# 5. Technical Guide: Agricultural Land Conservation

# Chapter 1 Overview

## 1.1 Background

The Sahel is an area of extremely low population density when viewed from a global perspective. That is due to the fact that the climate of the Sahel presents an extremely severe environment for human survival. The agricultural system in the Sahel has come to be based on extensive agricultural methods and extensive agriculture is another word for exploitation. The reason why this system has been capable of being productive is because of the overwhelmingly small population compared to natural resources. In other words, the reproduction of natural resources exceeds human demand.

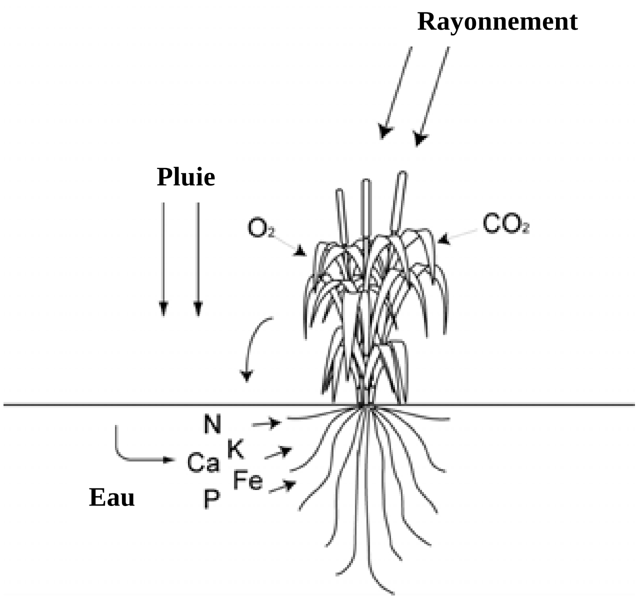
The foundation of the natural resources is the soil. The soil, in an area of rainfall retention, is the mother that nurtures the vegetation and the basis for the recirculation of nutrients. Natural reproduction differs by year due, for example, to the amount of rainfall and sunshine. The fluctuations are not so great if the soil has a certain degree of fertility and it is possible to obtain stable harvests if rainfall is plentiful. However, the deterioration and outflow loss of the soil means that the tolerance of resource reproduction itself has lessened. If that is the case, then, the yield will approach zero if there is a little rainfall and, even if rainfall is adequate, there will be a lack of nutrition and nature will have no energy to spare for reproduction. Desertification describes this decline in the tolerance of nature. The population, which has surged in the Sahel over the past 30-40 years, has destroyed the balance with the natural resources in the area and there is no longer any margin for the viability of extensive agriculture. Both the natural resources and the soil are limited and there is no promise of a bright future in the Sahel without the management and conservation of the soil.

The principles for the conservation of agricultural land are extremely simple and explicit. However, the effects of conservation are achieved in the long term and are not immediately apparent to the eye, which means that steady and persistent efforts are required. Past projects for the prevention of desertification have always advocated soil conservation as a major issue. Most of them have used Food for Work and other assistance measures in order to arouse concern and the labor of the local people for soil conservation. With these methods, however, the farmers do not necessarily accurately comprehend the phenomena that are occurring on their land or the need for the conservation of agricultural land since their activities are motivated by the need to acquire food. That has given rise to the issue of effects that are no more than temporary. As a trend in recent years, activities for the conservation of agricultural land are gradually shifting to the participatory method without compensation and it is becoming increasingly important for the farming people to undertake initiatives through their own willingness.

### 1.2 Objectives

The conservation of agricultural land, in short, means conserving soil and water. The elements required to nurture vegetation are moisture and sunlight together with nitrogen, phosphates, potash and other nutritional elements as well as trace elements such as iron and magnesium. Moisture and sunlight are supplied by rainfall and the sun while the other substances are basically obtained from the soil. Figure 1.2.1 shows this in simplified form. Vegetation produces sugar, its source of energy, through photosynthesis with air-borne carbon dioxide and water absorbed through the roots in the presence of sunlight. Growth is not possible, however, with sugar alone. Nitrogen, phosphates and the other nutritional elements are indispensable for developing the plant's structure and maintaining physiological activities.

**Figure 1.2.1 Plant growth and the cycle of rainfall and nutrition**




The conservation of moisture provides the minimum guarantee for the physiological activity of the plant known as photosynthesis and the absorption of nutritional elements by the root. What should be done then in order to conserve moisture? The answer is to cause rainwater to penetrate into the soil as much as possible without loss due to surface runoff. Rain in the Sahel area falls heavily for extremely short periods. Therefore, all of the rain that falls on the ground does not seep into the soil but is lost in part instead through surface runoff.

Let us think, for example, in terms of the extremely hard surface of glacis. If there were a 500mm rainfall and 200mm of it were lost through surface runoff, it would only be possible to expect productivity at a level equal to that of the northern extremity of the Sahel. The latent productivity of glacis would be improved, however, if an additional 100mm of rainfall were to seep into the ground due to the application of construction methods.

Soil conservation is linked to the maintenance of the tolerance of crop production. The most effective method for controlling agricultural land is to enhance the nutrition cycling of the land. In order to realize that, it is necessary to reduce the loss of nutrition. The soil of the Sahel has especially rich accumulations of nutrition in the surface stratum. Conversely, nutrition is poor in deeper strata.

Let us say, for example, that a 1mm layer is scraped from the surface of agricultural soil. Though that may seem trivial to the eye, if that were to occur on 1ha of agricultural land overall, it would represent a total loss in volume of $10m^3$. How many cartloads of soil would be required to replace this loss? It would definitely not be an easy task to do so. The conservation of agricultural land is a means for avoiding that loss of 1mm of soil from the surface of agricultural fields. In the end, that would be a much easier task than hauling in $10m^3$ of soil every year to replace soil that has been lost. As long as appropriate conservation is carried out, it would also be possible to replace the topsoil of denuded land.

This guide is to be used by technicians who support such activities as a reference work for the purpose of promoting countermeasures for soil erosion prevention and agricultural land conservation by the local people. It provides explanations first of the role of the soil and mechanism involved in its deterioration and furthermore introduces the characteristics of various conservation construction methods using descriptions that are as simple as possible also assuming support of activities by technicians who are not necessarily specialists in this field with the priority on the conservation of millet fields, which form the foundation of food production in the region. In addition, it also introduces actual examples of implementation by the JGRC in Niger, Burkina Faso and Mali of support activities for the purpose of developing a foundation that would enable the local people to become more aware of the phenomena of soil erosion and deterioration that are occurring on their own land, to understand the importance of agricultural land conservation and erosion countermeasures and to develop independent activities while also providing specific measures and methods for their implementation with the aim of establishing a sustained agricultural and livestock production foundation through their own efforts.

## Chapter 2 Characteristics of Soil for Millet Cultivation in the Sahel Region

### 2.1 Characteristics of the soil in the Sahel region

#### 2.1.1 Origin of the soil

The sandy soil that is used for millet cultivation in the Sahel region retains the effects of previous conditions of forest and heavy rainfall and is soil with progressive weathering and leaching. As a result, it is highly acidic with few minerals (base cations), such as K, Na, Mg and Ca, near the surface. Since the clay component consists primarily of kaolinite and there is little organic matter, there is little nutrient retention and the soil has a low buffer capacity.

**Figure 2.1.1.1 Typical terrain in southwest Niger**

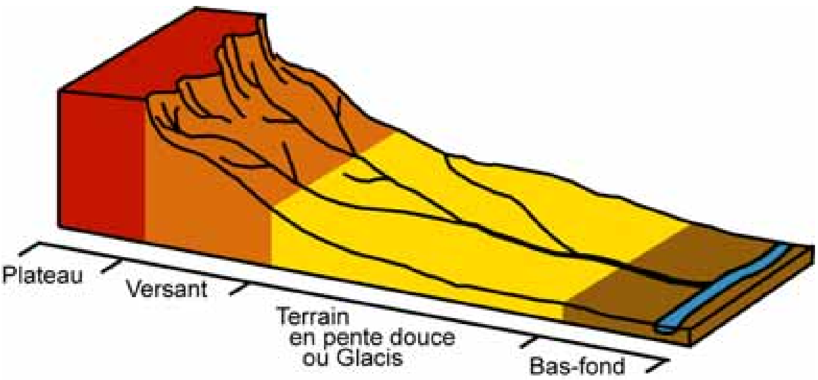
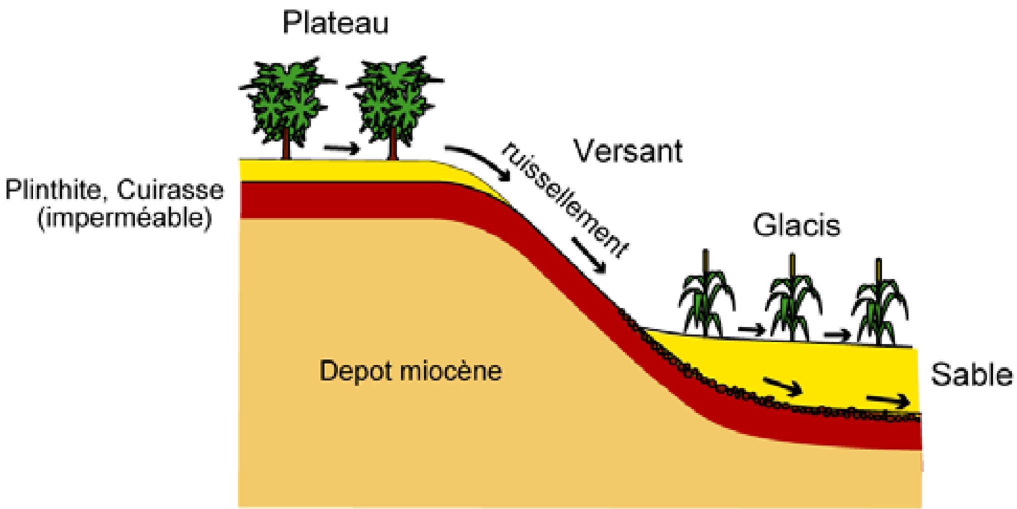



Figure 2.1.1.1 shows typical terrain in southwest Niger, which is also the same in northern Burkina Faso and Mali. The plateaus that can be seen in the Sahel region are alluvial deposits known as the Continental Terminal consisting primarily of deposits from about 25 million years ago (Miocene Epoch). The Continental Terminal exists at elevations near 220m, 240m and 260m along the Niger River. Continental Terminal sandstone, together with the ironstone stratum, is the host material of the sandy soil in the region. It is acidic and contains kaolinite and ferric oxide.

The plinthite stratum that covers the plateaus was formed during the pluvial period from the late Pliocene Epoch to the early Quaternary Period (about 2 million years ago). The plinthite extends for a thickness of 20cm – 1m and exists in continuous, block or gravel form. Plinthite is also known as laterite and, since laterite is a term that describes red-hued soil that contains an abundance of iron, that renders the definition ambiguous. We therefore decided not to use the term in the present text. Plinthite forms the foundation of the soil and is an impermeable stratum and a root growth limiting stratum. At the time when the Sahel region had a humid climate, ferric oxide leached into the soil and settled to a certain depth where it formed the stratum. It was formed by the relative increase in the ratio of iron and other sesoxides as other substances weathered and were lost due to leaching in the hot humid environment. As indicated in Figure 2.1.2.2, the ironstone stratum extends continuously at times from the plateau down the slope to low-lying areas and, in this case, it acts as a channel for intermediate flows as an impermeable stratum.

**Figure 2.1.1.2 Position of plinthite in the terrain**




The sandy soil deposited from the edge of the plateau to the valley has a thickness that extends for several meters. The sandy soil is eroded by the weathered product of the Continental Terminal and ironstone stratum. Meanwhile, clay, ferric oxide and other adhesive substances are thought to have been reduced in the process of transport by water and, lifted by the wind, deposited about 20,000 to 40,000 years ago. Generally, the reddish color becomes lighter as the content of clay and ferric oxide decreases, taking on a yellowish tone. Meanwhile, strata known as Dallols are coarse sand that were deposited in the rivers in fossil valleys and became an underground flow, said to have originated less than 1,000 years ago.

### 2.1.2 Physical properties of the soil

#### 1) Particle size distribution, permeability and water retainability

Areas of millet cultivation are located on sandy soil with essentially good permeability. These locations extend topographically from gently sloping surfaces of valleys to the plains. Sandy soil is usually deposited in such locations to a depth of several meters. The sandy soil consists primarily of alfisol, ultisol (USDA taxonomy) and leached ferruginous soil. The clay component of the soil surface is normally 10% or less and the content of clay when combined with silt is commonly less than 20%. The balance consists of fine and coarse sand. The soil surface that is not subjected to erosion has a low ratio of clay content and good permeability. Alfisol is characterized by having clay accumulation horizons (argillic horizons) that are formed when clay soil moves downward with seepage water and is deposited at a depth of several 10cm. The criterion for classifying ultisol is a lower degree of base saturation than alfisol. Soil with little clay content and high permeability has ongoing leaching and a lower degree of base saturation. A clearly-delineated clay accumulation horizon often cannot be observed in ultisol as it can in alfisol.

The particle size distribution of the soil in the test field in Magou and the sand dunes is shown in Table 2.1.2.1 and an example of the physical properties of alfisol soil is indicated in Table 2.1.2.2. Though permeability data is not given in Table 2.1.2.1, the soil of the dunes contains little clay and is highly permeable. There is little loss of rainwater due to surface runoff with soil such as this; however, since water retainability is weak, seepage water is readily lost through downward infiltration. There is advancing erosion of some of the topsoil of the slopes shown in Table 2.1.2.2 due to surface runoff. Soil density and the clay component increase with depth. Permeability declines notably at a depth of 34cm in Profile 1 and at a depth of 67cm in Profile 2 and these are thought to be clay accumulation horizons. Water retainability improves to a degree as the clay content increases; with this type of soil, however, penetration is frequently limited by the soil crust that forms at the surface. In addition, if the soil has a clay accumulation horizon and there is serious erosion causing the exposure of the clay accumulation horizon, there is a risk of constant denudation of the soil.

**Table 2.1.2.1 Soil particle size distribution in the dunes (Magou villge, Niger)**

| Profondeur | Granulométrie | | | |
|---|---|---|---|---|
| | Sable gros | Sable fin | Silt | Argile |
| cm | % | % | % | % |
| 0-6 | 26.1 | 62.6 | 8.2 | 3.1 |
| 6-40 | 37.1 | 48.6 | 9.2 | 5.1 |
| 40-72 | 36.2 | 48.3 | 8.5 | 7.0 |
| 72-119 | 33.3 | 51.9 | 7.7 | 7.1 |

**Table 2.1.2.2 Example of the physical properties of alfisol soil on slopes (Magou village, Niger)**

| Profondeur | Granulométrie | | | | Densité | Permeabilité | Humidité | | | Retention |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sable gros | Sable fin | Silt | Argile | | à saturation | pF 2.5 | pF 3.0 | pF 4.2 | Eau util |
| cm | % | % | % | % | $g/cm^{-3}$ | Mm/h | % | % | % | % |
| Profil 1 | | | | | | | | | | |
| 0-21 | 21.4 | 64.0 | 9.7 | 5.0 | 1.62 | 62.3 | 5.8 | 5.1 | 3.1 | 2.7 |
| 21-34 | 21.7 | 58.9 | 10.4 | 9.0 | 1.58 | 73.4 | 8.8 | 8.1 | 5.8 | 3.0 |
| 34-52 | 22.0 | 57.9 | 9.4 | 10.7 | 1.61 | 25.4 | 13.1 | 11.5 | 7.0 | 6.1 |
| 52-79 | 19.7 | 57.6 | 10.1 | 12.6 | 1.61 | 48.2 | 12.2 | 10.9 | 7.3 | 4.8 |
| 79-102 | 18.8 | 57.6 | 10.1 | 13.5 | 1.64 | 24.9 | 11.4 | 10.3 | 7.3 | 4.1 |
| 102-135 | 22.8 | 52.6 | 11.7 | 12.9 | 1.72 | 0.4 | 13.8 | 11.9 | 7.4 | 6.4 |
| 135- | 22.5 | 47.3 | 14.2 | 16.1 | 1.78 | 0.3 | 15.9 | 14.3 | 10.2 | 5.7 |
| Profil 2 | | | | | | | | | | |
| 0-10 | 25.7 | 62.1 | 8.5 | 3.8 | 1.56 | 127.4 | 6.3 | 5.2 | 2.2 | 4.0 |
| 10-42 | 22.2 | 59.6 | 12.1 | 6.2 | 1.49 | 122.0 | 6.7 | 5.8 | 3.3 | 3.4 |
| 42-67 | 21.0 | 59.7 | 12.2 | 7.2 | 1.58 | 58.0 | 9.9 | 8.7 | 5.5 | 4.3 |
| 67-92 | 21.7 | 56.0 | 13.0 | 9.3 | 1.71 | 16.9 | 10.8 | 9.5 | 6.0 | 4.7 |
| 92-125 | 21.3 | 60.3 | 9.6 | 8.8 | 1.72 | 6.1 | 16.7 | 14.6 | 9.3 | 7.4 |
| 125- | 24.4 | 59.4 | 7.7 | 8.6 | 1.67 | 9.9 | 13.6 | 12.1 | 8.5 | 5.0 |

### 2) Soil crust

The soil crust is a thin film that forms on the surface. The crust forms when the soil aggregate is destroyed by heavy rain, the soil particles in the surface are rearranged and dispersed micro-particles block the pores in the soil surface stratum. Once the crust forms, penetration of rainfall into the soil is conspicuously hindered, increasing surface runoff and accelerating soil erosion. The cause of progressive soil erosion in the Sahel area with its soil that fundamentally has rather good permeability is the decline in permeability due to the formation of the crust.

There are a number of processes that are involved in the formation of the crust, which occur either simultaneously or successively. Figure 2.1.2.1 illustrates the pattern.

#### a) Infiltration

When rain begins to fall, rapid infiltration occurs in soil with a dry surface. Air bubbles are incorporated and the aggregate is destroyed by pressure differences. Since the soil of the Sahel contains little clay or organic matter and the soil particles have weak adhesive force, soil breakup occurs readily due to the impact of the raindrops.

#### b) Impact of raindrops

Craters are formed in the surface of the soil due to the impact of raindrops, causing the rearrangement of soil particles.

**c) Formation of structural crust**

Large soil particles remain in the soil surface while fine particles scatter and, together with the interstitial water, block the pores in the process of infiltration, thereby forming a film with low permeability. This is generally referred to as structural crust.

**d) Occurrence of surface runoff**

When rain continues to fall and surface runoff occurs, the coarse particles remaining on the soil surface are washed away by the runoff and a dense substratum with blocked pores is exposed.

**e) Formation of erosional crust**

This is known as erosional crust and it is about 1mm thick in sandy soil. The surface has a smooth appearance without pores. The speed of surface runoff increases since the surface is less rough.

**f) Reinforcement of the erosional crust**

The erosional crust becomes more compact and stronger with each rainfall.

The ease of formation of the crust depends greatly on the stability of the soil particles and the energy of the rainfall. The following is an explanation with reference to influencing factors.

(1) Clay component

If there is much clay in the soil, the adhesive force of the aggregate increases, thereby inhibiting the formation of crust. It is generally said that crust forms readily in soil with a clay component of 20% or less and it has been reported that crust forms most readily in soil with a combined clay and silt content of about 10% (Poesen, 1986). This is applicable to the sandy soil of the Sahel area.

(2) Organic matter

Since organic matter, like clay, is an aggregate adhesive substance, the aggregate increases in stability as the content increases, thereby hindering the formation of crust.

(3) Initial water content

If the soil is dry when rain begins to fall, the soil aggregate is easily destroyed by rapid infiltration. Stability is greater if the soil is moist.

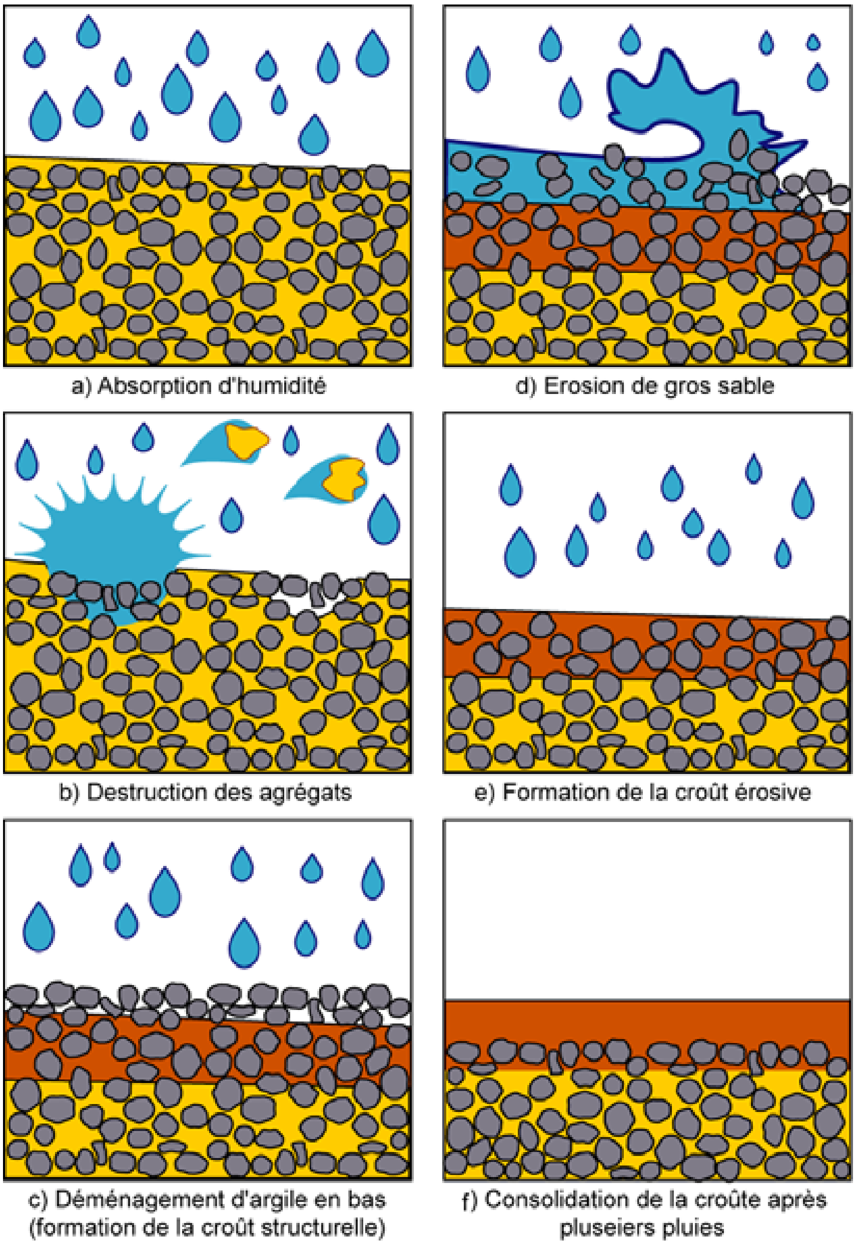
(4) Rainfall intensity

Crust forms more readily as the impact energy of the raindrops increases and also forms more readily the stronger the force of the rainfall and the length of continuous rainfall.

(5) Soil cover

The impact of raindrops on soil particles is eased if the soil surface is covered by vegetation, mulch or other material, which in turn inhibits the formation of crust.

**Figure 2.1.2.1 Process of crust formation**



### 2.1.3 Chemical properties of the soil

**1) Relationship between soil composition and base cations**

The primary components of sandy soil are quartz, kaolinite and ferric oxide. The quartz forms the framework for the particles, though the kaolinite, a clay mineral, and the ferric oxide weaken its adhesive force. Among clays, kaolinite has the lowest ability to absorb nutrients (cation exchange capacity (CEC)) and, furthermore, since it is also small in content, the soil has little ability to retain nutrients. It is the organic matter, which, along with the clay, has the role of retaining nutrients but this also accounts for less than 1% of the content. Potassium, sodium, magnesium, calcium other water-soluble and exchangeable bases are therefore readily leached. Since the Continental Terminal, the base material, is sedimentary sandstone with progressive weathering, the soil essentially has few base cations and, instead, is highly acidic with residual aluminum and hydrogen ions. The reasons for the acidity of the soil include (1) the acidity of the base material, (2) progressive acidification during past pluvial periods and (3) leaching of bases in the present-day climate.

The soil indicates strong acidity on plateaus and other areas where sandy soil is deposited thinly on the plinthite stratum. That is because the acidity of the base material is strong and the leaching of bases is progressing.

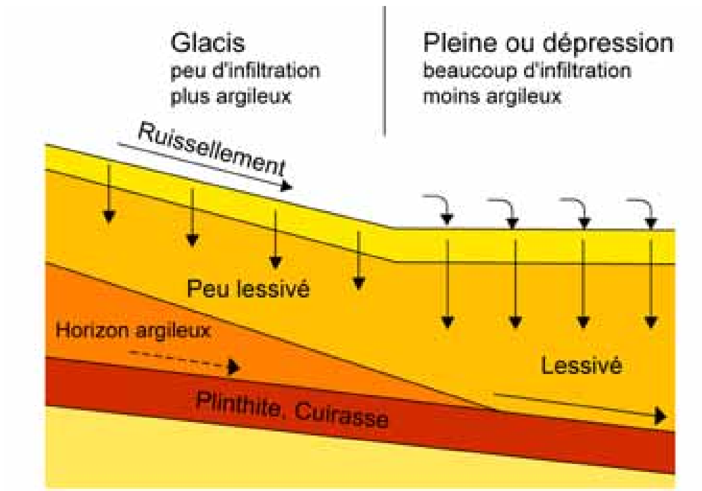
Table 2.1.3.1 shows the chemical properties of the soil of the dunes and glacis in the test field in Magou. Since the clay content is low in the dunes, the CEC is also low. Due to favorable permeability, however, the degree of base saturation, which indicates the amount of base cations in the CEC, is also low in value due to the leaching of base cations. Meanwhile, since the soil of the gracis contains much clay, there is a tendency for the CEC to be higher than in the dunes while the degree of base saturation is also high due to the low permeability and readily occurring leaching. The soil generally increases in acidity as the degree of base saturation declines.

Figure 2.1.3.1 shows the pattern of cation leaching according to the slope site. There is much clay and little leaching of cations at the central part of slope, which has a high rate of surface runoff and low permeability, while, in contrast, the lower part of the slope and depression, where runoff concentrates, are marked by high infiltration and progressive leaching.

**Table 2.1.3.1 Comparison of the chemical properties of the dunes and gracis (Magou village, Niger)**

| Profondeur | Granulométrie Sable gros | Sable fin | Silt | Argile | pH | Matière Organique | CEC | Saturation en bases | Phosphere Assim. |
|---|---|---|---|---|---|---|---|---|---|
| Cm | % | % | % | % | | % | meq/100 g | % | ppm |
| Dune, pente faible(2%) | | | | | | | | | |
| 0-6 | 26.1 | 62.6 | 8.2 | 3.1 | 6.0 | 0.27 | 1.59 | 38.4 | 2.42 |
| 6-40 | 37.1 | 48.6 | 9.2 | 5.1 | 5.8 | 0.26 | 1.33 | 34.6 | 2.31 |
| 40-72 | 36.2 | 48.3 | 8.5 | 7.0 | 5.6 | 0.20 | 1.41 | 47.5 | - |
| 72-119 | 33.3 | 51.9 | 7.7 | 7.1 | 5.8 | 0.12 | 1.18 | 34.7 | - |
| Glacis, pente forte (3-4%) | | | | | | | | | |
| 0-10 | 38.8 | 55.4 | 3.6 | 2.2 | 5.9 | 0.33 | 0.85 | 88.2 | 3.92 |
| 10-52 | 30.6 | 56.4 | 7.2 | 5.8 | 5.6 | 0.27 | 1.26 | 52.4 | 3.89 |
| 52-117 | 27.1 | 50.5 | 7.3 | 15.1 | 5.4 | 0.16 | 2.28 | 65.8 | - |
| 117-152 | 22.6 | 59.2 | 7.0 | 11.2 | 6.0 | 0.09 | 1.74 | 82.8 | - |

**Figure 2.1.3.1 Relationship between slope site and leaching**




When the acidity of the soil progresses and the pH is low, there is an increase in the amount of exchangeable aluminum and manganese. A pH value under 5 is the level of toxicity to vegetation. Millet is better able to withstand acidity than *niébé* (cowpea), peanuts and other legumes; it has been reported, however, that high concentrations can stunt the growth of millet (Chase et al., 1989). High concentrations of aluminum or manganese inhibit the growth of vegetation when absorbed. This is a problem in depressions and other areas where there is a high level of infiltration and leaching readily occurs.

**2) Limiting factors in the application of fertilizers**

Nitrogen and phosphate insufficiency is a problem that is equally or more serious than water shortages as a factor limiting agricultural production in the Sahel region. If the farmers were to achieve some degree of economic freedom in their lives, they would be able to alleviate such insufficiencies through the application of chemical fertilizers. There are factors, however, that should be noted in relation to the chemical properties of the soil. For example, if phosphate fertilizer is applied to soil that has a high concentration of aluminum or iron, the phosphates will readily combine with them, resulting in a decrease in absorbable phosphates that would be available to the vegetation. To assure that phosphate fertilizers function effectively, it is necessary to buffer the acidity by supplementing it with compost or other organic matter. The application of nitrogen fertilizers should also be avoided since ammonium sulfate or other substances accelerate the acidification of the soil in the mineralization process.

The chemical and physical properties of the soil have the mutual effects indicated above. Given these factors, resolving the insufficiency of nutrients by applying fertilizer is a problem when the soil is highly permeable and subject to leaching. On the other hand, leaching does not readily occur in soil with high clay content and low permeability and the capacity for nutrient retention is also high, though water retention is a problem.

## 2.2 Soil erosion and deterioration

### 2.2.1 Water erosion

#### 1) Principle of water erosion

When the intensity of rainfall exceeds the infiltration capacity of the soil, surface runoff occurs and flows downhill. The phenomenon in which surface runoff removes (erodes) the soil is known as water erosion. It consists of two processes, soil separation and transport. The energy required for these processes is supplied both by the rainfall and by the surface runoff.

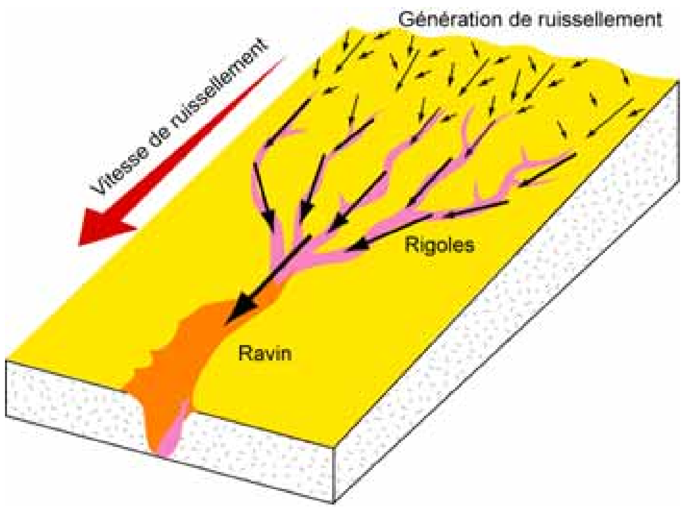
#### (1) Soil separation

The separation of the soil has already been treated in the section dealing with soil crust. The soil aggregate is destroyed by the energy of rainfall and scattering soil particles are washed away by surface runoff. In addition, surface runoff itself lifts and separates soil from the surface.

#### (2) Soil transport

The energy of surface runoff depends on the speed of the flow. Though the flow speed at which the movement of soil particles becomes noticeable differs depending on the type of soil, the finer the particles, the easier they are to transport even if the flow is slow in speed. Since the flow speed increases as the sloping surface becomes steeper, the ability to transport soil also increases. The increase in the angle of the slope increases the force of soil erosion exponentially and the effect of the length of the slope on erosion is determined by angle and shape. Transport force is generally considered to increase in proportion to the exponent of the slope length.

**Figure 2.2.1.1 Process of soil erosion advance**




**2) Erosion configuration**

Figure 2.2.1.1 shows the process of erosion advance. If surface runoff occurs during rainfall, first of all, there is a downward flow toward the bottom of the slope. In the meantime, the flow becomes concentrated along lines on the slope that are relatively low, forming channels that are known are rills. The surface runoff that flows in these rills increases dramatically in water depth and flow speed, boosting the force of both soil separation and transport. Rills therefore expand outwardly as they erode the surrounding soil with each successive rainfall. The merger of multiple rills further downstream is referred to as a gully. A gully is a channel configuration that is so deeply eroded that it cannot be restored by plowing or other means and they have sides that rise sharply. This readily occurs in locations where the subsoil is weak and liable to collapse. Overfalls in gullies, where erosion increases rapidly, gradually develop and progress in the downstream direction. Soil erosion inside gullies is far greater than that of surface runoff and rills.

**3) Factors that influence soil erosion**

Factors that influence soil erosion are expressed in their most extreme form in the universal soil loss equation (USLE). Since the USLE was originally developed for the purpose of estimating soil erosion in the U.S., it was based on extensive plot runoff tests conducted nationwide and calculates long-term soil erosion tendencies of the soil surface with rills or with multiple rills merged. It is currently in use throughout the world and is as indicated below.

$$A = (0.224)RKLSCP$$

Where, A: annual soil loss (kg $m^{-2}$), R: rainfall erosivity factor, K: soil erodibility factor, L: slope length factor, S: slope steepness factor, C: cropping and management factor and P: erosion countermeasures factor.

As indicated in the equation, annual soil loss can be expressed in the form of a product of factors expressing various elements. In other words, it is possible to reduce the annual soil loss by making efforts to reduce each of the factors as much as possible. The following is a simple explanation of these factors.

**(1) Rainfall erosivity factor (R)**

The rainfall erosivity factor is given as a function of two characteristics of rainfall, namely, the kinetic energy of rainfall and rainfall force. The kinetic energy of rainfall depends on raindrop diameter. Generally, the greater the rainfall force, the larger the raindrop diameter and the greater the kinetic energy. In other words, the stronger the force of the rainfall, the larger the value of R. It is not humanly possible to manipulate this value.

**(2) Soil erodibility factor (K)**

The dominant factor involved in the soil erodibility factor (K) is the ratio of silt (0.0002 – 0.05mm) and fine sand (0.05 – 0.1mm) in the soil. In addition, organic matter content, soil structure, permeability and other factors also have an effect. The value of K increases as the content of silt and fine sand increases, organic matter content decreases and permeability decreases. It is possible to reduce the value of K by artificially inputting organic matter and enhancing the stability of the soil aggregate or by assuring permeability and inhibiting the development of crust.

**(3) Slope length factor (L) and slope steepness factor (S)**

These are independent factors and are actually used as one single factor LS. Slope length is the length from the point of origin of the surface runoff to the bottom of the slope and steepness is generally expressed as a percentage (%). Since the speed of the surface runoff flow increases as the slope becomes steeper, the force of erosion increases. For example, the value of L decreases if the speed of the flow is reduced by dividing the slope length into short segments using stone lines and other conservation construction methods.

**(4) Cropping and management factor (C)**

The cropping and management factor is a factor that varies according to specific crop or vegetative surface cover conditions and changes due to the cropping system, growth conditions, length of the growing season, plowing system, crop residue management, location within rainfall distribution zones and so forth. If there is a high rate of vegetative or residue cover, that prevents rainfall from exerting a direct impact on the soil surface, which then decreases the factor value. In addition, the longer the period of vegetative cover, the smaller the value of C.

**(5) Conservation practices factor (P)**

The conservation practices factor is an adjustment factor that is applied when countermeasures are adopted for the purpose of inhibiting erosion in the case contour farming, strip cropping, terracing or other forms of cultivation in the vertical direction on ordinary slopes. Annual soil loss in the case of contour farming is decreased to 50-70% of the degree of erosion when countermeasures are not implemented on slopes with an angle up to about 15% and, in the case of terracing, it is reduced by about 15%.

Piecing all of these together, it is clear that the following are necessary in reducing soil loss.

a) Enhancing the stability of the soil through the input of organic matter, etc., preventing the formation of crust and maintaining a high level of soil permeability
b) Reducing the speed of the flow by building structures that decrease speed on long slopes and, in the long term, lessening the steepness of the slope by terracing.
c) Covering the soil surface with crops or mulch and avoiding denudation.

### 2.2.2 Wind erosion

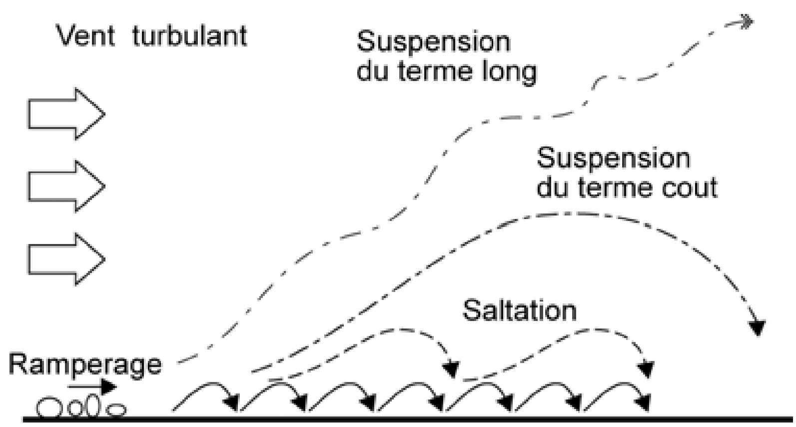
#### 1) Scale of wind erosion

The scale of water erosion and steepness differ variously depending on soil conditions and, in addition, since measurement is difficult in gullies and other water channels, there are few reports that provide specific figures. It has been reported that damage due to wind erosion is more serious than that due to water erosion in the northern part of the Sahel where rainfall is generally low. It has been estimated that wind erosion is 10-200t/ha/yr in regions in the northern latitudes of 14°-18° and about 10-50t/ha/yr in regions in the northern latitudes of 10°-14° (Lal., 1993). In contrast, water erosion is estimated to be about 5-40t/ha/yr.

**2) Principle of wind erosion**

There is a point of similarly between wind erosion and water erosion. Specifically, the force of erosion depends on the energy of the wind. Furthermore, to describe it in an easily comprehensible manner, the most important factor influencing wind erosion is the velocity of the wind near the soil surface. The movement of soil particles due to wind erosion takes three different forms as indicated in Figure 2.2.2.1. These are referred to as saltation, creep and suspension and the difference between these forms of movement depends on the size of the soil particle and wind velocity.

**Figure 2.2.2.1 Soil movement due to wind erosion**




Since not a great amount of energy is required to transport minute particles (70μm or less) such as clay or silt, they can be transported long distances (200 - 1,000 km) while remaining suspended in the air for several hours or several days once they are lifted above the surface. Conversely, large particles (0.5mm or more) such as coarse sand are not able to rise above the surface even at high wind velocities and only move along the surface as if creeping within a range of a few meters to several ten meters. This is known as creep. Saltation is involved in the movement of particles intermediary between these, in which particles move in a repeated cycle of being lifted by the wind, reaching a height of about 1m, falling back down due to gravitational force and impacting the surface. Movement due to saltation extends from several hundred meters to several kilometers. It has been reported in recent research that saltation is the dominant factor in soil and nutrient movement due to wind erosion.

**3) Time and phenomenon of wind erosion damage**

Damage due to wind erosion occurs primarily during the rainy season. Strong raging winds that blow prior to rainfall are the cause. As indicated above, wind erosion increases as the speed of the wind near the surface increases. In other words, flat denuded land is extremely susceptible to wind erosion since there is nothing there to block the flow of wind. Millet and other fields at the start of the rainy season are a typical example. Since the transport of soil by saltation involves relatively short distances, the soil is shifted and deposited around nearby tree groves, grasslands, obstacles and so forth with coarse surfaces that cause the wind speed to drop. In other words, as wind erosion progresses in denuded agricultural fields, the soil is deposited on fallow ground, grasslands and so forth. It is necessary to be aware that, unlike water erosion, with wind erosion, the soil is not absolutely lost with the flow of water but rather there is a change in the distribution.

# Chapter 3 Agricultural Land Conservation Methods

## 3.1 Physical and chemical property methodology of the conservation of agricultural land

The previous chapter provided an explanation of the characteristics of sandy soil and the causes of water and wind erosion. In order to conserve agricultural land, it is advisable to understand these well and take action in the direction opposite to that which causes soil deterioration. In this chapter, the principles of these actions are summarized in an easily understandable form. There are currently examples of success in initiatives (activities) in the Sahel region for the conservation of agricultural land combining various technologies. One method would be to take action learning from these; it is important, however, to understand the phenomena well and devise methods that match regional resources and socioeconomic conditions.

### 3.1.1 Prevention of water erosion and promotion of permeability

#### 1) Conservation at the origin of surface runoff

The most important point when considering the issue of the conservation of agricultural land is to specify the location where water erosion originates. For example, soil erosion frequently occurs in agricultural fields located halfway down a slope due to surface runoff from above. It is difficult to stop the flow of vast amounts of surface runoff flowing down from above in such cases regardless of the conservation efforts that are made in the field and, even if it were possible, maintenance and control would require tremendous effort. There is a great difference between the labor input required to repair small furrows that form in the surface and that required to repair large gullies. The most effective means is to implement conservation at a very location where surface runoff originates.

Before implementing conservation, it is necessary to fully ascertain the cause of the erosion at that point. Basically, it is best to implement the conservation of agricultural land from the upper end of a slope and expand downstream. Since surface runoff will decrease downstream if conservation is realized upstream, conservation measures of smaller scale will suffice. Nevertheless, since various limitations may come into play when undertaking these efforts, it is necessary to formulate the most effect countermeasures possible.

#### 2) Encouraging rainfall permeability

In order to prevent the occurrence of surface runoff and increase the amount of effective soil moisture for agriculture, it is most effective to maintain the permeability of the soil surface at a high level. In order to achieve that, it is important to prevent the formation of soil crust and the following can be cited as methods for realizing that.

a) Destroying the crust

b) Protecting the ground surface from raindrops

c) Retaining coarse sand in the ground surface

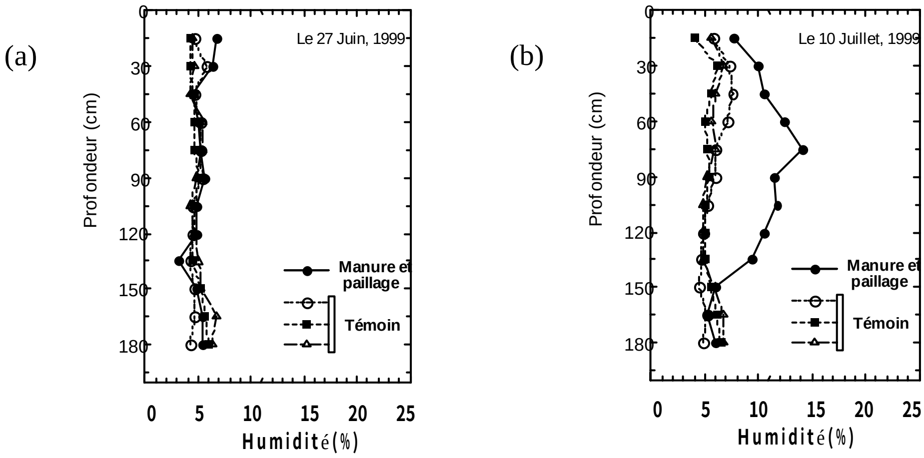
**(1) Destruction of the soil crust**

The usual method for destroying the soil crust is weed plowing. This is an extremely effective method that prevents the occurrence of surface runoff and promotes permeability. Still, in regions where plowing depends on human strength, it will require tremendous labor. In India, plowing is sometimes implemented using animal power at the start of the rainy season in order to effectively cause rainfall to seep into the ground. Since plowing basically only disturbs the ground surface, the crust is likely to reform after a few rainfalls subsequent to plowing.

One useful method that requires less labor is the application of mulch or compost using agricultural residue. If millet residue is left on the ground surface during the dry season following the harvest or if compost is scattered prior to the rainy season, termites gather and ingest it. They ingest the cellulose in the vegetation and take it to their nests several meters below the surface of the ground for the purpose of cultivating fungi. The crust that covers the ground surface is destroyed in this process and the pores formed as passageways for the termites develop vertically and promote water permeation during rainfall.

Mulching may be carried out using branches or grass. There are reports that mulching using tree branches and grass in northern Burkina Faso attracts termites, thereby contributing to the restoration of the permeability of denuded land on which a crust has formed (Mando., 1997, 1998). Figure 3.1.1 shows a comparison of the amount of soil moisture at the beginning of the rainy season in fields where millet residue from the previous year was left and then compost scattered at a rate of 1.5t/ha and other fields that received no application. (a) is at the beginning of the rainy season and (b) is immediately before the first weed plowing. It can be seen that the deep penetration of moisture is promoted in fields to which compost and mulching were applied. Even if efforts are not made to plow the soil during the dry season, the same effect could be realized with very much less work. This effect of promoting permeability, however, is lost when weed plowing is carried out.

**Figures 3.1.1.1 Comparison of soil moisture in areas where compost and mulch were applied and other areas**

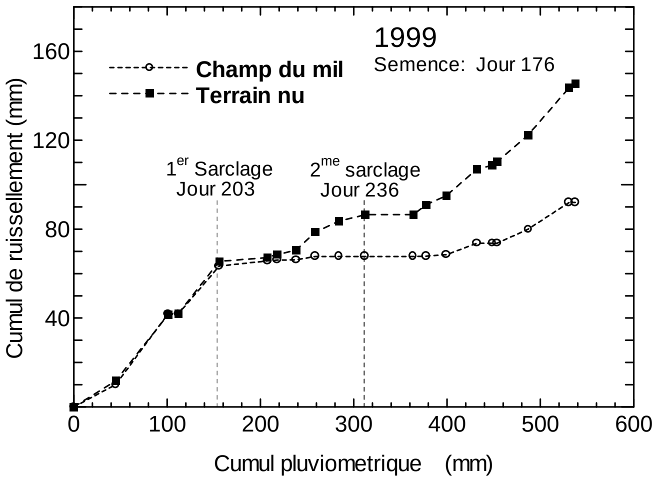



**(2) Protecting the soil surface from raindrops**

Crust originates and develops due to the impact of raindrops and soil particles on the surface of the ground. It is therefore possible to inhibit its formation by preventing direct impact by raindrops.

In the Sahel region, it is extremely difficult to entirely cover the ground surface with mulching or the material. At the start of the rainy season, in particular, the agricultural fields are in a denuded state and there is no effective means for covering them at the present time. However, since millet leaves begin to grow from the middle of the rainy season, direct impacts of raindrops on the surface decrease. Figure 3.1.1.2 shows a comparison of runoff rates from areas of millet cultivation and denuded areas. It is apparent that runoff from areas of millet cultivation decreases after the first plowing 30-40 days after seed sowing.

**Figure 3.1.1.2 Differences in runoff rates in millet cultivation and denuded areas**

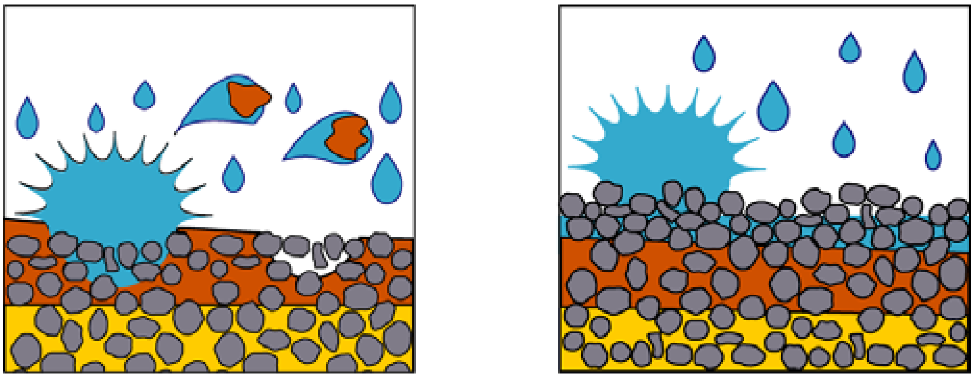


The graph above is the outcome on test areas with comparatively high sandy soil content. It is also possible that the runoff rates do not decrease noticeably due to the growth of millet in areas that have a hard surface. It is possible to obtain a greater effect in such cases by improving the surface coverage rate by cultivating crops combining *niébé* (cowpea).

**(3) Conserving coarse sand in the ground surface**

Structural crust, an early stage in crust formation, assumes a form in which coarse sand is on top of the crust. If this upper layer of coarse sand is lost, the crust progresses on further to erosion crust, a form of crust with low permeability. However, if the coarse sand remains intact on top, it will serve as a rainfall buffer. Coarse sand is extremely effective if it expands to a layer with a thickness of several centimeters. In order to conserve the coarse sand, it is effective to apply mulch or to build contour ridges between fields in order to prevent an acceleration of surface runoff speed. It is also effective to leave trees growing in the fields, thereby preventing wind erosion and promoting the deposit of soil transported by the wind.

**Figure 3.1.1.3 Buffering effect of coarse sand on the ground surface**



**3) Deterring surface runoff and reducing the speed**

It is frequently not possible to deter the occurrence of surface runoff by only promoting the permeation of rainfall. When surface runoff occurs, not only are mulch, compost and other light-weight materials subject to erosion but coarse sand and so forth are also subject. In order to prevent this, it is necessary to inhibit surface runoff by constructing conservation structures in the fields or decreasing the speed of the runoff.

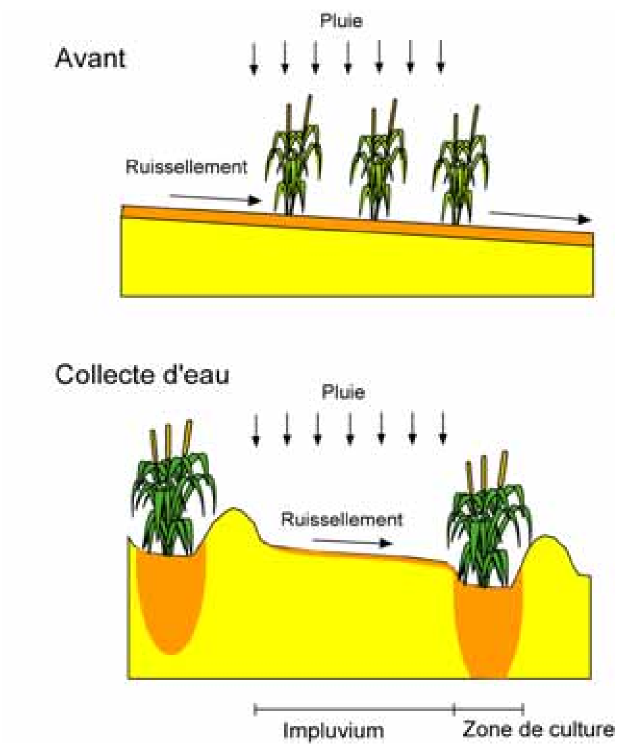
Earthen or ironstone ridges that follow the contour of the land are commonly used as structures for this purpose. If earth is used, it is non-permeable and has the function of stopping runoff and, in the case of ironstone, it temporarily retains the runoff and slows its speed. In either case, the ability of surface runoff to transport soil (erosive force) is reduced by decreasing the speed of the runoff.

In the case of locations with advanced erosion, even though initial effects are not so noticeable, the conditions will gradually be improved as the years pass.

**4) Concentrating water**

The lack of rainfall in the northern part of the Sahel region is a factor that hinders growth. It is also possible to concentrate the rain that falls over a broad area at one point by using the contour ridges described above and other construction methods. This is based on the approach of water harvesting. This is the approach of causing surface runoff in catchment basins and concentrating it in cultivation zones where crops are raised instead of allowing rainfall to permeate over the entire area. Figure 3.1.1.4 shows an outline of this approach. For example, by causing surface runoff to flow from catchment basins to cultivation zones in an area with no more than 400mm of rainfall, it becomes possible to increase the effective supply of water for agriculture by severalfold. The rate of increase depends on the runoff rate (amount of surface runoff/amount of rainfall) of the catchment basin and the area ratio of the catchment basin to the cultivation zone.

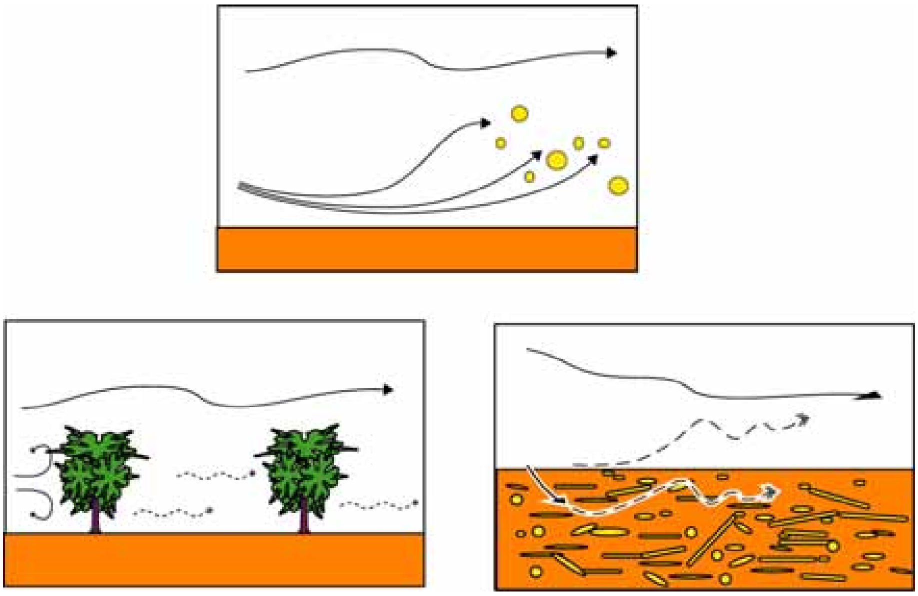
**Figure 3.1.1.4 Concept of water harvesting**



### 3.1.2 Preventing wind erosion

Methods for preventing wind erosion are limited to reducing the wind speed at the surface of agricultural fields. That can be achieved, for example, by increasing the roughness of the surface by mulching to avoid the denudation of the agricultural land and leaving trees and hedged in the fields for wind resistance, as indicated in Figure 3.1.2.1. There is not sufficient material in the Sahel region that can be used as mulch to cover the surface. The rate of surface coverage is no more than about 7% if 1.5t/ha of residue is left on the fields. However, the research of Sterk and Stroosnijder (1997) indicates that it is possible to reduce wind erosion damage 50-80% if the surface is protected by the input of 1.5t/ha of millet residue. Given the fact that saltation, the dominant force in wind erosion, moves soil short distances within the area, it is also possible to trap soil and nutrition by mulching. Sand deposited on the surface due to the existence of mulch also has an effect in promoting permeation. Leaving land idle and allowing it overall to return to grassland is also extremely effective in that sense.

**Figure 3.1.2.1 Methods of wind erosion prevention**



A seasonal northeasterly wind known as harmattan blows in the Sahel region during the dry season and transports fine particles (dust) originating in the Sahara Desert. The dust has a clay content of about 20-30% with silt accounting for the balance. The Qattara Depression in the Sahara Desert is thought to be the most likely origin of the dust and it has been estimated that soil to a thickness of 400m has been removed by the force of the wind during the past 2 – 3 million years (Stahr et al., 1996). The rate of dust deposition on the ground by the dry season harmattan is low. Wind storms prior the rainfall of the rainy season transport large quantities, guaranteeing that the rainfall that follows will deposit dust. It is estimated that 50-70kg/$m^2$ of dust passes through the Sahel region in the upper atmosphere during the year and, of that, several 100g/$m^2$ actually falls to the ground. Quartz is the dominant mineral component of the dust and clay content in the form of kaolinite is high. Though these do not change the properties of the soil, the supply of clay is linked to an improvement in nutrient absorption. Though the ratio of nutrients included in the dust, 16 mg K $g^{-1}$, 17mg Ca $g^{-1}$, 7mg Mg $g^{-1}$ and 0.7mg Na $g^{-1}$, that contribute to nutrient cycling is hardly great, the dust has 7-35 times greater nutrient density than the average soil surface. If it were possible to develop windbreak forests and cause the dust to be deposited there, it would probably be a positive factor in terms of nutrition.

### 3.1.3 Role of the organic component

The organic component in the Sahel region plays extremely diverse roles. The following examples can be given.

Chemical roles

- Absorption of soil nutrients (CEC improvement)
- Phosphate mobilization due to an improvement in the degree of base saturation
- Propagation of nitrogen-fixing bacteria due to the activation of soil microorganisms

Physical roles

- Restraining surface runoff due to the protection of the soil surface
- Physical improvement of the soil structure by attracting termites
- Prevention of wind erosion through mulching and promotion of wind-borne soil deposits

### 1) Chemical roles

Together with soil moisture, the organic component has the role of absorbing nutrients. According to Jone and Wild (1975), some 80% of the cation exchange capacity (CEC) of savannah soil is due to the contribution of the organic component. Nutrient leaching occurs readily if the organic component decreases. For example, if there is much rainfall early in the rainy season, the seepage line advances faster than the growth of millet roots and the nutrients move downward. It has been reported that, in such cases, the roots are not able to absorb sufficient nutrition in the early phase and millet growth deteriorates (Payne et al., 1990).

If the CEC increases and the degree of base saturation heightens due to the organic component, phosphorus united with aluminum is readily absorbed by vegetation as an absorbable phosphate (Bationo et al., 1990). In other words, adding organic matter rather than applying only chemical fertilizer increases the amount of phosphorus that is effectively absorbed.

It is also speculated that, if organic matter is applied, the vigor of the activity of soil microorganisms contributes to increased absorption of nutrients by crops (Hafner et al.,1993). Nitrogen-fixing bacteria exist in the millet rhizosphere (Wani et al., 1988). When crop residue is applied, nitrogen-fixing bacteria become vigorously active with the carbon in the residue as nutrition, increasing the amount of reduction of air-borne nitrogen to the soil. Because of this, there are examples of nitrogen being absorbed by crops in amounts greater than that applied as fertilizer. There is a strong possibility that the reason why millet grows to a certain extent even in fields that have not been fertilized is due to the contribution of these nitrogen-fixing bacteria. Plant hormones secreted by them stimulate the growth of the roots (especially hair roots) when the activity of soil microorganisms becomes vigorous (Joshi and Rao, 1989; Martin et al., 1989) and Hafner et al. state that, as a result, the absorption rate of phosphorus increases. In tests that they conducted, there was more than 3 times the difference in the amount phosphorus absorbed when only chemical fertilizer was applied and when crop residue was also added along with the fertilizer.

**2) Physical roles**

The physical roles were given in the previous section relating to the prevention of water and wind erosion and are therefore omitted here.

### 3.1.4 Effectiveness of chemical fertilizer

Even if all possible water and wind erosion measures are adopted, if millet is cultivated continuously without any fallow periods, desertification will proceed due to a lack of nutrients. As already stated in the section on soil, limiting factors in rainwater agriculture in the Sahel region are, on the one hand, a lack of soil moisture due to progressive soil erosion and, on the other hand, a lack of nitrogen, phosphates and other nutrients. The latter is an especially serious limiting condition in areas that originally had high water permeability. Improving the productivity per area unit of agricultural land even with the decrease in the per capita area of arable land every year will lead to a reduction in the area of land under cultivation, enable the appropriate fallowing of the land and realize a reduction in labor.

Using chemical fertilizers in the self-supply rain-fed cultivation of millet and other crops in the Sahel region is a risk in terms of cost. The first consideration is making maximum efforts to pursue the use of livestock manure, the recycling of plant residue back to agricultural land and other less costly methods and, if there is still a lack, it is

possible to assure sustainability by using chemical fertilizers. It is necessary to be fully aware, however, that overconfidence in the effect of chemical fertilizers and negligence in efforts to manage agricultural land will have a negative effect.
The amount of fertilizer to apply recommended by INRAN and ICRISAT in Niger is as indicated below (Ly et al., 1997).

| | | |
|---|---|---|
| (1) | Nitrogen | 30kg N/ha (urea conversion: 60kg/ha), two applications, 3 weeks after sowing and 6 weeks after sowing, applied after weed plowing. Half that amount if financial conditions do not permit. |
| (2) | Phosphates | 30kg $P_2O_5$/ha, scattered before the start of the rainy season |

This is considered to enable an increased harvest of about 300kg/ha in areas with 400-800mm in rainfall. According to the FAO (1991), given the cost of fertilizer, it is only possible to cover the cost of fertilizer without fail only in areas with fertile soil and with a rainfall of 300mm or more and a harvest of about 400kg/ha without the application of fertilizer. When fertilizer is applied, crop growth becomes vigorous and there is an increase in the consumption of moisture. It is therefore important to apply fertilizer in areas where sufficient permeability is assured through the conservation of agricultural land. In addition, in order to utilize phosphate fertilizer effectively, it is also necessary to secure ample organic matter by applying crop residue or compost. The same can also be said for the prevention of nitrogen leaching.

### 3.1.5 Significance of vegetation conservation

The farmers in the Sahel region are generally not amenable to leaving trees in their fields. The reasons include bird damage sustained during the harvest and the shade that is produced. The many benefits that this brings should, however, be reaffirmed. The following is a simple list of benefits.

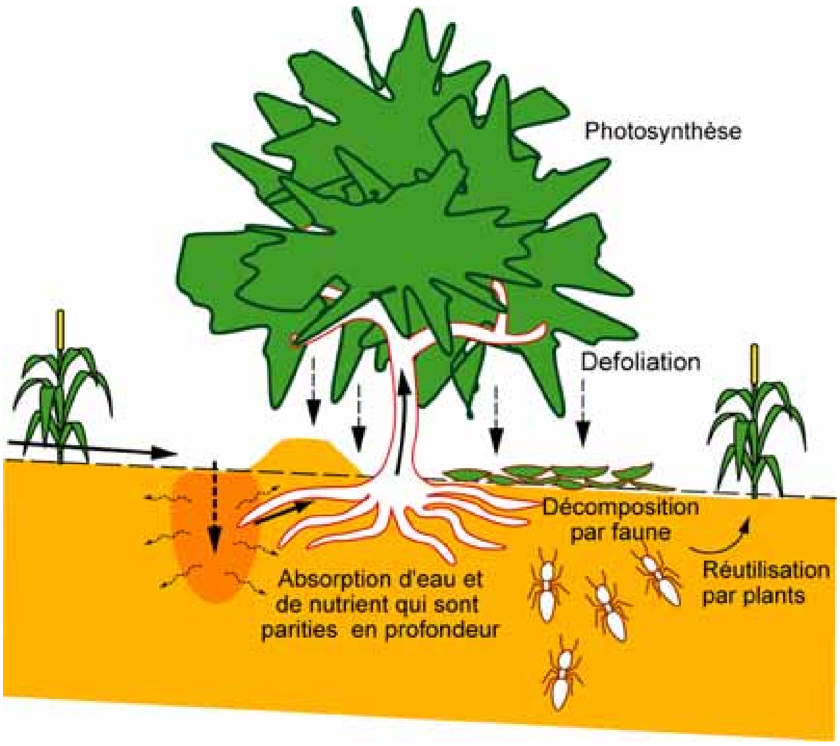
a) They weaken the wind on agricultural land, reduce wind erosion and stimulate the depositing of soil.
b) Grass protects conservation construction, achieves a complementary role and hinders surface runoff.
c) Trees absorb water deep underground and nutrients that move downward due to leaching that cannot be used by crops and are recycled to the soil surface as fallen leaves.
d) Most legumes have nitrogen-fixing bacteria and return nutrients to the

crops.

e) Fallen leaves are a source of supply of organic matter and invigorate the activity of soil microorganisms.

Items a) and b) above play a physical role and were pointed out previously. Earthen or ironstone ridges that follow the contour and other conservation structures lessen the effect of erosion and soil deposits year after year and, if grass or trees are raised making use of improvements in moisture conditions in the vicinity of conservation structures, an effect will be realized in protecting the structures and firmly establishing the soil. Item c) has an effect especially in the case of soil with high permeability. In years with heavy rainfall, the downward movement of nutrients due to leaching progresses earlier than the growth of plant roots, causing a reduction in crop harvest. Moisture that has moved downward is basically not available for reutilization; however, trees with deep roots are capable of returning this to the surface in the form of fallen leaves. If leaves or tree branches are used as mulch, termites will become more vigorously active, resulting in the restoration of permeability to surrounding fields. Agroforestry techniques combining tree planting and crop cultivation are extremely effective in assuring sustainability in areas with poor soil nutrition near the tropics. It is extremely important to enhance the effective use of nutrients and water in regions such as the Sahel with little biomass production through the combined use of crops and trees.

**Figure 3.1.5.1 Nutrient cycling using trees**



### 3.2 Agricultural land conservation methods in the Sahel region

#### 3.2.1 Historical transitions in the conservation of agricultural land

We will proceed with a simple explanation of the transitions in the conservation of agricultural land before introducing specific construction methods. The approach to construction methods has changed greatly from the 1960s to the present. Stated simply, it has shifted from the supremacy of technology to participation by the local people and, along with that, construction methods that are simple and low in cost have come to be used.

**1) Initial period to the early 1980s**

The Sahel region in the 1960s had above average rainfall and early projects were centered in soil conservation in the narrow sense rather than the prevention of desertification in the broad sense. Efforts consisted primarily of promoting the construction of ridges to prevent erosion on several thousand hectares of land using machinery. However, since the participation by the local people was not taken into account either in the plans or in the scale, management and repair were not carried out after the construction and the projects ended in failure for the most part. Entering the 1970s, though there was a notable trend toward less rainfall, most projects continued to be centered as before in narrowly defined soil conservation. Locally, NGO activities and projects emphasizing participation by the local people also began; however, not much change was evident overall. Momentum for a reexamination of the approach to projects based on a reflection of the past did not arise until the 1980s. *Terroir* management methods were introduced for the first time at the conference of CILSS (Permanent Inter-State Committee for Drought Control in the Sahel) member states held in Nouakchott, Mauritania, in 1984, and participation by the local people was clearly endorsed as a regional strategy for the prevention of desertification.

**2) Start of participation by the local people through *terroir* management methods**

*Terroir* refers to the territory of the village, that is, it indicates the space in which ownership and utilization are recognized by other communities. *Terroir* management is the generic term for activities such as systematization, improvement of socioeconomic conditions, management of natural resources and the introduction of technology for the realization of the sustainable management of that territory and improvements in productivity by the village residents.

In conventional desertification prevention countermeasures, project managers themselves or public institutions implemented everything from the analysis of land usage conditions to plan formulation and implementation and post facto assessments. The basic principle of *terroir* management is that the local people play the primary role in planning and in the actual activities. Therefore, the role of project mangers and public institutions is first of all to implement enlightenment and educational activities aimed at the local people and to have the *terroir* management plan prepared in the village. Secondly, they provide technical and economic assistance for the *terroir* management plans that are prepared. *Terroir* management is thus characterized by having the villagers to play the role as main entity in activities to prevent desertification while project managers and public institutions are clearly positioned as backup support.

**3) Period of the promotion of large-scale projects using Food for Work**

At the time of the major drought in 1983-84, the production foundation of the northern region was completely devastated, inducing a state of crisis. Large-scale restoration in catchment basin units became a matter of urgency at this time and the method that was frequently used was Food for Work. This is a type of participatory method using uncompensated food assistance provided by the United Nation’s organization World Food Program. The local people who participated in the restoration projects were given food in compensation for their labor. Unlike the promotion of *terroir* management, especially voluntary local people participation, which is positioned as socioeconomic assistance for the local people participation, it had the advantage of guaranteeing the livelihood of the local people who were in a state of crisis and providing opportunities for mastering restoration project techniques and management. In addition, besides stimulating the local people willingness to work, it also had the advantage of facilitating large-scale projects since it was possible to obtain broad participation including others who were not direct beneficiaries. Food for Work played a major role as a catalyst for participation by the local people; however, it also gives rise to various problems such as engendering a structure of dependence on assistance by beneficiary villages when this method is continued for a long time.

**4) Toward proactive participation by the local people**

Accordingly, projects for the prevention of desertification have been implemented in recent years by calling upon the local people for proactive participation without compensation. The following activities have therefore become more important (Yacouba et al., 1995).

- Respect for assessments by the local people
- Priority on the conservation of agricultural land of individuals (the realization

of conservation effects is faster than with shared land)

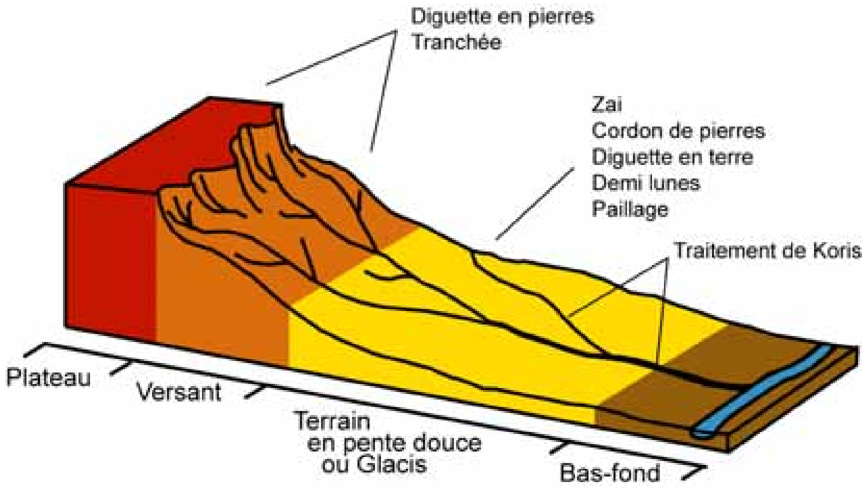
- Dissemination of education in natural resource management
- Amendment and enactment of laws at the regional or national level for the management of natural resources

Prompted by this trend toward participation by the local people, higher priority in terms of technology has come to be placed on low cost. The scope targeted by conservation projects has shifted to smaller scale at the village or agricultural land level while simplified technology that is more easily disseminated has been given greater importance. The combining of technology is also a major characteristic. The shift from soil conservation to soil and water conservation and water harvesting, from soil conservation to compound afforestation and grass planting is advancing (Reij, 1989).

### 3.2.2 Selection of construction methods reflecting the terrain

The need for countermeasures at the source of runoff in order to prevent water erosion is pointed out in section 3.1.1, *Prevention of water erosion and promotion of permeability*. However, when carrying out soil and water conservation through participation by the local people, both labor time and the number of workers are limited. In addition, since the results of conservation are only apparent in the long term, adequately motivating the farmers is itself a difficult task. Given the circumstances, starting soil and water conservation with agricultural land was found to be the second best policy. That is due to the fact that it is easier to stimulate willingness to work because, in the case of agricultural land, the results of soil and water conservation are reflected in the size of the harvest. However, slopes and plateaus are located far from settlements and it is difficult for individuals to reap the results of conservation. It is thus thought that conservation in such locations can be carried out more effectively once the concept of *terroir* management has become established in the village. Figure 3.2.2.1 summarizes the construction methods for soil and water conservation that are widely adopted in the Sahel by type of terrain. Construction methods for plateaus and steep slopes require joint operations in village units due to the considerable surface runoff. In the conservation of agricultural land, joint construction of stone lines and soil ridges is desirable. Other construction methods can be carried out at the individual level. Work to repair corries (including rills and gullies) increases in scale the further it is downstream, requiring many more workers. The various construction methods are described below in detail.

**Figure 3.2.2.1 Conservation construction methods according to type of terrain**

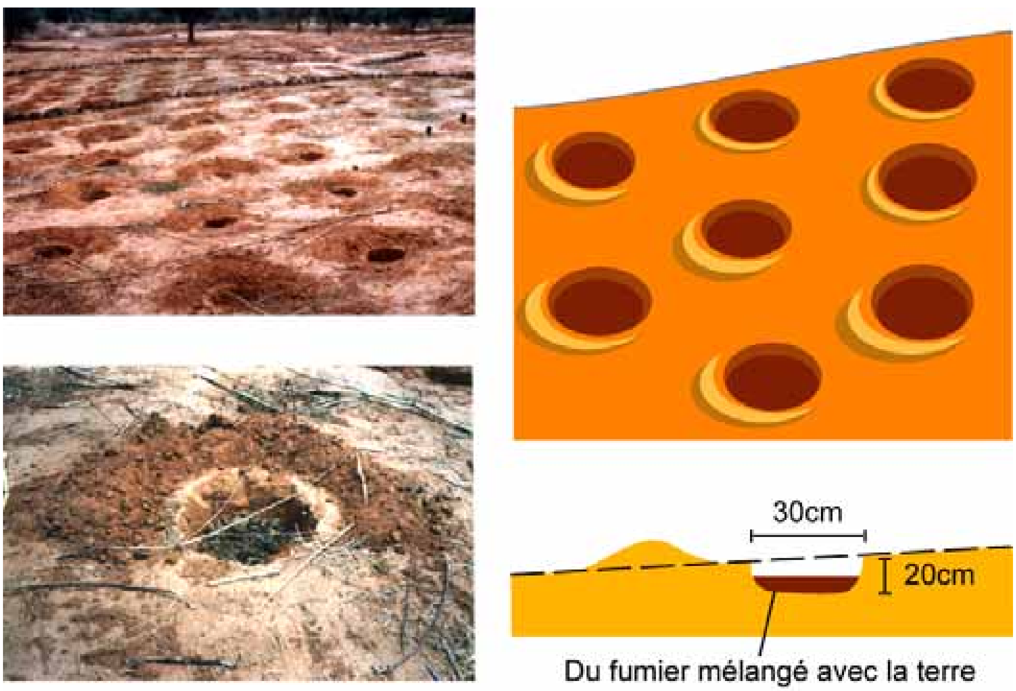



### 3.2.3 Conservation methods for agricultural land

**1) Zaï**

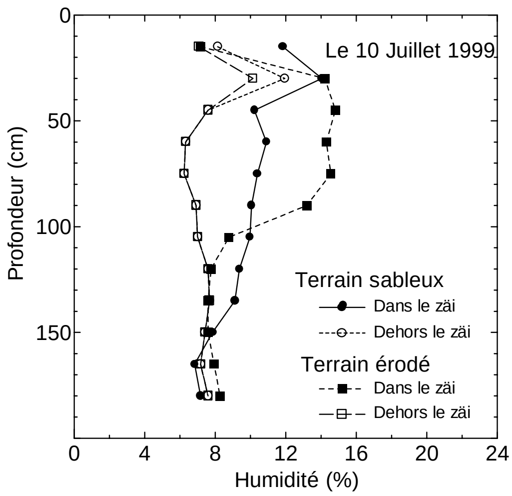
Zaï was a traditional agricultural method used in Burkina Faso and Niger; since it is labor intensive, however, it has been abandoned and forgotten virtually everywhere. In the latter half of the 1980s, however, it was revived in a technologically-refined form in the Yatenga area of Burkina Faso and has demonstrated success. It is also therefore becoming reestablished in Niger as a typical method for agricultural land conservation and improved cultivation.

**Figure 3.2.3 Summary of Zaï**



Zaï is a technology in which holes about 30cm in diameter are dug during the dry season spaced at the millet planting interval and the soil is replaced combined with about 500g of compost. The holes are refilled to a depth of about 10cm below the ground level and the remaining soil is mounded around the lower side of the hole in order to induce the trapping of surface runoff (refer to Figure 3.2.3.1). A type of simple water harvesting, it makes it possible to concentrate moisture at the spots where millet is grown and can be used effectively without losing any compost due to surface runoff. When sowing millet, it is ordinarily necessary to wait for a rainfall of 20mm or more. The advantage of zaï, however, is that the greater the amount of moisture that is concentrated in the holes, the less rainfall that is required before sowing seed. Though it would depend on the soil conditions, about 50 zaï holes can be prepared per person per day. The holes are usually spaced at the normal millet planting interval.

**Figure 3.2.3.2 Comparison of soil moisture with and without zaï**




When compost is combined with the soil with zaï, it is subject predation by termites prior to the rainy season. Micropores therefore form in the vicinity of the holes, even on denuded soil completely devoid of grass, thereby promoting infiltration. Figure 3.2.3.2 shows a comparison of soil moisture with and without zaï prior to the rainy season and it can be seen that seepage lines have formed to a considerable depth.
Zaï does not require joint work and individuals can undertake this task during the dry season. Since work following contour lines is not necessary, it is technologically the simpliest and is more widely used among farmers than any other construction method. Nevertheless, on slopes with progressive erosion, the holes are filled in by a single rainfall if zaï is used alone. The effect is more sustained by combining this with the use of stone lines, which are explained below. It is also necessary to be aware that,

if the zaï holes are too deep, millet seedlings will wither during the early growth stage due to submersion damage.

Table 3.2.3.1 shows the outcome of denuded soil restoration tests in the village of Magou using zaï. In 1998, a harvest of 1550kg/ha was realized using native varieties with the input of about 800g (4t/ha) of compost per hole. This is about twice the harvest of 780kg/ha in a zone nearby cultivated with no application. In 1999, the amount of compost was decreased to 300g (1.5t/ha) per hole. Buried seedlings and other damage was sustained due to a succession of heavy rainfalls at the beginning of the rainy season and ultimately there was no more than a slight increase in the harvest. Given the cost of labor input during the dry season with zaï, it would be advisable to input an additional measure of compost and increase the early survival rate of the millet.

**Table 3.2.3.1 Comparison of harvests with zaï and a native agricultural method**

| Année | Quantité du fumier (t/ha) | Rendment (kg/ha) | |
|---|---|---|---|
| | | Zäi | Témoin |
| 1998 | 4 | 1550 | 760 |
| 1999 | 1.5 | 710 | 556 |

**2) Stone lines**

As indicated in Figure 3.2.3.3, stone lines represent a technique in which ironstone is buried in rows to a depth of about one-third following contour lines, which has the effect of slowing the speed of surface runoff and inhibiting the loss of soil and organic matter. The ironstone material is brought down from the plateaus. The contour lines are measured by using a simple measuring device consisting of two poles connected by a length of transparent water-filled hose. Due to the burden of transporting the stone material, the distance between the location where the stone is collected and location of construction is a factor that limits the use of stone lines. Assistance is provided in the various regions for the purchase of carts and, if the distance is great, transportation by truck is also subsidized. The construction is promoted with tasks assigned by group. A significant effect can be realized by combing this with zaï.

In tests conducted by the JGRC on gentle slopes (2.8%) with sandy soil in Niger, stone lines reduced the amount of surface runoff on denuded soil by about 40%. Surface runoffs are temporarily stopped by the stone lines but they gradually flow out through gaps between the stones. The amount of moisture in the vicinity of the stone lines therefore increases as indicated in Figure 3.2.3.4 and infiltration also improves somewhat in other locations. If it were possible to protect the coarse sand on the surface, that would result in an overall improvement in infiltration in the long term. Grass begins to grow abundantly in the vicinity of the stone lines from the middle of the rainy season, which has the added effect of preventing soil erosion. The interval between stone lines is about 15-30m on gentle slopes with sandy soil. It would be best to shorten this interval if the soil has low permeability and the slope is steep. Basically, it should be an interval that slows the speed of the flow to the extent that rill erosion does not occur.

**Figure 3.2.3.3 Summary of stone lines**

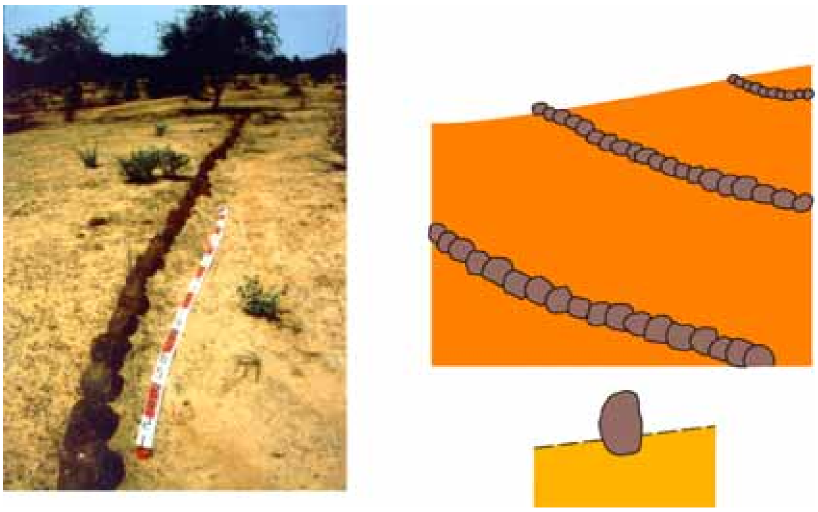
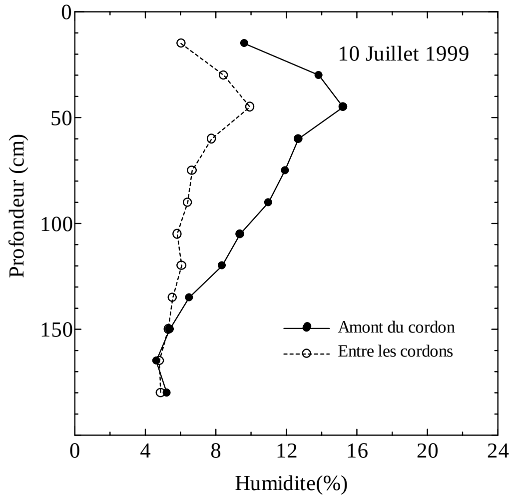


**Figure 3.2.3.4 Comparison of moisture in the vicinity of stone lines**



### 3) Contour earthen ridges

Contour earthen ridges represent a method in which soil at the site is mounded and tamped to form the earthen ridges indicated in Figure 3.2.3.5. The primary advantage is that there is no need to transport materials. In addition, unlike stone lines, it is possible to totally stop surface runoff as long as it does not overflow the top of the ridges. On the other hand, the ridges are easily destroyed if the runoff flows over the top. It is therefore necessary to precisely measure the contour lines and continue tamping the soil during the rainy season when it contains moisture. Thus, in light of the many technical limitations, it is not a construction method that can be readily promoted for technology transfer under current conditions. In terms of terrain, it can only be applied in areas where there is little surface runoff from upstream. In the long run, it is possible to anticipate the leveling and terracing of the slope.

**Figure 3.2.3.5 Summary of contour earthen ridges**


Since all of the runoff that collects around the ridge will infiltrate, the level of the soil moisture is extremely high, as indicated in Figure 3.2.3.6. Though the upstream side of the ridge is not suitable for millet cultivation, it is optimal for trees and other vegetation that consume much moisture. The downstream side, however, is extremely good for cultivating millet. As indicated in the diagram, the growth of crops planted between ridges differs according to soil quality. There is a tendency for growth to be better closer to the ridge on soil that has sustained erosion, while growth is irregular on sandy soil with good permeability. That is thought to be due to lack of uniformity in permeability. The range of moisture improvement on the downstream side of the ridge is about 1m. If the ridge is thoroughly tamped even with sandy soil, it will last for about five years. On non-eroded soil with an exposed clay accumulation horizon, the ridge will harden and become extremely strong when tamped.

**Figure 3.2.3.6 Distribution of soil moisture in the vicinity of earthen ridges**

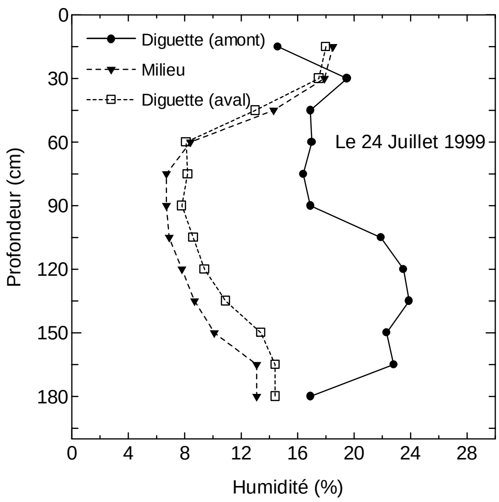
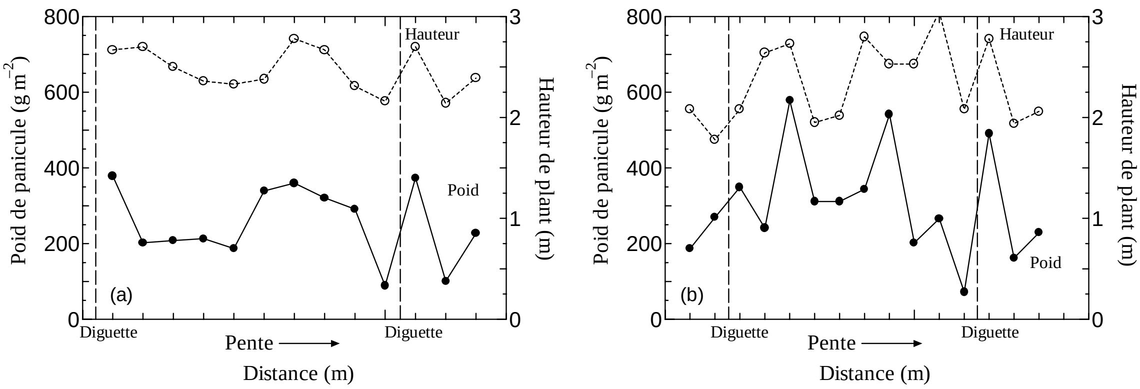



**Figure 3.2.3.7 Growth profiles of crops between ridges**

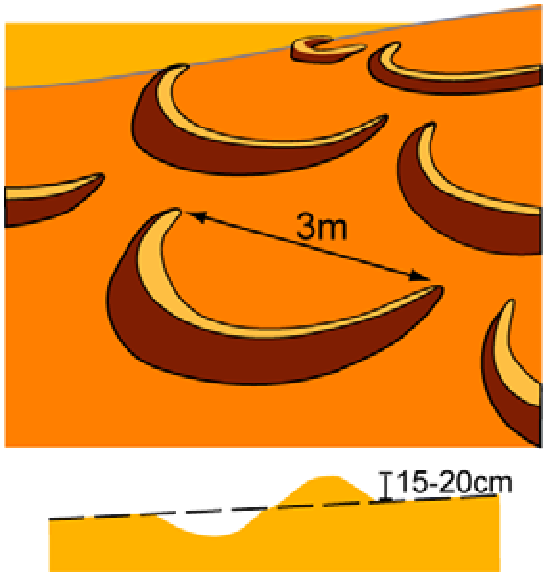
(a) Eroded soil, (b) Sandy soil




#### 4) Half-moon terraces

The half-moon terrace construction method is a method of water harvesting using earthen ridges opening in a crescent shape in the upward direction of slopes, as illustrated in Figure 3.2.3.8. A density of 625 per hectare (at 4m intervals lengthwise and crosswise) with a diameter of 3m each is recommended for areas with about 400mm of rainfall. Like the contour earthen ridges, this method is used in areas that do not have an abundant supply of ironstone to build stone lines. With an extremely simple structure constructed by mounding soil in a crescent shape with a shovel, they do not require any surveying; however, durability is low and they must be reworked at each planting. Forty of them can be constructed per day per person. It is advisable to improve the soil conditions inside of the crescent by adding compost. Along with the zaï method, half-moon terracing has the advantage of being constructable by individuals, though the long-term soil conservation effect is low.

**Figure 3.2.3.8 Summary of half-moon terracing**



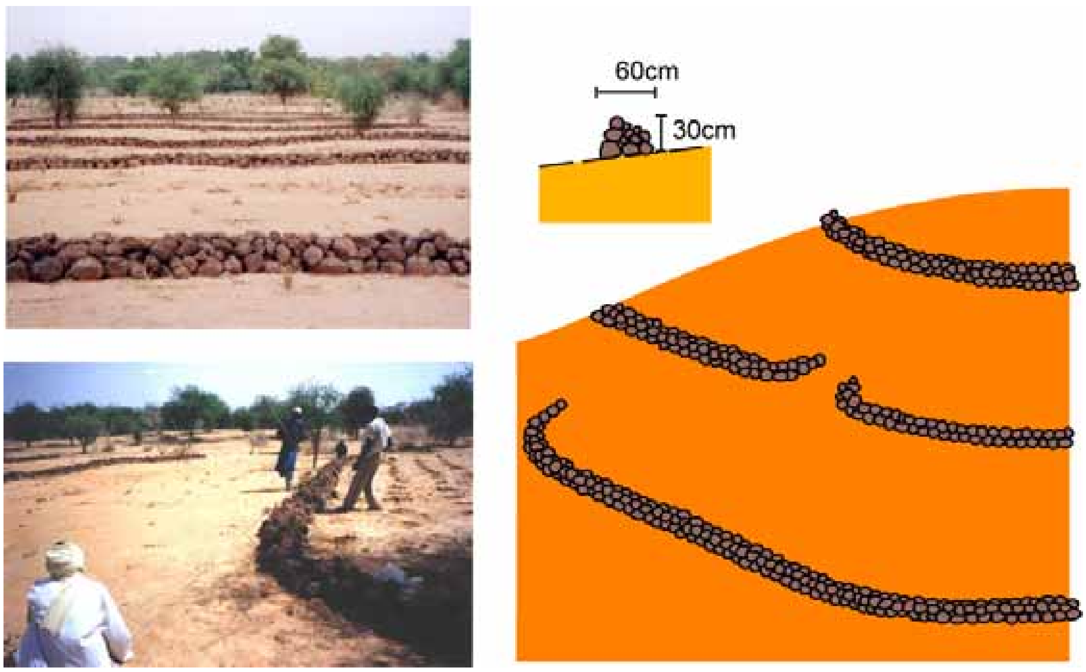

### 3.2.4 Conservation on plateaus and steep slopes

#### 1) Stone dikes

A summary of stone dikes, a method that uses more stone than the stone windrow method, is shown in Figure 3.2.4.1. It is a method that is suitable for conservation in locations with large quantities of surface runoff. In principle, stones are merely piled up in rows following the contour and it poses no technological difficulties. Though highly durable, much stone is used and it is suitable for conservation on plateaus and steep slopes where stone is readily obtainable at the site. It is also used for conservation in low-lying areas where surface runoff collects. It is basically a structure for the purpose of slowing the speed of surface runoff and a high level of precision in the surveying of contour lines, such as in the case of earthen ridges, is not necessary. Stone dikes are provided with flexibility in shape and they make it easy to deal with rills or gullies. Given the fact that they are constructed in locations with much runoff, soil is deposited on the upstream side quite rapidly and it is possible to anticipate the formation of terraces. Grass soon takes root even on denuded land and sufficient sandy soil will be deposited within a few years to enable cultivation.

When growing crops on hard surfaces such as plateaus, it is necessary to devise a means for assuring infiltration such as breaking the soil pan in the cultivation zone, using the zaï method and so forth. In addition, the cultivation of sorghum is more suitable than millet in such areas. The downstream side of the stone dike is also suitable for the planting of trees. The interval between stone dikes on flat land should be 20 – 50m with the area between unprocessed as a water harvesting discharge area. On steep slopes, an interval of 15m or less is desirable taking the formation of terraces into account.

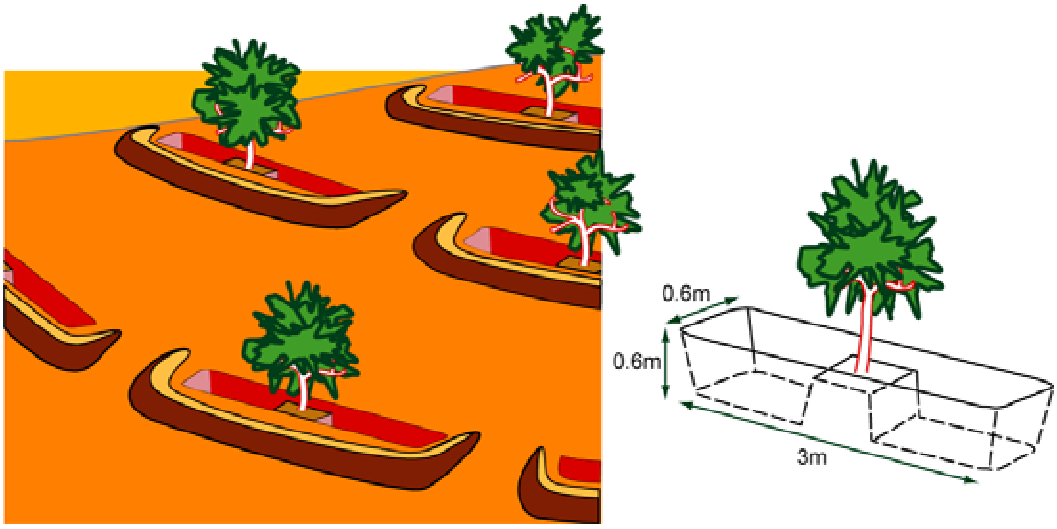
**Figure 3.2.4.1 Stone dike method**




### 2) Trench method

The trench method is a method for reducing runoffs from plateaus and steep slopes by planting trees and a summary is given in Figure 3.2.4.2. With the trench method, deep trenches (0.6m wide, 0.6m deep) are dug by hand and trees are planted in the center. Though it depends on the soil conditions, it is labor intensive work and only 2 or so trenches can be produced per day per person. It is therefore only feasible in a form that provides compensation for labor such as Food for Work or, if uncompensated, when there is an extremely strong awareness in the village of natural resource conservation. Soil is mounded in the center of the trench to a depth of about 0.3m and the trees are planted there. Grass seeds are also sown at the same time, which is very effective when used to supplement organic matter. Though the trenches become filled within a few years, there would appear to be no problems if the trees become well established by that time. The construction of 770 trenches per hectare on steep slopes is being promoted in the Projet Integré Keita in Niger.

**Figure 3.2.4.2 Trench method**




### 3.2.5 Restoration of rills and gullies

Rills and gullies are formed by runoff from further upstream. Therefore, before restoring them, it is necessary to take steps upstream to limit the runoff. It is necessary to be aware that, if restoration is attempted without doing so, rills and gullies ultimately will simply be transformed into channels and, rather than conservation, that could well be the cause of new erosion.

#### 1) Restoration of rills

Rills are small in size and it is possible to deal with them using the construction methods described above. It is also possible to deal partially with rills by constructing stone lines. As an additional method that does not require stone, there is also the sandbagging method using bags that are designed to grain or for other purposes. Though the cost of the bags is a problem, this method has the advantage of easy implementation using soil at the site. If a small amount of compost is mixed with the soil used to fill the bags and Andropogon seeds are embedded in a number of holes opened in the bag, Andropogon plants will take root due to the moisture during the rainy season and the effect will be maintained even if the bags rupture. It is necessary to be aware that the bags will be damaged due to the heat that is released in the process of decomposition if too much compost is added.

Whether stone lines or soil, it is necessary to reduce the force of the surface runoff by establishing them in a number of locations over the entire distance from upstream to downstream. It will also be necessary to increase the height if soil deposits form.

**Figure 3.2.5.1 Restoration of rills using stone lines**

**2) Restoration of gullies**

Since gullies increase in size the farther downstream they extend and the ability of the runoff to cause destruction also increases, it is necessary to adopt measures that are consistent with their size. If the gully is 1m both in width and in depth, restoration is possible through the practical application of stone dikes, as indicated in Figure 3.2.5.2. It is advisable to dig soil and fill the base at the bottom and sides in order to prevent scouring. Since the stones may be shifted by large-scale flows, it is necessary to check them periodically. If the gully is both deep and wide, it is best to use stone-filled gabion baskets to prevent stones from being washed away. Due to the large volume of stones, labor in village units is required. Structures such as this are important in decreasing the force of runoffs through multiple placement along the gully.

**Fig. 3.2.5.2 Example of gully restoration using a stone dike**

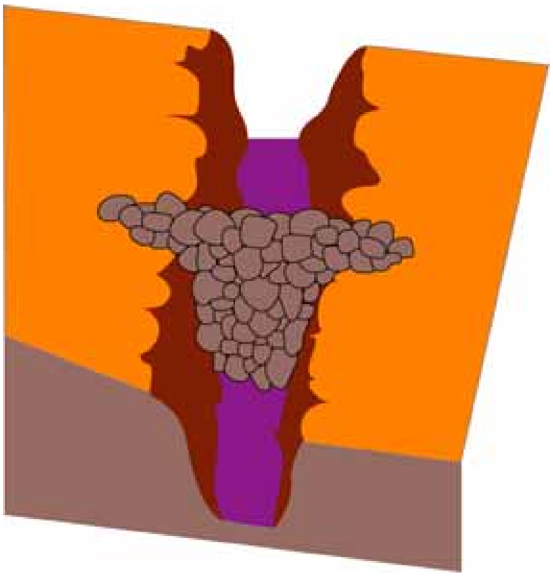


**Fig. 3.2.5.3 Example of continuous placement along a gully**

**Figure 3.2.5.4 Example of large-scale restoration using gabion baskets**

## Chapter 4 Activities for Agricultural Land Conservation

Agricultural land conservation consists of a series of activities for the purpose of establishing a foundation for sustainable production in the agricultural and livestock industries through self-help efforts by the local people based on their precise awareness of the phenomena that are occurring on their own agricultural land and an understanding of the importance of implementing countermeasures. In order to promote this awareness of the current conditions and understanding of the importance of countermeasures, it is necessary to appropriately comprehend the local situation. In addition, it is also necessary to support efforts to organize the local people, set up a structure for the implementation of countermeasures, select appropriate construction methods in line with the local conditions and plan means for implementing them and develop a mechanism enabling sustained self-help initiatives by the local people.

### 4.1 Field surveys

#### 4.1.1 Objectives

Field surveys are conducted for the purpose of properly comprehending the natural, geographical and social conditions of the relevant area as well as the awareness and inclinations of the local people in order to effectively implement measures for the prevention of soil erosion and the conservation of agricultural land. Besides comprehending the conditions of soil erosion and deterioration in the area and selecting appropriate construction methods to deal with them, the surveys are an important activity for the purpose of promoting an awareness of the conditions and an understanding of conservation activities by the local people conducted based on mutual cooperation utilizing the organizations of local people for the development of agricultural villages in the area. The collection of local information necessary for examining area-specific construction methods and means for promoting participation by the local people are explained below.

#### 4.1.2 Survey items

Field surveys are conducted for the purpose of examining the topography, soil quality and conditions of soil erosion in the area, vegetation, conditions of land usage and agricultural production volume and system as well as the mechanism of any existing joint communal activities and other items relating to the local society.

**1) Topographical surveys**

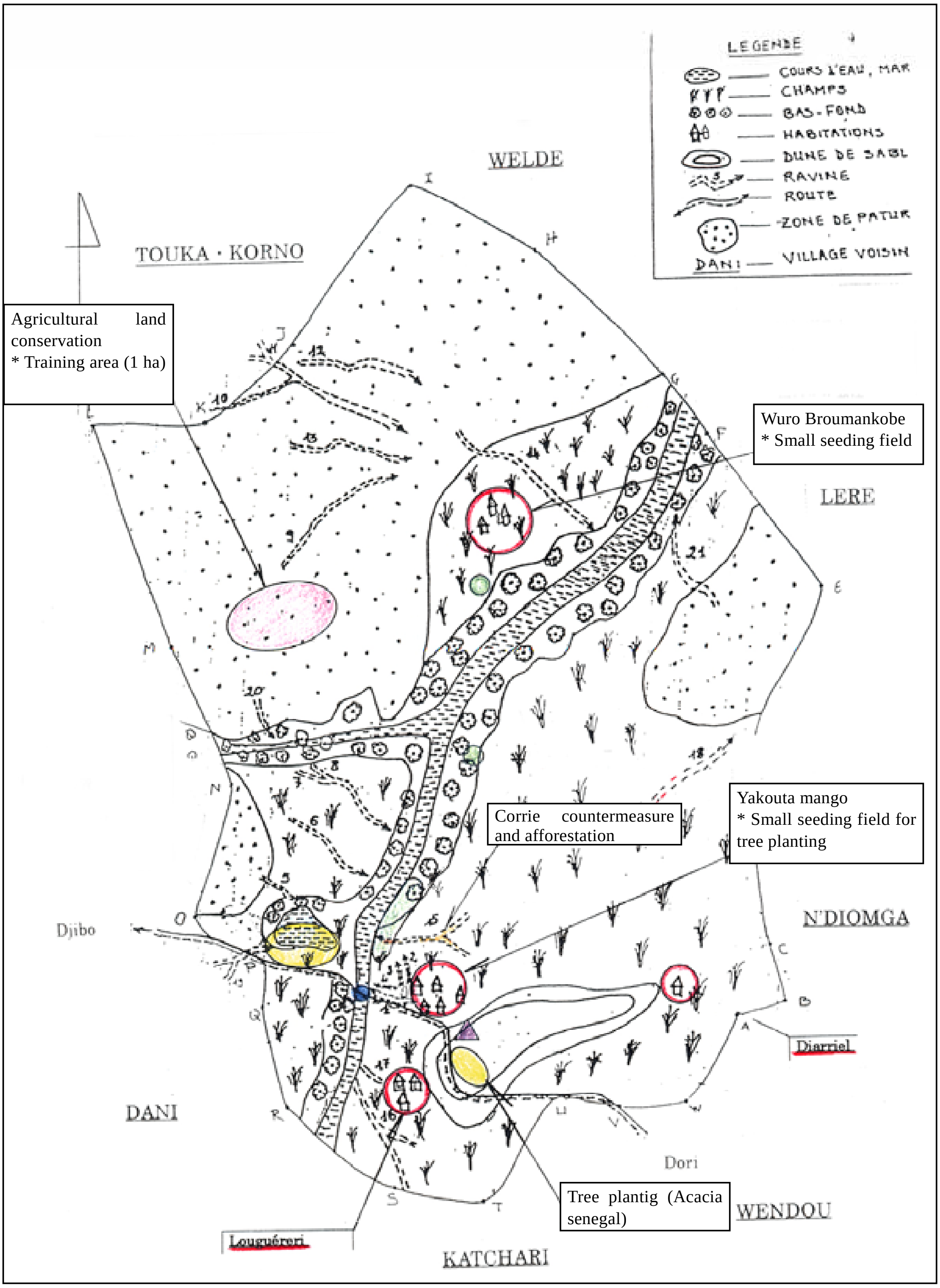
Local reconnaissance surveys are conducted to ascertain the topographical gradient, the location, scale and catchment area of wadis and corries (including rills and gullies, likewise below), land usage categories and *terroir* boundaries.  Though it would be desirable to indicate the results on topographical charts using existing charts (scale 1:1,000-5,000) or surveying the terrain, if there are no charts available and producing them poses difficulties, outline charts are prepared compiling the topographical data acquired through the reconnaissance surveys (refer to Figure 4.1.2.1).

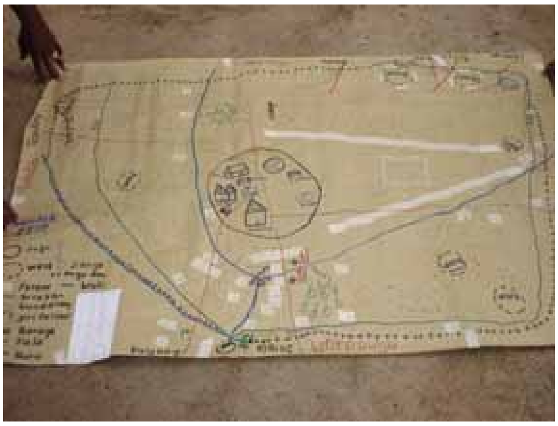
Since topographical gradient is information that is important in examining the selection of the appropriate construction method, placement interval and so forth, the slope steepness distribution of the area is ascertained by categorizing into slope angles, for example, of 0-2°, 2-5° and 5°+.

If there are any wadis or corries, their width, depth and length, catchment area and downstream destination are ascertained.  This is information that is required for determining the order of priority of development and the locations and number of riverbed consolidation works for the prevention of wadi and corrie expansion as well as sediment control measures downstream.

Land usage categories and *terroir* boundaries are important in clarifying the area requiring countermeasures and the size of settlements for conservation activities.

**Figure 4.1.2.1 Gully distribution within the *terroir* based on outline topographical charts**





Hand-drawn plane view of the *terroir*

**2) Geological surveys**

The geology of the surface is classified into sandy soil, clayey soil and rock based on the results of field reconnaissance surveys and the existence of crust formation and other surface conditions are ascertained and indicated on the above chart. This information is used as material for examining the scale of the area subject to countermeasures, selection of appropriate construction methods, construction location and other factors.

**3) Surveys of soil erosion conditions**

The conditions of soil erosion are also surveyed coupled with the examination of topography and soil properties and are indicated on the above chart. In addition to the thickness of the topsoil, degree of fertility, existence of rills and gullies and so forth, the harvest volume per unit area in the case of millet fields and the density and type of vegetation and so forth in the case of grassland are surveyed and used as material for examining the scale of the area subject to countermeasures, selection of appropriate construction methods, construction location and other factors.

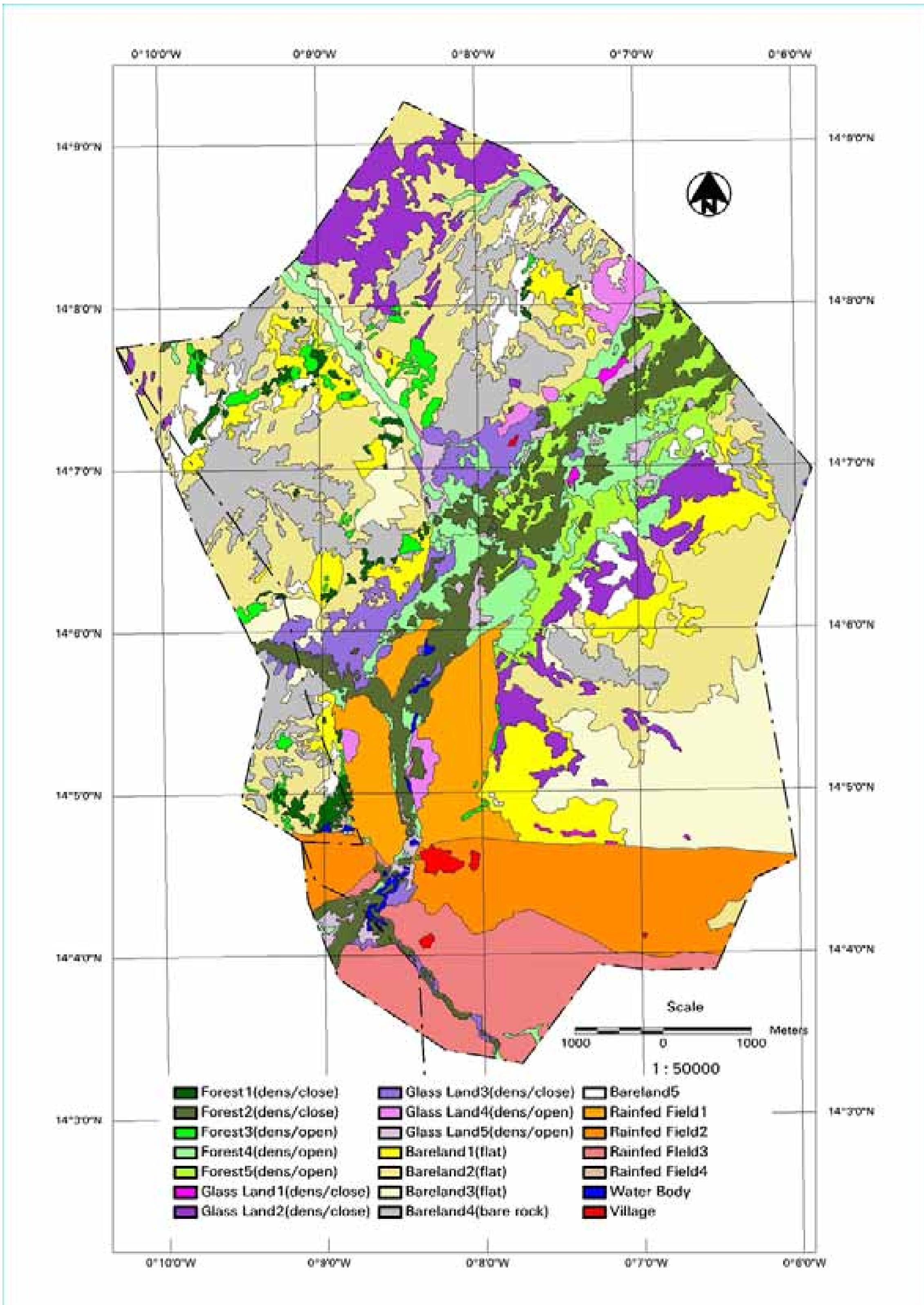
**4) Surveys of the regional society**

In addition to items relating to physical conditions such as those above, field surveys also seek information regarding the local agricultural production system, including frequency and length of fallow periods and area involved, as well as the organizations of local people, joint work schemes and so forth existing within the local society, which are used in the examination of combinations of multiple techniques including civil engineering and agricultural management measures together with measures to promote participation by the local people.

### 5) Other survey methods

Besides the surveys conducted directly in the field such as the above, it is also possible to ascertain categories of land usage such as agriculture, residential, forest and grassland as well as the general types and density distribution of vegetation by analyzing image data of satellite or aerial photographs (refer to Figure 4.1.2.2). However, due to the relatively high cost of the computer systems and software that would be required to obtain and analyze the image data, this has been entrusted to survey organizations that already have such facilities.

**Figure 4.1.2.2 Land usage classification based on aerial photograph data analysis**



### 4.2 Agricultural land conservation plans

In order to conduct field surveys effectively and formulate appropriate agricultural land conservation plans in line with the actual local conditions, the items below are first examined and plans for agricultural land conservation that include the results are formulated.

#### 4.2.1 Education and guidance plans

**1) Provision of information to the local people**

It is important for the local people to be aware of the phenomena that are occurring on their own farm land and in their villages and to understand the importance of plans for agricultural land conservation and need for countermeasures. To that end, field surveys are conducted accompanied by representatives of the organizations of local people involved in regional agricultural development and others, the local people receive reports of the results and meetings are held to allow them to voice their opinions regarding action to be taken. In addition, it is also effective to hold observation tours of established projects and actually observe the effects of countermeasures.

**2) Promoting organization of local people**

It is necessary to develop the organizations of local people as a mechanism for promoting participation by the local people in countermeasures for agricultural land conservation and implementing them effectively. When undertaking the development of such organizations, it is important to promote their development based on dialogs with the local people regarding the composition, sequence of establishment and the nature of their activities while showing respect for the traditional customs of the local society comprehended through field surveys of the society. In addition, if there are any mechanisms for joint work in existence already, it is necessary to thoroughly examine their potential for utilization. Refer to the separate Technical Guide: Promoting Organization of Local People for notes regarding specific sequence and assistance in the development of the organization of local people.

**3) Provision of training in technology**

It will be difficult to implement specific countermeasures for agricultural land conservation unless the local people master the technology. To achieve that, it is necessary to train instructors to instruct the local people in technology. Instructor candidates are selected through dialogs between the local people and they are provided with training in technology relating to countermeasures for agricultural land conservation and the prevention of soil erosion. It is furthermore necessary to examine the content of the technological training and means for procuring the necessary materials in advance in accordance with the conservation measures to be applied and the format of the organization of local people.

### 4.2.2 Plans for the implementation of conservation countermeasures

#### 1) Content of conservation countermeasures

Areas requiring countermeasures based on the outcome of field surveys are specified and the specific content of the conservation countermeasures, including the construction method, quantities and the like that will be actually used, are examined.

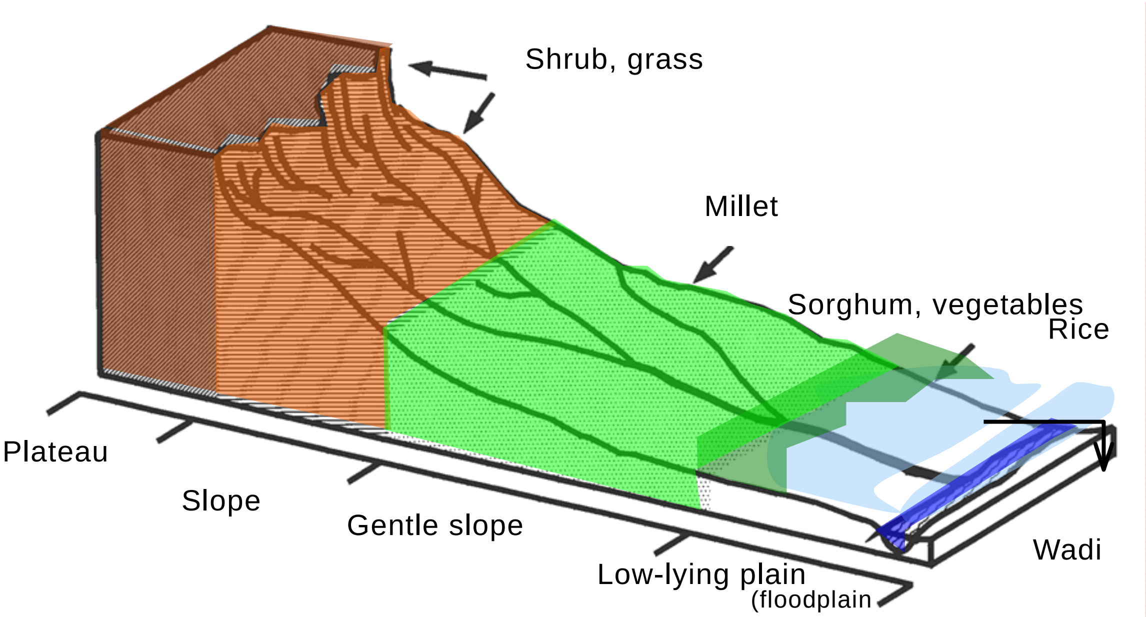
The construction methods indicated in Figure 4.2.2.1 are typical methods widely used for agricultural land conservation in the Sahel region. The optimal construction methods are applied alone or in combination depending on the topography, soil properties, targeted conservation effect and other regional characteristics. The various technological characteristics of these construction methods and conditions for their application are explained in detail in Section 3.2.3 of Chapter 3 and other cautions are summarized below.

- Is the method capable of application given the technological and economic level of the local people and the region?
- If it is method that requires joint work, is it possible to secure the necessary labor force through participation by the local people?
- If it is method that can be implemented by individuals, has each individual mastered the technology necessary for its implementation, or is it possible to easily procure the necessary tools, etc.?
- If it is a method that uses stone, is there an appropriate source of stone nearby?
- Is the extent of countermeasure to be implemented within the scope of the labor force that the local people are able to spare?

When proceeding with the application of a method, besides confirming the technological suitability, the method is to be decided after thoroughly scrutinizing these points.

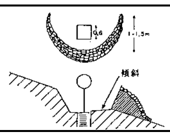
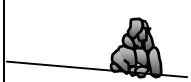
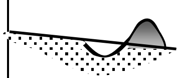
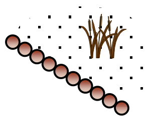
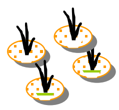
Furthermore, the amount of construction work required for each method to be implemented as conservation countermeasures is calculated and specific content, including type and amount of materials required for the job, number of workers, starting day and work period, is examined. Reference figures for the number of workers, quantity of stone and so forth, including the collection and transport of stone, per unit of length for a number of construction methods in JGRC surveys are given in Tables 4.2.2.1 – 5. It is necessary to note, however, that there are considerable differences in the figures due to the topography in the various regions, distance from the stone source, transport method and so forth. It would be desirable to actually gauge the unit worker count and other figures at the various sites after activities commence, review work schedules and promote improvements in the precision of the planning using the results.

**Figure 4.2.2.1 Topographical characteristics and land usage of the survey area and assumed soil conservation countermeasures**




| Plateau | Steep slope | | Gentle slope | Alluvial plain, floodplain | |
|---|---|---|---|---|---|
| | | Colluvium | Slope with deposits of collapsed soil at the bottom (cultivation area) | Riverbank | Low moisture area |
| Gradient 0-1% | 5-10 | 2-5 | 0-2% | 0-5 | 0-1% |
| Grazing ban<br>Grazing land management<br>Managed reforestation for lumber development | Grazing ban | Protection<br>Reforestation<br>Small embankments for protections<br>Stop zone with good permeability | Developed discharge channels<br>Hedges at zone borders<br>Introduction of water and soil conservation technology<br>Reintroduction of trees into agricultural fields | Reforestation<br>Riverbank protection | Development of reservoirs<br>Effective land usage (improvement of traditional rice cultivation, utilization of grass resources) |

Major soil conservation technology in this zone

| Conservation technology | Half-moon | Stone dike | Contour ridge | Stone windrow | Zaï |
|---|---|---|---|---|---|
| Outline diagram |  |  |  |  |  |
| Characteristic | No transport required | Few topographical restrictions | No transport required | Few material restrictions | Large harvests |
| Topographical restrictions (surveying required) | B | A | C | B | A |
| Ability to inhibit surface runoff | B | B | A | B | C (early rainy season only) |
| Terracing effect | C | A | A | B | C |
| Construction period | B | C | B (work during the rainy season) | B | C |
| Durability | C | A | B | B | C |
| Effect on cultivation | B | B | B (only around ridges) | C | A |
| Appropriate area | Eroded area | Plateau vicinity, gullies, etc. | Toward the bottom of slopes | Midway on slopes | Eroded area |

Note: A, and B C are relative assessment points meaning favorable, somewhat poor and poor, respectively.

**Table 4.2.2.1 Required consumption volume for stone windrow construction (total stone windrow length: 2,730m)**

| Category | Required volume/unit |
|---|---|
| No. of workers per 100m stone windrow | 23/100m |
| Required volume of stone per 100m stone windrow | $8m^3$/100m |

Results of JGRC survey in Yakouta village, Burkina Faso

**Table 4.2.2.2 Required consumption volume for stone ridge construction (total stone ridge length: 1,935m)**

| Category | Required volume/unit |
|---|---|
| No. of workers per 100m stone ridge | 35/100m |
| Required volume of stone per 100m stone ridge | $18m^3$/100m |

Results of JGRC survey in Magou village, Niger

**Table 4.2.2.3 Required consumption volume for half-moon embankment construction (interval: 4m, 625/ha)**

| Category | Required volume/unit |
|---|---|
| No. of workers per hectare | 16/day |
| Work volume per day per person | 40/day |

Results of JGRC survey in Magou village, Niger

**Table 4.2.2.4 Required consumption volume for zaï construction (interval: 1m, 10,000/ha)**

| Category | Required volume/unit |
|---|---|
| No. of workers per hectare | 200/day |
| Work volume per day per person | 50/day |

Results of JGRC survey in Magou village, Niger

**Table 4.2.2.5 Required consumption volume for gabion basket construction (3-5 units x 2 rows x 2-3 levels)**

| Category | Required volume/unit |
|---|---|
| Avg. no. of workers per unit | 70-340/day |
| No. of workers per gabion basket | 6-30/unit |

Results of JGRC survey in Magou village, Niger

**2) Plans to promote participation by the local people**

The implementation of conservation countermeasures is based on the provision of labor by the local people without compensation. The motivation for voluntary participation by the local people in the activities is therefore important. Moreover, depending on the local circumstances, if it is recognized to be effective to combine this with other motivations such as the utilization of Food for Work or simultaneous implementation with countermeasures desired by the local people, measures to promote participation by the local people should be examined that include such measures. However, as indicated in the results of JGRC surveys given in the next section, the promotion of local people participation that depends excessively on Food for Work as a trend in recent years is not necessarily achieving desirable results.

**3) Calculation of necessary expenses and plans for procurement**

The types and quantities of shovels, carts and other materials that are required to implement the countermeasures in line with specific implementation plans are estimated and categorized by those that can be brought by the participating local people and those that need to be purchased and the quantities and cost of materials requiring purchase are calculated.

# Chapter 5 Examples of Agricultural Land Conservation Activities

## 5.1 Stone lines and stone ridges

### 5.1.1 Prevention of sediment inflows to reservoirs and the restoration of vegetation

**1) Overview of the region and description of the development**

The village of Magou is located some 60km southwest of Niamey, the capital of Niger. The JGRC formulated a model agricultural development plan for water source development, conservation of agricultural land, livestock and so forth in the *terroir* of the village of Magou in 1995 and has carried out resident-based activities based on the plan since then.

Eda Marsh, adjacent to Magou to the southwest, was used by the village and other nearby settlements as a source of drinking water for livestock. However, with the progressive advance of soil denudation in the hinterland, the marsh was essentially filled in by inflows of sediment. The development of Eda Marsh was therefore implemented as a part of the livestock and agricultural land conservation plans included in the model plan for Magou village.

In the development of Eda Marsh, the buried marsh was preserved in its current state as a wetland for animal and plant life and low-lying land nearby was excavated for the development of a new pond, while soil erosion prevention measures were implemented with the aim of inhibiting the inflow of sediment from the hinterland and restoring vegetation in the hinterland marked by advancing soil denudation.

**2) Soil erosion prevention countermeasures**

It was decided to implement measures in the Magou village agricultural land conservation project for the prevention of soil erosion and the conservation of agricultural land throughout the entire *terroir* of the village using various construction methods (Figure 5.1.1.1). Of these, as measures adopted along with the development of Eda Marsh, stone ridges with a total length of 1,935m and 100 half-moon terraces were established on an area of about 5ha with progressive denudation on the north side. A total of about 350m$^3$ of stone was used for the stone ridges, which amounts to about 0.2m$^3$ per meter of length. Table 5.1.1.1 gives a breakdown of the expenses required for these measures.

**Table 5.1.1.1 Approximate expenses for soil erosion prevention measures**

Total: FCFA

| Category | Breakdown | Total Amount |
|---|---|---|
| Measures for Eda Marsh & vicinity | | |
| Afforestation | Saplings, etc. | 150,000 |
| Sediment discharge prevention measures | | |
| Stone collection & transport | Truck, power shovel and other heavy equipment | 400,000 |
| Misc. materials | Levels, pickaxes, etc. Set | 150,000 |
| Driver | | 250,000 |
| Sub-total | | 950,000 |
| Stone dike and half-moon terrace construction | Uncompensated local people labor | 0 |
| Total | | 950,000 |

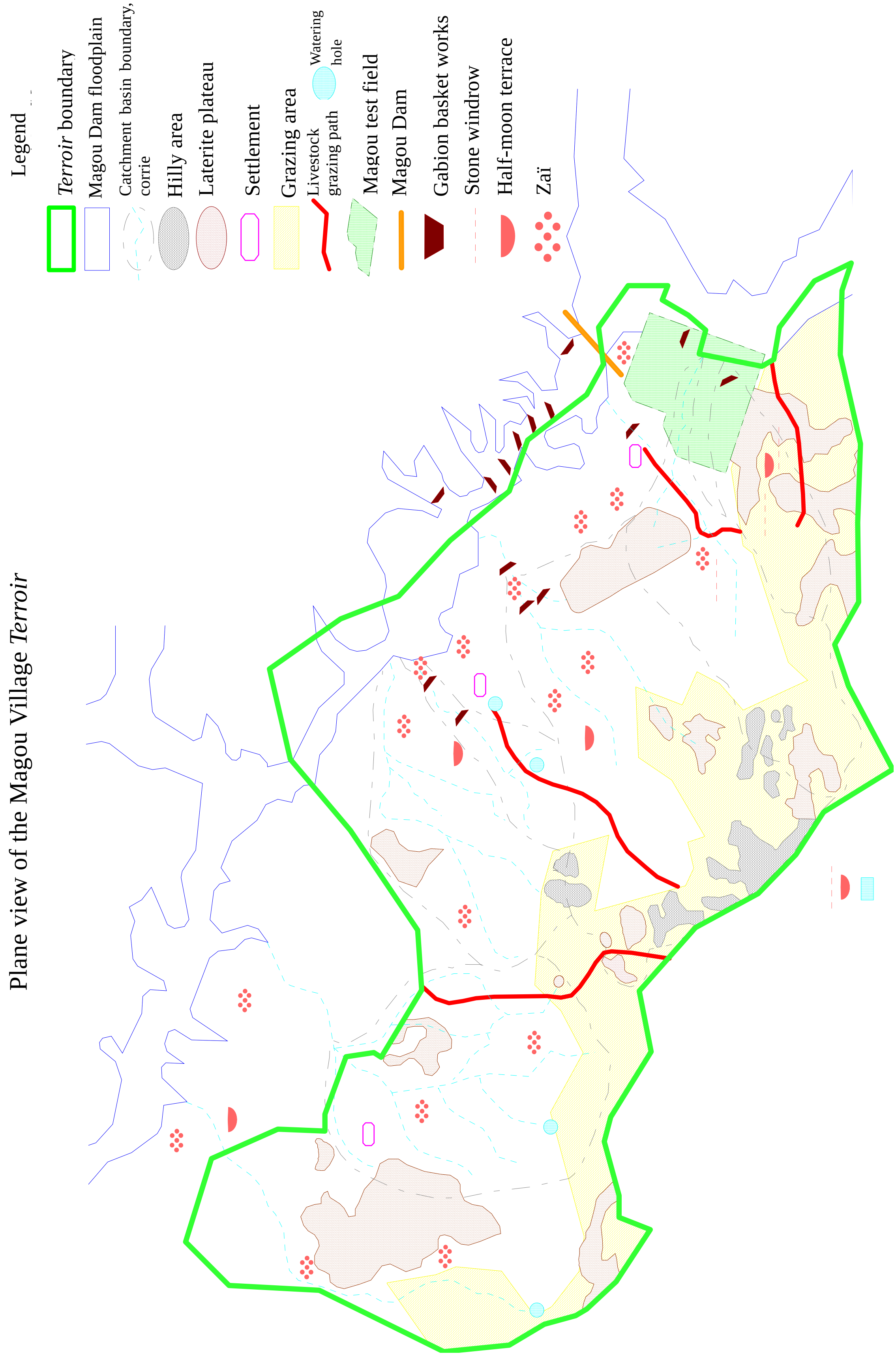
Loading & transport of collected stone

Building a stone ridge

Example of stone ridge built in the Eda Marsh hinterland

Vegetation beginning to recover due to the effect of the stone ridges

**Figure 5.1.1.1 Plane view of the implementation of agricultural land conservation countermeasures in Magou village**



### 3) Conditions of participation by the local people

Conservation countermeasures were implemented through the participation of the local people of Eda and Magou villages during the dry season of 1999-2000. The work continued for a total of about 2 weeks and there was an average of about 20 participants a day from each village. A sort of rivalry became apparent between the two villages in which, if more participants from one of the two villages showed up for work on any given day, a larger number would gather from the other village on the following work day, an interesting phenomenon that ultimately served to further promote participation by the local people.

## 5.1.2 Restoration of grassland with progressive denudation

### 1) Summary of the region

#### (1) Location and topography of the village of Yakouta

Yakouta village, which is located in the northeastern extremity of Burkina Faso, has a 5,337ha *terroir* in total and there are four settlements located there. A wadi known as the Gudebo River runs through the central part of the *terroir* penetrating from south to north. The southern part of the *terroir* is a region of sand dunes while gently undulating plateaus extend from the northeast to the northwest. Slopes gently inclined toward the wadi floodplain continue from there.

#### (2) Vegetation and land usage

Vegetation in Yakouta village is relatively dense in the region of the dunes in the south and forestland extends along the wadi floodplain. The vegetation on the gentle sloping surfaces from both banks of the wadi to the crest of the plateaus is in a state of transition from sparse woodland to grassland and to denuded soil and is declining in density. In regard to the categories of land usage, some 70% of land under cultivation is concentrated in the region of sand dunes in the south and the remaining agricultural land is scattered from the area in the vicinity of the wadi floodplain to the area bordering the sparse woodland and grassland. The denudation of the soil is progressing on the gentle slopes in the northeast and northwest over a broad area equivalent to 50% of the *terroir*, which is little used or not used at all.

#### (3) Soil erosion conditions and current countermeasures

As a result of field surveys conducted by the JGRC, relatively large-sized gullies were confirmed at 27 locations in the *terroir*, ten of which were diagnosed to require the adoption of urgent countermeasures. The gullies extended to 6m in width and 3m in depth and included some that had eroded a portion of the residential areas or cut across routes of transportation that isolated settlements when inundated.

In addition, there was also progressive surface erosion on denuded grassland due to water flows during rainfall or wind erosion. Regeneration of the vegetation was difficult and, even on agricultural land, the productivity of the soil had gradually deteriorated due to the loss of topsoil as the result of surface erosion.

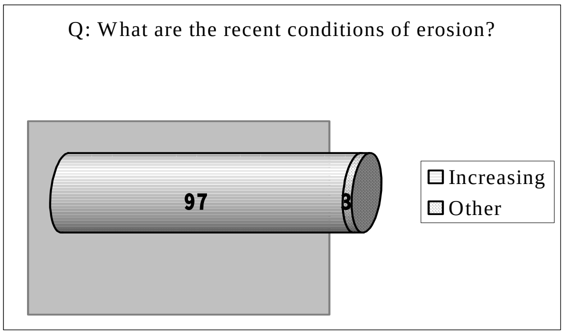
Conventional measures for the prevention of soil erosion, consisting of no more than the placement of logs at rills on agricultural fields, placement of sandbags at gullies in residential areas or the scattering of millet seed, had only been carried on a small scale by individuals without any substantial effect that could be observed and no systematic and rational countermeasures had been implemented.

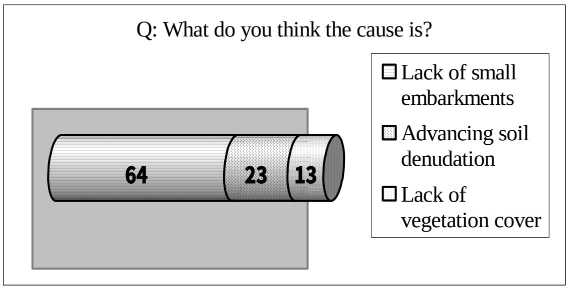
**(4) Awareness of the local people regarding soil erosion**

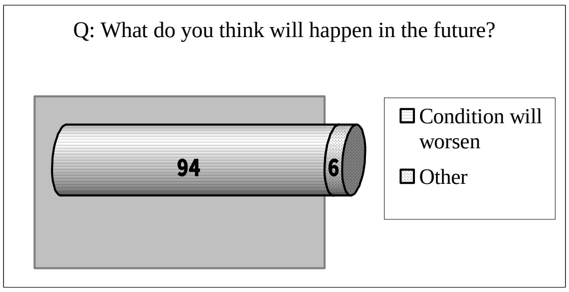
It is possible to get the awareness of the local people regarding soil erosion from the results of an attitude survey conducted in October 1999 targeting 111 residents in 4 settlements of Yakouta Village.

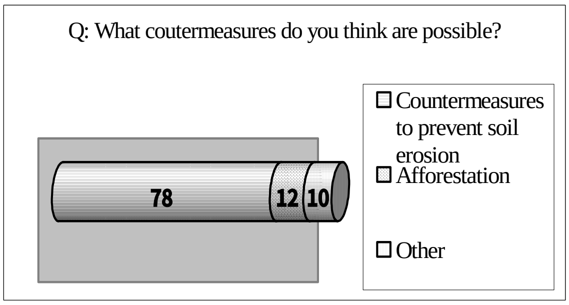
Based on the survey, a considerable number of residents had personally experienced the decline in the millet harvest, their main crop, and the reduction in the grassland area in the village surroundings and they were concerned that there would be increasing deterioration if something were not done. A considerable proportion of the residents cited soil deterioration and erosion as the cause and virtually all of them were conscious of a recent increase in soil erosion. In addition, they also considered it necessary to prevent soil erosion as a shared solution to the issues of smaller millet harvests and reduced grassland.

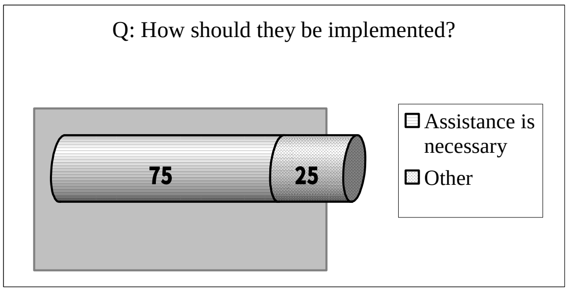
**Figure 5.1.2.1 Results of an attitude survey of the local people of Yakouta Village**

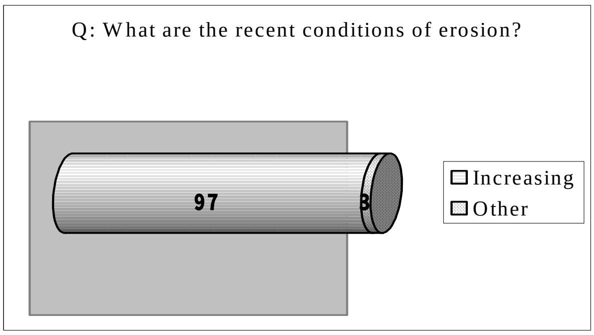


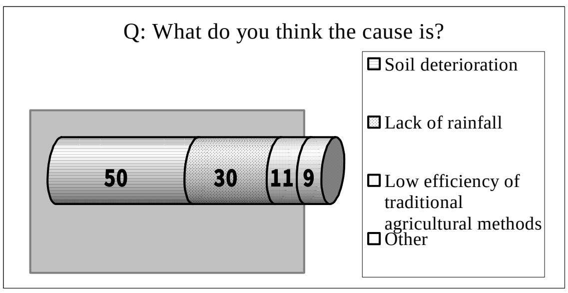



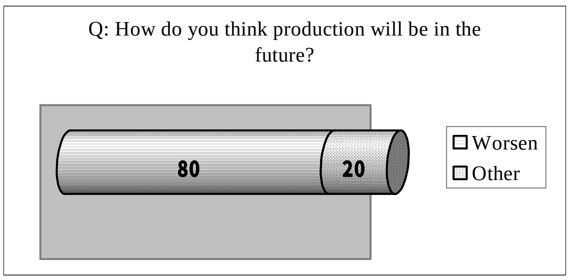



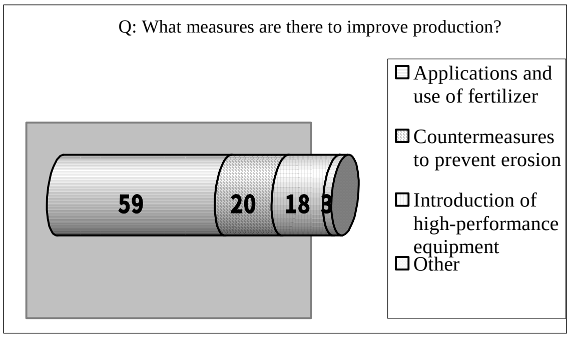



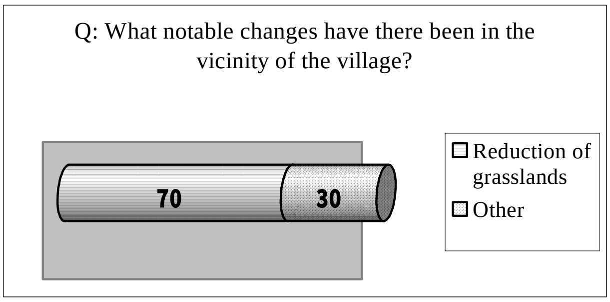



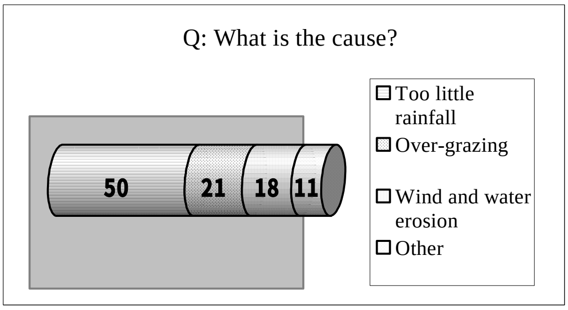



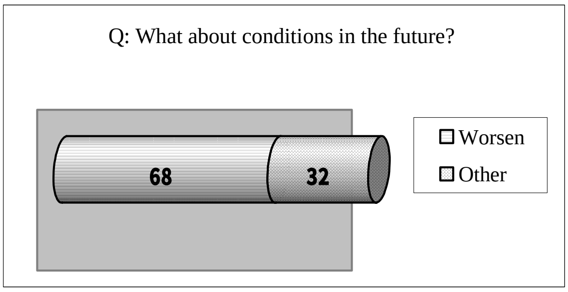



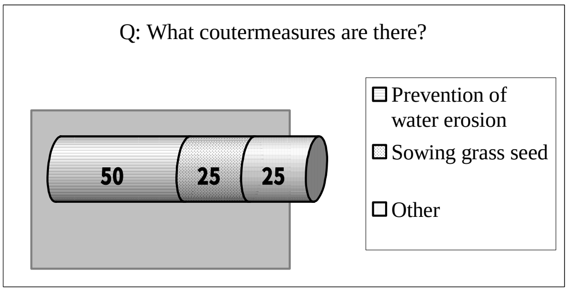




Q: What measures are there to improve production?
59
20
18
3
Applications and use of fertilizer
Countermeasures to prevent erosion
Introduction of high-performance equipment
Other


Q: What notable changes have there been in the vicinity of the village?
70
30
Reduction of grasslands
Other


Q: What is the cause?
50
21
18
11
Too little rainfall
Over-grazing
Wind and water erosion
Other


Q: What about conditions in the future?
68
32
Worsen
Other


Q: What coutermeasures are there?
50
25
25
Prevention of water erosion
Sowing grass seed
Other

## 2) Summary of the countermeasures

### (1) Target area

Prompted by the results of field reconnaissance surveys by the JGRC, the decision was made to construct stone lines on 10ha of common village grassland with advancing denudation in the northwest for the purpose of preventing soil erosion and restoring vegetation through runoff control. With the intention of carrying this out through participation by the local people, they were given technical training during the dry season of 1998-99 and moved ahead with full-scale construction during the dry season of 1999-2000.

### (2) Technical guidance for the local people

In June 1998, 26 residents of Yakouta Village (including 5 women) participated in an observation tour at a nearby area with an established agricultural land conservation project. In addition, a portion of the area described above was set aside as a training area and about 20 residents received technical training for a 5-day period in January 1999 in order to assure that they mastered the technology necessary for the practical application of countermeasures for the prevention of soil erosion and conservation of agricultural land. In content, the technical training included contour site construction methods using a simple water-tube type surveyor's level and methods for ground preparation and stone collection and placement under the guidance of agricultural bureau technicians.

### (3) Joint work through participation by the local people

Food for Work was utilized in order to induce participation by the local people in the stone windrow construction project. As a result, they participated actively and more than 70% of the target 10ha area scheduled for implementation the following year was completed ahead of schedule during the dry season of 1998-99. However, participation by the local people came to an abrupt end when the provision of food for work ceased and the busy farming season began and voluntary activities did not resume later during the dry season of 1999-2000.

### (4) Work days and materials, etc.

In undertaking the joint task of constructing the stone lines, the JGRC procured and provided a truck for hauling stone and the tools while everything else, including the collection, loading and unloading of the stone and the construction work itself, was realized through labor provided through the participation of the local people. Table 5.1.2.1 shows the number of participants by task and Table 5.1.2.2 gives a breakdown of materials used and accrued expenses. Incidentally, the items "wages" and "food assistance" in Table 5.1.2.2 were not actually disbursed but instead indicate estimates when converted to monetary amounts.

**Table 5.1.2.1 Summary of labor for the construction of stone lines**

| Category | # of work days a | Avg. # of work hours b | Actual converted work days c=a x b/8 | Avg. # of participants per day D | Total participants e=c x d | Avg. # of young participants (per day) | Total young participants (per day) |
|---|---|---|---|---|---|---|---|
| Stone collection | 15 | 6 | 11 | 28 | 308 | 9 | 101 |
| Contour line drawing | 6 | 4 | 3 | 21 | 63 | 6 | 18 |
| Stone windrow construction | 13 | 5.5 | 9 | 29 | 259 | 7 | 63 |
| Total | 34 | | 23 | | 630 | | 182 |

**Table 5.1.2.2 Breakdown of construction expenses**

| Category | Unit | Quant. | Unit cost (FCFA) | | | Expenses |
|---|---|---|---|---|---|---|
| Rental truck + gasoline a | Days | 15 | 55,000 | | | 825,000 |
| Wages b | Per capita per day | 630 | General local wages: 1,000 | | | 630,000 |
| Instructors c | All inclusive | 1 | 106,800 | | | 106,800 |
| Food assistance (PAM) d | Meals | 3,360 | Converted to local cost: 114 | | | 383,040 |
| Rental materials & equipment **e** | | | | | | 6,978 |
| Pickaxes | Per day | 78 | Purchase price | 1 yr. = | 10 F/day | 780 |
| Crowbars | Per day | 36 | Purchase price | 5 yr. = | 10 F/day | 360 |
| Wheelbarrows | Per day | 133 | Purchase price | 2 yr. = | 41 F/day | 5,453 |
| Donkey carts | Per day | 3 | Purchase price | 5 yr. = | 107 F/day | 321 |
| Levels | Per day | 32 | Purchase price | 3 yr. = | 2 F/day | 64 |
| Expenses per ha excluding wages | | | (a+c+e) / 7.5ha = | | | 125,170 |
| Expenses per ha including wages | | | (a+b+c+e) / 7.5ha = | | | 209,170 |
| Expenses per ha including food assistance | | | (a+c+d+e) / 7.5ha = | | | 176,242 |
| Expenses per ha including food assistance & wages | | | (a+b+c+d+e) / 7.5ha = | | | 260,242 |

### 3) Measuring the effects of stone lines

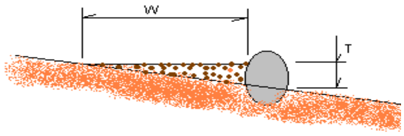
21 rows of stone lines were constructed each with a length of 130m. The interval between them was about 20-30m and the height was about 20cm above the ground surface. The soil in the target area was sandy in quality from about the twelfth row from the bottom in the downstream direction and gravelly in quality from there in the upstream direction.

### (1) Effect in inhibiting topsoil loss

The effect of the stone lines in inhibiting topsoil loss was assessed according to the amount of sedimentation intersected by them. Observations were made by setting up stakes with gradations in 3 locations each in 6 rows, 3 rows each with sandy and with gravelly soil, a total of 18. Based on measurement results indicated in the table below, it was assessed that 68.5 tons of sand and soil were deposited per ha as a result of the stone lines. That is equivalent to inhibiting the loss of about 3mm of topsoil over the entire area on average.

**Table 5.1.2.3 Stone windrow sedimentation by type of soil**

| Category | Gravelly soil on the upper part of the slope | Sandy soil on the lower part of the slope |
|---|---|---|
| Avg. thickness of sedimentation (T) | 10cm | 10cm |
| Avg. width of sedimentation (W) | 59cm | 41cm |
| Specific weight of the sedimentation ($\gamma$) | 2.154g/cm$^3$ | 2.493g/cm$^3$ |
| Sedimentation per 1m of stone windrow (V) | 130kg/m | 120kg/m |
| Sedimentation per ha (C) | 68.5t/ha | |




Conditions of stone windrow construction

Conditions of vegetation restoration due to stone lines

**(2) Effect in restoring vegetation**

To determine the degree of vegetation restoration, zones with and without stone lines, zones with wire fences to block access by livestock, zones with broken crust and with broken crust + stone lines were designated and the biomass of each was measured. The amount of vegetation in zones with stone lines was 2,200kg in areas with gravelly soil and 2,600kg in areas with sandy soil, while, in contrast, the respective amounts were 1,000kg and 1,435kg in zones without stone lines. This indicates that the amount of vegetation due to the construction of stone lines was 1.8 – 2.2 times greater. Furthermore, a comparison of the number of different types of vegetation in the area immediately upstream from a stone windrow and in the central portion between that and another windrow shows a difference, respectively, of 24 and 11 species. In areas of sandy soil, in particular, 4 species were confirmed that were not observed in any of the other areas being surveyed.

**Table 5.1.2.4 Results of biomass measurement**

| Category | Gravelly soil on the upper part of the slope | Sandy soil on the lower part of the slope |
|---|---|---|
| With stone lines | 2,200kg | 2,600kg |
| Without stone lines | 1,000kg | 1,435kg |
| Rate of increase in biomass | 2.2 | 1.8 |

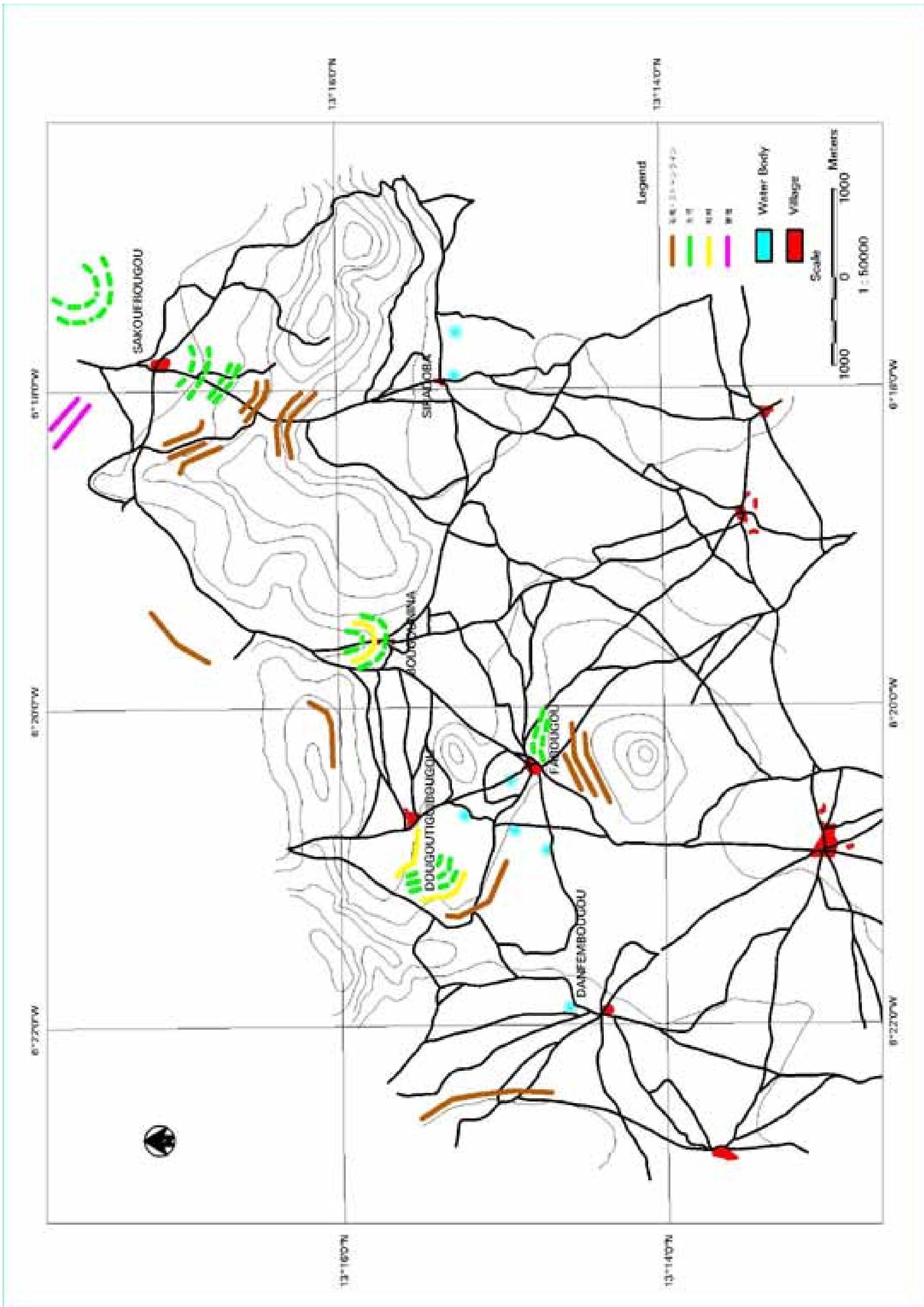
### 5.1.3 Countermeasures to inhibit water discharges from hilly terrain to agricultural land

**1) Summary of the region**

**(1) Location and topography of the 5 villages of Segu**

The five villages of Segu is a generic term used for convenience sake to indicate six settlements scattered in an area of comparatively gentle hills at an elevation of about 290-350m located between the Niger River and a major tributary, the Bani River, about 260km east of Bamako, the capital of Mali. The settlements are separated from one another by a distance of about 2-4km and their *terroir* are divided by gentle highland ridges. In regard to the terrain of each *terroir*, the area used for agriculture is flat land with a gradient of 0-2° spreading out after gently sloping surfaces at the bottom of hilly terrain with slopes of about 3-8° that have an appearance on one side like an open soup bowl.

**Figure 5.1.3.1 Conditions of agricultural land conservation in the 5 villages of Segu**



### (2) Vegetation, soil properties and land usage categories

In regard to the land usage categories in the five villages of Segu, about 70% is used for agriculture, 20% is woodland and 10% is grassland or denuded land. These essentially coincide with the ratios of the topographical categories of flat, hilly and sloping land. In regard to the vegetation and soil properties, coarse shrubby woodland with much exposed ironstone gravel covers the area from the ridges of the hills to the bottom, the area of gentle slopes at the bottom is an area of intermingled denuded land and grassland that is little used or unused and the flat land, though there is sparse woodland, is virtually all sandy or silty land used for agriculture.

### (3) Conditions of soil erosion and countermeasures

In the hilly area with a low density of vegetation, surface erosion due to rainfall runoff and wind erosion has advanced to the point of exposing many ironstone boulders and, in addition, compacted crust is forming on the surface of the gentle slopes with advancing denudation. This is causing an increase in the amount of surface runoff flowing onto the agricultural land, creating many rills there.

As a result of a survey conducted by the JGRC targeting 25 farming families, 40% responded that soil erosion was occurring on their own farmland. No technical guidance regarding the prevention of soil erosion or the conservation of agricultural land had ever been provided before in the area targeted for countermeasures and the local people had been eagerly waiting to receive assistance in methods for procuring labor and materials to implement conservation measures on their agricultural land.

## 2) Summary of the countermeasures

### (1) Content of the countermeasures

A basic course of action was decided upon for each category of terrain taking the results of the field surveys into account, as indicated in Table 5.1.3.1. Based on this, the decision was made to implement countermeasures for inhibiting runoff in the hilly area through participation by the local people while countermeasures for the prevention of soil erosion of agricultural land would be implemented by individual farming families. It was furthermore decided to provide technical training for the purpose of mastering the technology required for the activities and, moreover, to use the joint work organizations that continue to function in each settlement for local people participation. This is a mechanism for public work in the settlements consisting of participation by all men in good physical condition in mending roadways, repairing wells and other tasks one day a week during the dry season when agricultural is slack.

**Table 5.1.3.1 Countermeasures for preventing soil erosion and conserving agricultural land by topographical category**

| Topographical category | Angle | Characteristics | Conservation measures | Conservation activities |
|---|---|---|---|---|
| Plateau | 0 - 1 ° | Flat land on plateaus is virtually unused for agriculture | Restrict intentional burning, tree cutting and livestock grazing and manage natural vegetation appropriately | • Designate as zones where grazing is prohibited<br>• Control water channels using simple ridges<br>• Afforestation using water harvesting |
| Steep slopes - degraded land | 5 - 10 ° | This is the fragile portion of soil deterioration and erosion consisting of eroded cliffs and degraded soil and use is limited. | Reduce runoff speed to the utmost, promote the infiltration of rainwater and improve the density of vegetation | • Designate as zones where grazing is prohibited<br>• Thick hedges and stone dikes<br>• Afforestation using water harvesting<br>• • Construction of ridges |
| Gentle slopes | 0 - 2 ° | This is the portion where degraded land extends outward and is thinly deposited and where almost all agricultural use is concentrated. | Protect by causing rainwater flowing down from upstream to infiltrate or to flow down safely | • Construction of ridges<br>• Segmentation of agricultural land using hedges<br>• Contour ridges, zaï<br>• •Tree planting in agricultural fields |

### (2) Approach to and conditions of participation by the local people

#### a) Briefings to the local people

Briefings were held in each settlement in order to make sure that the local people were aware of the current state of soil erosion and understood the need to implement countermeasures. It was also decided to provide them with the technical guidance and materials required for the countermeasures. The following items were given special priority in the explanations given at the briefings in order to arouse the awareness of each individual resident.

- While the JGRC would provide the minimum required materials and technology, such assistance would be terminated after a given period of time.

- The local people must therefore master the necessary technology within a short time and establish a mechanism for undertaking sustainable joint work activities.
- Activities to conserve the foundation for their own production by making use this assistance and the technology that they learn will only be possible through the sustained efforts of the local people themselves.

**b) Provision of technical training and materials**

Five youths (4 to 6 depending on the size of the settlement) from each settlement were selected through dialogs with the local people as trainees for technical training. The training was carried out for a period of three days in January 1999 and technical education was provided relating to the operation of the surveyor’s level, the collection, transport and placement of stone and so forth using panels and textbooks.

In addition, the JGRC procured and provided each settlement with simple A-frame type surveyor’s levels, pickaxes and sickles for cutting underbrush. Donkey carts used for collecting and transporting stone were provided without compensation by the local people who participated in the work.

**c) Conditions of participation by the local people**

The conservation activities commenced after the conclusion of the technical training through participation by the local people from each settlement centered in the 30 technical trainees. The JGRC grasped the state of work progress and the number of participants in each settlement and also notified each of them of the results in the other settlements. As a result, a sense of competition unexpectedly emerged between the settlements and they began to rival one another in the number of participants and amount of work, actually promoting participation by the local people.

In the implementation of conservation activities, one of the settlements accomplished the construction of 1,400m of stone ridges in June 2000 with the participation of a total about 100 residents while another likewise completed the construction of 260m with about 40 participants.

### (3) Effects of the countermeasures

The stone ridges constructed on the hilly slopes of each settlement were grand in scale, each extending for a length of several kilometers. The height was set at about 25cm as the standard in order to be able to withstand the force of runoff. The infiltration of rainfall runoff and the prevention of topsoil loss were promoted through the construction of the stone ridges and recovery of the vegetation was also evident.

Conditions of stone ridge construction

Fine grain soil was deposited on the upstream side of the stone ridge, promoting the recovery of vegetation

## 5.2 Rill and gully countermeasures

### 5.2.1 Countermeasures using soil to inhibit rill development

#### 1) Summary of the countermeasures

The JGRC implemented countermeasures for the conservation of agricultural land using soil mixed with plant seeds with the aim of inhibiting the expansion of the rills that formed due to scouring caused by rainfall runoff during the rainy season in millet fields in the test area set up in Magou village. The slope angle of the millet fields was about 3° and the area of hinterland runoff was about 1-2ha. There were 3 rills that were subject to the countermeasures and the extent of erosion of each was about 30cm x several meters to 80cm by 1.2m (depth x width).

Sandbags were used here because of the unavailability of sufficient stone material in the near vicinity. The sandbags were made of nylon jute and were filled with soil combined with about 5-10% compost by weight. The bags were lined up in rows across the breadth of the rills and Andropogon seeds were embedded in holes in the bags at the beginning of the rainy season.

Conditions of sandbag placement

Conditions of seed germination after a number of rainfalls

**2) Effects of the countermeasure**

This measure was implemented prior to the rainy season of 1999. The rate of Andropogon seed germination at the beginning of the rainy season was about 30-60% and, as the plants matured, they secured the bags in place and improved the effect of reducing the force of the flow. Though some scouring due to overflows and rapid spurts of water through gaps was evident downstream from the lines of sandbags later in the rainy season, soil was deposited behind the sandbags to a depth of about 10-15cm, thereby inhibiting rill expansion. A problem occurred with nylon jute bags disintegrating prior to the germination of the Andropogon seeds due to heat released by decomposing compost in bags with too much compost. In addition, there were also some rows of sandbags that were partially washed away by the flow in rills with ongoing scouring deep enough to be considered gullies. This method is therefore effective with rills at the early stage on gentle slopes with relatively limited runoff area.

### 5.2.2 Rill recovery using hedges and stone lines

As introduced in Section 5.1.3 regarding conservation measures in the five villages of Segu in Mali, a countermeasure to inhibit runoff by constructing stone dikes on hilly slopes was implemented through participation by the local people while measures to deal with rills on agricultural land further downstream and on gentle slopes were carried out by individual farmers.


Rills formed by rainfall runoff from hills


Stone dikes constructed across rills


Purugeru hedge after transplanting


Established hedge demonstrates effect in reducing flow speed


Rill scoured to a depth of about 50cm


Conditions 1 year later (advancing soil deposition and restoration of the field)

The goal of rill countermeasures was to reduce the speed of the runoff flow, promote water infiltration and the deposition of soil, restore natural vegetation and control runoff to agricultural land further downstream and three construction methods were adopted for use.  One of them was to construct stone lines with a length of about

5-10m depending on the width of the rill at intervals of 20-30m if stone material were readily available nearby. The second was to plant hedges with the same width and interval if it were difficult to obtain stone. The final method was building brushwood fences. The plants used for the hedges were mainly *Euphorbia balsamifera*, *Jatropha Curcas* and *Císal*, all of which can be propagated by cuttings.

Brushwood fences and hedges were the primary methods used in the area of agricultural fields. With some being lost without realizing any effect at times of large volume runoff and the branches used for hedge stakes and bars eaten by termites, the lifespan of brushwood fences was extremely short. On the other hand, the hedges had a significant effect once they became established, restoring rills that had expanded to a depth of 50-80cm and a width of 3-5m to a cultivatable state by the following year.

Though it was necessary to select hedge plants that were adaptable to the growth environment, including amount of rainfall and soil properties in the area, and to purchase or cultivate nursery stock, the effect on rills on sandy soil with extremely gentle slopes was great.

### 5.2.3 Gully countermeasures using stone-filled gabion baskets

#### 1) Necessity for countermeasures

In the vicinity of Mago Dam, a reservoir established in the village of Magou in Niger, the local people of two neighboring villages are involved in reduced-water cultivation and paddy rice cultivation on the floodplain. Meanwhile, the Magou Dam reservoir, which has a capacity of about 85,000m$^3$, has an expected lifespan of several decades due to annual sedimentation of 1,400m$^3$ caused by inflows of sand and soil from the hinterland. If the denudation and soil erosion of the hinterland were neglected, the inflows of sand and soil would increase, shortening the lifespan even further. The local people of the two villages thus became aware of the need for measures to conserve agricultural land in the hinterland. Measures to prevent the inflow of sediment from the wadi that flows into the dam were first initiated as a part of activities based on the model development plan for Magou Village introduced in section 5.1.1.

#### 2) Summary of the countermeasures

As a measure to prevent the inflow of sediment from the wadi, it was decided to consolidate the riverbed using stone-filled gabion baskets in five locations on the mainstream of the Magou River and eight locations on tributaries. The riverbed consolidation project was carried out for the purpose of preventing the inflow of sediment into the reservoir by slowing the speed of the flow in the wadi and promoting sedimentation to the riverbed. Locations capable of adequately retaining sediment were selected for implementation taking the gradient and width of the wadi into account. They were also intended to function at the same time as roadways bridging the wadi as requested by the local people.

The JGRC procured a truck for use in hauling the stone material needed to implement the project as well as the material for the gabion baskets, while the collection, loading and unloading of the stone, basic excavation for the riverbed consolidation, gabion basket positioning, filling and incidental operations and other work were carried out through participation by the local people.

### 3) Conditions of participation by the local people

Five of the thirteen locations selected for the riverbed consolidation described above were completed in January 2000. The work was carried out with the local people divided into two teams and stonemasons were assigned to each team to guide the work. Participation by the local people totaled 1,029 persons (51 persons per day on average) during a 20-day period and 140 persons (16 persons per day on average) during a 9-day period.

Though the riverbed consolidation work itself was simple, it was necessary to mobilize many people, assign jobs appropriately and cooperate functionally. However, this was not easy for the local people, who had had no experience in organized activities. In spite of that, the local people, who brought the project to fruition through their own efforts, ultimately gained self-confidence in their own activities and later moved ahead with additional self-motivated tasks.

1. Basic excavation

2. Completion of basic excavation

3. Laying scour prevention sheets

4. Assembling gabion baskets

5. Basket filling operation

6. Completion

## 5.3 Water Harvesting

### 5.3.1 Half-moon terracing

#### 1) Content of the development

100 half-moon terraces were constructed between stone lines built on the hinterland with progressive denudation as a part of the countermeasures in the vicinity of Eda Marsh in Magou Village in Niger introduced in section 5.1.1.

The half-moon terracing was implemented by digging semi-circular holes about 20cm deep and 4m in diameter, mounding the excavated soil around the edge and building a ridge. In addition, since the half-moon terraces were used in combination with stone lines, they were constructed independently at intervals of 3-4m. Plants that would serve as forage for livestock were planted inside.

**2) Operation implementation and effects**

The half-moon terracing was carried out through participation by the local people at the same as the previously described construction of rock windrows during the dry season of 1999-2000. Refer to Table 5.1.1.1 and section 5.1.1 3), *Conditions of participation by the local people*, for information regarding the number of participants, number of tools and expenses for the purchase of seedlings.

The planting of forage plants has just been completed and specific effects of the half-moon terracing has not yet been adequately realized; however, restoration of the vegetation is beginning to become apparent along with the start of the rainy season.

Half-moon terrace interior and early signs of vegetation restoration around the edge

### 5.3.2 Zaï

The zaï farming method is being carried out in some areas with advancing denudation within the *terroir* of the village of Magou as a part of the model rural development plan of Magou in Niger introduced in section 5.1.1.

During the rainy season of 1999, 20 farming households constructed about 8,000 zaï holes. A technical summary of zaï is introduced in section 3.2.3, *Conservation methods for agricultural land.*

Zaï combined with stone lines

Germinated millet

### 5.4 Countermeasures for agricultural land conservation in crop cultivation areas

In addition to the above, the following is an introduction to conservation countermeasures being implemented on agricultural land by individuals as a part of the model rural development plan of Magou.

#### 1) Control of surface runoff using dead branches and harvest residue

This is an easy method requiring no more than the placement of dead branches in water channels on agricultural land. It is effective in preventing topsoil loss on farming land with rills in the initial stage of development and little runoff.

It is effective to construct a number of rows of dead branches at intervals of about 10-20m.

### 2) Using rubble in small gullies

The speed of the flow was reduced, sedimentation promoted and gully expansion inhibited in a gully that had formed on farming land by blocking the water channel with rock rubble.

It is effective to establish rows of rubble in multiple locations.

Gradual restoration of a gully through advancing soil sedimentation

### 3) Using soil to inhibit the expansion of small gullies

Sedimentation was promoted and gully expansion hindered by piling sandbags in the gully water channel in a location where the procurement of stone material was difficult. However, sandbags were washed away when the flow was high in volume. An effect was contrived through this countermeasure by placing the long side of bags parallel with the direction of flow, expanding the base width through the placement of multiple bags and so forth. In addition, Andropogon seeds were embedded in the bags in order to improve the effect in reducing the force of the flow and promote soil stability.

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