village water
reservoirs project
tamale
ghana

tamale
archdiocesan
development
secretariat

cebemo
the netherlands

Models for the prediction of soil erosion and silt sedimentation in artificial lakes in Northern Ghana in order to determine life time.

Alfred L. de Jager 1989a

36 pages 16 figures.

sawa
Schoolplein 7
3581 px Utrecht
the Netherlands

SAWA consultancy group for water supply,sanitation and water management
Schoolplein 7 Utrecht the Netherlands.
telephone (0)30 340 764
Village Water Reservoir Project, Yapei Road, above Lamashiegu.
P.O. box 163 Tamale Ghana.

A desk study for the
Village Water Reservoirs Project
executed by SAWA in
Northern Region Ghana.

Models for the prediction of soil erosion and silt sedimentation in artificial lakes in Northern Ghana in order to determine life time.

Alfred L. de Jager 1989a

36 pages 16 figures.

Contents.

Acknowledgements:

This study has benefited comments and corrections by Dick Bouman. The issues treated in this text have been discussed by all members at the SAWA office in Utrecht.
To them and the SAWA staff in Tamale, I wish to express my gratitude.

Alfred L. de Jager.

SUMMARY. USLE METHOD AND DRAINAGE DISCHARGE VALUES ARE USED TO ESTIMATE THE LIFE-TIME OF VILLAGE WATER RESERVOIRS IN NORTHERN REGION GHANA. THE REQUIRED DATA ARE HOWEVER NOT AVAILABLE, THEREFORE A FIELD SURVEY CONCERNING SOIL EROSION IS PROPOSED AND SOIL CONSERVATION IS DISCUSSED. FINALLY IT IS EXPECTED THAT THE LIFE-TIME OF PONDS DUE TO SILTATION IS AROUND 25 YEARS.

Keywords

Soil erosion, USLE, West Africa, Water project, Ghana, Northern Region, Vetiver grass.

1 Introduction.

This report is a desk study concerning soil erosion problems and their relation to surface watersupply reservoirs.
We will introduce soil erosion as the main agent determining life time of ponds and dug-outs with a water surface till 3 ha. and maintenance procedures for water purification means.
The former is rather obvious, soil erosion causes a high sediment yield in the stream which fills up a reservoir. The sediments will settle in the reservoir thus filling up the reservoir and diminishing the volume to be stored with water.
Waterpurification means are for their functioning very susceptable for turbid water. Especially filtration means like slow sand filters are susceptable for the turbidity of the water.

1a About the project.

This text is also written as a manual for a surface water supply project now realized in Ghana and constructed by SAWA (Dutch Consultancy group for water supply).
For readers not familiair with this project, the following serves as an introduction.
In Ghana's Northern Region villagers have a need for an enlarged (quantitative) and improved (water quality) water supply.
In the Tali-Tolon area (see figure 1), 30 kms west of regional capital Tamale, aquifers for water supply using ground water are reported to be too expensive to exploit at the moment. Boreholes and pumps will be costly, therefore the Archdiochiese of Tamale, financed by Cebemo (Holland) asked Sawa to construct dams.
Behind the dams, water flowing in the streams during the rainy season, is collected. The ponds should supply as much water for human and animal consumption as the nearby village needs during the dry season. The dry season lasts from november till may.
In the region people already constructed dams to store water. These dams are not providing enough water for the fast growing population (3%) and they are also filled in with sediments thus diminishing the water storage volume.

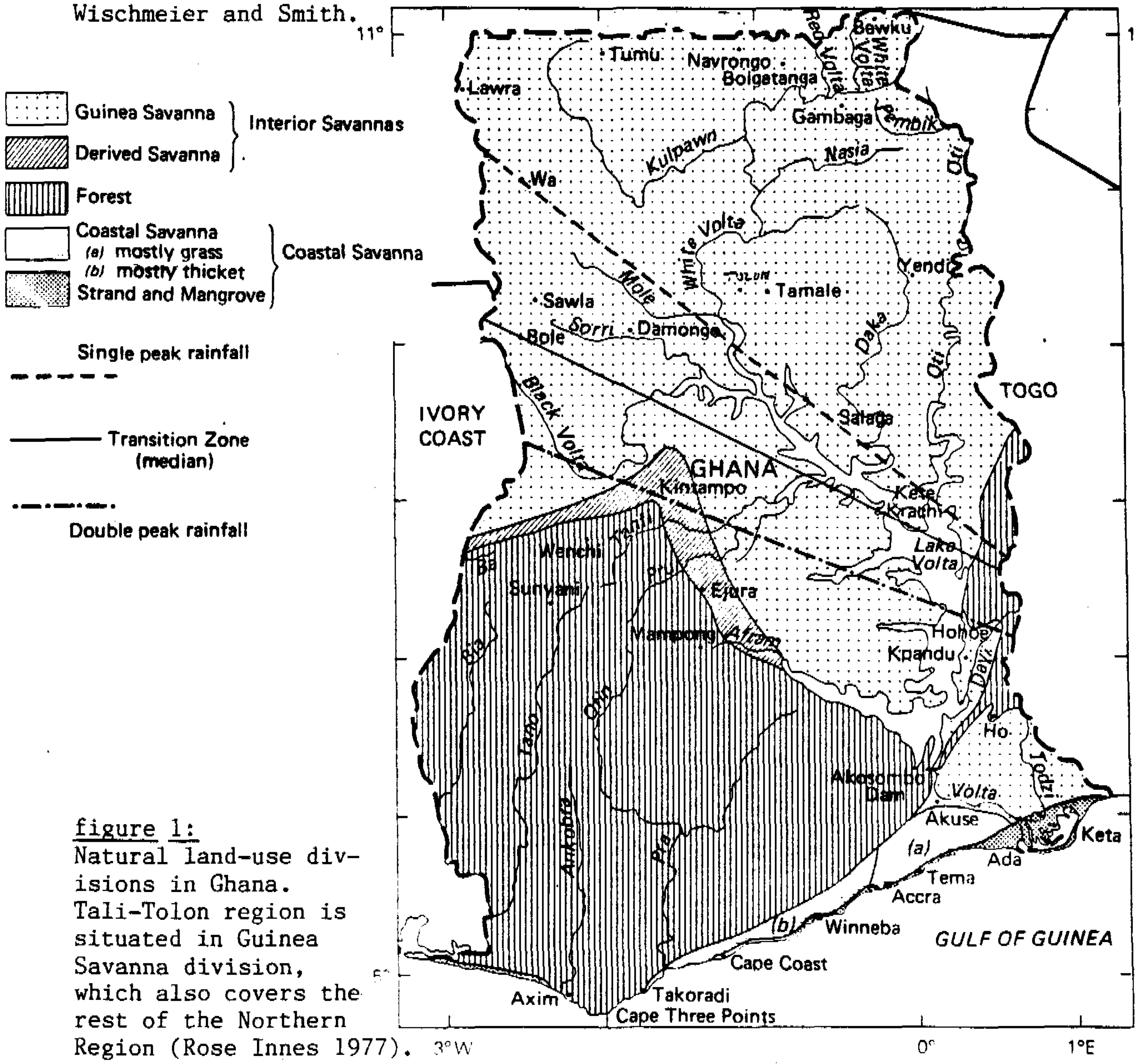
1b Health.

The not flowing water in the ponds are reported to promote several waterborn diseases in the supplied region. Guinea worm and Bilharzia are examples of these. If the water is purified these diseases can be controlled (Brussee 1988).
At the Chirifoyilli dam (figure 2) SAWA constructs infiltration galleries also as a purification means (Kuyper & Abdulai 1988). The gallery reliability is seriously affected by silt inwash.
Silt inwash retards the velocity of the water flowing through the gallery sandbody. The velocity determines the capacity of the well connected to the pond by the gallery. At a certain moment the capacity will be too low and the users will abandon the well. According to Gijsbers (1988) this happens when the silt layer on the gallery is 2 cm. thick, presuming that the hydraulic conductivity of the layer is 0,01 cm/day. Unfortunately it is

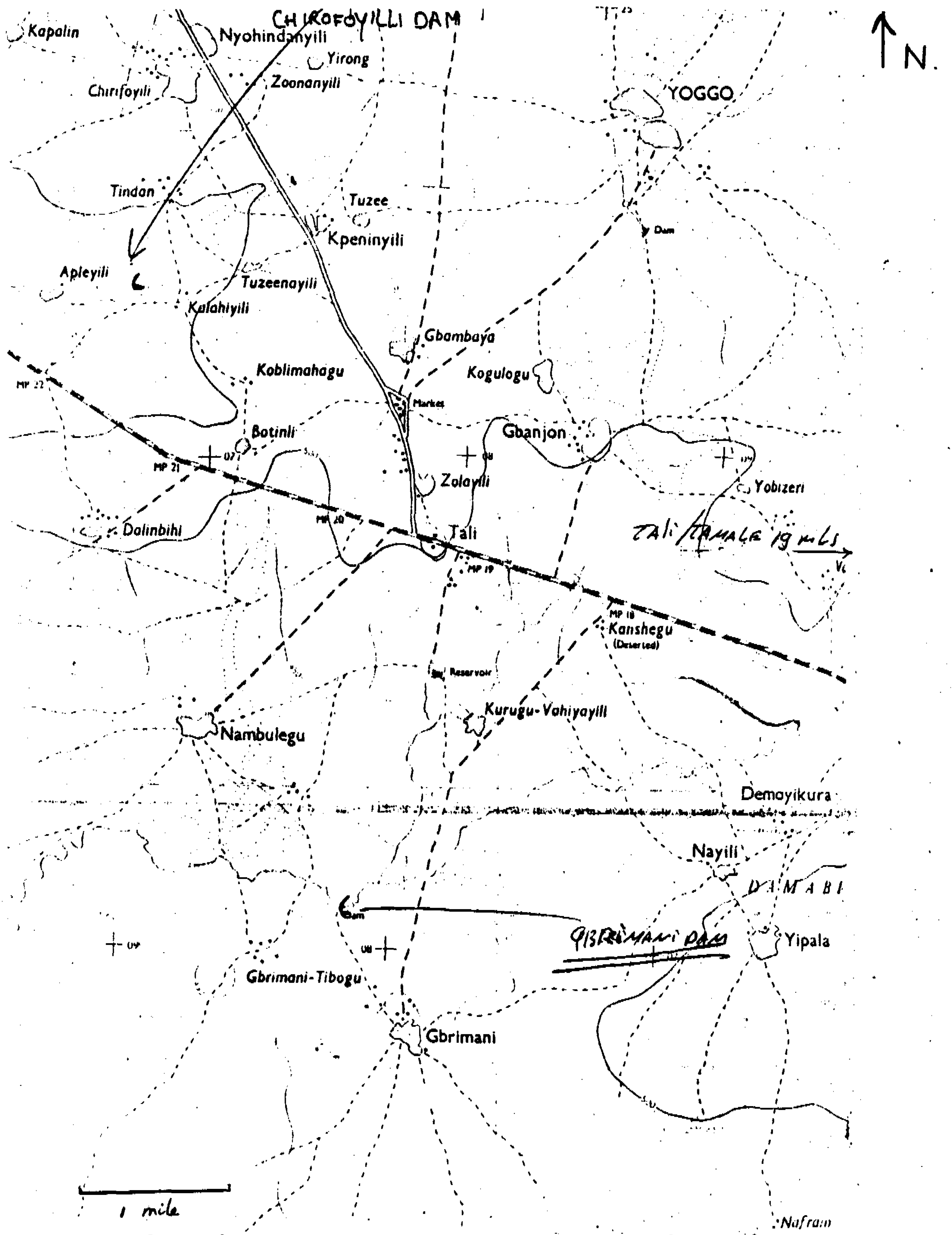
expected that the hydraulic conductivity is 100 times lower in a settled silt layer due to its lack in void structure and porosity.

<u>1c The rate of sediment inflow.</u>

Due to the importance of silt in the ponds, this report tries to hand out methods for the prediction of the intensity at which erosion and sedimentation processes are functioning in Northern Region in Ghana. Estimations concerning these issues are being made upon literature data.
We also try to discuss several measurements concerning erosion to be executed by SAWA in Ghana, in order to specify the susceptability for erosion of every small watershed in which SAWA is likely to construct or enlarge a dam. The method treated in the text concerns the so-called USLE method, developped by Wischmeier and Smith.



<u>figure 1:</u>
Natural land-use divisions in Ghana. Tali-Tolon region is situated in Guinea Savanna division, which also covers the rest of the Northern Region (Rose Innes 1977).



<u>figure 2:</u>
Project area situated 30 kms. west of regional capital Tamale
Projects are now executed in Chirifoyilli and Gbirimany.

2 Natural and Soil Erosion.
Qualitative description.

The silt and other sediment is delivered by the so-called catchment area. This is the area upstream the pond. The quantity (in ton/ha/year), as well as the quality (texture or grainsize distribution) of the sediment in the pond is dependent on the erosional features in the catchment area.
The erosion processes, caused by water movement, can be divided into two features.
The natural- or geologic erosion which causes the gradual development of a landscape. The erosional agents (streaming water) are in equilibrium with the soil forming processes (weathering), hence the soil stays of the same depth. The soil profile will therefore remain in an equilibrium. The profile can be recognised by the existence of all horizons. These horizons are divided into an eluviation- (A), an illuviation (B), and a weathered- (C) horizon.
Soil erosion or unnatural erosion is the feature which develops when e.g. the vegatative cover is changed by agricultural use. It can be recognised in the field by a truncation (a lack) of the A and B horizons. In extreme cases also the C horizon is distorted. We should however remember that this soil profile differentation can also be absent due to soil movement by termites, or pertubations caused by human activities like ploughing deeper as 50 cm.
If soil erosion is not controlled by so-called conservative measures it might finally wash away the fertile soil. Severe soil erosion damage can act in 1 day, during an excessive rainstorm.

2a Soil Erosion in Northern Ghana.

Main agents causing soil erosion in Northern Ghana are:
1. Rain or Splash Erosion.
2. Sheet Erosion.
3. Rill Erosion.
4. Gully Erosion.
5. Streambank Erosion.

In this text the aim is not to rewrite the erosion manuals, we need to quantify the problem in Ghana. First we should know roughly the impact of each agent. This is especially necessary in order to develop knowledge to judge the quality of the catchment area.

1. Splash Erosion.

During tropical rainstorms the kinetic energy of raindrops is very high. Therefore if the soil is bare, a drop falling on it will cause the development of a mini-crater (see figure 3). If this crater is situated on a slope the material falling downslope will be more as the material falling upslope. The resultive effect is a gradual creep of soil material downslope.

2. Sheet Erosion.

If the capacity of the soil for water infiltration is exceeded by the intensity of the falling rain, the not infiltrated water will flow over the soil surface. The fine particles dispersed by splash erosion also reduce the infiltration capacity and hence stimulate sheet erosion. Also a soil crust can develop by redistribution of the dispersed finer particles on the soil surface. The crust will diminish the infiltration capacity.
The sheetflow (also called surface run off) has the ability to disperse loose soil material, e.g. humic acids and dispersive clay types. Also the water obtains kinetic energy. This kinetic energy is dependent of the slopelength and angle. If the energy is higher than the soil resistance, the flow will take coarser, not dispersed, material also downslope.
Soil resistance is a soil property dependent on the soil type, roughness of the soil surface and soil microbial life (I Roelse & A de Jager 1988).

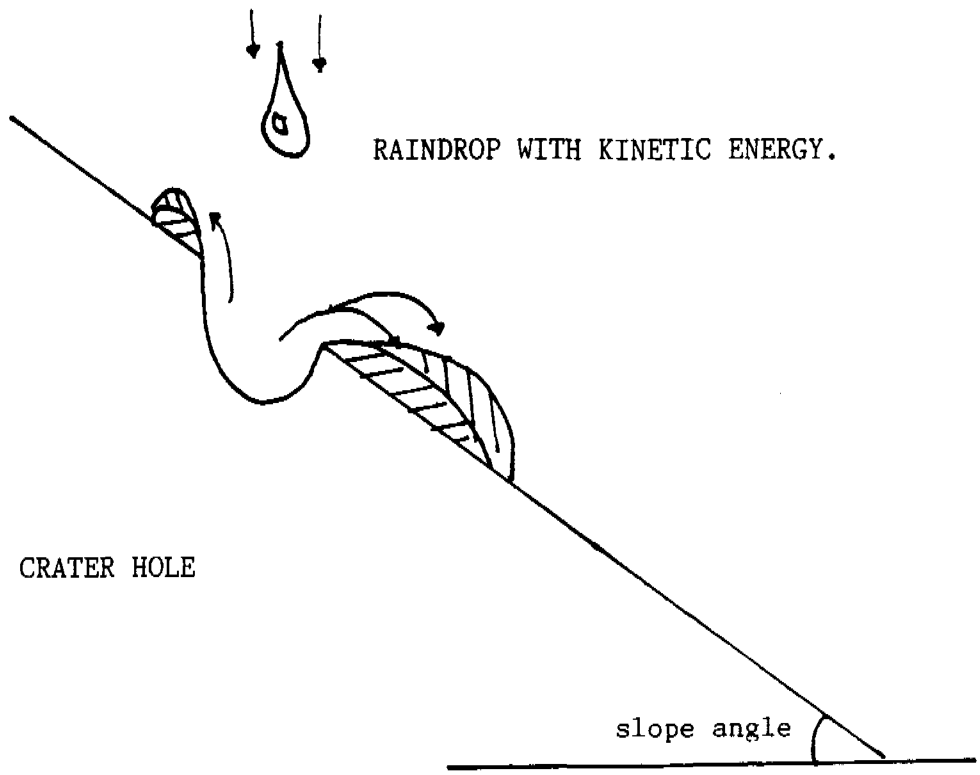


figure 3:
Raindrop falling on a slope. The expelled material will creep in larger amounts down than up. Resulting in a net down-slope movement if the soil is bare or slightly covered and the raindrop kinetic energy above a soil dependent triggervalue.

3. Rill Erosion.

Depending on the length of the slope covered with sheet flow, the water will concentrate into a rill. This process is also influenced by the micro-topography of the slope. A rill can be restricted in its further development by proper tillage.

4. Gully Erosion.

If the rill is too deep to be undone by human labour we speak of gully erosion. Concentration of many rills may cause the development of a gully downstream. A gully is to be seen as a hazard. Many gullies create a landscape called badlands. These lands will have to be abandonned. Further downstream the high sediment yield, it is the soil which is displaced, will cause rivers to change their flow patterns and thus inundations of lower areas.

5. Streambank Erosion.

Depending on the speed of the water flowing in a stream, material is carried downstream. During high floods the kinetic energy of the flowing water becomes so large that the stream is able to carry material from its embankments downstream. Thus increasing the sediment yield.

In Northern Ghana splash and sheet erosion are the dominant processes. However these two erosion types are difficult to observe for untrained people. Only precise observations during rainstorms and remarking the truncation of A and/or B horizons , if they were present, will prove their activity.
Sheeterosion can also be identified by bare roots above the soil surface on a more than 2% slope.

<u>2b Sedimentation of soil material in the pond.</u>

Rivers and streams discharge the eroded material if the run off or gully reaches a river. Rivers also discharge water without soil particles. The latter reaches the river through groundwater flow; this is called the baseflow. The ratio surface run off/baseflow is an important river characteristic. The sediment ratio will be low if the run off/baseflow ratio is low (see chapter 5).
SAWA is constructing dams in intermittent streams. In the Tali-Tolon area groundwater is difficult to reach. This is due to the lithography of the area (Bouman 1988).
The water stored behind the dam will therefore largely be originating from the surface run off developed during a rainstorm. The prevailing text states that surface run off is the agent for sheet erosion.
We should therefore expect a considerable sediment yield in this water.
When the stream water looses its velocity the sediments will settle.
In the ponds the velocity of the water will be very low or zero.

Therefore it is expected that all sediments settle and a small delta develops at the entrance of the stream into the pond.
For the functioning of the galleries the finer particles will cause disruption (Gijsbers 1988). The velocity of the water, flowing into the pond, determines the texture of the sediments to settle. A higher velocity will tolerate only coarser sediments to settle.
We can presume that coarser particles will settle first; it is at the entrance of the stream into the pond. Unfortunately, the galleries being made on the dam are in the low and no-velocity part of the pond. So the fine particles will settle above the galleries. The micro-delta which develops in any pond is designed in figure 4.
The actual development of a delta in a small pond is dependent of a large number of variables; like the saltcontent of the pondwater and the slope of the pond bottom.
In the situation that an old pond has to be enlarged, like in Chirifoyilli (see chapter 3a-1) we can attempt to preview the delta which will develop in a new pond, by a description of the delta present in the old pond.
A proper description can serve as a model for the future development of the delta in the enlarged pond.

2c Delta description.

We can quickly describe the delta of the old pond by taking soil samples in the pond, following a section from the stream entrance to the dam egde. Sampling can be done in every season, in the wet season we can sample with the aid of a boat or boots. The soil samples taken should revail the texture and as well the actual density of the sediments settling above the proposed infiltration gallery site. This latter density (qs) can be useful in the GES calculation system (see chapter 3a), when replacing the theoretical density (qt).

The description can be supplemented with information about the sediment charge of the water flowing into the pond during the rainy season. Also spill-water should be sampled when the pond is exceeding its design level and the spillway is used.
Sampling is done by taking a half liter of water from the stream or spill way using milk bottles or alike. Water should be sampled in the center of the flow, if possible. The description of how and when the samples are taken is essential. It is recommended to sample during the beginning , middle and end of the rainstorms, if possible at time intervals.

At the moment that the spillway is used and flow out of water is reported, it is expected that the coarser sediments will stay behind the dam. The finer sediments, clays especially, will suspend in the quick flowing water and wash away.

To calculate the life time of a pond we should know the speed at which the erosion processes are working in the catchment area. For this we need to quantify all erosion causing processes. Finally we should estimate the amount of soil material which will be discharged by the river into the pond.

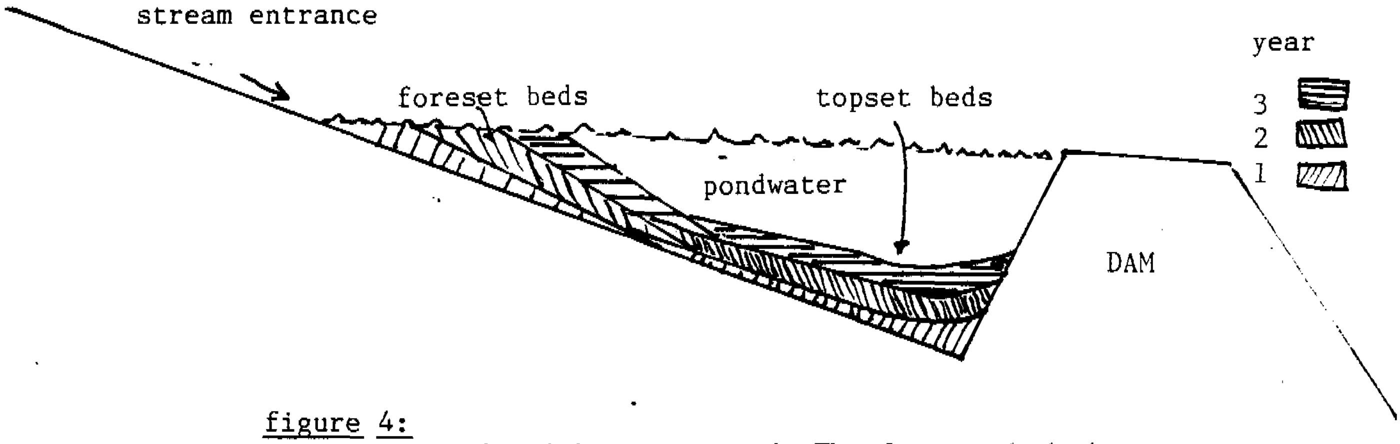


figure 4:
Development of a delta in a pond. The foreset beds have a coarser texture than the top set beds. We can recognise a layer settled every year like the rings of a tree.

3. Erosion and sedimentation.
Quantitative models.

Many attempts are made on the quantification of erosion processes. Most of them, unfortunately, are only applicable in a certain climate and under certain soil conditions.
We want to consider a General Estimation System (GES) and to propose on the basis of GES a catchment-area survey to make the GES more specific for the area in which the dam is built. We will use river discharge and sediment-ratio estimations as proposed by some authors.
In chapter 4 we will consider the USLE equation. This equation developped by Wischmeier & Smith for soil conservation purpose helps us to indentify erosion causing processes. It is a soil loss model requiring a number of data, to be obtained from data books and a limited field survey. Data are obtained from Roose (1977) and data to be obtained from a field survey are discussed.

3a A general estimation for semi-arid regions.

According to El Swaify and Douglas (1982) soil loss in semi-arid regions in Tanzania varies between 3 and 14 ton/ha/year (1 ha equals 10000 m2) soil loss in small catchment areas. For Northern Ghana they estimate soil loss (referred to as A) between 2 and 10 tons/ha/year.
Assuming that the dam sites are erected in an 'ordinary catchment area' we can calculate the thickness of the sediments which will settle on the bottom of the pond. We call this thickness the mud-height MH. The following exemplary calculation needs some assumptions. The implications of these assumptions will be dealt with later. The assumptions are: all sediments will settle equally spread on the bottom of the pond subsurface and not concentrate in a small delta at the entry of the pond; there is no outflow of sediments from the pond by e.g. overflow or inlet structures.

3a 1. The Chirifoyilli dam-site.

Catchment Area Surface (C) times Soil loss estimate (A) yields the total sediment quantity to be delivered to the pond (C*A)
if we know the total pond surface (P) then
C*A/P
gives the mud-weight (MW) distributed equally throughout the pond (in kg/m2/year).
For infiltration galleries as proposed for the Chirifoyilli dam site we will calculate a preliminar estimation to obtain an idea about the sedimentation in the pond.
For Chirifoyilli this yields;
A = 0,2 kg/m2/year (lower estimate El Swaify and Douglas).
C = 800 ha (estimated from 1:100000 map; june 1988 report).
P = 40000 m2 (estimated from 1:1000 map; june 1988 report).
then MW is,

800 * 10000 * 0,2 / 40000 = 40 kg/m2/year

if we take the theoretical density of sand qt = 1600 kg/m3;
we can rewrite MW as MH the mud-height.
so MH = 40 / 1600 = 0,025 m/year = 2,5 cm/yr
The higher estimate A, is 5 times higher (2 becomes 10) ;
MH being 12,5 cm./year.

<u>3a.2 The Gbirimani dam-site.</u>

For the Gbirimani dam the GES, is calculated as follows;

Catchment area surface C is = 5300 ha.
Pondsurface P = 3 ha.
then our lower estimate will be 0,2*5300*10000/3*10000 = MW
as mud-weight. = 353,3 kg/m2/year.
Using sanddensity again; qt = 1600 then 353,3/1600 = 0,21 m/year.
Thus higher estimate will be 1,05 m/year MH in the reservoir!

Remark; The Gbirimani dam-site is a dug-out system. Thus it is not constructed in the centre of the valley. Up till now we have no information about the sediments delivered to such a dug-out. MH is expected to be less than calculated.

<u>3b Elaboration of the GES calculation.</u>

The above shows that erosion causes a severe limitation in the reliability of infiltration galleries and reservoir life time.
The above calculation, however only takes the total sediment discharge of the Volta river basin into account.
GES compares the size of the catchment area to the subsurface of the pond. The values thus obtained are only an indication of what might happen in any area in the Volta river basin.
We can try to specify the GES calculation with a field survey to bring about more specific data. In the next chapter these measurements are worked out.

<u>3c Summarizing sedimentation measurements.</u>

The calculated yearly mud height at Chirifoyilli is approximately between 2,5 and 12,5 cm. Chapter 2 states that with some measurements data can be obtained in order to specify this prediction. Summarized we should take into account;
1. Distribution of sediments throughout the existing pond.
2. Actual inflow and outflow of sediments.
3. Density of the sediments to be expected at the infiltration gallery site.

ad.1 In order to predict the texture of sediments settling near and on the gallery.
ad.2 In order to proceed GES calculation with a specified estimate A.
ad.3 In order to predict the exact thickness and density of the sediments to settle on the galleries.

All we need for these measurements are an oven (105 C temperature); a balance (mg) and bottles and sieves.
With the bottles we can separate the finer fractions, the clays, while applying the law of Stockes. The sieves are to separate the

coarser fractions above 50 micronmeter.
Sampling can be done by untrained people, of coarse they have to be literate and a training of one day is required.
An indication of the clay mineralogy can be obtained by X-ray analysis. Samples can be send to the university of Legon or Kumasi. Clay dispersity is dependent of the clay type.
If a clay is easily dispersed it can be displaced as soon as splash erosion occurs.
In the tropical climate and along slopes a dominance of non-dispersive kaolinites is to be expected (Serno & v d Weg 1985).

The enormous sediment load in the Gbirimani pond is due to the GES calculation procedure in which the pondsize is compared to the catchment area size. If the former is very small compared to the latter obviously the equal distributed sediment height will be large.
In the Gbirimani context we have to correct the GES because the catchment area is smaller as it seems. This is due to other dams which are built upstream the Gbririmani dam. We first have to know the quantity of sediments stocked behind these dams. Actually we should only calculate the soil loss of the catchment area directly upstream the Gbirimani dam. Its size should be measured or estimated from aerial photo's.
Also it is reported (Kuypers 1988) that an inlet structure is used at Gbirimani. Depending on the rain intensity and catchment characterictics like soil types, the run off reaching the inlet structure can have a very variable sediment load. If we want to prevent high sediment load to flow into the pond we have to predict the moment when this will happen in a rainstorm. This aim is difficult to realize in an effective way if we want to prevent sediment inwash in the pond.
In general it is reported that at the beginning of a tropical rainstorm coarse textured material is discharged. After 30 minutes the developped sheet erosion causes clay to suspend and the finer particles will make up the larger part of the sediment load (A Rapp 1972). For the maintenance of the galleries it is better to prevent the finer particles from washing in.

3d Conclusions concerning the GES system.

The figures from El Swaify and Douglas (1982) show an alarming rate of sedimentation in the ponds. The GES system is however only an indication of erosion processes active in the large Volta river system. We can use the GES as an indication between the catchment area size and the soil loss per ha. in that area.
In order to indicate the erosion processes in a watershed smaller than 10 ha. we should indentify the land use and soil susceptability towards soil erosion in that area.
Wischmeier developped the Universal Soil Loss Equation (USLE) in order to quantify these and other erosion causing processes.

4. Erosion Susceptability of an area smaller than 25 square km. The USLE method.

Under the same circumstances like rainfall, land-use etc. each soil type will react differently depending on its so-called susceptability towards the erosional agents as described in chapter 2.
The susceptability can be quantified by the so-called USLE method (USLE = Universal Soil Loss Equation). In the United States many scientists contributed to the establishment of the USLE. The empirical equation could thus be based upon more than 10000 plot years of basic run off and soil loss data. This North American method quantifies all erosion causing phenomena. The USLE model can be succesfully applied in Northern Ghana as a completion of work done in Burkina Faso by Roose (1977).
An important advantage of USLE compared to GES is that the former takes all soil loss contributing factors into account. Thus measurement and data interpretation can be used for pond life time purpose as well as for soil conservation and improved land management.
The latter option will be dealt with in chapter 7.
The following text is written as a field manual for in order to estimate the six USLE factors from limited survey in the field in West Africa.

The USLE is an erosion model designed to predict longtime average soil losses in run off from specific field areas in specified cropping and management systems. Unpredictable short-time fluctuations, like excessive rainstorms, are not incorperated.
However for prediction of the life time of a pond or soil conservation the USLE has proved to be valuable (Wischmeier & Smith 1978).

The USLE proceeds as follows;

$A = R * K * L * S * C * P$ (Wischmeier & Smith 1978).

in which A = mean soil loss (ton/ha/year) compare to GES A.
R = rain variable.
K = soil erodibility variable.
L = slope lenght variable.
S = slope angle variable.
C = land use and crop management factor.
P = erosion control measure factor.

It is not in the scope of this report to outline every factor as well as to elaborate the theoretical impact of this widely used empirical equation.

4a USLE values for West Africa.

According to Roose (1977) the main variable for soil erosion in West Africa is the crop management factor C.
Slopes are long but not steep and the ferruginous or ferrallitic soils are reported to be less erodible as leached temperate

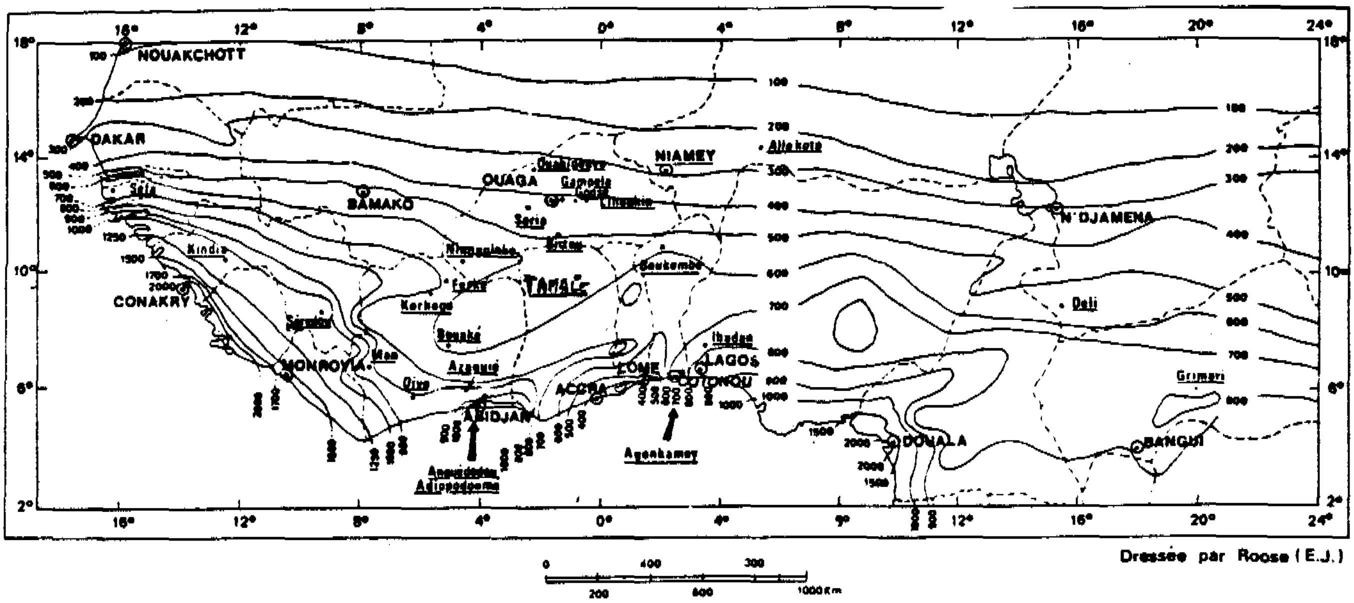
soils.
Finally the rain index R is high in West Africa as compared to the temperate climate.
Roose found that each index could vary as follows in West Africa;
R between 200-2000
K between 0,20-0,30
L*S between 0,1-2,5
C between 1-0,1
P between 1-0,1
Each index can be specified, a first specification will be given in the following chapters for the Tali-Tolon region.
The rain index and the crop management index, however, also vary during the growing season. Therefore Wischmeier & Smith (1978) hand out R and C approximations to be valued monthly. In is not in the scope of this report to promote this specification.
Our basic criteria will be the available data in literature and the time (probably one man-week for each dam) SAWA can spend on obtaining additional data from field surveys.
These criteria yield results which are an indication of the soil erosion activity in the specific area. They should not be quoted. Data are relaiable within large limits. This text serves as an aid to establish appropiate data.

4b R-value.

R-values are identified by keeping the five other erosion causing factors constant during plot experiments. Wischmeier later correlated the R-value to an easy obtainable value: called the EI parameter.
The EI-30 (energy times intensity) value equals for a given rainstorm the product of the total storm energy (E) times the maximum 30 minutes intensity (I-30).
Erosion speed due to rainfall is largely dependent on rainfall intensity (cm/hour) and the kinetic energy of a given amount of rain. The latter depents on drop size and terminal velocity at which the drop hits the ground (see chapter 2a).
The relation between rainfall intensity and kinetic energy is empirically derived and as follows:
$E = 210 + 89 * 10\log(I)$,
E is kinetic energy in metric ton meters per hectare.
I is rainfall intensity in cm/hour.
With this equation Wischmeier & Smith (1978) developped an 'isoerodent' map for the eastern U.S. Inspired on this map Roose (1977) derived a 'isoerodent' map for West Africa (see figure 5).
A lack on sufficient climatic data forced him to develop a statistical analysis. Therefore the values calculated for R are based upon records between 4 and 10 years.
Figure 5 shows that the Northern Region yields a R-value between 500 and 600.
Using table 7 with the data upon which Roose based his map and mean annual rainfall data as reported by Norrip (1983), we can derive a R-value determined by the mean annual rainfall.
According to Norrip Tali-Tolon region receives 1125 mm./ year (see table 6). This corresponds with a R-value of 565 for the Tali-Tolon region.

– Esquisse de la répartition de l'indice d'agressivité climatique annuel moyen (R_{USA} de Wischmeier) en Afrique de l'Ouest et du Centre

·Situation des parcelles d'érosion (lieux soulignés)



D'après les données pluviométriques rassemblées par le Service Hydrologique de l'ORSTOM et arrêtées en 1975

figure 5:
Climatic aggression index or R-value for West-Africa after Roose (1977).

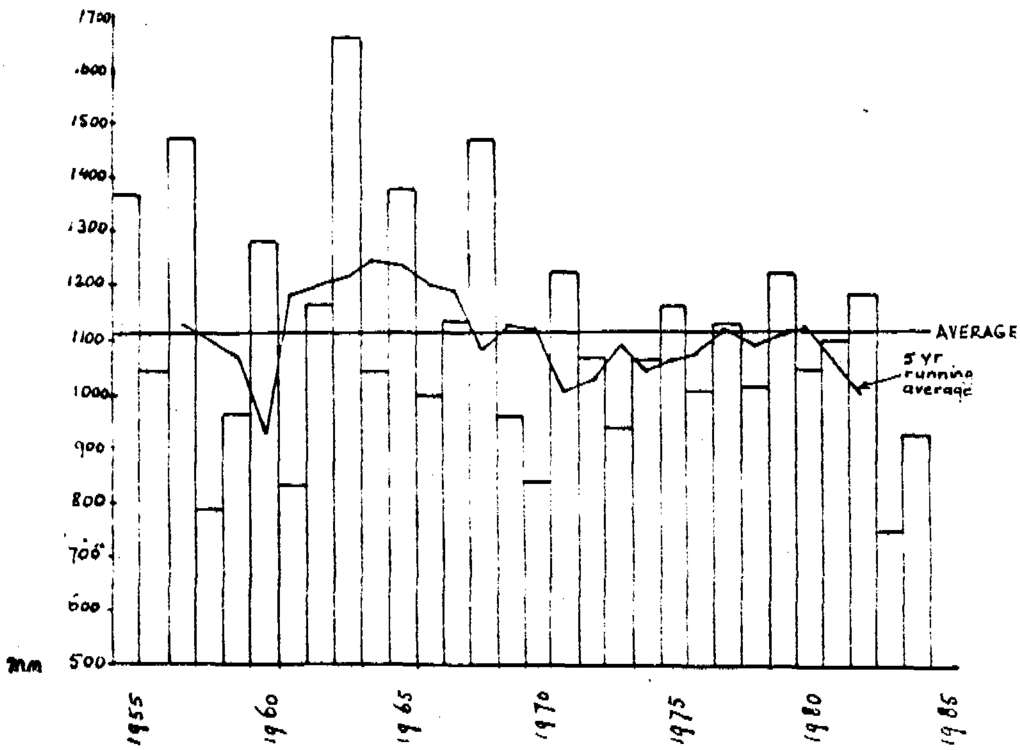


figure 6: Annual rainfall in Tamale during the years 1955-1984 with 5 year running average.

	Dépouillement sur courtes périodes				SOURCES	Moyennes sur longues périodes			
	Période	Pluie Ha (mm)	Index Ra	Ra/H		Nombre années	Hauteur pluie annuelle	Ra/Ha retenu	Rusa annuel moyen
Côte d'Ivoire									
. Abidjan (ORSTOM)	1966-73	1722	910	0.53	ROOSE, inédit, 1975	27	2100	0.60	1260
. Azaguié (IFAC-ORSTOM)	1963-73	1645	800	0.43	ROOSE, inédit, 1975	41	1770	0.50	865
. [illegible] (IFCC-ORSTOM)	1963-74	[illegible]	741	0.53	ROOSE, JADIN, 1968, 1975	29	1650	0.50	840
. Bouaké (IRAT-ORSTOM)	1960-71	1232	512	0.42	ROOSE, BERTRAND, 1972	60	[illegible]	0.45	520
. Korhogo (ORSTOM)	1967-74	[illegible]	673	[illegible]	ROOSE, inédit, 1975	47	1440	0.50	720
Haute-Volta									
. Niangoloko (IRHO)	1963-72	1265	656	0.52	GALABERT, MILLOGO, 1973	23	1340	0.50	670
. Gaoua (ASECNA)	1966-72	1124	538	[illegible]	GALABERT, MILLOGO, 1973	53	1240	0.50	620
. Bobo-Dioulasso (ASECNA)	1966-72	1142	554	[illegible]	GALABERT, MILLOGO, 1973	58	1150	0.50	575
. Farako-Ba (IRAT)	1967-72	1033	435	0.42	GALABERT, MILLOGO, 1973	-	-	-	-
. Ouagadougou (ASECNA)	1967-72	861	466	0.54	GALABERT, MILLOGO, 1973	21	880	0.50	440
. Gonsé (CTFT-ORSTOM)	1968-73	709	345	0.49	ROOSE, inédit, 1975	-	-	-	-
. Saria (IRAT-ORSTOM)	1971-74	694	392	0.55	ROOSE, inédit, 1975	30	840	0.50	420
. Saria (IRAT METEO)	1968-72	826	357	0.45	GALABERT, MILLOGO, 1973	30	840	0.50	420
. Mogtedo (IRAT)	1968-72	754	378	0.50	GALABERT, MILLOGO, 1973	-	-	-	-
. Fada N'Gourma (ASECNA)	1966-72	857	428	0.50	GALABERT, MILLOGO, 1973	48	890	0.50	445
. Ouahigouya (ASECNA)	1967-72	600	301	0.50	GALABERT, MILLOGO, 1973	49	700	0.50	350
. Dori (ASECNA)	1966-72	511	261	0.51	GALABERT, MILLOGO, 1973	47	540	0.50	270
Sénégal									
. Sefa (IRAT)	1964-68	1234	681	0.55	CHARREAU, NICOU, 1971	54	1310	0.50	655
. Bambey (IRAT)	1960-68	590	295	0.50	CHARREAU, NICOU, 1971	47	650	0.50	325
Niger									
. Allokoto (CTFT)	1966-71	437	199	0.46	DELWAULLE, 1973	25	500	0.50	250
Tchad									
. Deli (ORSTOM)	1965-72	976	514	0.53	AUDRY, inédit, 1974	22	1100	0.50	550

Figure 7: Relationships between mean annual rainfall and R-values as determined by Roose (1977). Locations are indicated in the map from figure 6.

4b continued of page 16

Due to the flatness of the landscape this R-value is expected to be valid for the entire Tali-Tolon region.
If hills are present in an other West African region, they tend to cause micro climats with higher R-values (more rain).

R-value = 565 for entire Tali-Tolon region.

4c K-value; soil erodibility.

The K-value is the average soil loss in metric tons per ha per unit of EI. The unit plots are made for each experiment by specifying the R, L, S, C and P values of the USLE equation. For an ideal plot R is measured with a pluviograph L is 22,1 m., S is 9 %, C is 1 (bare soil) and P is 1 (no measures taken, Wischmeier & Smith 1978).
During long term experiments, at least five years, on different soil types, soil losses are measured. Upon these experiments Roose and El Swaify obtained K-values for tropical soils.
El Swaify and Douglas (1982) found K-values between 0,17 and 0,24 for two common tropical soils, respectively Ustox and Torrox soils (Soil Taxonomy classification).
Roose (1977) proposed the following data, using FAO classification:

	K value app.
Tropical ferruginous soil carapac 20 cm. below	0,32 (+/- 0,05)
Tropical ferruginous soil carapac 50 cm. below	0,20 (+/- 0,06)
Tropical ferruginous soil leached with patches	0,17 (+/- 0,05)

According to Bouman (1988) Tali-Tolon region is situated in Upper Voltaian formation consisting of alternating shales and sand- or siltstones, covered by a lateritic (or carapac) top soil.
Roose (1977) made an estimation of the K-values of tropical soils developed on different geological formations.
In the figure below these values are summarized.
It seems that ferruginous soils, it is the soils of the savanna climate, are two times more susceptable to erosion compared to the ferrallitic soils of the humid tropics. They are very susceptable if used for permanent agriculture. In the Northern Region we find ferruginous soils due to the savanna climate and vegetation (see figure 1).

		K-value
ferrallitic on	tertiary sands	0,05-0,10
	granite	0,10-0,15
	schists	0,15-0,20
	gravally	0,01-0,03
ferruginous on granite,		K-value
	after clearing old fallow	0,03-0,15
	after 3-4 years cultivation	0,20-0,30

figure 8. K-values for soil erodibility after Roose 1977.

In Tali-Tolon region we expect ferruginous soils developped on schists (not given in figure 8).
The table also indicates us that on a gravelly surface soil erosion is substantially less and that long term cropping may increase K-values with 200 %.

Concluding remark: In Tali-Tolon region K-values vary between 0,37 and 0,12 depending on soil carapac (lateritic) layer and cultivation history.

Soil types will vary substantially in a small watershed, also in the same geological unit and parent material, due to spatial variations in topography and management (Duchauffour 1982).
It is therefore expected that K-values vary within a watershed.
In order to tackle this problem Wischmeier and Smith (1978) developped a K-value specification method based upon four data to be obtained from a field survey.

<u>4d Nomograph for the determination of K-values.</u>

Wischmeier and Smith empirically derived a relationship between four soil classification data. Using this relationship he made a nomograph, given in figure 9, from which we can quickly derive a K-value.
The relationship is as follows;

$$100K = 2,1\ M\ \exp 1,14 * \tfrac{1}{4} 0,0001\ (12-a) + 3,25(b-2) + 2,5(c-3)\ \tfrac{1}{2}.$$

in which M is particle size parameter, which equals percent silt (0,1-0,0002 mm) times the quantity 100 minus percent clay.
a = percent organic matter.
b = soil structure code used in (USDA) soil classification.
c = the profile permeability class.

In a catchment area SAWA can take several topsoil samples to analyse these four data.
Thusfar samples has been only analysed upon their textural characteristics in order to analyse soil suitability for embankment constructions.
But is not possible to predict the soil susceptability towards erosion upon the data thusfar collected by SAWA.
Data from the Nyankpala Agricultural Experiment Station, which is situated 15 kms east from Chririfoyilli and in the same geological unit (V3) are available (Serno & van de Weg).
The following calculation is illustrative for the nomograph procedure, the relaiability of the Nyankpala Station data for the Chirifoyilli catchment are subject for further research.

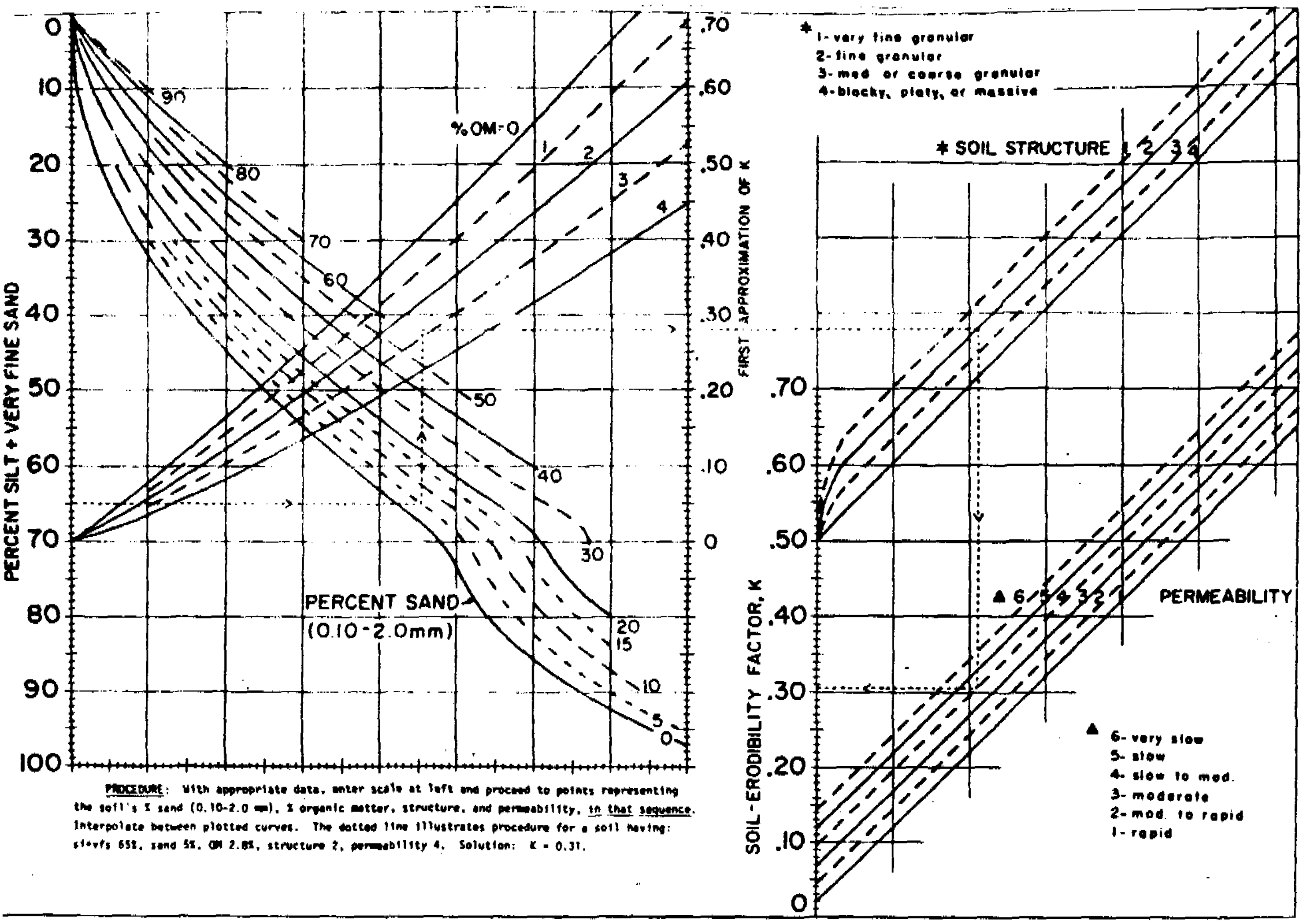
Serno and van de Weg (1985) gave the following data for the Kselesagua series;
(Classified as Plintic Luvisol (FAO) Plinthusalfs (USDA) or Groundwater Laterite (Ghana Class.))

topsoil analysis in %;
sand: 45-75, silt: 15-45, clay: 5-10, pH H20: 6,3-7,2

org.C: 0,8-1,4 struct.class: 3 permeability: 4

Assuming a soil analysis in these series yielding the following data, in % ;

sand: 20; very fine sand 0,1-0,05 mm (vfs): 20; silt 40; clay 8.
Characteristics classification;
org C: 1 Structure code: 3 permeability: 4



The soil-erodibility nomograph. Where the silt fraction does not exceed 70 percent, the equation is $100\,K = 2.1\,M^{1.14}\,(10^{-4})\,(12 - a) + 3.25\,(b - 2) + 2.5\,(c - 3)$ where M = (percent si + vfs) (100 − percent c), a = percent organic matter, b = structure code, and c = profile permeability class.

<u>figure</u> <u>9:</u> If K-value is determined with this nomograph we should convert the value from the english system to the S.I. system by multiplying it with 1,292.

Then we can solve the nomograph as follows:
enter figure 9 at vfs + silt = 60
go horizontal to sand curve at 25,
go from crosspoint vertical to OM curve 1;
read from left scale corresponding first K-approximation = 0,40
specify this value with second nomograph: K= 0,44
conversion to S.I. units with 1,292 yields the following K-value:

K= 0,57

The K-value thus calculated is two times higher as the general K-value as proposed by Roose (1977) for ferruginous soils.
We can conclude this chapter therefore with the statement that more data are neccessary concerning the erodibility of the soils in Tali-Tolon region. The nearby Nyankpala Agricultural Station could function as a host for the neccesary laboratory analysis.

4e Topographic factor LS.

Wischmeier and Smith (1978) developped a slope effect chart (figure 10) from which we can easily derive the USLE index for the combination of the L- (slopelength in m.) and S- (steepness in %) factor.
If we have at a certain slope in the catchment area a 100 m slope lenght of 5%, then our LS-value is 1,0 (see figure 10).
Slope length is defined as the distance from the point of origin of overland-flow to the point where either the slope gradient decreases enough that deposition begins, or the run off water enters a channel.
A change in land cover or gradient does not affect the LS factor. With the C and P factor USLE corrects for those important influences.

4f Irregular slopes.

Unfortunately for USLE users slopes do never have a regular form as suggested in section 4e.
If we use an average gradient for a certain slope we underestimate soil movement to the foot of a convex slope and we would overestimate it for a concave slope.
Wischmeier proposes to divide the slope into equal length segments with a nearly uniform gradient.
For these segmented slopes we can not use the LS chart from figure 10: because run off flows from one segment to a downslope segment.
Upon two assumptions Wischmeier and Smith (1978) developped a manner to cope with this problem.
The assumptions are:
1. The changes in gradient between segments are not sufficient to cause deposition on a segment.
2. The irregular slope can be divided into a small number of equal length segments with uniform gradient.
Than we can follow the procedure as follows.
Enter the slope-effect chart (figure 11) with the total slope length (all segments together) and list the value for each

gradient starting at the upper end of the slope.
Multiply these values with corresponding correction value, found in table 10, for each segment. Adding the values yields the LS-value for the entire slope.

4g Examples.

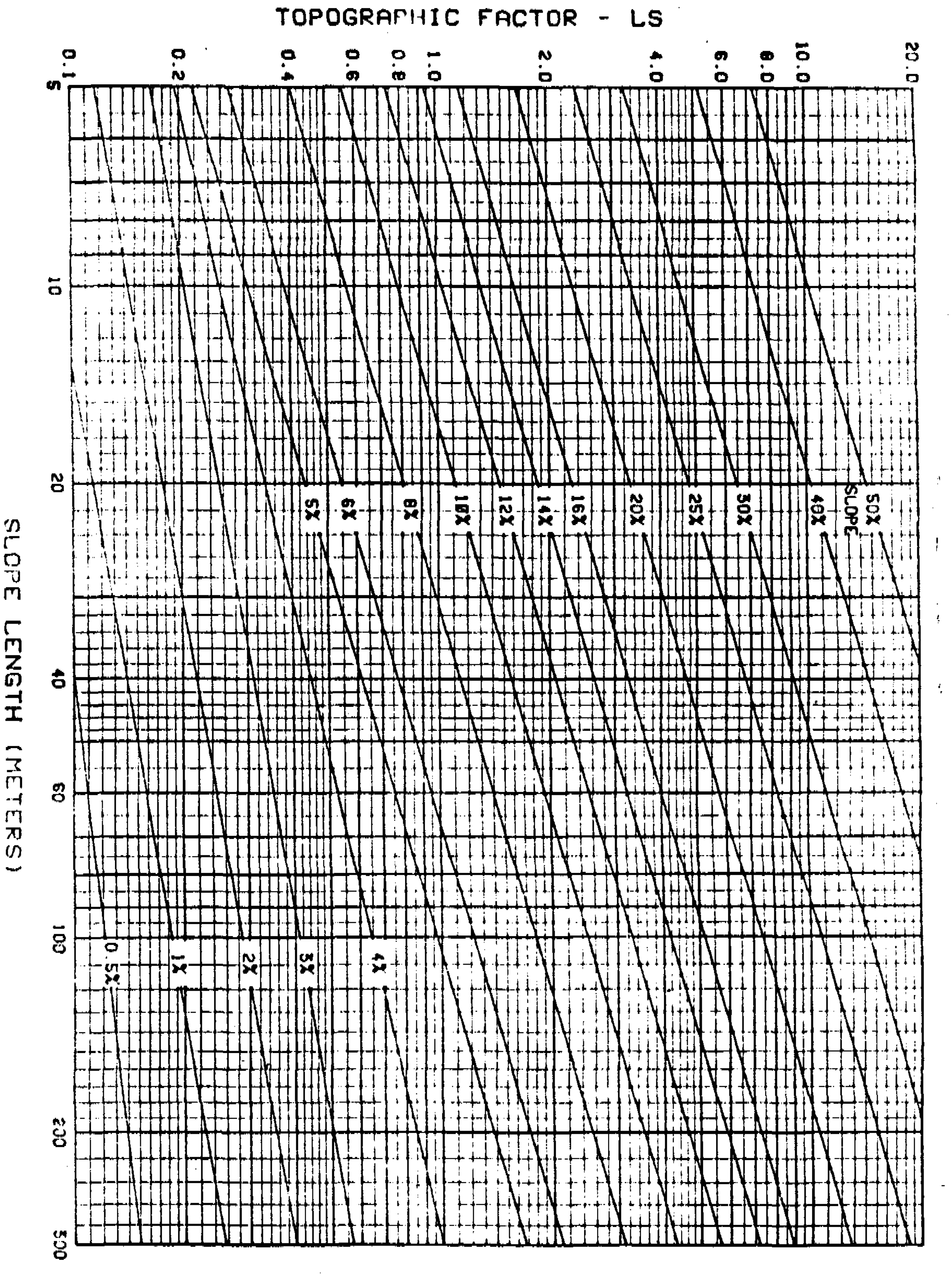
The following tabulation illustrates the irregular slope procedure for a 300 m convex slope on which the upper third has a gradient of 5 percent; the middle third, 10 percent; and the lower third, 15 percent.

Segment	percent slope	LS Chart	Table 11	Product
1	5	1,7	0,19	0,323
2	10	4,4	0,35	1,540
3	15	8,0	0,46	3,680
			total	+ 5,543

LS for this slope is 5,543.

Number of segments	Sequence number of segment	Fraction of soil loss m=0,5	m=0,4	m=0,3
2	1	0,35	0,38	0,41
	2	0,65	0,62	0,59
3	1	0,19	0,22	0,24
	2	0,35	0,35	0,35
	3	0,46	0,43	0,41
4	1	0,12	0,14	0,17
	2	0,23	0,24	0,24
	3	0,30	0,29	0,28
	4	0,35	0,33	0,31
5	1	0,09	0,11	0,12
	2	0,16	0,17	0,18
	3	0,21	0,21	0,21
	4	0,25	0,24	0,23
	5	0,28	0,27	0,25

table 10:
Estimated relative soil losses from successive equal-length segments of an uniform slope (Wischmeier & Smith 1978).
m=slope-length exponent; 0,5 for slopes $>$5%
0,4 for 4% slopes
0,3 for slopes $<$ 3%



U.S. GOVERNMENT PRINTING OFFICE: 1978 O—278-295 A503

figure 11: Slope effect chart.

4h Soil type or soil cover changes.

We can also use table 10 for correction if the soil type or soil cover changes on one slope.
The procedure is as in section 4g.
Divide the slope into equal segments assuming that no deposition occurs on the slope.
Then use LS Chart (figure 11) for total LS value for each gradient.
Tabulate for each gradient corresponding K-value.
Multiply LS and K-values for each segment.
Then multiply result with corresponding correction value from table 10.
Adding these segment LSK values yields total LSK values for entire slope and soil type.

4i Cover and Management factor C.

Roose (1977) states that variation in soil erosion in West Africa is mainly determined by management of soils.
He suggest that for regions in West Africa we can define a global R, K, and LS value. C-values should be specified during a field survey, added with results from a recent aerial photo interpretation.

Important of C-factor determination is the variation of C-values during the seasons.
If a heavy storm is falling on a bare soil at the beginning of the wet season, the soil has no protection against splash erosion.
It is too time consuming for SAWA to specify these variations.
We will therefore propose to incorperate global annual C-values.
Roose (1977) determined these C-values for several african crops, they are presented in table 12.
Important for West African field investigations are the high C-values for mais crops and cotton.
High C-values for these crops are explained by specific microbial life connected to the roots of these crops and the plant structure on which large drops develop (Roelse & de Jager 1988).
About the latter, rain is intercepted by the plant thus providing a protection against splash erosion but on the leaves large drops develop. When these drops fall from the leaves, 1 meter above the ground, they receive enough kinetic energy to provoke splash erosion while hitting the soil.
Roughly we can conclude;
a crop is protective (C is low), if the crop gives a total ground cover not higher as 15 cms. from the soil surface.

Therefore we should map, in each selected catchment area, consistently soil cover percentage at the beginning and half way the wet season.

In the Northern Region we can expect C-values to vary between 0,05 and 0,8 on respectively savanne or intensive cultivation.

Thus influencing the soil loss estimate (A) with a 6 times higher yield depending on land management.
Therefore an inventarisation of crop-use in the catchment area in which a dam is planned to be built has priority above a detailed soil investigation.
Aim of this investigation is to specify the annual C-values. For example from crop stage and plantation moment we can conclude if C equals 0,2 or 0,8 for manioc fields (see table 12).

		C annuel moyen
Sol nu		1
Forêt dense ou culture paillée abondamment		0.001
Savane et prairie en bon état		0.01
Savane et prairie brûlées et/ou surpâturées		0.1
Plantes de couverture à développement lent ou plantation tardive	. 1ère année	0.3 à 0.8
	. 2ème année	0.1
Plantes de couverture à développement rapide et plantation hâtive dès la 1ère année		0.01 à 0.1
Maïs, sorgho, mil (en fonction du rendement)		0.4 à 0.9
Riz en culture intensive		0.1 à 0.2
Coton, tabac (en 2d cycle)		0.5
Arachide (en fonction date de plantation)		0.4 à 0.8
Manioc (1ère année), igname (selon date de plantation)		0.2 à 0.8
Palmier, hévéa, café, cacao avec plantes de couverture		0.1 à 0.3
Ananas à plat (en fonction de la pente) pente 4 à 20 %	résidus brûlés	0.1 à 0.5
	résidus enfouis	0.1 à 0.3
	résidus en surface	0.01
Ananas sur billons cloisonnés (pente 7 %)		0,1

table 12: Influence of vegetative cover on erosion in West Africa after Roose (1977).

4j Support practice factor P.

Thus far we only evaluated erosion causing factors.
Soil-conservationists developped however a large number of techniques to prevent soil from eroding.
Roose (1977) evaluated these techniques for West Africa.
He found that especially mulching with straw yields good results.
In general, however, anti-erosive practises are based upon mechanical shortening of slopes by building earthen dikes or terrasses. Table 13 gives an idea of the result of these practices. We should take into account that if no measurements are taken P equals 1.
During a field survey concerning the C-value we can easily map the P-values at the same spots.
We can conclude that the more vegetation or mulch is covering the ground the lower the P-value will be. Isohyps ploughing and earthen dikes and stone walls can reduce soil erosion as well till a certain extent, till 90 % conpared to no measures taken. However these techniques require a constant maintenace, if this is not provided they represent a high risk due to collaps risk.

	P-value
Ploughing along isohyps.	0,20-0,10
Anti-erosion strips 2 till 4 m. large	0,30-0,10
Straw mulch	0,01
Curasol mulch 60 g/l/m2	0,50-0,20
Temporal prairy or weed cover	0,50-0,10
Stone walls or ditches, till 80 cm. level variation	0,10

table 13:
Anti-erosion practices index for West Africa after Roose (1977). Variation in the P-values are due to management and maintenance of the practices in the field. Expensive measures like terrasses made of stones are often reported to fail on the long term due to a lack of maintenance or farmer support in African countries (see Chapter 7).
If two practices are implemented the lower P-value has to be used.

4k Final calculation of soil loss value A.

The prevailing 10 sections helped us to evaluate roughly the soil loss to be expected in the Tali-Tolon area.
For detailed calculation procedures the reader is suggested to use the manual developped by Wischmeier & Smith (1978) and the studies of Roose (1977).
To illustrate the USLE method we will derive an A value for a northern region like situation.

presume that we find the following values
on one half of the catchment area:

R = 565
K = 0,57
L = 200
S = 3 % then LS is 0,5 (see figure 11)
C = 2nd cycle cotton fields; equals 0,5
P = contour ploughing but not very consistent; equals 0,2
(all values derived from tables in preceded chapters)

then A = 565*0,57*0,5*0,5*0,2 = 16,11 ton/ha/year.
area is 3 ha large then this area supplies 3 * A in the pond= 48,33 ton/year.
The other side of the stream in the catchment area has following characteristics:

R = 565 (same climate).
K = 0,25 (other soil type)
L = 100 m
S = 4% then LS = 0,55
C = savanne and burnt prairie = 0,1
P = no control measurements = 1

then A = 565*0,25*0,55*0,1*1 = 7,77 ton/ha/year
(compare this A-value with the A values form El Swaify and Douglas as presented in chapter 3a).

Area is 2 ha large, thus supplies pond with 2*7,77= 15,54 ton/year
The stream then supplies yearly 15,54 + 48,33 ton sediments = 63,87 ton.

If pond has subsurface of 1 ha.
with GES equation (section 3a) we find MW mud-weight is

63870 kg/ 10000 m2 is 63,8 kg/m2
sand density = 1600 so Mud-height MH will be 63,870/1600 = 0,039 m/year

if we find such a figure the life time of the pond can be found if we first establish the critical mud-height. This is the mud-height at which or the dam will collapse during a rainstorm due to the diminished capacity to store water, or the dam will store less water to provide the villagers at the end of the dry season. If the critical MH is one meter; this theoretical pond will last 26 years.

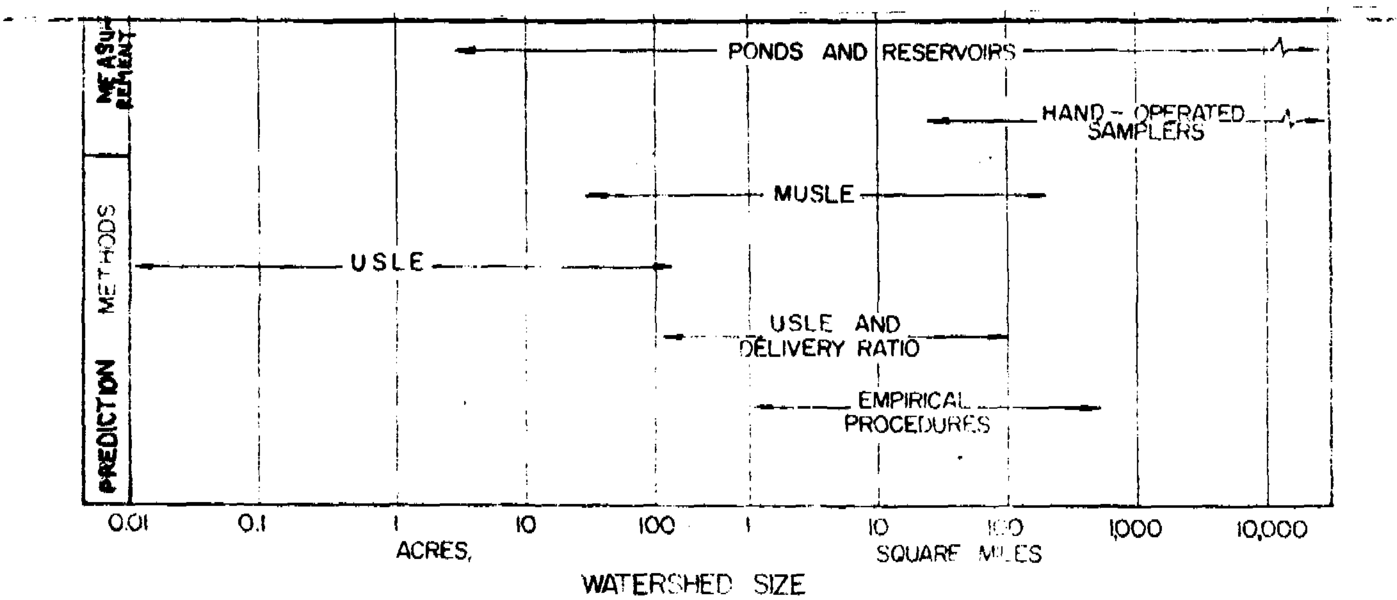


figure 14: In watersheds smaller than 100 acres the A-value found with the USLE method predicts the sediment flowing into the pond without a need for specifying the sediment delivery ratio. (see chapter 5) After Allen 1981.1 acre = 0,4047 ha.1sq ml = 258,9 ha.

5. The sediment delivery ratio.

The modified USLE (MUSLE).

The sediment delivery ratio is defined as the ratio of sediments delivered at a point in the stream to the gross erosion from all sources in the watershed above that point (= A-value USLE).
The soil loss A as computed with the USLE method does not consistently equal the sediment quantity which the stream transports to the pond.
The sediment yield, which finally determines our pond life time, is limited by sediment deposition in the stream. On the contrary sediment yield can be higher as well; due to streambank erosion (see chapter 2).
Also material can settle on the toes of slopes forming colluvial slopes.
In general, deposition occurs when sediment supply exceeds run off transport capacity. Sediment yield is therefore strongly related to flow characteristics of the stream and less to rainfall characteristics as is the USLE model.
Allen (1981) describes several flow characteristic based models, some of them based upon the USLE equation. Unfortunately these models require long period measured data; concerning runoff volume and peak flows and coefficients to be determined. These are not available in the Northern Region.
We can measure indirectly the sediment delivery ratio.
The experiment for determining this value is based upon the calculated USLE value.
In general SAWA is enlarging ponds, so the sediments are available in the old pond. As described in section 2c we can recognize the sediments settled in the old pond for their yearly settling. They develop horizontal lines, called strata, to be recognized for each rainy season.
The thickness of each strata corresponds to the total annual settled material in the old pond using the GES equation of section 3a.
Thus we can measure the A-values for several years.
If the land use did not change dramatically during the past five years we can assume that these A-values are still realistic.
The measured A-value divided with the evaluated USLE A-value then yields the sediment delivery ratio.
Thus we are able to calculate the life time of the pond to be constructed.
If control measures has to be taken, a survey done with the USLE technique reveals the causes of erosion, thus facilitating the choise of measures to be taken.

6. Workscheme regarding soil erosion and sediment estimation.

Before designing dams or dug outs we can characterize the catchment area using the following techniques;

In order of importance and priority.

1. Land-Use (mapping, interviewing, Aerial Photo interpreting) resulting in a Land Use map 1:5000. An example of a small scale land-use map is given in figure 15 for the Northern Region.

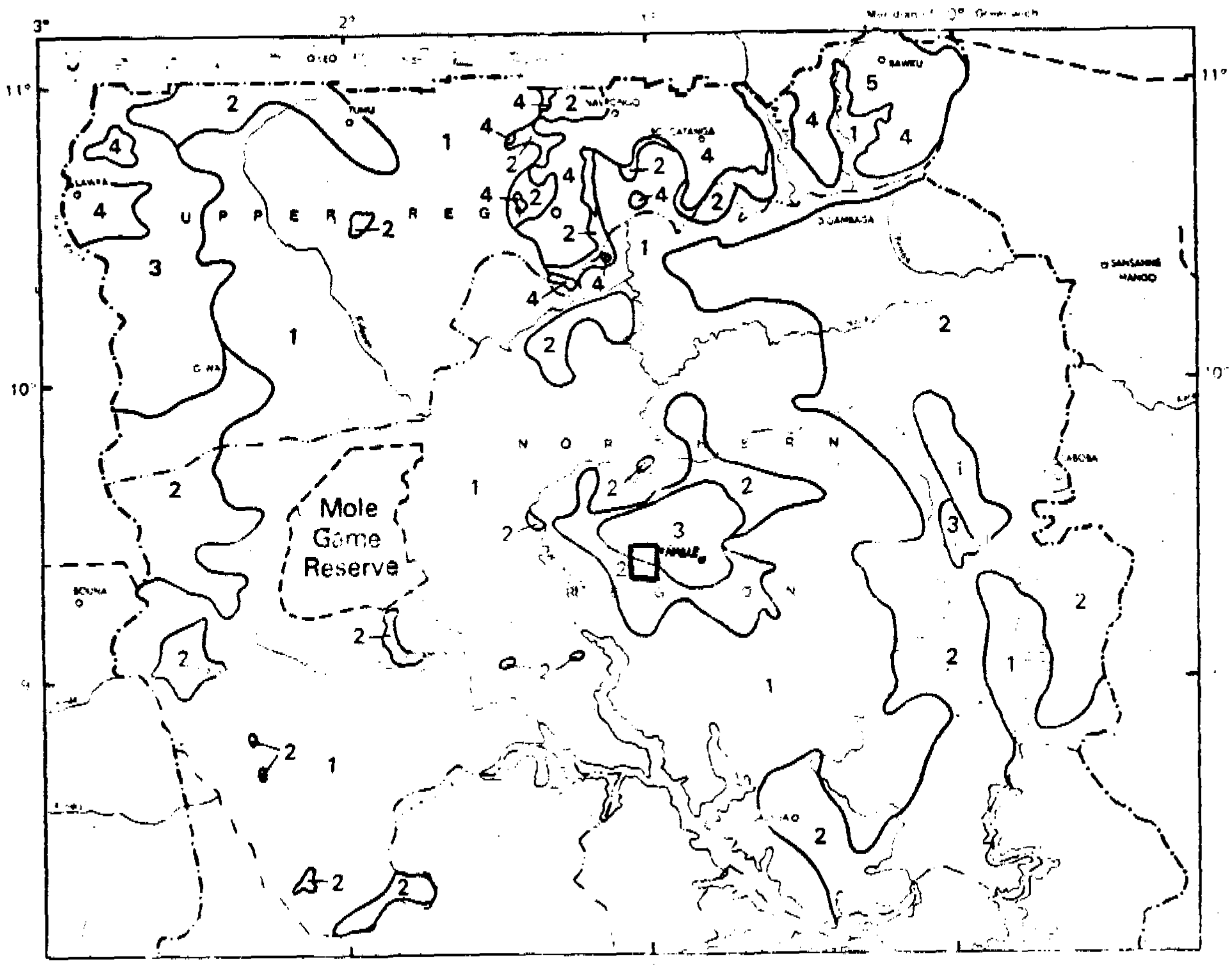
2. Soil Survey. Mapping the general Catenas, mapping truncated profiles. (FAO guidelines, digging of a few holes till 2 meters maximum) K-value determination with top-soil analysis, resulting in a soil erosivity map.
Slope-length map 1:5000 using abney-level.
1 and 2 result in the USLE evaluated A-value.

3. River/Stream characteristics reporting : small pond or cascades acting as sediment traps; meandering/flow pattern/intermittent.

4. River/pond sediment characteristics, sediment ratio inflow outflow. Sampling of stream and pond water at specified time intervals. Determinating the delta strata on thickness and extension. Resulting in specified A factor estimation in ton/ha/year.

5. Pond delta design, prediction of the best galleries spot in the pond. Sampling of sediment under the pond in a ray from dam till stream inflow point. Samples to be characterized on texture, structure (for permeability) and density.

6. Other specific catchment area features like gullies or rills or erosion control measurements should be reported and mapped. Also take notice of hardened roads or other areas in which rainwater is not allowed to infiltrate naturally.
Finally other dams in the same watershed or silttraps should be mapped. Causes for chemical pollution should be reported.



Interior Savanna vegetation and land use

☐ TALI-TOLON

1 Fire-proclimax tree savanna with perennial grasses. Nil to light cultivation and grazing

2 Somewhat degraded fire proclimax, with slight to moderate selection of *Butyrospermum* and *Parkia*, and perennial grass. Light to moderate cultivation and grazing

3 Moderately to highly selected *Butyrospermum* and *Parkia* in tree savanna or parkland with mixed perennial and annual grasses. Moderate to heavy cultivation and grazing

4 *Parkia - Butyrospermum* parkland disclimax with annual grasses. Very heavy cultivation and grazing

5 Treeless annual grass disclimax. Very heavy cultivation and grazing

<u>figure 15:</u>
Vegetation and small scale land-use map for Northern and Upper Region in Ghana. In legend unit 3 ,4 and 5 the C-value will be above 0,7.
After Rose Innes 1977.

7. Erosion control and run off.

It might be wise to integrate erosion control in the maintenance designs for our dams.
One has to realize that erosion control diminishes the surface run off in our catchment area. The run off, taken 15 % (Kuypers 1988) of precipitation, is the main agent for soil erosion. All control measurements are developped to diminish this runoff.
Thanks to erosion control the base flow might increase, on the long term (20 years). Thus establishing a (semi) permanent water table.
Main measurements to reduce run off are forest planting or slope shortening.
The ponds depending on this run off might suffer an important lowering in their watertable if control measurements are succesfully carried out.

7a Northern Region and Soil Conservation.

In Northern Ghana it is unfortunenately realistic to expect more landpressure due to an exceptional population growth rate of 3 percent. Remark that around towns always unit 3 revails in figure 15.
Land-pressure is always a cause for the sudden use of marginal soils which are susceptable for quick soil erosion.
There are no signs of awareness towards this problem, so soil erosion and run off are expected to increase in the Northern Region.
SAWA should therefore take into account the environmental degradation problems in the regions where Sawa is working.
Erosion is not only causing frequent maintenance of the infiltration galleries but also changes the soil fertility, soil water retention capacity and a general environmental degradation.

7b Soil Conservation and life time.

Soil Conservation measures could extent the life time of the ponds ten to hundred times (see table 13 P-factor).
A cheap conservation technique as described by Grimshaw (1988) concerns the promotion of Vetiver grasses (see figure 16) in the region. This grass can be found along rivers in Ghana (Rose Innes 1977) thus making it easy to introduce. In Dagomba language its name is Kulikarili (de Jager 1989c).
In India farmers already use Vetiver grass for 40 years as a soil and moisture conservator.
The grass should be cut every three months, thus providing an excellent mulch if used as a hedge between the fields of farmers.
If planted along the contour the grass prevents soil material to move down slope by reducing the run off speed till zero in the hedge. Due to its capacity to grow through the settled material it establishes a terras, which is stabilized by the Vetiver roots which grow vertically down till 2 meters (Grimshaw & Greenfield 1988).
The grass can be used also as an embankment stabilizer on the dams or as siltrap at the stream entry in the pond. Thus SAWA

can introduce it as a conservation means for their own direct aim (stabilisation of the dams and silt reduction) and as a pilot project for further extension of the technique.
Promotion and experiments can be realized by institutions like the Nyankpala Agricultural Station and the Agricultural Extension Service in Tamale.
If the technique is accepted and estabished, the farmers or extension services can use the stream-entries of the ponds as Vetiver Nurseries as suggested by Grimshaw and Greenfield.

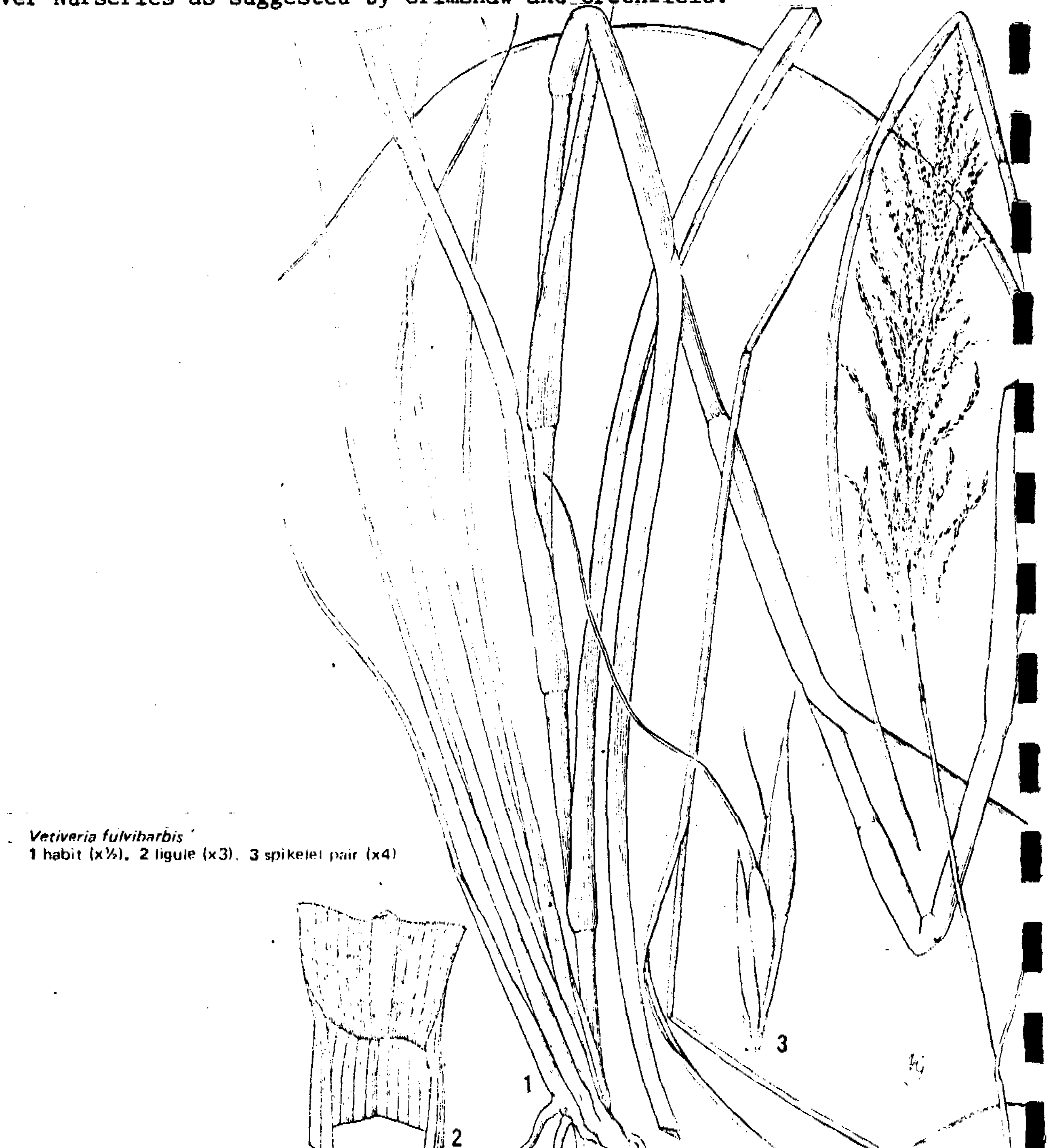


figure 16: Two Vetiver species originate in Ghana. Experiments with Vetiver Nigritana are carried out in Kano Nigeria. (drawing by Rose Innes 1977).

8. Conclusions.

Infiltration galleries are susceptible for sealing off by silt. Upon present data it is not possible to make a reliable sediment yield estimation; so we do not know when the silt will cause malfunctioning.

Most urgent required data are 1. catchment area characterization.
2. pond sediment density and hydraulic conductivity of the sediments.

With the figures available from literature we have tried to make some estimations. Calculations showed that sealing off by sediments is to be expected within one year of operation of infiltration galleries. We should therefore design the galleries in a sediment free-way. We should consider the possibility that the ponds, even if the galleries continue to function, silt up in a period of 15 to 30 years approximately (see section 4k). If we specify the Land Use and Management we can determine the life time of the ponds more precise using the USLE technique.

Erosion control should be considered on the ferruginious soils in Northen Region in Ghana as an important way to secure the future soil fertility. Cebemo and SAWA could function as a medium to stimulate soil conservation, it is in their own interest for assuring the life time of the ponds and providing less turbid water.

Low-cost techniques like Vetiver hedges are a promising soil conservation means. This is due to their availability in Ghana and their low technical input which makes the grass easy to promote on a large scale if accepted by the formal institutions.

9. Consulted Literature.

Allen P.B.1981 Measurement and prediction of erosion and sediment yield. U.S. Department of Agriculture. Agricultural Reviews and Manuals. ARM-S-15 23p

Bouman D. 1988 A preliminairy report on the avialable groundwater resources. SAWA Utrecht Holland reports 25p.

Brussee R. 1988 Alternative measures against bilharzia and guinee worm. SAWA Utrecht Holland reports 16p.

Driscoll F.G.1987 Groundwater and Wells. Johnson Division St Paul, Minnesota 55112 USA. 1089p.

Duchaufour 1982 Pedology; pedogenesis and classification. London George Allen & Unwin 448p.

Geijsbers A. 1988. SAWA internal report: village water reservoirs 40p.

Grimshaw R.G. & Greenfield J.C. 1988 Vetiver grass: A method of vegetative soil and moisture conservation. 2nd edition World Bank New Delhi, India 72p.

Holtan H.N., Stiltner G.J., Henson W.H. & Lopez N.C. 1975 Usdahl-74 revised model of watershed hydrology. A United States Contribution to the International Hydrological Decade. Technical Bulletin No 1518 USDA. 99p.

de Jager A.L. 1989c A note on Vetiver grass, identification and determination. 18p SAWA reports. Utrecht Holland.

Jahn S.A.A. 1981 Traditional Water Purification in tropical developing countries. 352p GTZ.

Kuypers A. & Abdulai A.S.1988 Archdiocese of Tamale Village Waterreservoirs Chirifoyili Project. SAWA Internal Report Utrecht The Netherlands 28p.

Kuypers A. & Abdulai A.S.1988 Archdiocese of Tamale Village Waterreservoirs Gbirimani Project. SAWA Internal Report Utrecht the Netherlands 20p.

Norrip Technical Unit,1983 the Northern Region, Ghana Volume 1 A descriptive overview. Ghana Cida and Wardrop-Deloitte.300p.

Roelse I. & de Jager A.L. 1988. Twee technieken voor de bepaling van de aggregaatstabiliteit in lossleembodems. 72p Universiteit van Amsterdam Fysisch Geografisch en Bodemkundig Laboratorium.

Roose E.1977 Erosion et ruissellement en afrique de l'ouest; vingt annees de mesures en petites parcelles experimentales. ORSTOM No. 78 Paris France 108p.

Rose Innes R. 1977 A manual of Ghana grasses. Land resources division, ministery of overseas development. U.K. 265p.

Rapp A. , Berry L. and Temple P.1973 Studies of soil erosion and sedimentation in Tanzania. Bralup Research Monograph Number 1 . University of Dar es Salaam Tanzania.

Serno G. & Weg R.F. van de 1985 A preliminary assesment of the (available) existing soil information of Nyankpala Agricultural Experiment Station (Tamale, Northern Ghana). STIBOKA Wageningen The Netherlands rapp.nr.1912 82p.

Ubels J. & Steen F. van den 1985. Rural watersupply in the Archdiochese of Tamale: evaluation and project proposals. Report of a six weeks mission to the Northern Region of Ghana. SAWA 161p.

Wischmeier W.H. and Smith D.D 1978 Predicting rainfall erosion losses-a guide to conservation planning. U.S. Department of Agriculture USDA, Agriculture Handbook No 537. 58p.

Wood A.D. and Richardson E.V. 1975 Design of small water storage and erosion control dams. Department of Civil Engineering. Colorado State University. 80p.