A review of rangeland inventory and evaluation techniques in anglophane Africa

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Abstract

The paper provides an account of the history of vegetation mapping and a description of survey and monitoring methods in the anglophone countries of Africa. Some methods of estimating carrying capacity are described and the problems are discussed.

Review

Since the seventeenth century explorers, missionaries and sometimes traders have collected plant specimens and recorded observations on the vegetation during their journeys which frequently involved unimaginable discomfort and sometimes danger. Some of these records are still of value but they are not always readily available.

Serious attempts to map vegetation only began in the early years of the present century and for many years the herbaceous vegetation was largely neglected. There is a two-fold reason for this neglect. In British Colonial Africa, the majority of botanists came from the ranks of the forestry departments and they were primarily concerned with the woody vegetation which, in its floristic richness required a considerable taxonomic effort. The identification of a diverse grass flora was difficult not only because of the complexity of the grass inflorescence, but also because in many countries fieldwork is restricted to a brief period of a few weeks, after the grasses have flowered and before the heads have shattered, or before the area is swept by dry season fires.

The majority of the early maps showed the distribution of a limited number of physiognomic categories; a very small number of maps were based on floristic units namely the more important tree species.

In Southern Africa, however, before the end of the nineteenth century there was concern that the veld had been adversely affected as a result of the introduction of domestic stock. This concern led to some of the earliest grassland investigations and veld mapping in Africa. Pioneer workiers included J.W. Bews, Burt Davy and I.B. Pole-Evans and as a result of their vision, interest in and enthusiasm for grassland work has been maintained. Distances and poor communications originally restricted the opportunity for contact between workers in the different countries and since the coming of air travel other factors have made contact difficult.

Although botanists and ecologists were commonly appointed to the Forestry Departments, there was a growing awareness among field staff of both departments that the shallower rooting herbaceous plant provided a better indication of the soil conditions and its suitability for arable farming then was afforded by the deeper rooting tree or shrub.

During the same period, particularly in East Africa, there was a gradual realisation that extensive pastoralism supported substantial numbers of people as well as providing others with animal products, but that comparatively little was known about the basic resources which supported this industry. In West Africa there was less interest in extensive pastoralism because it was confined in all anglophone countries to limited areas, largely as a result of trypanosomiasis. It is perhaps surprising that there has always been so much concern with animal health and sometimes with animal breeding but animal nutrition has until recently been almost totally neglected: this neglect was the result of uncertainty about the responsibility of animal husbandry and it occassioned friction betwen officers in the agricultural department and those in veterinary departments in many countries up to Independence.

The relatively simple mapping of plant communities initially involved slow journeys up negotiable paths and roads and the subsequent extrapolation of the boundaries between different communities; this task of vegetation mapping was transformed soon after the first world war by the widespread introduction of aerial photography. This technique had been used during the war and after the war it was quickly adopted by foresters (Wilson, 1920) in the northern hemisphere; in 1928 aerial photography was employed by Bourne in Northern Rhodesia (Zambia) and in 1931 Robbins produced a vegetation map of that country based on air-photo interpretation. Aerial cameras and films were improved; a black and white film sensitive to near infra-red wavelengths which are strongly reflected by plant mesophyll tissue was developed. Following the second world war, colour films became available; the critical processing requirements of these colour films together with initial misgivings about their suitability for photogrammetry tended to discourage their widespread introduction in large aerial camera format. These films are widely used in 70 mm and 35 mm cameras mounted on light aircraft and have become a very valuable source of information.
Today, aerial photographs, often complemented with data or imagery from satellite sensors are regarded as essential for any survey of natural resources. The growing awareness of the importance of the herbaceous vegetation resulted increasingly in its inclusion in description of the communities and then in the mapping of the grassland vegetation by itself. Trapnell & Clothier (1937) in Northern Rhodesia (Zambia) pioneered the integrated mapping of soils and vegetation and in 1937 Staples and Hudson were among the first workers to map the grassland types of a country, namely, the nearly treeless Basutoland (Lesotho).
In 1938 Edwards mapped the vegetation of Kenya with particular reference to the grassland communities.
In 1951 Acocks made an outstanding contribution with maps (1 : 1.5 m) and descriptive text of the grassland communities of Southern Africa. In

1956, Rose Innes produced a provisional map of the grassland association of the Gold Coast (Ghana). Rattray in 1957 provided a map of the grass cover of Southern Rhodesia (Zimbabwe) and subsequently (1960) he compiled a Grass Cover Map of Africa; Van Wyck (1979) provides additional information based on Rattray map and accompanying text.

Workers have now mapped and provided descriptive accounts of the vegetation for most anglophone countries of Africa; among their number, and the list is in no sense complete, are in Uganda, Langdale Brown (1960), in Nigeria Leeuw et al. (1972); for River Basin of Tanganyika (Tanzania) and of Northern Rhodesia (Zambia) Vesey-Fitzgerald (1963), for East Africa, Heady (1960) for floodplains in Zambia, Astle (1965) and Verboom (1964) and in Botswana, Blair Rains, Mc. Kay and Yalala (1965: 1972).
A number of these studies introduced quantified descriptions but until very recently measurements of herbaceous vegetation have not been adopted except for detailed investigations of areas of limited size.
This apparent failure by workers in anglophone Africa to employ the techniques developed by ecologists and grassland workers, from the early years of the century, in USA, New Sealand, and UK cannot be attributed to a lack of awareness of these measurement.
'Techniques' include cutting and weighing, and the measurement of plant frequency, plant numbers and plant cover using points, lines, belt transects and quadrats of varying seze and shape and they have been comprehensively reviewed by Brown (1954).
Few, if any of us, using these techniques have not been daunted by the heterogeneity of the vegetation communities and also by the seeming impossibility, in the time available, of obtaining a satisfactory sample; sometimes it seemed necessary to modify an existing method and the writer is probably not alone in having used a method without sufficiently understanding its statistical characteristics or the limitations of the particular technique.

Some of the techniques for the analysis of vegetation data which were developed during the fifties and sixties are described in a bibliography compiled by Morris (1967); (In any programme involving the measurement of grassland or of natural vegetation, the advice of a biometrician should routinely be obtained. The problem of the location of the sample can sometimes be resolved by using the aerial photograph before measurements are made on the ground).
Since the end of the Colonial era expatriate grassland workers have come from a number of European countries and from North America and national staff have gone from Africa to these countries for training; a result of these movements has been the introduction of new ideas and concepts and although many of these new ideas have increased our understanding and led to better rangeland management not every technique has been transferable without modification.

Since 1972, workers involved in the survey of natural resources and in the monitoring of changing patterns of land use, have had available data from sensors carried on orbiting and geostationery satellites. The first three satellites of the Landsat series orbited the earth at eighteen day intervals and they record the spectral reflectance of ground units (0.6 ha) in four bands of the electromagnetic spectrum in a swathe 180 km wide; the data can be obtained in film format or on magnetic tape which is suitable for computer processing and analysis. The synoptic view and the repetitive cover are among the most valuable characteristics of this satellite system; for a number of reasons there are only a small number of images of many African countries. The latest of the Landsat series has improved spatial resolution and records in a greater number of bands of the spectrum. Data from meteorological satellites is being used in soil moisture investigations (Wilkinson et al 1982) and to monitor vegetation biomass (Rosema 1982); the spatial resolution is poorer but data from the geostationery Meteosat is transmitted at two hourly intervals.

For some aspects of rangeland survey and rangeland monitoring the relatively poor resolution of the Landsat image is not a desadvantage. Among the workers who have investigated rangeland applications, are MacLeod (1973) Dijk et al (1977), Griffiths and Collins (1981) and Cooley and Turner (1982).

It is expected that some of the next generation of satellites will carry microwave sensors which although primarily intended for oceanographic investigations will provide data for land area; the interpretation of this data could be facilitated as the result of experience gained by the staff of Huntings during their interpretation of radar imagery which included the drier areas in the North of Nigeria (1977).
No account of rangeland inventory and evlauation techniques would be complete without reference to the contribution which has been made to the science not by workers concerned with domestic livestock but by a group primarily concerned with wild life conservation, the management of reserves in East and Southern Africa and the investigation of plant-animal systems.

For many years game counts (Norton-Griffiths, 1973) have been successfully undertaken in low flying light aircraft; this technique has been extended to the enumeration of many terrain features. Watson (1981) describes the multistage vegetation survey method which he developed and employed to map rangeland in Somalia. This is a multistage method using LANDSAT imagery, flying sample transects and undertaking ground sampling of soil and vegetation.
Gwynne and Croze (1975) reviewed methods of habitat monitoring in East Africa and Gwynne has subsequently been involved in the development of the environmental monitoring programme which is being undertaken by U.N.E.P. One of the airborne instruments used in this programme measures reflectance from vegetation in the visible and the near infra-red and by combining the data, monitors the state of vegetation in the line of flight. A similar radiometer can be hand held on the ground as a non-destructive method of measuring plant biomass and Leaf Area Index (Harris 1983).

In spite of these impressive technical developments in the survey and monitoring of rangeland there is still a need for workers to collect and identify

plants and to make measurements on the ground.
Most carrying capacity estimates are the result of subjective assessments althought the experienced worker will attempt to relate a veriety of factors. These factors include rainfall, soil, the type and condition of the grassland, the type and density of woody plants, the evidence of fire, the topography, the availability of water and the type and intensity of arable farming.
Rainfall records may not always be available for a sufficiently long period, or even reliable. In the more arid zones, rainfall is variable, both seasonally and spatially. Soil moisture and the length of the growing season are the most important factors affecting herbage growth in regions of 200-400 mm annual rainfall.
Soil nutrients often limit growth and the physical nature of the soil affects the entry, movement and retention of water.
The botanical composition and the condition of grasslands reflect rainfall, soil conditions, the incidence of fire and the intensity and frequency of grazing.
Year round grazing on some upland grasslands at a constant stocking level is not possible without a severe loss of animal production unless there is supplementary feeding. The utilisation of this type of grazing depends on the availability of alternative sources of fodder; traditional strategies include transhumance to upland grassland in a different zone or to floodplain grassland and the use of farm crop residues.
There is increasing opposition to transhumance movements; in many countries there is increasing cultivation of the floodplains and dry season farms frequently restrict access to uncultivated areas or to water.

The residues of cereals and grain-legume crops are in many areas an important source of fodder. Early harvested crops may deteriorate before other interplanted crops are harvested; harvesting and threshing methods can cause the loss of useful leafy material; in some countries there is little effort to collect and conserve crop residues (in a small number of countries the farmer is required to leave all residues in the field for communal use) in many countries the value of crop residues is appreciated and they will be sold or bartered. Crop residues are less important in the higher rainfall zones where root crops are cultivated to a greater extent than cereals.

The presence of woody plants can depress herbage growth, sometimes severely, modify the botenical composition of the herbaceous vegetation, this modification is often adverse, although under the canopy of clean boled trees, it can be favourable. Some trees and shrubs provide edible leaves and fruits (browse) which are often a rich source of protein and phosphorus and sometimes of energy.

It is always difficult to assess the incidence of fire and its significance in the destruction of fodder resources. In many countries, burning, as a result of accident or deliberately started, occurs widely most years.
Topography is often reflected in vegetation differences and it is a factor in the erodability of the soil.
The need for water may involve stock in long journeys during several months of the year. The exploitation of groundwater in arid and semi-arid

zones has usually resulted in the over-exploitation of the vegetation around the watering point. In the wet season the vegetation provides more moisture and stock will find temporary surface water.
With growing populations, arable farming expands, often into marginal areas. Crop residues may compensate for the lack of grazing land. An influx of cultivators can reduce the challenge of tsetse fly in higher rainfall ones and the grassy fallows may provide attractive grazing.
Objective methods of assessing carrying capacity are very desirable but methods must be practical and easily understood. Methods involve the use of one or more of the factors which have already been described. Rule of thumb methods have inherent dangers.
In Botswana, Field has mapped the potential carrying capacity according to the rainfall distribution. In East Africa, Pratt and Gwynne (1977) provide, for unspoiled rangeland, a guide to the approximate stocking rate based on the annual rainfall and they indicate increased variation in the stocking rate as rainfall decreases.
These authors recommend an initial investigation into the yield of herbage followed by a stocking level trial.

In N-E Nigeria, Leeuw, Lesslie and Tuley (1972) estimate carrying capacity combining (1) the yield of herbage at the end of the growing season, (2) its quality and the seasonal variation in quality and (3) limitations which include the availability of water and ease of access to the grassland. These workers also estimate the contribution of crop residues in terms of grazing days.
Raay and Leeuw (1974) identified the fodder resources, including upland and floodplain grazing, browse and edible crop residues of two areas in Northern Nigeria, on a month by month basis.
Blair Rains, Leeuw and Bille (1979) suggest that the amount of protein in the herbage might provide a better indication of the potential carrying capacity than is provided by the yield of dry matter.
The level of protein in herbage depends on the available soil nitrogen which, under a grass cover, remains at a low level for much of the growing season. Bell (1982) suggests that 'for a given rainfall and altitude, plant biomass tends to be lower in conditions of higher soil nutrient availability than in those of lower availability', and that low plant biomass is correlated with high animal biomass. (The carbon content of the undisturbed soil increases with increasing rainfall, while the carbon:nitrogen ration widens.)
Tainton Edwards and Mentis (1980) suggest a system of using four characteristics of the vegetation and of the site to derive the stocking rate for the area relative to that of a benchmark site within the same zone. The characteristics are, composition, basal cover, topography and soil erodability. The system is proposed for Natal but had not been exhaustively tested.
The assessment of the factors which these workers select requires technical skill and the system is based on benchmark sites but it should provide more reliable indication of the correct stocking level.
Although there have been many investigations of stocking levels, animal performance and botanical change, very few investigations have been undertaken for more than six or seven years. While some changes in plant

vigour and botanical composition under a system of defoliation will appear within a year or two, other changes may only occur after a far longer period. In some regions the occurrence of extended droughts is a significant factor in range utilisation.

However, in no country can we wait while we slowly increase our understanding of the plant-animal interaction, in every country there is an urgent need to implement measures based on our existing knowledge. A map, the report of an elegant investigation, a discussion about stability and resilience, or the consideration of seemingly intractable socio-economic problems, are not end products, our work must contribute to ensuring the continued productivity of the rangelands and to the improvement of the well-being of ordinary people as the result.

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Land evaluation as a part of integrated watershed management

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Introduction

In Tunisia, soil erosion is a widespread problem, affecting all categories of land: forest, rangelands and farmland. In the North, sheet- and gully erosion prevails, as a result mainly of violent autumn rains on land, often sloping, which is already denuded by heavy grazing throughout summer. In the South towards the Sahara Desert, wind erosion is the main problem. In Central Tunesia both phenomena occur with increasing intensity, the problem being aggravated by a relatively high population density (30/Km^2) under semi-arid conditions (200-400 mm, with high yearly variations).
In the past, as soil and water conservation is the responsibility of the Forestry Department, anti-erosion works have been carried out on the hill ranges first, with extensive terracing and reafforestation of non-cultivated slopes, often with good results. To create labour for the rural unemployed was an important element of the programme, and still is. The campaign was not without conflicts, as vast areas of mountain rangeland had to be excluded from grazing, with insufficient compensation given to the livestock owners. Anti-erosive treatment of the areas outside the 'forest lands' was spotwise (gully stabilization) without a true involvement of the farmer.

Under the new integrated approach, in which erosion control is seen as a part of overall rural development of an entire watershed, the basic motivation for the launching of a programme is the protection of an existing or future reservoir. In the case of the vital dam of Sidi Sa'ad which protects the town and plain of Kairouan against flash floods, this may involve an area of tens of thousands of square Km.: it has to be tackled in several phases, treating the most badly affected sub-watersheds first.
A major problem sofar in the involvement and collaboration of the population living in the watershed has always been that people living upstream of the dam will normally not draw any direct benefit from it and cannot be motivated for soil conservation only for the sake of the dam, which will give protection and irrigation water downstream.

Therefore, erosion control is now being integrated into agro-sylvo-pastoral development, with methods acceptable to the local people and aiming not only at diminishing of the silt load towards the dam, but at increased income for the farmers and an overall positive economic effect.

2. Methodology

Once the watershed which will require priority anti-erosive treatment for dam site protection, has been identified, the consecutive steps which will lead to the management plan are the following:

a. Exact delimitation of the watershed:

normally an easy task, with the help of 1:25.000 scale aerial photographs and 1:50.000 scale topo maps. At this early stage, it may already be decided upon whether the entire watershed will be included or only part of it.

b. Subdivision of the watershed into land units:
based on geology, geomophology, soils and vegetation. For this semi-detailed preparatory work, previously made surveys are often available.

c. Detailed and simultaneous survey:
for present land use, land classing and socio-economic situation.

c.1. Present land use ('occupation du sol').
Distinguished are:
- Forests: woodlands, almost exclusively of Aleppo Pine, with at least 20% ground cover by trees;
- Forest rangelands: 'parcours forestiers', open woodlands with less than 20% tree cover, often as small forest remnants scattered over the hill ranges; the domination is important: it indicates that these terrains, regardless of their administrative status, are used as grazing lands, and that their production potential for animal husbandry is more important than for timber production;
- Rangelands: 'parcours', open shrublands of *Rosmarinus*, *Cistus* and *Thymus*, all under intensive use for (mainly sheep) grazing;
- Abandoned croplands: 'jacheres permanentes', dwarfshrublands of various *Artemisia* species, in the French litterature usually referred to as 'steppes' on land which has always been cultivated before, but was abandoned due to loss of soil fertility or gully erosion. Soil depth is however still sufficient for cropping. Used for grazing;
- Croplands: 'cultures annuelles', annual crops almost exclusively of wheat and barley, occasionnally maize or chickpeas, all rainfed; the denomination holds no appreciation of the land capacity, it only describes the present situation;
- Plantations: of fruit trees (olive, almond, apricot, pistachio ...) and of *Opuntia* (prickly pear, both spiny and spineless).

The inventory of this present land use (with the aid of aerial photographs corrected by recent field observations) leads to a 1:25.000 scale land use map, from which respective areas can be measured.

c.2. Land classes:
Simultaneously but independantly of the previous, a 1:25.000 land classes' map is produced, exclusively through direct observations in the field. Six land classes have been used the main criteria being agricultural potential, erosion hazard, and status.

- Class 1: level or slightly sloping agricultural land of high potential and with little or no erosion hazards;
- Class 2: sloping agricultural land of good potential on which some precautions should be taken such as contour plowing or terracing, to encounter sheet erosion which may already be widespread;

- Class 3: marginal agricultural land, usually on steep slopes or on shallow, stony soils, which should not normally be cultivated according to modern soil conservation criteria; both sheet- and gully erosion are widespread; more suited for permanent crops such as fruit trees, and pastures;
- Class 4: partially or totally abandoned cropland, for various reasons:

a) cropland deeply dissected or surrounded by expanding gullies, which make access difficult;

b) cropland in the process of abandonement, as sheet erosion has removed most of the topsoil;

c) the extreme case of b), rock outcrops are the dominant feature, no more agriculture is possible;

- Class 5: typical 'badlands', mostly located on soft marls; although intensively used as grazing grounds, these areas are to be excluded from any land use;
- Class 6: land with an administrative forest status; this will in Tunisia almost never be land with agricultural potential; still, many old and recent illegal clearings exist inside the forest one: these small cultivated areas may then be classified as 6 b), 6 c) or 6 d) according to their value as cropland.

It should be noted that this land classes scale is highly pragmatical, with varying criteria practised throughout. Slight modifications may be carried out according to the characteristics of each watershed or also, for example, to indicate already existing anti-erosion devices such as terraces.
Contrary to the land use map, the map showing the land classes will already express an appreciation of the land suitability, it's production potential and will already point towards the anti-erosive interventions which are necessary. At this stage however, it does not yet take into account the opinions and desires of the farmers, nor climatic or economical criteria in order to determine the optimal land use.

c.3. The socio-economic situation:
A detailed survey is carried out, taking on the average 10% of the population as a sample. This means that one head of family out of ten is questioned on size and age of the family, size of the land holding, cropping system, number of livestock, sources of income, level of education, employment possibilities, health problems, and also on more subjective matters such as his desires for the future and his opinion on the support he is receiving. Young men and women are not questioned, although this might reveal interesting facts and opinions: this problem needs to be looked into in the future.

d) Delimitation of priority zones:
Throughout the watershed, erosion does not occur with the same intensity. Without repeating the error of the old strategy of soil conservation, where only problem areas such as badlands or deep gullies were treated with isolated, non-integrated actions, it is on the other hand not necessary to spread the limited ressources of the programme evenly over the whole area. Therefore, priority zones are identified according to the following criteria:

- proximity of the (future) dam site
- intensity of the ongoing erosion, and future erosion hazards

- fine silt load in the watercourses from each sub-basin
- population density and property status of the land

This way, in a watershed which covers 50.000 ha, it may be decided that 30.000 ha require no immediate treatment; the remaining 20.000 ha may then be divided into 5 priority zones of approx. 4.000 ha each.

e) Identification of sample areas, ('périmètres-type'):
Within each priority zone, a sample area is selected of approx. 100 ha, which should be as representative as possible for that particular zone. Care will be taken to include land classes, types of land use and erosion hazards occuring in the area; also, population density and size of land holdings must be taken into account. Practically, it will never be possible to locate so small an area including all situations that occur. To enlarge or to multiply the samples would be more valid statistically, but would considerably lengthen the programming, as the next chapter will make clear.

f) Programming of the interventions in the sample area:
The same as for the entire watershed, but on scale 1:5.000, land use and land class maps are made; the socio-economic survey covers all families having land in the sample area; after this, the essential phase takes place; identification and plotting of one or more anti-erosive measures to be taken on each situation found in the sample area; this may be of purely biological nature such as rows of cactus, windbreaks or the introduction of perennial forage species in the rotation system, or (seldom) of purely physical nature such as the construction of check dams and gabions, or mostly a combination of both as for example terrace embankment planted with fruit trees, or rows of stone walls doubled by strips of perennial grasses.
In this stage, the opinion of the farmer is of vital importance and it will greatly influence the solution finally maintained for one particular spot, even if it does not entirely correspond to what would appear technically evident. There may be a general resistance against terracing, as this would remove too much land from cultivation. There may be an over-enthusiastic response to the proposal for fruit tree planting, due to the hope it makes rise for subsidies, etc. If an intervention which appears necessary meets little approval from the farmers, it will not be cancelled in the programming, but it's size or frequency will be much reduced.
Finally a programme of interventions covering the entire sample area is produced. It is a document which can be immediately used for implementation by an engineer and his crew of foremen and labourers.

g) Extrapolation over the entire priority zone:
It is self-evident that the programming made for the sample area is too dense and too intensive as to be projected over the entire basin. Nevertheless this first, theoretical step has to be taken in order to adjust the programme to the size and proportion of the land classes as encountered in the area, for example: if in the sample area, fruit trees + lucerne on terrace embankments have been programmed in 20% of the land of class 3, if then there are 1.000 ha of class 3 land in the corresponding priority zone, then we have to programme 200 ha of such type of intervention.
This purely arithmetical extrapolation leads to a 'maximum programme',

which would appear as the ideal compromise between what is technically required to stem the erosion and what is desired or at least acceptable by the local population.

h) Elaboration of the optimal programme:
The factors which prevent the realization of the maximum programme, however desirable it may be for an effective protection of the dam site, are of logistic, financial and economical nature:

- logistic: it is estimated that the administrative unit responsible for a particular watershed cannot effectively treat more than 4.000 ha per year, due to limited numbers of engineers, supervisors, machinery, tree nurseries, seed supply and, although this may sound surprising, labour. Even in the economically most depleted areas, shortage of labour is one of the most seriously limiting factors, especially when planting operations are involved, which correspond with the peak work lead on the farm, seasonwise.
- financial: the financial resources of the Government will always be insufficient to cover the eroded area with sufficient intensity, especially as, like for the vital barrage of Sidi Sa'ad which protects the town of Kairouan, there is a watershed involved which covers the entire central part of the country.
- economical: as was said in the introduction, the idea that anti-erosive programmes should not be looked into from a cost-benefit point of view is no longer acceptable. The integrated treatment of a watershed should raise sufficient income through better cropping, less losses, increased production of livestock, new resources such as fruit trees, that the entire investment should have an economically positive balance over 20 years, even if the reservoir with it's beneficial effects downstream was not there.

This requirement shows immediately that totally unproductive interventions such as the stabilization of badlands and deep gullies can only be justified if taken into the overall agro-sylvo-pastoral development of the watershed. The rentability of each intervention is calculated over 20 years, seen in the overall agricultural development of the region. Sometimes items much wanted by the farmers such as olive trees raise a conflict with a nationwise planning policy not to encurage such crop any more. Special problems such as absentee landowners or livestock owners without any land property have to be looked into.

i) Final presentation of the programme:
Finally the work programme, having taken into consideration all limiting factors, is trimmed down as to represent a reasonable work lead for a forestry administrative unit (in our case: an 'Arrondissement Forestier') over 5 years. Extension and projection over more than 5 years is unpractical, as basis data such as unit costs and social facts may by then have changed too much. Moreover, 5 years is the period usually required by financing agencies which have to examine whether the project, as part of the dam construction or independant of it, is bankable. Sofar all work plans presented by the project (watersheds of Bzikh, Chiba, Nebhana, Sikiana) have been approved for financing.

An example is given of the work load involved in the anti-erosive treatment of an area of approx. 20.000 ha of the Oued Sbiba watershed in Central Tunisia in a hilly region under 300 mm annual rainfall:

	Intervention	Number	Effected area in ha
1	Planting of fruit trees	120.000 trees	1.200
2	Annual fodder crops, perennial fodder crops, improved pastures.	–	3.200
3	Fodder tree and cactus plantations	–	950
4	Reafforestation and gully planting	–	3.900
5	Terrace embankments	210 km	900
6	Stone walls	800 km	1.600
7	Ripping	900 km	1.400
8	Checkered terraces	–	3.700
9	Individual terraces for trees	5.000	85
10	Checkdams	5.000	–
11	Gully stabilization	800	–
12	Gabions	200	–
13	Rows of cactus or perennial grasses	450 km	1.170
14	Windbreaks	80 km	1.150
15	Dams	45	

The total cost of installation has been calculated to be almost US $ 3 million, or approx. 120 dollars per hectare, spread over the entire watershed. The cost for the construction of a medium-size dam may be 100 times that amount.

3. Results

The results of this integrated approach of watershed management can be theoretically calculated.

a) negative results:
they are: loss in cereal production due to a reduced cultivable area, loss in forage production due to numerous exclosures from grazing for badland stabilization or reafforestation.

b) positive results:
apart from the massive employment offered temporarily for earth-moving works, there are: preservation of soils and their fertility; fruit tree production; fodder production and better grazing from improved pastures; sale of animals, sale of fodder.

In terms of extension of the lifetime of the dam, in one case it was calculated that treatment of only 15% of the watershed area would already result in a 35% reduction of the silt load and an extension of the useful life or the dam by 14 years. If 40% of the area were treated, 25 years would be added. A 73% raise of income of the population could be expected, and the internal rate of return of the project would be above 15%.