLLUTION ....

THE COLLEGE WILL BE IN PART DESCRIPTIVE AND THEORETICAL, BUT SPECIAL ATTENTION WILL ALSO BE GIVEN TO PRACTICAL APPLICATIONS, INSTRUMENTATION, MEASUREMENT TECHNIQUES AND MODELLING OF PHYSICAL PROCESSES IN SOILS

EMPHASIS WILL ALSO BE PLACED ON INTERACTION/DISCUSSIONS WITH AND AMONG THE PARTICIPANTS, AND TIME WILL BE MADE AVAILABLE FOR THOSE PARTICIPATING TO GIVE SPECIAL PRESENTATIONS OF THEIR OWN EXP**ERIENCES**