

# Excursion To The Kaya Region, Burkina Faso

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## 1. Burkina Faso

### 1.1. FAO-UNESCO Soil Map of the World

The production of the Soil Map of the World at scale 1:5,000,000 began in 1961 on recommendation of the International Society of Soil Science (ISSS) at the Congress in Madison (USA, 1960).

The main objective was to make an overall world inventory of the soil resources in order to face the problems of land degradation, inequality of production potential and demographic charge capacity, which became international issues at that time.

### 1.2. Pedological units Burkina Faso

The different pedological units, represented on the Africa sheet of the Soil Map of the World (FAO-UNESCO, 1976), are given in table 1.

**Table 1.** Pedological units of the Soil Map of the World, Burkina Faso.

Units	Area in km <sup>2</sup>	Subunits
Luvisols	126,810	Plinthic, Ferric, Gleyic
Regosols	74,780	Eutric, Dystric
Cambisols	16,000	Vertic, Eutric
Vertisols	13,850	Chromic, Pellic
Planosols	12,660	Solodic
Arenosol	12,570	Luvic, Cambic
Lithosols	8,390	
Nitosols	3,090	Dystric
Acrisols	1,110	Plinthic

### 1.3. Global assessment of soil degradation with reference to Burkina Faso

The United Nations Environment Program (UNEP) signed a contract with the International Soil Reference and Information Centre (ISRIC, Wageningen, The Netherlands) for the preparation of a global assessment of the state of human-induced soil degradation at a scale of about 1:10,000,000.

Regional maps (Fig. 1) were collected and correlated to construct soil degradation map at exploratory scale. The Global Assessment of Soil Degradation (GLASOD) was published with an explanatory text in 1990 and 1991. This work was also used for the World Atlas of Desertification, published for UNEP in 1992.

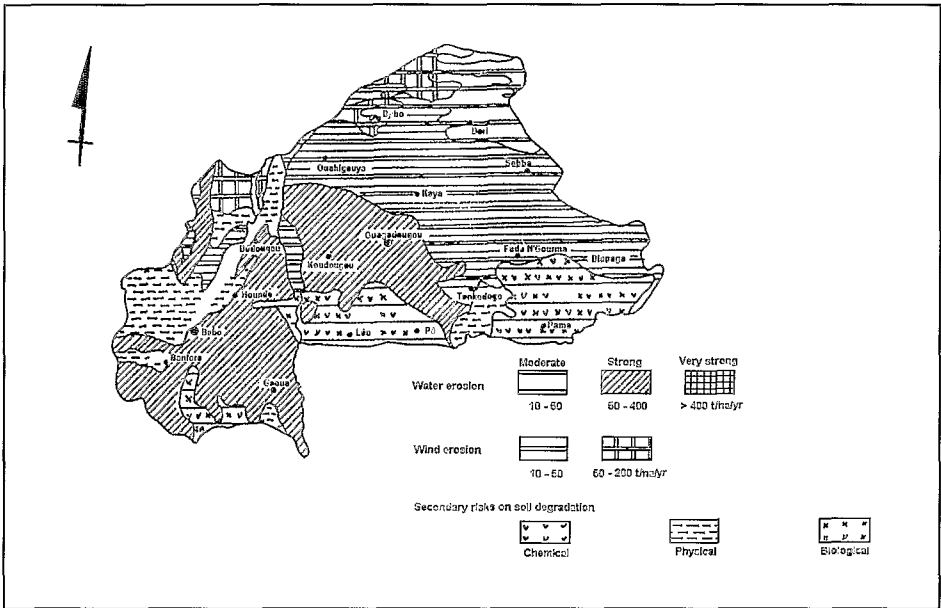


Figure 1. Risk of soil degradation in Burkina Faso according to FAO-UNEP-UNESCO (1980).

### 1.4. Overview on physical and human environment

#### 1.4.1. Situation and climate

Burkina Faso is a country in the middle of West Africa. The total area is 274,000 km<sup>2</sup>. The climate is Sahelo-Sudanese with an average annual rainfall of 400 mm in the north and 1200 mm in the south near to Ivory Coast. The isohyets are given in figure 2.

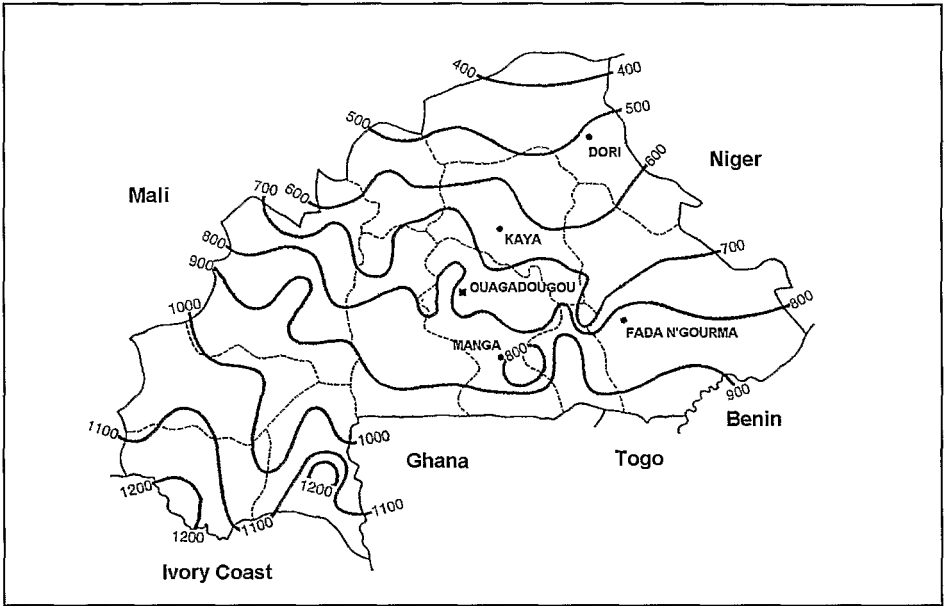


Figure 2. Isohyets of Burkina Faso.

#### 1.4.2. Topography, physiography and vegetation

The average height does not exceed 400 m with half of the country between 250 and 350 m. The soils are correlated with their geological origin:

- Soils of the African shield, usually gravelly and kaolinitic with low fertility, or montmorillonitic with high fertility but poor physical properties;
- Soils of the sedimentary basins, sands and sandy loams with low fertility or heavy textured with moderate fertility.

Burkina Faso is divided into two phytogeographical domains: the Sahelian and the Sudanese zones:

- The Sahelian zone is located north of the 14th latitude with an annual rainfall of less than 600 mm and is composed of steppes with discontinuous canopy of bush and annual *Poaceae*.
- The Sudanese zone is found south of the 14th latitude. In the centre of the country with 600-750 mm rainfall, a moderate coverage by trees, shrubs and perennial *Poaceae* are mainly found in the lowlands. The natural vegetation in the southern part of the country with rainfall more than 750 mm shows a relatively dense canopy of trees and shrubs, while forest is present in the lowlands.

### **1.4.3. Human environment**

In 1988, the population was estimated at 8,556,000 inhabitants with an average density of 29 inhabitants per square kilometer and varying widely over the country. There is a large number of ethnic groups (about sixty) of which the main groups are according the 1985 population census: Mossi (48%), Fulbe or Peuhl (10%) and other groups, each less than 10%: Lobi, Samo, Bobo, Sénoufo, Gourounsi, Gourmatché and Bissa. These ethnic groups are characterized by differences in cultural background, land use and land ownership.

The population increase is very high with an increase of 41% from 1975 to 1985 and current increasing rate of 2.8% per year. Therefore, the population is extremely young: 54% had an age of less than 19 years in 1985. Urban evolution is also important: the urban population was about 6.4% of the total population in 1975, but in 1985 this proportion already was 12.7%.

## **2. Physical and human environment of the province Sanmatenga**

### **2.1. Administrative situation**

The Sanmatenga province belongs to the northern-central region between 12°40' and 14°N latitude. The city of Kaya is located at 100 km north-north-east of Ouagadougou and is the county town of the province. The province has an area of 9,419 km<sup>2</sup> or about 3.4% of the national territory. It is composed of 11 departments.

### **2.2 Climate**

The climate is Sahelo-Sudanese with an annual rainfall of 500 mm in the north and 600 mm in the south. The dry season is from the middle of October up to the end of May, while the rainy season is from June to the middle of October.

The average temperature is between 27°C and 28°C with a minimum of 10.5°C and a maximum of 43°C. The temperature shows seasonal variations. There are two cold seasons (namely December to February and August) and two warm seasons, before and immediately after the rainy season.

From February to April, there is effect of a dry warm wind, the harmattan, issued from a Saharian anticyclone blowing from north to south.

### **2.3. Geology and soils**

Two geological formations of the Precambrian are dominant. The Antebirimian granitic formations are found in a more or less undulating landscape. They cover the

northern part of the province, extending to the south-east. The outcrops are composed of migmatites and calco-alkaline granites.

The Birrimian formations characterize the hilly subregions with schist and meta-volcano sedimentary formations.

The spatial split up of the pedological units largely follows the limits of the geological formations. The soils found range from well to poorly developed and can be hardened. Iron crusts are outcropping or covered by young soil material.

On the interfluvial tops of Birrimian hills, lithosols and poorly developed brown soils (Cambisols) are present.

#### **2.4. Vegetation**

The vegetation is globally characterized by savanna formations, often degraded.

In the south, *Butyrospermum paradoxum* trees are dominant besides low formations with *Combretum micranthum* and a relatively dense herbaceous cover under natural conditions.

In the north of the province, the savanna shows a Sahelian tendency with small shrubs, composed of *Combretaceae* and several thorny species. The herbaceous stratum contains mostly *Poaceae* in a discontinuous canopy, exposing bare soils with crusts, which hinder water infiltration.

The general distribution along toposequences is as follows: bushes occur at the tops and slopes of ironcapped mounts, crops and trees are found on faint slopes while tree lines are located along depressions.

A degraded vegetation condition results from combined effects of climate, rigorous cutting of trees, over-exploitation and agricultural and livestock pressure.

#### **2.5 Social and economic environment**

According to the results of the 1985 census, the population of Sanmatenga was 367,633 inhabitants with an average density of 39 inh/km<sup>2</sup> in the north against 56 inh/km<sup>2</sup> in the south of the province. The Kaya department had 67,104 inhabitants with a density of 69 inh/km<sup>2</sup>. The province contained 357 villages, subdivided into 1,861 quarters, while 7% of the population lives in the county city.

Agriculture is the main activity for 80% of the population. Crop growing in order of decreasing importance is the following: millet, sorghum, cowpea, groundnuts and maize. Furthermore, garden production is significant.

The availability of agricultural land is low. The National Soils Bureau (BUNASOLS, 1990) estimated this to be 0.76 ha/farmer in this region.

Livestock holding is the second major activity. It is characterized by a "not-fixed grazing system." Arranged according to their decreasing importance, it concerns: goats, sheep and cows.

Important ligneous formations are observed in the protected forests of the province, namely: Dem, Nakambé and Yabo with a total area of 3,450 ha.

### **3. Kaya region**

The Kaya region is located in the province of Sanmatenga; Silmiougou is a village in the centre of the excursion area at 4 km north of this town (for location, see Fig. 11).

#### **3.1 Land use Silmiougou region**

Diachronic analysis was done from two situations in the Silmiougou region:

- 1955 situation with aerial photographs of the AOF (French Occidental Africa) mission at 1:50,000 scale;
- 1994 situation with aerial photographs of IGB (Geographic Institute of Burkina Faso) mission at 1:10,000 scale.

Aerial photographic analysis of these photographs shows the widely spread environmental degradation.

In 1955, the area showed already a great rate of agricultural soil occupation (about 45%). Agricultural practices were concentrated in valleys and on faint slopes.

The area used for agriculture had strongly increased between 1955 and 1994: from 45% to 65%.

The lowlands, which are the moist and fertile zones, have been cleared and for more than 90% used for cropping. Hill slopes and tops were increasingly used for cropping, causing crusting, runoff and soil degradation. The 1994 condition showed extended areas with crusting and several barren zones, which were only used for extensive grazing.

The natural savanna vegetation had changed from 1955 to 1994: ligneous tree formations and small shrub savanna areas were reduced from about 50% to less than 10% of the total area.

#### **3.2 Physical and chemical measurements on the degraded watershed of Silmiougou under sylvopastoral land use**

##### **3.2.1 General data**

The study area consists of a 12.5 ha small (sub-)watershed directly north of Silmiougou. The average annual rainfall is about 650 mm. This watershed is heavily degraded, with a sparse vegetation of some shrubs, trees and grass.

In the Semi Arid Tropics very intensive rain showers occur (Fig. 3); about 15% of which has an intensity > 100 mm/hour (Fig. 4). The erosive power of showers increases

exponentially with the size of the showers (Fig. 5). For a shower of 40 mm the erosivity index EI30 is about 1,000 [J.mm/m<sup>2</sup>.h] for each millimeter of rain and this value doubles till 2,000 [J.mm/m<sup>2</sup>.h] for each millimeter of rain for a shower of 80 mm.

The landscape in Silmiougou is dominated by a very gentle long slope called *glacis*. The surface configuration of the watershed was determined, using various methods:

1. A topographic survey with a levelling instrument.
2. Constructing a digital height model using various types of software: SPATANAL (semi-variogrammes), MAPIT (geostatistical interpolation), SURFER (contours).
3. Import in a Geographical Information System (IDRISI 4.0).
4. Digitizing of surface phenomena (based on field observations) like crusts, gullies, annual and perennial vegetation using TOSCA.
5. Analysis of raw data with IDRISI (slopes, percentage cover, flowpaths etc.).

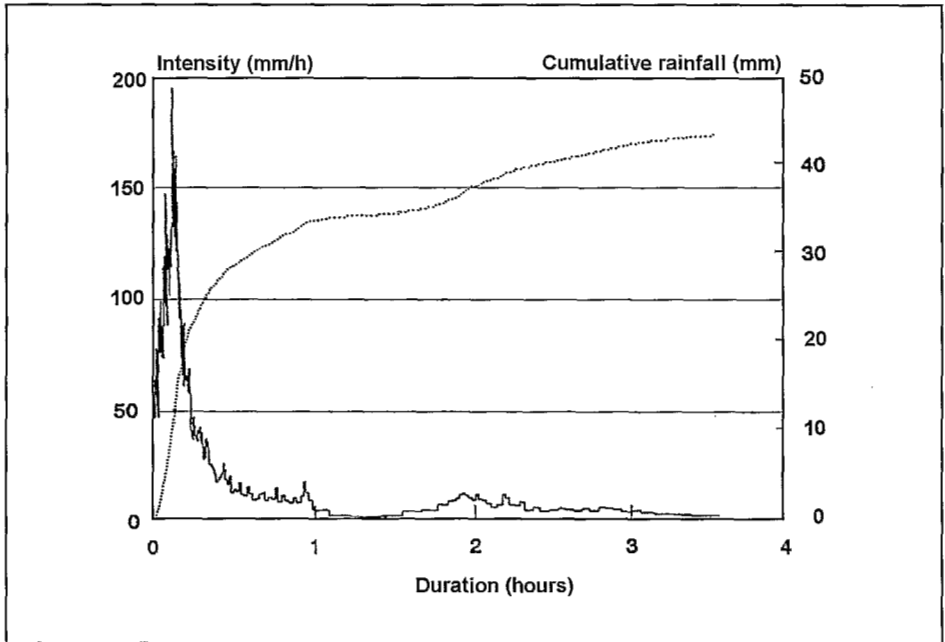


Figure 3. Intensity pattern of a typical shower in northern Burkina Faso (June 2, 1993).

Slopes in this watershed were classified in 5 classes (Table 2). The median slope of the watershed is 1.2 %.

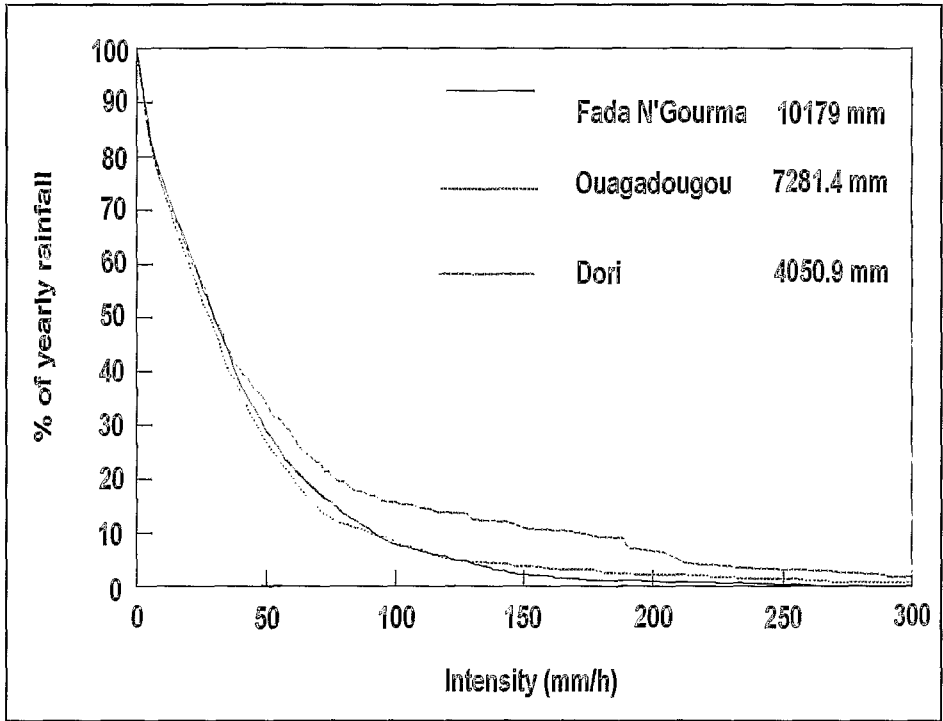


Figure 4. Rainfall intensity analysis for three locations in Burkina Faso.

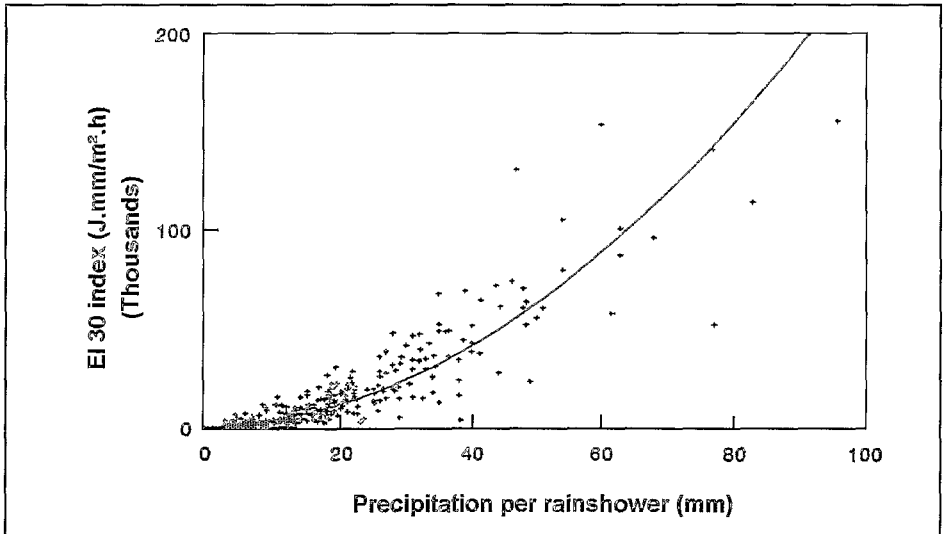


Figure 5. Erosivity index as a function of shower size for Burkina Faso.

**Table 2.** Typical slope classes for rangelands in northern Burkina Faso.

Slope class	% slope	% of watershed
1	< 1	40
2	1-2	33
3	2-3	15
4	3-5	6
5	> 5	6

### 3.2.2. Crust cover

Special attention was given to the *crust cover*: inventories were made on the basis of visual observations, using the classification as proposed by CASENAVE and VALENTIN (1989) as a guideline, and supported by measurements of the infiltration capacity. When degraded, glacia are partly bare and covered with 5 surface types:

1. Recent sandy dunes formed by deposition of aeolian sand. These small dunes are 10-50 cm high and cover an area of 2-20 m<sup>2</sup> and are often covered with rapid germinating pioneer vegetation. On this surface so-called drying crusts are found.

2. Older dunes where erosion has taken place, the soil surface contains more silt than the recent dunes, there is less vegetation cover and more algae growth. The algae crust type is a succession (in development) of the drying crust.

3. Crust on lateritic soil with gravel (laterite concretions) pavements.

4. So-called B-crusts which are supposed to be a succession of crust type 3 after removal of the protecting pavement.

5. Depositional (sedimentary) crusts are present in micro- as well as macro-depressions in 10% of the area.

Results of crust observations for Silmiougou are given in figure 6 and their classification according to their runoff properties into 6 classes (% runoff after 89 mm simulated rain shower) is presented in table 3. Class 1 represents arable land and classes 2-6 are sylvo-pastoral areas.

**Table 3.** Typical crust classes for rangelands in northern Burkina Faso and weighted mean runoff for a whole season and a design storm of 89 mm.

Crust class	% of watershed	% Runoff seasonal	% Runoff 89 mm
1	8	16	20
2	21	25	55
3	27	55	65
4	29	60	75
5	14	65	85
6	1	70	95
<b>Crust weighted mean runoff:</b>		<b>49</b>	<b>64</b>

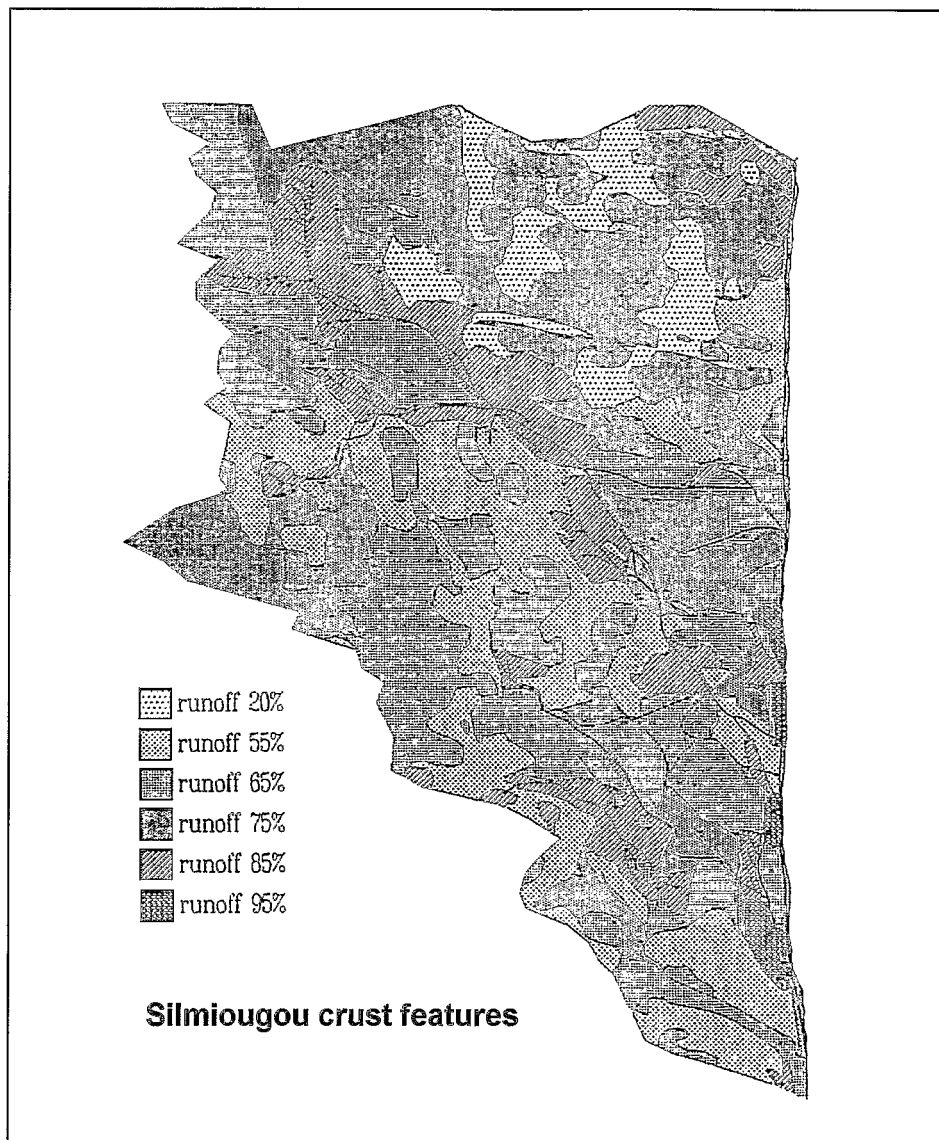


Figure 6. Spatial distribution of crusts classified according to their runoff behaviour.

### 3.2.3. Physical and chemical surface soil properties

With moisture retention curves and field capacity known, available water was calculated for the major surface soils in Table 4.

**Table 4.** Typical pF and available moisture data for 4 different crusted soils on rangelands in northern Burkina Faso.

	Soil Type	pF 2.0	pF 4.2	Available moisture (mm/mm)
1	Recent dunes	0.248	0.024	0.224
2	Older dunes	0.222	0.046	0.176
3	Laterite soil	0.267	0.107	0.160
4	B-crusted soil	0.280	0.189	0.091

Table 5 shows some physical characteristics of the soil underlying the most important crust types.

**Table 5.** Some physical and mechanical characteristics of the soil underlying the important crust types in Silmiougou.

Crust type	Tensile Strength (kPa)	Slump on Immersion (%)	Clay/Silt Ratio	% Sand (<53 $\mu$ m)	% Gravel (> 2 mm)	Bulk Density (g/cm <sup>3</sup> )
Drying crust on recent dunes	1,3	25	0,56	83	0,3	1,57
Algae crust on old dunes	28	19	0,62	68	0,3	1,59
Crust with gravel	89	39	1,43	47	48	1,74
B-crust	90	27	3,33	51	5	1,66

The sandy soils on which the drying and algae crusts have developed, show a high percentage of sand, a small amount of silt and a bulk density of just under 1.60, which is normal for these soils. The algae crusted soil has clearly collected more silt and clay material than the drying crust which becomes evident in the increased tensile strength and a lower slump percentage (less slump = more stable). The gravelly soil and the crusted soil where gravel has been removed are heavier (approx. 50% clay and silt). Their tensile strength is accordingly higher. This does not mean, however, that the fine material is more stable than sand: soil from the crust with gravel showed the lowest stability for the slump test.

This may explain why on this soil type, after removal of the protective gravel pavement, the crust becomes stronger and denser.

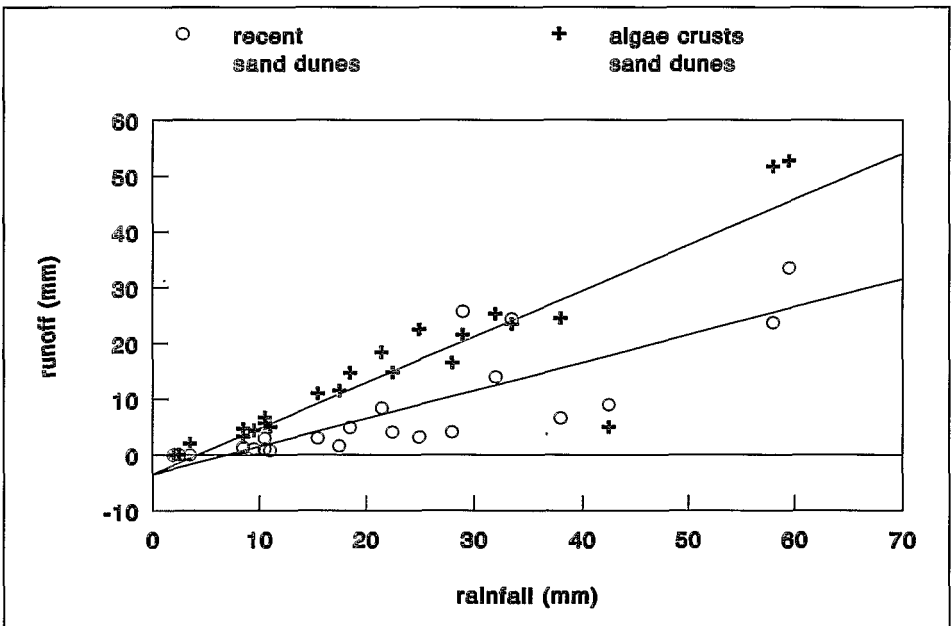
### 3.2.4. Runoff and erosion

Runoff as a result of natural rainfall from typical surfaces on the Silmiougou watershed was collected from small (1 m<sup>2</sup>) plots. These plots were made of sheet metal measuring 0.8 x 1.25 m (length along slope), with a collecting system consisting of an 80 l barrel, dug into the soil. In this way, only the total volume of runoff can be assessed.

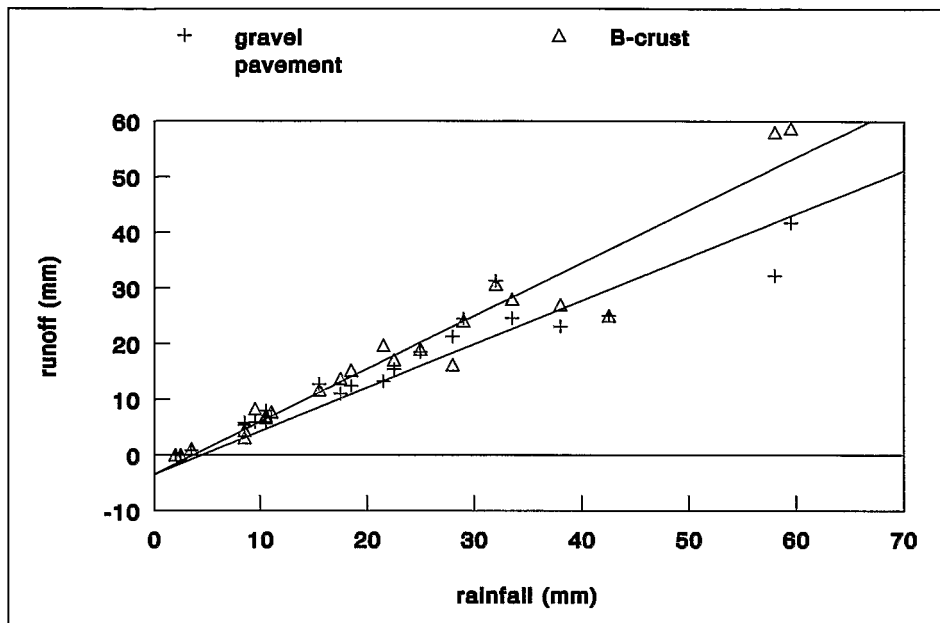
Runoff of individual rain showers appeared to be well correlated with shower size (intensity mm/hr x duration in hours). Linear regressions with  $R=aP-b$ , in which  $R$  (mm) is the runoff and  $P$  (mm) the shower size, show high correlations. The higher  $a$  is, the better the correlation is. In the above equation is  $a$  the slope of the linear regression and often called the runoff coefficient and  $b$  the intercept with the dependent  $R$ -axis. This makes  $b/a$  (mm) the threshold rainfall volume above which runoff starts so that the above equation is only defined for  $P > b/a$ . Results for young and older dunes are given in figure 7 and for gravel pavement and structural B-crusts in figure 8. Regression results are given in table 6.

**Table 6.** Runoff formulas and runoff threshold values for typical surfaces on degraded sylvo-pastoral soils in northern Burkina Faso.

Main crust types	Runoff formula	Threshold (mm)	Corr
Drying crust	$R=0.50*P-3.5$	7.0	0.68
Algae crust	$R=0.82*P-3.5$	4.3	0.81
Crust with gravel	$R=0.78*P-3.5$	4.5	0.92
B-crust	$R=0.95*P-3.5$	3.7	0.94



**Figure 7.** Runoff as a linear function of rainfall for recent and degraded (due to algae crust) sand dunes on Sahelian rangeland.

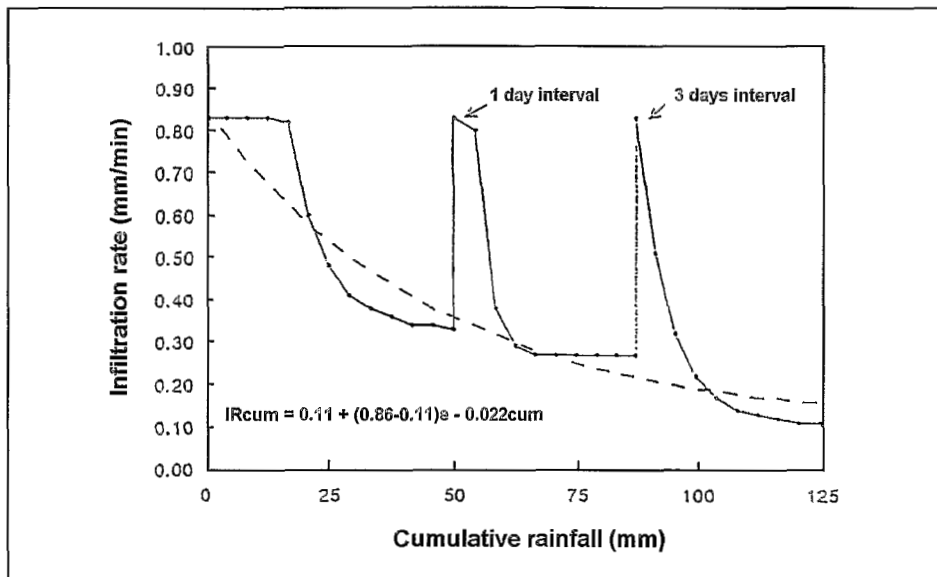


**Figure 8.** Runoff as a linear function of rainfall for degraded sylvopastoral soils with a gravel pavement (crust with gravel) and a B-crust.

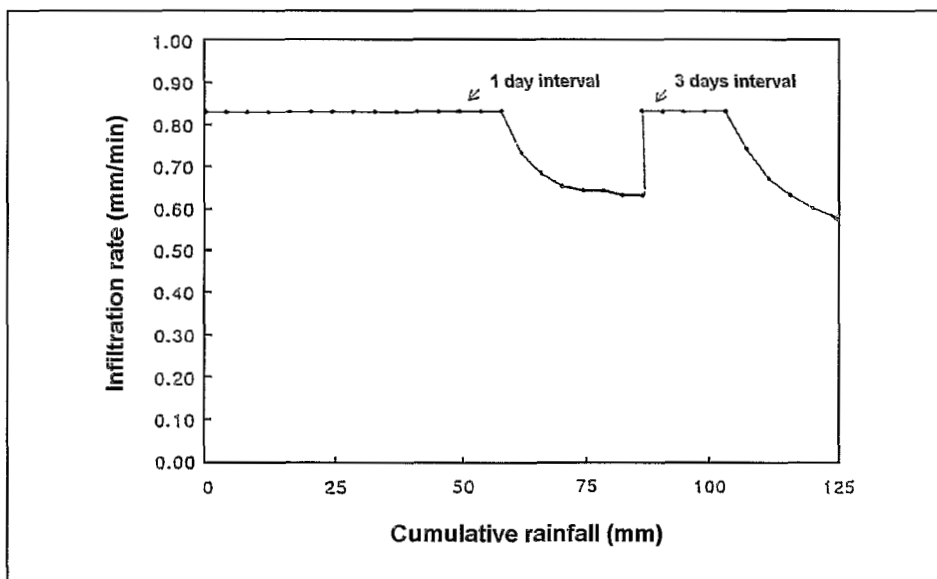
The process of crust formation and resulting runoff was measured under a rainfall simulator (type Orstom) using a T-jet nozzle spraying water from a height of approx. 4 m on a 1 m<sup>2</sup> plot (1 x 1 m). The rainfall simulator tests yield a curve showing the decrease of infiltration rate as a function of time or cumulative rainfall. This study showed that crusts on Silmiougou soils develop rapidly, after being broken by tillage, under influence of cumulative rainfall (Figs 9 and 10), and that the rate of crust formation is strongly determined by the organic matter content of the soil.

Soil loss shows a poor correlation with shower size, shower intensity or erosivity. This is probably due to soil deposited on the experimental plots by wind erosion. Therefore, soil loss is often expressed in the units kg/ha.mm rain. For sylvopastoral land use, values range between 3 and 45 kg/ha.mm rain so that annual soil loss ranges between 2 and 30 t/ha.yr.

Plant nutrients are lost through soil loss as well as in the runoff water. In the runoff water we have measured in 1993 in Silmiougou about 40 g/ha.mm runoff of plant available N. The annual runoff of degraded sylvopastoral areas is about 50% so that at an isohyet of 650 [mm/yr], the runoff amounts to 325 mm/yr containing 13 kg<sub>N</sub>/ha. The 650 mm of rain brings about 10 kg<sub>N</sub>/ha so that the net loss due to runoff is 3 kg/ha.yr.



**Figure 9.** Infiltration rate as a function of cumulative rainfall after crust breaking for degraded sylvopastoral soils with only 0.24% soil organic carbon (1 or 3 days interval).



**Figure 10.** Infiltration rate as a function of cumulative rainfall after crust breaking for agricultural soils with 1.24 % soil organic carbon.

Nutrient erosion can be expressed in terms of total elements or in terms of available nutrients, both methods have pros and cons. Results show that the majority of the total elements is in the eroded sediment while the majority of the plant available nutrients is in the runoff water (see table 7). Effects of long-term gradual nutrient loss on yield and the costs and benefits of conservation technology have been calculated. Taking into account the nutrient conserving function of certain soil conservation methods can make this technology economically viable.

**Table 7.** Distribution of annual losses of nutrients (kg/ha.yr) between sediment and runoff for two types of land use on degraded sandy loam soils in Burkina Faso (1994 data).

	Sylvopastoral			Agricultural		
	Sediment	Runoff	% in sediment	Sediment	Runoff	% in sediment
C	118	23	84	361	17	96
Total N	13	7	67	28	14	67
Avail N	0.2	6.6	3	0.2	13.7	2
Total P	1.5	0.0	100	4.8	0.1	99
Avail P	0.0	0.0	--	0.0	0.1	0
Avail K	1.1	3.3	25	1.1	7.6	13

The eroded sediment always contains higher concentrations of organic matter and nutrients than the topsoil from which it originates. This phenomenon is called enrichment. The ratio between the concentration of an element in the sediment to that in the soil is called the enrichment factor (*indice de sélectivité*). Enrichment factors for total elements are higher (2-4) than for available nutrients (1-2), see table 8.

**Table 8.** Chemical analysis of the original soil, the erosion sediment and runoff for two types of land use on degraded sandy loam soils in Burkina Faso.

	Sylvopastoral				Agricultural			
	Soil	Sediment	Enrichment	Runoff	Soil	Sediment	Enrichment	Runoff
C (%)	0.6	2.1	3.5	-	0.7	1.7	2.4	-
TOC (ppm)	-	-	-	6.0	-	-	-	5.4
Total N (%)	0.06	0.24	4.0	-	0.05	0.13	2.6	-
Avail N (ppm)	42	-	-	1.67	7	10.3	1.5	2.95
Total P (ppm)	105	277	2.6	-	75	219	2.9	-
Avail P (ppm)	0.44	-	-	0.00	0.02	-	-	0.01
Avail K (ppm)	94	-	-	0.80	53	50.3	0.95	1.56
pH	6.5	-	-	-	6.2	-	-	-

- : no data available. Note: TOC (Total Organic Carbon) determines 82% of C determined with Kirmies.

One can use the runoff relations in combination with crust areas for upscaling the information towards the watershed scale. This is especially important for the design of Soil and Water Conservation technology. For that case one uses not only an average seasonal rainfall distribution but also a so-called design rain shower. This is the shower with an occurrence chance of once in ten years which is for Silmiougou 89 mm. By multiplying the relative contributions of the various crust surfaces with their respective runoff coefficients one obtains a seasonal runoff of 49% of 650 mm and a design runoff of 64% of the 89 mm design storm (see also table 3). This latter value is compared with the Orstom-method for the calculation of the design discharge:

$$V_{10} = P_{10} \cdot A \cdot Kr \cdot S$$

In which:  $V_{10}$  is the 1 in 10 years design discharge,  $P_{10}$  is the 1 in 10 years design precipitation (89 mm based on 30 years of records),  $A$  reflects the size of the watershed ( $A = 1$  for  $< 25 \text{ km}^2$ ),  $S$  is the permeability class of the watershed and  $Kr$  is a factor for vegetation cover (1 for degraded Sahelian vegetation). For a choice of permeability class  $P2 = 0.75$ , for slope class  $R3$ ,  $V_{10} = 8,344 \text{ m}^3$  which implies a runoff percentage of 75% or if  $P3 = 0.35$  is chosen  $V_{10} = 3,894 \text{ m}^3$  and the runoff is 35%. The above calculated crust weighted mean of 64% is in between these values.

The following students of the Agricultural University of Wageningen have contributed in the period 1992-1995 to the results presented here (their reports are available at the *Antenne Sahélienne* in Ouagadougou): A. BLEUMINK, L. COOLEGEM, K. VAN DIJK, R. GEELHOED, M. DE HAAS, I. JANSSEN, S.J.T. POUTSMA, M. RIETKERK, B. TAMMES, J.D. WIJNHOUT, A.J. OTTO and A. DE WIT.

## 4. Excursion

The route Ouagadougou - Kaya is given in figure 11.

### 4.1. Outcrops of granite and porphyroïdic granite near Ziniaré

### 4.2. Baobab trees in the conservation forest of Bissiga

The Baobab tree or *Andosonia digitata* belongs to the *Bombaceae* family and is characterized by: great height, alternating leaves and capsulated fruit. The holes inside of the trunks are often occupied by wild animals.

The tree plays a cultural, social and economic role in the society. It is believed to be occupied by spirits and is used as worship area. The area under the tree is used as meeting zone for old men. Its products are used for feeding, medicines, rural chemistry and cooking tools.

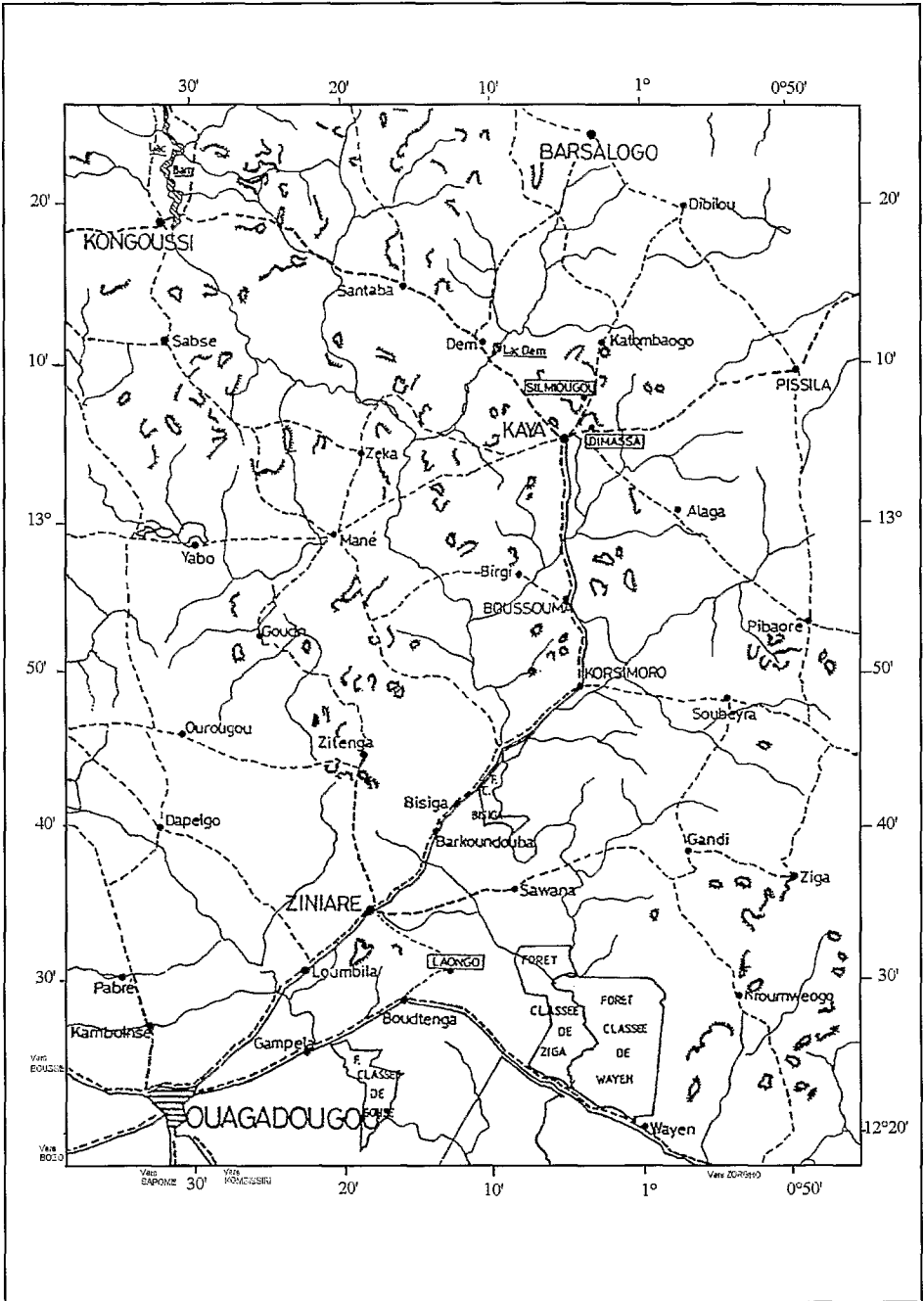


Figure 11. Topographic map showing the excursion route.

### **4.3. Green schist and dolerite of the Birrimian**

### **4.4. Eroded zone of Dimassa**

#### ***4.4.1. Demonstration of remote sensing imagery and physiographic map of the Kaya region***

In the area, two geologically defined landscapes are found:

- Schist and meta-volcanites;
- Granite and migmatite.

A further subdivision is done on the physiographic map, showing toposequences from high to low: schist hills and ironcapped plateaus, steep slopes, colluvial footslopes, faint slopes of the valley and valley bottoms. The ironcapped plateaus are clearly marked on Landsat TM imagery, while the valley bottoms show up by their more dense tree vegetation.

#### ***4.4.2. Demonstration of the Mini-IRIS field spectrometer***

This is a single field of view instrument, so a reference plate has to be used to determine the incoming solar radiation. The instrument measures in 140 wavelength bands between 400 nm and 2,500 nm.

For the use of field reflectance to explain the reflected radiance, registered by the satellite, the correlation between the two should be high. An example of this relation is given in figure 12. Different spectral curves measured in the Kaya region are given in figure 13.

#### ***4.4.3. Soil profile (92-4 bis): Eutric Fluvisols or Sols peu évolués d'apport alluvial sur Sols ferrugineux tropicaux lessivés***

Sedimentary cover derived from granite weathering and transported by runoff and wind, lying over an Early Holocene truncated B2t horizon with brown and red mottles at 80 cm soil depth. Profile situation: valley with nearby granite outcrops.

For soil analyses of profile 92-4, located at 100 m distance at the side of gullied land, the reader is referred to Table 9. The soil horizon in this profile at a depth of 81-120 cm (representing a truncated Bt horizon) is rich in iron concretions; a hardened ironstone layer is found at greater depth.

### **4.5 Soil profile (93-1) near Silmiougou: Eutric Cambisol or Sol brun eutrophe tropical**

A soil extending up to 55 cm depth with a cambic horizon, developed on schist exposed on a footslope.

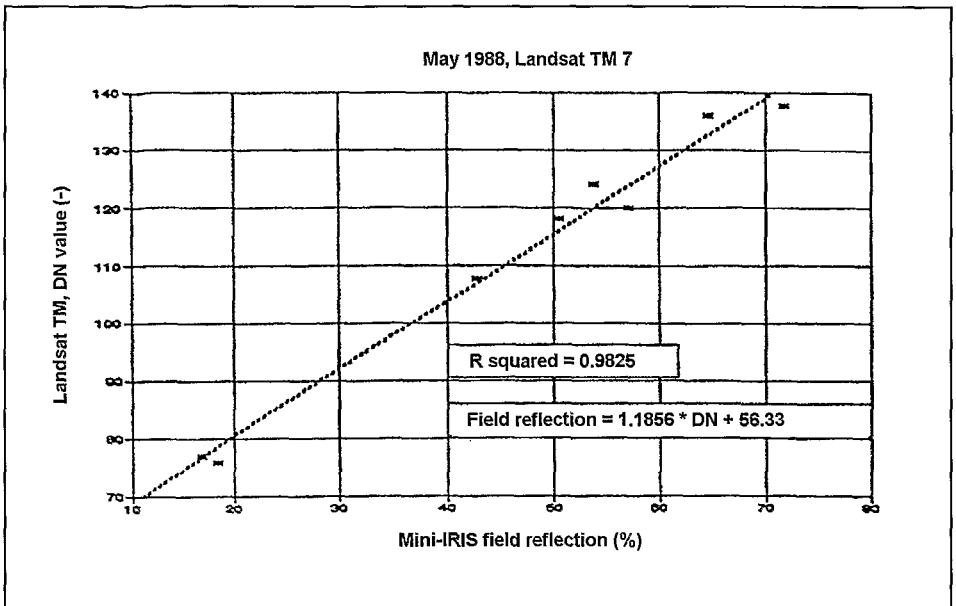


Figure 12. Regression between Landsat TM7 and the Mini-IRIS.

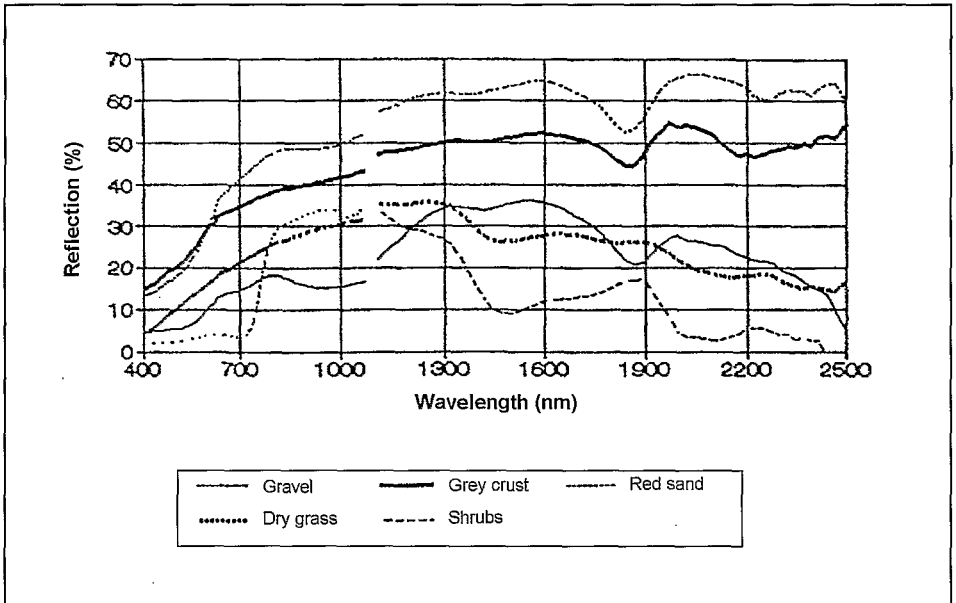


Figure 13. Different spectral curves of surfaces in the Kaya region, measured with the Mini-IRIS.

#### 4.6 Soil profile (92-2) near Silmiougou: Luvic Arenosols or Sols minéraux bruts d'apport alluvial sur Sols ferrugineux tropicaux lessivés

Sedimentary cover derived from granite weathering and transported by runoff and gullies, lying over an Early Holocene truncated B2t horizon with brown mottles at 90 cm soil depth. Profile situation: valley with nearby gully. For analytical data of sedimentary cover, see table 9.

##### Discussion on soil classification

A dispute arose about the following: although the plant has to extract most of the nutrients of the young sedimentary cover in the profiles 92-4bis and 92-2, the FAO-UNESCO Legend of the Soil Map of the World would force the classification of Luvisols. Furthermore, material transported over short distances by water in gully systems (*ravinement*) is regarded by most experts as colluvium. However, others claim a fluvic character for the same deposit.

In the criteria for classification of the Soil Map of the World, it is stated that if horizons are buried by 50 cm or more of newly deposited surface material, they are no longer diagnostic for classification purposes. This means that in both cases (92-4bis and 92-2), the soils have to be classified according to the characteristics of the sedimentary cover.

Is the material fluvic ? The organic matter content remains at 0.2% for the upper 89 cm of soil in profile 92-2. For profile 92-4bis, it remains at 0.2% for the upper 23 cm and between 81 cm and 120 cm, while it is above this value between 45 cm and 81 cm. There is some stratification but less than 25 % of the soil volume. Conclusion: the material of profile 92-4bis has to be regarded as fluvic owing to the irregular distribution of organic matter with depth. The material of 92-2, however, does not fulfil the carbon requirements to be considered fluvic.

The soil profile 92-4bis was arbitrarily classified as Luvic Arenosols in having clay accumulation within 125 cm of the surface. Arbitrarily, since the clay illuviation took place in a truncated buried soil.

Postexcursion, the mineralogical and chemical composition was determined. For this purpose, 4 types of soil material were sampled (between brackets, abbr. in tables 10 and 11):

- Schist derived soil (*schder*);
- Sedimentary cover of mixed origin in schist and meta-volcanites landscape (*mixsch*);
- Mottled subsoil in the granite and migmatites landscape (*subgran*);
- Sedimentary cover in the granite and migmatites landscape (*sedgran*).

X-ray diffraction of the soil fraction < 2 mm showed the mineralogical composition to be: dominantly quartz, common kaolinite, some feldspar; sample 92-4 (23-45 cm) was very rich in quartz. The schist-derived soil contained in addition: smectite and a little goethite. The latter was also present in sample 92-2 (100-105 cm).

**Table 9.** Soil analyses 92-2 and 92-4 (BUNASOLS, National Soils Bureau).

Soil analyses	92-2	92-2	92-4	92-4	92-4	92-4	92-4	92-4
Soil depth (cm)	6-43	43-89	4-11	11-23	23-45	45-61	61-81	81-120
Texture class	ls	ls	ls	s	ls	sl	sl	l
< 2 µm	7.5	8.3	7.5	6.3	7.5	17.5	16.8	26.8
2-50 µm	9.6	6.5	6.5	7.3	10.2	16.3	16.3	12.5
50-100 µm	27.8	20.1	27.8	28.9	21.5	17.6	26.4	20.1
100-250 µm	28.5	27.2	29.9	36.7	22.5	18.7	20.1	17.0
250-2000 µm	26.6	37.3	28.3	20.8	38.4	20.0	20.4	23.7
C <sub>total</sub> (%)	0.2	0.2	0.2	0.2	0.2	0.4	0.3	0.2
CaCO <sub>3</sub> (%)								1.8
pH <sub>water</sub> 1:2.5	5.9	6.2	5.4	5.8	5.4	4.9	5.3	7.0
pH <sub>KCl</sub> 1:2.5	4.4	4.7	4.1	4.4	4.4	4.0	4.5	5.8
Exch. H <sup>+</sup> (meq/100 g)			0.5		0.3	0.8	0.5	
P <sub>acc.</sub> (ppm)	2.2	1.6	1.3	1.7	0.6	1.6	0.9	5.4
K <sub>avail</sub> (ppm)	53.5	34.9	11.8	9.2	8.4	9.8	9.2	20.6
P <sub>total</sub> (ppm)	76.6	38.3	38.3	38.3	38.3	95.7	76.6	95.7
Free Fe <sub>2</sub> O <sub>3</sub>	1.2	0.3	1.0	0.8	1.0	1.6	1.6	1.5
Exch. Bases (meq/100 g)								
Ca <sup>2+</sup>	1.5	1.7	1.3	1.3	1.6	2.9	3.0	5.2
Mg <sup>2+</sup>	0.4	0.4	0.4	0.4	0.5	1.1	0.8	1.2
K <sup>+</sup>	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.1
Na <sup>+</sup>	0.2	0.1	0.1	0.1	0.3	0.2	0.1	0.1
Sum of bases	2.3	2.2	1.7	1.9	2.5	4.1	3.9	6.5
CEC (meq/100 g)	7.3	6.0	9.0	5.1	4.4	5.8	7.3	8.3
Base saturation (%)	31.4	38.8	18.7	36.5	56.6	70.7	54.1	

Evidence for differentiation between the 4 types of material was found by X-ray fluorescence spectrometry (Tables 10 and 11).

Considering the sedimentary cover in the granite and migmatites landscape (*sedgran*), this material was found to be for the greater part derived from granitic rock, witness its composition (Table 10). The mottled subsoil (*subgran*) is different from its sedimentary cover, showing some influence of schist and metavolcanic material (*schder*, Table 10).

The sedimentary cover of mixed origin in the schist and metavolcanites landscape was found to be intermediate between the mottled subsoils (*subgran*) and schist derived soil or between granite and schist derived soil.

**Table 10.** Results of XRFs-analysis for major and minor components (WAU, Soil Science and Geology).

Samples	Soil depth (cm)	SiO <sub>2</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)	TiO <sub>2</sub> (%)	K <sub>2</sub> O (%)	MgO (%)	CaO (%)	MnO (%)	P <sub>2</sub> O <sub>5</sub> (%)
<i>schder</i>										
93-1	50-55	66.75	12.18	8.38	1.21	0.49	1.04	1.50	0.13	0.06
<i>mixsch</i>										
92-3	9-40	83.57	7.89	3.53	0.75	0.65	0.26	0.10	0.04	0.03
92-3	40-54	85.68	8.35	3.48	0.78	0.65	0.22	0.08	0.05	0.03
92-3*	40-54	80.54	8.31	3.52	0.76	0.65	0.24	0.08	0.05	0.03
92-3	54-77	83.45	8.53	3.50	0.80	0.64	0.25	0.09	0.04	0.03
92-3	77-110	81.75	9.37	3.89	0.83	0.68	0.26	0.09	0.04	0.03
<i>subgran</i>										
92-4	81-120	76.57	11.06	3.95	0.59	0.81	0.24	0.07	0.04	0.02
92-4*	81-120	76.69	11.10	3.97	0.63	0.80	0.23	0.08	0.04	0.02
92-2	100-105	70.99	12.48	6.84	0.75	0.70	0.28	0.07	0.01	0.02
92-2*	100-105	71.53	12.48	6.83	0.73	0.69	0.29	0.07	0.01	0.02
93-4b	100-105	79.80	9.34	3.26	0.55	0.82	0.29	0.17	0.03	<0.01
<i>sedgran</i>										
92-4	23-45	90.59	5.09	1.87	0.44	0.85	0.14	0.05	0.02	<0.01
92-4	45-61	83.13	8.66	2.60	0.54	0.96	0.24	0.08	0.03	0.02
92-4	61-81	84.04	8.34	2.53	0.52	0.87	0.17	0.04	0.02	0.02

\* duplo. Other abbreviations: *schder*: schist derived; *mixsch*: sedimentary cover of mixed origin in schist and metavolcanites landscape; *subgran*: mottled subsoil in granite and migmatites landscape; *sedgran*: sedimentary cover granite and migmatites landscape. Rem : 92-3 was not visited during excursion.

Although weaker in evidence, the results on trace elements support these findings in most instances (Table 11).

Thin sections were studied by Dr. Ing. A.G. JONGMANS of the Laboratory of Soil Science and Geology (Wageningen Agricultural University). The results were as follows:

- Sample 92-2 (100-105 cm; *subgran*) had about 3 % argillans with many silica accumulations as result of ferrollysis;
- Sample 92-4 bis (100-105 cm; *subgran*) showed 1 % argillans with few silica accumulations as result of ferrollysis;
- Sample 93-1 (50-55 cm; *schder*) showed stress cutans (skelsepic and glaeseptic) but no sign of ferrollysis.

The presence of illuvial concentration in the mottled subsoil of the granite and migmatites landscape is proved by these results. The results point to a soil forming process under more humid conditions than today, witness the ferrollysis. Such conditions existed in the area during the Early Holocene.

Since the presence of new material on top of these horizons is proved, the soil profile 92-4bis is classified as Eutric Fluvisol in having a sedimentary cover with fluvic character and a base saturation of 50 percent or more at least between 20 cm and 50 cm from the surface (neglecting 20-23 cm with low base saturation in 92-4, Table 9), lying over an horizon with clay accumulation at a depth of more than 50 cm.

**Table 11.** Results of XRFs analysis for trace elements (WAU, Soil Science and Geology).

Samples	Soil depth (cm)	Zr (ppm)	Ba (ppm)	V (ppm)	Cr (ppm)	Sr (ppm)	Cu (ppm)	Ni (ppm)	Rb (ppm)	Nb (ppm)	Pb (ppm)	Co (ppm)	Ga (ppm)
<i>schder</i>													
93-1	50-55	444	279	280	84	79	113	52	32	34	17	28	23
<i>mixsch</i>													
92-3	9-40	519	200	158	63	47	48	40	37	34	19	25	18
92-3	40-54	516	225	159	61	50	59	34	38	33	20	17	19
92-3	54-77	522	210	153	52	45	45	35	37	31	16	11	21
92-3	77-110	539	209	178	60	49	57	41	42	35	20	14	20
<i>subgran</i>													
92-4	81-120	445	394	123	53	79	52	30	52	26	18	<10	21
92-2	100-105	410	286	163	91	76	49	28	43	27	26	<10	23
93-4b	100-105	474	410	112	51	97	49	26	42	24	19	10	20
<i>sedgran</i>													
92-4	23-45	527	335	90	40	75	35	49	32	32	16	31	15
92-4	45-61	451	356	108	40	75	45	30	47	29	15	14	18
92-4	61-81	508	358	106	41	73	39	38	40	29	19	19	18

For abbreviations on samples: see table 10. 92-3 was not visited during the excursion.

The soil profile 92-2 is classified as Haplic Arenosol in having a sedimentary cover of coarse texture and lacking fluvic properties; it also covers an horizon with clay accumulation at a depth of more than 50 cm.

This classification does justice to the fact that the upper 50 cm of soil is most important for plant growth and classification should reflect the genesis of that part of soil. However, it is regrettable that the presence of B2t horizons in the subsoil is not reflected in the class name.

Also, the geological term "colluvium" would be misused if applied to the deposits under consideration. Besides some minor aeolic influence, these are deposited after short fluvial transport in an active eroding and accumulating environment. The French terms "*ruissellement*" and "*ravinement*" are most appropriate for this. In this environment, only locally periods of soil formation are long enough to produce A-horizons with organic carbon contents of more than 0.2%.

The French soil classification system (CPCS, 1967) gives no solution for the classification of polygenetic soil profiles since the lower limit of newly deposited material on top of old soil material is not defined. Taking the same criterium of the Soil Map of the World (50 cm thickness), the two profiles (92-4bis and 92-2) have to be classified as: *Sols peu évolués d'apport alluvial*. To do justice to profile development, the addition is given: *sur Sols ferrugineux tropicaux lessivés* (subgroup *induré* for profile 92-4bis).

#### **4.7. Visit to degraded watershed of Silmiougou (for data, see 3.2)**

#### **4.8. Panoramic view from an ironcapped plateau edge**

The ironcap is regarded to be from Pleistocene origin. At many places, a thin aeolic cover is found where vegetation offered a take hold for the sediment.

The different maps of the Kaya region were presented and discussed at this place, maps on drainage pattern, physiography, land use and soils. These maps were derived from aerial photo-interpretation, satellite image interpretation (a.o. NDVI) and were used in GIS for further combination to arrive at erosion hazard estimates.

The discussion focused on land capability and development strategies.