TIGRAY LIVELIHOOD PAPERS No. 8

Establishment and Management of Woody Vegetation to Control Gully Erosion

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Since the last 10 years Mekelle University trains students from all over Ethiopia to solve problems which typically occur in semi-arid areas. Starting with a Faculty of Dryland Agriculture, Mekelle University took on the challenge to work with the farmers of the Tigray hinterland for a better future. The idea was to conduct, in a participatory manner, practical field research aiming at solving farmer's problems. The University has now 7 faculties, all aiming to work in this spirit.
The Flemish Inter-University Council (VLIR, Belgium) has been supporting this laudable evolution through a number of research projects in the field of soil conservation and rehabilitation of dryland forest.
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Foreword

In the framework of a Ph.D. research on integrated gully rehabilitation through the use of woody vegetation in Tigray, fieldwork has been conducted in woreda Dogu'a Tembien over the past four years. This Ph.D. is yet to be completed, but the end of the fieldwork is approaching, and it is therefore considered a good opportunity, also as a kind of appreciation towards everybody who joined this effort, to make the information collected in the field or read from literature accessible to all for whom this might be important, especially to those directly experiencing the problems related to gully erosion and with limited accessibility to appropriate information. That is why we decided to write this preliminary technical note on the case study of our experiment and on gully control by vegetation in general. Accessibility is also the reason why we wanted to make this a popularised text, in an English as well as a Tigrinya version.

Different aspects related to the erosion control potential of woody species have been studied in the context of this Ph.D. research, such as root system structural development under different conditions, hydrological characteristics and general use and functions of woody species. However, the aspect with highest practical value for immediate application is the in-situ study on seedling establishment and performance in and around gullies under different treatments and environmental conditions. That is what this document is about.

This text discusses only the first, preliminary results obtained up to 21 months after establishment of our experimental setup. It must be stressed that also the limited literature review is mainly focusing on the use of (woody) vegetation for gully erosion control, measures which should be used in a complementary way along with other techniques. Furthermore, evaluation of the described experiments will continue in the future, and hence we hope you may one day read about further knowledge and experience gathered through these efforts. We would like to encourage every reader, all experts, all people involved in soil and water conservation activities, and all people directly experiencing the effects of gully erosion to add more information and extend this original version to a more valuable one. Please feel warmly invited to contact the authors for comments and ideas for improvement. We would also like to invite everybody to spread the knowledge gathered in this manual to as many people as possible.

Bert Reubens
Hagere Selam, September 2008

0   Introduction: The practice of using vegetation as a gully control measure

In the highlands of northern Ethiopia, land degradation is dramatic, with loss of topsoil by water erosion and water-induced gully erosion and landslides as most important processes. This results in an irreversible loss of soil and biodiversity and constitutes a severe threat for sustainable agriculture and forestry. Gully erosion is responsible for significant on-site soil losses and off-site consequences such as sediment deposition in river channels and flooding. In addition, once developed, gullies transfer runoff and sediment rapidly from uplands to lowlands and further down to the drainage system. Reducing gully erosion will therefore lead to less sediment yield, less reservoir sedimentation, lower flood risk and more water in uplands to infiltrate.

The protective role of vegetation has long been recognised and demonstrated in many studies. Vegetation reduces water-induced erosion by intercepting rainfall, increasing water infiltration, reducing runoff at soil surface level and stabilizing the soil by roots. Especially for incisive erosion processes such as rill and gully erosion, roots are at least as important for the reduction of soil losses as the aboveground vegetation cover. The larger infiltration capacity and the higher surface roughness caused by roots reduce the volume and velocity of surface runoff, although it must be stated that the mentioned higher infiltration in the mean time increases landslide risk. Mechanically, roots reduce soil erosion by binding the soil particles at the soil surface.

Different types of vegetation are known to have different effects, and this effect will also depend on soil and environmental conditions. Herbs and grasses have shallow, dense fine root mats and are frequently cited as most useful in combating topsoil erosion by water and wind. Probably, most beneficial in many situations is a mixture of species or life forms of different dimensions and characteristics to control a wide range of soil loss processes. Not only does this result in a wide variety of plant and root types, each performing specific functions, but mixed vegetations also possess deeper and more completely developed structural roots than monocultures of the same species: competition for resources may favor root investments as a survival strategy. Moreover, for water erosion it is important to combine trees with a lower surface cover of herbs or grasses. If there is no contact cover, high soil detachment rates may arise from water drops with an increased drop size reaching the soil surface from a high fall height as leaf drip.

Trees have a higher capacity to be used in integrated, multipurpose management practices, as they often perform a whole range of socio-economic, ecological, cultural and other functions and uses besides their protection functions. This makes them highly recommendable for use in the context of northern Ethiopia,

where an important aspect is the overall land degradation, the alarming deforestation and the shortage of land and wood. A very important criterium to take into consideration when selecting appropriate species is therefore their multifunctional value.

However, whereas a species might seem theoretically very suitable for erosion control with regard to its multifunctional value and its rooting or other important characteristics, its success and above- as well as belowground development will depend on the specific circumstances under which it is used (e.g. for anchorage: species with a heart root system are expected to have the best anchorage in clay-like soils, whereas species with a taproot system perform better in sandy-like soils). Furthermore, there are many bottlenecks once effectively planting it in or along gullies. Besides the importance of a good planting practice, threats such as grazing, trampling, drought, water flood and sediment coverage have to be taken into account. Efforts previously made in using woody species for erosion control in this area show a very high mortality and hence very low efficiency. Experience on efficient woody species application is very limited, and there are many practical questions to be answered on suitable species, where exactly seedlings should be planted, and how they should be treated, for a guarantee of success with minimal effort and cost.

1   General recommendations for integrated gully control by vegetation

1.1   A short introduction on gully erosion and its consequences

Gully erosion is "the removal of soil or soft rock material by water, forming distinct narrow channels, larger than rills, which usually carry water only during and immediately after rains" (Geyik 1986)[1].

Gully erosion occurs when water is channeled across unprotected land and washes away the soil along the drainage lines. Under natural conditions, runoff is moderated by vegetation which generally holds the soil together, protecting it from excessive runoff and direct rainfall. Excessive cultivation and clearing, road construction, overgrazing and compaction of the soil caused by livestock often means the soil is left exposed and unable to absorb excess water. Surface runoff then increases and concentrates in drainage lines, allowing gully erosion to develop in susceptible areas.

Gully systems in Ethiopia can often be considered as discontinuous ephemeral streams, comprising a hillslope gully, an alluvial-colluvial cone at the foot of the hill and renewed incision with gully head formation further downslope in the valley (Nyssen et al. 2004b).

In a set of interviews performed in the Tigray highlands, many consequences of gully erosion were mentioned. On the one hand the interviewees stress the loss of farmland, the decrease of soil productivity and the difficulty to plough. On the other hand they refer to the lack of fodder for cattle, the decreasing water resources and the difficulty to cross gullies. Other remarkable consequences are the loss of cattle or even children taken by the flood. At regional scale, gully erosion increases land degradation and desertification.

1.2   Prevention of gully formation

(Adapted mainly from FAO 1977 and Geyik 1986)

Before discussing techniques aimed at controlling gullies once developing, it must be stated that preventing the formation of a gully is much easier than controlling it once it has formed. Small gullies in initial stages can also be easily controlled. Prevention is often more economic because cost of gully control and repair can be high in relation to the value of the land. In most cases gullies can be prevented by good land management practices aimed at maintaining even infiltration rates and a good plant cover. Strategies for preventing gully erosion include:

Proper soil, water and agronomic management practices

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[1] Not all references used are mentioned immediately in the text. A broad list of literature used for this manuscript or providing interesting information related to the issue, is added at the end of this paper.

- Protection of the soil by good crop canopy during rains.
- Control of sheet and rill erosion through proper land and tillage management practices.
- Immediate stabilization of sheet or rill erosion through specific slope treatment measures such as stone bunds, terraces and inter-bund land surface configurations.
- Maintenance of organic matter in the soil and soil fertility through proper inputs, crop rotation and control of land degradation.
- Revegetation or maintaining remnant vegetation in drainage lines and eliminating grazing from these areas.
- Control of grazing and revegetation of community land and grassed waterways in general.

Increased infiltration and diversion of runoff above the gully area

In many cases, the simplest, cheapest and safest gully control method is to reduce or divert runoff, and improve infiltration before reaching the gully. Most successful strategies for reducing runoff in upstream areas in semi-arid areas are the construction (and careful maintenance) of stone bunds and the establishment of exclosures. Diversion towards exclosures has been studied e.g. by Descheemaeker (2006a).

Improvement of infiltration can be done by maintaining e.g. grass strips (if appropriate supplemented with other useful or suitable woody species), infiltration ditches or live stakes above the gully head. These practices are particularly useful in woodlots and forest land. However, this is not always practically possible in grassland and cultivated land.

In any case, until infiltration within the gully catchment area has been improved, no attempt should be made to completely block a gully, as otherwise it will simply find another bed.

1.3 Vegetative control of gully erosion

(Adapted mainly from FAO 1977, Geyik 1986 and Roose 1996)

"A well treated gully behaves like a linear oasis" (Roose 1996)

The potential of vegetation in erosion control has been briefly mentioned in the introduction of this text. Vegetation provides protection against scouring and minimizes the erosion risk by reducing flow velocity. Besides the pure protective role, the biomass produced in the gully area can be used for different purposes such as cattle fodder, hence decreasing grazing pressure in other areas. The long-term success of gully

stabilization work depends on establishing a good vegetative cover on the gully floor which prevents further gullying and allows the gully floor to gradually silt up, hence reducing the fall over the gully head. As flow velocity falls, sediment is deposited, forming an ideal environment for new vegetative growth. Nearly all structural measures used, particularly in grassland areas, depend upon vegetation to support them and to stabilize the soil exposed to excessive runoff.

1.3.1 Natural revegetation

So which measures have to be taken to enhance revegetation? Of first importance is the exclusion of livestock or mechanical disturbance from the gullied area. Protection against disturbance is the slowest but nevertheless also the cheapest method of gully control. Good results may be obtained and heavy expenses avoided by the simple process of fencing the area to exclude grazing or cultivation. Any gully, regardless of its size or condition, usually will regain a cover of natural vegetation if it is properly protected and is in an area where vegetation will grow readily. Diversion or retention of the water, which causes the gully, protection from grazing or trampling by livestock, protection from fire, and the removal of other causes of disturbance usually result in growth of natural vegetation which will, in time, cover the gully and heal the erosion scars.

However, many gullied areas or gully banks are not in good condition for vegetative growth since the fertile topsoil has been washed away, slopes are steep, and the impacts of raindrops on the unprotected soil has produced conditions adverse to plant survival. Gullies often dry out very rapidly and usually have infertile subsoils. Bank sloping may be necessary before vegetation can be expected to do an adequate job of gully stabilization, although one must be very careful with this practice: you may widen the gully and the reshaped material can simply be washed away in the first storm. Furthermore, adapted grasses, trees or shrubs provide good protection to gullied areas planned for critical area planting. Check dams, log, concrete or a series of small weirs made from wire netting can trap sediment which encourages vegetative growth. Vegetative weirs can be established using species with erect growth forms such as vetiver (*Chrysopogon zizanioides*) or elephant grass (*Pennisetum purpureum*). If available, branches of dead shrubs or trees can play a useful role in stabilizing a gully floor by restricting access by grazing animals. They also retard run-off flow and hence encourage further sedimentation.

1.3.2 Active planting to enhance gully control

In general, it is management and protection rather than the type of the vegetative cover, which determines its effectiveness in gully control. Any vegetation which is well adapted to local conditions and which shows vigorous growth may be used.

Indigenous species should be considered and given priority, especially when introduced or considered exotic species involve certain risks, such as potential invasiveness, pests and diseases, or negative impact on soil environment. However, a number of exotic grasses and other species are well established in our agricultural lands and have been used with great success for controlling erosion. Vegetation that grows vigorously with a spreading, creeping habit is preferred. It is important to obtain local advice to see if a proposed plant has a weed potential in a particular area. Although plantation of *Eucalyptus sp*. (T: Bahir zaf) in or along gullies is a common practice in Tigray, it should be stressed that this certainly creates some serious problems and does not contribute to a sustainable control of gully erosion. The huge water consumption by *Eucalyptus* can lead to cracking, piping and further gullying, and also the suppression of undergrowth is problematic (World Agroforestry database 2002, Jagger and Pender 2003).

Although concrete actions will be different from site to site, and largely depend on the final objective, in general the first point is to fix sediment as soon as it is deposited. Planting rhizome grasses which will continue to grow as the sediment piles up can be interesting here. Unbroken, closely-planted lines of shrubs on the sides of the gully will help to centre the flow. Then, when enough soil has collected, larger fodder, fruit or other multifunctional trees can be planted along the gully to stabilize the slopes.

Fencing the gullied area is highly desirable. Stocks are attracted to gullied areas, especially if they include shade trees. These areas are then subject to heavy grazing and compaction. If it is available, some form of watering is desirable to assist in the establishment of vegetation. An initial application of a mixed fertilizer aids in rapid establishment of an effective cover. Trees are desirable in the areas surrounding gullies but are not likely to be successful in stabilizing an actively eroding gully head. Trees growing in gullies should not be too dense and should have an open canopy to allow protective vegetation to grow on the soil surface. Where subsurface flows are contributing to gully erosion, trees in the area above the gully head should assist by helping to dry out the soil profile and provide structural support to subsoils prone to slumping.

The possible uses of the area and its vegetation after stabilization will determine the type of vegetation to be established. A stabilized gully may be used as a wildlife habitat, woodland or a grass production area. It should not be used in a way that will weaken or destroy the re-established vegetation. The best possible use should be selected after considering the size of the gully, its location with respect to other land uses in the catchment, the control measures needed, and the type of maintenance required.

If it is to be used for a grassed waterway, the gully should be reshaped to proper size and proportion. Critical area planting of a gullied area in pastureland will be affected by the intensity of grazing on the area. Limited harvesting of grass vegetation during the establishment stage is often beneficial in controlling competitive weeds and shrubs. Nevertheless, overgrazing will seriously hinder establishment. Gullied areas in pastures might be better protected permanently from all grazing. In gullied areas adjacent

to woods, it is desirable to plant trees of adapted species and use the area as exclosure or protected woodland.

1.4   <u>Other and complementary techniques</u>

Vegetation is the primary, long-term measure in controlling gully erosion in situ: in the end, vegetation is what definitely stabilizes the gully. While structures may be subject to decay and become less effective over time, vegetation can multiply and improve over the years. Nevertheless, structures may be needed to stabilize a gully head or to promote siltation and vegetative growth in the gully floor. Check dams may be made of concrete, dry masonry, gabions, wood or other building material. They need various skills for their design and construction and may be expensive to implement. Check dams have an inherent risk of failure and may be undermined or bypassed.

Several of these techniques have also been discussed in Tigray Livelihood Papers No.7, which is why they will not be discussed in detail here. Among others, the following practices can be applied (see Figure 1):

- Control of runoff over gully head or away from the gully head using diversions, flumes, pipes or drop structures.
- Stabilization of the gully floor with sand bags, loose rock checkdams or gabions (wire net structures, filled with rocks). Such dams may also be combined with retaining walls parallel to the gully axis in order to prevent undercutting of the gully banks. Remark: it is important to transport the stones from a far distance, as excavating from the gully or hill side will again increase further erosion.
- Ground contouring to "smooth out" small gullies on low terraces (in combination with runoff control and surface vegetation).
- De-watering techniques
- Installation of a flood regulator

Some techniques combine a physical structure with the use of vegetation, such as:

- Vegetated stone dams or gabions
- Brush layers (live cut branches and rooted plants placed in layers onto excavated terraces and filled up with soil material)
- Use of straw, mulch, intermediate grass planting or stones to reduce water loss from the soil
- Timber or pole debris dams
- Live dams
- Diversion of water into exclosures

1.5   Important rules and considerations

(Adapted partly from Roose 1996 and Nyssen et al. 2004b)

The techniques discussed are not always successful. Applicability and effectiveness will strongly depend upon the type of gully and specific circumstances, which have to be very well understood. The size of the gully catchment area, the gradient and the length of the gully channel are some of the main criteria for selecting control measures.

Any structure built must be properly maintained:
- Repairing weak points (e.g. by supplementary planting);
- Adding a filter of plant residues;
- Making sure that the water cannot flow around the barrier, by planting protective vegetation along the banks, reinforcing this with branches if needed;
- Preventing undermining below the barrier by limiting the height of the structure, and by planting certain species immediately below it. Good options are *Agave* (T: I'qaa) and fast-growing forage plants.

When using physical structures (whether in combination with vegetation or not), correct spacing of these structures is important as well, since too much spacing between them will result in undermining their base, leading to potentially high costs of repair operations.

As for the position along the gully, in principle, priority should be given to taking measures in the upstream sections, where the chances of success are higher. Once these sections have been treated, it will also be easier to treat the lower sections.

Mechanical and biological treatment of a gully may be done gradually, but must take account of the whole watershed from the outset.

Figure 1: Examples of some interesting techniques. Left: Water diversion into exclosure (Tigray, Dogu'a Tembien, May Zeg Zeg watershed. Photo © Reubens B.), Right top: young live fence (Tigray, Dogu'a Tembien experimental site Reubens. Photo © Reubens B.), Right bottom: sand bag check dam (Tigray, Lenche Dima watershed. Photo © Hagos Woldekidan)

2   Case study in Dogu'a Tembien

2.1   Present gully control in the study area

Field observations around Hagere Selam reveal how natural vegetation, in combination with check dams, is capable of rapidly slowing down further gullying or even completely stabilizing gully beds and banks. Good examples are found in exclosures, where absence of grazing and trampling allow such vegetative recovery fairly rapidly. While check dams, with an important initial function, in the long term loose their strength, can be bypassed under some circumstances, or even collapse, vegetation takes over their stabilizing role and becomes stronger over the years.

Nevertheless, even despite successful examples in other parts of Ethiopian highlands, so far, control measures with vegetation are rarely used in the study area, because this requires a careful protective management which is not always realistic. Gullies are intensively grazed and keeping livestock out of gullies requires the presence of a paid guard, which is only deemed profitable where small, but spectacular, patches of improved grassland can be established in gullied areas, especially on Vertisols. Besides the expensive permanent gabion technique (Figure 2), implemented in critical places, check dams built of loose rock are the most widespread gully control technique in the study area (Nyssen 2004b).

Figure 2: Gabions used to control gully erosion. <u>Left</u>: New gabion collecting a huge sediment deposit which could easily be used for vegetation planting. <u>Right</u>: Gabion bypassed by the flood. This could have been prevented by using appropriate complementary vegetative measures. (Photos © Reubens B.)

However, we believe that there is a good potential for effective implementation of vegetative control, in a way which is even economically beneficial in the long term. Yet, this requires more experience and thorough knowledge on the practical questions raised in the introduction part:

- Which species are most suited under different specific circumstances, taking into account establishment chances, growth speed, beneficial effects and multifunctional value?
- When, where and how should seedlings be planted?
- What kind of further management do the planted seedlings need for a guarantee of success with minimal effort and cost?
- Do these seedlings show a beneficial effect on gully erosion control? How fast?

2.2   Objective

The primary aim of the presented experiments is to gain a better understanding on practical aspects related to gully segment closure and tree plantation as a measure for gully erosion control.

More specific research objectives are:

- to evaluate survival, growth and development of seedlings of different tree species under different site conditions and treatments;
- to determine the most suitable conditions and the minimum level of protection/treatment required for good seedling establishment of every species;
- to assess species overall ecological suitability for gully rehabilitation;
- to assess growth bottlenecks and the magnitude of their effects on plant establishment;
- to determine if and in which term effects of closure and/or plantation on further gully development and environmental characteristics can be expected;

For the discussed field trial, we therefore mainly experimented with different growing conditions and treatments for different species.

2.3   Selected research sites and species

The experiments are conducted in two kushets (villages), namely Adi Kolakol and Adi Worho located in tabias (community – group of villages) Ayninbirkekin and Selam, 7 km east and 10 km northeast of Hagere Selam town (capital of the Dogu'a Tembien woreda (district)), respectively. Research started with one experimental site in each village in August 2006, but was extended to a second site in both places in August 2007, resulting in a total of 4 experimental sites. All sites were selected in agreement with the local communities and based on suitability for experimental setup, with homogeneity in soil and environmental conditions being the most important criteria.

Both sites in Adi Kolakol are on the same gully, on a soil consisting mainly of sandy colluvium covering a Vertisol in the upper site (further denoted as site 01), and a Calcisol in the lower site (further denoted as site 04). Surrounding land use is a mixture of rangeland and cropland. This gully is situated downstream from a culvert of the Mekelle-Hagere Selam road and has been the subject of a road impact study before (Nyssen et al. 2002).

In Adi Worho, the first site (further denoted as site 02) is situated in a lower slope position, in a Calcic Vertisol, surrounded by rangeland. The second site (further denoted as site 03) is situated in a different gully in an area where alluvial deposits cover a Vertisol.
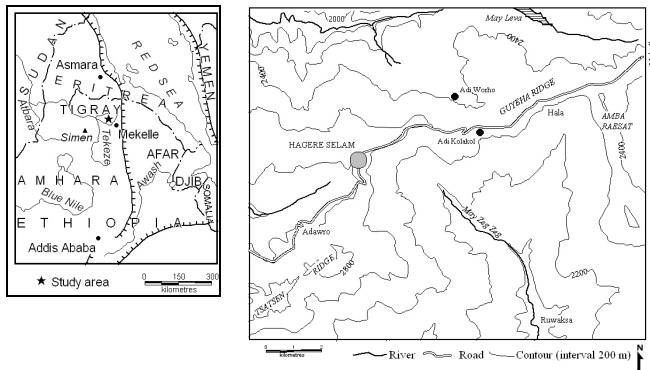
Figure 3: *Location of the study area*

Species selection was based on a multi-criteria analysis taking into account e.g. ecological suitability, socio-economical functions, protection functions and root characteristics (see Moeremans 2006). Specific important features are: fast growth, resistance to covering by sediment (forming adventitious roots), resistance to temporary water logging and/or drought, resistance to grazing, potential for stabilization.

Three woody species were selected for the original setup:

- *Dodonea angustifolia* [T: tahses]: many uses, soil improver and good hedge, easily growing, easy multiplication, growing in riverine as well as dry environments;

- *Sesbania sesban* [T: sesbania]:important fodder species with several other uses, very fast growing, easy to establish even in waterlogged soil and dry eroded soil, prolific seeder, nitrogen fixing;

- *Acacia etbaica* [T: seraw]: fire wood, very common species in the research area, resistant species with re-sprouting characteristics, capacity to recover degraded land.

For the second phase in August 2007, another three species were selected:

- *Faidherbia albida* [T: momona]: many uses, nitrogen fixing, extensive deep root system, resistance to both drought and wet conditions, tolerant to heavy clay soils and periodically waterlogged soil, resistance to seedling breakage, not competing with crops;

- *Cordia africana* [T: awh'i]: fast growing, indigenous important multipurpose species with hard and durable wood, easy to raise;
- *Psidium guajava* [T: zeitoon]: fast growing, important fruit tree, drought hardy.

All seedlings were raised at the Endayesus tree nursery (Mekelle University) before transplanting to the field.

2.4 Methodology setup

2.4.1 Experimental setup and variations in growth conditions

In the field trial sites, the tree seedlings were planted in and around existing gullies, following a schematic design. In every site, four different experimental factors were varying between the specimens:

1. **Species**
2. **Water** availability
3. **Sheltering** as protection against sun, flood and/or animals
4. **Gully position** relative to its topography

Furthermore, as the sites were selected in different sites, between the sites an extra factor was varying between the seedlings, being **soil type**. See also schematic representation in Figure 4.

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                          Growth conditions

   ┌──────────┐   ┌──────────────────┐   ┌──────────┐   ┌────────────────────┐
   │ Soil type │   │ Water availability │   │ Shelter  │   │ Position in the gully │
   └──────────┘   └──────────────────┘   └──────────┘   └────────────────────┘

                             Evaluation of:

   ┌──────────────────────────────────────────────────────────┐
   │ - Seedling survival - vitality                            │
   │ - Growth (height, diameter, nr and area of leaves, …)     │
   │ - Stress (drought – flooding)                             │
   └──────────────────────────────────────────────────────────┘

        Link with environmental      •Soil characteristics
        conditions:                  •Topography
                                     •Gully characteristics
                                     •Climatic conditions
                                     •Land use
                                     •…
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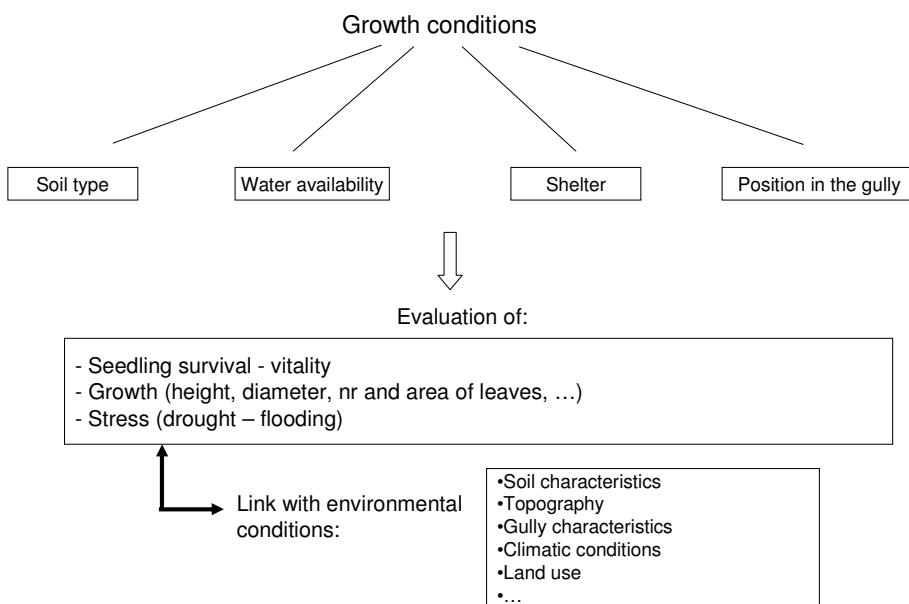
Figure 4: schematic representation of the variation in growth conditions per species and the characteristics under evaluation

We started from the assumption that protection against cattle is needed anyway, especially if we want to perform research and hence be able to assess results. Therefore, every site was fenced and guards were assigned to guarantee that no disturbance could take place.

A distinction has to be made between the two original sites and the two newer sites, in which other species were used and which also knew a slightly different selection of treatments.

For the different factors, the following treatments were selected for the original sites:

1. *Water availability*: Differentiation between seedlings who receive:
   - Small volume of water by watering (twice a week) during the dry season (October – June);
   - Higher volume of water by watering (twice a week) during the dry season (October – June);

   Remark: determination of watering amounts happened through testing. At the onset of the experiment, 1 and 4 liter of water were provided twice a week to the low and high water treatment seedlings, respectively. This volume was gradually reduced to 0 and 1.5 liter twice a week after 1 year. No water was provided during the rainy seasons.

2. *Shelter protection*: Differentiation between:
   - Freely growing seedlings without shelter
   - Seedlings having an open shelter of Giant reed [T: shambaqo] or sorghum [T: mashela] branches.

3. *Position in gully*: Differentiation between seedlings positioned:
   - On the gully floor
   - On the gully side wall
   - Outside, on top of the gully

Per site, seedlings were distributed over six plots, with every plot consisting of 72 seedlings, equally distributed over the three species, the two shelter treatments and the three gully position treatments. This resulted, per plot, in four replicates per species-treatment combination. Of the six plots, three full plots received more water, and three received less water, which finally resulted in 12 replicates per species-treatment combination (2 water treatments*3 species*2 shelter types*3positions*12 replicates=432 seedlings in total). The same setup was repeated in both sites, hence also including the last factor, being soil type. This setup is schematically represented in Figure5.
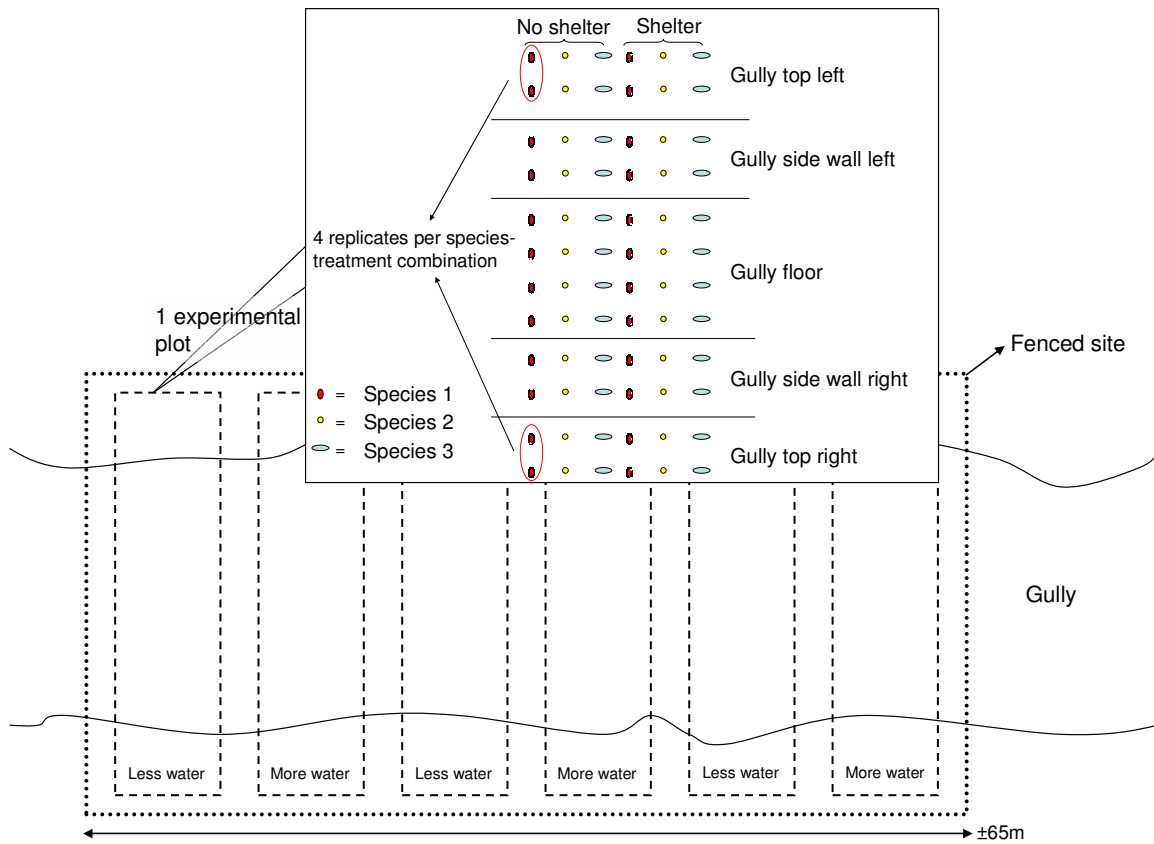
Figure 5*: Schematic setup*

2.4.2 Site preparation and infrastructure

All planting holes were dug prior to planting, hence enabling rainfall to be collected in these holes to ensure high water availability for the seedlings immediately after planting. Seedlings were then planted according to the presented scheme and received an individual label with their specimen code. Around every planted seedling, a small 'half moon' earth ditch was constructed and maintained, to improve water uptake. Other important preparatory constructions include the upstream runoff discharge measurement construction, tubes for water level measurement, cross-section mark points and sediment sites. See 'methodology evaluation' for their purpose. At the onset of the experiment, reparation of the present check dams was also performed.

2.5   Methodology evaluation

A whole set of plant as well as environmental and soil characteristics was monitored on a regular basis, hence enabling to assess and understand plant growth and survival, gully evolution and effect of treatments.

2.5.1   Seedling characteristics evaluated

The following characteristics were (and still continue to be) assessed for every planted seedling:

1. Survival and vitality score
2. Growth: periodical measurements of
    · Plant height;
    · Plant crown dimensions in 2 perpendicular directions;
    · Crown density for the upper, middle and lower plant part;
    · Diameter at the base;
    · Number of stems and branches;
    · Leaf length and width (used for calculation of leaf area), initially for every individual leaf (>1cm) and later on a representative sample of 10 leaves;
    · Presence of flowers and/or fruit.

Survival was continuously evaluated every single week. Other growth characteristics were initially evaluated on a monthly basis, reduced to a 3 monthly (4 months after setup) and finally 6 monthly (one year after setup) evaluation.

At three intermediate moments with a one year interval, a limited number of destructive samples were collected enabling determination of:

· Leaf area, allowing the establishment per species of a regression function between this area and leaf length & width;
· Fresh and dry weight of stem, leaves and roots;
· Root system dimensions.

3. Plant-water relationships:
    · Leaf stomatal conductance (indicating the rate at which the leaf can evaporate water at a specific moment);
    · Leaf water potential (indicating the suction force, which a plant has to develop or can develop, in order to extract water from the soil).

These measurements followed seasonality and were assessed together with evaluation of soil water content (see below).

2.5.2 Biotic and abiotic environmental characteristics evaluated

1. Natural vegetation (repeated measurements):

   · Plant growth characteristics as described before were measured also for every naturally growing woody specimen inside the site as well as within a fixed area outside upstream and downstream of the site. This should enable assessment of the effect of fencing on growth and regeneration of natural vegetation;

   · Similarly inside and outside the site, an estimation of grass cover was made, and presence & density of herb and grass species was assessed using 1x1m site frames;

   · Fine root density: to assess effect of fencing and seedling plantation on changes in root density, root samples were taken at three depths within each plot for two specimens per species at a distance of 30 and 80 cm from the seedling, both at top and floor positions. Additionally, 20 control samples were randomly taken outside the fenced sites at top and floor positions;

   All these measurements took place at regular time intervals, approximately every 6 months.

2. Environmental characterization (one time measurements):

   · Previous and present land use, grazing pressure and human disturbance;

   · Gully drainage area determination using GPS;

3. Environmental characterization (repeated measurements):

   · Light intensity: measured with luxmeter in order to evaluate reduction in intensity due to shelter;

   · Minimum and maximum temperature: daily measurements using thermometer in well-ventilated Stevenson shelters, positioned 1.5m above ground level;

   · Rainfall: daily measurements using rain gauges;

   · Runoff discharge in the gullies: measurement during the rainy season. Upstream of each site, a uniform stream section was prepared, using two concrete constructions, separated 10 meter from each other. During rainfall, water height was measured at both constructions, and speed was measured by dropping a floating object into the water at the level of the first construction and measuring the time for the floating object to reach the second construction, 10 meter downstream. Surface in between was smoothened, not to hinder stream speed. Width was kept approximately uniform;

   · Maximum water height in the gully floor: assessed using a simple plastic tube with an inlet at the bottom and a top cap that can be taken off. Inside there is a pole with water-

sensitive tape attached. The dye on this tape is washed away on contact with water, allowing to read maximum height of flow;

· Gully cross-sections: changes in gully dimensions were evaluated using a Total Station theodolite, on five marked cross-sections inside and five cross-sections outside every site.

4. Characterization of soil and gully morphology (one time measurements):

· Surface characterization: evaluation of stoniness, rock outcrop, cracks, sealing, roughness;

· Gully characteristics: these include evaluation of local landscape position, slope, orientation, gully initiation and channel expansion, as well as gully wall morphology.

· Soil sampling for chemical and physical analysis, along top-wall-floor gradients. If remarkable soil spots were present (e.g. burnt horizon), it was made sure these were also sampled;

· Detailed soil profile description.

5. Soil characteristics (repeated measurements)

· Soil water content: assessed gravimetrically (measuring difference between fresh and dry weight) following a similar strategy as for fine root density, hence enabling evaluation of site, seedling and fencing effects. These samples were also used for interpretation of plant-water relationships;

· Changes in sediment level: evaluated on metal bars fixed in the gully floor.

2.6   Preliminary results

As the experiment is still going on, the results presented here are far from complete and only give some first indications. Nevertheless, some promising intermediate results were obtained so far. In this text, we focus on plant survival and growth in the original setup (site 01 in Adi Kolakol and 02 in Adi Worho; species *Acacia etbaica, Sesbania sesban, Dodonea angustifolia*).

2.6.1   Seedling survival and growth

Survival rate after 20 months was 80% in Adi Worho and 73% in Adi Kolakol, with flooding in the gully floor during the initial rainy season being the main cause of mortality. A second, much smaller, mortality peak appears in the second rainy season (after one year). These results clearly indicate that the first year is most critical for seedling establishment. Whereas differences in mortality between the three species were relatively small in Adi Kolakol (19% for *Acacia*, 22%

for *Sesbania* and 33% for *Dodonea*), *Sesbania* had a remarkably lower mortality (6%) in Adi Worho as compared to *Acacia* and *Dodonea* (27% and 22%, respectively).


Figure 6: Views on the gully in Adi Worho. <u>Left</u>: Shortly after planting in August 2006; <u>Right</u>: Condition at the same place after 1 year.

One explanation might be its fast development of a deep and far reaching root system. As for *Acacia*, mortality would have been low as well, was it not for the high amount of seedlings uprooted by animals in Adi Worho (see below). *Dodonea* had the lowest overall survival rate (63%), although this is still a successful achievement. Of the total mortality, the main part took place in the gully floor for *Acacia* and *Dodonea*, whereas gully position did not affect survival for *Sesbania*. Shelter seemed to provide an important protection, improving survival not only in the floor, but also on the top and wall positions. This effect was strongest for *Acacia* and *Dodonea* seedlings. At first sight, for all species, differences in watering did not seem to significantly affect mortality. Although not discussed in detail here, it is important to remark that the zero-watering treatment in the extended setup (sites 03 and 04) resulted in a significantly higher mortality: 80% of *Psidium* (guava), 42% of *Cordia* and 46% of *Faidherbia* seedlings without watering died within the first half year. This might indicate that watering to overcome the first critical rainy season is necessary, but that small volumes of water attributed at a regular base might be sufficient.

So far, growth characteristics have been evaluated 8 times in the field, with the currently last measurement after 21 months, in April 2008. Nevertheless, evaluation continues in the future. Differences in growth between the species are very pronounced, with *Sesbania* clearly being the

fastest growing: it had an average growth of 19.5 cm/month (23 cm/month in the rainy season), see also Figure 7.
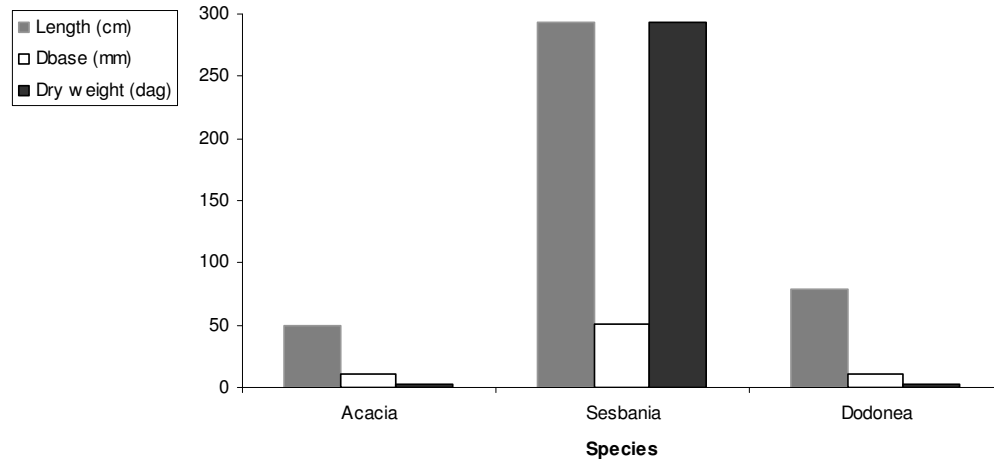
Figure 7: *Growth characteristics of the three species clearly showing the fast development of Sesbania. Length: vertically measured plant length; Dbase: diameter at the stem base; dry weight: weight of total plant after drying - in decagram (10^1 g). Results after 21 months.*

Preliminary analysis clearly indicates how the growing site, mainly determined by soil type, is the most important factor for seedling growth performance, as can be observed for the examples given in Table I. For all species and at all evaluation times, soil type significantly affected most plant characteristics, such as e.g. length, diameter and crown development, with a clearly better performance in the Vertisol of Adi Worho. Average growth of *Sesbania* e.g. was 30 cm/month on the Vertisol in Adi Worho and only 9 cm/month on the sandy colluvium in Adi Kolakol.

Table 1. Some important growth characteristics (mean ± standard deviation) for the different species in both sites

	Acacia		Sesbania		Dodonea	
Variable (unit)	**Adi Kolakol**	**Adi Worho**	**Adi Kolakol**	**Adi Worho**	**Adi Kolakol**	**Adi Worho**
Length (cm)	38.40 ± 2.60	60.18 ± 3.11	162.40 ± 10.39	347.60 ± 9.09	46.95 ± 4.28	102.82 ± 3.97
Dbase (mm)	8.54 ± 0.60	13.85 ± 0.72	33.66 ± 2.82	71.33 ± 2.47	7.47 ± 0.61	13.25 ± 0.57
LratioD (mm/mm)	56.24 ± 1.56	63.70 ± 1.83	78.00 ± 2.04	79.12 ± 1.78	81.26 ± 1.91	91.93 ± 1.77
Crown (cm²)	1007.30 ± 203.04	1605.92 ± 228.35	26604 ± 4851	87401 ± 4199	469 ± 271	2405 ± 251
CrownratioD (cm²/mm)	85.78 ± 10.68	127.80 ± 11.02	504.72 ± 58.13	1386.27 ± 49.39	45.87 ± 8.68	133.30 ± 8.10
Leaf.area (cm²)			15.22 ± 0.34	21.15 ± 0.29	4.06 ± 0.14	5.38 ± 0.13
N.twigs (-)	7.32 ± 0.76	12.64 ± 0.91	28.36 ± 14.86	229.18 ± 12.92	21.05 ± 9.70	100.41 ± 8.99

Dbase: Diameter of the stem measured at the stem base; LratioD: ratio of length over Dbase; Crown: surface of the leaved crown calculated as an ellips; CrownratioD: ratio of crown over Dbase; N.twigs: number of twigs or branches.
Values for the situation after 21 months

Also the gully position often significantly influenced plant development, although the effect here was different for the different species (see example given in Figure 8). *Acacia* seedlings clearly performed least in the floor and best on the top, closely followed by the wall. The opposite was true for *Sesbania*, with a clearly better development in the floor, followed by the wall, and least on the top. For *Dodonea*, effect was limited, with a slightly lower development in the floor as compared to top and wall.
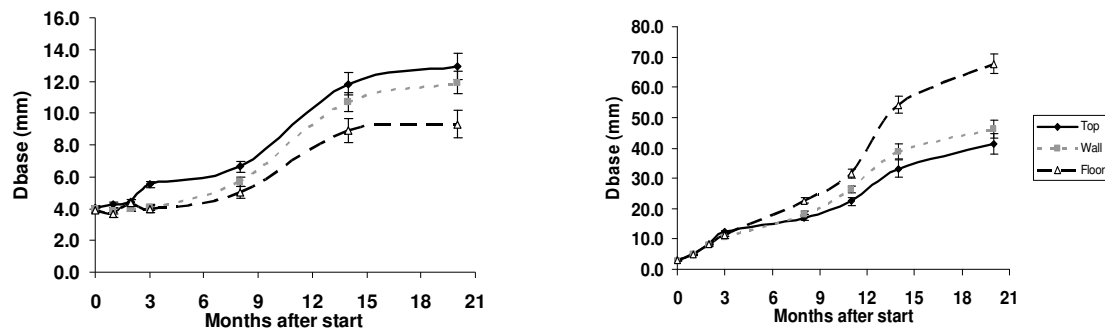
Figure 8: *Two examples showing the effect of gully position on diameter development through time. Left: Acacia etbaica, Right: Sesbania sesban*

The effect of the gully position did not only depend on the species evaluated, but was also influenced by the growing site (soil type). *Acacia* for example, performed best on the top position in Adi Kolakol, and on the wall in Adi Worho. Similarly, *Sesbania* had the lowest growth on the wall in Adi Kolakol, and on the top in Adi Worho.

It is difficult to assess one single explanation for the observed trends, but it is suggested that in general variation in soil characteristics, water and nutrient availability between the gully positions could be important aspects. In the gully floor, there is a higher supply of water and nutrients, which could be why *Sesbania* performed better there. Given the ability of *Dodonea* and *Acacia* to grow on dry and degraded sites, they might have been less influenced by that effect. On the other hand, the latter two species were probably more affected by the higher water flood and sediment transport stresses in the floor, given their slower growth.

For all species, sheltering resulted in a reduction of diameter and in an increase in length. In other words: the plant rushes to grow to the light and invests relatively more in an increase in height. Another explanation could be the higher exposure to wind disturbance for the freely growing seedlings, resulting in a bigger investment in thickening to resist these wind forces. This effect

was smallest for *Sesbania*, which is growing relatively fast out of the shelter, hence reducing this shelter effect. For *Acacia* also crown dimension and number of twigs decreased when there was a shelter.

Although on average seedlings with higher watering had somewhat bigger dimensions, <u>watering</u> didn't seem to make any significant difference in growth for all species. This is probably because both water treatments brought soil moisture content above a minimum threshold, as discussed above for the survival. Furthermore, during the rainy season there was no differentiation regarding the watering treatment. It is also important to mention that, at the onset of the experiment, repeatedly mistakes in watering have been made by the guards, probably resulting in a diminished effect of this factor.

Destructive measurements after the first year demonstrated how also root system development was most spectacular for *Sesbania*. Mean root dry weights after 14 months in Adi Worho were around 1000g for *Sesbania* and around 20g for *Acacia* and *Dodonea*. In Adi Kolakol, not enough samples were taken yet to give representative results, but averages were seriously lower for all species. *Sesbania* roots horizontally reached up to more than 350cm from the stem, and up to 80cm deep. For *Dodonea*, maxima observed were 60cm distance from stem and 35cm depth,

while roots of *Acacia* maximally reached 60cm far and 65cm deep. Although absolute root dry weight is highest for *Sesbania*, it has the lowest root-to-shoot ratios (root dry weight/shoot dry weight), averaging around 0.25, while *Dodonea* and especially *Acacia* have remarkably higher root-to-shoot ratios, averaging around 0.50 and 0.86, respectively. From this it can be concluded that, at least for this first period, *Acacia* invests relatively most of its resource allocation in root system development, which, together with its development of a taproot structure, makes it a potentially interesting species for slope stabilization.

Figure 9*: Sesbania root system after 9 months.*

Other remarkable field observations, not yet analysed in detail, are e.g. the interesting characteristic of *Acacia* to re-sprout after complete coverage by sediment deposition, the similar possibility of *Sesbania* to re-sprout after being completely cut to the base, and the very fast reproduction of *Sesbania*. Eight months after germination, this species already produced new seedlings in the sediment-rich gully floor. Nevertheless, *Sesbania* seems to be easily affected by different pests. Several yet unidentified types of scale insects (*Coccoidea*) and caterpillars were

frequently noticed on the branches. Later, also bigger animals (probably rats, rabbits or squirrels) ate its bark. Although often reducing growth and vitality, this did not frequently result in mortality. Similar problems have been observed in several semi-arid lowland regions of eastern and southern Africa, where the establishment of *Sesbania sesban* has either failed, or substantial crop losses have been incurred, because of the activities of root-knot nematodes. Besides *Sesbania*, in Adi Worho also *Acacia* seedlings suffered seriously from being cut and uprooted by an unknown animal, which entered the site at night. This resulted in mortality for about 25 *Acacia* seedlings.

2.6.2 A short note on natural vegetation and the effect of fencing

During the first inventory in September 2006, in Adi Kolakol, species found naturally in and around the studied gully were *Solanum incanum* (T: Engule), *Becium ovovatum* (T: Tebeb)*, Acacia abyssinica* (T: Cha'a)*, Acacia etbaica* (T: Seraw)*, Rumex nervosus* (T: Hohot)*, Sida schimperiana* (T: Ingriwia)*, Asparagus racemosus* (T: Qasta anesti) and *Senna singueana* (T: Hambo Hambo). Inside the site, 250 woody specimens were measured, of which *Solanum* (39%), *Becium* (32%) and *Acacia abyssinica* (15%) were the most common. One year later, no significant changes were noticed in the number of woody specimens inside the site, while 20% less specimens were found outside the site, probably as a result of human or cattle disturbance. Species composition and relative importance remained the same. In Adi Worho, less specimens were found (63 inside the site during the first inventory), but species diversity was somewhat higher than in Adi Kolakol, with presence of *Buddleja polystachya* (T: Metere)*, Carissa edulis* (T: Egam)*, Euclea racemosa* (T: Kiliaw)*, Nicotiana glauca* (T: Mengedido), *Solanum incanum*, *Acacia abyssinica, Acacia etbaica, Rumex nervosus,* and *Senna singueana*. Most common species were *Solanum* (29%), *Nicotiana* (29%) and *Acacia abyssinica* (14%). After one year, inside the site a 20% increase in the number of specimens is noticed, with also 2 new species observed: *Vernonia bipontini* (T: Shugu elle) and an unidentified *Solanum* species (T: Alalimo). Nevertheless, a similar increase was also observed outside the site, so it is difficult to attribute the changes to the effect of fencing.

As for plant dimension changes in both sites, in general promising increases are observed, although it is difficult to observe a clear effect of fencing, as shown for some examples in Table II.

It is however very important to mention here that these data will need a more detailed analysis and no firm conclusions can be taken so far. Evaluation of e.g. average dimension changes might

be disturbed by the appearance of new natural seedlings, which can significantly reduce the average values. Moreover, as for the planted seedlings, the growth evolution and survival of natural woody species is influenced by many other factors besides fencing. In Adi Worho e.g., *Nicotiana* knew a higher survival rate and better growth outside the site due to its favourable position on the gully wall, whereas the individuals inside the site were found mainly in the floor, resulting in a high loss during the rainy season. Last but not least, it must be understood that in the present setup we are unable to evaluate the pure effect of fencing on natural woody vegetation changes, as naturally growing woody species inside the site have to compete with the many planted seedlings for light, space and nutrients.

TABLE II. Mean percentage of change in length, crown size and base diameter as observed for some common naturally growing species in both plots after 1 year.

	Adi Kolakol			
Variable (unit)	A. abyssinica IN	A. abyssinica OUT	B. ovovatum IN	B. ovovatum OUT
Length change (%)	135	122	53	26
Crown size change (%)	71	83	33	27
Diameter change (%)	36	57	38	11
	Adi Worho			
Variable (unit)	A. abyssinica IN	A. abyssinica OUT	N. glauca IN	N. glauca OUT
Length change (%)	234	321	42	97
Crown size change (%)	141	75	14	62
Diameter change (%)	50	10	-54	12

Although an adapted experimental setup (with control fenced sites without planting action) would be needed to prove statistically, it can be clearly observed in the field that the exclusion of human and cattle disturbance has a serious beneficial effect on natural vegetation recovery in the gully. After one year, a far more dense grass and herb cover as well as far a higher biomass had developed in both sites inside the sites when compared to the situation outside the sites (see Figure 10). When carefully managed, this natural vegetation cover seriously increases the ecological and economical value as well as the protective effects of the planted seedlings on gully control.

Figure 10: Effect of fencing on grass and herb cover in Adi Kolakol, comparing initial situation (left – August 2006) and situation after 1 year (right – September 2007).

The effect of fencing was also clearly observed for fine root density, with average values in the top 15 cm of 0.55 mg/cm³ inside contrasted to 0.40 mg/cm³ outside the fence in Adi Worho, and 0.33 mg/cm³ inside contrasted to 0.07 mg/cm³ outside the fenced site in Adi Kolakol after 1 year of fencing. Several previous studies found that the rate at which soil is detached, decreases exponentially with increasing root density. Especially if root density is still relatively small, as is the case here, soil detachment rate decreases very fast even with very small increases in root density. From these results it can hence be concluded that fencing seriously enhances soil fixation.

3   Concluding remarks and suggestions for future research

3.1   <u>A short conclusion on management from these first results</u>

It has probably been repeated and repeated again by many people, but keeping out grazing and browsing animals from vulnerable places is a very important management rule. It is a precondition when aiming at efficient and effective planting of seedlings, and it allows natural vegetation to recover and hence protect the soil surface against further erosion. A mixture of both naturally growing and planted species of different life forms is most efficient.

Necessary treatment of planted seedlings will depend on the selected species and environmental conditions, although some basic rules have to be taken into account. Everything starts with a good planting technique, correct seed or seedling treatment, carefully preparing the planting holes (on slopes preferably with a half moon structure), ensuring soil coverage of seedling roots, and providing the seedlings with an initial amount of water to overcome the transplantation stress.

If time, material and budget are available, sheltering seedlings, if done in an appropriate way, can be very beneficial. Although the shelter treatment in this study was initially designed to reduce overexposure to sunlight, it quickly became clear that sheltering has several other advantages, such as the capture of rough plant material (branches, grass) transported by the flood, the mechanical barrier protection against the flood, and the ability to avoid browsing by e.g. rats or rabbits if constructed nicely. It is important to keep the shelter open at the top, however, in order not to hinder the growth of the plant itself. Ideally, bamboo sticks or sorghum stalks are approximately 60 cm long, firmly inserted in soil and stacked close to each other. An alternative method is to directly sow a small amount of seeds of valuable species under the canopy of dense, naturally growing, shrubs, as was done for *Olea* [T: auwli] seeds under *Euclea* shrubs [T: kiliaw] by Aerts et al. (2007). This will increase germination and protect the young seedlings against drying and predation.

The ability to develop deep roots and to access soil moisture is decisive for seedlings' survival of drought, regardless of species-specific drought tolerance. A minimum threshold of water availability is hence crucial during the first year. Even very small volumes of watering can be sufficient to keep soil moisture above certain thresholds and improve survivorship. This threshold will vary depending on soil properties and the species involved.

3.2   A short conclusion on the studied species from these first results

Based on the preliminary results, we formulate some hypotheses here, to be validated in the near future:

Acacia etbaica seemed to perform best on top and wall positions. Given the fact that it develops a taproot (studied by Windey in 2006), this could be an interesting opportunity for stabilisation of the gully walls. On the top, if managed as a dense shrub, it could be a suitable species for development of a natural fence around vulnerable places where vegetation recovery has to be given a chance.

Sesbania sesban showed a very fast above- as well as belowground development, and appeared to be a species suited for wall and floor stabilization where its growth is best and its mortality low. Pruning at young age is probably interesting to stimulate investment in leaf development and to keep the plant fresh and strong. The latter is important since *Sesbania* seemed to be easily affected by several pests and diseases. It is important to remark here that, despite its interesting characteristics (fast growth, easy multiplication, nitrogen fixation), *Sesbania* should be used carefully and moderately: it is an exotic species with probably often an invasive behaviour, which may have negative effects on other, indigenous species.

Dodonea angustifolia had its best development on top gully positions. Although this species is said not to be browsed by cattle, and could hence serve as a natural fence around the gully, browsing is observed in the study area. Its extensive shallow root system makes it useful in soil binding and erosion control.

These and other species still need more attention before taking firm conclusions.

3.3   Suggestions for future research

First of all, long-term evaluation of more species would be very interesting. At first instance, more knowledge on the potential role of a wide range of indigenous species is needed, although it is also of high importance to study the potentially beneficial as well as detrimental effects of some high-value exotics, such as *Jatropha curcas* (T: jatropha), *Malus domestica* (T: apple) or *Leucaena leucocephala* (T: lucina). Also comparing the use of cuttings versus rooted plants could be valuable.

During the continuation of these experiments, not only sapling and tree establishment will be followed-up in the long term, but especially effects of these techniques on further gully development and environment will be evaluated. Besides the effect on changes in gully

dimension and sedimentation, also the effect on water household in and around the gully is an important aspect for evaluation. One interesting option would be to construct a set of control sites in which no active seedling plantation is done, to assess the differences in speed and efficiency of gully control between merely fencing on the one hand and the combined action of fencing and active planting on the other hand. This would however require a relatively high number of such sites, making sure that the compared pairs of 'planted' and 'non-planted' fenced sites are set up under similar environmental conditions, as gully development is of course seriously determined by important environmental conditions, such as amount of rainfall, runoff discharge, slope, catchment area, soil type and many others. Although this knowledge could be very important, such comparison was not done so far, as our primary objective was not exactly to compare different techniques in their efficiency to control gully erosion, but to assess practical possibilities, most suitable conditions and minimal necessary level of protection and treatment needed for good seedling establishment, aiming at an integrated way of controlling gully erosion, resulting in additional socio-economic and ecological benefits.

Another interesting topic would be to experiment with potential management practices. The latter could be e.g. pruning or thinning activities, as the aim is to make use of the products gained from the woody species and as it is important to maintain an open canopy structure, to allow protective vegetation to grow on the soil surface.

Last but certainly not least, we strongly recommend further field trials with promising gully control techniques (see examples in Part 1), especially those combining a physical structure with vegetative measures. This should be done under different circumstances, to gain a more thorough understanding on effectiveness of different techniques under variable environmental conditions.

3.4   From research to an integrated practice and management

Let it be clear that this is an experiment set up for the specific aim of performing research. It is NOT a good example of integrated gully erosion control as it should be done in practice. For real application, more possibilities should be taken in consideration, and ideally integrated action should be taken at the scale of a whole catchment. Woody vegetation is only one aspect of a wide range of measures which can be undertaken. We refer therefore first of all to the suggestions made in the literature review (part 1).

Although not evaluated as a part of the research setup, we tried to add something extra to our sites, by planting some bamboo in the gully head at Adi Worho, by protecting the gully head in Adi Kolakol with *Agave* [T: I'qaa], and by constructing a small 'live wall' in the floor at both sites. Their construction is far from perfect, and other species could probably do much better, but the main aim is to show local communities and everybody visiting our sites that more can be done than merely seedling planting. One should constantly think of how to get the maximum out of a minimum investment and effort. A lot of similar constructions can be made with different materials, depending on what is readily available and easy to implement. Some small suggestions:

- Unused cut branches from the seedlings could be used in the construction of live crib walls (usually consisting of a hollow, box-like arrangement of poles, filled with slope material and layers of live branch cuttings or rooted plant inlays) or brush layers.

- Besides being very interesting for increasing infiltration and reducing flood speed, planting fast growing Giant reed in the gully head has the huge advantage of providing free material for sheltering, year after year. This is especially interesting in valley-floor gullies where enough water is available;

- Protecting the area can be done with a variety of fencing methods. One could use long thorny branches instead of barbed wire to connect the poles, or even completely replace poles and barbed wire by planting dense, thorny and fast-growing species, hence reducing the cost and guaranteeing a double function as fence as well as gully stabilisation.

Of course it is often difficult to bring good ideas into a manageable practice. As with any other measure taken, there are several difficulties related to the active planting of (woody) vegetation as a gully control measure: it consumes land, it asks time and money before any results are visible, and it asks convincement of the whole community in order to protect the site against any serious disturbance. Nevertheless, we do believe that the idea is promising and can relatively easily be implemented in existing soil and water conservation programs. The well-known 'safety net' or 'food for work' programs are such examples, although it has to be stressed that alternative incentives should be found, as the current strategy of providing cereals leads to the negative effect of decreasing the market price for cereals, hence discouraging local production. Alternative possibilities should be discussed upon with the local communities. Although indeed an initial investment of labour and money is needed to establish the site, efforts are relatively low in the long term when compared to other measures taken. Checkdams e.g. (which remain important to create suitable conditions for vegetation establishment!) have to be rebuilt from time to time if not supplemented with vegetative measures, and do not result in any other significant output than

controlling further gullying and building up sediment. In contrast, vegetation grows stronger by itself and doesn't ask for much maintenance. Moreover, if interesting species are selected and planted on appropriate places, this vegetation can be profitable in the long term, offering different kinds of socio-economic outputs (e.g. fodder, fire wood, wood for tools, food, moisture conservation and several others) next to merely controlling gully erosion. A well-controlled policy of sustainable management and use will most probably be more efficient, cost-effective and beneficial for all involved parties than a policy of 'non-using protection'. Effectiveness and cost-benefit ratio will thus depend not only on the species selected, but also on the attitude of the people, on careful treatment (especially during the first year) and maintenance, and on the location of the sites selected. We hope to have offered enough examples, ideas and suggestions in this text to encourage any stakeholder to give these techniques the chance they deserve.

To conclude, we once more want to remind the reader that it is very important to keep in mind that there exists no such thing as a standard effective way to combat gully erosion. Success or failure will depend on a lot of conditions, and selection of control measures have to be based on a wide set of environmental as well as socio-economic criteria. Several types of gullies can be differentiated in the study area (e.g. a rough classification as hill slope gullies and valley bottom gullies), in several soil types and under specific local circumstances. It must not be forgotten that plant, soil and environment form one continuum, influencing each other in different ways and determining together if and how a specific species or technique will be effective. Each situation will need its own adapted technique.

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