"Water and soil fertility management" (G.C.E.S.)
A new strategy to fight erosion in Algerian mountains

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Introduction

The Northern part of Algeria is the most productive, but also, a very fragile area: young mountains, often soft argilites, marl and schist alternating with calcareous sandstone hardrocks. The climate is mediterranean, semi-arid with low energetic but saturating rainfalls during the fresh Winter and with dangerous storms in the hot Summer. The soils (regosoils, vertisoils, brown calcareous, red fersiallitics soils) are sealing and often stony and have low nitrogen and phosphorus content. After successive colonizations (Romain, Turkish, French) and a recent very high demographic pressure (51 inhabitants per km2), one can observe overstoking (6 sheeps per hectare), vegetation and soil cover degradation in the mountains, sheet, gully and mass erosion, Wadi river embankment migration, roads destruction and very fast silting of reservoirs (in 15 to 50 years).

Facing these hard erosion problems, was developped (between 1940-70) a strategy of heavy rural equipment (The D.R.S. = Défense et Restauration des Sols = defens and soil restoration) including:

- reforestation of steep slopes and higher areas of watersheds,
- gully correction and
- terracing cropped fields (banquette algérienne = graded channel terraces) concerning more than 300.000 hectares at 5 to 10.000 FF/ha.

The main objective was to delay soil degradation and reservoir siltation. But in 1977, the failure of this "equipment approach" was clear. The farmers rejected the terracing system, the wood production was quite low and the reservoir siltation rate remained high. Terracing was abandonned for economical reasons (Heusch, 1986). Foresters continued the reforestation and gully restoration, but the farmers were abandonned except for some land improvements (subsoiling calcareous crusts) (Roose, 1987).

The first data on runoff plots (Kouidri, Arabi, Roose, 1989) confirmed that sheet erosion from hillslopes gave only a very light part (0,2 to 1 t/ha/year) of river sediments (Heusch, 1970; Demmak, 1982). That could explain why terracing was not efficient to reduce silting. Nevertheless, runoff from hillslopes can be very high (up to 80 %) during exceptionnal storms falling on sealed or compacted soils (overstocking of pastures, roads, paths, abandonned fallows, etc...): that run off water flowing on steep bare slopes create gullies, high wadies peak flows, mass movement and important sedimentation in reservoirs.

Presently, industries know difficulties and the algerian Government proposes to maintain population in the country and to intensify the agriculture in the mountains without degrading dams and water reservoirs needed for the increasing cities and for irrigation.

From 1985 to now was developped a cooperative program of research and formation with participation of a dozen researchers of the National Algerian Institute for Research in Forestry (INRF) and the French Institute for Research in Cooperation (ORSTOM). This program named "Water and Soil fertility management" (G.C.E.S. = Gestion Conservatoire de l'eau et de la fertilité des Sols) covers three sub-programs:

1 Inquiries on the D.R.S. approach efficiency first by the Forestry Administration and then by interdisciplinary groups of researchers;
2 Management of microwatersheds (20 to 300 ha) near Medea, Mascara and Tlemcen;
3 Measurement of various erosion processes with a network of runoff plots and gullies.

The objective of this program is a attempt to develop in Algeria a new strategy to fight erosion in agreement with farmers (G.C.E.S.): how to increase the biomass production (the yield and the farmers income) by improving the soil infiltration capacity, the structural stability and the soil fertility, the green cover and consecutively by reducing runoff and erosion losses on the cropped fields but also in the drainage system (Roose, 1987; Arabi, 1991).

In this paper are proposed the main results obtained at the Ouzera Station (1987-90) (Arabi et Roose, 1990), but similar results were obtained near Tlemcen (Mazour, 1992).

2. "G.C.E.S.", a new strategy for soil and water conservation

In Algeria, water disposal (and reservoir siltation) is one of the first problem: with the industrialization of the preceeding 30 years, the urban population has grown very fast. However soil conservation and terracing do not interest farmers very much because there do not valorize the supplemental labour and do not increase significantly the ground productivity. Degraded soils are already so poor... why preserve them? Without strong investment they will produce very few. Therefore to interest farmers to preserve the land and the water quality it seems necessary to answer first to their immediate problems: how to increase the farmers income and their production security by improving first **water and nutrients management** on their productive fields? Consecutively the green cover will increase and the runoff + erosion risks will decrease. That approach change completely the point of vew of the land manager. With farmers the first action is to look to the production system, the water and nutrient balance, the main obstacles to the productivity of the best fields. If necessary it will be intervened to stop gully erosion and to valorize the sediment management but badland treatment will generally not be the main objective of the farmers. It was the main objective of the traditionnal land managers. It is the Administration rule to restore the forest and manage sediments in the torrential wadies.

This cooperative strategy must be applied in 3 steps:

1 - Dialogues to get confidence between farmers, researchers and technicians. Farmers generally know the local environment better than technicians, but technicians have complementary knowledges. Inquiries should be undertaken:

- What are the farmer feelings about their problems (and their solutions) about soil degradation? Physical, chemical, biological problems ?
- What type of erosion: when (what season), where (on the toposequence) associated with wich cultural practice ?
- Where is the runoff source? How to reduce the runoff volume and manage the drainage?
- Importance of erosion and runoff risks?
- What are the local disponibilities ressources to reduce runoff and erosion risks?

2 - Experimentation of improved farming systems in farmers fields

- Evaluation of faisablity, efficiency and risks of antierosive practices.
- Economical aspects: increase of production in relation to labour and cost surplus.

3 - General survey of the little watershed management with the rural community:

Comparison of the capability and land utilization maps to determine where it is necessary to intervene to modify the production system.

In this paper, will be presented the first results of this GCES approach in Algeria where it has been worked only on the two first steps: inquiries and experimentation.

3 - First results for steep slopes farming systems improvement near Medea (fig. 1)

3.1. Experimental conditions

Fifteen runoff plots (22.2 m x 4.5 m) were built on farmers fields around the INRF research station of Ouzera at 90 km South of Alger. The landscape looks like a succession of plateaus (900 to 1.200 m of altitude), steep hillslopes (12 to 40 %) and deep wady valleys. Soils are in relation with the lithology and the topography situation (Pouget, 1974; Aubert, 1987). There are:

- clear lithosoils on calcareous sandstone colluvium, rich in $CaCO_3$ but poor in organic matter,
- grey vertisoils on limestone well structured, 2 % of O.M., pH 7 to 8, calcium satured, very resistant to splash but sensitive to gully and mass movement,
- red leached fersiallitic soils on soft sandstone, poor in O.M., very fragile, instable,
- brown calcareous soils on colluvium, 2-3 % of O.M., well structured top soil but thin profile.

In this montainous area, forest cover decreased from 18 to 13 % and vineyards and orchards surface increased from 2 to 7 % and 8 to 14 % between 1982 and 1991. That means that more people are earning their living in the mountains. Cultural practices are limited: plowing for weed control, then cross cover cropping for fertilizers burrying (N_{33}, P_{45}, K_{90}) and clods diameter reducing. The average rainfall amount on 40 years is 680 mm at the Medea Station but between 1986 to 1990, rainfall at Ouzera Station varied between 408 to 566 mm and the erosivity index (RUSA) around 46.

The objective of this research is to compare the bare cultivated standard plot to four production systems **(vineyard, orchard, cereals/leguminous pasture and sylvopastoral systems)** on 4 soils representative of this area. The improvements introduced are correct plowing, herbicides, pesticides, selected seeds, correct fertilization, leguminous fallow, mixt cropping and rotations under orchards. The parameters measured are rainfall (amount, intensity, erosivity), runoff (KRAM % is the yearly average coefficient of runoff and KRMax %, the max. coefficient for one storm), soil erosion (suspension and coarse sediments), biomass production, net income and soil surface parameters.

3.2. Results and discussion

Rainfall was 100 to 250 mm (see fig. 1 and table 1) shorter than the normal amount (680 mm). There was no exceptionnal storm event.

The Ram/Ham ratio (Ram = average annual rain erosivity; Ham = average annual rainfall amount for the same ten years) was 0,1 for Medea Station. Therefore the rainfalls are much less energetic than in tropical african countries, where Roose (1977-88) found 0,5 for Ivory Coast and O,25 for mountains of Cameroun, Rwanda and Burundi.

Runoff: On cultivated plots the average annual runoff (KRAM % see table 1) was light (0,5 to 4 % of the rains) and the maximum for one storm (KRMAX) increased from 8 to 36 %. On bare plots KRAM were still light (10 to 18 %) compared to tropical situations (25-40 % in Ivory Coast); whereas on bare or compacted and saturated ground the runoff can exceed 80 % in the Winter. Here begin the risks of gullies, wady peak flow and mass movement.

As cultural practices were similar on bare and cropped plots, it appears that crop covers and also their improvement, were efficient to reduce runoff rate (see tables 2 and 3).

As many authors, it was observed that deep plowing increased infiltration. For instance in vineyards, if herbicides replaced plowing to destroy weeds, the runoff increased significantly and the topsoil became very compact so that erosion decreased. Whereas for exceptionnal storms, the soil water capacity would be saturated: the runoff would increase and the soil resistance to runoff aggressivity would be less important on plowed soils, principally on steep slopes.

Under natural vegetation, cover was important (more than 80 % of litter) so that runoff was frequent but never dangerous (< 7 %). Nevertheless, it was often observed in Algeria runoff and gullies coming out from degraded, overgrazed pasture land, chiefly on paths used by animals (or even between trees plantations).

The runoff begins generally after 20 mm of rainfall on dry soil conditions and 3 mm on wet or compacted soil surface. This threshold and the runoff are depending on rainfall characteristics (intensity but also volume of rains after saturating the soil water storage capacity), but mainly on soil surface characteristics (moisture on 10 first centimeters, cracks, seeling crust, green cover litter, rocks and clods). The largest runoff event become only when all conditions are optimal, generally between November and March, or during an exceptionnal intensive storm in Summer (once in 1 to 5 years).

Sheet erosion: was very moderate (0,1 to 2 t/ha/year) on cropped fields and 1.5 to 9 t/ha/year for cultivated bare fallow, even on 40 % slopes because rainfall aggressivity was weak (R<50) and soils are very resistant (K = 0.02 to 0.01), rich in clay saturated with calcium and often stony. Even if erosion atteins 9 t/ha/year (0.6 mm) more than 3 centuries are needed to scour the 20 centimeters humiferous plowed horizon. Experimentally, it was proved that erosion is selective for organic and mineral colloids and nutrients, but rill erosion is not selective so that where rill erosion increases, the humiferous horizon is generally scroured. If sheet erosion is not the major processus, rill erosion is important but dry mechanical creeping by cultural practices seems to be the most efficient in that mountainous landscapes.

For instance, near Ouzera station, an orchard was planted 30 years ago: now 30 centimeters of soil are missing between trees ! Even if sheet erosion actually measured reached 1.5 t/ha/year (0.1 mm), for thirty years, 3 cm would be lost and 27 centimeters would be removed by dry creeping (crossed deepplowing twice a year with the tractor !).

Probably the slope steepness increases the dry mechanical creeping by cultural practices (Roose, Bertrand, 1971).

Influence of soil type and slope (table 2)

The soil erodibility was small, even after three years of bare cultivated fallow (K = 0.01 to 0.02). Sheet and rill erosion increased from years to years: it was max. on red fersiallitic soil (9 t/ha/year), medium for grey vertisoil (2.7 t/ha/year) and minimum on brown calcareous soils (1.5-1.8 t/ha/years). The stone protection seems efficient. It is difficult to compare their runoff ability because the slope steepness changes with soils !

On the other land, it seems clear that the average and the maximum runoff coefficient decrease when the slope steepness increases... on bare cultivated fallow. That type of result was already found in Marocco by Heush (1970) and Roose (1973) in Ivory Coast.

This shows that many equations (Ramser, Saccardy, etc...) increasing the terrace frequency on increasing slopesteepness are not adapted to these mediterranean conditions. Heusch (1970) has already shown that plot position in the toposequence is sometimes more important on runoff and erosion than slope steepness.

Influence of improved cultural system (table 3)

The improvement of crop cover (plant density, fertilizers, leguminous rotation, cropping in the Winter between vineyards and orchards) seems to be moderately efficient on runoff and erosion.

But the most interesting fact is the significant increase of net income: from 2.500 dinars per hectare for traditionnal cereal cropping to 35.800 and even 42 and 65.000 da/ha if crops are associated under orchards and vineyards.

Thus these data show it is possible at the same time to intensify the mountain agriculture and to reduce environment degradation.

Yield and net income (table 1)

Yields observed on traditionnal systems runoff plots are very low as on the farmers fields (0.7 t/ha/year of Winter wheat, 2.8 t/ha of grapes and 0.8 t/ha of apricot). On runoff plots (100 m2) with improved cultural practices, the yield of wheat increased up to 4.8 to 6.5 t/ha/year and that of grapes up to 4 t/ha, but in addition, 3.4 t/ha of beans or 3 t/ha of wheat associated Winter crops.

At the same time straw, leguminous leaves and other crops residues production also increased significantly (0.2 to 2 or 3 t/ha/year) so that animal production but also manure and other organic residues could improve the soil fertility and their resistance ability to erosion.

Probably the yield increase will not be so important on large fields than on small runoff plots (100 m2), but the first step was to demonstrate it is possible to improve significantly the production and also the rural environment.

The next step is to show it is rentable! If you cut off the price of improved seeds, fertilizers, pesticides, herbicides, labour increase for cropping and yielding, it remains to the farmers a net income much higher than for traditionnal fields:

1) for extensive grazing in the woodland you can earn about	500 dinars/ha
2) for traditional Winter wheat	2500 da/ha
3) for extensive apricot or vineyard	10 to 17000 da/ha
4) for intensive improved wheat and leguminous forage	28 to 33000 da/ha
5) for associated beans under apricot or vineyard	42 to 65000 da/ha

That means in the same production system you can multiply the net income by ten for cereals or by 3 for vineyards after intensification. If you change of production system and intensify you may earn more than 20 times the initial income.

With that benefit in vew, it is not difficult for the farmers to understand their interest for changing their traditional system with improved cultural practices. And at the same time, it is easy to propose a package of improved practices where water and soil conservation are included.

We were surprised to observe after 4 years experiments that neighbouring farmers have copied our improved system without any pressure!

Conclusions:

This paper summarizes the results of 3 years data on 15 runoff plots, on 4 soils, 4 production systems representative for this very steep hilly area of limestone, sandstone and calcareous stone on Mediterranean mountains.

Introducing a package of improved cultural practices, it was proved that it is possible to reduce a little runoff and erosion risks and to increase significantly yields and farmers net income without degrading the environment.

The intensification of mountainous agriculture seems to be possible without risk of soil fertility degradation or silting the reservoir if developping a new strategy of Water and Soil Fertility Management.

Bibliography

Arabi, M. & Roose, E. (1989). Influence de 4 systèmes de production en zone méditerranéenne de moyenne montagne en Algérie. Bulletin Réseau Erosion, 9 : 39-51.

Arabi, M. (1991). Influence de 4 systèmes de production sur le ruissellement et l'érosion en milieu montagnard méditerranéen. Thèse doctorat géographie, Grenoble, 276 p.

Aubert, G. (1987). Erodibilité des sols de la région d'Ouzera. Bulletin Réseau Erosion, 8 : 97-99.

Demmack, A. (1982). Contribution à l'étude de l'érosion et des transports solides en Algérie septentrionnale. Thèse doct. ing. Paris, 323 p.

Heusch, B. (1970). L'érosion du Pré-Rif. Une étude quantitative de l'érosion hydrique dans les collines marneuses du Pré-Rif occidental. Annale Rech. Forestière du Maroc, tome 12, 176 p.

Heusch, B. (1986). Cinquante ans de banquettes de DRS en Afrique du Nord : un bilan. Cah. ORSTOM. Pédol., 22(2) : 153-162.

Kouidri, R. ; Arabi, M. ; Roose, E. (1989). Premiers résultats de mesure du ruissellement et de l'érosion en nappe : Medea, Algérie. Bull. Réseau Erosion, 9 : 33-38.

Mazour, M. (1992). Les facteurs de risque de l'érosion en nappe dans le bassin versant d'Isser : Tlemcen, Algérie. Bull. Réseau Erosion, 12 : 300-313.

Pouget, M. (1974). Etude agro-pédologique de la région d'Ouzera. ANRH, Alger, 72 p.

Roose, E. (1977). Erosion et ruissellement en Afrique de l'Ouest : 20 années de mesures. In: Travaux et Documents ORSTOM, Paris, n° 78 : 108 p.

Roose, E. (1987). Evolution des stratégies de lutte antiérosive en Algérie ; nouvelle démarche : la GCES. Séminaire INRF de Medea (Algérie). Bull. Réseau Erosion, 7 : 91-96.

Roose, E. (1988). Water efficiency and soil fertility conservation on steep slopes of some tropical countries. Workshop SWCA Puerto Rico. Edit. Moldenhauer and Hudson, Ankeny USA: 296 p.

Saccardy, L. (1949). Nécessité de la lutte contre les érosions. Méthodes modernes de conservation des sols et des eaux. Bull. Techn. des ISA, n° 142, Revue Terres et Eaux, n° 9, Alger.

Table 1 : Runoff (% of rains), Erosion (t/ha/year) yields (t/ha) and net income for 15 runoff plots (22 x 4.6m) of INRF Ouzera Research Station Algeria
Average values for 3 years: observed rainfall: 579-530-405 mm

	KRAM % Average Runoff %	KRMax % Max. Runoff %	EROSION t/ha/year Med - Max ()	Yields t/ha/year	Net income Dinar/ha/year 28 Da = 1 US$
AGRO-PASTORAL System VERTISOIL, 12 % slope					
1° Internat. Reference bare cultivated fallow	18.2	7 to 86	2.7 (6)	0	0
4° Local reference wheat, extensive grazing	2.1 ↗	7 to 16	0.19 (0.3)	0.7 grain 0.2 straw	2500
2° Improved: wheat + leguminous	0.6 ↘	1 to 8	0.11 (0.2)	4.8 grain 3.1 straw 5 beans	36200
3° Improved pasture *Medicago*	0.6 ↘	0 to 9	0.05 (0.3)	6.5 grain 2.2 straw	35800
Sylvo-Pastoral System Brown calcareous soil, 40% slope					
8° Internat. reference bare	11.3 ↗	- 34 ↗	1.8 (2.7)	-	-
6° Very overgrazed mattoral	12.0 ↗	3 to 25	1.7 (2.1)	-	-
5° Pine forest = litter	0.5	1 to 3	0.02 (0.04)	-	-
7° Diss pasture + litter	0.8	2 to 7	0.03 (0.04)	-	-
APRICOT ORCHARD Red fersiallitic soil, 35% slope					
9° Internat. reference bare	15.5 ↗	25 to 50	9 (20) ↗	-	-
11° local reference: apricot 8 x 8m	3.1 ↗	11 to 12	0.66 (1.3)	0.7 fruit*	10000*
10° improved apricot + wheat/beans rotation + fertilizers and buffer strips	0.6 ↘	0 to 9	0.09 (0.2)	0.8 fruit* 6.0 beans 2.0 straw	42200
Vineyard 30 % slope Brown stony calcareous soil					
15° Internat. reference, bare	9.5 ↗	16 to 36	1.53 (2.3) ↗	-	-
12° Local ref: vineyard 30 years + 2 tillage	1.5	3 to 8	0.11 (0.2)	2.8 grapes	34300
13° Improved vineyard zerotillage + herbicides	4.3	8 to 26	0.13 (0.2)	3.0 grapes	35100
14° Improved vineyard + wheat/beans rotation + 2 tillages + fertilizers	0.2	0 to 3	0.004 (0.1)	4.0 grapes 3.4 beans 1.5 straw	65400

Med = median Max = maximum in 1990
* Apricot fruit yield was very low because of severe insect attacks

Table 2: Influence of soil type and slope steepness % on runoff and erosion on bare cultivated fallows

	stone cover %	slope %	KRAM %	KRMax %	Erosion t/ha/year
brown calcareous SPK8	16	40	11	34	1.8
brown calcareous colluvial VK15	20	35	10	36	1.5
red fersiallitic ARK9	0	30	16	50	9.0
grey vertisoil APK1	4	12	18	86	2.7

Table 3: Effect of improved cultural system on runoff (average and max. in % of rainfall), erosion (t/ha/year) and net income (1US dollar = 28 dinars)

Situation		KRAM %	KRMax %	Erosion t/ha/year	net income DA/ha
Agropastoral on vertisoil	tradit	2.1	16	0.189	2504
	improved	0.6	8	0.054	35810
Sylvo pastoral on brown soil	degraded	12	25	1.740	?
	reforested	0.5	3	0.034	?
	regrassed	0.8	7	0.020	?
Orchard on red fersiallitic soil	traditional	3.1	12	0.656	10000
	improved	0.6	9	0.088	42187
Vineyard on brown colluvial soil	traditional	1.5	8.3	0.114	34333
	improved	0.2	2.7	0.009	65364

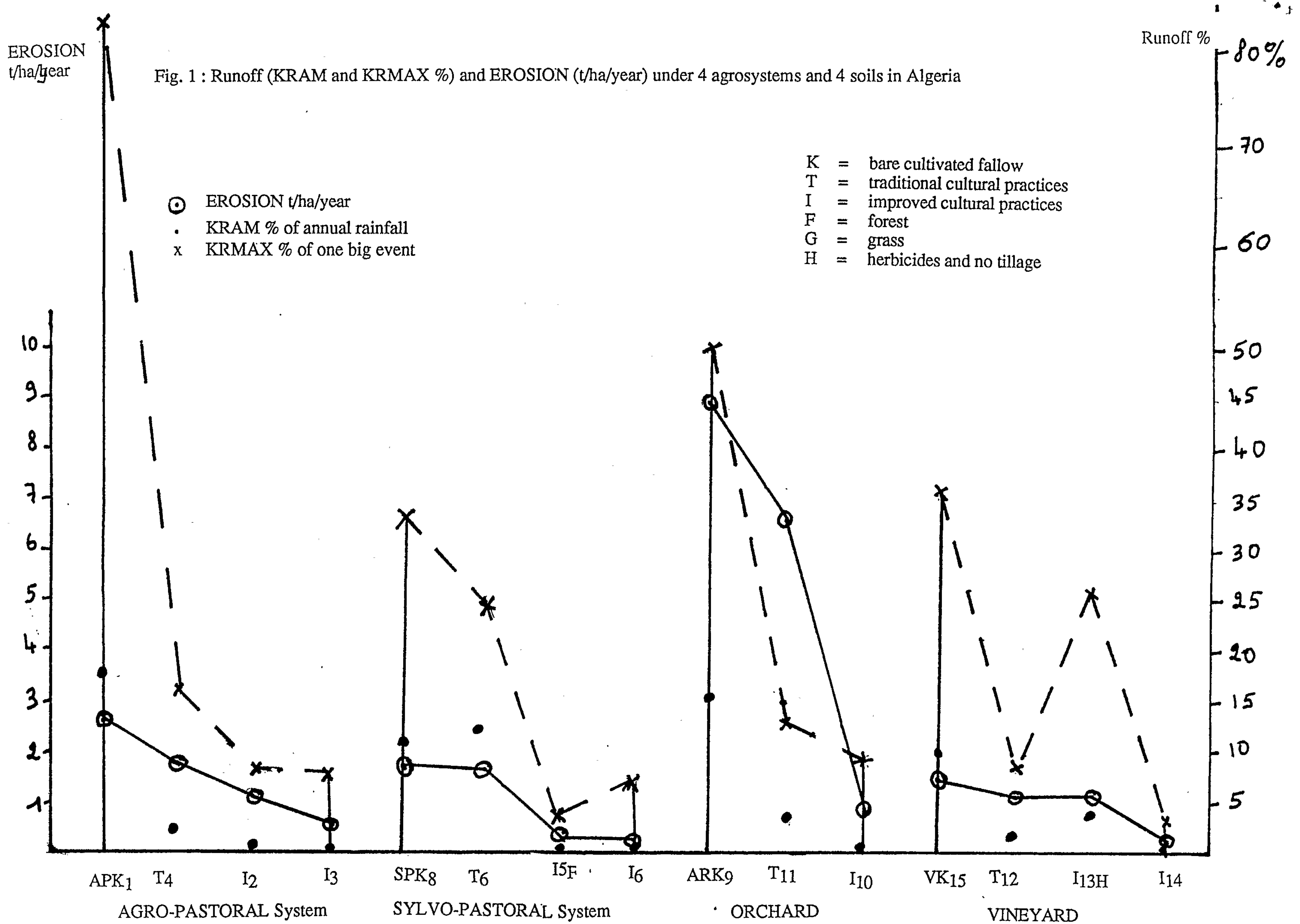

Fig. 1 : Runoff (KRAM and KRMAX %) and EROSION (t/ha/year) under 4 agrosystems and 4 soils in Algeria