Traditional and Modern Strategies for Soil and Water Conservation in the Sudano-Sahelian Areas of Western Africa

Eric Roose

Erosion is a concept covering many processes that show great spatiotemporal variation. Consequently, different soil conservation strategies must be employed in different places and among different peoples.

Geological erosion is generally a slow process (a few t/km²/yr), although catastrophic phenomena such as landslides that level hillsides, centennial forests or villages can occur suddenly. Accelerated erosion now occurs in relation to the following human activities: overgrazing, clearing of forests, repeated fires, poor cultivation practices, and reduced fallow. The resulting imbalance of nutrients and soil organic matter leads progressively to soil degradation, runoff and further erosion.

In places where poor management increases the risk of erosion, agrosilvo-pastoral systems can be introduced and adapted to local ecological situations. Often rural communities can select soil and water conservation strategies that will preserve the local environment.

This paper will analyse the diverse strategies developed by various societies in the Sudano-Sahelian areas of western Africa and suggest the need to take these strategies into account in order to increase production through water and soil fertility conservation management. Before analysing these diverse, traditional soil and water conservation strategies, however, a brief description of ecological conditions in the areas inhabited by various ethnic groups will be necessary (see Table 1).

Four ecological zones can be distinguished in Sudano-Sahelian western Africa: the Sahelian area (rainfall between 150 and 400 mm/yr); the southern Sahelian area (rainfall between 400 and 700 mm/yr); the northern Sudanian area (rainfall between 700 and 1,000 mm/yr); and the southern Sudanian area (rainfall >1,000 mm/yr). Annual rainfall ranges from 1,200 mm downward to 150 mm/yr, but over the last 10 years (which were very dry) rainfall has decreased approximately 35%. The rainy season continues for 3 to 6 months with great intensity, in contrast to the low infiltration capacity of the sealed soil surface (infiltration=3-12 mm/hr). Daily rainfall events reach 50 to 75 mm each year, 90 to 120 mm once every 10 years, and 110 to 170 mm once in a century (Brunet-Moret 1963).
### TABLE 1

**Diversification in the Sudano-Sahelian area**

<table>
<thead>
<tr>
<th>Area rainfall case study</th>
<th>South Sudanian &gt;1,000 mm Korhogo</th>
<th>North Sudanian 1000 to 700 Koutiala</th>
<th>South Sahelian 700 to 400 Yatenga</th>
<th>North Sahelian 400 to 150 Mare d'Oursi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R mean annual</td>
<td>350</td>
<td>900</td>
<td>625</td>
<td>525</td>
</tr>
<tr>
<td>R max. month</td>
<td>318</td>
<td>250</td>
<td>207</td>
<td>177</td>
</tr>
<tr>
<td>R day 1/1-1/10-1/100</td>
<td>76-119-169</td>
<td>62-107-166</td>
<td>55-101-145</td>
<td>49-79-109</td>
</tr>
<tr>
<td>[30 1/1-1/10]</td>
<td>75-108 mm/h</td>
<td>60 78</td>
<td>59-82</td>
<td>32-45</td>
</tr>
<tr>
<td>Drainage, mm</td>
<td>468 to 185</td>
<td>180 to 70</td>
<td>50 to 6</td>
<td>0</td>
</tr>
<tr>
<td>Density, hab./km²</td>
<td>30 to 80</td>
<td>30 to 50 près de Koutiala</td>
<td>70 &gt; 100</td>
<td>10 hab.</td>
</tr>
<tr>
<td>Soils on hillslopes</td>
<td>Ferrallitic</td>
<td>Leached ferruginous SC gravelly + vertisols + brown on basic rocks</td>
<td>Leached ferruginous SC gravelly + vertisols + brown on basic rocks</td>
<td>Not leached ferruginous, sandy sheet on red brown subaride soil.</td>
</tr>
<tr>
<td></td>
<td>SC gravelly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation cover</td>
<td>Arborescent savanna, Daniella, Parkia biglobosa, Butyrophorum + Andropogon + grass.</td>
<td>Arborescent savanna, Daniella, Parkia biglobosa + thorny bushes + Andropogon + various grass.</td>
<td>Bush savanna, Combretum, Baobab, Acacia + thorny + scarce Andropogon.</td>
<td>Steppe, bush, Baobab, Acacia, Balanites, Ziziphus and annual grass.</td>
</tr>
<tr>
<td>Farming system</td>
<td>Rainfed farming Drainage of excess water</td>
<td>Rainfed farming Drainage of hillslope runoff</td>
<td>Runoff farming Trapping of rain and runoff</td>
<td>Valley farming Intense cropping limited in valleys</td>
</tr>
</tbody>
</table>

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**Notes:**
- Rainfall decreases are provided in mm for the specific years and locations mentioned.
- The drainage farming systems are categorized based on the type of water management practices used in each area.
| Traditional management | Yams on large mounds. Maize + intercropping on ridges. Millet + peanut + various on ridges. Intercropping + agroforestry. Drainage between plots. | • Superficial tillage. • Cropping on the flat. • Two weedicings. Sorghum/cotton or Millet + sorghum/peanuts + cowpeas. Hillslope runoff on waterways. Total infiltration or rain in the field. Stone bunds and walls. Grassed, stone, cut branches lines. | • Superficial tillage. • Cropping on the flat. • Two weedicings. Sorghum or millet, then peanuts and cowpeas, Mulching Zai + Boli stone line/bund stone, grass or branches, stalks, lines. On sandy soils tied ridging (sometimes). | Sowing on the flat + 2 weedicings. Millet on sandy soils. Sorghum on clay soils of the lower grounds. Grazing on the hillslopes. Gardens in lower areas. Retreat flooding. Farming around the “Mares.” |
| Modern management suggested | Afforestation of laterite screes. Grassed buffer strips. Gully restoration. Rice fields protection. | • Improvement of grassland. • Protection diguettes. • Living hedges + stone bunds or grassed buffer strips. • Grassed waterways. • Low grounds management. | • Improvement of grassland. • Ponds for cattle watering + supplementary irrigation of gardens. • Stone bunds protected by Andropogon grass line. • Gully and lower grounds management. | • Shrub forage plantation in half moon or ditches. • Management of grassland. • Ponds for cattle. • Trapping runoff on hillslopes. • Permeable diguettes and stone bunds on pediment. • Low ground management. |
The most frequent landscapes, on granite and sandstone, are composed of a lateritic tableland, a short scree of lateritic blocks, and a long glacis or pediment of gravelly soils covered with a sandy silt loam layer thicker near the river, which is more or less deeply embanked. Hillslopes are generally gentle (0.5–4%) but very long. They can be covered by recent or ancient dunes, or they may be steeper, on quartzitic or basic rocks.

The red tropical ferrugineous soils on hillslopes (Alfisols) are leached and often hydromorphic, generally poor chemically (N, P and often K deficiencies, pH between 6 and 4), and unstable physically (low in organic matter content but rich in silt and loam). As soon as the soils are cultivated they develop a sealing crust which drastically reduces their infiltration capacity. After a few cropping seasons with ploughing and two weedings done by animal traction, there appears a discontinuity (a kind of plough pan) that roots can rarely penetrate, so that the pedoclimate is still drier for annual crops than for trees and shrubs. In the valleys, soils are hydromorphic or vertic, chemically richer but still more difficult to manage. They are hard to work when dry and fluent during the rainy season.

Crops cover the soil surface poorly and leave very little residue. Cotton, peanuts, cowpeas and various beans are cultivated in rotation with cereals like sorghum, millet, fonio, and some maize and rice (in the hydromorphic areas). Cotton stalks are burnt. Peanuts and leguminous straws are used as fodder. Cereal leaves are grazed in the field and their stalks used for roofs or for various handicrafts. Fallow is vanishing because time is too short and the land too overgrazed for efficient regeneration of soil fertility.

The natural vegetation, originally a dense tree savanna, has deteriorated badly in recent decades owing to drought, overgrazing, extension of cropping areas, the need for fuelwood, erosion, and a decrease in the level of the water table. Herds were developed during the wet years in the Sahelian area. During a drought, therefore, the reduced biomass production cannot feed village herds or transhumant herds going from the Sahel to the Sudanian savannas (Quilfen and Milleville 1984; Hallam and Van Campen 1985).

In this area the most active erosion processes are sheet, gully and wind erosion, although only sheet erosion research has been well developed (Roose 1988).

THE KORHOGO CASE STUDY IN THE SOUTHERN SUDANIAN AGROCLIMATIC ZONE

THE ENVIRONMENT

All experimental components (rain gauge, runoff plots, lysimeters) were located in the Waraniene watershed, 5 km east of Korhogo, in represent-
tative tree savana with *Parkia biglobosa*, *Butyrospermum parkii*, and *Daniella oliveri* on granite. The herbaceous stratum is dense (*Andropogon*, *Hypparenia*, *Pennisetum*, *Panicum*). This natural vegetation is severely degraded by annual bush fires, selective clearing and traditional cultivation, however.

The climate—transitional tropical—is dry and warm for 4 months but can be very rainy for 4 months (rainfall=150-320 mm in August), during which 160-450 mm of drainage can be measured (Roose 1979).

The toposequence is classic: a lateritic plateau (red ferrallitic soil), one or two scree, a long concave pediment (2-4% slope), red gravelly ferrallitic soils under the scree, ochre soils some 100 m lower, and grey hydromorphic soils in the colluvial plain.

Traditional cropping systems begin with yams planted on very large mounds (80 cm high) during the cool season after progressive clearing and burning. The following year the mounds are transformed into high ridges (60 cm high and 150 cm apart). Then maize and sometimes cassava are planted and intercropped with other crops. For the 3rd and 4th years the ridges are broken (covering weeds and crop residues) to build a more modest ridge planted with millet, sorghum, maize, tobacco, peanuts and various vegetables. The valley bottoms are covered with irrigated paddy fields as far as colluvium extends.

**Erosion and Runoff**

Sheet erosion, gravel spread on the topsoil, sandy colluvium, and small gullies on hillsides are signals of abundant runoff during the rainy season. Measurements on runoff plots in Korhogo (Roose 1979) and Niangoloko (Christoi 1966) show that ferrallitic soils are very permeable when covered with natural savanna (Kram$^{2}=1-7\%$) but the topsoil structure can be degraded by cropping, which provokes a significant runoff rate (Kram$^{3}=40-80\%$) during the decennial storm event on bare and moist soil surface. Soil loss with traditional crops is moderate ($E=0.2-6t/ha/yr$), thanks to gravel mulch cover, moderate slopes and ridges along the contour.

**Traditional Soil and Water Conservation Management**

Hillslopes are covered with a patchwork of fallows and ridged, cropped fields, some on the contour, others along the slope. This system allows good drainage at reduced speed, thanks to rice cropping in the furrows, oriented ridges, or ties at the field borders. The fields are separated by a ditch draining excess water from the fields, but it is not uncommon for such ditches to turn into small gullies bringing a lot of sand and gravel to the plain, severely disturbing the paddy fields.

$^{2}$Kram is the mean annual runoff (% of rainfall).

$^{3}$Kram is the maximum daily runoff (% of rainfall).
When clearing the savanna, farmers respect certain useful trees and the stumps of bushes (often leguminous) which will cover the land quickly after the field has been abandoned to fallow. The mediocre level of fertility is maintained thanks to household ash, dry faeces mixed with compost, ploughing in weeds and crop residues when ridging, and, of course, fallowing, whose duration depends on demographic pressure. Senoufo farmers easily accept multiuse trees on their fields to produce fruits, medicines, fuel, perches and timber.

Well-adapted cultivation practices (mounds and ridges higher than 60 cm) improve the production of long tubers and soil infiltration capacity (Camus et al. 1976). Senoufo farmers also reshape the valleys to enlarge their paddy fields.

Modern Strategies of Watershed Management

In 1964–68 a programme for soil conservation (CES) was developed in the densely inhabited area of Korhogo. It had the following three objectives:

1. Protection of paddy fields against silting up from the gullies.
2. Reafforestation of the plateaus to produce firewood and insure good flow in the river during dry seasons.
3. Protection of cultivated land on the hillsides against runoff and gully erosion.

Lateritic screes were reafforested, bush fires were forbidden, firebreak tracks were opened, and grass buffer strips were traced along the contour and planted with reference trees (Anacardium, Tectona, Gmelina). Finally, gullies were corrected and low ground managed as irrigated rice fields.

This management was undertaken after the failure of area closure and soil regeneration (DRS) management by the European Group for Soil Regeneration (GERES) near Ouahigouya (Burkina Faso). Gosselin (1965) sought to reduce soil conservation investments (300 m of buffer strip cost 650 CFA/ha as against 7,000 CFA for graded channel terraces) and select structures easy to construct without an expert topographer (grass strips between two lines of bunds) that require very little maintenance but develop vegetation cover.

To reduce cattle straying Gosselin suggests:
- Improvement of corrals to increase manure production.
- Planting fodder trees around villages as forage for cattle.
- Improvement of fallows by sowing stylosanthes or legumes that remain green during the dry season.
- Fencing pastures for rational and exhaustive grazing and elimination of bush fire hazards.
Management aims could currently be characterised as follows:

1. Improve the drainage of excess rainfall by tied ridging and broad grass waterways.
2. Improve infiltration, biomass production and therefore soil surface protection.
3. Improve the biomass management (fire, cattle, forage, manuring, composting, mulching).
4. Improve the use of agroforestry.
5. Improve the livestock management in relation to forage availability.

THE KOUTIALA CASE STUDY IN THE NORTHERN SUDANIAN AGROCLIMATIC ZONE

Environment

The environment in Koutiala is very similar to that of the southern Sudanian area except for less frequent storms, reduced drainage risk, many thorny bushes (such as *Acacia albida*), leached ferrugineous tropical soils (Alfisols) that are much more fragile than ferralitic soils, and a very long pediment of gentle slopes. The human environment is heavily influenced by the Koutiala cotton factory, by extension agents, and by the very efficient villagers’ organisation. Clearings are extended quickly, with only 10–30 useful trees per hectare being retained.

Formerly, under the traditional system, the chief crops were cereals located on gravelly soils at the top of the pediment. At present, cotton (peanuts or cowpeas on poor soils) is rotated with mixed cereals (often sorghum or millet and maize) on the silty glacis with animal traction. Planting takes place as soon as possible after ploughing; two weedicings are done after 3 weeks and 6 weeks and sometimes tied ridging is carried out. After harvesting, the farmer concludes an agreement with a *Peulh* pastoralist to graze the crop residue and leave the manure (pasturing/manuring contract). Then cotton stalks are burnt for phytosanitary reasons while most cereal straws are used for handicraft, cooking and livestock. The remaining stalks (10–25%) are burnt on the field before ploughing. In the old days, the low ground was a reserve of green forage during the dry season. Currently it is planted with sorghum or rice in hydromorphic areas or as kitchen gardens.

Runoff and erosion

Measurements on runoff plots have shown that ferrugineous tropical soils and brown tropical soils are as permeable as ferralitic soils as long as they

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*This is a study of the Minianka farmers in the Koutiala region in Mali.*
are covered by a tree savanna or even an old bush fallow. But when cultivated, these soils are less stable and have an unacceptably high level of runoff for semi-arid areas (Kram = 6–25% and Krmax up to 75% during the heaviest rainfalls). Despite smooth slopes (0.5–2%) and good cultivation practices, soil loss is too heavy on bare plots (14–20 t/ha/yr), while with crops that provide poor surface cover (E = 3–6 t/ha/yr) on the superficial gravelly soil of Gampela, the tied ridging system retains soil and water more readily but does not increase the yield because it cannot store water. At Goné the date of bush fires was observed to have a major influence (Krmax may reach 1%, 15% and 75% if the fire is forbidden—early and superficial, or late and slow; Roose 1980). If the savanna burns late, the runoff can be as high as on a bare cultivated plot (Krmax = 75%; Roose and Piot 1984).

Traditional Soil Conservation Techniques

Traditional conservation practices are limited to stone walls if the soil is stony (on sandstone, quartzite and amphibolite) or to stone lines, grass strips or cut-branch lines. Cultivation practices are superficial but repeated every 3–4 weeks before the crops cover the soil surface extensively: they break the sealing crust, eliminate the weeds, and maintain a high infiltration rate in the profile.

Management Planning for Village Lands

After experience at Fonsebougou (southern Mali), the Division de Recherche sur les Systèmes de Production Rurale (DRSPR) developed a more flexible approach in Kaniko and three other villages. After lengthy discussion, the village association decided on the following priorities for general soil conservation planning (Hallam et al. 1985; Roose 1985):

1. Protecting cropping blocks against runoff coming from the hilltops by means of extensive pasture management (total protection, reforestation in forage bushes, grass strips and stone bunds in the waterways), protection provided by earth dikes leading runoff safely to waterways, and a village tree nursery.

2. Protecting farming land and fields against stray cattle with multipurpose hedges and trees such as Acacia albida, Parkia, Butyropermum, etc. Management of waterways with grass and stone bunds that help to export the yield during the dry season.

3. Improving infiltration on cropped fields. This would involve:
   a. Superficial bunding during the dry season, ploughing on flat surface, two weedings, and, finally, tied ridging.
   b. Introduction of legumes in rotation or in association (Mucuna or cowpeas where the main crop has not grown).
c. Maximum recycling of crop residues (manuring, composting and mulching).

d. 25-metre grass buffer strips or stone bunds between the field to slow down runoff coming onto the field.

4. Management of stream banks and low ground (paddy fields or kitchen gardens with multistory vegetation: vegetables or forage crops, fruit trees, palm trees and very high trees). Microdams, stone or earth bunds (H<2 m) with a lateral rocky outlet.

If the order of management is reversed, there is a risk of silting up the valley. The system tries to encourage the farmers' initiatives even if the initial sequence of action is not completely respected. Thus the entire village was involved in village land management and its technical experience grew out of the community experience. This soil conservation project, sponsored jointly by the Division de Recherche sur les Systèmes de Production Rurale and the Compagnie Malienne des Textiles, corresponds well with the water and soil fertility management (GCES) strategy in the fight against runoff and erosion, which is an integral part of the effort to improve the farming system.

THE YATENGA CASE STUDY IN THE SOUTHERN SAHELIAN AGROCLIMATIC ZONE

THE ENVIRONMENT

The climate in Yatenga is much more arid than the Sudanian climate. Even during the rainy season drought is so frequent that wind erosion can be observed (dust bowl, sandy sheet on the soil surface, sand mounds under tufts of perennial grass, nebka and ancient dunes spread on lateritic hills). Annual rainfall varies from 400 to 700 mm. The vegetation is stunted and scattered. *Butyrospermum* disappears, making way for *Baobab*, *Pterocarpus lucens*, and thorny shrubs (*Balanites*, *Ziziphus*, *Acacia albida*, and others which grow in the valleys). Perennial grasses (*Andropogon*) become infrequent, leaving the ground to annual grass with a short growing cycle (1–3 months).

The lateritic granitic landscapes disappear in the north under sand dunes (sandy ferrugineous tropical soils), while brown and vertic soils on amphibolite are deeply gullied. Groundwater tables are no longer nourished by deep hillslope drainage but by gravelly or stony areas and by the colluvial valleys. The population, which is very dense in this area (70–110 inhabitants/km²), used to migrate for the dry season or for a period of years to coastal countries to earn more for their labour. During the dry

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5This is a study of the Mossi farmers in the Yatenga area in northwest Burkina Faso.
season the countryside is populated by old people, women, and children, most of the workforce having moved to the coast. This must be taken into account when planning management in rural areas in western Africa.

Runoff and Erosion

Measurements on large plots are made on a sandy hillslope at Bidi (Lamachère and Serpantié 1988). Surprisingly, the annual runoff is more than negligible with traditional cropping systems (Kram = 10-30%). Stone bunds have not significantly reduced either the global runoff (1-5% less) or the maximum runoff event (Krm = 60-85%). Nevertheless, during heavy showers, stone bunds have delayed and prolonged the runoff and reduced the maximum flow rate (25% less) and therefore reduced the risk of erosion (30-50%). Intensive farming systems (progressive fertilisation and repeated soil cultivation practices) can be developed between stone bunds. These systems improve infiltration capacity and reduce resistance to rainfall erosivity. Runoff from the hilltops accounts for a surplus of approximately 100 mm on the plots, which improves water storage in the ground only if stone bunds (>25 mm) and deep ploughing (>75 mm) are used to improve surface rugosity and thus increase the infiltration rate. This surplus increases biomass production (chiefly near the stone bunds) and yields (increases range between 33 and 88%) unless rainfall ceases too soon (grain production dropped 11% in 1985). The effect of stone bunds on infiltration depends on rainfall events, the status of the soil surface, and the quality of the bunds. Stone bunds and soil surface rugosity must be maintained.

Traditional Farming System and Water Management

Mossi farmers behave like pioneers. They clear new fields, burning almost all the trees (except some Acacia, Sclerocarya, etc.) After the first storms they plant sorghum on the best soils and millet on sandy soils in seed holes 1 m apart without working the soil. They will sow 2 to 5 times if necessary because of drought, then weed twice using hoes. On sandy ground in the northern area weeding takes place with off-mounding. This improves infiltration (Serpantié 1986).

Animal traction has been reduced since animals and equipment have been sold owing to the long drought period. To avoid complete soil depletion, farmers use organic matter (5 t/ha of dry corral manure), household ashes and compost or a light mulch of cereal stalks and legume bush branches which are not browsed by cattle (such as Pilostigma reticulatum), or they leave the field fallow to be browsed.

The Zai method of restoring degraded fields is highly original. It combines runoff trapping, localised organic fertilisation and termite boring.
activity to improve infiltration. Toward the end of the dry season, the farmers dig a small hole (10-50 cm in diameter, 10 cm deep) into which they put a bit of manure or compost. Organic matter of this sort attracts termites, which dig galleries through the topsoil and the sealing crust to feed on the organic matter. They cover their galleries with excreta. During the first storm, runoff flows through the galleries and water percolates deeply into the soil, temporarily protected from the risk of evaporation. The 5 to 15 seeds put in the seed hole the following day will quickly germinate and find water and nutrients stored in depth that will nurture them until the next storm. The influence of a light mulch (2 cm) set on infertile soil is similar; termites dig the macroporosity while straw protects the soil against raindrop splash (Roose and Piot 1984).

Traditionally, Mossi farmers are crop-growers but also keep some cattle. They dig holes, arranging the spoil in a half-moon shape in order to collect several cubic metres of runoff to water a few cattle near the pasture land or to irrigate a small kitchen garden (Dugue 1987). Finally, when new ground is scarce, the Mossi restore the fertility of degraded soils (Zipelle: bare compacted and crusted area) where infiltration capacity is so low that even fallow cannot grow. They surround their small field with stone, grass and branches to slow runoff and provoke sedimentation of permeable particles (sand, aggregates and organic matter). In the second year, this sandy horizon is cultivated, manured and planted. It is not unusual to harvest 600 to 800 kg/ha of sorghum grain (Wright 1985). In subsequent years, the restored plots are planted with leguminous trees and a new stone bund is positioned to trap the flow running from the hilltop.

SOIL CONSERVATION IN YATENGA PROVINCE

A succession of soil conservation management measures has been practised on a large scale in Yatenga Province for over 25 years in order to slow the rapid degradation of vegetation and soil cover on fragile landscapes at the Sahel border.

"Défense et restauration des Sols (DRS)" from 1960-65

The forestry department, and later the Groupement Européen de Restauration des Sols (GERES), managed 200,000 ha for 3 years, dug 35,000 km of diversion ditches, did cross-rooting in gravely compacted areas, and built 70 km of stone bunds in the waterways and 24 earth dams between hills, as well as other small, half-moon-shaped ponds to increase infiltration on very grassy hilltops and protect cropped plains. While technically well-conceived, this management quickly met with failure because it did not involve the farmers, who failed to maintain it and continued their traditional practices.
"Conservation de l'eau et des Sois (CES)" from 1976-85

Farmers groups were consulted and it was decided that diversion bunds of earth would be built on cropped blocks of 25 to 100 ha. More than 47,000 ha of cropped land were managed in 10 years (Mietton 1986). But owing to management rhythm (maximum 9,000 ha/yr) and the brief lifespan of hillslope management (2–4 years without vegetation cover on the bunds), it would take many centuries to provide protection for all the fields needing it. As a result, it seems useful to consider the traditional strategies studied by various non-governmental organisations (Wright 1985).

"Gestion Conservatoire de l'eau et des sols (GCES)" from 1985 to the Present

Among the numerous anti-erosion projects rapidly developing (OXFAM, AFVP, PAF, PAE, etc.), the joint research project conducted by a team from the Institut National d'Etude et de Recherches Agronomiques (INERA), the Centre International de Recherche en Agronomie et en Développement (CIRAD) and the Département des Systèmes Agraires du CIRAD (DSA) at the Centre d'Encouragement Régional à la Production Agricole (CERPA) in Ouahigouya (Dugué 1984-88; Rodriguez 1989; Roose 1986-87) will be discussed here. The GCES strategy is the same as that applied in Koutiala (Mali).

1. The farmers are questioned closely about their environmental management problems: degradation of soil fertility, infiltration and organic matter content.
2. Experimental research is conducted on the best traditional system for improving infiltration rate and biomass production and ensuring better cover on cultivated fields.
3. Consultation with farmers determines a general schedule for soil conservation management for the whole landscape (Roose 1987-88).

The Mossi selected different priorities than those chosen by the Mōnianka (Mali), however.

1. The Mossi preferred to begin with their own field management and try to capture all the runoff of the teposquence with the following methods:
   a. Rock bunds or lines to be protected by *Andropogon gayanus* lines to spray runoff and with hedges to retain the rocks in place.
   b. Tree plantations around the plots.
   c. Management of crop residues: manure pit near the village and compost on the fields.
   d. Soil rippering after the first storms, ploughing on the flats, plus two weeding and one tied ridging to break the sealing crust as often as possible.
e. Recovery of road runoff on the neighbouring fields and diversion from small gullies.

2. Management of gravely top hills to capture runoff from grazing land. Rotational exclosure of grazing land with planting of trees and fodder shrubs:
   a. Cisterns on the gully heads, developing into microdams to water the livestock and provide supplementary irrigation on 1,000-m² gardens (first maize and then watermelon).
   b. Earth or rocky bunds trapping runoff from the hilltop in order to provide additional water for a field (Bedu 1986).

3. Progressive management of low ground:
   a. Permeable rocky bunds at the heads of the valleys (cf AFVP at Rissian and ORSTOM at Bidi).
   b. Microdam of earth (H<2 m) with a rocky lateral outlet.
   c. Gabions microdams with a central outlet.

At each level of the landscape it is necessary to capture, slow and redistribute runoff to increase surface or deep-water storage in order to increase food production and reduce risk. Conducting supplementary runoff onto cultivated fields is hazardous (probable development of gullies). But digging cisterns or little ponds at the gully head should improve the situation (if a manual pump can be found capable of lifting 10 m³/day 1 m above the soil level).

Where stones are scarce, biological microdams must be perfected. Hedges and perennial grass buffer strips seem to be difficult to grow when cattle are free to move about everywhere during the dry season. Segments of earth bunds could be protected by a stony outlet for security every 5 m. A new sorghum barrier has recently been tested with success.

THE "MARE D'OURLS" CASE STUDY IN THE NORTHERN SAHELIAN AGROCLIMATIC ZONE

ENVIRONMENT

Annual rainfall is less than 400 mm. The contrast with the Sudanian area is evident. Rainfall is erratic: its intensity and duration are much more limited in time and space (see Table 1). If soils are sandy, runoff is limited on fallow and even on cultivated fields, but wind erosion is important (overgrazing and weak vegetation cover). On piedmont and silty loam glacis, however, cultivated soils are quickly sealed. Runoff is important and causes very active gullies with sorghum (Chevalier et al. 1985).

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6This is a study on Peulh, Songhai, and Bella farmers in the "Mare d'Oursi" area in Burkina Faso.
Measurements were made by the Centre Technique Forestier Tropical (CTFT) for 3 years around the Mare d'Oursi on a fine sandy dune at the bottom of a gabbro hill. Runoff is generally low (5-10%). Cultivation practices that break the sealing crust improve soil infiltration capacity, which is already very high on these sandy dunes. Nevertheless, during intense storms runoff increases up to 40%, even on protected fallow. Erosion is still important on bare fields (5% slope) but moderate in dry years on millet and fallow. Wind erosion, which is very intense as soon as any sandy area is cultivated, will not be discussed here.

**Traditional Farming and Management Systems**

While there are numerous well-known systems for collecting rainfall and runoff to grow trees and cereals (e.g., jessour, tabia, meskat, foggara, cistern) in the Mediterranean area of northern Africa, the runoff farming systems in the tropical Sahel are very limited. In reality, they involve the selection of crops and cultivation practices in relation to soils (millet on sandy soils, sorghum on heavy clay soils and low ground, irrigated kitchen gardens around ponds), adaptation to storm occurrence (very weak cultivation practices, direct sowing repeated if necessary because it is very cheap: 3 kg/ha of seed and 9 hours of cultivation), very large surfaces sown (even if weeding cannot be ensured), and short-distance migrations to harvest natural fonio and nemuphar bulbs. Farmers live on the cultivated fields from November to August near granaries and migrate with the livestock to temporary grazing land during the rainy season (Milleville 1982).

According to Milleville (1982), the cereal cropping limit is based on 350 mm of average annual rainfall. The Mare d'Oursi case study is limited in this regard as annual rainfall has been 130 mm lower in the last 15 years and the yields are heavily dependent on soils and rainfall distribution. Furthermore, the grain yields (150–250 kg/ha/yr) are so low that livestock and nomadism are necessary to ensure survival in the Sahel.

**Introduced Management Systems**

Since the environment is so fragile, it is dangerous to advise that an agropastoral system be developed to keep pace with the rate of population growth. Today it seems that development has stopped because almost all the ground suitable for cultivation is already cultivated. Fallows are disappearing, soils are exhausted, and the cost of fertilisation and short-cycle selected seeds makes agropastoral systems profitable in years when rainfall is abundant and well distributed during the growing season (Milleville 1982).
Nevertheless, experiments were possible on lands like Keita in Niger. They included the following measures:

1. Planting living hedges or thorny bushes of forage like *Balanites* or *Acacia albida* on sandy dunes.
2. Harvesting runoff water to bring supplementary water to small fields ridged on the glacis.
3. Agroforestry management of low ground with stone bunds, hedges, fruit or forage trees.
4. Management of the "mare" borders in order to intensify and diversify crops (forage for milk cows, cereals, vegetables and some fruit trees).

But it must be made clear that agricultural production is in the valley and that livestock and nomadism over short distances are better adapted to this very fragile Sahelian area.

CONCLUSIONS

The semi-arid zone of western Africa is highly diversified in terms of space (water resources, localised storms, infiltration capacity of various soils) and time (seasonal and annual variations). Natural vegetation varies according to climatic area and how it is used by man and cattle. Furthermore, the various ethnic groups living in this zone today have adapted their systems of exploitation and their systems for managing water economy and maintaining soil fertility to this diversity.

These traditional management systems, facing demographic and socioeconomic pressure, are no longer well adapted. Vegetation and soil cover are deteriorating. The modern strategies of rural management imposed by centrally located administrative engineers are too rigid and poorly adapted to ecology and human diversity. Their failure can often be explained by resistance on the part of tradition-bound farmers.

In the light of these failures, observed in the USA as well as northern and western Africa, the author suggests a new approach oriented to rural development: water and soil fertility management (WASOFMAN, or GCES in French). This approach begins with inquiries about degradation risks and traditional soil, water and fertility conservation strategies. Then the most feasible and suitable techniques are tested on farmers' fields to determine their effect on infiltration rate, biomass production and erosion risk. Finally, a general programme of soil management is scheduled with the village community.

Generally, runoff is abundant on long, thinly covered pediment in these semi-arid areas. Antierosive structures are not sufficient to reduce water and nutrient losses. Often they are useful in establishing a more intensive production system with a better infiltration rate (superficial work
breaks the sealing crust), a better structural stability (crop and animal residue management) and better growth conditions for plants (mineral and organic fertilisation).

Water and soil fertility management take time and are difficult to fund but they represent a new experimental field open to interdisciplinary research teams. Indeed, there is a serious lack of good quantitative measurements of productivity and soil conservation, economic and sociological aspects of erosion, methods to improve the security of the production systems and even of measurement methods for wind and water erosion in the Sahelian area.

REFERENCES

Milleville, P. 1982. Etude d'un système de production agropastoral sahélien de Haute Volta. Ouagadougou: ORSTOM.
Conservation in Western Africa


Wright, P. 1985. La gestion des eaux de ruissellement au Yatenga (Burkina Faso). Ouagadougou: OXFAM.

ABBREVIATIONS

DRS Défense et restauration des sols
Area closure and soil restoration
CES Conservation de l'eau et des sols
Soil and water conservation
GCES Gestion conservatoire de l'eau et des sols
WASOFMAN (Water and soil fertility management)
ORSSTOM Institut Français de recherche scientifique pour le développement en coopération
CTFT Centre technique forestier tropical
ORD Office régional de développement
Regional office for development
GERES Groupement Européen de restauration des sols
European group for soil restoration
Kram Mean annual runoff coefficient (% of rainfall)
Kmax Maximum daily runoff (% of rainfall)
K Soil erodibility after Wischmeier and Smith (1960) in USA units
AFVP Association francaise des volontaires du progrès
Association of French Volunteers for Progress
PAE Projet agriculture écologique
Ecological agriculture development programme
PAF Projet agro-forestier
Agroforestry development programme
CIRAD Centre international de recherche en agronomie et en développement
DSA Département des systèmes agraires du CIRAD
Farming system department of CIRAD
INERA Institut national d'étude et de recherches agronomiques du Burkina Faso
CERPA Centre d'encouragement régional à la production agricole
Erosion, Conservation, and Small-Scale Farming

Edited by Hans Hurni and Kebede Tato

Geographica Bernensia
International Soil Conservation Organisation (ISCO)
World Association of Soil and Water Conservation (WASWC)