CROSS-SLOPE BARRIERS

Fanya juu with grass for stabilisation, Kenya. (Hanspeter Liniger)

In a nutshell

Definition: Cross-slope barriers are measures on sloping lands in the form of earth or soil bunds, stone lines, and / or vegetative strips for reducing runoff velocity and soil loss, thereby contributing to soil, water and nutrient conservation. This is achieved by reducing steepness and / or length of slope. Terraces are not usually constructed per se, but rather develop gradually behind earth bunds, vegetative strips (usually grass) or stone barriers, due to soil movement from the upper to the lower part of the terrace. Erosion between the barriers helps to achieve the levelling of the terrace bed. While cross-slope barriers are primarily intended to reduce soil erosion, they also enable / ease cultivation between the barriers, which are usually sited along contours. However, in high rainfall areas they may be graded at 0.5 – 2.0% across the slope to allow safe discharge of excess surface water along the barriers to reach watercourses. Some common technologies used by smallholder farmers include contour bunds, *fanya juu* and *fanya chini* terraces, stone lines and vegetative barriers. Bench terraces can be the eventual result – though in some circumstances may be constructed through excavation and shaping.
To ensure sustained fertility of the land it is necessary to employ soil fertility management measures such as composting, green manures, cover crop, etc. (see group on Integrated Soil Fertility Management).
Applicability: Applicable from gentle to steep slopes. Suitable for the whole range of arid to humid areas; in subhumid and humid areas cross-slope barriers are used for protection against soil erosion, whereas in semi-arid areas they are employed for in-situ water conservation and even water harvesting purposes.
Resilience to climate variability: Terraces and vegetative strips can, to a certain extent, cope with extreme rainfall events.
Main benefits: Improved water management through reduced soil erosion by water in subhumid areas, increased water infiltration and storage in semi-arid areas - hence helping to maintain soil fertility, increase crop yields and food security.
Adoption and upscaling: Depending on the type of measure, very often the investment costs for establishment exceed the short term benefits. Due to these high initial costs, incentives to compensate land users for part of the establishment investments may be needed. However, land users and communities should be able to maintain the system without any external support.

Development issues addressed	
Preventing / reversing land degradation	++
Maintaining and improving food security	+
Reducing rural poverty	+
Creating rural employment	+
Supporting gender equity / marginalised groups	+
Improving crop production	++
Improving fodder production	++
Improving wood / fibre production	+
Improving non wood forest production	na
Preserving biodiversity	+
Improving soil resources (OM, nutrients)	+
Improving of water resources	++
Improving water productivity	++
Natural disaster prevention / mitigation	++
Climate change mitigation / adaptation	++

Climate change mitigation	
Potential for C Sequestration (tonnes/ha/year)	0.5-1.0*
C Sequestration: above ground	+
C Sequestration: below ground	+

Climate change adaptation	
Resilience to extreme dry conditions	++
Resilience to variable rainfall	+
Resilience to extreme rain and wind storms	+
Resilience to rising temperatures and evaporation rates	+.
Reducing risk of production failure	+

** based on expert estimation for a duration of the first 10-20 years of changed land use management*

Origin and spread

Origin: Terracing steep lands in Africa is an indigenous technology. The same is true of earth bunds, stone lines and vegetative strips. New methods have evolved over the years in response to increasing population and land pressure. Under colonial regimes, large areas of communal lands were compulsorily terraced in the 1950s (e.g. in Kenya, Malawi and Zambia) through the construction of ridges or bunds. Often rejected immediately after independence such techniques made a come-back in the 1970s having been improved and promoted through projects / programmes. *Fanya juu* terraces first developed in the 1950s and are currently spreading throughout East Africa. The period of rapid spread occurred during the 1970s to 1980s with the advent of the National SWC Programme in Kenya. In the West African Sahel, contour stone lines (and vegetative barriers) have been promoted successfully since the 1980s, as water harvesting structures.
Mainly applied in: Terracing systems in steep areas throughout Africa; Stone lines on low slopes mainly West Africa (Burkina Faso, Mali, Niger); Earth bunds / ridges mainly in East Africa (Ethiopia, Kenya) and Southern Africa (Malawi, Zambia, Zimbabwe, etc.), *Fanya juu* mainly in East Africa (Kenya; also Ethiopia, Tanzania, Uganda); vegetative strips throughout Africa especially in the more humid zones.

Principles and types

Bench terraces are commonly developed on steep slopes as a result of constructing cross-slope barriers, and then erosion (water and tillage) progressively causing the bed to level. A bench terrace is defined by a flat or slightly backward or forward-sloping bed. Stone-faced terrace risers are characteristic of areas where stone is available (e.g. the Konso terraces in Ethiopia), otherwise the earth risers are protected by grass. Due to the heavy labour input they are usually constructed to support production of high-value crops such as irrigated vegetables and coffee. The design of the benches is usually calculated by a formula that relates their size and spacing to the slope. Bench terraces are rarely excavated and constructed directly, as this is very expensive.
Earth bunds (sometimes referred to as ‘ridges’ in Southern Africa) are soil conservation structures that involve construction of an earthen bund along the contour by excavating a channel and creating a small ridge on the downhill side. Usually the earth used to build the bund is taken from both above and below the structure. They are often reinforced by vegetative cover to stabilise the construction. Bunds are gradually built up by annual maintenance and adding soil to the bund.
Fanya juu (‘do upwards’ in Kiswahili) terraces are made by digging ditches and trenches along the contour and throwing the soil uphill to form an embankment. A small ledge or ‘berm’ is left between the ditch and the bund to prevent soil sliding back. In semi-arid areas they are normally constructed to harvest and conserve rainfall, whereas in subhumid zones they may be laterally graded to safely discharge excess runoff. The embankments (risers) are often stabilised with fodder grasses. *Fanya juu* terraces can develop into bench terraces.
In a ***Fanya chini*** system (‘do downwards’ in Kiswahili) soil is piled below a contour trench. These are used to conserve soil and divert water and can be used up to a slope of 35%. *Fanya chini* involve less labour than *Fanya juu*, but they do not lead to the formation of a bench terrace over time as quickly as the former.
Stone lines and bunds: In areas where stones are plentiful, stone lines are used to create bunds either as a soil conservation measure (on slopes) or for rainwater harvesting (on plains in semi-arid regions). Stones are arranged in lines across the slope to form walls. Where these are used for rainwater harvesting, the permeable walls slow down the runoff, filter it, and spread the water over the field, thus enhancing water infiltration and reducing soil erosion. Furthermore, the lines trap fertile soil sediment from the external catchment.
Vegetative strips are the least costly or labour-demanding type of cross-slope barriers. Such strips are a popular and easy way to terrace land, especially in areas with relatively good rainfall. The spacing of the strips depends on the slope of the land. On gentle sloping land, the strips are given a wide spacing (20-30 m), while on steep land the spacing may be as little as 10-15 m. Vegetative strips can also provide fodder for livestock if palatable varieties of grass (or densely spaced bushes) are used.

Top: Konso Terraces in Ethiopia. (Rima Mekdaschi Studer)
Top middle: *Fanya juu* terrace with napier grass, Kenya. (Hanspeter Liniger)
Bottom middle: Vegetative strips along contour line for reducing surface runoff and erosion, Kenya. (Christoph Studer)
Bottom: Stone lines catching run-off water and fertile soil sediments, Niger. (Hanspeter Liniger)

Applicability

Land degradation addressed

Soil erosion by water: mainly loss of topsoil / surface erosion, partly gully erosion / gullying
Physical soil deterioration: runoff can contribute to crusting and soil sealing
Water degradation: sedimentation and pollution of water downstream, partly aridification

Land use

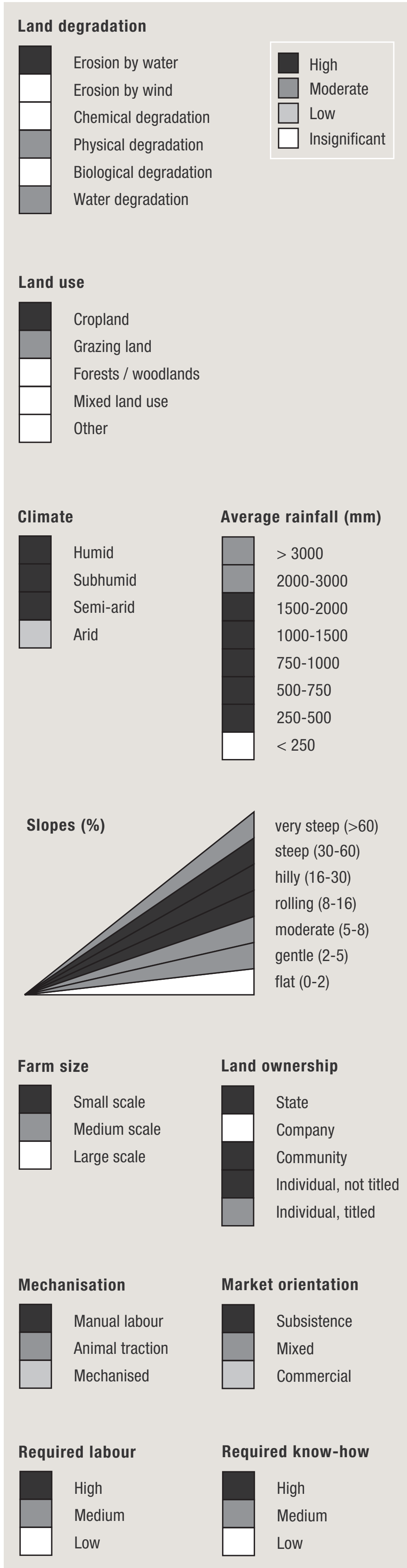
Mainly on annual cropland and / or partly on mixed land with tree and shrub cropping.
Partly on intensive grazing fodder production: rarely on grazing land.

Ecological conditions

Climate: Mainly in subhumid and semi-arid, partly in humid and arid areas. In subhumid to humid areas mainly for protection against soil erosion, whereas in semi-arid areas mainly for water conservation purposes.
Earth bunds are not suitable for very wet areas unless graded; Vegetative strips are most effective in moist areas and least effective in dry areas; *Fanya juu* terraces are not suitable in dry areas unless used for rainwater harvesting.
Terrain and landscape: Bench terraces: moderate to very steep slopes; Earth bunds: gentle to moderate slopes; Stone bunds: gentle to steep slopes; *Fanya juu* terraces: moderate to steep slopes (up to 50%); *Fanya chini* terraces: moderate to hilly slopes (up to 35%); Vegetative strips: gentle to steep slopes.
Soils: Not suitable for very shallow and sandy soils – bench terraces must not be built on shallow soils (to avoid risk of landslides).

Socio-economic conditions

Farming system and level of mechanisation: Mainly animal traction (oxen, with plough) and manual labour (hand tools, on steeper slopes where oxen can not be used, etc.), very often a combination of animal traction and manual labour; only partly mechanised (e.g. for transportation of stones)
Market orientation: Mainly subsistence (self-supply), partly mixed and partly commercial / market.
Land tenure and land use / water rights: Secure individual land use rights are needed, otherwise the land users are not willing to invest in structural conservation measures. Land tenure is often formally state- or communal-(village) property and individually not-titled.
Skill / knowledge requirements: A high level of know-how is required for the establishment and the maintenance of terraces and bunds.
Planting and construction of vegetative strips is relatively simple and can be done by local land users with minimum investment and with local equipment.
Labour requirements: The establishment of terraces and bunds requires high input; sometimes outside labour needs to be hired for the construction of the terraces or the bunds. *Fanya juu* terraces are associated with hand construction, and are well suited to small-scale farms. In Kenya they are often established through self-help groups.
Maintenance can usually be done by individuals and is very important for all kind of terraces and bunds. Earth structures often need considerable maintenance - building up and reshaping the structure every year and stabilising through vegetative cover.
Vegetative strips often require less establishment work compared to terraces and bunds. Maintenance work is also very important e.g. grass strips require trimming and gap-filling to keep them dense.



Economics

Establishment and Maintenance costs

	Establishment costs (US$/ha)			Maintenance costs (US$/ha)		
Costs	Terraces	*Fanya juu*	Veg. strips	Terraces	*Fanya juu*	Veg. strips
Labour cost PDays*	High 150-1200 150-600	High 40-600 40-300	Medium-high 7-80 7-40	Medium 10-300 10-150	Low 10-60 10-30	Low 0-30 0-15
Equipment	Low-medium 10-50	Low-medium 20-60	Low 10-50	Low 0-20	Low 0-10	Low 0-10
Material inputs	Medium-high 50-300	Low-medium 10-80	Medium 20-100	Low 0-50	Low 0-15	Low 0-10
Total	**210-1350**	**70 – 740**	**37-230**	**10-370**	**10-85**	**0-50**

PD: Person days (labour is valued as 1-2 US$ per day), (Source: WOCAT, 2009)

Comment: Very often the high establishment costs related to labour for the construction of terraces are the main obstacle for establishment. The construction costs depend on the slope of the area (number of barriers needed), the distance to the material (e.g. stones), the level of mechanisation and labour costs. The construction of vegetative strips requires least working days and can provide a cost-saving alternative to terracing. The equipment needed does not differ a lot between the three measures.

Production benefits

	Yield without SLM (t/ha)	Yield with SLM (t/ha)	Yield gain %
Maize, Kenya	2.1 – 3.4	2.3 – 3.7 (grass strips) 3.1 – 4.5 (*fanya juu*)	10-45%
Beans, Tanzania	1.5 – 1.8	2 (grass strips) 2.8 (*fanya juu*) 2.1 – 2.7 (bench terraces)	10-85%
Sorghum, Ethiopia 15% slope 25% slope 35% slope	Non-terraced 0.96 0.67 0.43	Terraced (stone bunds) 2.18 1.83 1.7	 127% 173% 297%

(Sources: Mwangi et al., 2001; Tenge et al., 2005; Alemayehu et al., 2006)

Comment: With increasing slope the difference in sorghum yields between terraced and non-terraced lands increases. Terraces result in remarkably higher yields on steep slopes compared with non-terracing.

Benefit-Cost ratio

	short term	long term	quantitative
Bench terraces	– –	++	Internal rate of return, Tanzania: 19%
Bunds	–	++	
Stone lines	–	++	
Fanya juu	–	++	14%
Vegetative strips	+/–	++	6%
Overall	–	++	

– – negative;– slightly negative; –/+ neutral; + slightly positive; ++ positive; +++ very positive
(Sources: Tenge et al., 2005 and WOCAT, 2009)

Comment: The internal rate of return as shown above suggest that, farmers who are able to invest in bench terraces, will be able to recover their investment faster than from the *fanya juu* and grass strips. However, the short term benefit-cost ratio for cross-slope barriers is mostly negative due to high investment costs. It can take up to 2 years until the barriers lead to a positive return. The profitability of barriers also depends on the opportunity costs for labour. For land users with an off-farm income the establishment of cross-slope barriers is often financially not attractive.

Examples: Burkina Faso
The analysis of different structural conservation measures in Burkina Faso, has shown shown that the construction of stone lines generally leads to the highest establishment costs (140-400 US$/ha), the construction of earth bunds is slightly cheaper (95-200 US$/ha), whereas vegetation barriers show relatively low establishment costs if local grasses are used (approx. 60-70 US$/ha) (Spaan, 2003).

Example: Tanzania
A study in the West Usambara Highlands has shown significant increase in the crop yield for maize and beans by implementing bench terraces, fanya juu or grass strips (see production benefits). However, the results clearly showed that cross-slope barriers alone may not significantly increase crop yields unless these are followed by other practices such as manure and fertilizer. Grass strips and / or the introduction of grass on the risers, can lead to an additional increase in yield which can be either used as fodder for livestock or it can be sold (Tenge et al., 2005).

Example: Burkina Faso
A cost-benefit analysis for stone lines in the region of Kaya shows that, from the farmer's point of view, the implementation of stone lines alone is only profitable if a lorry is provided for the transport of stones. If the farmer has to pay the transport himself the net present value of stone lines is negative. The benefits (20% yield increase in wet years and 30% yield increase in dry years) are not high enough to compensate for the costs of transport and construction. Thus profitability of stone lines depends closely on transport and distance to the source of the stones (Kempkes, 1994).

Impacts

Benefits	Land users / community level	Watershed / landscape level	National / global level
Production	++ increased crop yield (long term) ++ increased grass / fodder production (through grass strips and / or grass on risers) can be used for livestock, sold, as mulch or to thatch roofs + increased wood production	++ reduced risk and loss of production + access to clean dinking water	+++ improved food and water security
Economic	++ increased farm income (long term)	++ less damage to off-site infra-structure + stimulation of economic growth	+++ improved livelihood and well-being
Ecological	+++ reduced soil loss (mainly in subhumid areas) ++ increased soil moisture (mainly in semi-arid areas) ++ reduced soil erosion (by wind / water) ++ increased infiltration rates ++ decrease in runoff velocity and control of dispersed runoff + improved soil cover + increase in soil fertility (long term) + biodiversity enhancement + improved micro-climate	++ reduced degradation and sedimentation ++ improved water quality + increased water availability + intact ecosystem	++ increased resilience to climate change ++ reduced degradation and desertification incidence and intensity ++ enhanced biodiversity
Socio-cultural	++ improved conservation / erosion knowledge + community institution strengthening	++ increased awareness for environmental 'health' ++ attractive landscape	++ protecting national heritage

	Constraints	How to overcome
Production	• Loss of land for production due to risers of terraces, ditches for *Fanya juu* / chini, vegetative strips, etc. • The constructions can easily be damaged by cattle interference • Planting of vegetative strips falls in the period with highest agricultural activity • If not adequately managed soil and water conservation function can be lost or can even be accelerated • Competition for water and nutrients in the case of vegetative barriers	➜ integrating and incorporating vegetative measures in the system, widen the spacing between bunds, make bund area productive (e.g. grass on terraces for livestock), increase productivity of fod-der trees on bunds, etc. ➜ controlled grazing management of the terraces ➜ needs good capacity building and training for appropriate manage-ment of the measures
Economic	• High investments costs, usually exceeding short term benefits • Shortage of labour, especially for the construction; very high labour input is needed. Some cross-slope barriers can also lead to high maintenance requirement, e.g. soil bunds. • Shortage of construction material and hand tools • Lack of market infrastructure	➜ credits and financial incentives for initial investments should be easily accessible to land users ➜ establishment with labour-sharing groups, financial incentives or credit facilities or phasing the establishment over several years to overcome. For maintenance less support is needed but land users should be organised (individually or in groups) to undertake main-tenance and repairs
Ecological	• Possible waterlogging before bund / embankment • Uneven flood water distribution, breakages of terraces • Rodent and other pests hiding in the vegetation • Competition of vegetative strips + bunds with crop • Unprotected bunds, which have not been planted with grass, are prone to erosion	➜ additional measures such as vegetation / mulch cover ➜ maintenance and adjustments of the barriers ➜ provision of appropriate measures, provision of rodent and pest controlling mechanisms ➜ trimming of vegetation during crop growing period ➜ additional measures such as vegetation / mulch cover to reduce runoff
Socio-cultural	• Often traditional system, but not properly maintained, especially when populations move away from rural areas	➜ incentives for 'renovation' of traditional structures (e.g. Konso ter-races in Ethiopia)

Adoption and upscaling

Adoption rate

The labour requirement can be a major constraint to the adoption of cross-slope barrier technologies. Vegetative strips have the lowest labour requirements leading to higher adoption. However, establishment of these very often coincides with the labour peak of the normal agricultural activities.
The loss of land and temporal yield decline in the short term are the main obstacles, especially for small-scale farmers, to adoption of structural measures such as terraces or bunds, even though long term benefits are likely.
High investment costs and the uncertain benefits in the short term further hinder the adoption and upscaling of this group of measures.

Upscaling

For adoption, a substantial yield gain is essential to overcome the high investment costs and the loss of agricultural productive land. Land users need to be well informed in terms of yields and / or monetary values which can be gained through the implementation of cross-slope barriers.
Awareness raising: Land users need to recognise the multiple resource losses due to runoff and erosion on sloping land.
Clear **land use rights** are needed for investments to be made in structural measures.
Access to knowledge must be ensured for land users; training of land users is essential to establish knowledge and technical skill about appropriate establishment and also maintenance.
Micro-credit for financial investments: The self-financing capacity of farmers needs to be strengthened and credits must be easily accessible also for small-scale land users.
Access to material inputs and markets is necessary for establishment of cross-slope barriers.

Incentives for adoption

The construction of cross-slope barriers usually requires considerable labour but material inputs also, and hence the investment costs often exceed the short term benefits. Therefore it is crucial that land users have access to micro-credit to enhance self-financing. Incentives should only be given if there is no other possibility of establishing cross-slope barriers. Two reasons to justify the provision of incentives are: (1) the costs are only slowly recuperated by on-site benefits; (2) part of the benefits are obtained by people downstream. Possible options for incentives can be transport facilities for stones (for example) or subsidies on inputs such as seedlings for the vegetative strips. Payment for ecosystem services (PES) is another incentive that specifically addresses the benefits of downstream users. Maintenance work should be conducted without any external support.

Enabling environment: key factors for adoption	
Inputs, material incentives, credits	++
Training and education	++
Land tenure, secure land use rights	++
Access to markets	+
Research	++
Infrastructure	+
Conflicts of interest	+

Example: Kenya
During the colonial period in Kenya, in the 1950s, bench terracing used to be forced on local people, and after independence in 1963, many terraces were destroyed or neglected. After the soil conservation extension campaigns of the 1970s-1980s, bench terraces were adopted by farmers living on steep mountain slopes of Central and Eastern Provinces, especially on farms where coffee was grown (Mburat, 2006).

Example: Tanzania
Despite decades of efforts to promote cross-slope barriers in the West Usambara Highlands in Tanzania, there is still minimal adoption by land users. Among the major reasons for this could be that land users do not recognise the losses caused by runoff and soil erosion, that the recommended measures are not effective enough or not financially attractive. Furthermore, the establishment period competes with other activities for scarce labour resources and equipment. It is crucial that land users are well informed about costs and benefits of implementing the measures in order to achieve greater motivation to implement cross-slope barriers (Tenge et al., 2005).

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ALOE VERA LIFE BARRIERS - CAPE VERDE

Aloe vera is a drought tolerant, fleshy plant which is planted in the form of live barriers to recuperate degraded slopes on the Cape Verde Islands. The plants are closely planted along the contour to build an efficient barrier for retention of eroded sediments and surface runoff. The hedgerows stabilise the soil, and increase soil humidity by improving infiltration and soil structure. Soil is accumulating behind the *Aloe* strips and slope angle is considerably reduced over time. Groundwater is recharged indirectly. Soil cover is improved, and thus evaporation reduced.

Implementation is relatively simple. The contour lines are demarcated using line- or water-levels. Seedlings are planted at a distance of 30-50 cm between plants; Spacing between the rows varies between 6–10 m according to the slope. The technology is applied in subhumid and semi-arid areas, on steep slopes with shallow soils, sparse vegetative cover and high soil erosion rates. These areas are generally used by poor subsistence farmers for rainfed agriculture with crops such as maize and beans, which are considered inappropriate for such slopes. On slopes steeper than 30% the live barriers are often combined with stone walls (width 40-50 cm; height 80-90 cm). The plants stabilise the stone risers, making this combined technology one of the most efficient measures for soil erosion control on Cape Verde.

Aloe vera is well adapted to the local biophysical conditions and to the prevailing land use system: it can be used with any crop and is available to all farmers; establishment and transport is simple, its leaves are not palatable to livestock, the plant is extremely resistant to water stress and grows in any bioclimatic zone on the island. Furthermore, *Aloe vera* is known for its multiple uses in traditional medicine.

SLM measure	Vegetative
SLM group	Cross-Slope Barriers
Land use type	Annual cropping (maize, beans)
Degradation addressed	Soil erosion by water
Stage of intervention	Mitigation and rehabilitation
Tolerance to climate change	Tolerant; *Aloe vera* is resistant to water stress, and establishes well in different climatic zones

Establishment activities

1. Demarcation of contour lines, using line or water levels; spacing between barriers is minimum 6 meters (early June).
2. Collection of *Aloe vera* plants; *Aloe vera* is growing naturally in abundant quantity on the upper slopes, in depressions / hollows, in arid as well as in more humid zones.
3. Planting of *Aloe vera* seedlings, one next to the other, or at a spacing of 30-50 cm between plants; (end of June) manually, using hoe / pickaxe.
4. From the second year on the gaps between the plants are plugged by naturally expanding *Aloe vera* plants.

Maintenance / recurrent activities

1. Vegetative control: removal of *Aloe vera* plants that are invading cropland (maize, peas) between the life barriers.
2. Replanting of *Aloe vera* to fill gaps in life barriers (very rare; survival rate is over 95%).

Labour requirements

For establishment: medium
For maintenance: low

Knowledge requirements

For advisors: low
For land users: low

Photo 1: Well established *Aloe vera* life barriers on steep slopes. (Jacques Tavares)
Photo 2 and 3: Detailed view of *Aloe vera* life barriers; soil is accumulating on the upper side of the barriers. (Jacques Tavares)
Photo 4: *Aloe vera* life barriers are often combined with stone walls to enhance the erosion control on steep slopes. (Hanspeter Liniger)

Case study area: Santiago, Cape Verde

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 65 person-days	215
Equipment: levels, hoes, shovels	13
Agricultural inputs: 5,000 plants	0
TOTAL	**228**
% of costs borne by land users	0%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 1 person-day	3
Equipment	0
Agricultural inputs	0
TOTAL	**3**
% of costs borne by land users	100%

Remarks: Labour inputs for implementation are rewarded by project: Individuals of poor communities receive a salary of 3 US$ per day. Plants are collected locally. Establishment costs do not include labour-intensive construction of stone risers (supportive measure). Maintenance costs are borne by land users.

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly negative	very positive
Maintenance	neutral / balanced	very positive

Remarks: Maintenance is not costly, it's simply vegetative control and punctual replanting.

Ecological conditions

- Climate: mainly semi-arid, partly subhumid
- Average annual rainfall: mainly 500-750 mm, >800 mm in wetter areas
- Soil parameters: mainly shallow loamy soils, with medium fertility and low-medium organic matter content; drainage is medium while water storage capacity is high to very high
- Slope: steep (30-60%), partly less
- Landform: mountain slopes and ridges
- Altitude: mainly 500-1,000 m a.s.l., partly 100-500 m a.s.l.

Socio-economic conditions

- Size of land per household: 1-2 ha (poor), 2-5 ha (better-off)
- Type of land user: small-scale, poor; partly medium-scale, better-off
- Population density: 100-200 persons/km^2
- Land ownership: individual (titled) and communal (Diocese)
- Land use rights: mainly leased, partly individual or hereditary
- Level of mechanisation: mainly manual, few farms are mechanised
- Market orientation: mainly subsistence, few mixed (subsistence and commercial)

Production / economic benefits

++ Reduced risk of production failure
+ Increased crop yield
+ Increased fodder production
+ Increased production area

Ecological benefits

+++ Improved harvesting / collection of surface runoff
+++ Reduced surface runoff
++ Improved soil cover
++ Increased biomass / above ground carbon
+ Increased soil moisture
+ Increased water quality
+ Increased water quantity

Socio-cultural benefits

+++ Improved conservation / erosion knowledge
+ Conflict mitigation
+ Improved food security / self-sufficiency
+ *Aloe vera* is used in traditional medicine / personal hygiene: pills against anaemia, diabetes and digestion problems; bactericide for wound treatment

Off-site benefits

+++ Recharge groundwater table / aquifer

Weaknesses ➜ and how to overcome

- Reduction of the production area, which is occupied by strips of *Aloe vera* ➜ annual vegetative control within cultivated area and by cutting *Aloe vera* plants growing outside the life barriers.

Adoption

Most of the land users have implemented the technology by receiving financial incentives (payments). Totally 380 land users have adopted the technology; the area treated with *Aloe vera* life barriers is 71.5 km^2. There is a small trend towards spontaneous adoption.

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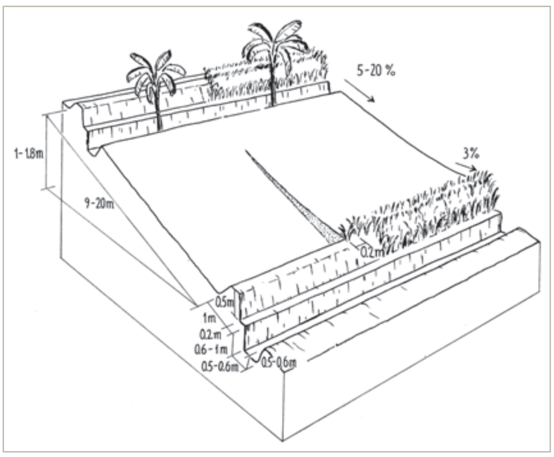
GRASSED *FANYA JUU* TERRACES - KENYA

A *fanya juu* terrace is made by digging a trench and throwing the soil uphill to form an embankment. A berm prevents the embankment soil from sliding back into the trench. On the embankment a grass strip is established, serving a triple purpose: it stabilises the earth structure through its roots, it enhances siltation of eroded soil particles, and it is used as a fodder source for livestock. Often napier (*Pennisetum purpureum*), or makarikari (*Panicum coloratum* var. *makarikariensis*) are used in the drier zones.

In semi-arid areas the structures are laid out along the contour to maximise water retention, whereas in subhumid zones they are laterally graded to discharge excess runoff. Spacing of terraces ranges from 9 - 20 m, according to slope and soil depth. On a 15% slope with a moderately deep soil, the spacing is 12 m between the structures and the vertical interval around 1.7 m.

The purpose of the *fanya juu* is to reduce loss of soil and water, and thereby to improve conditions for plant growth. The embankment impounds runoff water, eroded soil and nutrients. As a consequence of water and tillage erosion, sediment accumulates behind the bund, making it necessary to periodically build up the embankment (by throwing silted material from the trench upslope). In this way *fanya juu* terraces gradually develop into forward sloping terraces. Grass strips require trimming to keep them dense.

Fanya juu terraces are associated with hand construction, and are well suited to small-scale farms. *Fanya juu* is applicable where soils are too shallow for level bench terracing and on moderately steep slopes (e.g. < 20%), they are not suitable for stony soils.



SLM measure	Structural combined with vegetative
SLM group	Cross-Slope Barriers
Land use type	Cropland: annual crops
Degradation addressed	Loss of topsoil (water erosion); Soil moisture problem
Stage of intervention	Mitigation
Tolerance to climate change	Tolerant to climatic extremes (e.g. rain storms); Water conservation effect increases resilience to periods of water stress

Establishment activities

1. Layout (alignment and spacing) of terraces: (a) on the contour in dry areas; (b) on a slight grade in more humid areas, using 'line levels'.
2. Loosen soil for excavation (forked hoe, ox-drawn plough).
3. Dig a ditch / trench and throw the soil upwards to form a bund, leaving a berm of 15-30 cm in between (using hoes and shovels).
4. Levelling and compacting bund.
5. Digging planting holes for grass.
6. Creating splits of planting materials (*Makarikari* or Napier grass).
7. Manuring and planting of grasses.

All activities are done manually before the rainy seasons start (March and October) except planting of grasses, at the onset of rains. Duration of establishment: usually within one year.

Maintenance / recurrent activities

1. Desilting the trench and throwing silt upslope.
2. Repairing breaches in embankment where necessary.
3. Building up embankment annually.
4. Cutting grass to keep low and non-competitive, and provide fodder for livestock.
5. Maintaining grass strips weed-free and dense.

Labour requirements

For establishment: high
For maintenance: low to medium

Knowledge requirements

For advisors: moderate
For land users: low

Photo 1: Napier grass strip on the upper part of a *Fanya juu* bund; maize trash was deposited in the ditch below after harvest. (Hanspeter Liniger)
Photo 2 : *Fanya juu* terraces with well established grass strips in a semiarid area have developed over time into bench terraces. (Hanspeter Liniger)
Technical drawing: Schematic representation of *fanya juu* terraces with dimensions of structures; initial stage (left) and mature stage with well established grass strip and soil accumulating on the upper side of the embankment (right). (Mats Gurtner)

Case study area: Eastern Province, Kenya

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 90 person-days	270
Equipment / tools	20
Agricultural inputs: compost, manure	30
Grass establishment	60
TOTAL	**380**
% of costs borne by land users	100%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 10 person-days	30
Equipment	
Agricultural inputs: compost	
TOTAL	**30**
% of costs borne by land users	100%

Remarks: These calculations are based on a 15% slope with 830 running metres of terraces per hectare with typical dimensions and spacing (see technical drawing).

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly negative	positive
Maintenance	positive	very positive

Remarks: As the terrace is built up gradually over the years, establishment costs can be limited.

Ecological conditions

- Climate: subhumid, semi-arid
- Average annual rainfall: 500-1,000 mm
- Soil parameter: moderately deep, loamy soils, with medium soil fertility, low to medium organic matter content; medium water storage capacity, medium to good drainage
- Slope: mainly moderate-rolling (5-16%); partly hilly
- Landform: hillslopes and footslopes
- Altitude: 500-1,500 m a.s.l.

Socio-economic conditions

- Size of land per household: mainly < 1ha, partly 1-2 ha, some 2-5 ha
- Type of land user: small-scale, average level of wealth to poor land users
- Population density: 100-200 km^2
- Land ownership: individual titled and individual not titled
- Land use rights: individual
- Market orientation: subsistence and mixed (subsistence and commercial)
- Level of mechanisation: mainly animal traction, partly manual labour

Production / economic benefits

++ Increased crop yield (25%)
++ Increased fodder production and fodder quality
\+ Increased farm income

Ecological benefits

++ Increased soil moisture (semi-arid)
++ Increased efficiency of excess water drainage (subhumid)
++ Reduced soil loss
++ Increased soil fertility (in the long term)
++ Improved soil cover

Socio-cultural benefits

++ Improved conservation / erosion knowledge
++ Community institution strengthening

Off-site benefits

++ Reduced downstream siltation
\+ Increased stream flow in dry season
\+ Reduced downstream flooding

Weaknesses ➜ and how to overcome

- Loss of cropping area for terrace bund ➜ site-specific implementation: only where *fanya juu* terraces are absolutely needed, i.e. where agronomic (e.g. mulching, contour ploughing) and vegetative measures are not sufficient in retaining / diverting runoff; use the bund for production of valuable fodder / fruit (trees).
- High amounts of labour involved for initial construction ➜ spread labour over several years and work in groups.
- Risk of breakages and therefore increased erosion ➜ accurate layout and good compaction of bund.
- Competition between fodder grass and crop ➜ keep grass trimmed / harvest for livestock feed.

Adoption

Fanya Juu is a wide-spread technology – covering approx. 3,000 km^2 in the case study area – with high degree of spontaneous adoption throughout East Africa, and further afield also. The terraces first came into prominence in the 1950s, but the period of rapid spread occurred during the 1970s and 1980s with the advent of the National Soil and Water Conservation Programme.

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KONSO BENCH TERRACE - ETHIOPIA

The traditional Konso Bench Terraces are established by building up stone embankments along the contour and gradually levelling the land in between risers. Levelling is done actively and by siltation processes. Stone walls have to be enhanced periodically. The appearance of the technology evolves over time from stone embankments to bench terraces. The stone walls are supported on the downslope side by trees and / or legumes including coffee, pigeon pea, etc. The purpose of the structures is to break the slope length and reduce run-off concentration thereby controlling erosion, increasing water stored in soil and harvesting eroded sediments.
Terraces have a long tradition in the area, and farmers are specialists in construction of stone walls. The first step during terrace establishment is to dig foundation up to 30 cm. Then stone walls are gradually built up to an impressive height of 1.5 - 2 m above the ground. The technology is very labour intensive: Establishment takes 5 years and bi-annual maintenance is required. However, it is worth the effort, since without terracing crop production would not be thinkable in a marginal area characterised by shortage and high variability of rainfall, shallow, stony soils on steep slopes, high levels of soil erosion and (thus) frequent food shortages.
Social systems for labour-sharing and voluntary assistance have evolved to manage heavy labour inputs. Multiple cropping is practised for risk aversion. Growing leguminous crops helps to further improve soil fertility. Additional water harvesting measures are needed to further raise yields.

SLM measure	Structural combined with vegetative
SLM group	Cross-Slope Barriers
Land use type	Annual cropping
Degradation addressed	Soil erosion; Fertility decline; Aridification / soil moisture problem
Stage of intervention	Rehabilitation and mitigation
Tolerance to climate change	Tolerant to climatic extremes (e.g. rain storms). Water conservation effect increases resilience to periods of water stress

Establishment activities

1. Survey / layout.
2. Collecting stones.
3. Digging foundation (0.3 m deep; 0.3 m wide).
4. Establish stone wall (0.7 m high).
5. Land levelling.
6. Option: plant trees on the upper part of the stone riser.

All activities carried out by manual labour, using water level, poles, scoop hoe, spade. All activities carried out in the dry season.

Maintenance / recurrent activities

1. Stabilising terraces / enhancing walls by putting additional stones.
2. Repairing broken terraces and replanting of vegetative material.
3. Include inter-terrace management measures.

All activities carried out by manual labour, using crowbar, hammer, hoe, spade (1-2 times a year).

Labour requirements

For establishment: very high
For maintenance: high

Knowledge requirements

For advisors: moderate
For land users: moderate

Photo 1 and 2: Meticulously built terrace risers reaching a height of 1.5 – 2 meters; frequent maintenance is needed to enhance risers and repair breaches.
Photo 3: Bench terraces with maize, cassava and sunflowers.
Photo 4: Overview of a terraced hillside with annual crops and trees. (All photos by Hanspeter Liniger)

Case study area: Konso; Ethiopia

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 1,650 person-days)	1,650
Equipment	70
Agricultural inputs: seeds and manure	40
Construction material: stones	300
TOTAL	**2,060**

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 25-30% person-days of establishment	500
Equipment	0
Agricultural inputs	40
TOTAL	**540**

Remarks: Duration of establishment phase is 5 years. Land users maintain the terrace at least twice a year, mainly while preparing the land for crops. Labour inputs for maintenance are usually 25-30% of construction. Daily wage of hired labour is about US$ 1; material costs include collection and sizing of stones.

Benefit-cost ratio

Inputs	short term	long term
Establishment	negative	slightly positive
Maintenance	slightly positive	positive

Remarks: The profit is very marginal but without the terraces no harvest is expected. The land users continue to invest on the terraces as long as they can make a living from the land this way.

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 500-750 mm
- Soil parameters: low to very low fertility, low soil organic matter, good drainage
- Slope: moderate – hilly (5-30%)
- Landform: hillslopes and footslopes, ridges
- Altitude: 1,500 - 2,500 m a.s.l.

Socio-economic conditions

- Size of land per household: 0.5-1.5 ha
- Type of land user: poor / better-off small-scale farmers; in groups or individually
- Population density: 50-100 persons/km^2
- Land ownership: state
- Land use rights: individual
- Market orientation: mostly subsistence
- Level of mechanisation: manual labour

Production / economic benefits

+++ Increased crop yields: sorghum yield raised by 50% (from 0.4 t/ha to 0.6 t/ha)
++ Increased farm income

Ecological benefits

+++ Reduced soil loss (>50%)
+++ Reduced runoff (60%)
++ Increased infiltration and increased soil moisture
++ Increased soil organic matter (sediment harvesting)

Socio-cultural benefits

+ Social organisation: establishment of community organisations and strengthening of groups
+ Maintenance of cultural heritage

Off-site benefits

++ Reduced downstream siltation
+ Reduced downstream flooding

Weaknesses ➜ and how to overcome

- The terraces require very frequent maintenance which makes the technology highly labour-demanding ➜ use bigger stones for construction; avoid free grazing (animals damage the structures).

Adoption

The technology is wide-spread in the case study area, covering approx. 1200 km^2. 90% of land users have implemented the terraces without receiving any external support other than technical guidance.

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