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Traditional strategies for soil and water conservation in Mediterranean areas

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ABSTRACT

Mediterranean mountains have got a bad reputation concerning erosion. As these semi-arid landscapes are never well covered, rains are erratic and slopes steep or long, gully erosion, landslides and floods may be dramatic during the cool rainy seasons and wind erosion frequent during the hot summer. As long as natural vegetation covers the hillslopes, erosion is relatively moderate, but with successive civilisations, people extended cropping and grazing on the mountains, built cities and roads, provoking high peakflow, degradation of riverbeds and fast siltation of reservoirs. To survive to this increasing aridity, farmers and helders developed numerous traditional strategies to manage scarce water, biomass and soil fertility. In this paper, some examples have been taken in the Maghreb, in Israel and a few in southern Europe. The systems have been classified in relation to their objectives, their functioning and their ecologic situations:

- *systems collecting runoff water under impluvium and storing it in the soil:* half moon and micro-watersheds, furrows or paved tracks collecting runoff from overgrazed hilltops, meskats, stone bunds, stone walls and terracing systems;
- *systems storing runoff in tanks* for watering men, animals and gardens: little pounds (magden or paved lavogne) down the paths, cemented cisterns at the bottom of cliffs or hillslopes, stony cistern storing the rain from the roofs;
- *runoff harvesting in the valley:* narrow terraces with a seguia, "jessour" collecting runoff and sediments in aridic Tunisia, limans (in Israel desert) and earth dams for flood harvesting to irriguate lateral terraces (Tunisia);
- *total infiltration:* Mediterranean graded terraces, tied ridging, mulching and deep tillage;

- *runoff diversion:* diversion ditches in cereals fields (France and Maghreb) and in Banyuls vineyards, oblique ridging when too much rain falls in one season;
- *runoff energy dissipation:* progressive terraces, living hedges, stone bunds/walls, bench terrasses, direct drilling under litter mulch which slow down the runoff velocity.

In semi-arid areas, water is one key for life: most of the traditional SWC systems insure irrigation supplement and soil fertility restoration. Today most of them are abandoned, not because they aren't efficient any more, but because labour is better paid down town. The study of these traditional systems allows to better know climatic and human conditions of marginal grounds. An effort must be made to complement these well adapted traditional systems with modern technology (fertilization, etc.) in order to improve their economic efficiency.

Key Words: Mediterranean areas, soil and water conservation structures, traditional systems, cultural practices, ecological classification

INTRODUCTION

Areas around the Mediterranean Basin have the reputation of very high erosion hazard for ecological and human reasons (Hudson, 1987). Because the rains are erratic and cannot cover the vegetation transpiration demand, these semi-arid landscapes are poorly covered during the winter rainy season. For geological reasons, the relief is very young (earthquake, soft rocks protected by hard limestone or sandstone), the hillslopes are very steep and long, often convex with narrow deep valleys or concave with large alluvial plains near the seaside. Finally because numerous civilisations were living around the Mediterranean sea, the forests were cleared up for 3 millenaries for fire wood, cropping and grazing and for building commercial or battle fleets. During the very hot summer, wind erosion is common. At the end of the cool rainy season, soils can be saturated provoking high runoff, rills becoming gullies, high peak flow degrading the riverbeds, landslides, floods and inundation, sedimentation in the reservoirs and destruction of roads, bridges and constructions. As long as natural vegetation (forest, mattoral or steppes) covers the slopes, erosion and runoff are moderate, but they become spectacular when very heavy or long storms fall on bare saturated ground (Roose, 1991).

Historically, the Mediterranean area was the birthplace or a passage for many civilisations. For centuries people built numerous large cities (with high runoff hazard), cleared the forest, and extended agriculture in the plains, but also cropping and grazing on the mountains to escape enemies invading the country. Successive civilisations have met degradation problems of the green cover, soil fertility, salinization of plains, soil crusting or scouring, gullies along the roads, inundations and destruction of cities. A fly over southern Europe, Maghreb and Near East areas (or satellite imagery) should show stunted vegetation, skeletal stony soils on the semi-arid hillslopes and plains wounded by deep gullies and torrential wadies filling the reservoirs with sediments.

Therefore, for centuries people developed strategies to minimize erosion hazard and degradation of natural resources in water, biomass and soil fertility (Lowdermilk, 1975 ; Roose, 1996). This Mediterranean basin is thus an excellent area to analyse traditional soil and water conservation systems developed before the modernisation and the mechanization of the agriculture in the 20th century.

This paper is a synthesis of studies of traditional strategies observed in some countries around the Mediterranean sea and particularly in the Maghreb (Morocco, Algeria, Tunisia) and Israel in the Near East and southern Europe (France, Spain and Crete partially). That does not mean there are no traditional SWC systems elsewhere, but most of the structures studied are also present in other similar ecological areas. After a description of diversity and originality of semi-arid to semi-humid Mediterranean areas, we will analyse the relative importance of various erosion processes in relation to hillslope management for agricultural production. Facing the most important problem of water management in these semi-arid areas, we will classify traditional antierosive systems taking into account the rainfall and runoff hazard at the level of fields (cultural practices) and hillslopes (conservation structures). Because the point of view of an agronomist and soil scientist must take care of the farmers objectives, the biomass and soil fertility management will be also presented, but shortly.

THE SPECIFIC MEDITERRANEAN ENVIRONMENT

Steep slopes and gullied landscapes

On satellite imagery and aerial photographs, Mediterranean areas appear as deeply gullied hillslopes, stony colluviums, torrential wadies and sediment filled reservoirs: all of these signals are indicators of important runoff, even on semi-arid areas. Nevertheless, measurements on the fields showed that these landscapes with a very old human colonization are less fragile as it seems at a first superficial sight. Of course, the mountains are young, the slopes steep and often long, the valleys narrow and the wadies torrential, but as long as these mountains are covered by forests or not too overgrazed mattoral, runoff is limited (generally less than 20%), and soil losses on the hillslopes are not very significant: more or less 1mm / year after Heusch (1970) on marl hills of Rif and Laouina (1992) in Morocco, Delhumeau (1981) and Delhoume (1987) on limestone of Tunisia and Roose et al. (1993) on various soils of Algeria. Many gullies are inherited and no more functional, except during exceptional rains falling on bare saturated soils. In semi-arid areas, rare events are much more important than in the tropical countries. As ground is generally poorly covered, the exceptional rains or rainfall series have a deep impact on runoff, gullies, landslides and peak flow leaving the landscape definitively marked by spectacular erosion manifestations (Roose, 1972). Slope steepness does not always increase runoff and even erosion: rocks and crusted compacted soil may protect the summit of many hills but the colluviums at the contact of concave hillslopes with the valley may collect a huge amount of runoff and cause rills and deep gullies. The topographic position of a field may be more important than the slope steepness (Heusch, 1970; Roose, 1972; Roose et al, 1993).

Historical circumstances (successive colonizations), demographic pressure (population doubled in the last 25 years) and economic pressures (importance of deforestation, grazing, cereals or cannabis cropping for poor farmers survival) have broken the precarious landscape stability.

A stunted vegetation deeply degraded by overexploitation for energy and grazing

Semi-arid vegetation, deeply exploited by man, cropping cereals and overgrazing, poorly protect the soil during the cool rainy winter season and the dry hot summer (Masson, 1980, Roose et al., 1993). Pine and Eucalyptus plantations are susceptible to frequent bushfires and their intensive exploitation leaves the soils exhausted. Bush fires accelerate runoff and soil losses for a few months, but as soon the rains allow to weeds to cover the soil surface, erosion decreases rapidly (Martin, 1997).

Presently, not only forests (<5% of the surface) are overexploited but overgrazed areas are cleared by farmers for cereal cropping and ground appropriation (Roose et al., 1999). This can develop landslides where the slopes are steepest, rills and gullies at the middle of the slope, sedimentation in the valley, degradation of the riverbeds, destruction of the best soils of the recent terrace and finally aridification of the whole landscape.

Nor fruit trees plantations, nor extensive cereals-legumes rotations, nor grazed fallow, nor vineyards protect efficiently soils against rainfall and runoff energy during the rainy periods (100 to 300 mm in one to three days). Tillage practices delete rills and other indicators of concentrated runoff, but the depth of soils is scoured and the soil productivity has decreased (Masson, 1980; Roose et al., 1993). Because soils are poor (deficiencies in N and P.), the yield of extensive crops are very low (0.4 to 1t/ha) and the cover very poor.

Mediterranean climates: importance of exceptional rains

Mediterranean areas receive most of their rainfalls during the cool winter and spring seasons: during that cool period many trees have no leaves and cereals cover the sealing soil surface very poorly. Moreover, Mediterranean areas are well known for their erosive rainstorm. Some summer or autumnal storms are actually redoubtable and provoke disasters. For example in 1999, it rained 350 to 600 mm between 12 and 14 November in the Carcassonne vineyards (Audes departement, South West of France): mud flows, flood flow and rapid inundations devastated the regional economy and killed 35 people. On the 3th October 1988, a storm of 420 mm in 6 hours fell on the hills around the city of Nimes: that storm left 11 dead people and 4 milliards of French francs damages (Davy, 1989).

But after Demmak (1982), the local storms don't bring so many sediments in the large reservoirs but the long rains falling for many days in the winter on saturated soils of vast denuded areas, compacted by grazing or finely tilled. These heavy rains lead to high runoff peaks and remove free sediments cumulated during dry months (or years) in gullies and wadies (Olivry & Horelbeck, 1989).

Contrary to general opinion, the ordinary rainfalls have much less energy in Mediterranean mountains than in tropical areas (Roose, 1980; Arabi et Roose, 1989). Therefore it is important to note that the erosion source depends more on the energy of runoff concentrated at the bottom of the slopes and in large wadies, than on rainfall energy (Heusch, 1970). Therefore the fight against erosion must be organized chiefly around the concepts of water management on the hillslopes, improvement of infiltration capacity and soil resistance to runoff energy for exceptional storms.

Lithology: succession of soft and hard rock beds

After Heusch (1982) and Demmak (1982), there is a strict relationship between lithology, erosion shape and sediment transport intensity in Algeria. To the most resistant rocks (sandstone, hard limestones) correspond the steepest slopes, the densest vegetation cover and the weakest sediment transport. But on soft clay and marl terrains, slopes are relatively smooth, human activities more intense, greencover very light and sediment transport abundant.

Soils are resistant to rainfall but not to runoff energy

Regosols, red fersiallitic alfisols, brown calcareous soils, black rendzines and grey vertisols who take up most of the hillslopes, are generally well structured, well aggregated, rich in clay, calcareous or free iron, stony, permeable and resistant to splash, but not necessary to gullying or slumping. The presence of gypsum and soluble salts into marl increases the terrain fragility (tunnelling). The high resistance of soils under natural vegetation is limited in space and time (K_{USLE} varied from 0.001 to 0.30). With overgrazing or cropping without any organic matter recycling, runoff on the field remains clear because there are many traps (clodiness, grassturf, stony surface) but as soon as rills appear the sediment in suspension (MES) increases from MES = 1 - 3 g/l in sheet erosion to 5 - 20 g/l in rills and up to 20-200 g/l in gullies and wadies.

Two main consequences for soil conservation

For many years, the landscape seems to be stable, but one rainstorm of 1/5 years or 1/10 years frequency may change the hillslopes deeply. Soil conservation strategies must be adapted to delay the runoff beginning and to disperse the runoff energy on stabilized surfaces (litter, grass, high-density crops) instead of concentrating it in channels and waterways (evolutioning easily in gullies during exceptional rainfall events).

In temperate and tropical areas, drop splash is necessary to prepare the ground material before moving it by sheet runoff. On Mediterranean hillslopes, runoff energy is so high that it can undermine the soil mass and erode gravels and entire clods. Little selective sheet erosion has been observed, but more frequently rills scouring the topsoil, gullies, landslides, and deterioration of riverbeds.

THE MAIN EROSION PROBLEMS IN MEDITERRANEAN AREAS

Because ecological and human situations are various, there is a large diversity of erosion problems, but traditional systems are adapted to specific problems of natural resources management.

Soil fertility degradation

Forest and mattoral bring to the soils 3 to 10 t/ha/year of organic matter as litter and dead roots : as in all tropical regions, mineralization is very fast. As soon as the forest is cleared, grazed, or burned and cropped, the balance is broken and the soil organic matter (SOM) content decreases until a lower equilibrium in relation to the new farming system. Under a threshold of 0.8 to 1.5 % of SOM (depending on clay content), the mesofaunal activities decrease, the macropores collapse and the infiltration capacity is reduced: the aggregate stability decrease indicates increasing risk of runoff and erosion (Barthes et al., 2000). It is the reason why the management of biomass (and mineral fertilizers) is essential for soil conservation and water management in semi-arid areas. (Roose and Barthes, 2001).

Sheet erosion

Selective sheet erosion is active every where on bare soils : where raindrops strike the soil, packing and sealing the surface, they decrease the infiltration capacity to less than 10 mm/h and increase runoff and erosion risks. Measurements of sheet erosion on runoff plots in Morocco, Algeria, Tunisia and France aswell showed that sheet erosion is not very significant (less than 1 mm/year) but has an effect on soil fertility degradation (Roose and Barthes, 2001).

A quick analyse of the Wischmeier and Smith (1960) USLE model shows that improving vegetal and stones cover (C variations between 1 to 1/1000) and slope (SL variations from 0,1 to 20) will be much more efficient than modifying soils (K varies from 0,01 to 0,30) and antierosive practices (P = 1 to 0,1). But the more arid is the field, the more mechanical practices must be used to fight erosion because vegetation cover is scarce. Sheet erosion is not quite well discerned by farmers so that very few traditional strategies take it into account and most of the time there is not even a local word for this selective erosion processes (Roose, 1996).

Linear erosion

This is the erosion process best discerned by farmers and most of the traditional systems of soil and water conservation are considered to decrease linear erosion manifestations. If nothing is made on cropped fields after the rainstorms, sheet runoff will organise it in rills, gullies and later in torrential gullies and badlands: these are indicator signals that runoff is abundant and that runoff energy pass beyond rainfall energy. In Mediterranean areas where runoff often begins with soil saturation, green cover is less efficient than in tropical countries to reduce runoff and erosion problems: it will be necessary to develop water management systems well adapted to steep slopes, rock debris or soft soil covers.

The main factors influencing gully processes are the runoff volume (depending on the watershed surface, the saturation of the topsoil, the infiltration and the water storage capacity, the depth of the soil over the hard rocks and the volume of rains), the runoff speed (related to the slope steepness, the surface roughness and conservation structures) and finally the soil resistance to the shearing stress developed by running water.

There are three types of gullies functioning differently:

- *U shape gullies* developing by "chute energy" on the head of the gully or by hydraulic pressure of the watertable causing landslide of the gully embankments: the soil profile is heterogeneous (ex., lavakas of Madagascar).
- *V shape gullies* on homogeneous ground on schist, argillite and marl when the peak flows carry away the materials weathered and eroded from the borders.
- *Tunnelling gullies* when runoff can dissolve salts at the top of the weathered rock or when waters are moving fast in large cracks of vertisols.

Generally it is possible to stabilize them with weirs blocking sediments at the bottom of the gully and covering them naturally with weeds, grass and trees (Roose, 1996).

Mass movements

Processes of mass movements are various but frequent. Landslides, solifluxion and torrential lava are related to exceptional rainstorms: farmers are afraid of them but have no parade (except eucalyptus plantation). Creeping is active on steep slopes but also on tilled fields: tillage erosion is accelerated by mechanization and slope angle (1 to 4 mm/year) (Roose, 1996). Embankments at the end of the cultivated plot are growing about 10 to 20 cm each year mainly by tillage erosion.

In conclusion, the studies about traditional strategies of SWC are mainly concerned with runoff management on hillslopes: to capture runoff locally in cisterns or in the soil to irrigate fruit trees or cropped fields elsewhere, to improve the soil infiltration rate, to capture excess water, to drain it outside cropped fields or to dissipate the runoff energy through permeable microdams. This paper will not discuss traditional strategies to fight wind erosion, sheet erosion nor mass movements: it will focus the discussion on attempts to manage surface water in order to increase the crops productivity.

WATER MANAGEMENT FOR SOIL CONSERVATION IN RELATION TO THE MEDITERRANEAN CLIMATE

Systems harvesting runoff under impluvium in arid and semi-arid areas

Reij et al. (1983) have studied runoff harvesting systems in semi-arid regions of Africa. We report here a part of them with personal observations in the Mediterranean area.

Runoff harvesting and storing into soils

"Runoff farming" (Fig.1.1): hilltop overgrazed producing runoff caught in the cereal fields planted in the colluvium at the bottom of a marl hillslope was observed near Gabes in Tunisia (Bourges et al, 1979). With mechanization facilities, farmers plow the base of the hills overgrazed, hoping that once in 2 or 3 years, the field will catch enough rain (100 to 250 mm) and runoff to produce 4 to 8 quintals of cereals and as much of straw for sheep grazing.

"Meskat" (Fig.1.2) system cover 200 000 ha in Sousse region in Tunisia .With 200 mm of rainfall, olive trees need a double surface to produce fruits. The stony and crusted tops of the hill are kept in bare fallow and the runoff is lead to the cultivated area (called manka). A bund (tabia) is constructed around the cultivated plot, which can retain the 50 years daily maximum amount of runoff. (El Amami, 1977). At present the pressure on the land is so hard that trees have invaded the impluvium itself.

"Half moon" (Fig.1.3) of ground and stones limiting a basin of 4 to 10 m? have been built at the bottom of a rocky hillslope and planted in olive trees in the Kairouan province of Tunisia. (Rainfall 300 mm).

"Canals" collecting runoff around desert slopes irrigated trees in microwatersheds or cereal fields in Israel desert (Evenari, Shanan, Tadmor, 1968).

We recently observed "paved tracks" (Fig.1.4) around a stony overgrazed hilltop collecting the runoff and distributing it to the graded terraces intensively cultivated (fruit trees, vegetables and cereals) in occidental Rif area of Morocco (Roose et al., 1999).

From a stony hillslope in oriental Rif (Morocco), people are often observed removing stones building "piles" over a big rock that they cannot move. Later these piles are growing in discontinue stone bunds, then "contour stone bunds" (Fig.5) dissipating the

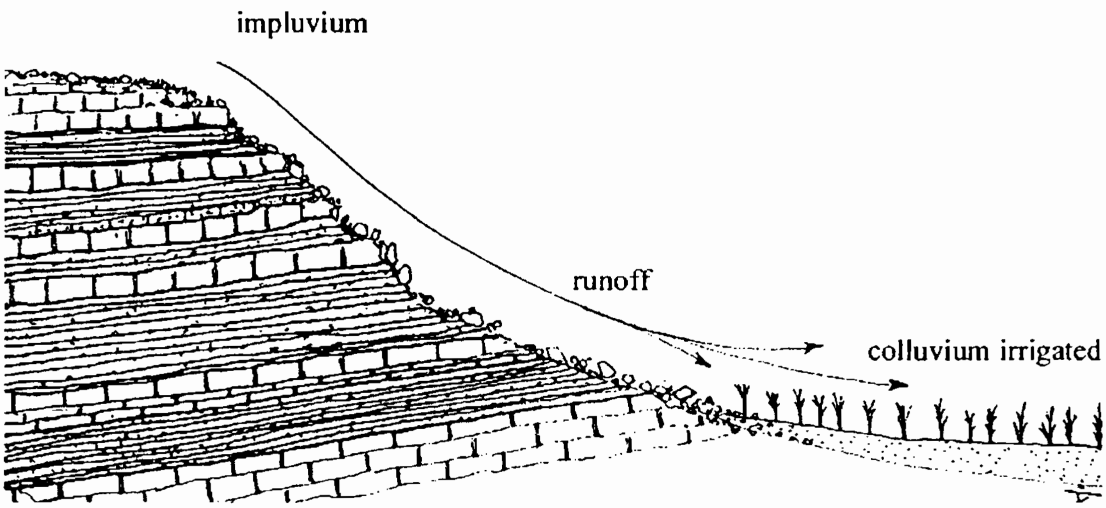


Fig. 1.1. Runoff farming in the colluvium (Gabes, Tunisie)

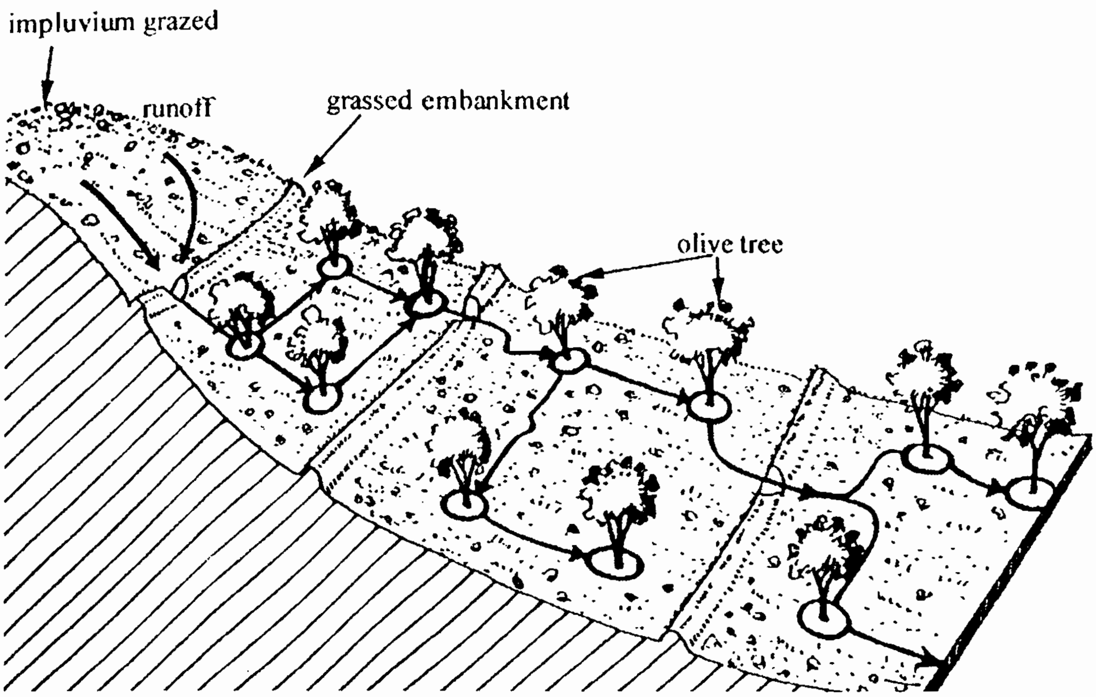


Fig. 1.2. Meskat: olive trees irrigated by impluvium runoff (Kairouan, Tunisie)

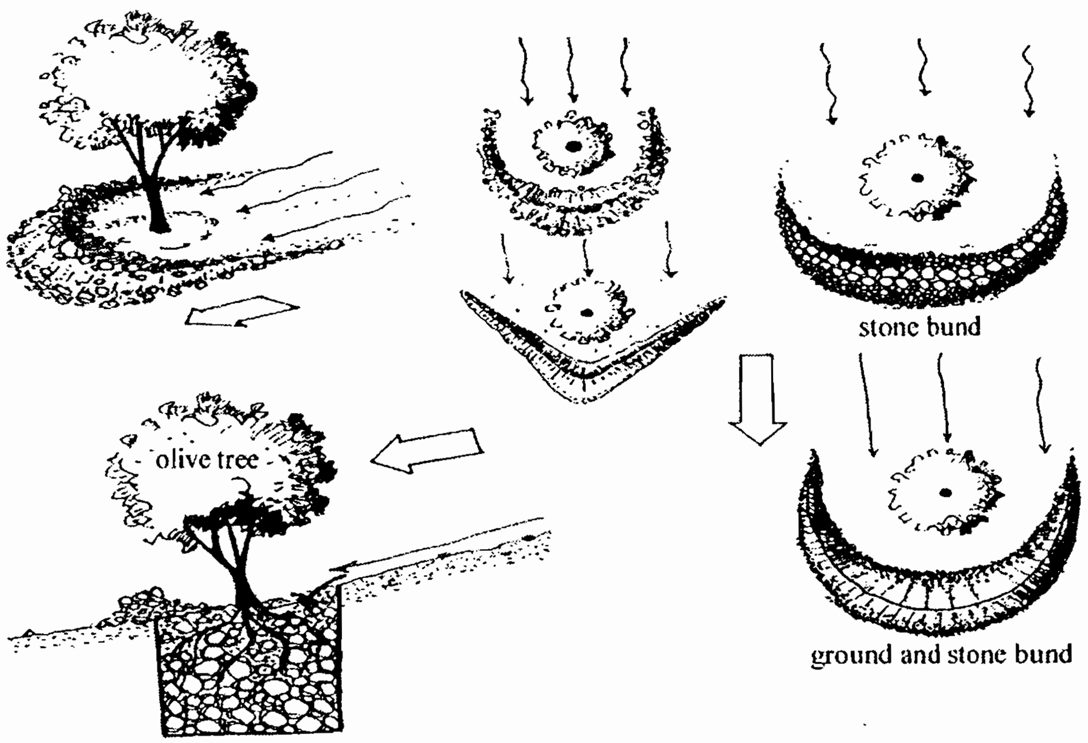


Fig. 1.3. Micro watersheds

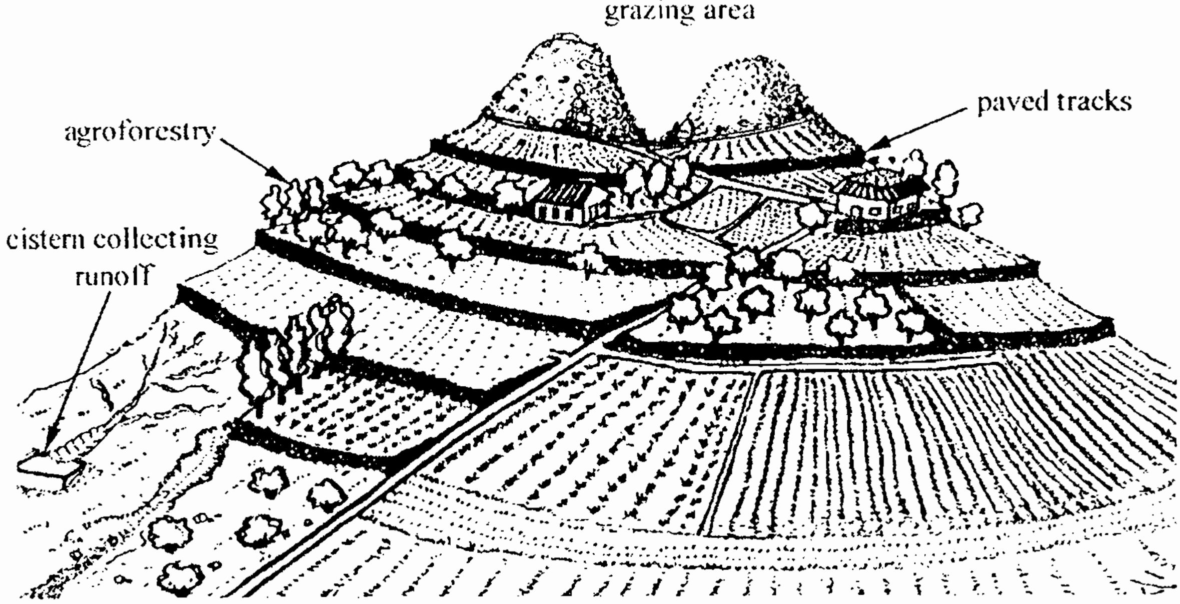


Fig. 1.4. Paved tracks collecting runoff around the grazed hills (Rif, Morocco)

runoff energy. The stones are mixed with numerous bushes grazed by goats (Afkiren village). "Stone walls" are progressively built around individual fields to protect them from the livestock.

"Irrigated traditional bench terraces" (Fig 3.5) developed in China and in Far East 3000 years ago, came in Mediterranean areas with silk and slave traders about ten centuries ago: they were improved by stone walls protecting the embankment against storms. They are still working as well in Spain, in southern France, as in Oriental Morocco (Ait Hamza, 1996; Chaker et al., 1996). Their construction is progressive and may take 800 to 1500 days of labour per hectare managed. Their maintenance is also time consuming, so that traditional bench terraces are abandoned if their production is not profitable enough. In favourable areas (vineyards or citrus plantations), stone walls are cemented to reduce the maintenance (seen near Valencia in Spain).

Systems storing runoff in tanks for men and animal watering and garden irrigation

"Magden" (fig. 2.1) in Maghreb or "lavogne" in South of France are openfield ponds catching runoff from roads, short stony or silty loam crusted impluvium. (Roose, 1996)

With 80 m^3, it was possible in Algeria (oued Mina) to maintain 40 sheep, a little garden and a family in the mountains receiving 300 mm per year. The main problems are to improve the quality of the water (MES), to reduce sedimentation in the pond and maintain animals out of the pond for health reasons.

Around the Mediterranean sea, Romans and Arabs have built many "stony cemented cisterns storing rainfall water" (fig. 2.2) from the roof in the mazet near Montpellier, or runoff water from rocky hillslopes (fig. 2.3) : examples were studied near Gabès and

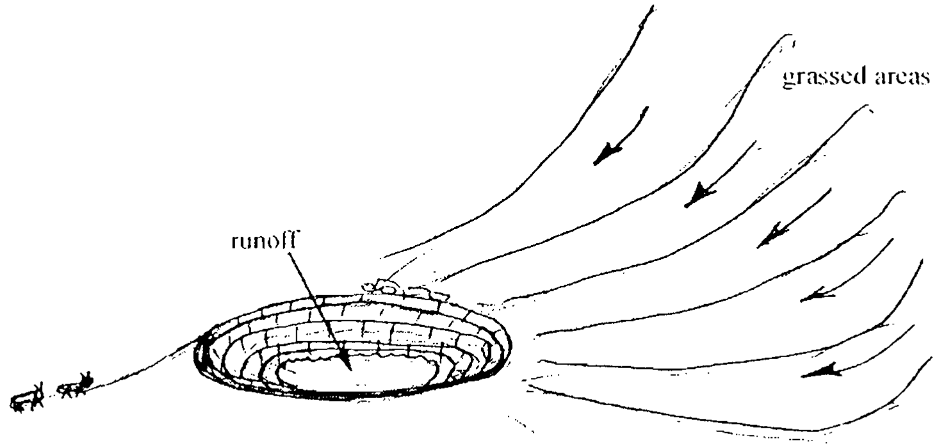


Fig. 2.1. Pound collecting runoff from hillslopes or roads called *Lavogen* around Montpellier and *Magden* in Algeria

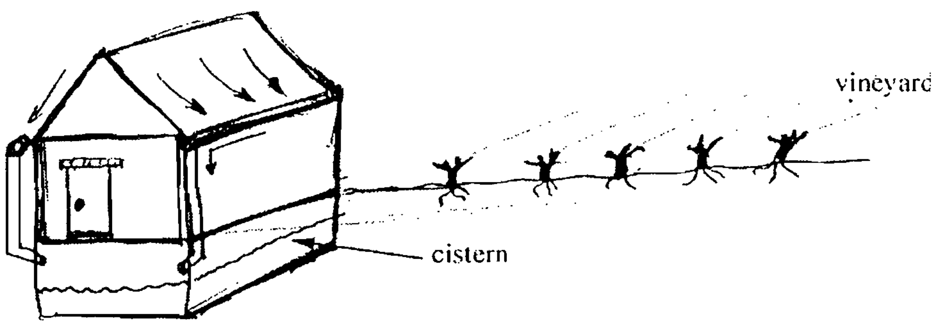


Fig. 2.2. Rainwater harvesting from the rooff to the cistern under the mazet (Languedoc, France)

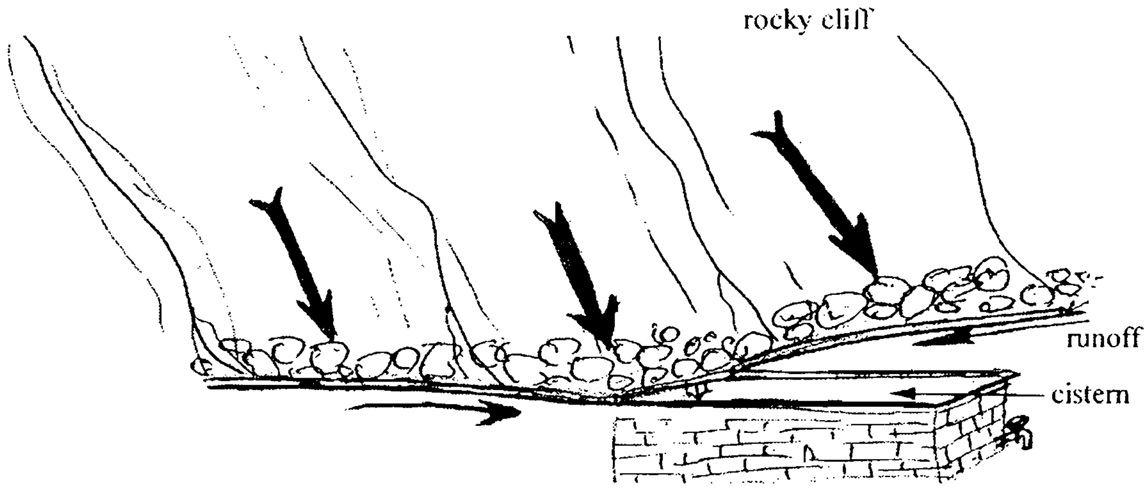


Fig. 2.3. Cemented cistern (=100 m^3) collecting runoff from rocky hillslope for cattle watering or garden irrigation (Kairouan, Tunisia; Rif, Morocco)

Kairouan in Tunisia (Bourges et al., 1979). In the Kairouan mosque built in the 11th century, the rainfall falling on the roof is filtered and stored in a big cistern under the courtyard. In the Languedoc vineyard near Montpellier, it was traditional to catch rain water in a stony cistern from the mazet roof where the watertable is too far (in order to prepare phytosanitaire products). In Almeria Province of Spain, 51 underground cisterns (called "aljibes") were described in relation to the catchment area. This aljibe system is still viable provided the runoff coefficient of the catchment is high and the volume is large enough to prevent overflow (> 60m^3/ha) (van Wesemael et al., 1998).

Runoff harvesting in the valley

"Narrow terraces" (fig. 3.1): in semi-arid areas where it is difficult to crop cereals on hillslopes, living hedges are implanted in the broad wadies to decrease the flood velocity, and harvest runoff and sediments in order to build a narrow terrace for gardening during the dry season, or to harvest clear water to nourish a "seguia" (fig. 3.2), a channel running along the hillslope to irrigate the last terrace. The most frequent plants used are *Provence cane, populars, salix, fraxinus, oleander* and various permanent herbs (Ait Hamza, 1996).

"Jessouri (fig. 3.3). In arid areas of southern Tunisia, earth dykes are built in the valleys to harvest runoff water and sediments from bare hillslopes and to build a serie of terraces planted progressively with fruit-trees (figs, olive and palm trees) and cereals or leguminous like peas (Bonvallot, 1986).

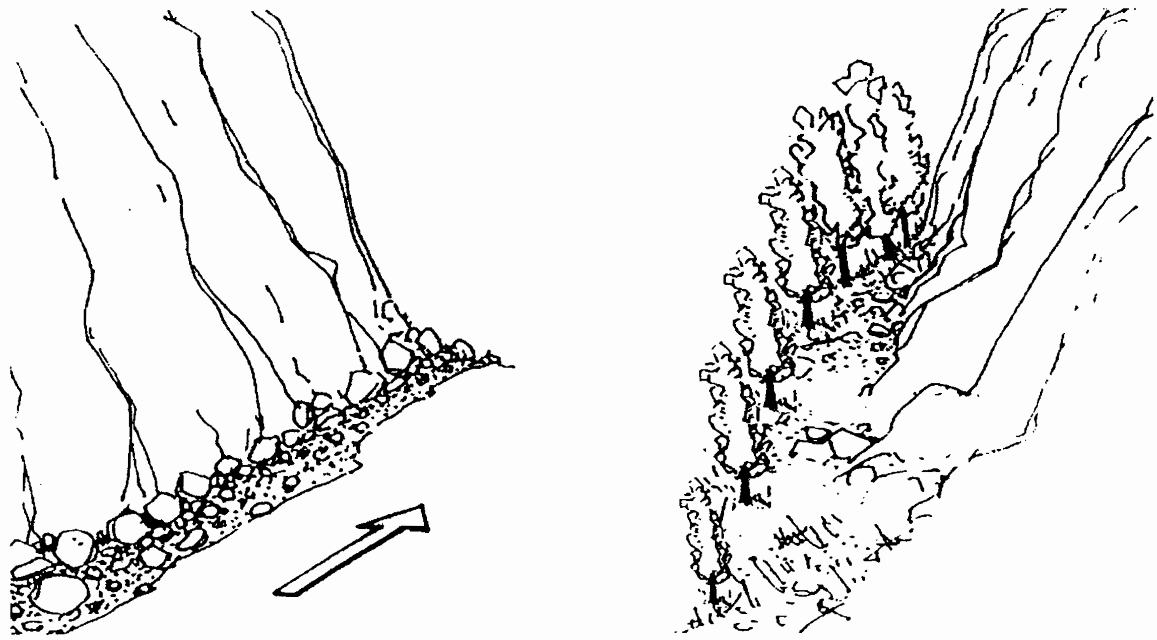


Fig. 3.1 Narrow terraces (Rif, Morocco)

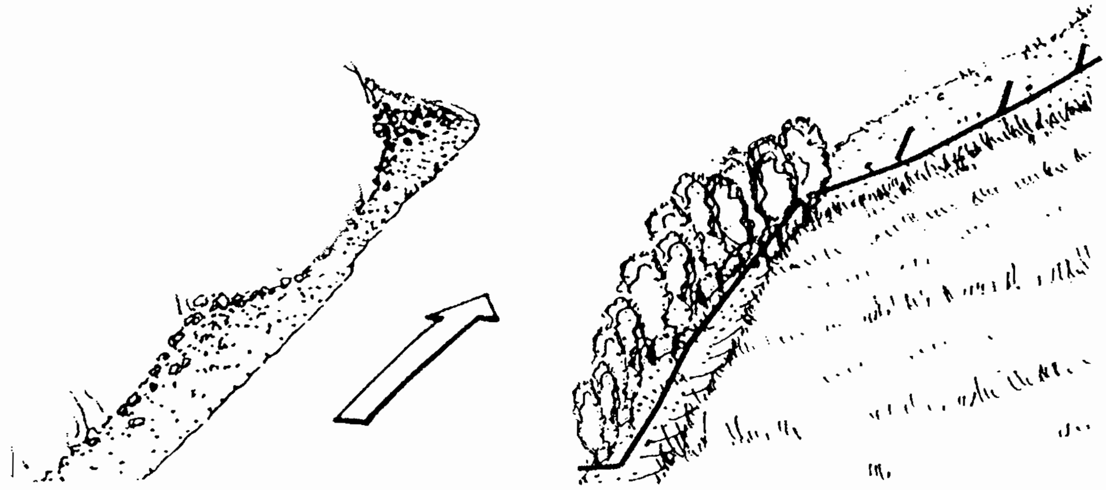
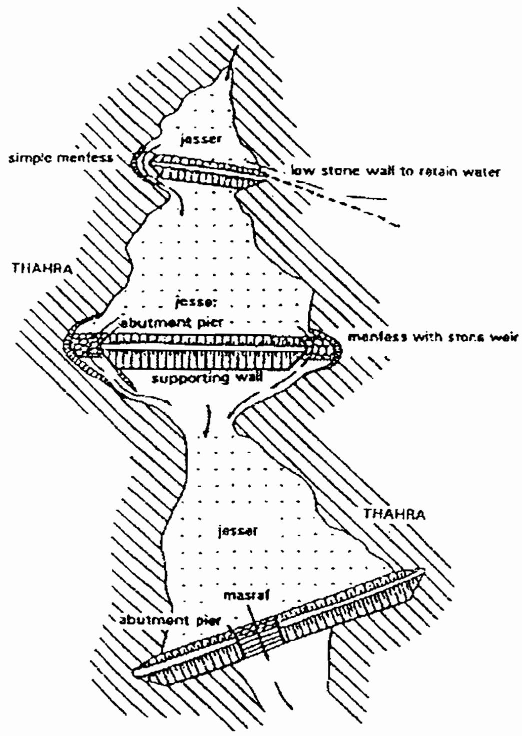


Fig. 3.2. Water harvesting in seguia for terraces irrigation (Rif, Morocco)



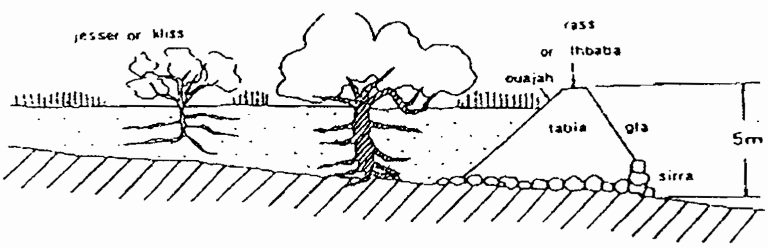


Fig. 3.3. Jessour (Tunisie), after Bonvallot, 1986

"Limans" (fig. 3.4). In the desert of Israel, rare floods are caught by a earth dyke built through the head valleys: cropping in front of the dam will be organised after complete infiltration of the runoff (Evenari et al., 1968).

"Earth dams" are built in Central Tunisia to harvest runoff from little watersheds which will be used for irrigation of lateral terraces downstreet, or pumped on hillslopes for market gardening. (Albergel et al., 1998).

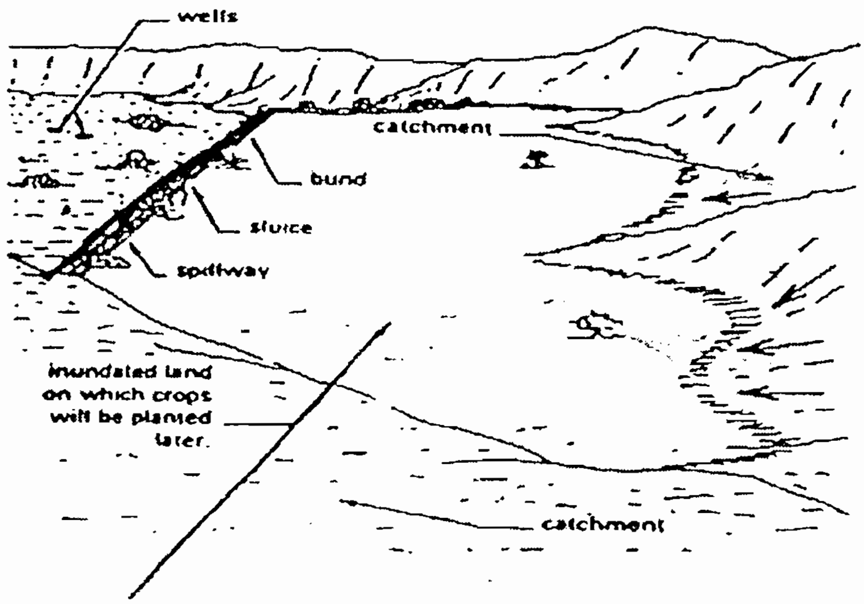


Fig. 3.4. Limans (Israel) after Evenari, 1986

Systems allowing total infiltration

Where annual rainfalls are inferior to 400 mm, farmers developed the famous "Mediterranean graded terraces" (fig. 3.5) covering the whole hillsides up to 40% slope: on steeper slopes risks of landslide are increasing, mainly on argillite, marl, schist and gneiss. Depending on local material available, embankments are built in soil (Asian loess), reinforced with grass stufs or stone walls (Morocco). More frequent are cultural practices oriented to maximise infiltration like deep tillage on the contour, tied ridging or mulching (for market gardening).

Diversion of excess runoff during the humid periods (fig.4)

"Diversion ditches": in Aveyron (Southern France) aswell in Algeria (and Maghreb), farmers open oblique ditches with the plow in order to drain rapidly the beginning runoff out of the cereal fields (plowed on the contour) to the plot boundaries or to waterways

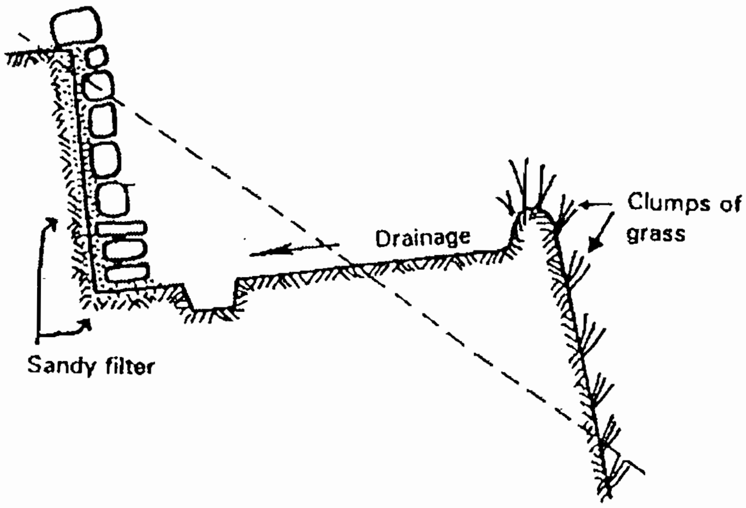


Fig. 3.5. Mediterranean bench terrace

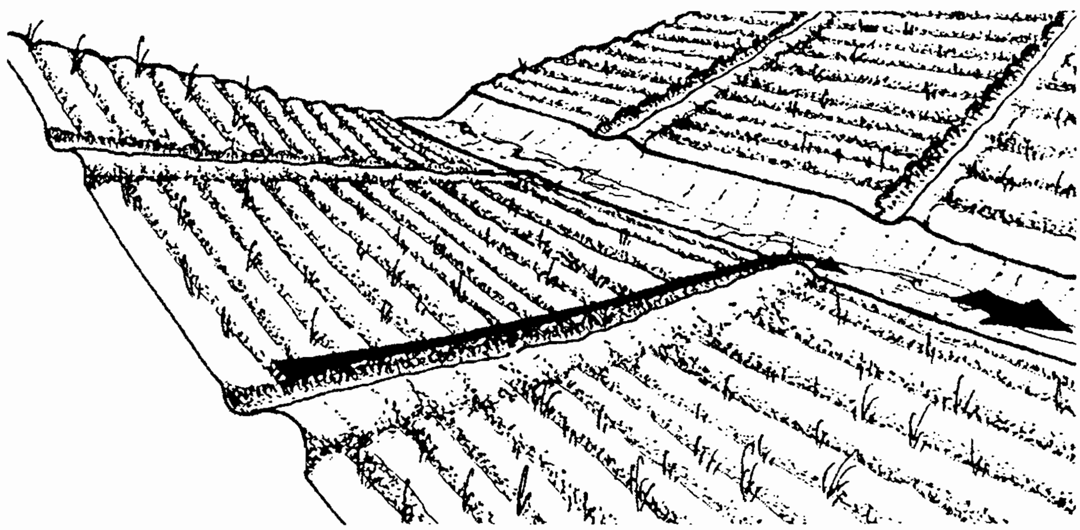


Fig. 4.1. Diversion ditches in Aveyron (France) or in Magreb

protected by grass or stones. Within the ditches, the slope must remain lower than 5% not to provoke gully formation.

In the vineyard of Banyuls (Southern France), farmers have built stone walls on steep slopes to increase the soil depth but to avoid landslide on schist lithosols, they open oblique ditches draining excess water to stony collectors (Alcaraz, 1997). These systems have very similar objectives to oblique ridging, a cultural practice allowing slow drainage from the fields to waterways at the plot boundaries. These ditches reduce the risk of accumulating excess runoff leading to gully formation, but have the inconvenience of reducing the flow collecting time and increasing the flood peak in the valleys. If any mismanagement, these systems lead to gully formation where the excess water is cumulating.

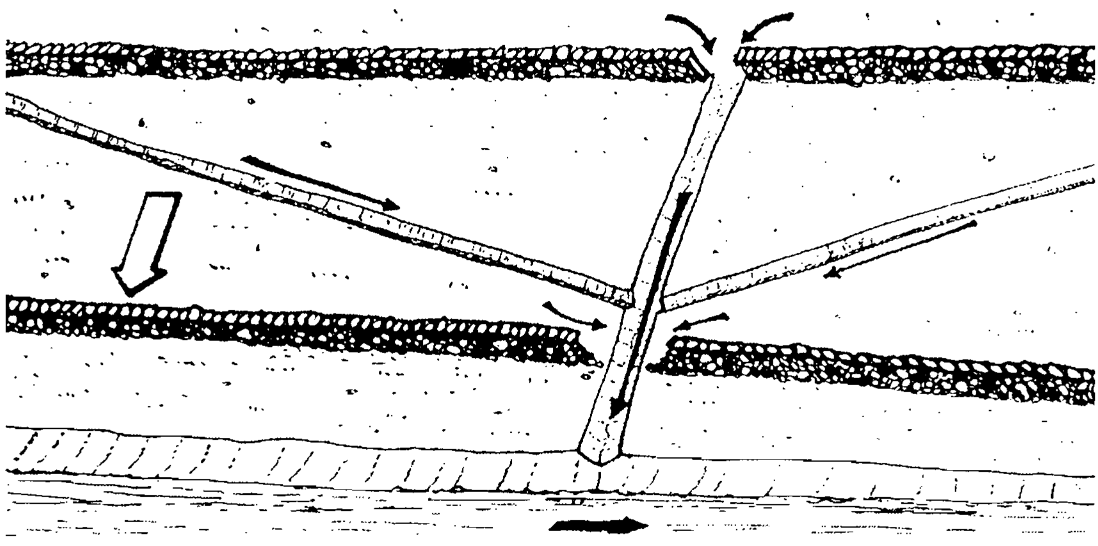


Fig. 4.2. On superficial schist lithosol, oblique and vertical drainage organized on the hillslopes

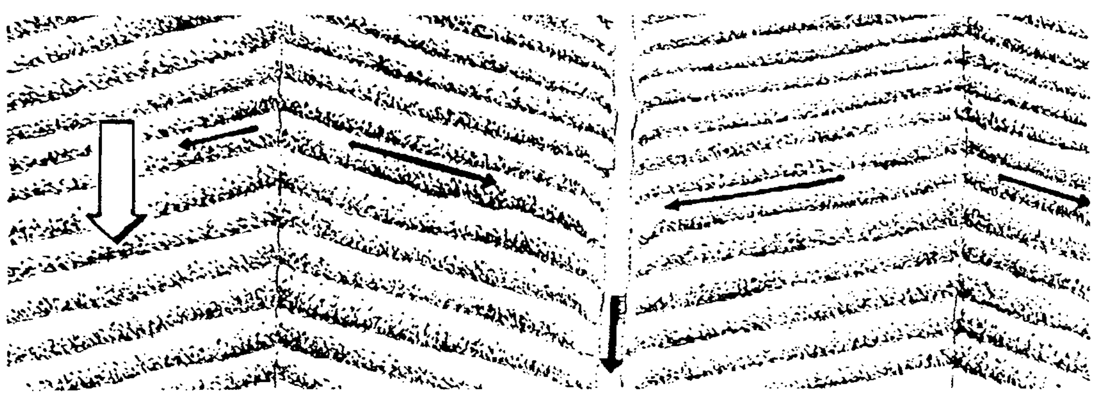
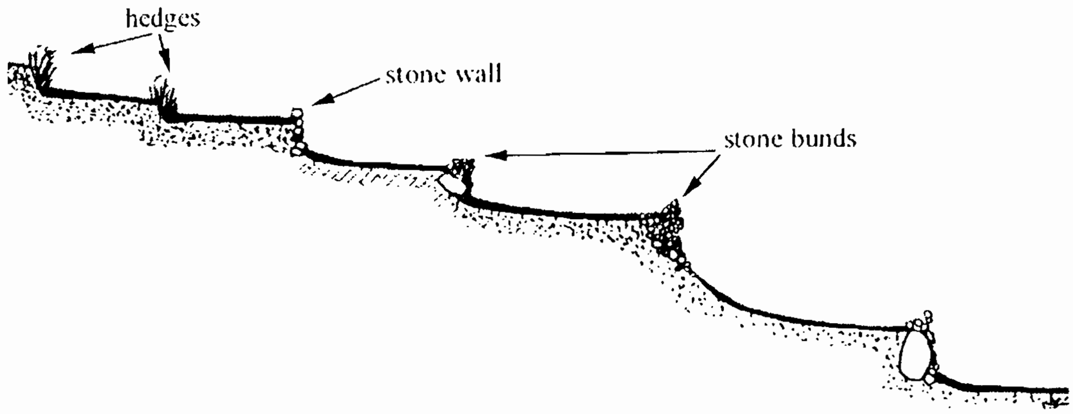


Fig. 4.3. Oblique ridging and waterways (Banyuls, France)

Runoff energy dissipation

"Progressive terraces with permeable barriers" (Fig. 5). Instead of concentrating sheet runoff in diversion ditches or channels, this system tries to dissipate the runoff energy while dispersing excess water on the roughness of the soil surface (clods, mulch, weeds) and on permeable structures (like grass strips, hedges, stone bunds, etc.) which reduce the runoff velocity of water going down the hillslopes. In Mediterranean area, this system is very frequent with embankments covered with various natural bushes and grasses (olive, almond trees, doum palm trees, etc). On lithosoils, stones are accumulated on piles, stone bunds or stone walls, depending on the stone qualities and quantities. While the embankments are built progressively by tillage erosion (5 to 20 cm / year), the slope steepness decreases to a limit, but the runoff keeps draining down the hillslope in diffuse sheet, with low velocity and energy (Roose, 1996).



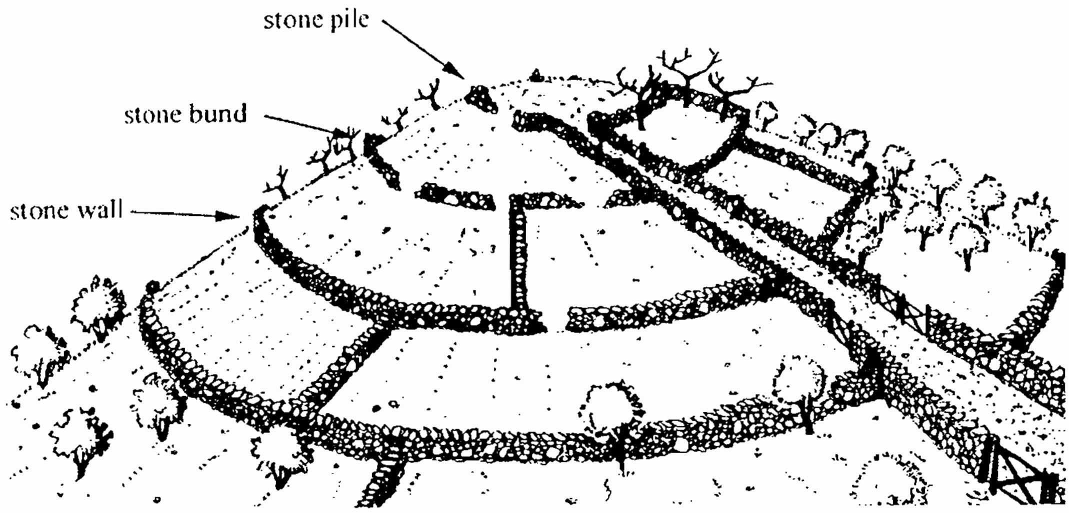


Fig. 5. Progressive terrasing with permeable microdams (stone piles, stonesbunds, stone walls, living hedges, grass strips). (Rif, Morocco)

"Bench terraces with stone walls". In Spain, it is possible to observe presently graded terraces built since the 4th century under the pressure of Romans and later of the Arabs (ex. In Benicadell, Valencia). "Bancales" built on the smooth slopes of the piedmont support rich olives and cereals mixed cropping systems. On the superficial lithosoils of the concave hilltop, "terrazas" support more rustic tree cropping (almond) which are abandoned to the pine forest in case of labour shortage. (Rubio and Asins, 2000).

In the field, cultural practices increase the efficiency of these terraces, like rough plowing, mulching or direct drilling in the litter of crop residues

BIOMASS AND SOIL FERTILITY MANAGEMENT

In semi-arid areas, vegetal production is limited not only by water supply but also by nutrient deficiencies, mainly phosphorus and nitrogen, continually exported with cereal grains.

To restore the soil production capacity, farmers developed traditional farming systems: cereals in rotation or association with leguminous plants, farm manure (generally poorly managed and in limited quantity), various compostage systems, fallow and grazing areas, agro-forestry (olive- or almond-trees with cereals/beans rotation), sylvo-pastoralism (cork oak and grazing), etc. These complex restoration systems helped to maintain a minimal production of 4 to 15 quintals/ha/year. A complementary supply of N and P is needed with water management systems to improve the production.

DISCUSSION AND CONCLUSIONS

Traditional soil and water conservation systems are numerous around the Mediterranean sea: their extension areas and efficiency are limited to climatic and socio-economic conditions, which are very variable in relation to space and time. Because they are concerned chiefly by water management on the hillslopes, a classification was proposed in relation to local water budget, topography and functioning. In this limited list, probably some are not described yet because we did not visit all the Mediterranean countries; nevertheless, many systems have been observed in various countries south and north from the sea side.

Most of the traditional systems are managed to catch water and its load for supplemental irrigation. Here irrigation improves water availability and soil fertility at the same time, but supplemental fertilizers (N+P. mainly) are needed to valorise the natural soil and water resources.

Presently, many of these traditional systems have been abandoned, not because they are not efficient to preserve the land, but because human conditions have changed. In countries south of the Mediterranean sea, the population has grown too fast and farmers ask for more productive systems; these systems require a lot of labour for maintenance and labour is better paid in town or in Europe. Because of young people emigration, the maintenance is not insured by lack of labour and finance. In European countries, the farmer's population has decreased and these systems are abandoned because they are not adapted to mechanisation. At present, European Union helps farmers of southern Europe to maintain or restore some traditional management for touristic reasons (landscape protection) and to protect cities and managed plains against peak flow, sedimentation and mudflow. In Maghreb, some private owners (coming back from Europe) invest in soil conservation to insure their land property.

In the last 50 years, population pressure increased south of the Mediterranean sea. In Maghreb large plains, the governments organized irrigation and intensification of the agriculture, but nobody was responsible for improving agriculture in the mountains. In the mountains poor farmers still survived, extending subsistence crops on steep slopes, sacrificing forests, mattoral and crop residues for breeding (which is the farmers bank), and for energy (30% of their time is spent to collect fire wood and forage), or cannabis production (the most profitable crop in the Rif mountains). In many places rills became gullies, the bare ground left the hills to sediment in the reservoirs, leading to badlands formation and accelerated emigration.

To fight against this high erosion hazard last century, two strategies were proposed by central governments:

- SWC: Soil and Water Conservation (Bennet, 1939), but soils are already so degraded that it is rarely profitable to restore them.
- DRS, Defens and Soil Restoration by forest plantation, terraces, gullies correction...but where the farmers may live and produce?

The failure of these conventional strategies is now recognised (Hudson, 1991).

At the workshop of Puerto Rico (1987), after the analyse of the failure of these modern conventional approaches, a new strategy was proposed (Land Husbandry) based on farmers participation in the solution research for their problems: "sustainable valorization of their land and their labour". The challenge is to increase their productivity and simultaneously to reduce erosion risks. To give a chance to crops to better grow and cover the soils, infiltration capacity and nutrients availability must be encouraged (Shaxson et al., 1988). At the level of research, this approach has been tested already in various countries such as France, Algeria, Burkina, Cameroon, Cabo-Verde, Rwanda, Burundi, Haïti, etc. In Algeria on vertisols, the yield increased from 8 to 50 quintals of cereal grains and the net income was multiplied by 10 with a simultaneous decrease of runoff and erosion risk (Roose et al, 1993, Roose, 1996).

Traditional strategies studies are of great interest as a new departure point for a research about the sustainable management of natural resources at the regional level where erosion and runoff problems cannot be solved by technical approaches alone. Farmers participation is necessary to improve our knowledge on their ecological and human environment and for the maintenance of rural management. Researchers, in close relation to farmers and state technicians, have to study the systems limitations and their possibilities for improvements.

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