"Water and Soil Fertility Management" - A New Approach to Fight Erosion and Improve Land Productivity

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Summary

Traditional soil and water conservation strategies are numerous around the world: they reflect ecological but also socio-economical systems. If the demographic pressure or the sociological demand increase, the system fails.

Then the central state authority sends engineers to diagnose the environment collapse and to impose mechanical equipment to improve soil conservation but chiefly water quality conservation, which is very important for industries and cities. Around 1980, there was a general observation of more than 50 % failure for that kind of technocratic strategy.

Now, many people think that erosion is not only a technical problem but also a society crisis. So it is evident that if we need farmers participation to maintain rural environment, it is necessary to interest them in the definition as well as the realization of this program. Beforehand however, we need to answer three priority problems (security + productivity + labour valorization improvement) and to propose simple solutions (based on improved traditional strategy of water and soil fertility management) where farmers' communities will select the solution adapted to their own socio-economic situation.

Two case studies have been chosen from the semi-arid Mediterranean (Algeria) and Sudano-Sahelian area (Burkina Faso). This "Water and Soil Fertility Management" approach seems much more positive and acceptable by farmers than soil conservation because a majority of tropical soils are already so poor that mechan-

ical conservation terraces cannot improve the productivity significantly and presently without restoration of soil fertility and water management.

Introduction

Nearly all the projects of rural development in tropical areas do face soil fertility and physical degradation problems after a few years. For that crisis status, often experienced in the past in Europe, solutions will be found by progressively adapting production systems to the human economical environment.

Governments that generally face problems of demographic pressure, promote the extension of new cropped land :peasants then clear new fields and cultivate even more fragile lands without foreseeing their management in order to preserve infiltration capacity and soil fertility. We are therefore experiencing the extension of degraded and abandoned bare fields in the Sahel (Marchal, 1979).

But even though people try to intensify the production on their fields that are already cultivated, by increasing inputs such as fertilizers, pesticides, selected seeds and tillage system, sooner or later people cause impoverishment and acidification of the topsoil by altering the nutrient balance (increasing losses due to erosion and exportation)and by degrading the physical properties (organic matter mineralization, sealing crust and subsoil compaction).

Erosion is a term governing many processes varying very much in time and space ...Consequently, soil conservation strategies must be adapted from one area to another to ecologic and socio-economic conditions. Geological erosion is generally slow (a few tons/km^2/years) but, some catastrophic phenomena can occur suddenly, like landslides taking down hillsides, centennial forest and villages. Accelerated erosion which interests us in this paper is developing in relation with human activities: overgrazing, clearing the forest, repeated fires, poor cultural practices, reduced fallow, unbalance of nutrients and soil organic matter will progressively lead to soil degradation, runoff and erosion.

If poor management, however involves increasing erosion risks, people can progressively adapt its agro- sylvo- pastoral systems to local ecological situations. Often rural communities are able to select soil and water conservation strategies for maintaining their environment. Ahead of those environmental degradation problems, most of the projects develop various technocratic approaches that give importance to landscape equipment in order to protect water and road users from runoff damages. We would like to remember traditional strategies and to propose an agronomic approach that takes into account the peasants' problems and the possibilities of dealing with erosion problems at their origin by a progressive adaptation of the production system to the ecological situations. Two examples taken from a program which is presently in progress in Burkina Faso, in Algeria, in Cameroon and in Rwanda will allow a discussion about the advantages and limitations of this new approach in water and soil fertility conservation.

1. Traditional Strategies

Facing these vegetation and soil degradation problems, successive generations of farmers developed various strategies of water economy and soil fertility management as a function of ecological and socio-economic conditions. Many of them are spread over the world but their occurrence is related to specific economic conditions.

So shifting cultivation has been practiced all over the world when the population pressure was low (10 to 40 inhabitants/km^2 in relation to climate and soil productivity). After clearing and burning the forest, crops are grown on ashes and the land is abandoned to fallow as soon as it does not give enough yield for the labour required. If the demographic pressure increases, the fallow duration decreases and the soil fertility will progressively be degraded.

Bench terracing. On the other hand, when population is dense, the flat land scarce and the labour plentiful and cheap, bench terraces occur with irrigation or drainage to promote high profitable crops: numerous terraces were built around the Mediterranean area, in Asia and Latin America. People will never accept investing 500 to 1200 men-days/ hectare without being obliged for military, religions, demographic reasons: nobody will maintain them without good economic reasons.

Ridging, intercropping and agroforestry. In volcanic areas of South Western Cameroon moist forest, the Bamileke have successfully maintained their environment despite high population density (100 to 500 inhabitants/km^2) (Fotsing, 1992).

They have combined large ridges with intercropping covering the soil all the year long with various agroforestry systems. One child only receives the ground in heritage, so that in the oldest farms, people have built a bocage with quickset hedges and fences to manage properly breeding, manuring, ridging and covering the soil with multilayer cultivated vegetation. Other children must find new land on communal ground in competition with herders. The less dense areas have less secure ground regime and more erosion problems. Of course there is a ceiling to population density above which environment problems are so heavy that people must change their way of living (Roose, 1992).

Stone lines, stone walls and manuring. Some centuries ago, Dogons from Mali took refuge in the sandstone cliffs of Bandiagara to resist Muslim influence. For survival they have developed many kinds of soil and water conservation systems:

- stone lines along their little piece of land to catch sand during the dry season and runoff during the rains;
- stone walls after bringing earth from the sandy plains in order to build new soils on sandstone flag (run-off harvesting);
- Mulching and composting with familial waste, animal faeces and cropping residues.

Bocage, close association of trees, crops and animals. European areas have already met many erosion crises. The most famous happened in medieval times when the natural fallow had to be abandoned because of high demographic pressure. Manuring and ploughing were introduced to restore the chemical and physical fertility of soils faster. Breeding was associated with cropping and forests: landscapes were divided by quickset hedges to separate groves, fields and meadows. This system existed until after the Second World War, and an other crisis has developed with actual motorized farming systems which resulted in large fields and destruction of many embankments, hedges, ditches.

Runoff farming. In semi-arid areas around the Mediterranean, people collected runoff from hillslopes and developed many systems to use it carefully in the best soils of the valleys. Let us quote the famous Jessour of Tunisia, Magden of Algeria, microwatersheds in the Neguev desert (Bonvallot, 1986; Roose,1991; Reij et al,1988; Critchley et al, 1992).

Many of these traditional systems are still efficient for soil and water conservation purposes but for economical reason, most of them are abandoned by lack of labour: it is often more profitable to find a job in cities! It should be very interesting to study more accurately how these systems were efficient, in what socio-economic conditions they are adapted, what are the area characteristics and the climatic, ecological circumstances where they are extended, what improvement should take place. International soil conservation experts generally ignore them arrogantly or described them as souvenir of the past ; but it is rare to find documented analysis of their functioning, for their extension or their disappearing, modern methods for improving their efficiency or their economic adaptation. But today, mechanization and industrialisation of agriculture and the economic crisis call into question certain types of traditional management. A new erosion crisis is being developed and we need new strategies of water and soil fertility management. (Roose, 1992)

2. Modern Strategies for Rural Equipment

During the last century various modern soil conservation strategies have been developed.

2.1 Mountainous land restoration

Mountainous land restoration was developed in France after 1850, then in European mountains to protect fertile valleys, roads and railway lines through the mountains. Forestry departments bought degraded land in the mountains, restored vegetation and corrected torrential mountain streams with mechanical and biological methods. (Lilin, 1986)

2.2 Soil and water conservation

Soil and water conservation of cropped soil have been organized in the USA since 1930. The quick extension of industrial crops planted in rows which poorly cover the soil surface (like cotton, maize, tobacco, peanuts) provoked catastrophic wind and water erosion. In 1930, 20 % of the USA arable land was declared degraded by erosion. Under Bennet's compulsion (1939), the Soil and Water Conservation

Service was constituted in each county, with the objective of advising and helping farmers who ask for technical and financial assistance to protect their land. A central department achieved technical studies for the projects.

Two schools of soil conservation are still fighting today on the field:

— That of Bennet who observes that gullies induce spectacular soil losses in relation with the energy of runoff which is a function of its mass and the square of its velocity (Ec. run-off = 1/2MV2). The struggle against erosion try to reduce runoff velocity and its erosive energy (by graded terrasses, weirs, dams, grassed waterways, etc.) without reducing runoff volume on the field.

— That of Ellison (1944) and Wischmeier (1960) calls back to mind that runoff develops after topsoil structure degradation by raindrop kinetic energy. The struggle against erosion tries to improve the soil infiltration capacity of the field with farming techniques increasing the vegetation cover with a minimum of mechanical anti-erosive structures in the landscape.

2.3 Integral protection and soil restoration

This strategy was developed in Algeria and around the Mediterranean sea in 1940-60 facing the dramatic problems of accelerated silting of reservoirs, degradation of bridges, roads and cropped or overgrazed hillsides. The main objective was to protect degraded land from clearing, cropping or overgrazing and to restore the soil infiltration capacity by planting trees considered as the best way to improve soil fertility. Tremendous amounts of financial and mechanical means were used to intercept sheet runoff in the fields (various terrace systems, Monjauze's dykes, etc.) to reforest degraded land and to structure areas for intensive agriculture (Plantie, 1961; Monjauze, 1962; Greco, 1978).

In solving these "runoff-erosion-sedimentation problems" with limited resources, specialists have discovered the variability of erosion in space and time: the major part of the sediment comes from less than 10 % of the watershed surface and during a short period of the major showers once in 5 to 10 years.

The engineer in charge of the project has to find out in 2 or 3 years the most efficient interventions, and to localize the most severe erosion damages (gullies, etc.), their cause and the factors which would limit the risks' extension. He must produce a series of maps on present erosion processes, land erodability risks, land use, and then propose a limited number of structures (dams, terraces, draining ditches, waterways, roads, etc.) where it would be easy to use heavy motorized means. In a few years the project has imposed to a rural community a whole hydraulic structure that has probably decreased the sediment flood problems elsewhere, but does rarely solve the infiltration rate at field. That type of "equipment strategy" rarely works successfully in developing countries.

Let us now analyse some aspects of the " equipment logic" (Koohafkan and Lilin, 1986).

— The engineer in charge of the project has no time to discuss the traditional soil and water conservation strategies included in production systems and land management with the rural communities. He is "The representative of the knowledge" for he comes from a High School: the peasants have never been to school and are therefore not competent. In taking into account the general interest of the Nation, the engineer will define the structures and, if necessary, he will try to weaken the farmers' resistance.
— A good engineer knows there is always one technically applicable solution to each erosion problem; it is often an hydraulic or mechanical solution. He is in charge of the project conception and he will take high security coefficients (that increase the cost).
— Conception, execution and maintenance are different jobs shared between people differently qualified: They have few dialogue opportunities. In a financial concept, a "good project" must be carried out in a short time, that is why conception engineers rarely meet people in charge of maintenance.

This explains some repeated failures in soil conservation projects.

3. A Strategy for Rural Development

Since 1975-80, numerous critical papers from researchers, socio-economists and agronomist have established frequent failure of soil conservation projects looking more at rural equipment than farmers' needs (Lovejoy, Napier, 1986). The premium to engineers was not completely beside the point of heavy equipment used for soil conservation.

In USA, despite 50 years of remarkable work of the Soil Conservation Service, 25 % of arable lands are still losing more than 12 t/ha/year of soil, which is the tolerance admissible for deep soil erosion.

In Northern and Western Africa, farmers often prefer to abandon land managed by state technichal services rather than maintain conservation structures whose objectives and ownership they are ignorant of (Heusch,1986).

The reasons for failure are numerous (Marchal, 1979;Lefay,1986; Reij et al, 1986; Hudson, 1991).

1) Selection of techniques poorly adapted to local soil, climate and society;
2) Poor planning, bad implementation or lack of maintenance;
3) Lack of farmers' participation and rejection of the project because of the loss of useful soil surface without compensing yield improvement between the structures;
4) Disorganization of the land for cultivation practices.

So it was urgent to develop a new strategy that we call G.C.E.S (gestion conservatoire de l'eau et de la fertilité des sols = water and soil fertility management or land husbandry) (Shaxson, 1980; Shaxson et al, 1989; Hudson, 1992). It takes farmers and herders needs better into account and proposes methods improving soil infiltration capacity, biomass production, vegetation cover and yield or net income (Roose,1987). The starting point is the way farmers feel about the problem of soil fertility degradation. It develops into three phases:

First phase: Dialogues and diagnosis. Preliminary dialogues between farmers, researchers and technical services. This phase begins with two inquiries in order to localise problems (type of erosion, beginning of runoff, when during the season, where on the hillslope), to assess damages, their importance, their causes and the factors with which it will be possible to reduce runoff and soil degradation. It is time to walk onto the land to meet farmers on their fields, talk about their feeling on water management, erosion and fertilizer problems, analyse their traditional strategies to use available water economically, to maintain soil fertility and to keep herds.

Second phase: Experimentation and demonstration on farmers' fields. When the researcher has got farmer's confidence, simple experiments have to take place in farmers' fields to quantify and compare feasibility, efficiency, yield, runoff and erosion risks under various farming techniques and management systems. An evaluation of the relative efficiency of various management systems must be done by farmers and by specialists before the end of this experimental phase.

Third phase: General planning. An overall management plan of the village territory must then be drawn up after 1 to 5 years of dialogue in order to improve the use of the land, the structure of the landscape and to correct gullies, rivers and roads with simple methods easily controllable by the farmers. Nothing can be done without the farmers agreement, who have to learn to manage their own environment and to maintain it.

Thus that approach must take better into account the socio-economical constraints and the variability of the ecological environment. The agronomist must find compromises between efficiency with the methods on field and their acceptability by the farmers. He must work for the benefit of the rural population and always try to inform, advise and give demonstrations on field. He resorts more to biological solutions rather than to mechanical approaches. Changing farmers and planners mentality takes time (5 to 10 years)!

4 G.C.E.S.: A Case Study in Algerian Mountains

4.1 Introduction

The Northern part of Algeria is the most productive, but 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 cool winter and with dangerous storms in the hot summer. The soils (regosoils, vertisols, brown calcareous and red fersiallitics soils) are compacted and often stony. They have low nitrogen and phosphorus content. After successive colonizations (Romain, Turkish, French) and a recent very high demographic pressure (51 inhabitants per km^2), overstocking is seen (6 sheeps per hectare), vegetation and soil cover degradation in the mountains, sheet, rill, gully and mass erosion, Wadi river embankment migration, road destruction and rapid silting of reservoirs (in 15 to 50 years).

Facing these serious erosion problems, a strategy of heavy rural equipment (the D.R.S. = Défense et Restauration des Sols = defense and soil restoration) was developed (between 1940-70) which included:

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

The main objective was to delay soil degradation and reservoir siltation. In 1977 however, the failure of this "equipment approach" was clear. The farmers rejected the terracing system, wood production remained quite low and the reservoir siltation rate remained high. Terracing was abandoned for economic reasons (Heusch, 1986). Foresters continued the reforestation and gully restoration, but the farmers were not assisted except for some land improvements (subsoiling calcareous crusts) (Roose, 1987).

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

Currently, urban industries are experiencing difficulties and the Algerian Government proposes a strategy to maintain the population in the countryside and to intensify the mountain agriculture without degrading dams and water reservoirs essential for the expanding cities and for crop irrigation.

Since 1985, a cooperative program has developed research and training with the 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 = land husbandry) covers three sub-programs:

1. Surveys on the soil restoration 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 to develop a new strategy to fight erosion in Algeria with the agreement of farmers (G.C.E.S.). The Program will investigate 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 and in the drainage system (Roose, 1987; Arabi, 1991).

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

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

In Algeria, water disposal (and reservoir siltation) is a priority problem. Due to 30 years of industrialization the urban population has grown very fast. However soil conservation and terracing do not interest farmers very much because they do not return profit to the supplemental labour and do not increase the land productivity significantly. Degraded soils are already so poor... why preserve them? Without significant investment they will produce little. Therefore in order to interest farmers to preserve their land and the water quality it seems necessary to answer their immediate problems first: how to increase income and reduce production risks by improving first water and nutrients management on their productive fields? At the same time, the green cover will increase and the runoff + erosion risks will decrease. This approach changes completely the point of view of the planners and the extension staff. With farmers, the first action is to look to the production system, the water and nutrient balance, which are the main obstacles to the productivity of the best fields. If necessary he will stop gully erosion and valorize the sediment management but badland treatment will generally not be the main objective of the farmers. It was for traditional planners. The Governmental priority is to restore the forest and manage sediments in the torrential wadies.

4.3 First results for steep slopes farming systems improvement near Medea

4.3.1. 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 Algier. The landscape is a succession of plateaus (900 to 1.200 m of altitude), steep hillslopes (12 to 40 %) and deep wady valleys. Soils are related to the lithology and the topographic situation (Pouget, 1974; Aubert, 1987). The main soils 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, unstable,
— brown calcareous soils on colluvium, 2-3 % of O.M., well structured topsoil but thin profile.

In this mountainous area, between 1982 and 1991, forest cover decreased from 18 to 13 % and vineyards and orchards surface increased from 2 to 7 % and 8 to 14 %. That indicates that more people are earning their living in the mountains. Cultural practices are limited: generally ploughing for weed control, followed by cross covercropping to bury fertilizers (N33, P45, K90) and to break clods. The average rainfall over 40 years is 680 mm at the Medea Station but between 1986 to 1990 rainfall at Ouzera Station varied between 408 to 566 mm. The erosivity index (RUSA) is about 46.

The objective of this research is to compare the bare cultivated standard plot with four production systems (vineyard, orchard, cereals/leguminous pasture and sylvopastoral systems) on 4 soils representative of this area. The improvements introduced are correct ploughing, herbicides, pesticides, selected seeds, correct fertilization, leguminous fallow, mixed 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.

4.3.2. Results and discussion (see Fig. 1 and Table 1)

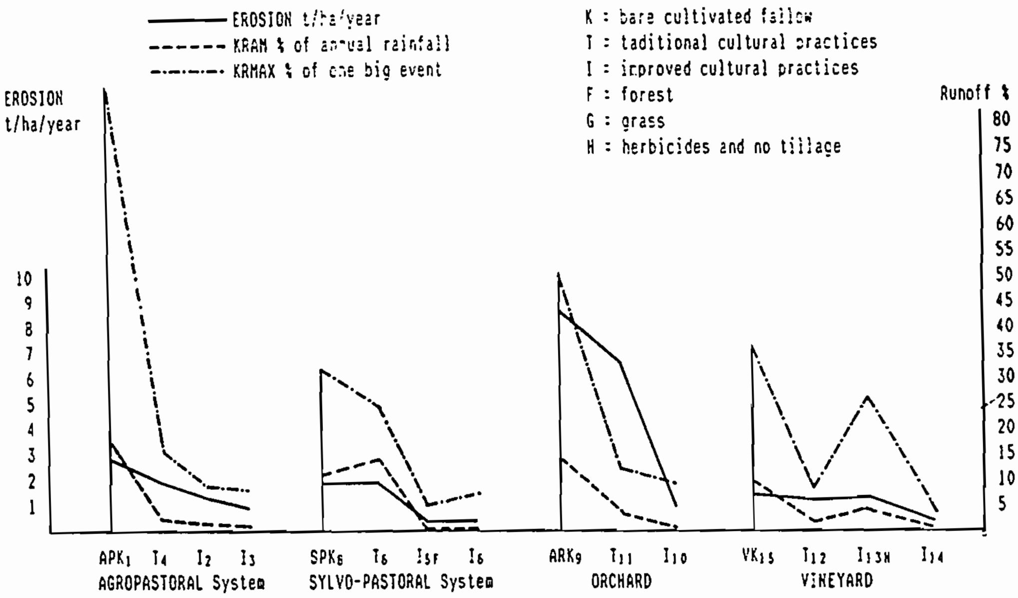
Rainfall was 100 to 250 mm less than the long term average (680 mm). There was no exceptional storm event. The Ram/Ham ratio (Ram = average annual rain erosivity; Ham = average annual rainfall amount for the same ten years) was 0,1 for Medea Station. Therefore, rainfall is much less energetic than in tropical African countries, where Roose (1977-88) found Ram/Ham = 0,5 for Ivory Coast and O,25 for mountains of Cameroun, Rwanda and Burundi.

Runoff: on cultivated plôts the average annual runoff (KRAM % see table 1) was small (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 small (10 to 18 %) compared to tropical situations (25-40 % in Ivory Coast). However 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 both bare and cropped plots, it appears that crop cover and crop improvement were efficient at reducing the runoff rate (see tables 2 and 3).

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

Figure 1: Runoff and erosion under 4 agrosystems and 4 soils in Algeria



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

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 amount depend partly 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 centimetres, cracks, sealing crust, green cover litter, rocks and clods).

Table 1: Runoff (% of rains), Erosion (t/ha/year), yields (t/ha) and net income for 15 runoff plots (22 x 4,6 m) 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	0,9(0,3)	0,7 grain 0,2 straw	2500
2° Improved: wheat + legumes	0,6 ↘	1 to 8	0,11(0,2)	4,8 grain 3,1 straw 5,0 beans	36200
3° Improved pasture Medicago	0,6 ↘	0 to 2	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 ferrallitic soil, 35 % slope					
9° Internat. reference bare	15,5 ↗	25 to 50	9(20) ↗	—	—
11° local reference: apricot 8 x 8 m	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 tillages	1,5	3 to 8	0,11(0,2)	2,8 grapes	34300
13° Improved vineyard zero tillage + herbicides	4,3	8 to 26	0,13(0,2)	3,0 grapes	35100
14° Improved vineyard + wheat/beans rotation + 2 tillages and 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 becvause of severe insect attacks

The largest runoff event occurs only when all conditions are optimal, generally between November and March, or during an exceptional 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 (R2) and soils are very resistant (K = 0.02 to 0.01), rich in clay saturated with calcium and often stony. Even if erosion reaches 9 t/ha/year (0.6 mm) more than 3 centuries would be needed to scour the 20 centimeters humiferous ploughed horizon. Experimentally, it was proved that sheet erosion is selective for organic and mineral colloids and nutrients, but rill erosion is not selective. Consequently where rill erosion increases, the humiferous horizon is generally scoured. If sheet erosion is not the major process, rill erosion is important. However dry mechanical creeping caused by cultural practices seems to be the most efficient in mountainous landscapes.

For instance, near Ouzera station, in an orchard that was planted 30 years ago, there is now 30 centimeters of soil missing between trees! Even if sheet erosion currently measured of 1.5 t/ha/year (0.1 mm) continued for thirty years, only 3 cm would be lost, while 27 centimeters would be removed by dry creeping (crossed deep ploughing twice a year with the tractor!).

It is likely that the rate of dry mechanical creeping by cultural practices increases with increases in slope.

Influence of soil type and slope

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 year to year: it was maximum 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 however to compare the runoff risk because the slope steepness changes with soils (Table 2).

On the other hand, it now seems clear that, contrary to commonly held opinion, the average and the maximum runoff coefficient decreases when the slope steepness increases . . . on bare cultivated fallow. This type of result has already been found in Morocco by Heush (1970) and by Roose (1977) in Ivory Coast.

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 ferrallitic ARK9	0	30	16	50	9,0
grey vertisoil APK1	4	12	18	86	2,7

This shows that many equations (Ramser, Saccardy, etc.) increasing the terrace frequency on increasing slope steepness 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

The improvement of crop cover (plant density, fertilizers use, leguminous rotation, cropping in the Winter between vineyards and orchards) seems to be moderately efficient at controlling runoff and erosion. But the most interesting aspect of these techniques is the significant increase of net income: from 2.500 dinars per hectare for traditional cereal cropping to 35.800 and even 42 and 65.000 da/ha if crops are associated under orchards and vineyards. These data show it is possible simultaneously to intensify profitable mountain agriculture and to reduce environment degradation (Table 3).

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

Situation		KRAM %	KRMax %	Erosion t/ha/year	net income DA/year
Agropastoral on vertisoil	traditional	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 ferrallitic soil	traditional	3,1	12	0,656	10000
	improved	0,6	9	0,088	42187
Vineyard on brown colluvial soil	traditonal	1,5	8,3	0,114	34333
	improved	0,2	2,7	0,009	65364

Yield and net income

Yields observed on traditional systems' runoff plots are as low as on the farmers' fields (0.7 t/ha/year for Winter wheat, 2.8 t/ha of grapes and 0.8 t/ha for apricots). On runoff plots (100 m2) with improved cultural practices, the yield of wheat increased to 4.8 to 6.5 t/ha/year and of grapes to 4 t/ha. In addition, there were 3.4 t/ha of beans or 3 t/ha of wheat associated Winter crops (Table 1).

At the same time, straw, leguminous leaves 'and other crops residues' production also increased significantly (from 0.2 to 2 or 3 t/ha/year) so that animal production can improve and increased manure and other organic residues are available to improve the soil fertility and their resistance ability to erosion.

The yield increase will probably not be so important on large fields than on small runoff plots (100 m^2), but the first step was to demonstrate that it is possible to improve the production significantly and also the rural environment.

Table 4: Erosion measurement on runoff plots in Burkina Faso. After Roose & Piot, 1984.

	Runoff KRAM %	Runoff KRMax %	Erosion t/ha/year
Gampela (Roose, Piot, 1984)			
— Bare fallow	—	—	16,0
— Traditional on the flat	22,5	40	4,1
— Diguettes + ridging/slope	23,7	45	5,9
— Diguettes + ridging on the contour	18,2	37	4,4
— Diguettes + tied ridging on the contour	4,6	31	1,4
Gonsé (Roose, 1980)			
— Sav. Integral protection	0,3	1	0,033
— Sav. early bushfires	2,6	10	0,147
— Sav. late bushfires	15,3	73	0,344

Gampela 1967-72: tropical ferrugineous soil on lateritic ironpan around 25 cm. Slope 0,8 %, surface 5000 m^2, crops = sorghum, millet, peanuts. Rainfall: 731 mm/year, RUSA = 319.

Gonsé: leached tropical ferrugineous soil on ironpan around 150 cm. Slope 0,5 %, surface 250 m2. Rainfall: 691 mm/year, RUSA = 321. Tree Savanna + Andropogan = influence of bushfire timing.

The next step is to show it is profitable! If you exclude the price of improved seeds, fertilizers, pesticides, herbicides, labour increase for cropping and yielding, the farmers net income is much higher than for traditional 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

This means that in the same production system you can increase the net income by ten for cereals or by 3 for vineyards after intensification. If you change the production system and intensify you may earn more than 20 times the original income.

With that benefit in view, it should not be difficult for the farmers to appreciate their interest in changing their traditional system to improved cultural practices. At the same time, it is easy to propose a package of improved practices where water and soil conservation are included. We were not surprised to observe after 4 years experiments that neighbouring farmers have copied our improved system without any pressure!

4.4 Gully sediment management for optimum land use

If sheet erosion is not a big source of sediment for the wady rivers (0,2 to 10 t/ha/year), gully erosion is much more dangerous because all the weathered material is flushed during the big storms once in 2 or 5 years(100 to 300 t/ha/day). Our research program is focused on 3 points.

4.4.1 Decrease the price of mechanical systems (weirs) to stop scouring of runoff at the bottom of the gully and keep sediment in gullies (Bourougaa and Monjengue, 1989) . For a 4 m^2 gabbion weir about 110 US $ was paid :

— for the same weir but of stone work	78 %
— for the same weir but of iron net 5 mm mesh	33 %
— for the same weir but plastic net 5 mm mesh	22 %
— for the same weir but of plastic bag (1 x 0.6 m)	15 %

We observe that each kind of weir catches fine sediments very fast but an iron net weir is the best to keep the sediment in place during successive storms.

4.4.2 How to valorize sediment caught above weirs?

It appears that certain forage grass can grow on fixed sediments and certain species of trees planted along the bottom of the gully can give forage, fruits and wood. The best species tried are Populus alba, Fraxinus oxyphyllus, Eucalyptus camaldulensis, but also pear-tree, apricot tree, and probably apple, cherry and walnut trees. It is very important to find a good valorization system that interest farmers because the State has not the possibility to maintain managed gullies. So gullies become a "linear oasis" producing forage, fruits, and wood in a semi-arid area where they are generally absent.

4.4.3 Ecological site studies

A large gully is an interesting situation to test the growing ability of grasses, shrubs and trees to grow in those semi-arid regions because there is a wide variability of ecological positions: sun or wind exposed side, bottom receiving excess water during some days but better irrigated than slopes, complementary storage of water held back in the sediment . . .

If we keep in mind that the management of a gully of 1 km long, 10 metres wide, 5 metres deep costs about 100.000 US.$, it is easy to understand that this GCES approach of gully restoration can interest the State government and also farmers, proprietors of the land gullied.

In conclusion, introducing a package of improved cultural practices, it was shown that is possible to reduce some runoff and erosion risks and to increase significantly yields and farmers' net income without degrading the environment.

The intensification of mountain agriculture seems to be possible without risk of soil fertility degradation or silting the reservoir if developing a new strategy of water and soil fertility management.

5 Improving Traditional Conservation Practices in Semi-Arid, Burkina Faso

5.1 Introduction

The Yatenga province, a soil conservation laboratory

For 25 years, the Yatenga province has known a succession of soil conservation management on a large scale to slow down the fast degradation of vegetation and soil cover of these fragile landscapes at the Sahel border.

a) Soil restoration from 1960 to 1965
The forestry department and after the GERES (European Group for Soil Restoration) have managed 200.000 ha in 3 years, dug 35.000 km of diversion ditches, cross-rooting of gravelly compacted area, built 70 km of rocky diguettes in the waterways, 24 earth dams between hills and other little half-moon shaped ponds to increase infiltration on the extensively grassed hilltops and to protect cropped plains. This management, technically interesting, appeared quickly to be a failure because farmers, not concerned, did not ensure the maintenance of the management and continued to live on their traditional practices.

b) Soil and water conservation from 1976 to 1985
The F.D.R.(Fond de Developpement Regional) called to farmers' groups, decided to build diversion earth diguettes on cropped blocks of 25 to 100 hectares. More than 47.000 ha of cropped land were managed in ten years (Mietton,1986). But because of the management rhythm (max 9000 ha/year) and the brief life span of hillslope management (2 to 4 years without vegetation cover on the diguettes), it would take many centuries to protect all the fields where necessary. Then it seems useful to come back to old traditional strategies which were studied by various Non Governmental Organisations (Wright,1985).

5.2 The G.C.E.S. from 1984 until now

In 1984 a tentative application of the G.C.E.S. approach began over a six years period in ten villages in the Yatenga. (Roose, Dugue, Rodriguez, 1992).

An extension research program on soil conservation practices was developed by CIRAD at the Regional Center of Rural Promotion in Ouahigouya (CRPA) in north west Burkina Faso. Dr Dugue (1984-1989) adapted to the local farming communities the new agricultural practices developed over the past 20 years in research stations (short cycle varieties, fertilization, soil tillage, rotation, manure production). Rodriguez (1986-1990) developed new methods which were proposed in ten villages and Dr Roose (1986-1990)evaluated the efficiency of the water management and soil fertility restoration program.

Phase 1: diagnosis

Erosivity due to rainfall (350 to 800 mm annually) is high (Rusa 300 to 500). Risks of runoff (20 to 40 % on cropped plots and up to 80 % of a storm) and of selective erosion (E = 1 to 20 t/ha/year on 1 % to 3 % slopes) are very high at the beginning of the rainy season (sealing crust). Potential evapo-transpiration is very high (2000 mm) so that risks of leaching are low (0 to 200 mm in a wet year).

Soils are poor chemically (N and P deficiencies), badly structured, and easily eroded (K = 0.2 to 0.4), with compressed horizon and sealing crust. Because of the rapid mineralization of organic matter and selective erosion, the soils are degraded in ten to fifteen years (... 12 % of clay and 1 % of organic matter). Consequently water management must be improved by cultivation methods (dry tillage, tied ridging) and permeable micro-structures (live hedges, stone lines, grassed embankments, etc.) (Roose, Piot, 1984).

Phase 2: Management of cropped plots

The Mossi farmers, grouped in 30 workings, chose to manage their individual plots first (the best land) and then the collective areas (stony-gravelly glacis) and the valley bottom soils (hydromorphic soils flooded during very heavy storms).

The soil conservation stuctures tested were stone bunds, hedges of perennial grass (andropogon) and various shrubs (Acacia, Ziziphus, etc).

Trees: replanting of the old stock with 120 trees on lines around roads, field boundaries and stone bunds to produce poles, fruits, forage and biomass rich in nutrients.

Improvement of soil fertility: ditches for composting, manuring, household refuse bins: small extra amounts of N.P.K, Ca and mineral fertilization.

Soil cultivation methods: ploughing, 2 weedings, 1 ridging, and tied ridging to destroy the topsoil sealing crust.

Phase 3: Planning the management of the watershed

1. On the gravelly hills (30 to 60 % of the land): localised defensive devices and planting of perennial graminaceous plants and shrubs.

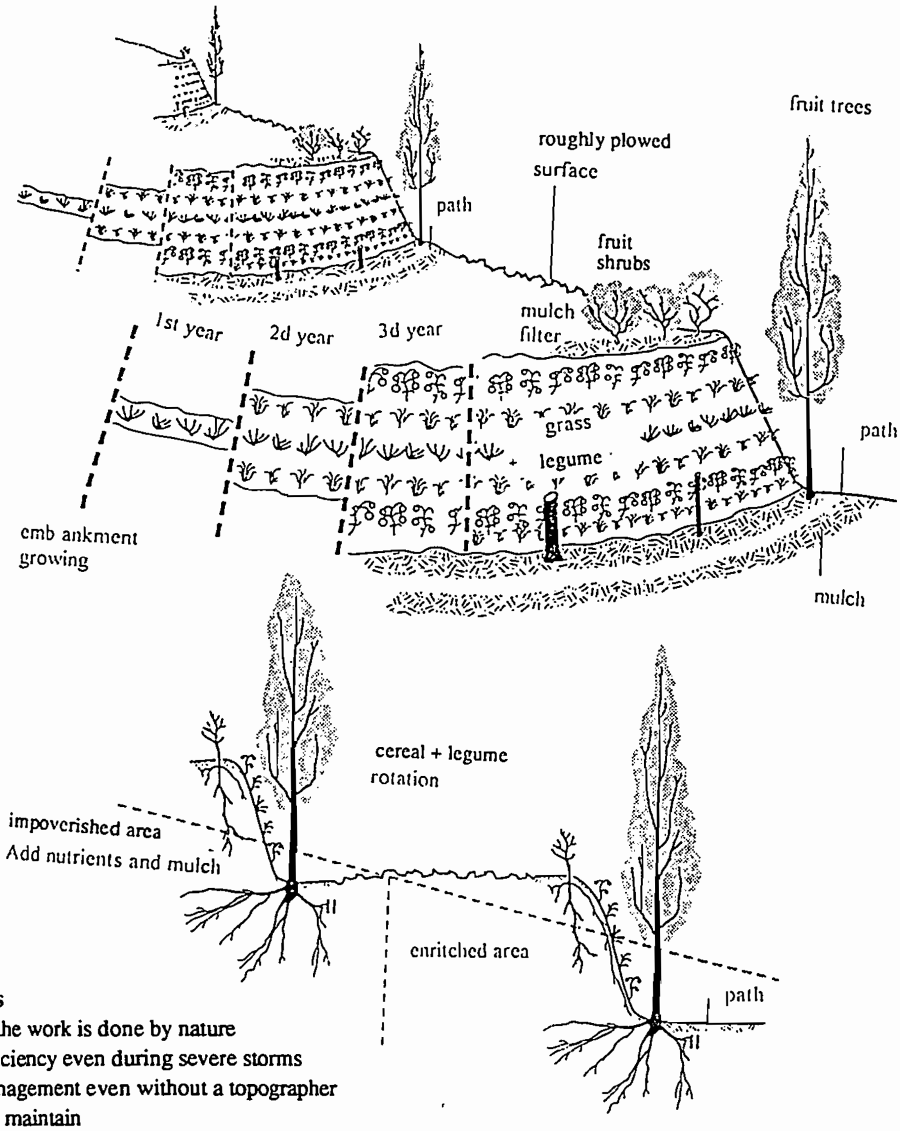
2. On silty clay cropped glacis (30 to 50 % of the land): bocage with live hedges, tree lines along roads or farms' boundaries, and stone bunds.

3. On sandy gravelly glacis: artificial ponds of 50 to 300 cubic metres to water livestock, and to provide additional irrigation for a small garden of fruit trees and crops.

Zaï and tree-planted zaï to restore the fertility of completely degraded soils:

— Management of gullies and valley bottoms.
— Stone barriers to prevent gullying in the villages.
— Orchards and vegetable gardens in the dry season.
— Gully fixation at road crossing points.

Figure 2: Permeable microdam and progressive terracing system.



Advantages

— Most of the work is done by nature
— High efficiency even during severe storms
— Easy management even without a topographer
— Cheap to maintain
— No surface lost for production
— Cultivated fields with constant width
— Creation of sub-horizontal terraces in 4-10 years
— Diversification of production (Wood-Forage-fruit)
— Decrease of wind speed effects/erosion
— Excess rainfall does not accumulate locally but irrigate the whole hillslope
— The biomass produced on the embankment improves the nutrient and organic contents of topsoil
— Facilitate the introduction of modern intensive agricultural practices such as: fertilizers, pesticides, herbicides

— Processes

Runoff velocity reduction by permeable micro-dams sedimentatation of organic substance and coarse particles; infiltration rate increase

Mechanical earth transport by cultivation practices. (± 1 to 10 t/ha for one soil tillage)

Slow down earth movement

Improvement of positive biological interaction between roots, crop residues, mesofau-

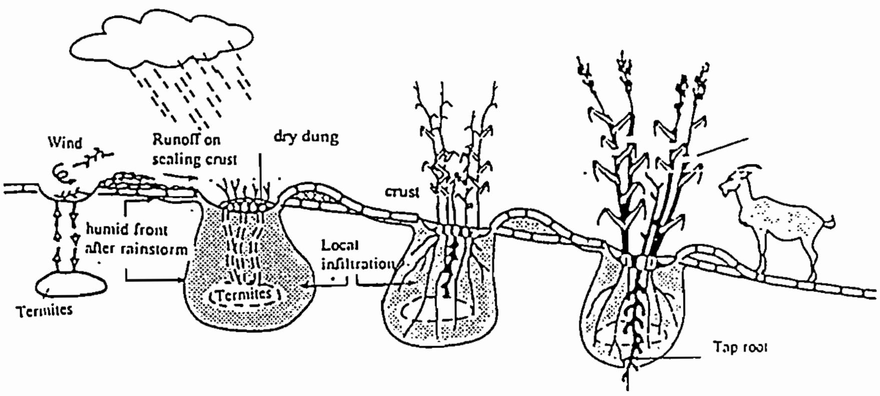
Figure 3: Zaï traditional Mossi method for resorting soils. (after Roose, Dugue, Rodriguez, 1992)

December to April
- Pitting each 80 cm. ø = 40 cm, H = 15 cm ground below
- Harmattan desert wind brings sands and organic matter.

April to June
- After the first storm application of two handfull of dry dung (= 3 t/ha).
- Termites dig galeries coated with secretion.
- Seeding before the second storm in seed holes.
- Water and nutrients deeply stored far from

June to July
- Beginning of rainy season.
- Early raising.
- Deep rooting.
- Weeding limited to seed holes.
- Forest seeds raising.
- Water and nutrients concentrated.

November
- Harvest of grains and forage.
- Cutting of straws around 1 meter to hide young seedlings from animals.
- These stalks protect against wind erosion.



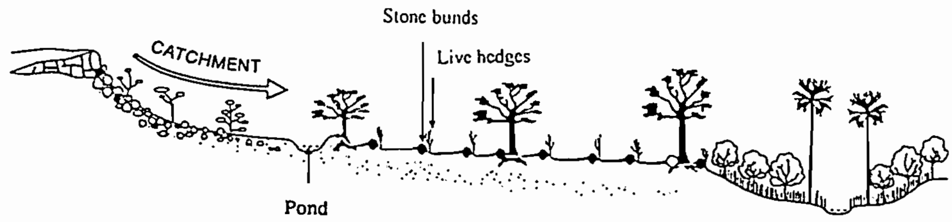
- Zaï (in moore) will say: "hurry to dig the crusted soil early in the dry cool season."
- It restores abandoned cultivated land and produces about 800 kg/ha of grains in the first year.
- It maintains soil fertility for more than 30 years.
- It concentrates water and nutrients in the seed holes.
- It allows to develop agroforestry in semi-arid areas.

Limitation:
- Zaï demands 300 hours of hard labour to manage one hectare.
- 2 to 3 tons of manure, compost or dry dung for one hectare.
- Rocks to build stone lines around the plot against runoff.

Improvement:
- Deep ploughing with one tine up to 12-18 cm after harvest, each 80 cm, that takes 11 hours, with oxen,
- then dig Zaï approximately 150 hours,
- improve manuring with mineral N and P,
- introduce other forest seedlings 3 months old from nursery.

Figure 4: General schedule of a granite catena of the Mossi plateau N.W. Burkina Faso - Western Africa.

Lateritic plateau	Rock scree	Gravel pédiment	Cultivated silty loam pediment on lateritic pan	Valley — sandy upstream — loam downstream
slope < 0,5 %	< 20 %	5 to 2 %	2 to 0,5 %	0,9 to 0,1 %
Communal extensivcly grazed land		Fragile grounds	Fields of intensive cropping.	Grazing during dry season - rice or sorghum garden. ± complementary irrigation



Gravelly lithosoils ± lateritic pan on deep kaolinitic weathering rock.

Ferrugineous tropical soils with lateritic pan ± hydromorphic in deep horizons.

Sandy or loamy hydromorphic soils.

— Poor soils: N and P deficiencies and sometimes K+Ca+Mg: pH = 5 to 6,5.
— Fragile soils: sealing crust, weak infiltration capacity, plough pan, low organic matter content.
— Soil fertility restoration (See Zaï) = deep ploughing + localized manure + NPK mineral fertilization + runoff management + deep rooting legumes.

Catchment

— Runoff harvesting
  . microcatchment, half-moon
  . ponds for storing of water or for complementary irrigation of a garden.
— Total defence contracted for 3 to 5 years.
  . forage-trees planting.
  . Andropogon around bunds.
  . fire protection.
— Herdes to keep animals all the year round.

Rainfed cropping

— Permeable microdams.
  . stone bunds + live hedges.
  . grass lines each 10 to 25 meters.
— Maintain the wind breaks.
— Tied ridging and early planting.
— Manure / compost pit around homestead.
— Complementary fertilization if necessary.

Irrigated cropping

— Decrease the peak flow by stone dams.
— Capture fertile sediment.
— Increase deep waterable.
— Avoid high trees which evaporate too much.
— Maintain forage grass strips to filter runoff.

Conclusion

In the Yatenga province, there is a wide range of traditional techniques of water management(boulis, stone bunds, grass strips, etc) and soil fertility management (zaï, manuring, mulching, agroforestry, etc.) that could be improved. Their study could facilitate the diagnosis of risks and the identification of local ecological conditions (average and extreme situations).

Farmers want their best land to be protected first and communal areas subsequently. Experts in combating erosion take the opposite view.

Lastly, farmers accept new anti-erosive techniques more readily if they improve water retention in the soil and protect soil fertility ,as in the case of permeable micro-dams such as stone bunds, live hedges and grassed embankments which demand less labour to build than diversion terraces and maintain the anti-erosive stuctures of the soil better.

6 Discussion

During numerous workshops, expertises on the field and trials with students and farmers, it appears clearly that technocratic approach of erosion problems is not sufficient: erosion is also the signal of an economical crisis of the society. To answer this crisis, the matter is not only to limit the inconviency of erosion for industries, irrigation programs and cities expanding but it is to find the deep reasons of this crisis and to solve urgent problems of land managers (farmers and breeders) which is how to live tomorrow without destroying land, water and other natural resources.

Parallely to other researches (Shaxson, 1980; Wright, 1985; Hudson, 1992) we developed a participating approach based on following observations:

1. The State can not protect soil productivity and maintain anti-erosive devices on the whole village territories.

2. Consequently, active farmers participation and simple methods are a necessity;

3. To ensure their participation, a soil conservation program must first take care of farmers priority problems:
   a) increase soil and labour productivity;
   b) release subsistence risks and ensure the sustainability of the production;
   c) improve the quality of life for man but also for women!

4. Numerous trials made with farmers on their own fields have shown that it is possible to increase the yield of biomass and grains significantly if there is a correct repartition of more than 400 mm of rains.

5. Soil conservation of poor land does not interest farmers: it asks a lot of labour to build and maintain terraces but does not change the production of the land very much!

   To get farmers participation it is necessary to discuss with them about their problems and their feeling on the best way to solve them. Then propose and compare the efficiency, the feasibility and the profitability of a package of techniques able to improve the productivity.

6. Simultaneously it is necessary to improve the surface water intake and the organic + mineral nutrients management to create a pool of intensification of the production and a possibility of money capitalization to improve the level of life.

7. Traditional soil conservation experts in order to manage large watersheds begin by the worst badlands (5 % surface) which produce the largest part of sediment in the river. From an economic point of view and also for the farmers, it is better to begin with the management of good soils before they are completely degraded, because the yield increase will be much higher on these "great promise" soils than on rocky completely eroded plots. This light management on farmers cultivated plots and the package of good agricultural technology will give back confidence to farmers to manage their hillslopes correctly and later, their village territory.

8. Nevertheless, in some cases it appears necessary to manage degraded plots quickly:

a) if the hilltop soil is scoured to rocks, the water storage capacity of these soils is very limited and a lot of runoff is going to gully good pieces of land below. In that case it is necessary to restore a perennial vegetation on spots where water, soils and nutrients are concentrated, and/or to catch the runoff in little ponds for animal watering and irrigation of an intensive garden (Like in Haïti and Yatenga).

b) If there is a hard problem of land availability, it is important to restore the productivity of deep soils applying the six rules for soil rehabilitation (manage runoff, plough deeply, stabilization of macroporosity by $CaCO_3$, gypsum , plant deep rooting plants, manure+ NPK+ pH > 5.

c) If land problems and demographic pressure are still more serious, farmers would like to restore gravelly soils or soft rocks: it is necessary to concentrate soil, water and nutrient storage capacity on spots (1 m^3) with a distance of 5 to 10 meters and to plant banana or fruit tree and leguminous forage creeping all around for covering all the ground.

What has been changed in comparison with proceeding approaches ?

1. The dialogue between experts and farmers. It is a little community (30 farmers) who will receive a sensibilization program, which will decide to do something together (maps of vegetation, soils capability, erosion type and magnitude): they will propose and realise simple managements for water, nutrients and soil structures.

2. Feasibility, efficiency and profitability of each method will he tested by farmers' on farmers fields. The specialist must look to the coherence of the individual efforts and guide to a complete management of a hillslope or the village territory.

3. It is only when the method has been demonstrated and when the majority of the farmers' community are convinced of the interest that the general scheme for the village territory will be drawn up.

This approach is quite different of the technocratic one because it recognises that erosion is not only a technical problem but also a socio-economic problem. It probably takes longer to discuss with the farmers the best way to solve environment problems and to increase the productivity, than to come up with "prefabricated programs" of soil conservation management . . . but it is probably the price to pay for a sustainable agricultural development.

7 Conclusion

It is now accepted that soil conservation problems have some technical and some socio-economic aspect. They are two main participants (state engineers and the farmers) and two complementary objectives.

7.1 The State has large possibilities to create a favourable socio-economic environment to improve the rural economy: good legislation about land propriety, a price policy for rural products, roads and markets to sell easily the production, provision of fertilizers, pesticides, selected seeds and equipment to cultivate efficiently.

The State alone has engineers and finance to protect public goods against natural catastrophic events, torrential gullies, major landslides, river floods, reservoir filtration, river embankment degradation, reforestation of degraded hilltops, etc.

The State must ensure good quality water for expansive needs of irrigation, industries and cities. It is in charge of teaching engineers, specialists and extensionists and for general extension in the country.

7.2 But the State can not do everything and be everywhere! The maintenance and the improvement of the land productivity is a matter for farmers and breeders.

Most conservationists now agree of the necessity of the farmers' participation in the village territory management, if sustainability is required. But many engineers are still fascinated by great and costly operations on large watersheds with mechanical approach. We observed that it is more efficient to select low-cost-improved traditional systems, which are well adapted to each village. In theory, it is more efficient to manage a large watershed and to begin on the worse badlands from where the largest part of the river sediment comes. But practically, farmers prefer to begin their effort on their own productive fields and later to extend the management system on the whole hillslope, village territory and may be a little watershed.

There are still some more technical aspects of soil conservation to improve.

— How to manage rainfall+ runoff+ deep watertable for the best production of each part of the toposequence: runoff harvesting, total infiltration, runoff diversion or runoff energy dissipation? (Roose, 1986, 1992).
— How to increase biomass production (agroforestry, leguminous, cover crops, etc.) and optimize their use to restore and maintain the soil fertility with the help of organic matter (compost and manure), mineral nutrients complementation for soil deficiency and crop residues management (improved manure, deep ploughing or mulching)?
— How to cover the soil all the year long? How to increase the infiltration capacity: deep ploughing to break an impermeable layer or harrowing to destroy sealing crusts?
— How to improve and measure the efficiency, feasibility and profitability of conservation structures? etc.

But simultaneously there are still socio-economic problems to solve!

— How to give to poorest farmers the opportunity to improve their situation in the village society, to find land to restore, animals to feed, labour to increase the family incomes, food for their family, school for children, etc.
— How to improve the life quality of women who insure generally more than 50 % of the labour necessary for soil conservation management.
— How to manage a village cooperative by utilize labour and financial availability (credit and cereal bank) to get better prices to sell excess production and to buy selected seeds, fertilizers, necessary medicines, etc.

All these problems overstep the fight against erosion but are linked to water conservation and soil fertility management of a village territory!

In this paper, we have shown on two situations that it is possible to increase significantly the yield and the net income even on steep slopes (40 %) without degrading the rural environment, on runoff plots but also on farmers' fields. It is still too early to evaluate the generalization possibility of this participating approach where farmers and non-governmental organisations and researchers try to utilize their particular knowledge to take up the challenge: how to double production faster than the population?

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