left: Stone wall bench terrace with fruit trees in Tal Lata Village. (Michael Zöbisch)
right: Group of researchers and farmers discussing the technology at Tal Lata. (Hanspeter Liniger)

Stone wall bench terraces

Syria – المدرجاتالحجرية

Ancient level bench terraces with stone walls, built to stabilise slopes, retain moisture, and create a suitable environment for horticulture.

Stone wall bench terraces in the hill ranges of western Syria comprise an ancient indigenous technology, introduced by the Romans and Byzantines about 2,000 years ago. Some new terraces are, however, still being built. The walls are constructed with limestone, largely found on site. The terraces are located in steep terrain (usually on slopes more than 25%) under low (and erratic) rainfall regimes of between 250 and 500 mm per annum. The terrace walls are 1–2.5 m high and the level beds 3–25 m wide, depending on slope.

Deep soil profiles (more than 2 m) have developed on steep slopes, where original soil depth was only shallow to medium. The terraces are very efficient in preventing soil erosion and in the retention of rainfall. They support trees and annual crops where they could not otherwise be grown.

These terraces are usually found near settlements. Construction is very labour intensive, considering how little land is effectively protected from erosion and brought into cultivation. High labour investment makes the construction process slow and retards further extension of the technology. However, if soundly constructed, maintenance requirements are low. Underlining this point, a large number of very ancient terraces can still be found intact, supporting a productive crop. Sometimes localised collapse of a terrace occurs due to concentrated runoff. In that case, the terrace in question may need to be rebuilt. To prevent such breaches, it is important to allow for discharge of excess runoff along drainage lines.

Currently, most terraces are used to grow fruit trees. These include olives, cherries, almonds, plums, pomegranates, apricots, and peaches. Husbandry practices are normally carried out by hand. Where space permits, however, draft animals are used for tillage. The curves of the terraces and access to the steep slopes make it very difficult/impossible to use tractors. Animal power is more versatile in this irregular landscape, but it is more expensive than tractor power, due to shortage of fodder.

Location: Tal Lata Village, Ariha District, Idleb Province, Syria
Technology area: >5 km^2
SWC measure: structural
Land use: cropland
Climate: semi-arid
WOCAT database reference: QT SYR01
Related approach: not documented
Compiled by: Zuhair Masri, ICARDA, Aleppo, Syria and Michael Zöbisch, Germany
Date: August 1999, updated May 2004

Editors' comments: Bench terraces with stone walls (risers) are a very common technology, with ancient origins. They are found, worldwide, on steep hillsides where erosion is a problem and stone is available. Labour rates for initial construction are high, but the terraces are effective in multiple ways, and durable – given regular maintenance. Comparisons can be made with the examples from South Africa and Peru.

Classification

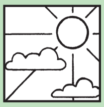
Land use problems

Before terracing, water erosion resulted in shallow to medium colluvial soils. Terracing made cultivation possible, but the beds tend to be very narrow and/or irregularly shaped, with large boulders set in them, making tractor cultivation (which is cheap) impossible.

Land use

tree crops: fruit trees

Climate



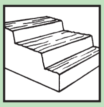
semi-arid

Degradation

water erosion: loss of topsoil

water degradation: soil moisture problem

SWC measures



structural: level bench terraces

Technical function/impact

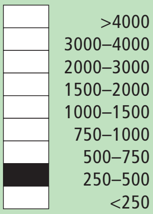
main:
- reduction of slope angle
- increase of infiltration
- water harvesting
- increase in soil fertility (long-term)

secondary:
- control of concentrated runoff
- increase water stored in soil (improvement of ground water)
- sediment harvesting

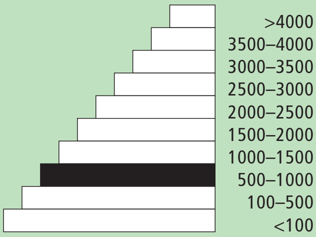
Environment

Natural environment

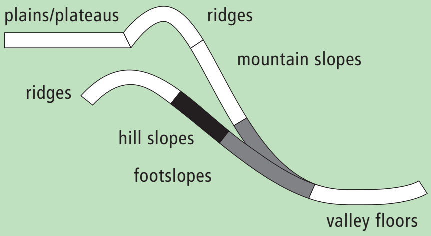
Average annual rainfall (mm)



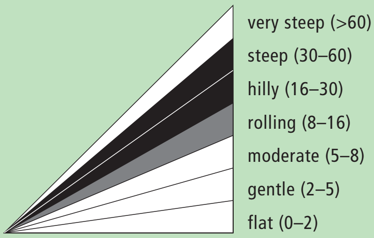
Altitude (m a.s.l.)



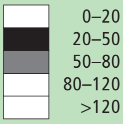
Landform



Slope (%)



Soil depth (cm)

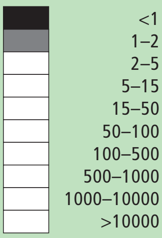


NB: soil properties before SWC

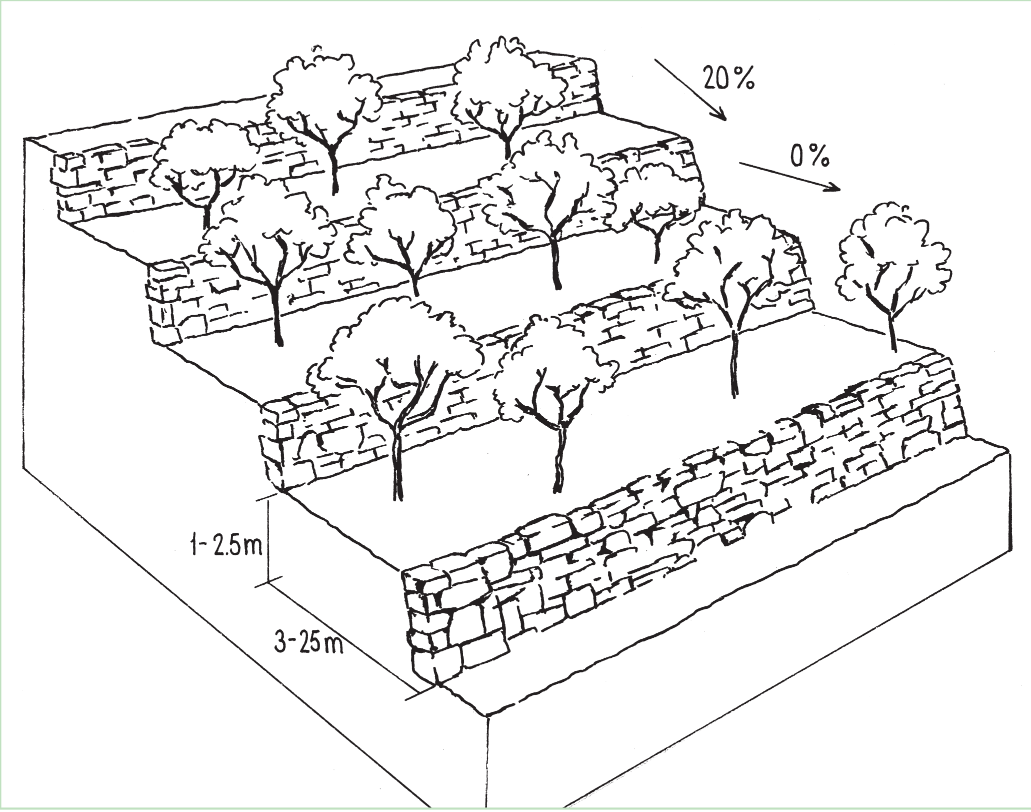
Growing season: 180 days (November to April)
Soil fertility: mainly medium, partly low
Soil texture: mainly medium (loam), some fine (clay)
Surface stoniness: some loose stone, but a lot of large buried rocks and rocky outcrops
Topsoil organic matter: medium (1–3%)
Soil drainage: medium
Soil erodibility: medium

Human environment

Cropland per household (ha)



Land use rights: individual
Land ownership: individual titled
Market orientation: mainly commercial (market), partly mixed (commercial and subsistence)
Level of technical knowledge required: field staff/extension worker: high, land user: high (to manage the various types of fruit trees)
Importance of off-farm income: on average, 70% of the income is from off-farm activities



Technical drawing
Stone wall risers constructed in ancient times: these hold back the earth for production of fruit trees on the level benches.

Implementation activities, inputs and costs

Establishment activities

For terraces built currently:

1. Levelling the terrace bed by bulldozers where necessary.
2. Blasting rocks in the fields using drill and explosives (ammonium nitrate).
3. Collecting stones for wall building – which are available locally.
4. Building the stone walls with 1–2.5 m vertical interval (and therefore this height), a width of 60–80 cm and terrace beds 3–25 m wide.
5. Levelling land between stone walls.

Duration of establishment: 3–6 months (several persons)

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (420 person days)	1,260	100%
Stone collection	50	100%
Equipment		
- Bulldozer (4 hours)	50	100%
- Hand Tools	50	100%
- Drill	5	100%
Materials		
- Ammonium nitrate (50–100 kg)	15	100%
- Detonators (50–100)	10	100%
- Fuses (25–50 m)	20	100%
- Stone (840 m^3)	0	
TOTAL	**1,460**	**100%**

Maintenance/recurrent activities

Repairing terraces by hand requires an average of 5 person days every year.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (5 person days)	15	100%
Equipment		
- Hand tools	5	100%
Materials		
- Stone (small quality)	0	
TOTAL	**20**	**100%**

Remarks: Manual construction work requires 0.35–0.7 person days per metre length of terrace wall. Establishment costs were calculated for an average of 600 m length of stone wall (height 2 m, width 70 cm) per hectare on a 12% slope, with terrace beds therefore about 16–17 metres wide. Narrower terraces on steeper slopes are considerably more expensive to construct.

Analysis/assessment

Acceptance/adoption

- 95% of the land users (37 families) who have recently adopted the technology did so without incentives.
- The other 2 families received incentives ('soft' loans from the Agricultural Bank).
- Old and poor people needed incentive support – such as free soil levelling and rock blasting, transporting of stone, and construction. Cash-oriented, fruit growing, households build terraces themselves.
- The rate of spontaneous adoption is low because of the high costs.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	negative	positive
maintenance/recurrent	positive	positive

Impacts of the technology

Production and socio-economic benefits
- +++ crop yield increase
- + farm income increase

Production and socio-economic disadvantages
- −− high labour inputs in field operations (mechanisation is not possible)

Socio-cultural benefits
- +++ improved knowledge SWC/erosion

Socio-cultural disadvantages
- − potential socio-cultural conflicts (if the community refuses to participate in joint maintenance activities)

Ecological benefits
- +++ soil loss reduction
- ++ increase in soil moisture
- + increase in soil fertility
- + biodiversity enhancement

Ecological disadvantages
- none

Off-site benefits
- ++ reduced downstream flooding
- ++ reduced downstream siltation

Off-site disadvantages
- none

Concluding statements

Strengths and ➜ how to sustain/improve

The terraces make the cultivation of trees on hill slopes possible.

Soil and water is conserved and fruit crop yields are maintained/increased ➜ Combine with soil fertility improvement (such as farm yard manure).

The maintenance requirements are low. The terraces need little repair ➜ Natural drainage lines must be prepared/maintained to prevent collapse during heavy rainfall.

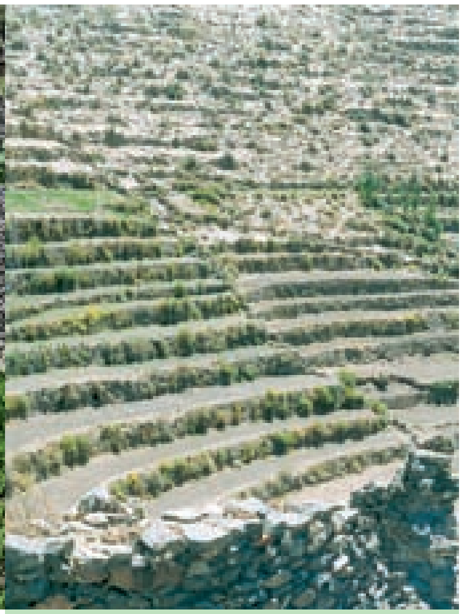
Weaknesses and ➜ how to overcome

The establishment costs are high ➜ Plant high value cash crops.

The mechanisation of farm operations is impossible because there is no access to the terraces for tractors, while animal power is constrained by high maintenance costs (fodder). Thus, field operations are limited to hand labour because ➜ Subsidise mule ploughing.

Key reference(s): Mushallah AB (2000) *The visible and the hidden in the country of olives.* Akrama Publ. Office. Damascus, Syria. pp 463

Contact person(s): Masri Zuhair, ICARDA, PO Box 5466, Aleppo, Syria; z.masri@cgiar.org, soilcons@scs-net.org

left: The rehabilitation of ancient terraces with integrated irrigation and drainage system leads to considerable increase of productivity in semi-arid Andean areas with slopes ranging from 8–60%. (DESCO)
right: Abandoned terraces in the background clearly contrast with those recently rehabilitated. The agroforestry component (shrub rows along the terrace walls) is an optional supportive measure. (DESCO)

Rehabilitation of ancient terraces

Peru – *Andenes / Anchacas / Patapatas*

Repair of ancient stone wall bench terraces, and of an associated irrigation and drainage system.

The level bench terrace system in the Colca valley of Peru dates back to 600 years AD. Since then the terraces have been continuously used for crop production, but due to lack of maintenance they have deteriorated, and the population has lost its traditional knowledge of repair.

The rehabilitation of the terraces recreates their original structural design. Broken sections are cleared and the various materials – stones, topsoil, subsoil and weeds – are removed and separated. The foundation is re-established, followed by construction of the stone wall (the 'riser'). Backfilling with subsoil then takes place; this is consolidated and finally covered with topsoil. Simultaneously the complementary irrigation and drainage systems are reconstructed.

The rehabilitated terraces efficiently conserve soil and water on steep slopes, and they create a favourable microclimate for crops, reducing loss of stored heat at night by minimising air movement (preventing frosts) and mitigating dry conditions through moisture conservation. The main economic benefits are from increased yields and crop diversification.

Terraces are spaced and sized according to slope, eg on a 50% slope, terraces are 4 m wide with a 2 m high riser between terrace beds. Stones of ancient terraces had been widely used to build walls for boundary marking after privatisation of land, therefore a large amount of stone had to be provided by splitting rocks and transporting from other locations.

The area is characterised by steep slopes with loamy-sandy, moderately deep soils (on the terrace beds). Most of the annual precipitation (ca. 350 mm) falls within a period of 3 months, which makes irrigation necessary. The farmers in the area own, on average, 1.2 hectares of arable land, divided into around six plots in different agro-ecological zones. Production is mainly for subsistence.

Important supportive technologies include agronomic measures such as improved fallow, early tillage, ridging, and intercropping. Tree and shrub planting at the base of terrace walls is an optional measure with the aim of stabilising the walls, diversifying production and again ensuring a good microclimate. On average 250 trees/ha are planted; these are mainly native species such as *c'olle (Buddleia spp.), mutuy (Cassia sp.), molle (Schinus molle:* the 'pepper tree') and various fruit trees including *capulí (Prunus salicifolia).*

Location: Río Colca, Caylloma, Arequipa, Peru
Technology area: 100 km^2
SWC measure: structural
Land use: cropland
Climate: semi-arid
WOCAT database reference: QT PER01
Related approach: Participatory catchment rehabilitation, QA PER01
Compiled by: Aquilino P. Mejia Marcacuzco, Center for Studies and Promotion of Development – DESCO, Arequipa, Peru
Date: July 2002, updated June 2004

Editors' comments: Terracing systems on hillsides date back to the beginning of agriculture. Often these feature walls ('risers') built of stone, and sometimes they are used for irrigation – as in this case from Peru. While many ancient systems have fallen into disrepair with out-migration of rural populations, this is an example of project-based rehabilitation.

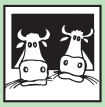
Classification

Land use problems

- Loss of productive capacity: 30% of the agricultural land lost due to degraded terraces, severe deforestation (through cutting for fuelwood), overgrazing and burning of grazing areas.
- Inefficient irrigation practices (flooding) due to poor maintenance of irrigation system (and drainage system in poor condition), flood irrigation leads to deterioration of terraces.
- Loss of traditional knowledge of ancestral crop management practices (abandonment of appropriate rotation practices, lack of residue incorporation/recycling, unsystematic crop layout).

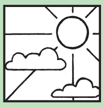
Land use

annual crops: potatoes, maize, beans, etc (irrigated)



intensive grazing: alfalfa (cut and carry)

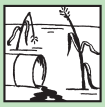
Climate



semi-arid

Degradation

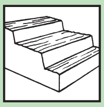
water erosion: gully, loss of topsoil



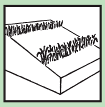
chemical: fertility decline

water degradation: soil moisture problem

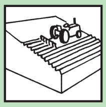
SWC measures



structural: level bench terraces



vegetative: aligned shrubs (opt.)



agronomic: various (supp.)

Technical function/impact

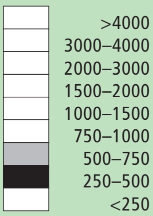
main:
- retain/trap dispersed runoff
- reduction of slope angle
- reduction of slope length
- increase of infiltration
- water harvesting
- improvement of microclimate

secondary:
- improvement of soil structure
- increase in organic matter
- impede/retard concentrated runoff
- sediment harvesting
- increase/maintain water stored in soil
- impede/retard dispersed runoff

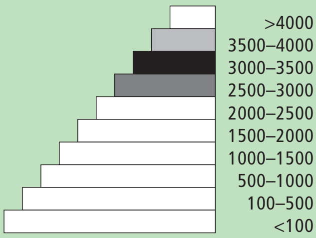
Environment

Natural environment

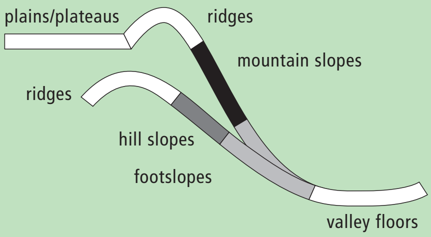
Average annual rainfall (mm)



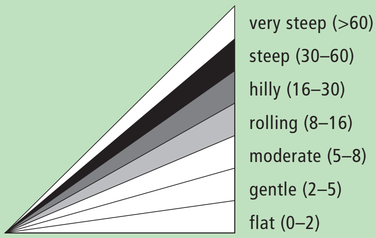
Altitude (m a.s.l.)



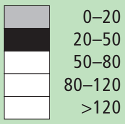
Landform



Slope (%)



Soil depth (cm)

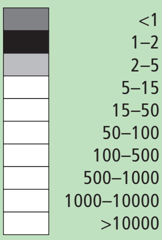


NB: soil properties before SWC

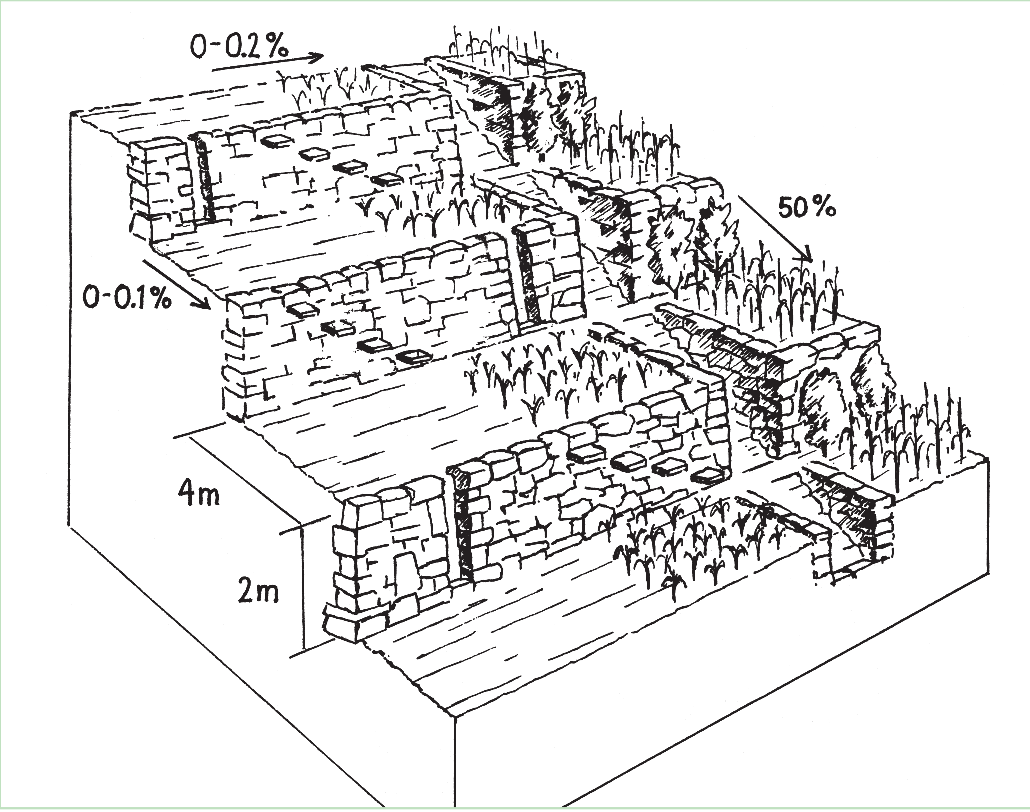
Growing season: 120 days (December to April)
Soil fertility: mostly medium (used for maize), partly low
Soil texture: mostly medium (loam)
Surface stoniness: mostly abundant loose stone
Topsoil organic matter: low (<1%), low recycling of organic matter
Soil drainage: mostly moderate
Soil erodibility: high

Human environment

Cropland per household (ha)



Land use rights: mostly individual, partly leased
Land ownership: mostly individual not titled, partly individual titled
Market orientation: cropland: mostly subsistence (self-supply), partly mixed (30% for market); livestock: subsistence (complementary to crop production), commercialisation (income generation to meet basic needs)
Level of technical knowledge required: field staff/extension worker: high, land user: moderate
Importance of off-farm income: <10% of all income: main source is wage labour in the valleys



Technical drawing
Rehabilitated ancient terraces with high stone risers. Two options for irrigation and drainage of excess water are shown: outlets in the risers (left) and a broad water channel cutting perpendicularly through the terraces (right).

Implementation activities, inputs and costs

Establishment activities

1. Separation of materials of collapsed wall: subsoil, topsoil, stone, weeds.
2. Cleaning and re-establishment of the foundation according to original structure.
3. Cutting stones from rocks (blasting and splitting); transporting.
4. Reconstruction of the stone wall, building on the basis of remaining intact structures of ancient terraces; simultaneous reconstruction of irrigation channels and complementary structures.
5. Backfilling with subsoil, moistening soil and consolidation with motor or manual compressor.
6. Covering with fertile topsoil.
7. Levelling of terrace bed and completion of riser edge (lip).
8. Planting of trees below terrace walls (optional).
9. Improved fallow, early tillage, ridging, and intercropping (supportive measures).

All activities carried out in dry period.
Used tools: A-frame, tape measure, motor drill, wheelbarrow, shovel, pick, steel bar, sledgehammer, hoe, hand compressor.
Duration of establishment: not specified

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (130 person days)	560	40%
Equipment		
- Machines (compressor etc: 20 hours)	180	40%
- Tools (various: see description)	300	40%
Materials		
- Stone (450 m^3)	200	40%
Agricultural		
- Seedlings (trees)	100	0%
Others		
- Construction supervisor (7 days)	60	0%
- Transport of inputs	0	
TOTAL	**1’400**	**35%**

Maintenance/recurrent activities

1. Irrigation system cleaning.
2. Clearing weeds from stone wall (dry season).
3. Inspection of the stone walls’ stability (before sowing).
4. Repair structures (rainy season).
5. Tree and root pruning.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (6 person days)	25	100%
Equipment		
- Tools	100	100%
TOTAL	**125**	**100%**

Remarks: Person days needed for rehabilitation of 1 ha of ancient terrace system depend on degree of deterioration, the dimensions of the wall, slope angle (the steeper the more terraces) and availability of stones. In the case of the project, under a typical situation, for physical rehabilitation of 1 ha with 6 terraces, each ca 600 m long, 3–4 m wide and 2 m high, with one third of the main structures in disrepair, 18 men and 7 women work for 5 days; shrub planting is extra. Land users bear 35% of the overall costs: they also provide food for the group during work. The programme pays the rest. 450 m^3 of additional stones are required to repair the broken parts, the cost includes blasting/splitting rocks and transport to the construction site. Supportive agronomic measures and agricultural inputs (seeds and manure) are not included. Maintenance costs vary considerably, depending on the specific situation: an average is taken here.

Assessment

Acceptance/adoption

- 90% of the land users (2,160 families) who applied the technology, did so with incentives.
- 10% land users (240 families) adopted the technology without incentives, on their own, aware of the need for SWC.
- 40% of terraces have been rehabilitated in 7 districts (8 micro-watersheds) of the Colca valley.
- The project provided incentives, through financing 65% of the overall implementation costs (labour, tools, explosives etc).
- There is a moderate trend towards spontaneous adoption.
- 95% of the repaired terraces have been well maintained, and land users are satisfied with the benefits; 5% of the terraces have been damaged again due to lack of maintenance, but land users continue using them for crop cultivation.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	neutral/balanced	very positive
maintenance/recurrent	positive	very positive

Impacts of the technology

Production and socio-economic benefits

+++	easier crop management (level bench, alignment of crops)
+++	efficient use of irrigation water and fertilizers
++	crop yield increase (average 30%)
++	farm income increase

Production and socio-economic disadvantages

– – –	increased input constraints (tools)
– –	increased labour constraints: heavy work (establishment), constant maintenance

Socio-cultural benefits

none

Socio-cultural disadvantages

none

Ecological benefits

+++	soil loss reduction
+++	efficiency of excess water drainage
+++	regular crop growth and development
++	biodiversity enhancement
++	soil cover improvement
++	increase in soil moisture
++	increase in soil fertility
++	improved microclimate (reduced wind; conserving heat)

Ecological disadvantages

none

Other benefits

none

Other disadvantages

– –	careful management required (water and livestock)
– –	scarcity of stones (in some places)

Off-site benefits

++	reduced downstream flooding
++	increased stream flow in dry season
++	reduced downstream siltation

Off-site disadvantages

–	reduced sediment yields (downstream)

Concluding statements

Strengths and ➜ how to sustain/improve

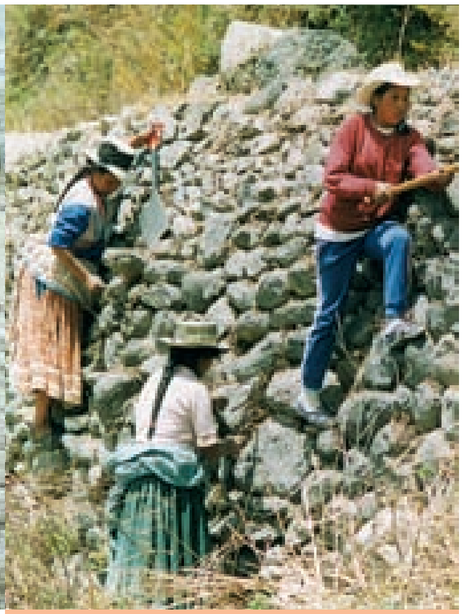
- Traditional technology is of great value and adapted to local conditions ➜ Awareness raising of the local population on maintenance of terraces.
- Successful implementation is product of evaluation, analysis and documentation of experiences ➜ Further appraisal of the technology.
- Soil maintained on steep slopes, no soil loss due to water erosion ➜ Continuous maintenance and appropriate management through training.
- More efficient use of irrigation/rain water, longer storage of soil moisture ➜ Continuous maintenance of the system.
- Maintenance of soil fertility ➜ Recycling of organic matter.
- Facilitation of crop management activities (crop alignment, easier tillage with oxen plough, efficiency of pest control, etc) ➜ Appropriate crop management (see measures mentioned in description).
- Improved microclimate facilitates crop growth and crop diversification ➜ Complete with improved agronomic practices and agroforestry.
- Increased yields and food security ➜ Conserve crop diversity and genetic variety.
- Cultural heritage ➜ Conservation of traditional practices.

Weaknesses and ➜ how to overcome

- Specialised work, not easy to carry out – complex system of different structures ➜ Promote applied research and extension.
- High rehabilitation costs; increased by loss of traditional forms of reciprocal work, and a trend towards individualism ➜ Reactivate and strengthen traditional labour systems based on reciprocity and mutual help.
- Limited availability of stones impedes the rehabilitation process ➜ Carry stones from adjacent or remote places, give training in rock splitting.
- Not appropriate for use of agricultural machines ➜ Awareness creation.
- Private properties, but not titled ➜ Promote the legalisation of titles to facilitate the access to credit and technical assistance.
- Vulnerability of terraces to damage by grazing animals ➜ Do not allow grazing on short terraces with high stone walls.
- Land users are not skilled in repair of broken sections in the terrace system ➜ More training on maintenance and conservation.

Key reference(s): Mejia Marcacuzco AP (undated) *Folleto de divulgación: Andenes, construcción y mantenimiento* ▪ Treacy, JM (undated) *Las Chacras de Coporaque: Andenes y riego en el valle del Colca.* Instituto de Estudios Peruanos. DESCO

Contact person(s): Rodolfo Marquina, Centro de Estudios y Promoción del Desarrollo – DESCO, Calle Málaga Grenet No. 678 Umacollo, Arequipa, Perú; descolca@terra.com.pe; www.desco.org.pe



left: Initial labour input for rehabilitation activities is high. Incentives were provided and equipment was partly subsidised to motivate the participation of land users. (DESCO)
right: Women participating in the rehabilitation of ancient terraces. The community was involved in planning, implementation and evaluation of the SWC activities. (DESCO)

Participatory catchment rehabilitation

Peru – *Participación comunitaria para la rehabilitación de cuencas*

Promoting the rehabilitation of ancient terrace systems based on a systematic watershed management approach.

The Center for Studies and Promotion of Development – DESCO, a Peruvian NGO, started the Terrace Rehabilitation Project in 1993 to re-establish ancient terracing and irrigation practices that had largely been lost. The project is part of a general integrated development programme. Its overall purpose is to restore the productive capacity of terraced cropland, and to generate better living standards in the Colca valley. The project has the following specific objectives: (1) to increase the productive infrastructure through soil conservation and better use and management of existing water resources; (2) to increase levels of production; (3) to stimulate people in soil conservation and land management; and (4) to encourage/promote relevant local institutions.

For implementation, a systematic watershed management approach was introduced. The catchment was considered the basic unit for development planning. Physical and socio-economic baseline studies were carried out. A strong community-based organisation, the catchment committee, was then founded. This consisted of representatives of major local grassroots organisations (irrigation committee, farmers' community, mothers' club etc). Responsibilities, commitments and rules were defined. Committee meetings and land user assemblies were the entities for planning, organisation and execution of project activities. DESCO initiated a process of 'concerted planning' in collaboration with other private and public institutions in Caylloma province.

In summary the project stages comprised: (1) project planning; (2) baseline studies; (3) catchment management plan; (4) constitution of the executive committee; (5) concerted planning of district development; and (6) organisation, execution, technical assistance and follow-up activities. Land users were required to participate in training courses and in fieldwork, to provide local materials and their own tools, and to fulfil duties within the organisations. Leaders and directors of grassroots organisations were responsible for planning and organisation of activities – implementation, training and follow-up – and for control and administration of project materials and inputs. The directors were also elected as representatives in the District Development Councils to participate in the evaluation and monitoring activities of the project.

Location: Río Colca, Arequipa, Peru
Approach area: 8,250 km^2
Land use: cropland
Climate: semi-arid
WOCAT database reference: QA PER01
Related technology: Rehabilitation of ancient terraces, QT PER01
Compiled by: Aquilino P Mejia Marcacuzco, DESCO, Arequipa, Peru
Date: July 2002, updated June 2004

Editors' comments: The community action used under this terrace rehabilitation project is a form of a broader, integrated systematic approach. This latter approach is widespread in the whole Andean region, and a Latin American network of watershed management has been established. Within Peru, a broad range of NGO-driven development projects use this approach.

Problem, objectives and constraints

Problem

- lack of employment opportunities/depopulation of rural areas
- lack of planning and action in 'concerted development'
- little value associated with terrace rehabilitation
- low and unequal participation of women in field work
- general impoverishment of land users

Objectives

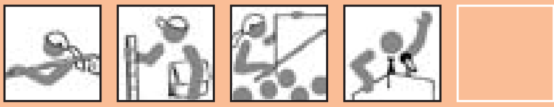
- to achieve higher levels of agricultural production and productivity through integrated development/management of soil and water resources
- to build capacity for planning, organisation and implementation of development activities

Constraints addressed

Major	Specification	Treatment
Social/cultural/religious	Women were treated unequally in terms of opportunities and salaries.	Equal treatment in salaries and better opportunities were ensured for women.
Financial	The poorest land users lacked the money to invest in terrace rehabilitation.	Manual labour and tools were subsidised.
Institutional	Coordination of planning and activities was lacking between different institutions and projects.	District Development Councils (CODDIS) were strengthened as entities for coordination and concerted action.
Minor	**Specification**	**Treatment**
Legal	There was a lack of legal (registered) institutions to coordinate planning and strategies for sustainable land use at community level.	An active effort was made to promote legalisation of, and give support to, grassroots organisations (eg Union of Land Users).
Economical	Investment in cash crops was a problem for poor small-holders.	Training/technical assistance was given for more profitable crops: eg potatoes, beans and peas.
Technical	Local specialists in terrace rehabilitation and for construction supervision were lacking.	Training and competitions were organised to develop skills and select the best.

Participation and decision making

Target groups



Land users | SWC specialists/extensionists | Teachers/students | Politicians/decision makers

Approach costs met by:

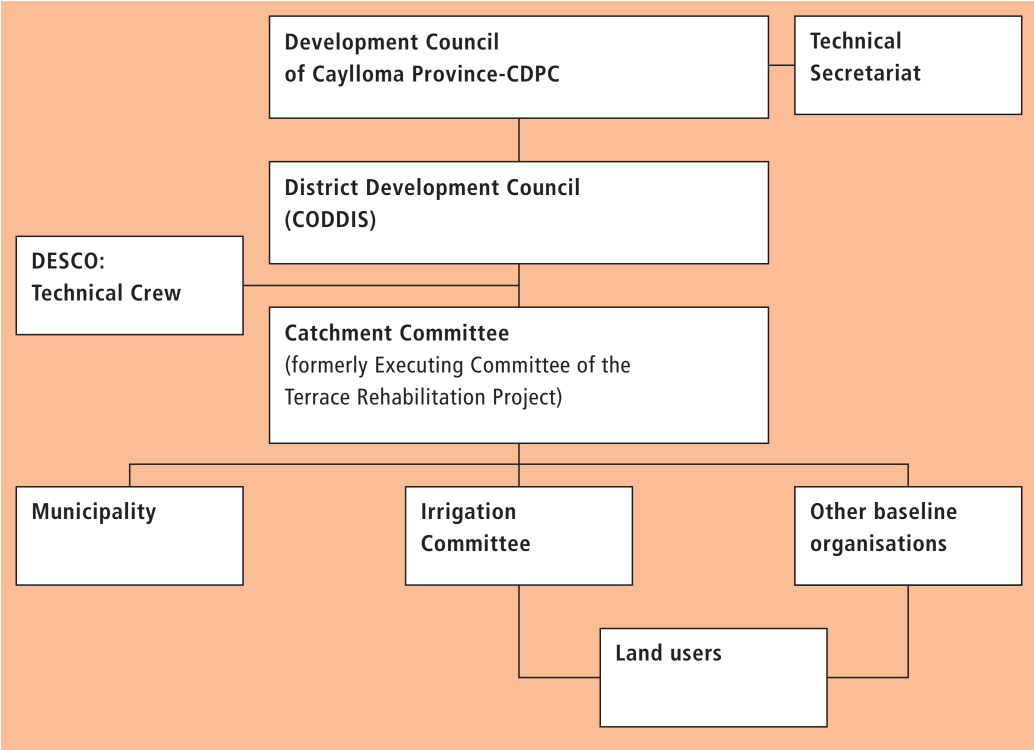
International NGO	60%
National government	20%
Community/local	20%
	100%

Decisions on choice of the technology: Mainly by SWC specialists with consultation of land users; the terraces were in an advanced stage of collapse and the local population did not have the means to reverse the process due to lack of economic resources.
Decisions on method of implementing the technology: Mainly by land users supported by SWC specialists; the technology is indigenous and adapted to the area. Evaluation workshops of, and activities permitting discussions on, the technology were carried out.
Approach designed by: National specialists.

Community involvement

Phase	Involvement	Activities
Initiation	interactive	rapid/participatory rural appraisal with public meetings, workshops, interviews
Planning	self-mobilisation	assemblies for decision making, workshops for local concerted planning
Implementation	interactive	casual labour, responsibility for minor steps (land users in general); responsibility for major steps (leaders)
Monitoring/evaluation	interactive	workshops, measurements/observations (directors of baseline organisations/leaders), reports (directors), interviews (directors/teachers), public meetings (land users)
Research	none	

Difference in participation between men and women: There were no differences in terms of salaries, but there were in terms of job opportunities: in a working group of 20 persons, typically only 5 women were contracted as terrace rehabilitation is very heavy work.



Organogram
District Development Council (CODDIS): social organisations, public and private institutions jointly prepare economic and social development plans in a participatory manner, and under the leadership of local government (prioritising development actions according to the needs of different stakeholders).

Extension and promotion

Training: A training plan at three levels was drawn up, addressing the following target groups and topics: (1) Selected land users, leaders, supervisors: in-depth training on the interrelations between water, soil and plants; terrace and canal construction; institution/enterprise management; natural resource management, conservation practices, and crop production. (2) Directors of grassroots organisations and municipalities: treating organisational and administrative topics. (3) Farmers in general: treating topics of general interest and focussing on awareness raising. Training was carried out mainly on-the-job, but complemented by exchange of experiences and public meetings.
Extension: Key elements were technical assistance and sustained follow-up, supervision by specialised engineers, evaluation (reflection) and systematisation of gained know-how and developed practices with different stakeholders, and function testing of rehabilitated structures. Capacity for extension continuation has been built up within the catchment committee. However PRONAMACHS, a governmental SWC programme, is limited by lack of budget and through bureaucratic problems. The impact/effectiveness of training and extension on land users and SWC specialists was reported to be 'good', whereas the impact on extension workers, teachers and politicians/decision makers was only 'moderate' and on students and planners was given as 'poor'.
Research: Technology: research has been ongoing regarding functioning of the terrace and irrigation systems. Economy/commercialisation: research regarding agronomic production, catchment appraisals and market studies have been carried out for the main products of the area. Research activities and studies carried out led to readjustment of the approach at catchment and field level.
Importance of land use rights: The fact that the land being rehabilitated is private property of the land users facilitated their commitment, as the project activities raised the value of the land.

Incentives

Labour: 60% of the labour costs were met by the project.
Inputs: Hand tools and equipment (A-frames, tape measures, motor drills, wheelbarrows, shovels, picks, steel bars, sledgehammers, hoes, and compressors) were partly subsidised. Seedlings of tree species for establishment of the agroforestry component on terraces were produced in a project-owned nursery, and they were given free of charge to interested farmers. Fertilizers, biocides and seeds were not financed.
Credit: Credit was provided by FONDESURCO to land users who participated in the rehabilitation project (for seed supply) with a lower interest rate than on the market. FONDESURCO is an NGO (of which DESCO is a member) specialised in microfinances in the rural sector.
Support to local institutions: Support was provided to existing institutions (in the form of training, organisation and financial inputs). But with the formation of a catchment committee, an important grassroots organisation was built up.
Long-term impact of incentives: A slight negative impact is expected in the long term: a few farmers do not maintain rehabilitated terraces (which leads to collapse of structures), however this is more due to negligence or carelessness than lack of awareness, or lack of ongoing incentives.

Monitoring and evaluation

Monitored aspects	Methods and indicators
Technical	regular measurements of improved structures, results of technology tests
Socio-cultural	ad hoc observations of land users changing attitudes of SWC
Economic/production	ad hoc measurements of crop production increase
Area treated	regular measurement of rehabilitated area
No. of land users involved	regular measurement of number of households that benefited directly
Management of approach	ad hoc observations of number of catchments rehabilitated with terraces and agroforestry

Impacts of the approach

Changes as result of monitoring and evaluation: There were various changes/readjustments of the approach: eg the concerted planning through the Local Development Councils was incorporated 5 years after the initiation of the project.
Improved soil and water management: There have been great improvements: introduction of high-value crops; 100% of the area cultivable; reduction of irrigation frequency by 20% due to higher efficiency of water storage by the terraces; various other SWC benefits.
Adoption of the approach by other projects/land users: A few other projects have adopted the approach: eg the project of the *Banco de Vivienda* PRATVIR in the Coporaque area; also 'Popular Cooperation' in Ichupampa (covering just 2 ha).
Sustainability: Land users can continue the activities without external support, using traditional systems of mutual help and new forms of local organisation (catchment committee). With increased income through integration of cash crops the maintenance of the structures can be sustained.

Concluding statements

Strengths and ➜ how to sustain/improve
An effective systematic watershed management approach applied at catchment level ➜ Other projects/institutions should apply this approach.
Soil conservation activities integrated in the plans of 'concerted development' ➜ Strengthening of the Local Development Councils (CODDIS).
Human capacity building: 60 specialists trained in rehabilitation technology ➜ Create opportunities to ensure continuation of their work.
80% of land users have changed attitudes towards SWC, and are convinced of the benefits of terrace rehabilitation ➜ Promote SWC training and extension activities.
Strengthened customs and traditions: rituals of offerings to the earth, to crops and animals; customs of mutual help in labour *(ayñi, minka)* and of exchanging food products *(treque)* ➜ Create spaces and mechanisms for daily practice of important cultural rituals/customs.
Institutional capacity building: strengthening of organisations; increased participation ➜ Continue the training of leaders.
Complementary conservation practices have been integrated into the terraces system: agroforestry, improved fallow, etc ➜ Training of land users in the advantages and disadvantages of these practices.

Weaknesses and ➜ how to overcome
Changes in leadership interrupt planned processes (of activities) ➜ Permanent training to encourage leadership qualities.
Small holdings and land fragmentation are constraints for cost-effective agriculture ➜ Accelerate the process of land consolidation and entitlement.
The economic incentives provided by the project affected the existing reciprocal relationships (eg labour exchange) ➜ Cash for work incentives are sometimes useful to overcome labour constraints due to depopulation.
The generation of income encourages the purchase of industrialised products ➜ More training regarding consumption of local products.
The approach requires the participation of all social and political stakeholders – which is practically impossible ➜ Strengthen the Local Development Councils (CODDIS).
Labour overload in the family ➜ Better planning of work at the household level.
Lack of a crop and irrigation plan for better water management ➜ Elaboration and application of a plan.

Key reference(s): none available

Contact person(s): Rodolfo Marquina, Centro de Estudios y Promoción del Desarrollo – DESCO, Calle Málaga Grenet No. 678 Umacollo, Arequipa, Perú; descolca@terra.com.pe; www.desco.org.pe

left: Field treated with traditional stone terrace walls, *mitsheto:* this is one of the best constructed series of walls in the area. (William Critchley)
right: Detail from the terraced field: behind the wall sediment has built up to a depth of approximately 50 cm over time. (William Critchley)

Traditional stone wall terraces

South Africa – *Mitsheto*

Stone walls built on sloping fields to create terraces for cultivation and conservation: both ancient and contemporary.

In this hilly, mixed farming area, stone terrace walls are a tradition. They are built across the slope when new land is cleared of loose stone and brought into crop cultivation. The dimensions of the terrace walls and the spacing between them depend on various factors, especially the slope and the amount of stone in the field. The walls may be up to 1.25 m high, from 1.0 to 1.5 m in base width, and between 20 and 50 m long. Spacing is from 3 to 10 m apart. Design of stone terrace walls varies. Some walls are very neatly built, others are merely piles of stone across the slope: this depends on the individual land user. The walls are built up each year with further stones: this may just be as more loose stone comes to the surface when ploughing, or also by digging out larger stones to deliberately build up the height of the walls as it silts up behind. Such terracing is generally confined to slopes between 20% and 50%. From 12% to 20% contour grass strips *(thambaladza)* are normally used, but below 12% land is rarely protected with structures or strips.

The purpose of terracing, apart from simultaneously clearing the land of stone, is to guard against loss of topsoil. Together with contour ploughing this helps to keep soil fertility in place on sloping cropland in a subhumid area. Rainfall is around 1,000 mm per annum and maize is the most common crop, but various other annuals (beans, pumpkins, sorghum etc) and perennials (peaches, avocadoes, oranges etc) are also grown.

This example of land conservation is probably unique in a former South African 'homeland'. In such areas, where the black population were concentrated at high population densities under the former *apartheid* regime, land degradation rather than soil conservation was the rule. These terraces continue to be built to this day as new land is opened up, despite the high amounts of labour (300–500 person days per hectare) involved in establishment. A study of the conservation systems used in the area and local attitudes to them, showed that the benefits of conservation were well understood by local farmers (see reference). Those questioned identified retention of soil – and of soil fertility in particular – as being of paramount importance. No mention was made of terraces being built simply to remove surface stone. The only downside mentioned (by a few) was the loss of cultivable land area. The key to the persistence of the terraces in this area is, therefore, that the land users understand and appreciate the place of terraces in maintaining soil fertility, and their considerable contribution to crop production.

Location: Thohoyandou District, Limpopo Province, South Africa
Technology area: 8 km^2
SWC measure: structural
Land use: cropland
Climate: subhumid
WOCAT database reference: QT RSA03
Related approach: Community tradition, QA RSA03
Compiled by: William Critchley, Vrije Universiteit, Amsterdam, Netherlands
Date: May 1997, updated February 2004

Editors' comments: Traditional terraces with stone walls are common throughout Africa, and the rest of the world, wherever there is a combination of loose surface stone, sloping land and erosion. This is a good, living example from a former 'homeland' in South Africa, where many agricultural traditions had effectively been lost.

Classification

Land use problems

- decline in fertility of soils due to erosion and nutrient mining
- erosion from/caused by poor road drainage
- burning *veld* (rangeland) leading to runoff onto cropland

Land use

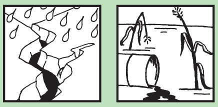
annual crops: maize, beans, sorghum, pumpkins

tree crops: peaches, oranges, avocados

Climate

subhumid

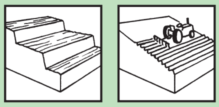
Degradation



water erosion: loss of topsoil

chemical: fertility decline

SWC measures



structural: stone wall terraces

agronomic: contour ploughing (supp.)

Technical function/impact

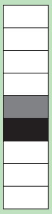
main: - control dispersed runoff
- conserve/improve soil fertility

secondary: - reduction of slope length
- reduction of slope angle

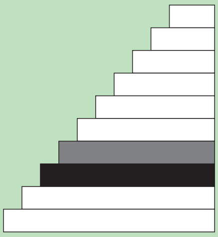
Environment

Natural environment

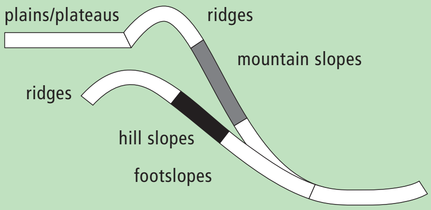
Average annual rainfall (mm)



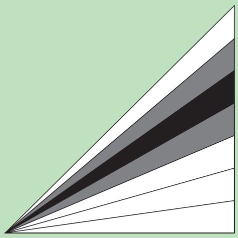
Altitude (m a.s.l.)



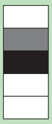
Landform



Slope (%)



Soil depth (cm)



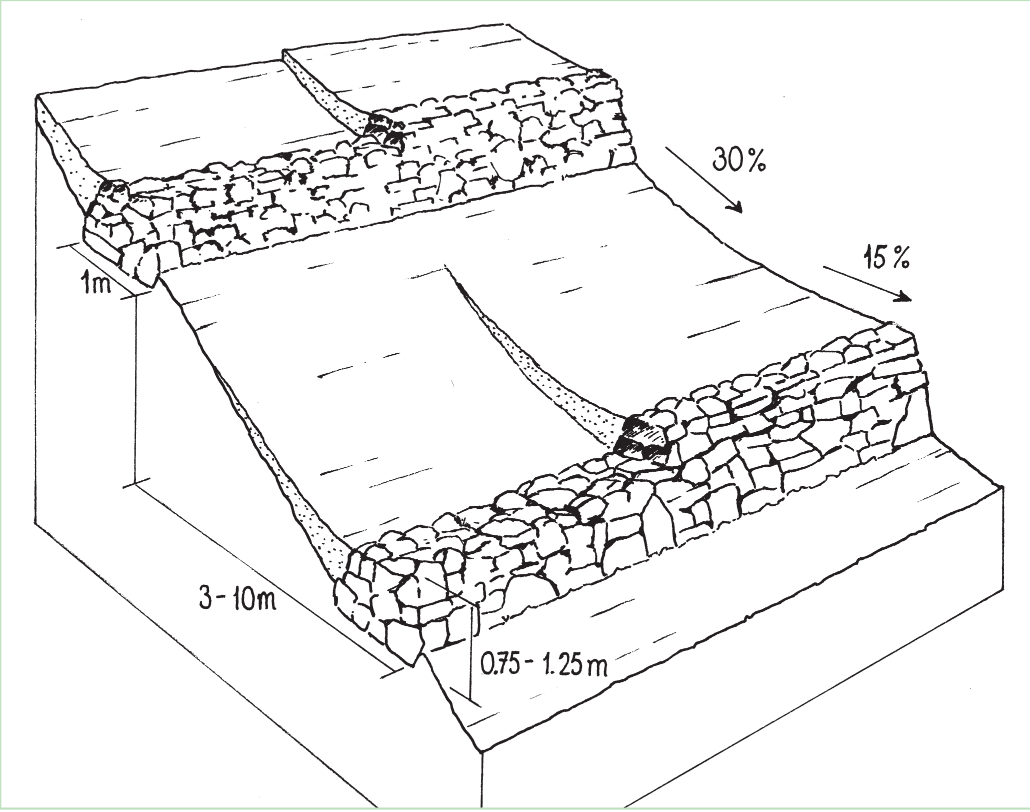
NB: soil properties before SWC

Growing season: 150 days (December to April)
Soil fertility: medium
Soil texture: medium (loam)
Surface stoniness: abundant loose stone
Topsoil organic matter: medium (1–3%)
Soil drainage: good
Soil erodibility: medium

Human environment

Cropland per household (ha)

Land use rights: individual
Land ownership: individual not titled
Market orientation: mixed (subsistence and commercial)
Level of technical knowledge required: field staff/extension worker: not involved; land user: moderate
Importance of off-farm income: >50% of all income: agriculture is not the main income earner in this former 'homeland' where most men are still employed in industry – temporarily migrating to other parts of the country



Technical drawing
Layout of stone wall terraces: the walls are built up over time (right) as soil accumulates behind the barriers.

Implementation activities, inputs and costs

Establishment activities

1. Layout is by eye: no instruments used.
2. Construction of new stone walls begins with a shallow trench into which large foundation stones are laid (or rolled downhill with a 'crowbar' – a long steel lever – if very big).
3. Terrace walls are then built up with successively smaller stones: design depends on the individual.
4. Stiles (low points) are generally left in the walls to allow human passage, but these are 'staggered' (ie not all in a straight line up-and-down slope) to avoid gullies forming.

Construction is carried out during the dry/non-growing season.
Duration of establishment: usually spread over 2 years

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (375 person days)	1,250	100%
Equipment		
- Tools (pick axe,crowbar)	20	100%
Materials		
- Stone (750 m^3)	0	
Others		
TOTAL	**1,270**	**100%**

Maintenance/recurrent activities

1. The walls are increased in height each year as it silts up behind.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (50 person days)	160	100%
Materials		
- Stone (100 m^3)	0	
TOTAL	**160**	**100%**

Remarks: Calculations are based on average-sized stone terrace walls (cross section 0.5 m^2) spaced 6.5 metres apart on a typical slope of 30% (implying, in this case, a vertical interval of 2 metres). There is however a wide range of costs depending on amount of stone available and slope. Maximum establishment input may be as much as 550 person days per hectare on the steepest slopes, and may take 3 years to complete. While a small number of farmers have received subsidies, this calculation is based on the majority of cases where all inputs are met by the land user him/herself.

Assessment

Acceptance/adoption

- 95% of land users have built terraces without incentives; the remaining 5% received some ad hoc relief funds from government in drought years
- the knowledge of the SWC impact, plant growth benefits and need to cultivate stony land are the reasons behind acceptance of terracing
- there is a moderate trend to increase the amount of land terraced as people begin to cultivate the steeper slopes

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	very negative	positive
maintenance/recurrent	slightly positive	positive

Impacts of the technology

Production and socio-economic benefits
- + + crop yield increase
- + + farm income increase

Production and socio-economic disadvantages
- − − − increased labour constraints

Socio-cultural benefits
- + + + improved knowledge SWC/erosion
- + + community institution strengthening

Socio-cultural disadvantages
- none

Ecological benefits
- + + + soil loss reduction
- + + increase in soil fertility
- + + increase in soil moisture

Ecological disadvantages
- none

Off-site benefits
- + + reduced downstream siltation
- + + reduced river pollution

Off-site disadvantages
- none

Concluding statements

Strengths and ➜ how to sustain/improve

This is an important example of a thriving traditional technology in a country where most such ancient practices were ended by *apartheid* ➜ It has the potential to persist, if the Department of Agriculture acknowledges the importance of the system, encourages and gives training and organises exchange visits between farmers. Exchange of knowledge from farmer to farmer is facilitated by 'Landcare' and supported by the government.

It makes use of abundant existing materials in the field (stone) and therefore input costs apart from labour are low: this is a win-win situation, clearing and building.

Maintenance is simple – merely building up the walls gradually – and is effectively absorbed in everyday farming activities.

Weaknesses and ➜ how to overcome

High labour investment for establishment ➜ Hand tools, for example pickaxes and crowbars, could be supplied to the poorest families.

Key reference(s): Critchley W and Netshikhovehla E (1998) Conventional views, changing paradigms and a tradition of soil conservation. *Development Southern Africa,* Vol 15, no 3, pp 449–469

Contact person(s): Rinda van der Merwe, Institute for Soil, Climate and Water, P/Bag x79, 0001 Pretoria, South Africa; rinda@arc.agric.za

left: A retired miner, Elias, expanding his field and making new terrace walls as he proceeds: at this stage the stones are loosely arranged before construction of the walls takes place. (William Critchley)
right: Masonry skills are employed to build the houses (which are then plastered over) and to construct stone walls around the homesteads. (William Critchley)

Community tradition

South Africa

Inherited, and still practiced, tradition of stone terracing – passed down from generation to generation.

The *VhaVenda* people of Limpopo Province in South Africa have a tradition of building with stone which has been passed down from generation to generation. They construct stone walls around their houses for example, taking a pride in the appearance of their homesteads. There is a historical monument nearby, the stone-built *kraal* at Dzata, the ruins of which are situated within a few kilometres of the study location. There may even be some evidence that the *VhaVenda* came originally from the area of the Great Zimbabwe (the famous stone-built fortress in Zimbabwe). It is not surprising therefore that the *VhaVenda* have used their masonry skills to build terraces in fields to counter erosion and simultaneously to make cultivation – along the contour by oxen – possible. This tradition has been passed down through the ages: it is institutionalised in the community and is practised together by men, women and children on a family basis. It is encouraged by community leaders: a particular example of this was in the 1960s when local chiefs were concerned at the sacred Lake Fundudzi 'turning red' – with sediment eroded from the land - and as a result they launched a conservation campaign to prevent soil wash into the lake. There has been modest and occasional support by the Department of Agriculture, in the form of ad hoc drought relief funds. There is quite a range of technical ability/care taken in terracing. Some walls are meticulously built; others are merely piles of stone across the slope. One of the reasons for this is that work tends to be done on an individual basis. Another result is that fields may take two years or more to be fully terraced. What is evident is that the land users – as well as being experienced masons – appreciate the benefits of the terraces they construct. An investigation of local environmental knowledge and conservation practices has demonstrated this clearly (see reference). The causes of erosion were explained by the interviewees as being part natural (rainfall, slope etc) and part anthropogenic (poor road building, up and down ploughing, burning of grassland etc). The main negative impact of erosion was considered to be loss of soil fertility: hence terracing for protection. This indigenous knowledge also extends to soils: eight local soil types and their differences in terms of texture, fertility and erodibility are recognised in the study area.

Location: Limpopo Province, South Africa
Approach area: 8 km^2
Land use: cropland
Climate: subhumid
WOCAT database reference: QA RSA03
Related technology: Traditional stone wall terraces, QT RSA03
Compiled by: William Critchley, Vrije Universiteit, Amsterdam, Netherlands
Date: May 1997, updated February 2004

Editors' comments: Traditions of stone terracing are abundant all over Africa – as well as in Asia and Latin America, where they are better known and documented. This is a particularly good example of a conservation tradition embedded in a community, and probably unique in South Africa.

Problem, objectives and constraints

Problem

- the tradition presumably arose as a spontaneous local response to degradation: it remains well entrenched
- underlying problems of no flat land to cultivate, soil erosion/fertility decline on sloping fields, and loose stone and rocks impeding animal-draw ploughs

Objectives

The objective of the local people is simply to continue making cultivation possible and sustainable, through the local tradition of using stone walls to create terraces and to remove abundant stones from the field.

Constraints addressed

	Specification	Treatment
Labour	High labour demand to remove stone from inhibiting cultivation.	Traditional teaching that such stone can be used constructively to improve conservation and yield benefits.

Participation and decision making

Target groups

Land users

Approach costs met by:

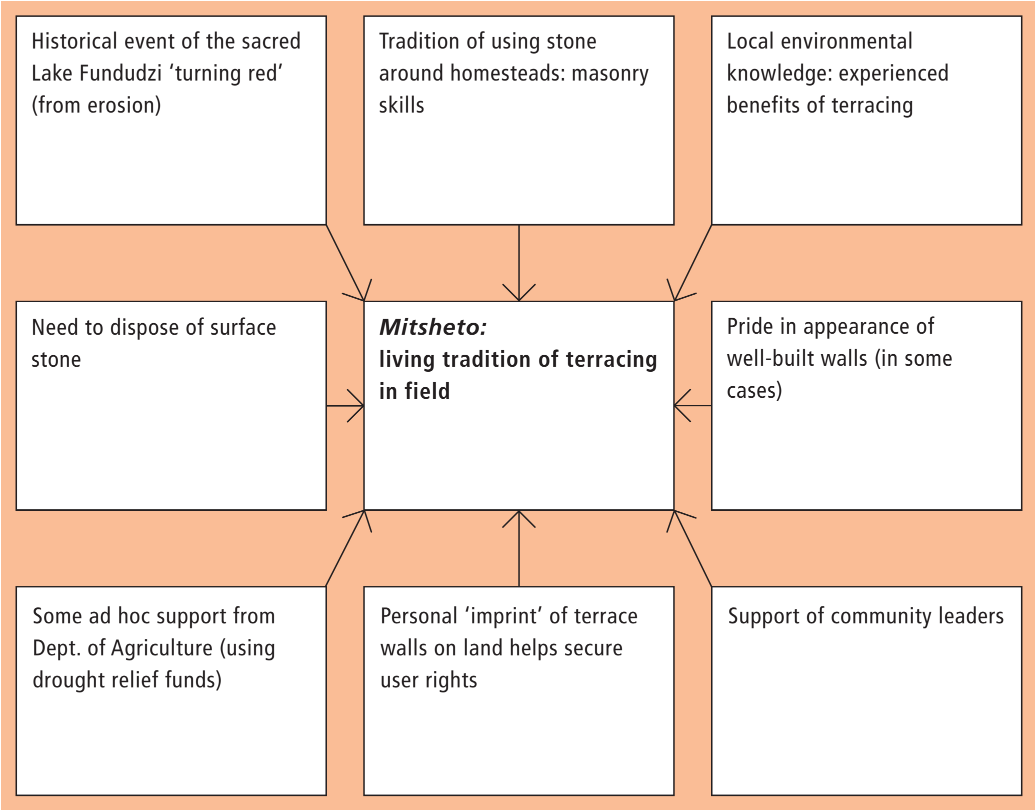
National government	5%
Community/local	95%
	100%

Decisions on choice of the technology: Made by land users alone.
Decisions on method of implementing the technology: Made by land users alone.
Approach designed by: Land users alone.

Community involvement

Phase	Involvement	Activities
Initiation	self-mobilisation	passing on of knowledge from generation to generation
Planning	self-mobilisation	family-based (or individual) construction
Implementation	self-mobilisation	family-based (or individual) construction
Monitoring/evaluation	not applicable	
Research	not applicable	

Differences in participation between men and women: There are no differences. Women can be seen constructing stone walls as well as men.



Enabling environment
Factors supporting the terracing tradition

Extension and promotion

Training: There was/is no formal training – just father to son/mother to daughter.
Extension: Some encouragement from Department of Agriculture especially during soil and water conservation campaigns/drought relief periods.
Research: None.
Importance of land use rights: Land is officially held, and allocated, by the chief. But building stone terraces on allocated land makes a personal 'imprint' and helps secure it.

Incentives

Labour: Almost entirely voluntary: some small support (approx 5% of the sample monitored) through Government during times of food scarcity with paid relief work.
Inputs: A (very) small amount of drought relief in recent years from Government (see above).
Credit: None.
Support to local institutions: Moderate support for SWC campaigns from local leaders (chiefs etc).
Long-term impact of incentives: There are no negative impacts as virtually no incentives have been used here.

Monitoring and evaluation

Monitored aspects	Methods and indicators
Biophysical	informal farmer observations only
Technical	informal farmer observations only
Economic/production	informal farmer observations only
Area treated	informal farmer observations only

Impacts of the approach

Changes as result of monitoring and evaluation: There have been no changes.
Improved soil and water management: Great: as part and parcel of the local tradition – for example contour ploughing is facilitated by the fact that the stone lines are on the contour, making this type of ploughing easier.
Adoption of the approach by other projects/land users: Only within this small pocket of Thohoyandou District (as far as known).
Sustainability: The *VhaVenda* have built terraces for generations so far, so no reason to think that things will change.

Concluding statements

Strengths and ➜ how to sustain/improve	**Weaknesses** and ➜ how to overcome
Traditional approaches have the potential to endure ➜ Acknowledgement and encouragement by the Government and/or NGOs will help this.	This tradition was largely unrecognised until recently: therefore an opportunity was lost to encourage people and help the approach spread ➜ Publicise widely and carry out farmer-to-farmer/community-to-community visits to further its spread and the spread of local SWC knowledge more generally.

Key reference(s): Critchley W and Netshikhovehla E (1998) Conventional views, changing paradigms and a tradition of soil conservation. *Development Southern Africa,* Vol 15, no 3, pp 449–469
Contact person(s): Rinda van der Merwe, Institute for Soil, Climate and Water, P/Bag x79, 0001 Pretoria, South Africa; rinda@arc.agric.za

left: *Fanya juu* terraces in a semi-arid area which have developed over time into benches: note well established grass strips along the bunds. (Hanspeter Liniger)
right: *Fanya juu* bund in maize field after harvest: napier grass strip on upper part of bund, and maize trash in ditch below. (Hanspeter Liniger)

Fanya juu terraces

Kenya

Terrace bund in association with a ditch, along the contour or on a gentle lateral gradient. Soil is thrown on the upper side of the ditch to form the bund, which is often stabilised by planting a fodder grass.

Fanya juu ('throw it upwards' in Kiswahili) terraces comprise embankments (bunds), which are constructed by digging ditches and heaping the soil on the upper sides to form the bunds. A small ledge or 'berm' is left between the ditch and the bund to prevent soil sliding back. In semi-arid areas, *fanya juu* terraces are normally constructed on the contour to hold rainfall where it falls, whereas in subhumid zones they are laterally graded to discharge excess runoff. Spacing is according to slope and soil depth (see technical drawing). For example, on a 15% slope with a moderately deep soil, the spacing is 12 m between structures and the vertical interval around 1.7 m. The typical dimensions for the ditches are 0.6 m deep and 0.6 m wide. The bund has a height of 0.4 m and a base width of 0.5–1 m. Construction by hand takes around 90 days per hectare on a typical 15% slope, though labour rates increase considerably on steeper hillsides because of closer spacing of structures.

The purpose of the *fanya juu* is to prevent loss of soil and water, and thereby to improve conditions for plant growth. The bund created is usually stabilised with strips of grass, often napier *(Pennisetum purpureum),* or makarikari *(Panicum coloratum var. makarikariensis)* in the drier zones. These grasses serve a further purpose, namely as fodder for livestock. As a supportive and supplementary agroforestry measure, fruit or multipurpose trees may be planted immediately above the embankment (eg citrus or *Grevillea robusta),* or in the ditch below in drier areas (eg bananas or pawpaws), where runoff tends to concentrate.

As a consequence of water and tillage erosion, sediment accumulates behind the bund, and in this way *fanya juu* terraces may eventually develop into slightly forward-sloping (or even level) bench terraces. Maintenance is important: the bunds need annual building-up from below, and the grass strips require trimming to keep them dense. *Fanya juu* terraces are associated with hand construction, and are well suited to small-scale farms where they have been used extensively in Kenya. They 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. *Fanya juu* terraces are spreading throughout Eastern African, and further afield also.

Location: Eastern Province, Kenya
Technology area: approx. 3,000 km^2
SWC measure: structural
Land use: cropland
Climate: subhumid, semi-arid
WOCAT database reference: QT KEN05
Related approach: Catchment approach, QA KEN01
Compiled by: Donald Thomas; Kithinji Mutunga and Joseph Mburu, Ministry of Agriculture, Kenya
Date: January 1999, updated June 2004

Editors' comments: The *fanya juu* terrace is literally the structural mainstay behind Kenya's success story of soil and water conservation on small-scale farms. While similar terraces – with the bund above the ditch – can be found in many parts of the world, they are especially popular in Kenya. The area of focus here is Machakos District in Kenya's Eastern Province.

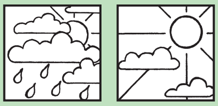
Classification

Land use problems

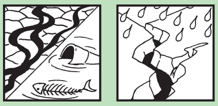
Low and erratic rainfall, soil erosion, surface sealing, water loss through runoff, low soil fertility as well as shortage of land and thus a need to conserve resources.

Land use | **Climate** | **Degradation** | **SWC measures**

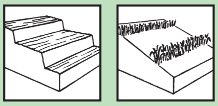
annual crops: mainly maize and beans



subhumid | semi-arid



water degradation: soil moisture problem | water erosion: loss of topsoil



structural: bunds | vegetative: grass strips (supp.), aligned trees (opt.)

Technical function/impact

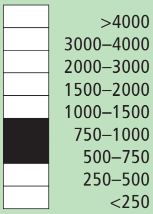
main:
- control of dispersed runoff
- increase/maintain soil water storage
- increase infiltration
- reduce slope length
- reduce slope angle

secondary: - none

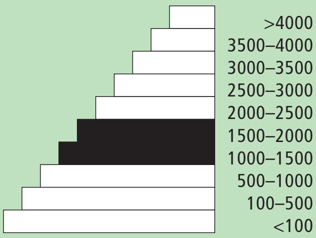
Environment

Natural environment

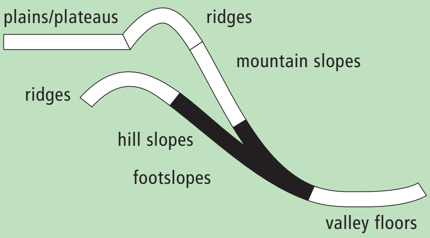
Average annual rainfall (mm)



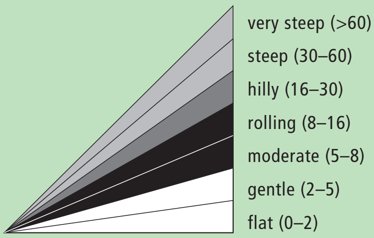
Altitude (m a.s.l.)



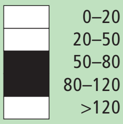
Landform



Slope (%)



Soil depth (cm)

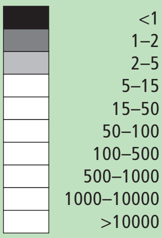


NB: soil properties before SWC

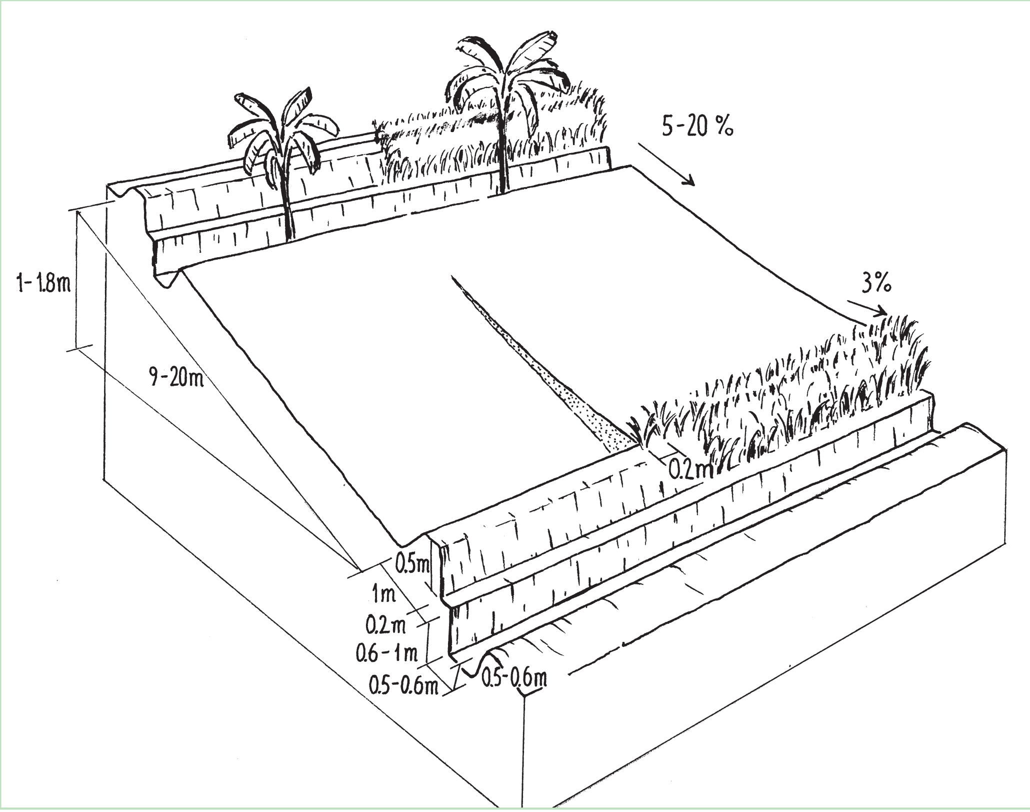
Growing period*: 180 days (March to August) and 150 days (October to February)
Soil fertility: mostly medium, partly low
Soil texture: medium (loam)
Surface stoniness: mainly no loose stone
Topsoil organic matter: medium (1–3%) or low (<1%)
Soil drainage: good or medium
Soil erodibility: medium
*note: this applies to the subhumid zones

Human environment

Cropland per household (ha)



Land use rights: individual
Land ownership: individual titled and individual not titled
Market orientation: subsistence and mixed (subsistence and commercial)
Level of technical knowledge required: field staff/extension worker: moderate, land user: low
Importance of off-farm income: 10–50% of all income: from local employment, trade and remittances – this depends very much on the location: the nearer a large town, the greater the importance of off-farm income



Technical drawing
Fanja juu terraces: newly constructed (left) and mature (right) with bananas planted below the bund and fodder grass on the riser: note leveling occurs over time (right).

Vertical interval and spacing for *fanya juu* terraces

Slope	Terrace spacing	
	Vertical Intervals	Horizontal Distance
(%)	(m)	(m)
5	1.00	20
10	1.35	14
15	1.73	12
20	1.80	9

Formula: Vertical Interval = (% slope / 4 + 2) x 0.3
max vertical interval = 1.8 m
(Source: Thomas 1997)

Implementation activities, inputs and costs

Establishment activities

1. Layout (alignment and spacing) of terraces either on the contour (dry areas) or on a slight grade (more humid areas) often using simple farmer operated 'line levels'.
2. Tilling soil to loosen for excavation (forked hoe, ox-drawn plough).
3. Digging ditch/trench and throwing the soil upwards to make the bund, using hoes and shovels.
4. Levelling and compacting bund.
5. Digging planting holes for grass.
6. Creating splits of planting materials (of vegetatively propagated species such as napier – *Pennisetum purpureum* and *P. makarikari – Panicum coloratum var. makarikariensis)*.
7. Manuring (of napier grass and fruit trees)
8. Planting grasses.

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

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (90 person days)	270	100%
Equipment		
- Animal traction (ox-drawn plough)	0	
- Tools (hoes, shovels, machete)	20	100%
Materials		
- Earth (275 m³)	0	
Agricultural		
- Compost/manure (1,000 kg)	10	100%
- Grass splits (20,000)	20	100%
TOTAL	**320**	**100%**

Maintenance/recurrent activities

1. Repairing breaches in structure where necessary.
2. Building up bund annually.
3. Cutting grass strips to keep low and non-competitive, and provide fodder for livestock.
4. Maintaining grass strips weed-free and dense.
5. Manuring of napier grass.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (10 person days)	30	100%
Equipment		
- Tools (hoes, shovels, machete)	5	100%
Agricultural		
- Compost/manure (250 kg)	3	100%
TOTAL	**38**	**100%**

Remarks: These calculations are based on a 15% slope (with 830 running metres of terraces per hectare) with typical dimensions and spacing: according to table and drawing above. In some areas tools are supplied free – but this is normally just for demonstration plots and is not included in this calculation.

Assessment

Acceptance/adoption

- 30% of those adopting have done so with incentives; the other 70% have done so without material incentives.
- The incentives referred to are tools – supplied by development programmes in some locations.
- There is some growing spontaneous adoption outside the area due to recognition of the benefits by farmers. This is especially so through women's groups. Within the area specified, Machakos District, almost all cropland is terraced.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	slightly negative	positive
maintenance/recurrent	positive	very positive

Impacts of the technology

Production and socio-economic benefits

+ +	crop yield increase
+ +	fodder production/quality increase
+ +	farm income increase
+	wood production increase

Production and socio-economic disadvantages

− −	increased labour constraints
− −	loss of land (cropping area)
−	increased input constraints
−	awkward to walk/carry burdens through the field

Socio-cultural benefits

+ +	improved knowledge SWC/erosion
+ +	community institution strengthening
+	national institution strengthening

Socio-cultural disadvantages

none

Ecological benefits

+ +	increase in soil moisture (semi-arid)
+ +	efficiency of excess water drainage (subhumid)
+ +	soil loss reduction

Ecological disadvantages

none

Off-site benefits

+ +	reduced downstream siltation
+	increased stream flow in dry season
+	reduced downstream flooding

Off-site disadvantages

none

Concluding statements

Strengths and ➜ how to sustain/improve

- Control runoff and soil loss ➜ Ensure good design, maintenance of structures and adapt design to local conditions.
- Storage of water in soil for crops ➜ Ditto.
- Maintenance of soil fertility ➜ Ditto.
- Increased value of land ➜ Ditto.

Weaknesses and ➜ how to overcome

- Loss of cropping area for terrace bund ➜ Site-specific implementation: only where *fanya juu* terraces are absolutely needed, ie agronomic (eg mulching, contour ploughing) and vegetative measures are not sufficient in retaining/diverting runoff.
- 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 and harvest for livestock feed.

Key reference(s): Thomas D (editor) (1997) *Soil and water conservation manual for Kenya.* Soil and Water Conservation Branch, Nairobi

Contact person(s): Donald Thomas, Kithinji Mutunga and Joseph Mburu, Ministry of Agriculture, Nairobi, Kenya; Kithinji.Mutunga@fao.org

Catchment approach

Kenya

left: Catchment planning in action: local farmers and extension workers discuss technical interventions based on a participatory map. (Hanspeter Liniger)
right: Construction of *fanya juu* terraces is heavy work. The name *fanya juu* means 'throw it up' in Swahili and refers to the first step of establishment: ditches are excavated and the soil is thrown upslope to form an embankment. (Hanspeter Lingier)

A focused approach to integrated land and water management, including soil and water conservation, where the active participation of the villagers – often organised through common interest groups – is central.

The catchment approach promotes sustainable land management systems by conservation of a defined area (so-called 'micro-environments') through the active participation of the communities living there. It was launched in Kenya in 1988 to achieve greater technical and social impact – and at a more rapid pace – than the previous focus on individual farmers. This case focuses on a single 'catchment' in a subhumid area of Central Kenya. The emphasis is on structural measures – especially *fanya juu* terraces – but vegetative systems are promoted also. Other activities are supported such as spring protection, improved crop and animal husbandry, agroforestry, fodder production, fish ponds and others. The specific objectives are to stimulate the implementation of a variety of SWC measures leading simultaneously to improved production.

Each approach area is defined by cultural/administrative boundaries rather than strict hydrological watersheds or catchments (as its name confusingly implies). A conservation committee is elected from amongst the focal community before problem identification begins. Technical staff from relevant government and non-government agencies (NGOs) are co-opted onto the committee. The approach then involves participatory methods of appraisal and planning of solutions. Land users, together with the co-opted subject matter specialists, pool their knowledge and resources. Common Interest Groups (CIGs) are formed, with the aim of self-help promotion of specific farm enterprises. Training is given to the members of the CIGs by the Ministry of Agriculture. The farmers carry out the majority of the work themselves: monetary or other tangible incentives are few.

The end result is the micro-environment (catchment area) conserved for improved production, and left in the hands of the community to maintain and sustain. The catchment approach was developed under the National Soil and Water Conservation Programme – supported by (Swedish) Sida – and continues to be promoted as the Focal Area Approach (FAA) under the National Agricultural and Livestock Extension Programme (NALEP), which is again supported by Sida. However, under NALEP there is less emphasis on soil and water conservation than the previous programme, and more focus on promotion of productive enterprises.

Location: Muranga District, Kenya
Approach area: 1 km^2
Land use: cropland
Climate: subhumid
WOCAT database reference: QA KEN01
Related technology: *Fanya juu* terraces, QT KEN05 and other technologies
Compiled by: James Njuki and Kithinji Mutunga, Ministry of Agriculture, Kenya
Date: August 2002; updated June 2004

Editors' comments: The catchment approach is linked to cultural or administrative boundaries, rather than to hydrological watersheds. This emphasis on social units and integrated land management is becoming more common worldwide. In Kenya the approach is constantly evolving and has recently been renamed the 'Focal Area Approach'.

Problem, objectives and constraints

Problem
- lack of tangible and assessable impact of SWC activities, technically or socially
- slow implementation of SWC
- underlying problems of poverty, declining soil fertility, soil erosion and fuelwood shortage

Objectives
Contribute to increased and sustained environmental conservation and improved agricultural production among communities, through participatory approaches to better land husbandry/SWC.

Constraints addressed

Major	Specification	Treatment
Financial	Lack of capital hinders farmers from investing in structures.	Group work encouraged.
Technical	Lack of conservation knowledge.	Training through courses and field days.

Participation and decision making

Target groups

Land users | SWC specialists/ extensionists | Teachers/ students | Planners | Politicians/ decision makers

Approach costs met by:

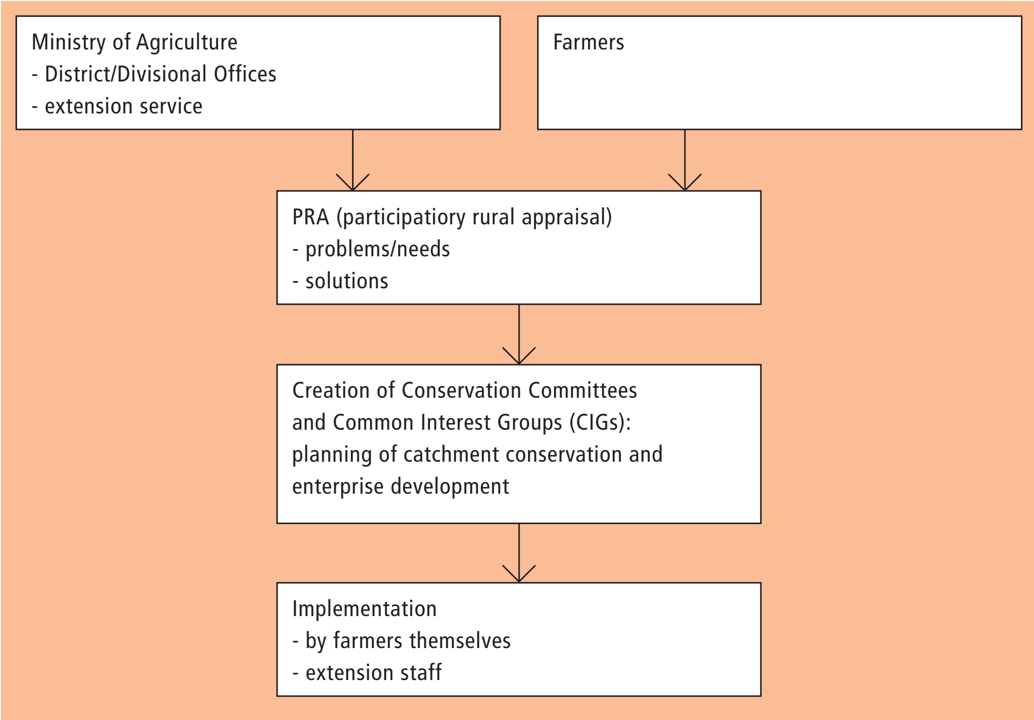
International agency	70%
National government	20%
Community/local	10%
	100%

Decisions on choice of the technology: Some by land users supported by SWC specialists, others initiated by SWC specialists.
Decisions on method of implementing the technology: Mainly by land users supported by SWC specialists.
Approach designed by: National specialists.

Community involvement

Phase	Involvement	Activities
Initiation	interactive	public meetings
Planning	interactive	public meetings/Participatory Rural Appraisal etc
Implementation	self-mobilisation	implemented by community members
Monitoring/evaluation	passive	interviews
Research	none	none

Differences between participation of men and women: Many joint activities but men and women still stick to some traditional gender-related agricultural activities. For example women often concentrate on food crops, men on cash crops.



Flow chart
Activities and actors within the Catchment approach.

Extension and promotion

Training: Training is provided: including layout of measures; agroforestry; energy conservation; food preservation – as well as for specific farm enterprises. Carried out mainly through farm visits by Ministry of Agriculture agents. Impact is good both for farmers and extension workers.
Extension: Extension comprises farm visits, field demonstrations and field days. The extension service is said to be 'quite adequate' to take this process forward into the future. Impact is 'good' for farmers and teachers, and 'excellent' for technicians.
Research: Specific problems are researched as they arise. A strong research-extension linkage is being built up. Monitoring of the progress of the overall programme also takes place.
Importance of land use rights: Most land is individually owned, so there is no problem in that situation. Where land is rented, land users need to be persuaded to co-operate.

Incentives

Labour: All labour is provided on a voluntary basis.
Inputs: Seedlings and tools used to be partially financed through the catchment approach, though now the common interest groups are required to solicit help and assistance as need arises.
Credit: This is not provided directly, though a savings and credit 'stakeholder kitty' revolving fund is being promoted and developed.
Support to local institutions: This is moderate, and takes the form of training.
Long-term impact of incentives: Incentives (other than education and motivation) have been used at very low levels, and this now relates to the past. There is therefore little or no carry over of negative attitudes regarding activities currently undertaken. On the contrary, because people have seen the positive effects of conservation, they are motivated to continue.

Monitoring and evaluation

Monitored aspects	Methods and indicators
Bio-physical	ad hoc observations of production
Technical	ad hoc measurements of physical achievements and costs
Socio-cultural	ad hoc observations of CIG function
Economic/production	none
Area treated	regular observations
No. of land users involved	regular surveys
Management of approach	ad hoc observations

Impacts of the approach

Changes as a result of monitoring and evaluation: There have been few changes, but there is some enhanced collaboration between agencies, and – more income generating activities have been identified and implemented through common interest groups for crop production, marketing and livestock.
Improved soil and water management: The improvements to SWC are moderate: these have been mainly through *fanya juu* and level bench terraces.
Adoption of the approach by other projects/land users: Spread has been limited to one Non-Governmental Organisation in this particular case study area.
Sustainability: Interventions are likely to continue and be maintained, but this depends on common interest groups continuing to function actively.

Concluding statements

Strengths and ➜ how to sustain/improve	**Weaknesses** and ➜ how to overcome
Genuine community participation has been achieved under this approach ➜ Continue with participatory training.	Technologies tend to be implemented uniformly, not site-specifically ➜ SWC practices should be matched to each particular situation, eg structural measures such as *fanya juu* terraces should be promoted only where necessary, that is where agronomic and vegetative measures do not provide sufficient protection.
There is evidence of 'ownership' by the community which implies a feeling that what has been achieved is due to communal efforts and belongs to them ➜ Further training is more effective when benefits are appreciated in this way.	As yet uncertainty about continuation in specific areas if direct support stops after only one year ➜ Don't abruptly terminate this support after one year: continue approach for at least two or three years in each catchment (approach area).
Much improved extension/training – research linkages have been forged ➜ Continue focussed training/strengthen research-extension linkage.	Too small an area (of the country) is currently covered by NALEP ➜ More staff required: more effective use of staff.
New and productive farm enterprises have been promoted under the catchment approach alongside better SWC ➜ Continue to introduce/support where appropriate through Common Interest Groups.	In many places there is a lack of availability of inputs ➜ Provide better credit facilities for CIGs/farmers generally.

Key reference(s): Yeraswarq A (1992) *The catchment approach to soil conservation in Kenya.* Regional Soil Conservation Unit (now: Regional Land Management Unit, RELMA, a project under ICRAF, The World Agroforestry Centre, Nairobi) ■ Pretty JN, Thompson J and Kiara JK (1995) Agricultural regeneration in Kenya: The catchment approach to soil and water conservation. *Ambio* 24, no 1, pp 7–15
Contact person(s): James Njuki: njukig@yahoo.com (Ministry of Agriculture, Nairobi, Kenya) ■ Kithinji Mutunga: Kithinji.Mutunga@fao.org


left: Establishment of small bench terraces, using hoes, in Chiang Mai Province, Thailand. The steep risers are compacted and a small drainage channel is formed on approximately every fourth terrace. (Samran Sombatpanit)
right: Well-established small bench terraces under horticultural crops, Chiang Mai Province, Thailand. (Samran Sombatpanit)

Small level bench terraces

Thailand – ขั้นบันไดดินขนาดเล็ก

Terraces with narrow beds, used for growing tea, coffee, and horticultural crops on hillsides cleared from forests.

The terraces described in this case study from northern Thailand are found on hilly slopes with deep soils. The climate is humid and tropical, with 1,700–2,000 mm of rainfall annually. The main aim of the terraces is to facilitate cultivation of tea or coffee on sloping land: erosion control is secondary. Coffee and tea, as well as flowers and vegetables, are good alternatives to opium poppies – which it is government policy to eradicate.

After clearing natural and secondary forests by slash and burn, terraces are aligned by eye – and constructed by hoe. The width of the bed is 1.0–1.5 m depending on slope, though there are no specific technical guidelines. The length of each terrace can be up to 25 m. Down the slope, after every 3–4 terraces, there are lateral drainage channels, approximately 20–30 cm wide and 10 cm deep. Situated at the foot of a riser, each channel has a gradient of 0.5% or less. Excess water – some of which cascades over the terrace risers, with some draining through the soil – is discharged through these channels, generally to natural waterways. The risers are steep, with a slope of above 100%, and without a defined lip.

Natural grass cover develops on the risers: this is cut back by hand hoe or machete, or completely removed. The grass is often burned. After harvest (of annual crops), the land is left until immediately before the next rainy season. The terraces at this stage are covered by weeds and grasses. Land is then tilled by hoe. The weeds and grasses are removed and heaped in piles outside the cropped area. They are not composted or used for mulching – and here an opportunity is missed. Where soil fertility is a problem, chemical fertilizers are used. Maintenance includes building up/repairing of risers and levelling of terrace beds as required.

The technology was pioneered, and continues to be practiced, by refugee immigrants from China looking for new areas to start farming. These immigrants first came in the 1950s, and cultivated simply through slash and burn techniques. During the 1970s they visited relatives in Taiwan and brought back the idea of small terraces. Originally they settled illegally, but eventually they were given official permission to stay. However, official title deeds to their land have not yet been allocated.

Location: Amphur Mae Fa Luang, Chiang Mai, Thailand
Technology area: 5 km^2
SWC measure: structural
Land use: forest land (before), cropland (after)
Climate: humid
WOCAT database reference: QT THA25
Related approach: not documented: immigrants own initiative
Compiled by: Prasong Suksom and Samran Sombatpanit, Bangkok, Thailand
Date: 2000, updated April 2004

Editors' comments: Small level bench terraces are found in various parts of the world. They are sometimes called 'step terraces' (or 'ladder terraces') because of their small size. They help in ease of cultivation as well as providing erosion control. This is a case study from northern Thailand, where immigrants introduced these terraces in the 1970s and 1980s.

Classification

Land use problems

- soil erosion on cultivated hillsides
- practical difficulties in tending tea, coffee, vegetables and flowers on sloping land: farming is much easier on levelled land

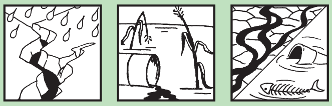
Land use

forest land (before) | perennial crops: tea and coffee (after) | annual crops: vegetables, flowers (after)

Climate

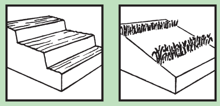
humid

Degradation



water erosion: loss of topsoil | chemical: soil fertility decline | water degradation: soil moisture problem (in dry periods)

SWC measures



structural: small bench terraces, drainage channels | vegetative: grass on risers (opt.)

Technical function/impact

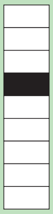
main:
- reduction of slope length
- reduction of slope angle
- control of dispersed runoff

secondary:
- control of concentrated runoff
- increase of infiltration
- increase/maintain water stored in soil

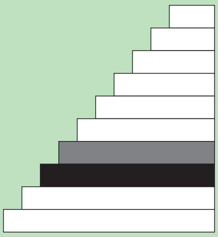
Environment

Natural environment

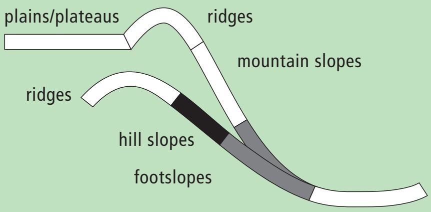
Average annual rainfall (mm)



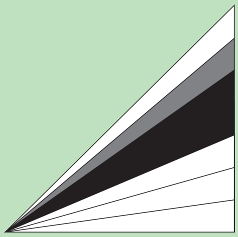
Altitude (m a.s.l.)



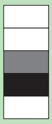
Landform



Slope (%)



Soil depth (cm)



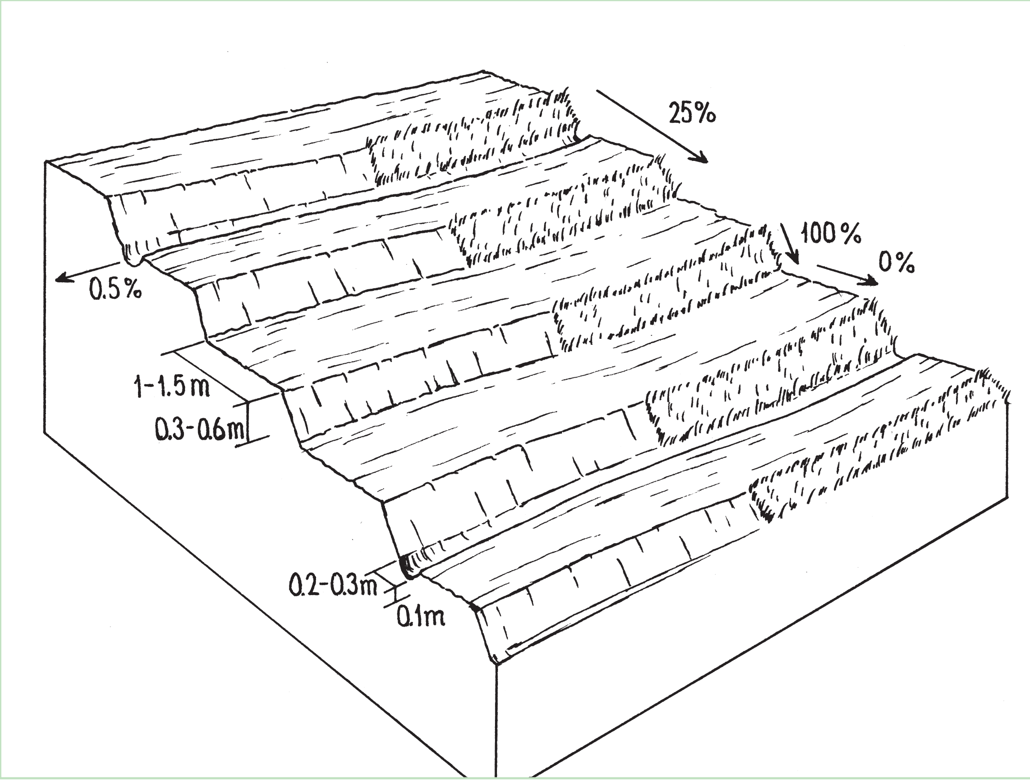
NB: soil properties before SWC

Growing season: 150 days (December to April)
Soil fertility: mostly low, partly very low
Soil texture: medium (loam)
Surface stoniness: mostly some loose stone, partly abundant loose stone
Topsoil organic matter: low (<1%)
Soil drainage: medium to high
Soil erodibility: medium

Human environment

Cropland per household (ha)

Land use rights: initially – illegal immigration and use of the forest land by slash and burn; over time – land has been allocated to individuals but without official title deeds
Land ownership: state (still officially forest land)
Market orientation: mainly commercial (market) through tea, coffee, vegetable and flower production, partly subsistence (self-supply)
Level of technical knowledge required: field staff/extension worker: moderate, land user: moderate
Importance of off-farm income: 10–50% of all income: farmers spend much time as farm labourers on other farms or in food processing factories – and some have jobs at construction sites, for example road building



Technical drawing
Layout of small level bench terraces. After every third or fourth terrace a lateral drainage channel is built. Later, protective grass cover is established on the risers (right).

Implementation activities, inputs and costs

Establishment activities

Clearing of forest is not included in the cost calculations.

1. Layout is simply by eye and best judgment.
2. Work begins on the lower part of the slope, and then progresses uphill.
3. Farmers cut into the hillside with hoes and drag the soil down to form the risers and level the terrace beds.
4. Risers are then stabilised/compacted by hoe.

Duration of establishment: one hectare of terraces can be constructed within a year by a family

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (125 person days)	270	100%
Equipment		
- Tools (hand hoe)	5	100%
TOTAL	**275**	**100%**

Maintenance/recurrent activities

1. Land is prepared through tillage by hoe.
2. Weeds and grasses are removed and piled outside the cropping area.
3. Risers are built up/repaired where necessary.
4. Terrace beds may need levelling.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (20 person days)	45	100%
TOTAL	**45**	**100%**

Remarks: This calculation is based on a typical slope of approximately 20%, with risers of 0.2 m in height and beds 1.0 m wide. Maintenance costs include basic land preparation (for annual crops) or weeding etc for perennial crops.

Assessment

Acceptance/adoption

- 450 land users (90% of families who have adopted) took up the technology without incentives. These farmers grow various kinds of cash crops.
- 50 land users (10% of families who have adopted) accepted the technology with incentives: Doi Tung Crop Growers Group was supported by a private marketing company with cash to construct the terraces. The incentive helped farmers improve their farming systems, control erosion and make land management more sustainable – all in order to increase the amount of produce available to the company.
- There is a little growing spontaneous adoption: for example in the Mae Salong area farmers accept these terraces increasingly, but fruit growers tend to prefer intermittent 'orchard terraces' – terraces spaced apart, with 5 m or more of undisturbed land in-between. The benches in this case are backward sloping.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	slightly positive	positive
maintenance/recurrent	slightly positive	positive

Impacts of the technology

Production and socio-economic benefits

+ +	ease of cultivation
+	crop yield increase
+	farm income increase

Production and socio-economic disadvantages

none

Socio-cultural benefits

+ +	improved knowledge SWC/erosion

Socio-cultural disadvantages

none

Ecological benefits

+ + +	soil loss reduction
+ +	increase in soil moisture during dry spells due to increased infiltration
+	increase in soil fertility

Ecological disadvantages

none

Other benefits

+ +	can walk and work easier in the cropped area

Other disadvantages

none

Off-site benefits

+ +	reduced downstream siltation
+	reduced transported sediments
+	reduced river pollution
+	reduced downstream flooding
+	increased stream flow in dry season

Off-site disadvantages

none

Concluding statements

Strengths and ➜ how to sustain/improve

A relatively cheap method of terracing which makes cultivation easier and provides erosion control ➜ Should be further promoted by extension agencies (in areas where cultivation is officially allowed). Allocation of official title deeds to land will speed up the adoption automatically.

Compared with normal bench terraces, construction does not bring infertile subsoil to the surface.

Weaknesses and ➜ how to overcome

Does not lend itself to mechanisation: the terrace beds are narrow and only suited to hand hoeing.

In this situation grasses and weeds are merely piled and burned rather than being used to improve soil fertility ➜ Teach farmers techniques of composting and/or mulching.

Key reference(s): none specified

Contact person(s): Prason Suksom, Samran Sombatpanit, 67/141 Amonphant 9, Soi Sena 1, Bangkok 10230, Thailand; phone/fax: ++66-25703641; sombatpanit@yahoo.com

left: Longan plantation on degraded hillsides. Bahia grass covers the terrace risers, the slopes between and partly the terrace beds to protect the soil from erosion. (Xinquan Huang)
right: The slope-separated orchard terraces are built along the contour. They help retain water and reduce soil erosion.
(Hanspeter Liniger)

Orchard terraces with bahia grass cover

China – 果园套种百喜草

Rehabilitation of degraded hillsides through the establishment of fruit trees on slope-separated orchard terraces, with bahia grass planted as protective groundcover.

In this case study orchards were established between 1991 and 1992 on degraded and unproductive hillsides (wasteland), with slopes of 12–45%. This was achieved by constructing level beds on the contour, mainly as continuous slope-separated orchard terraces, but in some cases as individual planting platforms. Terrace construction was generally undertaken by hand using hoes and shovels.

A typical terrace has a 4–5 m wide bed and a 1.0–1.5 m high riser. Commonly, a raised earth lip (0.3 m high) is constructed on the terrace edge to retain rainwater. The terrace riser walls are not protected. Even before terrace construction there was little topsoil and in some places the upper subsoil had been lost to erosion. The establishment of fruit trees (lychee, *Litchi chinensis* and longan, *Dimocarpus longan*) therefore required deep planting holes (1 m^3), filled with organic matter/manure, into which seedlings were planted. In subsequent years additional large quantities of organic matter/manure were applied in circular trenches to the side of the trees, succeeding trenches being gradually further away as the trees grew. Bahia grass *(Paspalum notatum)* was planted for SWC purposes as a cover crop, to stabilise terrace risers and to improve soil fertility. It has not been used for fodder in this case. The germination rate of bahia grass seeds is comparatively low; therefore instead of direct seeding, nurseries were established to produce seedlings. The bahia grass seedlings were transplanted onto the terrace risers and beds (leaving a space around each fruit tree) and on the hillside slopes between the terraces. The grass grew and spread quickly, restoring a protective vegetative cover following terrace construction.

The primary overall purpose of the technology was to rehabilitate degraded hillsides through the planting of economically valuable fruit trees. Terracing reduces soil erosion while retaining most of the rainwater. The application of organic matter creates improved rooting conditions, while restoring and maintaining soil fertility. The bahia grass further provides protective groundcover preventing splash erosion, increasing surface roughness, and thereby slowing down runoff velocity, while contributing to the restoration of the soil's biological, chemical and physical properties. Irrigation ditches dug along the terraces help to reduce erosion further. This project was planned by SWC specialists: around 6,000 families were allocated orchard plots and provided with seedlings at a subsidised price.

Location: Gu Shan small watershed, Yongchun County, Fujian Province, Peoples' Republic of China
Technology area: 55 km^2
SWC measure: structural, vegetative and agronomic
Land use: wasteland (before), cropland (after)
Climate: humid
Wocat database reference: QT CHN21
Related approach: not documented
Compiled by: Liu Zhengming, Soil Conservation Office, Yongchun County, Fujian, PR China
Date: June 2001, updated August 2004

Editors' comments: In China, large areas of degraded hillsides have been brought back into production by constructing terraces on which fruit trees are planted. In this example the technology has been further improved through planting of bahia grass, as a groundcover, to restore the structure and increase the soil organic matter. On a much smaller scale a case of degraded land conversion is presented from Tajikistan.

Classification

Land use problems

Degraded and unproductive hillside slopes (wasteland), with low and declining soil fertility, subject to severe soil erosion (sheet, rill, gully and mass movement) during periods of heavy and prolonged rainfall.

Land use

wasteland (before)

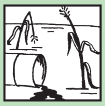
fruit trees: lychee and longan (after)

Climate

humid

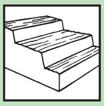
Degradation

water erosion: loss of topsoil, gully, mass movement

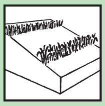


chemical: fertility decline

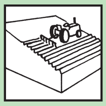
SWC measures



structural: slope-separated terraces (forward sloping)



vegetative: dispersed grass, aligned trees



agronomic: organic matter application

Technical function/impact

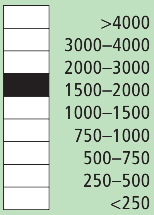
main:
- reduction of slope angle
- control of dispersed runoff
- control of raindrop splash
- improvement of ground cover
- increase in organic matter
- increase in soil fertility

secondary:
- increase of surface roughness
- improvement of soil structure
- increase/maintain water stored in the soil

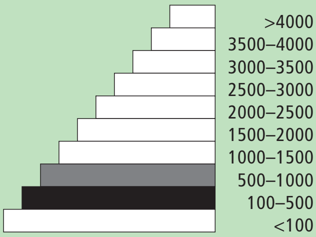
Environment

Natural environment

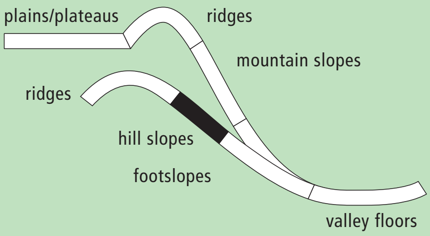
Average annual rainfall (mm)



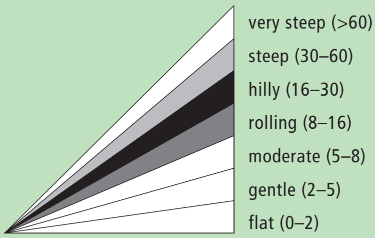
Altitude (m a.s.l.)



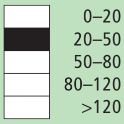
Landform



Slope (%)



Soil depth (cm)

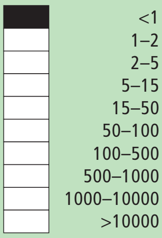


NB: soil properties before SWC

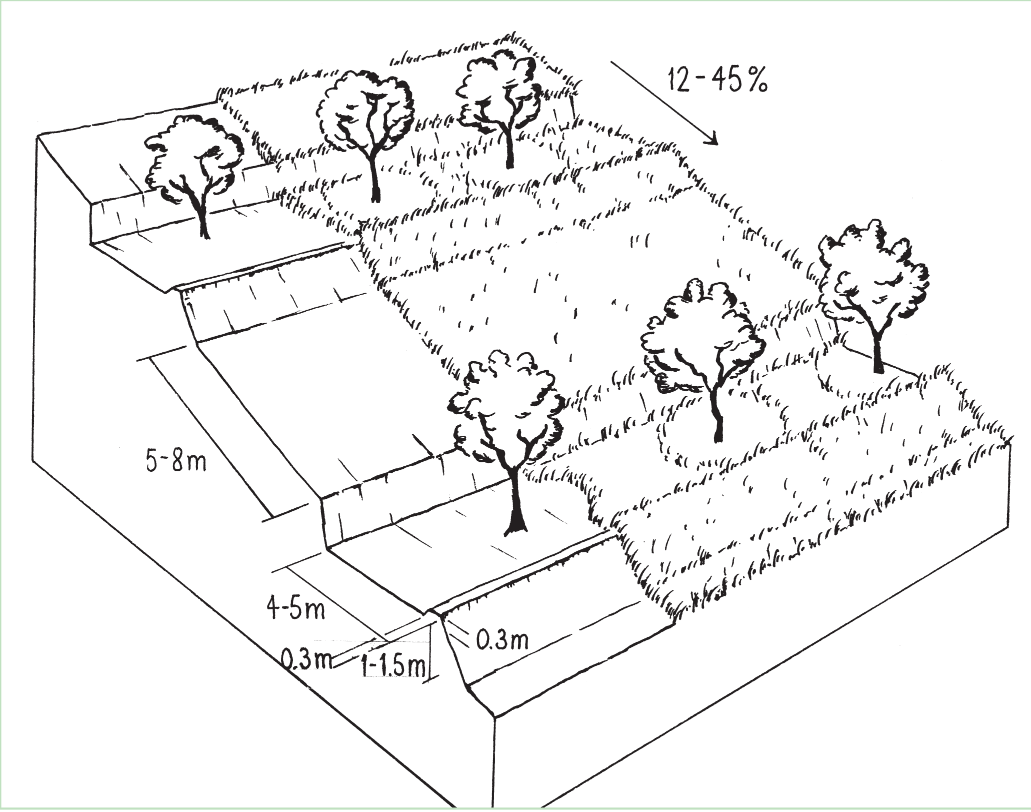
Growing season: 365 days (main period: May to September)
Soil fertility: medium
Soil texture: mostly coarse (sandy), partly medium (loam) and fine (clay)
Surface stoniness: no loose stone
Topsoil organic matter: mostly low (<1%), partly medium (1–3%)
Soil drainage: medium
Soil erodibility: mostly high, partly medium

Human environment

Cropland per household (ha)



Land use rights: leased (under the individual household responsibility system)
Land ownership: state
Market orientation: commercial (market)
Level of technical knowledge required: field staff/extension worker: high, land user: moderate
Importance of off-farm income: 10–50% of all income: off-farm income is mainly from factory labour



Technical drawing
Fruit trees on slope-separated terraces with a spacing of 5–8 metres between (dependent on slope). Terrace risers and beds are protected by the fast spreading bahia grass (right): note a grass-free space is maintained around each tree.

Implementation activities, inputs and costs

Establishment activities

1. Terraces were constructed by hand (during winter). Soil was excavated from the upper portion of the terrace and used to build up the lower portion behind the terrace riser wall to create a level platform (bed). Part of the excavated soil was used to build a terrace lip.
2. On each terrace one line of fruit trees was established. Deep planting holes (1 m^3) were dug by hand and filled with organic matter/manure. Fruit tree seedlings were planted (in spring). Spacing between trees was approx. 6 m.
3. Bahia grass was transplanted onto the terraced hillside (in spring).

Duration of establishment: 2 years

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (350 person days)	840	100%
Equipment		
- Tools (hoe, shovel)	0	
Materials		
- Earth	0	
Agricultural		
- Fruit tree seedlings (300)	350	60%
- Bahia transplants (60,000)	435	0%
- Fertilizers (1,000 kg)	145	100%
- Compost/manure (15,000 kg)	70	100%
TOTAL	**1,840**	**70%**

Maintenance/recurrent activities

1. Repairing terraces damaged by storms.
2. Digging trenches by the side of the fruit trees and filling with organic matter/manure.
3. Filling any gaps in the bahia grass.
4. In the first 1–2 years maintenance also involves replacing any fruit tree seedlings that do not survive.
5. Subsequently as the trees grow they require regular pruning, fertilization and pest control.
6. Weeding around the trees.

All maintenance activities through hand labour with simple tools.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (60 person days)	144	100%
Equipment		
- Tools (hoe, shovel)	0	
Agricultural		
- Fruit tree seedlings (30)	36	100%
- Bahia transplants (8,000)	58	100%
- Fertilizers (700 kg)	84	100%
- Biocides (20 kg)	10	100%
- Compost/manure (9,000 kg)	44	100%
TOTAL	**376**	**100%**

Remarks: For establishment: 200 person days for terrace construction, 100 for digging pits and planting trees, 50 for transplanting bahia grass. For maintenance: 15 person days for terrace maintenance, 40 for digging organic matter trenches, 5 for bahia grass gap filling. The SWC department produces bahia transplants in nurseries; these are then distributed to the farmers.

Assessment

Acceptance/adoption

All land users in the case study watershed applied the technology. 88% of them (5,755 families) accepted the technology with incentives. This project was planned by SWC specialists. Farmers were then allocated orchard plots. The government provided the fruit tree seedlings at 60% of the cost and the bahia transplants for free. Land users had to come up with 70% of the total costs (mainly their own labour). 12% of the land users (784 families) did not require incentives. There is a slow spontaneous adoption of the technology, based on the fact that bahia grass is remarkably helpful in controlling soil erosion.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	slightly positive	very positive
maintenance/recurrent	slightly positive	very positive

Impacts of the technology

Production and socio-economic benefits

- +++ farm income increase
- ++ crop yield increase (fruit)

Production and socio-economic disadvantages

- − − − increased input constraints (organic matter/manure)
- − − increased labour constraints

Socio-cultural benefits

- +++ improved knowledge SWC/erosion
- ++ national institution strengthening
- ++ community institution strengthening

Socio-cultural disadvantages

none

Ecological benefits

- +++ soil cover improvement
- +++ soil loss reduction
- +++ rainwater retention
- +++ decrease erosion due to raindrop splash
- ++ increase in soil fertility, organic matter content
- ++ increase in soil moisture

Ecological disadvantages

- − − competition between fruit trees and bahia grass for water and nutrients

Off-site benefits

- ++ reduced downstream siltation
- + increased stream flow in dry season
- + reduced downstream flooding

Off-site disadvantages

none

Concluding statements

Strengths and ➜ how to sustain/improve

An increase in vegetative cover reduces erosion, improves the ecological environment, increases soil fertility and organic matter content, improves water retention and thereby raises fruit tree yields ➜ Control weeds and fertilize well.

The combination of structural and vegetative measures has a quick impact on reducing soil erosion and preventing mass movement on hillside slopes ➜ Increase the vegetative cover and improve soil properties through the addition of plenty of organic matter/manure.

Improved land management practices bringing back degraded wasteland sites into economic production ➜ Demonstration and extension while also improving the enabling legislative environment.

Weaknesses and ➜ how to overcome

Orchard development can extend too far up the slope, onto steep mountain sides ➜ Reserve the upper slopes for forest, and restrict orchards to the lower slopes.

Potential competition for water and nutrients between the bahia grass and the fruit trees ➜ Clean weed (bahia grass included) in the area immediately around the fruit tree.

Increase in farm income becomes very positive only after fruit trees start producing ➜ Consider replacing bahia grass with a more palatable perennial fodder plant to improve farm income in the short term.

Low germination rate of bahia seeds ➜ Expand experimental studies (seed treatments, cuttings, taking splits, etc).

Key reference(s): none

Contact person(s): Liu Zhengming, Soil Conservation Office of Yongchun County, No. 99 Liuan Road, Yongchun County 362600, Fujian Province, People's Republic of China ▪ Nie Bijuan, Xuezhen Yang, Fujian Soil and Water Conservation Experimental Station, No. 6 Tong Pan Road, 350003 Fuzhou, People's Republic of China; fjswc@fjstbc.gov.cn ▪ Zhangou Bai, ISRIC, PO Box 353, 6700 AJ Wageningen, The Netherlands; baizhanguo9910@hotmail.com, zhanguo.bai@wur.nl

Zhuanglang loess terraces

China – 庄浪水平梯田

left: Aerial view over Zhuanlang county where 90% of the hillsides are covered with terraces. Reducing runoff and erosion, maintaining soil fertility and making farming operations easier are key for rainfed agriculture in this semi-arid environment. (He Yu)
right: A 4 m high terrace riser, where the lower part is vertical and bare – demonstrating the stability of the loess soil at this depth. The upper part is sloping, and stabilised with grasses, bushes and trees. (Hanspeter Liniger)

Level bench terraces on the Loess Plateau, converting eroded and degraded sloping land into a series of steps suitable for cultivation.

The Loess Plateau in north-central China is characterised by very deep loess parent material (up to 200 m), that is highly erodible and the source of most of the sediment in the lower reaches of the Yellow River.

The plateau is highly dissected by deep gullied valleys and gorges. The steep slopes, occupying 30–40% of the plateau area, have been heavily degraded by severe top soil and gully erosion. Over the whole Loess Plateau approximately 73,350 km^2 of these erosion prone slopes have been conserved by terraces.

In the case study area (Zhuanglang County) the land that is suitable for terracing has been completely covered. The total terraced area is 1,088 km^2, accounting for 90% of the hillsides. The terraces were constructed manually, starting at the bottom of the slopes and proceeding from valley to the ridge. The terraces comprise a riser of earth, with vertical or steeply sloping sides and an approximately flat bed (level bench). Depending on farmers preference some terrace beds are edged by a raised lip (a small earth ridge) which retains rainwater, others remain without lip. The semi-arid climate does not require a drainage system. For typical hillside terraces on slopes of 25–35% the bed width is about 3.5–5 metres with a 1–2 metre riser, involving moving about 2,000–2,500 cubic metres of soil (see table of technical specifications). Generally the risers are not specifically protected, but there may be some natural grasses growing on the upper part. The lower part of the riser is cut vertically into the original soil surface, and has no grass cover, being dry and compact. However it is not erosion-prone since it has a stable structure.

Over most of the Loess Plateau, the soil is very deep and therefore well suited to terrace construction. In addition to downstream benefits, the purpose is to create a better environment for crop production through improved moisture conservation, and improved ease of farming operations. In an average rainfall year, crop yields on terraced land are more than three times higher than they used to be on unterraced, sloping land. The implication is that terrace construction – though labour intensive – pays back in only three to four years when combined with agronomic improvements (such as applying farm yard manure and planting green manure). Some farmers try to make the best use of the upper part of terrace risers by planting cash trees or forage crops – including *Hippophae rhamnoides* (seabuckthorn), *Caragana korshinskii* (peashrub) and some leguminous grass. This is locally termed 'terrace bund economy'. The plants stabilise the risers and at the same time provides extra benefits.

Location: Zhuanglang County, Gansu Province (Loess Plateau Region), PR China
Technology area: 1,080 km^2
SWC measure: structural
Land use: cropland
Climate: semi-arid
WOCAT database reference: QT CHN45
Related approach: Terrace approach, QA CHN45
Compiled by: Wang Yaolin, Gansu GEF/OP12 Project Office, Lanzhou, PR China; Wen Meili, Department of Resources and Environmental Sciences, Beijing Normal University, PR China; Bai Zhanguo, World Soil Information, Wageningen, Netherlands.
Date: March 2006

Editors' comments: China has a history of terrace construction dating back thousands of years – for both rainfed crops and paddy rice. In the period since the 1950s, the Loess Plateau region has been extensively terraced to reduce off-site sediment levels in the Yellow River, and to create better conditions for crop production. The results are effective and spectacular covering an area of over 73,000 km^2.

Classification

Land use problems

Cultivation of unterraced hillside slopes leads to serious soil erosion and problems of downstream sedimentation. Loss of topsoil and rainwater in uncontrolled runoff has contributed to declining crop yields.

Land use | **Climate** | **Degradation** | **SWC measures**

- annual crops: wheat, maize, potato, peas, millet, sorghum
- fruit trees: apple, pear and peach; walnut
- semi-arid
- water erosion: loss of topsoil, gully
- chemical: fertility decline
- water degradation: soil moisture problem
- off-site: downstream siltation of the Yellow River
- structural: level bench terraces

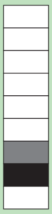
Technical function/impact

main:
- reduction of slope angle/slope length
- retains runoff in-situ
- increases infiltration
- water harvesting/increases water stored in soil
- reduces downstream flooding and sediment deposition (a national/regional concern)

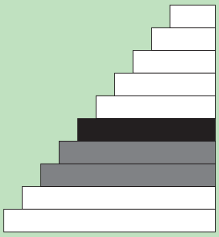
Environment

Natural environment

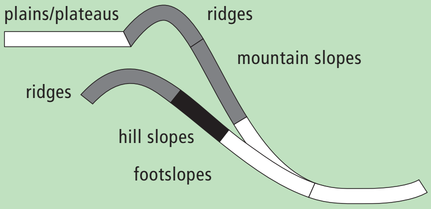
Average annual rainfall (mm)



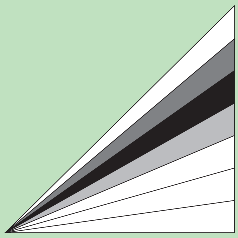
Altitude (m a.s.l.)



Landform



Slope (%)



Soil depth (cm)

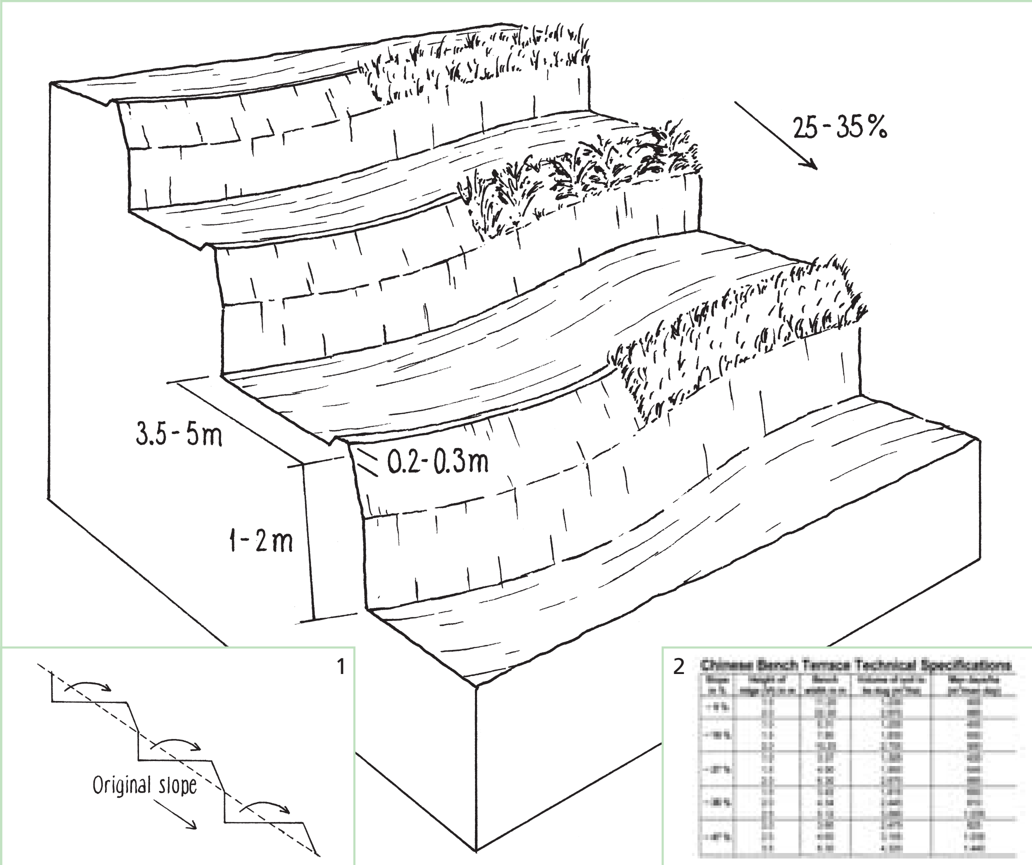
NB: soil properties before SWC

Growing season: 160 days (May to September)
Soil fertility: medium to low
Soil texture: medium (loam)
Surface stoniness: no loose stone
Topsoil organic matter: low (<1%)
Soil drainage: good
Soil erodibility: very high

Human environment

Cropland per household (ha)

Land use rights: cropland: individual, subject to reallocation by authorities; forest land: communal (organised)
Land ownership: state
Market orientation: mixed (subsistence/commercial): cash crop (peas) and food crops (potatoes, wheat, maize, millet, sorghum)
Level of technical knowledge required: field staff/extension worker: high, land user: low
Importance of off-farm income: 10–50% of all income: working in construction, temporary employments



Technical drawing
Layout of level bench terraces on the Loess Plateau: the lower, vertical section is cut into the compacted soil. Natural grasses – or planted grass/ shrub species – protect the more erodible and less steep upper part of the riser.
The low 'lip' is optional.
Insert 1: Method of construction: the volume of soil to be excavated from the hillslope (see table below) equals the volume 'returned' to form the outer part of the terrace.
Insert 2: Chinese Bench Terrace Technical Specifications.

Implementation activities, inputs and costs

Establishment activities

1. Contour lines are marked out using pegs to show the location for the base of each terrace wall (after harvest in September).
2. A trench is dug out along the marked line to serve as the foundation for the terrace wall.
3. The topsoil between the pegged lines is removed and put aside.
4. Alternative ways of constructing the wall/riser and bed: (a) Subsoil is placed in the trench and compacted to form the base of the terrace wall. Subsoil excavated from the upper portion of the terrace is then placed behind the wall. The wall is progressively built up (by compacting earth) with the excavated soil placed behind until a level terrace has been formed. (b) Terraces may be built without constructing an initial wall: soil excavated from the upper part of the (eventual) terrace bed is simply moved downslope to level the bed, while soil from the terrace below is thrown upwards to help build up the wall/ riser. This is done progressively.
5. The wall is raised slightly higher to form a lip to retain rainwater on the terrace bed (optional).
6. The set-aside topsoil is then spread over the terrace surface.

Duration of establishment: 3–4 months

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour		
- Construction: 600 m person days	1,200	97%
- Survey	60	0%
Equipment		
- Shovel, two-wheel carts	30	100%
Materials		
- Earth (2,000–2,500 m^3)	0	
TOTAL	**1,290**	**93%**

Terrace construction (steps 2–6) usually begins just after harvest (in October) and continues over the winter months, being completed before the start of the next cropping season (January).Terraces were constructed entirely by hand, using shovels and 2-wheel carts to move soil from the back of the terrace to the front.

Maintenance/recurrent activities

1. Repairing any collapses in the terrace wall – often caused by heavy storms.
2. Re-levelling of the terraces where necessary.

This work is usually done by hand, using shovels and two-wheel carts.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (12 person days)	25	97%
Equipment		
- Tools (shovel, two-wheel carts)	10	100%
Materials		
- Earth (1–2 m^3)	0	
TOTAL	**35**	**98%**

Remarks: Calculations above are based on the following situation: slopes of about 25–35%, bed width of 3.5–6 m, and a 1–2 m high riser, involving moving about 2,000–2,500 cubic metres of soil. Note: these calculations are based on several years experience in Zhuanglang: that is why they differ in some respects from the standardised table above.

Assessment

Acceptance/adoption

- The technology was implemented on a large scale through government initiated mass campaigns.
- The technology has generally not spontaneously spread beyond the areas developed through government intervention: the area that is suitable for terracing has been covered.
- Uncertainty over future land use rights limits the willingness of households to meet the costs of terrace construction.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	negative	very positive
maintenance/recurrent	positive	very positive

Impacts of the technology

Production and socio-economic benefits

+++ crop yield increase (wheat: from 750–900 kg/ha before terracing to 3,000–3,750 kg/ha within 3–4 years: includes agronomic improvements)
+++ easier field operation
+ farm income increase

Production and socio-economic disadvantages

− reduced production (first year only)

Socio-cultural benefits

++ community institution strengthening
++ improved knowledge SWC/erosion

Socio-cultural disadvantages

none

Ecological benefits

+++ soil loss reduction
+++ increase in soil moisture

Ecological disadvantages

none

Off-site benefits

+++ reduced downstream siltation
++ reduced downstream flooding
++ reduced transported sediments

Off-site disadvantages

− reduced river flows

Concluding statements

Strengths and ➜ how to sustain/improve

Reduced erosion, reduced loss of rainwater through runoff (increased in water use efficiency) and reduced fertility loss due to reduced slope angle and length ➜ Maintain the quality of terrace construction.

Increased soil moisture ➜ Construct/maintain a terrace lip to retain rainwater on the terrace.

Increased crop production (before 1983 hunger and starvation in the area) ➜ Combine with improved crop husbandry.

Easier field operations: the level terrace is easier to cultivate than the original hill slope.

Benefits pay back the investments after only three to four years; approx. calculated on the basis of US$ 450 extra income per annum per hectare (for wheat) vs US$ 1,200 labour investment per hectare.

Improvements of farmers' living standard and decline in poverty stricken population.

Diversification of production: terracing makes cultivation of new cash crops possible: flax (for linseed oil), pears, apples, apricots, water melon; all these give high returns and thus make terrace construction profitable.

Weaknesses and ➜ how to overcome

Decrease in production in first year ➜ Apply manure and fertilizer.

Terrace riser can be destroyed by storms – and, sometimes, rodent holes ➜ Good and timely repair and maintenance: planting upper parts of the risers with grass, bushes or even trees help to stabilise the risers but can lead to competition with the crop for water.

High cost/input for construction and establishment ➜ Given the high erodibility of the soil and the steep slopes there is no real alternatives to labour-intensive terracing.

High loss of soil moisture due to evaporation from the soil surface. Wind erosion due to tillage ➜ Protect soil surface for example by conservation agriculture – comprising permanent cover, crop rotation, reduced tillage – could be supplementary agronomic and vegetative options.

Key reference(s): *Terraces In China.* Published By Ministry Of Water Resources Beijing, PRC. 1989 ■ *Conservancy engineering budgetary estimate ration.* Issued by Ministry of water resources of PRC, Published by Yellow-river water conservancy publishing company, Zhengzhou, PRC, 2003 ■ *A Great Cause for Centuries – 50 Years in Water and Soil Conservation in China.* Published by Department of Soil and Water Conservation, Ministry of Water Resources Beijing, PRC, 2000 ■ Additional references: Dongyinglin, Changpiguang, Wangzhihua 1990: Discussion on several questions on increasing production of the terrace with two banks; *Soil and Water Conservation Science and Technology in Shanxi.* No. 1, p 36–37 ■ Liumingquan, Zhangaiqin, Liyouhua 1992. Pattern engineering of reconstruction the slope cropland; *Soil and Water Conservation Science and Technology in Shanxi,* No. 3, p 18–21 ■ Liangqichun, Changfushuang, Liming 2001. A study on drawing up budgetary estimate quota of terraced field; *Bulletin of Soil and Water Conservation,* Vol. 21, No. 5, p 41–44 ■ Lixuelian, Qiaojiping 1998. Synthetic technology of fertilizing and improving production on the new terrace. Terraces in China. *Soil and Water Conservation Science and Technology in Shanxi,* No. 3, p 13–14

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left: Mass mobilisation showing people from several villages helping each other. Initially, farmers were not paid but from the 1980s onwards farmers received cash and other support for their work. (Photo: from 'Terraces in China' Ministry of Agriculture)
right: Construction of terrace risers – following instructions given by a specialist. (Photo: from 'Terraces in China' Ministry of Agriculture)

Terrace approach

China – 庄浪梯田

Highly organised campaign to assist land users in creating terraces: support and planning from national down to local level

Before 1964, the slopes on China's Loess Plateau were cultivated up and down by machinery. Consequently soil and water were lost at high rates, and fertility and yields declined. Accessibility to cultivated land became more and more difficult due to dissection by gullies. The first terraces were established by self-mobilisation of the local land users. However there was no standard design. Furthermore, as the individual plots were very small and scattered all over the village land, terracing needed better coordination. Between 1964 and 1978, the local government at the county level took the initiative of organising farmers and planning terrace implementation according to specific technical design on a larger scale. At that time the land was still communally managed by production brigades. Through mass mobilisation campaigns people from several villages were organised to collectively terrace the land – village by village – covering around 2,000 hectares each year. Labour was unpaid.

The Yellow River Conservancy Commission (YRCC) came into being in 1948 – and the Upper and Middle Yellow River Bureau in 1977. This gave greater impetus to the implementation of SWC in the Loess Plateau. After 1978, land use rights were allocated to individuals (though official ownership was still vested in the state). SWC specialists and county level SWC bureaus started to work with groups of farmers who had land use rights within a given area. Survey and design were carried out. The farmers organised themselves, consolidated the parcels of land, and then after the conservation work was done they redistributed the terraced fields.

In the 1980s the government started to financially support land users involved in SWC projects. Subsidies ranged from (approx.) US$* 20/ha in projects at county level, to US$* 55/ha for national projects (eg through the Yellow River Commission), and up to US$* 935/ha when World Bank projects were involved – as in the recent past. Implements were provided by the farmers themselves. Then, in 1988 a nationwide project in SWC – which originally was proposed at county level – was approved by the national government. Furthermore, in 1991 a national law on SWC came into force. Protection of the Yellow River and associated dams became a priority at regional and national levels. In total, within Zhuanglang County, 60 SWC specialists/extensionists cover an area of 1,550 km^2, and most of the terraces were built with low levels of subsidies. Annual plans about implementation of new SWC measures were made during summer. Small areas were planned at village or township level, whereas bigger areas (> 7 hectares) were designed at county level. Implementation then took place during winter. Terracing was implemented first where access was easiest and closest to settlements, and only later, further away.

* exchange rate: 1 US$ = 8 Chinese Yuan (May 2006)

Location: Zhuanlang County, Gansu Province, Loess Plateau Region, Northern China, People's Republic of China
Approach area: 1,555 km^2
Land use: cropland
Climate: semi-arid
WOCAT database reference: QA CHN45
Related technology: Zhuanglang loess terraces, QT CHN45
Compiled by: Wang Yaolin, Gansu GEF/OP12 Project Office, Lanzhou, PR China; Wen Meili, Department of Resources and Environmental Sciences, Beijing Normal University, P R China; Bai Zhanguo, World Soil Information, Wageningen, Netherlands.
Date: May 2002, updated October 2005

Editors' comments: The terraces covering China's Loess Plateau are one of the most outstanding SWC achievements in the world. The evolution of this remarkable feat is worthy of note. It is an example of local initiative developing into an organised, structured campaign. The implementation process, through local government initially, and then taken up at national level, was supported by legislation and mass mobilisation.

Problem, objectives and constraints

Problem

- lack of organisation, capital and technical knowledge in farmer communities to counter the underlying problems of water loss, soil loss, fertility decline and downstream effects on the Yellow River (floods and sediment) at catchment level
- absence or poor maintenance of erosion control measures

Objectives

- water conservation (this is a semi-arid area)
- soil conservation: reduce soil loss on the sloping and erosion-prone land of loess plateau
- enhancing soil fertility, and consequently production
- improve people's living conditions

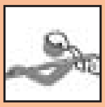
These primary objectives were to be achieved by building level bench terraces on a large scale through a structured and organised campaign. Finally at the national level, a fourth aim was added: the protection of the Yellow river (avoiding floods and reducing the sediment load).

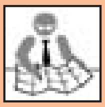
Constraints addressed

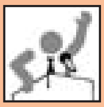
Legal	Land users leased the land from the state and land users' rights were insecure in the long term. Investments in SWC were not encouraged.	National government persuaded land users to implement terraces by 'selling' the benefits (increased yield and easier workability of the land). After 1978, individual user rights motivated farmers to invest in SWC.
Technical	Poor knowledge of how to reduce water loss, soil loss and fertility loss. Technical solutions were needed at the catchment level, involving the whole population.	Enhanced guidance by SWC specialists.
Financial	Initially farmers were not paid and as they had no immediate benefit from, or security over, the use of the land. The investment in construction was a heavy burden on poor farmers.	After 1988, labour inputs by farmers started to be partly covered by subsidies provided by local and national government.

Participation and decision making

Target groups


Land users


Planners


Politicians/ decision makers

Approach costs met by:

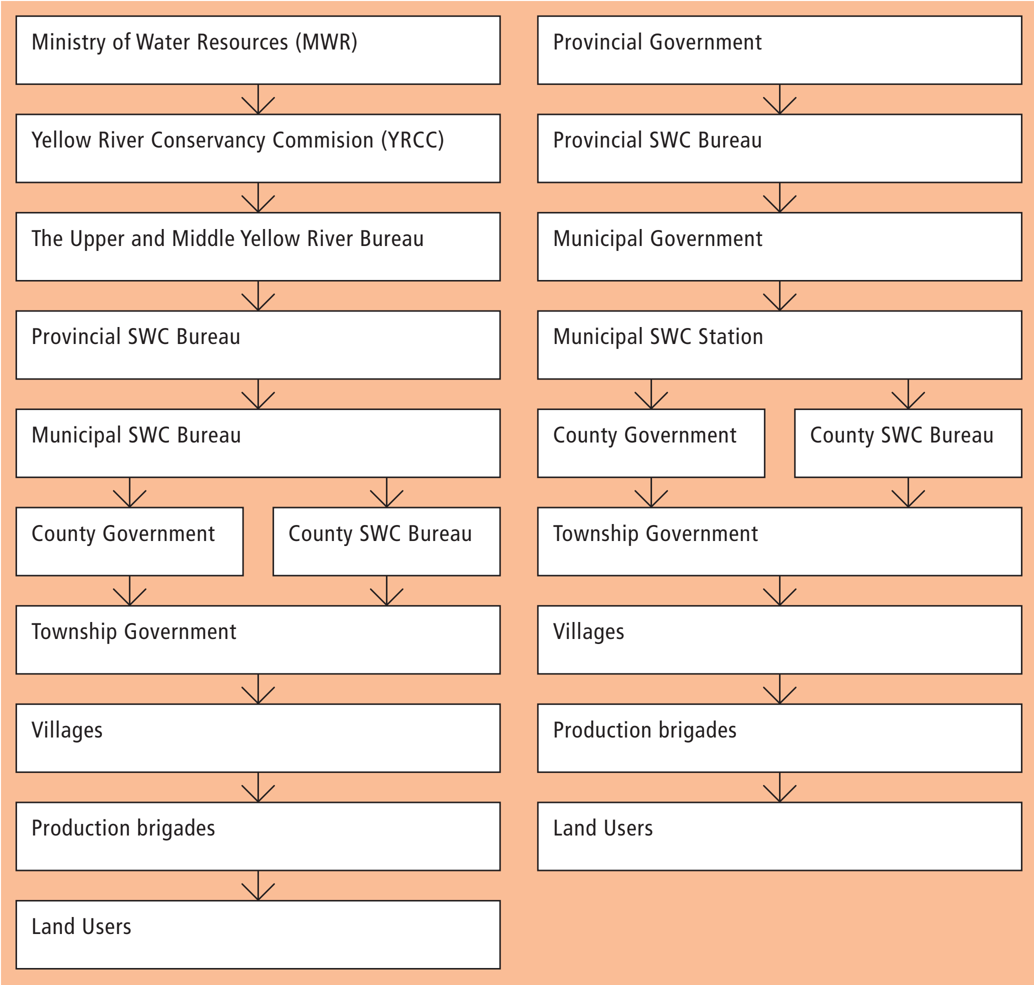
Government	10%
Community/local	90%
	100%

Decisions on choice of the technology: Mainly made by SWC specialists with consultation of land users.
Decisions on method of implementing the technology: Decisions are made by politicians/SWC specialists; land users are consulted in the planning phase (experienced farmers may be involved initially).
Approach designed by: County level and national specialists.

Community involvement

Phase	Involvement	Activities
Initiation	self-mobilisation/interactive	Land users started implementing terraces but SWC specialists at the country level assisted in designing standards for terrace construction and township governments and production brigades organised whole villages and watersheds
Planning	passive	Being consulted in the planning phase. Experienced peasants may be involved in introducing the local situation.
Implementation	interactive	Major organisation done through the SWC bureau specialists with the village organisation including land users. Land users were actively involved in implementation.
Monitoring/evaluation	none	Reporting. No participation of land users
Research	none	On-station research. No participation of land users

Differences in participation of men and women: For manual labour, men can do more work and they have greater technical knowledge and skills related to terrace construction than women.



Organogram
Terrace construction supported by projects from MWR, YRCC and international organisations (left) and terrace construction supported by provincial funds (right).

Extension and promotion

Training: Until 1978 the 'pyramid system' was used: the county level trained the township level, which trained the village level, which in turn trained the production brigades/farmers, who then trained other production brigades and farmers.
Training was on-the-job, focussing on design and construction of terraces on sloping land (provided by the county level specialists and by land users from villages where implementation was already carried out; at a later stage national trainers were involved as well). With respect to courses, demonstration areas, and farm visits – these were effective for all target groups.
Extension: The pyramid system is also used for extension. At each government level (at the county, district and provincial levels) there is a SWC division which is in charge of SWC activities including extension (demonstration, farm visits, etc). Effectiveness with respect to land users has been good. With rural economic development, more and more land users plan to invest in the SWC activities, including terrace making. The extension system is quite adequate to ensure continuation of activities.
Research: Mostly on-station research; carried out at the provincial and national levels, mostly by technical staff. Land users have not been involved. Topics covered include economics/marketing, ecology, technology. Terrace building is based on scientific design, according to local conditions.
Importance of land use rights: The ownership of the land and its resources belongs to state and communities: land users can only lease the land for a period of time. Due to uncertainty over future user rights and possible reallocation of the land every few years (5, 10 or 20) by the village in response to changes in population and household needs, additional investments into land/SWC measures may be hindered. 1978 a first major change took place by allocating some individual land use rights.

Incentives

Labour: In the 1960s and 1970s farmers were not paid for their labour inputs. From the 1980s onwards the government started to reward the community for establishment of terraces with cash: projects paid on the basis of area treated, and at different rates.
Inputs: Shovels and carts were provided by land users.
Credit: Credit was available at interest rates (0.5–1% per year) lower than the market rates.
Support of local institutions: Financial support to local institutions was made available through SWC Bureaus.
Long-term impact of incentives: As more and more payment is currently being made to land users on the basis of the area treated, land users rely more and more on being paid for investments into SWC. The willingness to invest in SWC measures without receiving financial support has decreased. Thus the use of incentives in the current approach is considered to have a negative long-term impact.

Monitoring and evaluation

Monitored aspects	Methods and indicators
Bio-physical	regular measurements of runoff loss, sediment load, soil moisture
Technical	regular measurements of structure of terraced areas, slope of risers, levelness of terrace surface
Socio-cultural	ad hoc observations of land users' perceptions of terraces
Economic/production	regular measurements of yield, income of land users
Area treated	regular measurements of terraced area
No. of land users involved	ad hoc measurements of the numbers of farmers directly involved in terracing and farmers benefited directly
Management of approach	ad hoc observations of number of small watersheds terraced

Impacts of the approach

Changes as result of monitoring and evaluation: The approach changed fundamentally from self-mobilisation to organised mass movements guided by the government.
Improved soil and water management: Soil and water management have improved a lot: easier workability, intensified land use, in-situ water retention, top soil and fertilizer/manure are not washed away, etc.
Adoption of the approach by other projects/land users: As the Zhuanglang area was one of the pioneering areas for the Loess Plateau other regions were able to profit from the approach. But likewise, experiences gained in other counties helped improve the approach, and a basically similar approach has been applied over the whole Loess Plateau – though the level of subsidies for construction is much higher under World Bank projects.
Sustainability: Given the recent escalation in payments made to land users for implementation under certain projects it seems that the costs will be too high to sustain. Currently the Ministry of Finance is demanding that in-depth cost-benefit analyses are carried out involving environmental, social as well as economic assessments.

Concluding statements

Strengths and ➜ how to sustain/improve*
Efficient organisation, planning to cover a large area, which is very susceptible to land degradation.
Heavy investment made by the land users and local as well as national government to reduce land degradation.
Many people involved and trained at different levels (pyramid system; see training/extension); commitment by all stakeholders.
The collective activities/organisation strengthens the community and enhances social stability and coherence within villages; collective activities are expanded to other sectors, such as road construction, supply of agrochemical inputs, etc.
Farmers are getting direct benefits: marked increase in productivity, improved workability of the land, etc.

* no recommendations provided on how to sustain/improve the strengths in this case study

Weaknesses and ➜ how to overcome
High costs: farmers depend on external support from the government, they are not willing to invest their labour without payments (as it used to be in communist times) ➜ New approach: give farmers loans for construction as now they use machines to do the work. In addition, search for cheaper SWC technologies and for improving the benefits.
The steeper slopes which are also further away from the village, are now often not cultivated and maintained as they are too far and marginal in production ➜ Solutions need to be found for these areas, eg afforestation.

Key Reference(s): Water and Soil Conservation Department of Yellow River Water Resources Committee of Ministry of Water Resources and Electric Power 1987: Corpus of economic benefits of water and soil measures, p77–102, 510–514 ■ Suide Water and Soil Conservation examination station of Yellow River Water Resources Committee, 1981. Corpus of Test Research of Water and Soil Conservation, p130–185 (the second volume) ■ Jiangdingsheng, ACTA CONSERVATIONIS SOLI ET AQUAE SINICA, 1987. Discussion on section design of the terrace on the Loess Plateau; Vol. 1, No. 2, p28–35
Contact person(s): Wang Yaolin, GEF/OP12 Project Office, Gansu Desert Control Research Institute, Lanzhou 730030, People's Republic of China; phone ++86 13919467141; Gansu@gefop12.cn, yaolingw@gsdcri.com ■ Bai Zhanguo, World Soil Information, Wageningen, The Netherlands ■ Liu Baoyuan, Department of Resource and Environmental Science, Beijing Normal University, Beijing 100875, PR China; phone ++086-10-62206955/9959; baoyuan@bnu.edu.cn ■ He Yu, Zhuanglang SWC Bureau, 744600, phone ++86 933 6621681; gszlheyu@163.com


left: Paddy fields on bench terraces are very effective in impounding water for rice cultivation, and in preventing soil erosion. Ifugao, Philippines. (Jose Rondal)
right: Close-up showing rice crop on the narrow benches. (William Critchley)

Rainfed paddy rice terraces

Philippines – *Palayan*

Terraces supporting rainfed paddy rice on steep mountain slopes: these have been in existence for more than a thousand years.

Terraced paddy rice on steep mountain slopes is the main method of rice cultivation in Cordillera Administrative Region (CAR) of the Philippines. This is a traditional technology: most of the terraces are at least a thousand years old. The terraces were constructed manually on steep hill slopes (30–60%) with small portions located in narrow valley bottoms. Farmers generally own one hectare or less of terraced land, and cultivation is intensive. The terraces ('paddies') curve along the contour, and are narrow, ranging from one to five meters in width, depending on the slope. The height of the riser is between one and two meters. Water supply for the rice crop depends on rainfall, and only one rice crop is grown per year.

The terraces impound rainwater – average rainfall is around 2,000 mm – and thus prevent soil erosion. Soil fertility is largely maintained because the impounded water and a zero rate of erosion preserve organic matter levels. Some nutrient loss occurs however with each harvest. The terraces are multi-functional: in addition to their agricultural use, they assist in environmental protection through flood mitigation, and they contribute to biodiversity. Furthermore they have become a tourist attraction.

Land preparation is mainly manual. Farmers puddle the soil with their bare feet. Excess water is drained to the terrace below by a small opening in the lip on top of the riser. Maintenance consists basically of repairing breached bunds/risers. Every planting season, a few centimetres of soil is added. To strengthen the bunds, some farmers plant grasses, which may be cut and carried for animal fodder: napier grass *(Pennisetum purpureum)* is an example. It is important not to disturb the soil of the bund, as this may encourage breaching.

The area where the technology is practiced is mostly between 2,000 and 2,500 m. Because of the cool climate caused by the high elevation, crop maturity takes longer than in the lowlands. In some cases, vegetables such as cabbages and sweet potatoes are grown after the rice is harvested. The farmers, indigenous to the area, have a distinct culture that is different to lowland rice farmers. Rituals connected with farming are widely practiced. There is an added economic benefit from tourism, as people from all over the Philippines – and beyond – travel there for the spectacular views and mild climate.

Location: Cordillera Region (Ifugao, Apayao, Kalinga, Mountain Province, Benguet), Philippines
Technology area: 15,000 km^2
SWC measure: structural
Land use: cropland
Climate: humid
WOCAT database reference: QT PHI12
Related approach: not documented (traditional)
Compiled by: Jose Rondal, Bureau of Soils and Water Management, Quezon City, Philippines
Date: September 2003, updated May 2004

Editors' comments: Paddy rice terraces – irrigated or rainfed – have been used in many parts of Asia for thousands of years (see 'Traditional irrigated rice terraces' from Nepal with many similarities). The upland rural landscape is characterised by these traditional terraces, which not only provide the livelihoods for millions of people, but the beauty of the sculpted hillsides also attracts tourists.

Classification

Land use problems

The terraces allow crop cultivation in an area characterised by steep slopes and high rainfall. However, farming in this marginal areas is labour intensive, mechanisation is not an option on the narrow paddies, and even animal traction is rarely possible due to the steepness of the terrain and the high terrace risers. Non-terraced hill slopes are prone to very high runoff and soil erosion, production is zero.

Land use

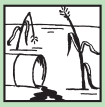
annual crops: rice

Climate

humid

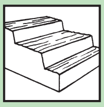
Degradation

water erosion: loss of topsoil

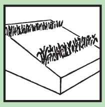


chemical: fertility decline and reduced organic matter content

SWC measures



structural: level bench terrace



vegetative: grass on bunds/ risers (supp.)

Technical function/impact

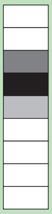
main:
- control of dispersed runoff (retain/trap)
- increase/maintain water stored in soil

secondary:
- reduction of slope angle
- reduction of slope length
- indirect maintenance of fertility

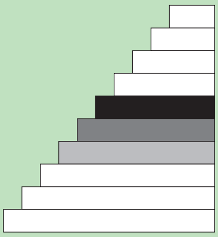
Environment

Natural environment

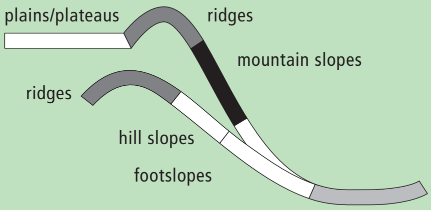
Average annual rainfall (mm)



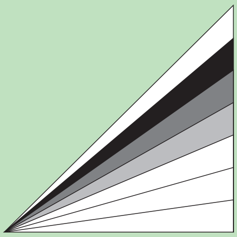
Altitude (m a.s.l.)



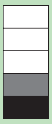
Landform



Slope (%)



Soil depth (cm)



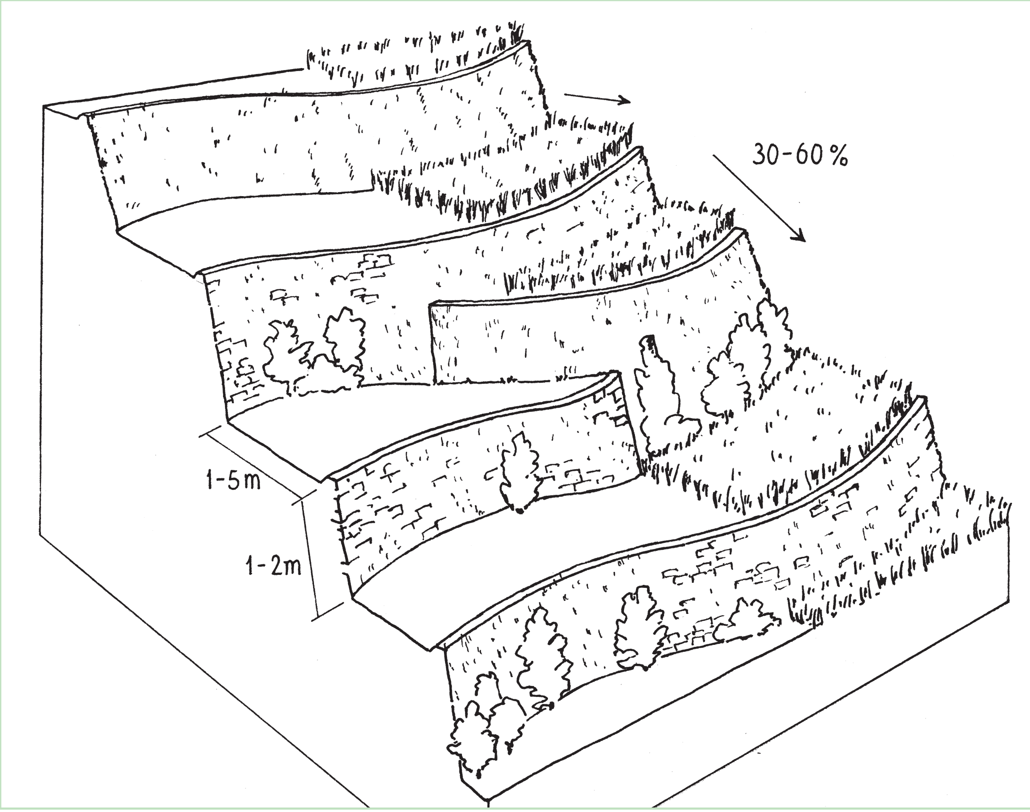
NB: soil properties before SWC

Growing season: 210–240 days
Soil fertility: mainly low due to continuous mono-cropping for several years, partly medium
Soil texture: mainly fine (clay), partly medium (loam)
Surface stoniness: mostly no loose stone, partly some loose stone
Topsoil organic matter: mostly medium (1–3%), partly low (<1%) due to bad management of crop residues
Soil drainage: mainly poor, partly medium
Soil erodibility: medium

Human environment

Cropland per household (ha)

Land use rights: individual
Land ownership: individual titled
Market orientation: mainly mixed (subsistence and commercial), partly only subsistence, rarely only commercial
Level of technical knowledge required: field staff/extension worker: moderate, land user: moderate
Importance of off-farm income: 10–50% of all income: carpentry, trading, labour for neighbouring farms, overseas employment, transport services, activities associated with tourism



Technical drawing
Layout of rainfed paddy rice terraces. The level terraces allow cultivation of paddy rice (right) on steep slopes. In some places the terrace risers are as tall as the beds are wide.

Implementation activities, inputs and costs

Establishment activities

1. Determination of contour lines by eye.
2. Levelling by moving soil from the upslope to the downslope part of the terrace.
3. Construction of bunds (lip at the terrace edge) of about 50-100 cm width and 30 to 40 cm height. Stones may be used if available on-site.

Only hand tools are used (hoe, spade, iron bars).
Duration of establishment: 1 year

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (800 person days)	2,500	100%
Equipment		
- Hand tools	200	100%
TOTAL	**2,700**	**100%**

Maintenance/recurrent activities

1. Weeding by cutting grasses on the bund/riser using hand tools. Hoeing to remove weeds is not done as this will disturb the soil.
2. Repairing breached portion of the bunds. Adding a few centimetres of soil on top of the bund/riser for bigger storage volume.
3. Land preparation by puddling. In most cases, the use of animal traction is not possible because of the steepness of the slope and height of the risers.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (10 person days)	30	100%
Equipment		
- Hand tools	10	100%
TOTAL	**40**	**100%**

Remarks: The costs of establishment are estimates – as new terrace construction no longer takes place. The land has already been terraced for centuries. The 800 person days are for land levelling and bund construction, which comprises the main activity. The calculation was based on a land slope of 30–60%. The maintenance figure assumes regular light maintenance – and does not include major repairs to bunds.

Assessment

Acceptance/adoption

The technology is widely accepted. As the terraces were constructed hundreds of years ago and construction of new terraces is no longer done the question of 'adoption' is not relevant.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	not applicable	not applicable
maintenance/recurrent	positive	very positive

Impacts of the technology

Production and socio-economic benefits
- +++ crop yield increase (compared with zero in the non-terraced scenario)
- +++ farm income increase
- ++ fodder production/quality increase

Production and socio-economic disadvantages
- −− labour constraints conflicting with other income generating opportunities
- −− inputs needed for fertility improvement

Socio-cultural benefits
- ++ community institution strengthening
- ++ national institution strengthening
- ++ improved knowledge SWC/erosion

Socio-cultural disadvantages
- none

Ecological benefits
- +++ increase in soil moisture
- +++ efficiency of excess water drainage
- +++ soil loss reduction
- ++ biodiversity enhancement

Ecological disadvantages
- none

Off-site benefits
- +++ reduced downstream siltation
- ++ reduced downstream flooding

Off-site disadvantages
- none

Concluding statements

Strengths and ➜ how to sustain/improve

Low maintenance cost ➜ Regular maintenance.

Farmers are well versed (very familiar) with the rice production system – it is part of their culture ➜ Continuous 'Information Education Campaign' (IEC).

Terracing allows paddy rice production on very steep slopes, which are prone to very high erosion and water loss in such a monsoon area. It transforms steep unproductive slopes into productive land ➜ Incentives to encourage continuation of the use and maintenance of the terraces.

Weaknesses and ➜ how to overcome

Lack of moisture for about six months ➜ Moisture conservation (mulching): construction of water harvesting structures for supplementary irrigation.

Continuous mono-cropping ➜ Crop diversification. Other crops (such as sweet potato, cabbage, chilli) could be grown after rice towards the end of the rainy season through minimum or zero tillage.

Severe soil fertility decline in some locations – and therefore declining yields ➜ Fertility enhancement using organic and inorganic sources (manure, crop residues, compost, fertilizers etc).

Key reference(s): Breemen van N, Oldeman LR, Plantinga WJ and Wielemaker WG (1970) The Ifugao Rice Terraces. In: *Miscellaneous papers* (7) 1970, eds. N van Breemen et al Landbouwhogeschool, Wageningen, The Netherlands.
Contact person(s): Jose Rondal, Bureau of Soils and Water Management, Elliptical Road, Diliman, 1100 Quezon City, Philippines; joserondal@yahoo.com

left: Irrigation of traditional paddy rice terraces. The water is drained from one terrace to the next through narrow openings. Note a pile of manure on the upper terraces ready to be applied to the field. (Hanspeter Liniger)
right: Maintenance: farmer scraping/slicing the terrace riser. The material is then spread on the fields, improving the soil fertility. (Hanspeter Liniger)

Traditional irrigated rice terraces

Nepal – *Tari khet*

Level bench terraces with risers protected by fodder grasses, used for irrigated production of rice, potatoes and wheat.

The level bench terrace is a traditional technology that makes irrigated crop production possible on steep, erosion prone slopes. The majority of such terraces in Nepal were constructed by hand many generations ago, but some new land – mostly already under rainfed cultivation on forward sloping terraces – is still being converted into irrigated terraces. The initial costs for the construction of the terraces are extremely high – and annual maintenance costs are considerable also. The climate is humid subtropical, slopes are steep (30%–60%) and soils generally have a sandy loam texture. Terraces are cropped by small-scale farmers who have less than half a hectare of land each. Two to three annual crops are grown per year starting with paddy rice during the monsoon, followed by potatoes and/or wheat.

While terrace beds are usually 2–6 m in width, to save labour they are made as wide as they can be without increasing the danger of slips/land slides. Surveying was traditionally done by eye, but now a water-tube level may be used. Risers are 0.8–1.5 m high with a small lip (20–25 cm). The slope of the riser varies from 80 to 160%, depending on the initial gradient of the hill. Stones are incorporated in the risers if available, and grass species such as bermuda grass *(Cynodon dactylon)* and napier *(Pennisetum purpureum)* may be planted for stabilisation and as cattle fodder. The risers are compacted (with hoes) to improve ponding conditions for the paddy rice. Twice per year the risers are scraped with a special tool: (1) at the time of land preparation for paddy rice the lower part of riser is sliced, but the upper part is left protected with grasses against the monsoon rains; (2) at the time of wheat planting the whole riser (including the lip) is scraped and spread as green manure on the terrace.

Terraces are flooded with water for paddy rice cultivation: a smaller amount of water is diverted into the fields for other crops. Excess water is drained to the lower terrace by openings in the lip, which are filled with rice straw in order to filter out sediments. The depth of water for rice – when flooded completely – is normally between 10 and 15 cm. Fertility is maintained by addition of farmyard manure, spreading the scraped soil from the riser, and also through sediment carried in the irrigation water. Nowadays, mineral fertilizers are also applied.

Location: Sankhu Bhulbu, Manmata Subwatershed, Kathmandu Valley, Nepal
Technology area: 1 km^2
SWC measure: structural, vegetative and agronomic
Land use: cropland
Climate: humid
WOCAT database reference: QT NEP10
Related approach: not documented (traditional technology)
Compiled by: Ramanand Bhattarai, District Soil Conservation Office, Lalitpur, Nepal
Date: November 2003, updated August 2004

Editors' comments: Irrigated bench terraces are a very common traditional technology, widespread in Nepal on footslopes and the middle hills of the Himalayas. There are close similarities with the paddy rice terraces of South East Asia: the Philippines (presented in this book), Indonesia and China. This is a case study from the Kathmandu valley.

Classification

Land use problems

- steep slopes, not suitable for agriculture in their original state (better for forestry, agroforestry, horticulture, and fruit trees)
- small and scattered plots of land
- land users find chemical fertilizers and water expensive
- there is water scarcity from September to May and too much rain in the monsoon period (June to August) with the danger of erosion and collapse of the terraces

Land use

annual crops: rice, potatoes, wheat

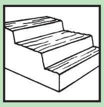
Climate

humid

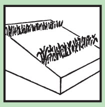
Degradation

water erosion: gully, loss of topsoil and mass movement

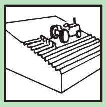
SWC measures



structural: level bench terraces



vegetative: fodder grass at risers



agronomic: green/farmyard manure, inorganic fertilizers

Technical function/impact

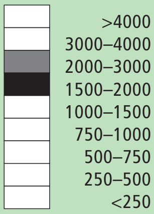
main:
- control of dispersed and concentrated runoff
- reduction of slope angle and length
- increase/maintain water stored in soil
- increase in soil fertility

secondary:
- water harvesting
- water spreading
- improvement of ground cover

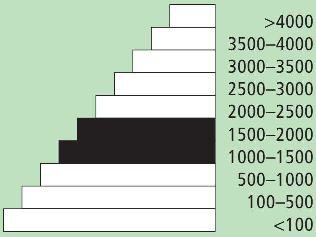
Environment

Natural environment

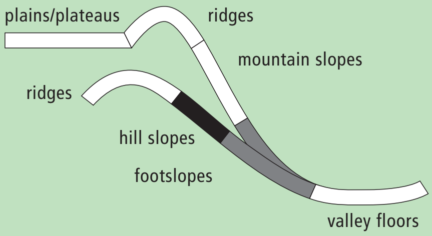
Average annual rainfall (mm)



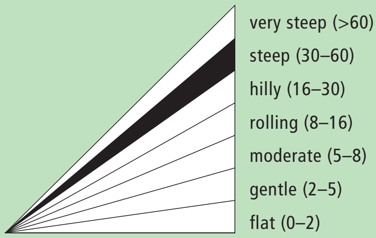
Altitude (m a.s.l.)



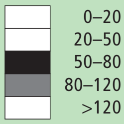
Landform



Slope (%)



Soil depth (cm)

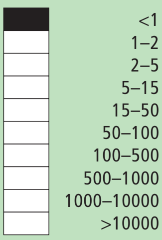


NB: soil properties before SWC

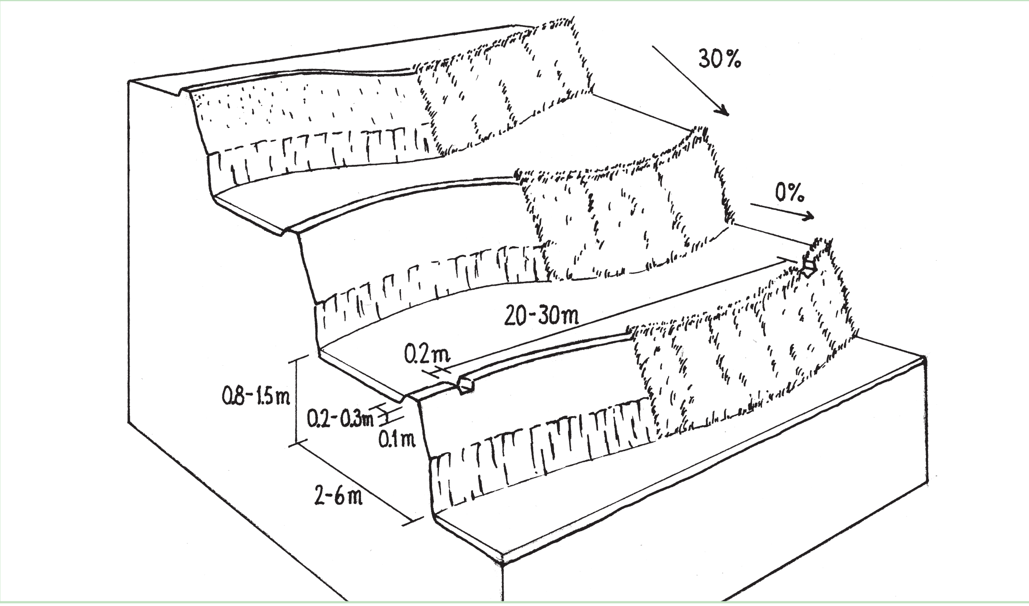
Growing season: monsoon from June to August but irrigation extends the growing period to around 330 days (allowing 2–3 crops per year)
Soil fertility: medium
Soil texture: mainly medium (loam), partly coarse (sandy loam)
Surface stoniness: no loose stone
Topsoil organic matter: medium (1–3%)
Soil drainage: good because of the geology and soil texture (loam)
Soil erodibility: mainly high, partly medium

Human environment

Cropland per household (ha)



Land use rights: leased (90% of farmers), individual (10%)
Land ownership: individual not titled
Market orientation: mixed: subsistence (rice/wheat) and commercial (potatoes)
Level of technical knowledge required: field staff/extension worker: high, land user: high
Importance of off-farm income: 10–50% of all income: hired labour (on other farmers' fields) or as porters



Technical drawing
Layout of irrigated terraces. Openings in the lips drain excess water. Grass cover stabilises lips and risers (right). After harvesting of rice, the grass is scraped off the lower part of the risers (left) and spread on the terrace beds.

Implementation activities, inputs and costs

Establishment activities

1. Construction of bund (riser) with soil from upper and lower sides (soil transported in jute bags).
2. Levelling terrace bed (soil moved from upper to lower part of terrace).
3. Making lips on edges of terraces.
4. Compacting risers.
5. Constructing irrigation canal.
6. Making openings in lips for excess water drainage.
7. Test-irrigating terrace for accurate levelling.
8. Planting grasses including bermuda grass *(Cynodon dactylon)*.
9. After 2–3 years: some narrow terraces may be merged to form a single, wider terrace.

All activities are done by hand: 1–6 before, 7–8 during the monsoon.
Duration of establishment phase: not specified

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Refer to remarks below		

Maintenance/recurrent activities

1. Harvesting of potato/wheat (January-March).
2. Transportation of cattle manure with *doko* (basket, carried on the back) to the field and leaving it in heaps (March).
3. Spreading the cattle manure (normally April).
4. Land preparation (ploughing/breaking compacted soil) for rice (April).
5. Flooding the paddy fields (June/July). Repeated 3–4 times during cultivation.
6. Slicing/scraping grass and soil on lower part of risers and spreading on terrace (when flooded, June/July).
7. Planting of rice. Application of mineral fertilizer (June/July).
8. Harvesting of rice (September/October).
9. Manuring (cattle manure), after harvest of rice (October).
10. Slicing/scraping grass and soil from whole of risers and spreading on terrace (October/November).
11. Repair of small collapses/slumps in risers (Oct./Nov.).
12. Land preparation (November).
13. Planting of potatoes, wheat. (November).
14. Application of mineral fertilizer (November/December).
15. Irrigation (Nov. repeated several times during cultivation).

All activities done by hand, except land preparation sometime done with small tractors or power tiller.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (125 person days)	350	100%
Equipment		
- Tools: hoe, spade, baskets *(doko)*	5	100%
Agricultural		
- Fertilizers (650 kg)	185	100%
- Compost/manure (30 t incl. transport)	300	100%
TOTAL	**840**	**100%**

Remarks: Current establishment costs are very difficult to determine since the majority of the traditional terraces were established a long time ago. Costs depend closely on the present status of the land (forward sloping terraces or uncultivated) and the need for irrigation canals. Farmers state that construction now could cost up to US$ 10,000 per ha if carried out by hand at full labour cost. Maintenance quoted above (approx. US$ 840 per ha) includes all associated annual crop production costs. In this case study 100% of the construction costs were borne by land users.

Assessment

Acceptance/adoption

- All the land users in the case study area who applied the technology did so without incentives, but in a nearby area 50% of costs have been met by the Bagmati Integrated Watershed Management Programme, when converting existing rainfed forward sloping terraces into level terraces (which can be irrigated).
- Maintenance has been continuously good over many generations.
- Main motivation: irrigation guarantees high returns from small areas.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	very negative	positive
maintenance/recurrent	positive	very positive

Impacts of the technology*

Production and socio-economic benefits

- +++ crop yield increase
- +++ farm income increase
- +++ increase in livestock fodder
- ++ fodder production/quality increase

Production and socio-economic disadvantages

- −−− increased labour constraints (high labour inputs needed)
- −− increased economic inequity (not everyone has access to land for irrigation)
- −− increased input constraints
- −− loss of land due to terrace risers

Socio-cultural benefits

- +++ improved knowledge SWC/erosion
- ++ community institution strengthening

Socio-cultural disadvantages

- − socio-cultural conflicts may arise when the agreed and scheduled water extraction amounts are exceeded
- − as part of a complex farming system the technology is vulnerable to changes in norms and traditions, (influence of the nearby city with possibilities of jobs)

Ecological benefits

- +++ increase in soil moisture
- +++ efficiency of excess water drainage
- +++ increase in soil fertility
- +++ soil loss reduction
- ++ biodiversity enhancement
- ++ soil cover improvement

Ecological disadvantages

- − crabs in irrigation water make holes in the terrace risers, which in turn can cause pipe erosion and collapse of risers

Off-site benefits

- +++ reduced downstream flooding
- +++ reduced downstream siltation
- +++ increased groundwater recharge
- +++ increased soil moisture and nutrients downstream
- ++ reduced river pollution

Off-site disadvantages

- −− reduced river flows (during dry season: river water is used upstream for terrace irrigation)
- − poor maintenance of terraces in the upper parts may cause landslides

* In this case: impacts of traditional paddy rice terraces in comparison to forward sloping rainfed terraces

Concluding statements

Strengths and ➜ how to sustain/improve

Income and production increase ➜ Proper management of the terraces (including all maintenance activities).

Easier to cultivate flat terraces/less labour required (after establishment of the terraces).

Work sharing: the traditional terraces are part of a long tradition of work sharing within the community – no external labour is required ➜ Prevent loss of well established traditions and norms.

Technology is easy to understand/apply.

The irrigation element of this particular technology fosters social bonds within the community ➜ Prevent loss of well established norms and traditions.

Increased opportunities for irrigation facilities: farmers without level terraces are not allowed (by the irrigation committee at village level) or do not make claims for irrigation water.

Weaknesses and ➜ how to overcome

Decreased grass production (grazing area reduced) ➜ Promote the planting of high value grass species on risers (such as bermuda grass).

In the opinion of the farmers terraces are still too narrow (for efficient use of tractors); they would like to have them even wider ➜ Investigate possibilities of constructing wider paddy rice terraces on steep slopes, which – according to present experience – is not possible.

High labour costs for establishment.

Key reference(s): There is considerable literature on the construction and maintenance of irrigated terraces in general, but no references that specifically describe the traditional paddy rice terraces in Nepal

Contact person(s): Ramanand Bhattarai, District Soil Conservation Office, Lalitpur, Nepal; phone: +977 1 5520289; rnbhattarai@hotmail.com

left: Fence-line contrast between treatment paddocks with different utilisation rates: medium utilisation on the left and high utilisation paddock on the right. (CSIRO)
right: The impact of poor grazing land management: woodlands with a dense cover of '3P grasses' (top), degraded area with annual grasses, forbs and bare soil after heavy grazing (bottom). (CSIRO)

Ecograze

Australia

An ecologically sound and practical grazing management system, based on rotation and wet season resting.

Open eucalypt woodlands cover approximately 15 million hectares in the semi-arid plains of north-east Australia, and support about a million head of cattle. Keeping these grazing lands productive and healthy demands good management, and getting the right balance between stock numbers and the forage resource is a considerable challenge.

Land in good condition has a healthy coverage of so-called '3P grasses': native perennial, productive and palatable grasses, important to cattle and to the health of the landscape. Less palatable plants include annual grasses, native and exotic forbs and shrubs. The heterogeneity of the pasture resource results in uneven utilisation, and thus overgrazing in parts.

In order to prevent pastures in good condition from degrading, or to restore/ improve deteriorated pastures, utilisation needs to be adjusted according to climate and the state of the '3P grasses'. In practice, the only means of manipulating pasture composition over large areas are grazing, resting from grazing, and burning.

The flexible Ecograze system includes wet season resting, and is based on the establishment of three paddocks with two herds within a rotational system. The key is that all paddocks get some wet season rest two years out of three. Wet season rests are divided into two phases: (1) the early wet season rest starts after the first rains in November/December and continues for 6–8 weeks, it is particularly good for perennial grass recovery; (2) the late wet season rest lasts until March/ April and aids both seed set and vegetative recovery.

Average paddocks of around 3,000 ha in size are sub-divided into three relatively equal sizes, though some flexibility is required to balance variation in the productive capacity of different land types within the paddock. The paddocks are fenced and extra water points through polythene piping and additional water troughs, and where required, pumps are established. The return on investment can be realised within a few years.

The main management challenges are: (1) the timing and length of the early wet season rest, which depends on how effectively the early rains promote vegetative growth of perennial grasses, and (2) the movement of animals during the wet season. The number of stock movements are fixed – but the timing is flexible and should be responsive to the situation: the challenge is to learn to assess the pasture condition, read the situation, and schedule the timing and length of the rest period accordingly. The main criterion is the recovery state of perennial grasses.

Location: Lakeview/Allan Hills, Cardigan, Hillgrove/Eumara Springs, North-east Queensland, Australia
Technology area: 10 km^2
SWC measure: management, vegetative
Land use: grazing land
Climate: semi-arid
WOCAT database reference: QT AUS01
Related approach: Development and promotion of Ecograze, QA AUS01
Compiled by: Andrew Ash, CSIRO, Queensland, Australia
Date: June 2001, updated December 2004

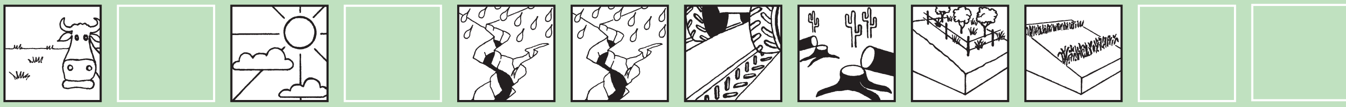
Editors' comments: Though degradation of rangelands is a global problem, there are few documented cases of successful management practices. Ecograze provides a flexible system that has been developed through collaborative research. Its principles of rotation and resting are relevant to most of northern Australia's tropical rangelands – and to other countries also.

Classification

Land use problems

Over the last 20 years there has been a decline in the condition of grazing lands in north-east Australia. The evidence is a decline of palatable, perennial, productive grasses ('3P grasses'), reduced ground cover and an increase in sediment and nutrient movement into streams. As a consequence of economic pressures and over-optimistic expectations of good rains, stocking rates have often been too high.

Land use | **Climate** | **Degradation** | **SWC measures**



grazing land: extensive grazing | semi-arid | water erosion: loss of topsoil, gully | off-site: sediment deposition, nutrient flow into streams | physical: sealing and crusting, compaction | vegetation: reduced cover and quality (overgrazing) | management: change of intensity level, resting | vegetative: improved grass cover

Technical function/impact

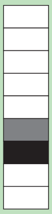
main:
- improvement of ground cover and fodder quality
- increase/maintain water stored in soil
- improvement of soil structure
- increase in organic matter

secondary:
- retain/impede dispersed and concentrated runoff
- increase in soil fertility

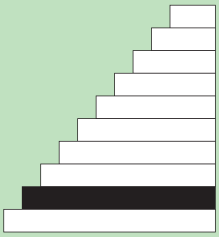
Environment

Natural environment

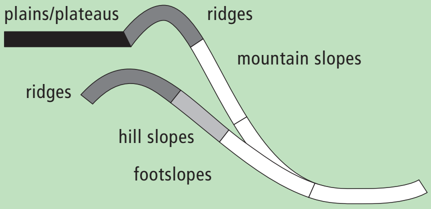
Average annual rainfall (mm)



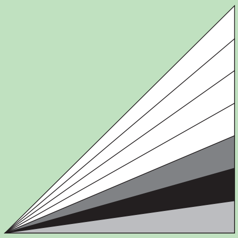
Altitude (m a.s.l.)



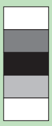
Landform



Slope (%)



Soil depth (cm)



NB: soil properties before SWC

Growing season: 120 days on average (November to April), but high variability
Soil fertility: low
Soil texture: mostly medium (loam), some fine (clay)
Surface stoniness: mostly no loose stone, some rock outcrops
Topsoil organic matter: mostly low (<1%), partly medium (1–3%)
Soil drainage: mostly good, partly poor
Soil erodibility: mostly high, partly medium

Human environment

Grazing land per household (ha)

Land use rights: mostly leased, partly individual (freehold)
Land ownership: individual
Market orientation: commercial (market)
Level of technical knowledge required: field staff/extension worker: moderate, land user: moderate
Importance of off-farm income: 10–50% of all income: usually constitutes off-farm financial investments (eg shares in companies, investment properties, etc)

Year	Season	Paddock A	Paddock B	Paddock C
Year 1	Early Wet	Rest	Graze	Graze
	Late Wet	Graze	Rest	Graze
	Dry	Graze	Graze	Rest
Year 2	Early Wet	Graze	Graze	Rest
	Late Wet	Rest	Graze	Graze
	Dry	Graze	Rest	Graze
Year 3	Early Wet	Graze	Rest	Graze
	Late Wet	Graze	Graze	Rest
	Dry	Rest	Graze	Graze

Layout of Ecograze system
The drawing refers to the 'two herd/three paddock Ecograze system'.
Paddock A is rested in the early wet season, while Paddocks B and C are grazed. Paddock B is then rested for the late wet season while Paddocks A and C are grazed. Paddock C is then rested for the dry season and the next early wet season while Paddocks A and B are grazed. Paddock A is then rested for the late wet season and the rotational cycle continues in this fashion for the three years of the full rotation.
Early wet season spelling should commence after the first significant rains in November/December and should continue for 6–8 weeks, depending on how effectively the early rains promote vegetative growth of perennial grasses.
Late wet season rest typically last until March/April, depending on length of growing season.

Implementation activities, inputs and costs

Establishment activities

1. Paddocks first need to be surveyed to understand the various plant communities and soils.
2. Based on the survey and location of water points, and the most practical location for fences, a paddock design is developed: paddocks are subdivided into relatively equal sizes.
3. Fencing the paddocks (2 person days per km); Material: barbed wire or plain wire for electric fences, steel fence posts, wooden or steel end assemblies to strain the fence, energisers (for electric fences).
4. Provision of extra water points through polythene piping and additional water troughs – and where required, pumps.

Duration of the establishment: 1 to 4 years

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	4	100%
Equipment		
- Tools (various)	0	
Materials		
- for fencing: metal wire, wooden poles, etc	4	80%
- for extra water provision: PE pipes	2	80%
TOTAL	**10**	**90%**

Maintenance/recurrent activities

1. Mustering (gathering) and shifting (moving) livestock.
2. Monitoring pastures and soils.
3. Repair fences

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	1	100%
Materials		
- wire, poles, etc (for repair)		
TOTAL	**1**	**100%**

Remarks: Current average paddock size is 3,000 ha – commonly 6 km x 5 km. To sub-divide the paddock into three requires two internal fences, each of 5.0 km. Costs of fencing and associated gates are about US$1,200 per km. Labour for fencing is also approximately US$1,200 per km (note: because of the large paddock size, on a per hectare basis this is equivalent to US$ 4.0 per hectare).

Assessment

Acceptance/adoption

There are indications that around 700 (of a total of 15,000) farmers across northern Australia have already adopted some aspects of Ecograze. Surveys indicate spontaneous adoption beyond the region as well. In time a large number of farmers are expected to adopt the technology. Three of the five farm families involved in the on-farm research/development of Ecograze have taken up some aspects of the research.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	negative	positive
maintenance/recurrent	slightly negative	very positive

Impacts of the technology

Production and socio-economic benefits

- +++ fodder production/quality increase
- +++ farm income increase

Socio-cultural benefits

- ++ improved knowledge SWC/erosion

Ecological benefits

- +++ soil cover improvement
- +++ increase in soil moisture
- ++ soil loss reduction
- ++ biodiversity enhancement
- + increase in soil fertility

Off-site benefits

- +++ reduced downstream siltation
- +++ reduced transported sediments
- + reduced downstream flooding

Production and socio-economic disadvantages

- − increased economic inequity
- − increased labour constraints

Socio-cultural disadvantages

none

Ecological disadvantages

none

Off-site disadvantages

none

Concluding statements

Strengths and ➜ how to sustain/improve

Increased perennial grass cover, improved pasture productivity, increased animal carrying capacity and associated increased profit ➜ Wide and long-term adoption of Ecograze system.

Improved soil cover reduces erosion and sediment flow into streams and dams ➜ Manage pasture condition through Ecograze to maintain '3P grasses'.

Greater stability of forage supply leading to less problems and less stress in farm management ➜ Wide and long-term adoption of Ecograze system.

Soil carbon reserves maintained/improved ➜ Wide and long-term adoption of Ecograze system.

Plant biodiversity protected ➜ Wide and long-term adoption of Ecograze system.

Weaknesses and ➜ how to overcome

Adoption of technology needs long-term approach to accommodate for slow rate of change by ranchers ➜ Continue to demonstrate the advantages of the technology.

Implementing rotational grazing incurs (moderate) investment costs in the form of fencing and new water points ➜ Investigate government subsidies and educate about long-term economic benefits.

Key reference(s): Ash A, Corfield J and Taoufik T (undated) *The ECOGRAZE Project: developing guidelines to better manage grazing country.* CSIRO, Meat and Livestock Commission and Queensland Government ■ Tothill JC and Gillies C (1992) *The pasture lands of northern Australia: their condition, productivity and sustainability* Occasional Publication No. 5, Tropical Grassland Society of Australia, Brisbane ■ Tothill J and Partridge I (1998) *Monitoring grazing lands in northern Australia* – edited by Occasional Publication No. 9, Tropical Grassland Society of Australia, Brisbane

Contact person(s): Dr Andrew Ash, CSIRO Sustainable Ecosystems, 306 Carmody Rd, St Lucia, Qld, 4067, Australia; andrew.ash@csiro.au; www.csiro.au

left: Ecograze principles are part of the Grazing Land Management education package delivered through workshops. (CSIRO)
right: The effect of defoliation on root vigour with lightly clipped spear grass on the left compared with frequently clipped spear grass on the right. (CSIRO)

Development and promotion of Ecograze

Australia

Research-based development and promotion of Ecograze principles and practices through on-farm testing and demonstration.

In 1992, Meat and Livestock Australia (MLA), a producer-owned company that provides services to the entire Australian red meat industry, initiated the Ecograze project. Ecograze was intended to provide innovative management options for the pastures in the eucalyptus woodlands of north-east Queensland. It was an eight-year collaborative research project undertaken by staff of the CSIRO (Commonwealth Scientific and Industrial Research Organisation) Sustainable Ecosystems and Queensland Department of Primary Industries with input from Queensland Department of Natural Resources and Mines. It formally concluded in 2001. However, many of the analyses and extension activities have been ongoing since then.

Ecograze was conducted on five commercial grazing properties that spanned different conditions and consequently allowed extrapolation of results to a much wider area across northern Australia. Practical grazing management strategies have been developed. The Ecograze team assessed the economic implications of managing land in various states by linking a pasture production model, to a model of farm economics.

Research teams are currently testing the grazing management technology in commercial situations to understand the real costs and implications of implementing the research-derived Ecograze recommendations. The on-farm tests are supported by a number of new initiatives. These include a MLA funded project to specifically implement the Ecograze principles on farms as a means of reducing sediment and nutrients pollution of waterbodies. The National Action Plan for Salinity and Water Quality, through incentives, supports land management practices to reduce erosion, increase ground cover and minimise runoff. Funding is also provided by the Natural Heritage Trust to fence and sub-divide paddocks.

All of these initiatives are supported by State Government agencies, who have extension staff based in the regions to assist farmers with implementing new practices. In the case of Ecograze, there are extension officers in the NE Queensland region who are actively promoting its management principles and are assisting producers in planning new strategies. Many of the Ecograze principles are also included in a new Grazing Land Management (GLM) Education package, developed by MLA and research and development agencies. The GLM package, which is delivered via a three-day workshop, is being extended to producers across northern Australia.

Location: Northern Australia
Approach area: 1000,000 km^2
Land use: grazing land (extensive)
Climate: semi-arid
WOCAT database reference: QA AUS01
Related technology: Ecograze, QT AUS01
Compiled by: Andrew Ash, CSIRO, Queensland, Australia
Date: June 2002, updated December 2004

Editors' comments: This approach highlights the importance of active collaboration between researchers, farmers, the beef industry and the government – in this case to develop a system to improve the condition of grazing lands. Through the central involvement of research, management options have been identified to suit different land users' needs, climates, grazing pressures and pasture conditions.

Problem, objectives and constraints

Problem

- poor rangeland management leading to loss of productive palatable perennial grasses ('3 P' grasses) resulting in reduced ground cover, soil erosion, profit loss and in some cases irreversible land degradation
- lack of understanding of underlying problems regarding mismatch of animal numbers to forage supply (pressure on grazing land) in a highly variable climate
- no clear technical recommendations regarding resting and rotation of rangeland

Objectives

Development and promotion of Ecograze principles leading to adoption and thereby enhancing pasture productivity, soil condition and improved livelihoods for pastoralists.

Constraints addressed

	Specification	Treatment
Financial	Investment costs for fencing and water points can be burden on individual land holders.	There are various possible subsidies available (see 'Inputs', under 'Incentives').
Social	Many pastoralists are conservative and change their systems only slowly.	There are ongoing education programmes and demonstrations on target properties.

Participation and decision making

Target groups

Land users | Govt. agencies/ extensionists | Planners | Politicians/ decision makers

Approach costs met by:

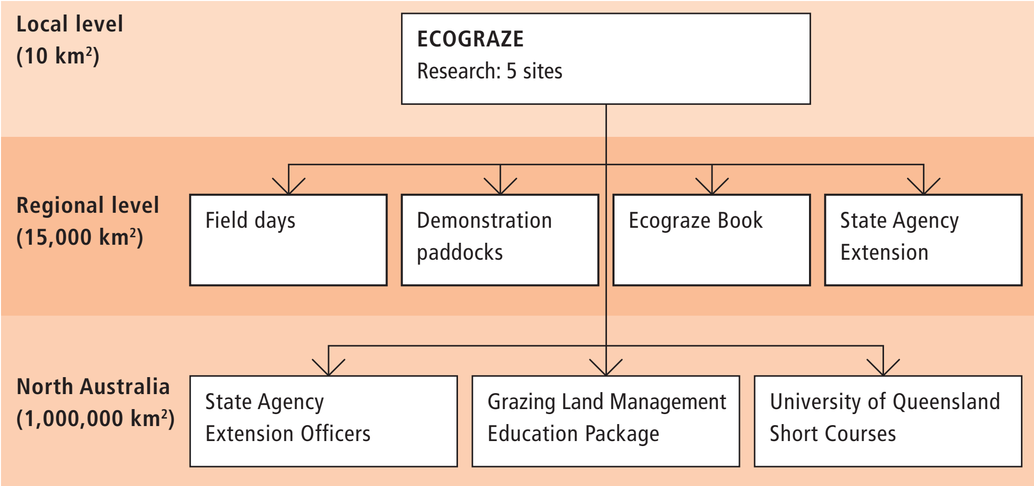
National government	40%
Community/local	60%
	100%

Decisions on choice of the technology: Mainly made by land users in consultation with technology experts and government agencies; recognition that Ecograze principles can benefit land users and the environment due to research results of field trials.
Decisions on method of implementing the technology: Mainly made by land users.
Approach designed by: National and state specialists together with land users.

Community involvement

Phase	Involvement	Activities
Initiation	passive	field days, workshops
Planning	self-mobilisation	consultation with specialists
Implementation	self-mobilisation	fencing and water points
Monitoring/evaluation	self-mobilisation	field observations of pasture composition; economic assessments
Research	interactive	on-farm field trials and demonstration areas

Differences in participation between men and women: Traditionally, men undertake on-farm planning, implementation of activities and provide labour. Women play an important role in planning and management of finances, and tend to take a more strategic view on NRM issues than the men.



Programme organization
Components and activities at different levels of the Ecograze programme.

Extension and promotion

Training: The Ecograze principles and findings have been incorporated into a training course entitled 'Grazing Land Management (GLM) Education Package'. To date (2005) over 100 farmers have participated in the course and it is anticipated that in the next three years this number will reach over 1,000 producers.
Extension: In on-going research trials in cooperation with land-users, government officers build up their knowledge and capacity to support farmers . Field days form part of the extension and education process. Government assistance with extension and training through free advice provided by extension officers is helpful. Subsidies to attend training courses like GLM Education also assist with the uptake and adoption of Ecograze. There is also a significant interaction between neighbouring properties in sharing of ideas and successes and failures. Commonly, these neighbouring properties are linked through catchment or 'Landcare' groups.
Research: The impact of the ongoing research on understanding and implementing the technology through the Ecograze project is significant, and continues to be so. Research into various technical aspects of grazing management has been recently supplemented by economic analyses of costs and benefits.
Importance of land use rights: In general, implementation of Ecograze principles is undertaken by an individual on private leasehold land. Ecograze is well suited to this individualised system.

Incentives

Labour: Labour inputs for implementation are voluntary.
Inputs: During the research phase of Ecograze, incentives were not available. However, since then, newly established Government initiatives such as the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality, which commenced in 2003, have increased the number of incentives (eg support for on-ground works such as fencing, relocation of water points etc) available to implement management practices such as those recommended in Ecograze.
Credit: Credit was not, and will not be, provided as part of ongoing extension of the technology.
Support to local institutions: Local Landcare groups often request assistance, and this is provided either from the research agencies or from extension officers or through grant applications to the Natural Heritage Trust.
Long-term impact of incentives: This technology is focussed on changing attitudes to management rather than requiring on-going financial inputs or support. As a result, financial support is more through incentives to help with changing management practices rather than any provision of ongoing support in the form of stewardship payments.

Monitoring and evaluation

Monitored aspects	Methods and indicators
Bio-physical	regular measurements of pasture composition, forage supply and soil surface condition
Socio-cultural	ad hoc evaluation of farmers' observations and constraints
Economic/production	regular monitoring of real costs is carried out to be used in analyses
Area treated	ad hoc measurement of area being subject to new management practices
No. of land users involved	ad hoc surveys of landholders to assess uptake rates

Changes as result of monitoring and evaluation: Further research and testing, on-going monitoring and evaluation is underway after the initial project. It is too early to state what changes are likely other than obviously needing to adapt to individual land-users resources and available finances.
Improved soil and water management: Ecograze leads to retention of 3P grasses ('perennial, productive and palatable' grasses), and therefore better pasture coverage, soil retention and greater water use efficiency.
Adoption of the approach by other projects: Ecograze principles have been included in the new Grazing Land Management Education package – which is being used across northern Australia by Meat and Livestock Australia and other agencies also. It has also now been incorporated into university courses on grazing management.
Sustainability: Progress is continuing with further field trials and participation from land users. Those land users who have begun with the Ecograze system can continue without external support.

Concluding statements

Strengths and ➜ how to sustain/improve	**Weaknesses** and ➜ how to overcome
The approach is focussed on changing attitudes to management in the long term ➜ Continue with training and education programmes.	One-off training programs such as the Grazing Land Management Education package (a 3-day course) may not be enough to sustain initial commitment to testing new management options ➜ Create support network and supply follow-up training and/or support.
Adoption of the technology should result in financial reward ➜ Continue ongoing economic analysis as an indication of technology success.	
The system has been very well documented and adapted to the land users conditions through the involvement of research, the land users, primary industry, and extension ➜ Continued support for applied/on-farm research to adapt the system to the needs of the land users and the environment. Support for long-term monitoring.	
State government extension agencies have also readily accepted Ecograze and are actively promoting its principles with landholders.	

Key reference(s): Ash A, Corfield J and Taoufik T (undated) *The ECOGRAZE Project: developing guidelines to better manage grazing country.* CSIRO, Meat and Livestock Commission and Queensland Government
Contact person(s): Dr Andrew Ash, CSIRO Sustainable Ecosystems, 306 Carmody Rd, St Lucia, Qld, 4067, Australia; andrew.ash@csiro.au; www.csiro.au

left: Rehabilitation of degraded rangeland in its initial stages: stone lines are established after the area has been cleared of invasive tree species: the branches are used for 'brush packing' and fencing. (Anuschka Barac)
right: Oversowing with grass seeds, manuring with cattle dung and application of lime speeds up regeneration of the grass cover. (Anuschka Barac)

Restoration of degraded rangeland

South Africa

Eradication of invasive species and revegetation of degraded rangelands by different treatments, including oversowing with grass seed mixture, supplementing with lime, cattle dung, and 'brush packing' (laid out branches).

A research investigation was undertaken in an area of degraded communal rangeland, which had been invaded by an alien tree species *(Acacia mearnsii* – black wattle). Competition from the water-demanding *A. mearnsii,* combined with overgrazing, had resulted in an almost total absence of palatable grasses. All that was left were a few patches of star grass (or bermuda grass: *Cynodon dactylon).* Prior to the research, discussions were held between personnel of the 'Working for Water' programme of the South African government and community members.

The purpose of the trials was to determine how best to eradicate the invasive trees and revegetate the rangeland. The restoration area was not fenced off and was thus open to grazing. The trials comprised five treatments, with three replicates each, on plots of 10 m by 20 m. In all treatments the *A. mearnsii* was eradicated manually, and chemical biocide applied to the stumps to prevent regrowth. Lime and grass seed (of palatable species) were applied to the loosened surface and covered with soil. The five treatments were:
(A) oversowing with grass seed mixture, supplementing of dolomitic lime, cattle dung, and 'brush packing' (see below for explanation of term);
(B) oversowing with grass seed mixture and supplementing with cattle dung;
(C) oversowing with grass seed mixture and supplementing with dolomitic lime;
(D) oversowing with grass seed mixture and brush packing;
(E) oversowing with grass seed mixture only.

In addition stone lines were laid out along the contour, between plots. The 'brush packing', referred to in treatments A and D comprised branches laid out in strips across the slope to retard runoff, trap soil, improve the micro-climate for establishing grass seedlings and protect the young plants from browsing by animals. The results showed treatment A to be the most effective in restoring the productive and protective function of the rangeland. From the trials, the estimated costs of applying the best technology would be US$ 230 per hectare. The key constraints for successful adoption however are not just technical, but include: (1) the need to protect the area from grazing and trampling by animals during the establishment period; (2) stopping removal of brushwood for firewood; and (3) the need for community agreement on initial protection and subsequent sustainable utilisation of the restored range.

Location: Elandsfontein, Johannesburg, Gauteng Province, South Africa
Technology area: 9 km^2
SWC measure: vegetative, structural and agronomic
Land use: grazing land
Climate: subhumid
WOCAT database reference: QT RSA42
Related approach: not documented
Compiled by: Anuschka Barac, Potchefstroom, South Africa
Date: July 2001, updated May 2004

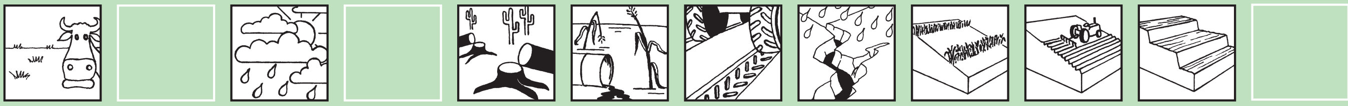
Editors' comments: Attempts to restore degraded rangeland have long been on the agenda in Africa. There are three basic variations: (1) excluding livestock (2) treatment with vegetative and other interventions or (3) a combination. The experimental treatments here were of type (2). Long-term success, however, depends on management of livestock to sustain improved cover.

Classification

Land use problems

Lack of grazing for livestock as the rangeland has become unproductive due to the invasion of an alien woody species *(Acacia mearnsii),* and unrestricted open access grazing due to a lack of community control.

Land use | **Climate** | **Degradation** | **SWC measures**



extensive grazing: open access to cattle and goats. | subhumid | vegetation: reduced cover, quality and quantity decline | chemical: soil fertility decline | physical: compaction of soil surface, crusting | water erosion: loss of topsoil | vegetative: oversowing grass seed mixture | agronomic: manuring, lime, 'brush packing' (trash lines) | structural: stone lines

Technical function/impact

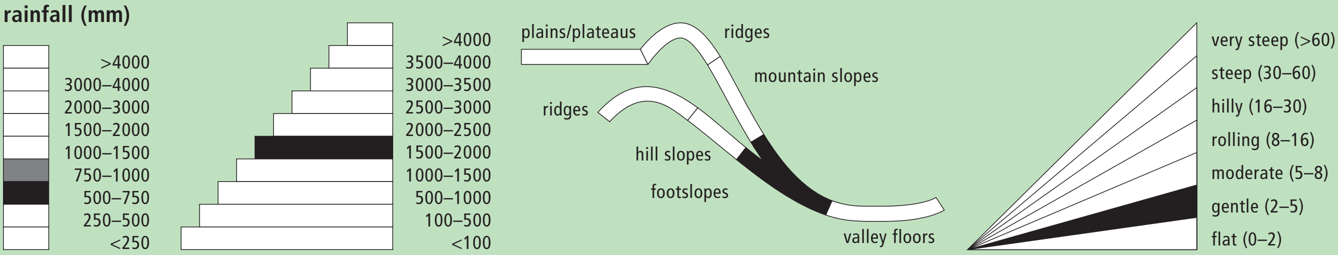
main:
- improvement of ground cover
- control of raindrop splash
- retards dispersed runoff
- increase in organic matter
- increase in soil fertility

secondary:
- improved soil structure
- increased infiltration
- sediment harvesting
- reduced slope length (due to stone lines)

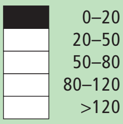
Environment

Natural environment

Average annual rainfall (mm) | **Altitude (m a.s.l.)** | **Landform** | **Slope (%)**



Soil depth (cm)

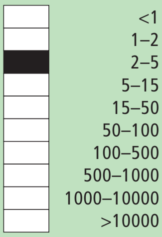


NB: soil properties before SWC

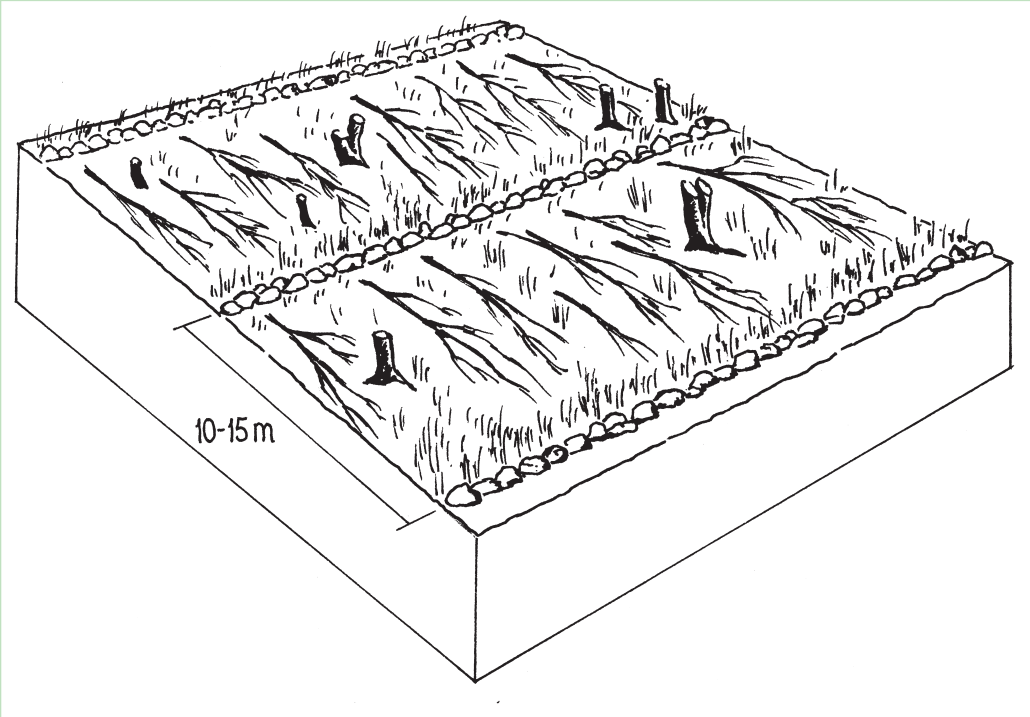
Growing season: 210 days (October to April)
Soil fertility: low
Soil texture: mostly medium (loam), some coarse (sandy) and fine (clay) soils
Surface stoniness: some loose stone
Topsoil organic matter: low (<1%)
Soil drainage: poor
Soil erodibility: high

Human environment

Grazing land per household (ha)



Land use rights: open access unorganised
Land ownership: state
Market orientation: mixed (subsistence and commercial): livestock raised on grazing land for a mixture of subsistence (self-supply) and commercial (market) purposes
Level of technical knowledge required: field staff/extension worker: high, land user: moderate
Importance of off-farm income: >50% of all income: off-farm employment in the city/mines and old age pensions are very important sources of household income



Technical drawing
Trees of invasive acacia species cut and branches spread as 'brush packing' for protection of degraded rangeland: note also stone lines and regenerating grass.

Implementation activities, inputs and costs

Establishment activities

Note: all activities described here as for treatment A: not all relevant to each treatment (see details in description)

1. Manual eradication of trees with chain saw and axe.
2. Application of chemical biocide to the stumps to prevent any regrowth.
3. Ripping of soil surface to a depth of 5 cm using a three tined hand implement.
4. Application of dolomitic lime and raking it into soil.
5. Application of organic material (cattle dung).
6. Oversowing with grass seed mixture.
7. Brush packing along contour and construction of rock contours across the slope.

All the branches and stones were collected from the restoration area. Total duration of restoration: 3 years, from removal of trees until revegetation trials were laid out and technology was established

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (10 person days)	35	0%
Equipment		
- Machines (chain saw)	65	0%
- Tools (rake,shovels, axe 3-tined hand hoe)	5	0%
Agricultural		
- Seeds (16 kg/ha)	70	0%
- Fertilizers (4 t/ha)	25	0%
- Biocides (1.5–2 kg/ha)	30	0%
- Compost/manure (whatever available)	0	
TOTAL	**230**	**0%**

Maintenance/recurrent activities

Following initial establishment maintenance was limited to two follow up applications of herbicide (after 3 and 5 months). Maintenance of contour lines was not carried out after restoration. The total maintenance period was for one year.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (2 person days)	7	0%
Equipment		
- Tools	5	0%
Agricultural		
- Biocides (1.5–2 kg/ha)	20	0%
TOTAL	**32**	**0%**

Remarks: These costs were calculated by upscaling to one hectare from the test plots – and treatment A is the one detailed here (oversowing with grass seed mixture, supplementing of dolomitic lime, cattle dung, and 'brush packing') which is the most successful and most expensive. Note that the whole period including establishment and maintenance was four years.

Assessment

Acceptance/adoption

The research investigation formed part of a Government scheme for poverty alleviation of rural poor communities ('Working for Water' under the Department of Water Affairs and Forestry: this programme focuses on removal of invasive alien species which threaten water supplies), but has been purely a research activity. The need for community agreement on the initial protection and subsequent sustainable utilisation of the restored range is a key constraints for acceptance of the technology.

Benefits/costs according to land user

Benefits compared with costs*	short-term:	long-term**:
establishment	negative	positive
maintenance/recurrent	slightly negative	positive

* costs not met by community

** long term refers to the period of the experiment

Impacts of the technology

Production and socio-economic benefits

- +++ fodder production/quality increase
- +++ farm income increase

Socio-cultural benefits

- +++ community institution strengthening (research was done in a communal area)
- +++ improved knowledge SWC/erosion
- +++ job creation

Ecological benefits

- +++ soil loss reduction
- +++ biodiversity enhancement
- +++ reduction of wind velocity
- +++ soil cover improvement
- ++ increase in soil moisture
- + increase in soil fertility

Off-site benefits

- + reduced downstream flooding
- + reduced downstream siltation

Production and socio-economic disadvantages

- −−− brushwood needed for firewood
- − increased labour constraints

Socio-cultural disadvantages

none

Ecological disadvantages

none

Off-site disadvantages

none

Concluding statements

Strengths and ➜ how to sustain/improve

Improvement of grazing resources ➜ Fencing rehabilitated areas to keep cattle out until the grasses are sufficiently established, should be part of the technology in future.

Improved soil moisture availability by removing an alien species with a high water demand ➜ Use of a biocide on the cut stems to prevent any regrowth of the alien species.

Reduced erosion by controlling runoff ➜ Regular maintenance of the contour stone lines.

Weaknesses and ➜ how to overcome

The question of controlling 'open access' grazing by the community is the key to long-term success of rehabilitation ➜ It is incumbent on the local municipal council to negotiate with communities regarding grazing control and community-based natural resource management more generally.

Removal of brushwood for firewood by community members and other aspects of long-term maintenance ➜ See above: perhaps also seeking funds to pay labourers and buy biocides.

Key reference(s): Harris JA, Birch P and Palmer J P (1996) *Land restoration and reclamation – Principles and Practices.* Addison Wesley Longman, England. 230 pp.

Contact person(s): Ms. Anuschka Barac, Principle Nature Conservation Scientist (Botanist), North West Province DACE – Mafikeng, South Africa; phone: ++27-18-389-5201, fax: ++27-18-389-5640; abarac@nwpg.gov.za


left: *Desho* grass *(Pennisetum pedicellatum)* and multipurpose trees established to increase productivity of grazing lands. (Daniel Danano)
right: Cut and carry of grass for stall-feeding from improved pasture. (Daniel Danano)

Improved grazing land management

Ethiopia – *Gitosh masheshal*

Rehabilitation of communal grazing lands, through planting of improved grass and fodder trees and land subdivision, to improve fodder and consequently livestock production.

This case study focuses on the highly populated, humid highland regions of Ethiopia that experience serious shortages of pasture. Due to rapid population growth, communal grazing areas are increasingly being converted into cropland. This has led to enormous pressure on the little remaining grazing land, through overstocking of dairy cows and oxen, and thus overgrazing, resulting in considerably decreased productivity.

Improved grazing land management is vital to increase food security and alleviate poverty, as well as to bring environmental rewards. To address these problems, the national SWC programme in Ethiopia initiated a grazing land management project over a decade ago. Implementation of the technology includes the initial delineating of the grazing land, and then fencing to exclude open access. This is followed by land preparation, application of compost (and, if necessary, inorganic fertilizers) to improve soil fertility, then planting of improved local and exotic fodder species, including multipurpose shrubs/trees such as *Leucaena sp.* and *Sesbania sp.* and the local *desho* grass *(Pennisetum sp.)*. *Desho* has a high nutritive value and regular cuts are ensured. It is planted by splits, which have high survival rates and establish better than grasses which are seeded. Other grass seeds, as well as legumes, including alfalfa (lucerne: *Medicago sativa)* and clovers in some cases, are mixed with fodder tree seeds and then broadcast.

Maintenance activities such as weeding, manuring and replanting ensure proper establishment and persistence. Fodder is cut and carried to stall-fed livestock. Once a year, grass is cut for hay, which is stored to feed animals during the dry season. Experience shows that such grazing land is best managed when individually owned and used. In the study area, the community has distributed small plots (<0.5 ha) of communal grazing land to individual users to develop, manage and use.

The overall purpose of the intervention is to improve the productivity of grazing land and control land degradation through the introduction of productive techniques and improved fodder species, which consequently improve livestock production. Commercialisation of animals and marketing of their products increases the income of farmers. The government provides technical assistance, close follow-up, and some inputs for initial establishment. Land users are trained in compost/manure application, planting of seeds, splits and seedlings, and general maintenance.

Location: Chencha, Ethiopia
Technology area: 20 km^2
SWC measure: agronomic, vegetative and management
Land use: grazing land (before), mixed: silvo-pastoralism (after)
Climate: humid
WOCAT database reference: QT ETH26
Related approach: Local level participatory planning approach (LLPPA), QA ETH25 (p 321)
Compiled by: Daniel Danano, Addis Abeba, Ethiopia
Date: July 2003, updated October 2004

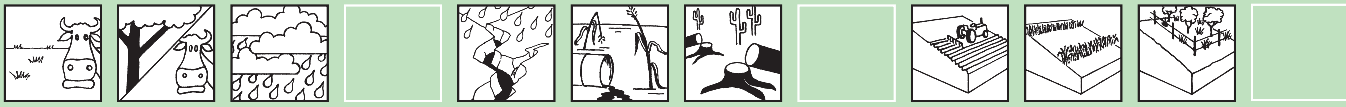
Editors' comments: Rehabilitation of communal grazing lands is both a technical and social challenge. Here is a promising example from Ethiopia that is spreading quickly. The key is subdivision of land into individual plots where cut-and-carry of grass and stall-feeding of livestock is practiced. This is only a possible option, however, where rainfall is favourable.

Classification

Land use problems

Population growth has resulted in a substantial reduction in land holdings (<0.5 ha per family) and this in turn has led inevitably to encroachment onto communal grazing lands for cultivation. Livestock numbers on the other hand have remained unchanged, and this has led to overstocking of the few areas left. Livestock production, which accounts for 40% of the average household income, is thus reduced and farmers' income declines correspondingly.

Land use | **Climate** | **Degradation** | **SWC measures**



extensive grazing (before) | silvo-pastoral: cut-and-carry, legumes, trees (after) | humid (local term: *wett dega)* | water erosion: loss of topsoil, gully | chemical: fertility decline | vegetation: reduced cover and quality (overgrazing) | agronomic: compost/manure application | vegetative: dispersed grasses and trees | management: change of intensity level

Technical function/impact

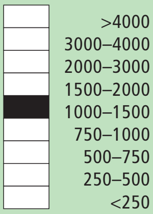
main:
- improvement of ground cover
- control of dispersed runoff
- increase in soil fertility

secondary:
- increase of infiltration
- improvement of soil structure
- control of concentrated runoff

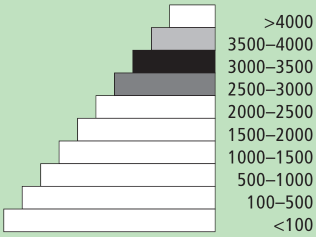
Environment

Natural environment

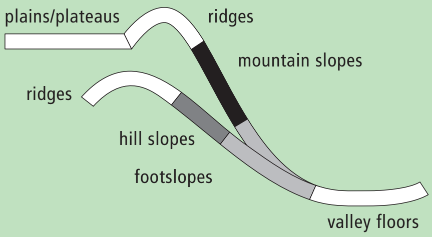
Average annual rainfall (mm)



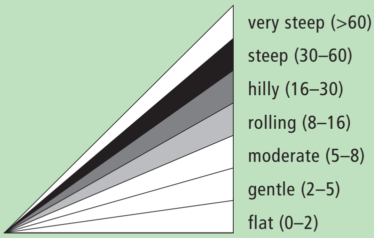
Altitude (m a.s.l.)



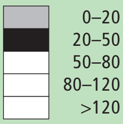
Landform



Slope (%)



Soil depth (cm)

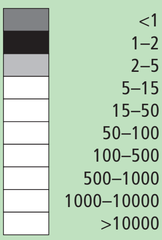


NB: soil properties before SWC

Growing season: 210 days (March to September)
Soil fertility: mostly medium, partly low
Soil texture: medium (loam)
Surface stoniness: mostly some loose stone, partly no loose stone
Topsoil organic matter: mostly medium (1–3%), partly low (<1%)
Soil drainage: good
Soil erodibility: mostly medium, partly high (on slopes)

Human environment

Mixed land per household (ha)



Land use rights: individual for cropland, open access (unorganised/communally used) for grazing land, except for the case study area where the rights to rehabilitated grazing land are given to individuals
Land ownership: state
Market orientation: subsistence (self-supply)
Level of technical knowledge required: field staff/extension worker: high, land user: moderate
Importance off-farm income: 10–50% of all income: source of off-farm income includes petty trade and weaving

Technical specifications for grazing land improvement: Splits of *desho* grass *(Pennisetum pedecillatum)* are planted in lines, using a hand hoe, after good seedbed preparation. Spacing between grass splits is 10 x 10 cm. The white line is a boundary between two households' plots (width of plot: 15–20 m). Trees are planted at irregular spacing (around 5 m apart), layout is not specified. (Daniel Danano)

Implementation activities, inputs and costs

Establishment activities

1. Delineation of the area to be conserved and establishment of a fence (mostly of deadwood, available before the onset of rains).
2. Subdivision of communal land into individual plots of 0.3–0.5 ha.
3. Planting material preparation in nurseries: grass splits *(desho: Pennisetum pedecillatum)* and tree seedlings (multipurpose trees, eg *Leucaena sp.* and *Sesbania sp.)*.
4. Good seedbed preparation with a hand hoe, sometimes with oxen plough depending on plot size (at the onset of the rains).
5. Compost/manure preparation. Material used includes animal manure, leaf litter, wood ash, soil and water.
6. Planting of grass splits and tree/shrub species in lines; sowing of grass seed by broadcasting (early in the rainy season).
7. Compost application (one month after planting).
8. Weeding.

Duration of establishment: 1 year

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (450 person days)	320	100%
Equipment		
- Tools (hand hoe)	5	50%
- Animal traction (1 pair of oxen, 4 days)	17	100%
Materials		
- Fencing with dead wood	55	100%
Agricultural		
- Grass splits (240,000 tillers)	450	0%
- Tree seedlings (1,000)	5	0%
- Fertilizers if applied (100 kg)*	60	100%
- Compost/manure (4,500 kg)	140	100%
TOTAL	**1035**	**56%**

*Farmers usually cannot afford fertilizers

Maintenance/recurrent activities

1. Cut-and-carry, to stall-fed animals, begins when fodder is ready (after 2–3 months growth). A sickle is used for cutting. In good seasons two to four cuts are possible (in April, June, August and October).
2. A final cut for hay is taken early in the dry season (end of October) when the grass has matured well.
3. Weeding each year.
4. Compost/manure application, mixed with soil, during seedbed preparation (only where plants have died and need replacement and fertilisation).
5. Enrichment planting and gap filling after a year, repeated each year.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (50 person days)	35	100%
Equipment		
- Tools (hand hoe, sickle)	4	100%
Materials		
- Fencing with dead wood	5	100%
Agricultural		
- Seeds (25 kg of *desho)*	30	100%
- Tree seedlings (250)	2	100%
- Fertilizers (25 kg)	15	100%
- Compost/manure (1,000 kg)	35	100%
TOTAL	**126**	**100%**

Remarks: Seedlings are given by the government for initial establishment. For further extension of area and replanting, the land users set up their own nurseries. After 2–3 years maintenance costs decrease substantially as the grass cover closes up and maintenance activities such as replanting/enrichment planting and compost application are reduced or cease. The local daily wage is about US$ 0.70 a day, but varies depending on the intensity of the work. In this calculation the standard rate has been applied.

Assessment

Acceptance/adoption

The 50 households who accepted the technology in the initial phase, did so with incentives. They were provided with planting materials (seeds, seedlings, grass splits) and hand tools.
The rate of spontaneous adoption is very high. At present over 500 households have taken up the technology and the total area covered is about 20 km^2.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	slightly positive*	very positive
maintenance/recurrent	positive	very positive

*Milk production compensates for some of the high investment costs (previously, production was low).

Impacts of the technology

Production and socio-economic benefits
- +++ increase in livestock production
- +++ increase in fodder production
- ++ increase in fodder quality
- ++ Increase in income (selling animals and their products)
- + wood production increase

Production and socio-economic disadvantages
- − − − initial dependence on incentives such as free seeds, seedlings, tools
- − − decrease in size of grazing plots due to land fragmentation
- − − labour constraints

Socio-cultural benefits
- +++ community institution strengthening
- +++ national institution strengthening (increased willingness of the national institution to assist and support organised farmers groups, ie community institutions)
- +++ improved knowledge SWC/erosion

Socio-cultural disadvantages
- none

Ecological benefits
- +++ soil cover improvement
- +++ increase in soil fertility
- +++ soil loss reduction
- ++ increase in soil moisture
- ++ biodiversity enhancement

Ecological disadvantages
- none

Other benefits
- +++ improvement in household diets (milk), improve health
- ++ increase in the availability of livestock products on the market lowers prices to the consumer

Other disadvantages
- none

Off-site benefits
- +++ reduced transported sediments
- ++ increase in stream flow in dry season
- ++ reduced downstream siltation
- ++ reduced downstream flooding

Off-site disadvantages
- − − grazing pressure has increased on remaining open access grazing land

Concluding statements

Strengths and ➜ **how to sustain/improve**

Availability of fodder (grass, hay, shrubs) in sufficient quantities, and all year round ➜ Increase the area under such development.

Reduction in soil loss and land degradation ➜ Maintain adequate cover by planting more grass.

Introduction of high yielding species as well as increase in land productivity and livestock production ➜ Introduce bigger variability of quality species and improve maintenance activities such as weeding and cultivation.

Improved diet: livestock by-products such as milk, butter and cheese are essential food items required by the households ➜ Keep on increasing/improving quantity/quality of livestock feed.

Increased income through commercialisation and marketing of animals and their by-products. Meets financial needs for paying taxes, school fees, clothes etc.

Increased national income due to export of animals and their products.

Weaknesses and ➜ **how to overcome**

At the initial stage of establishment it is very labour intensive ➜ Use of improved land preparation methods such as oxen ploughing.

Substantial cash for inputs, particularly seedlings, is required ➜ Produce seedlings of improved species and making compost in backyards.

Needs high fertilizer application ➜ Focus more on organic fertilizers.

High pressure on remaining grazing areas ➜ Keep animals in stall (stable) or park, at least part of the day and during the night, and introduce cut-and-carry more widely.

Key reference(s): Adane Dinku, *Chencha Wereda, Natural Resources Management Annual Report*, 2001 and 2002
Contact person(s): Daniel Danano, Ministry of Agriculture, PO Box 62758, Addis Ababa, Ethiopia; ethiocat@ethionet.et

left: Structural measures in the enclosed area, such as stone and earth bunds, speed up the rehabilitation process: they improve soil moisture and thus facilitate growth of natural vegetation or planted seedlings. (Daniel Danano)
right: Women planting local grass species on a severely degraded hillside in a recently closed area. (Daniel Danano)

Area closure for rehabilitation

Ethiopia – *Meret mekelel*

Enclosing and protecting an area of degraded land from human use and animal interference, to permit natural rehabilitation, enhanced by additional vegetative and structural conservation measures.

Area closure involves the protection and resting of severely degraded land to restore its productive capacity. There are two major types of area enclosures practised in Ethiopia: (1) the most common type involves closing of an area from livestock and people so that natural regeneration of the vegetation can take place; (2) the second option comprises closing off degraded land while simultaneously implementing additional measures such as planting of seedlings, mulching and establishing water harvesting structures to enhance and speed up the regeneration process. The focus of this case study is on this second type.

The selection of measures chosen for rehabilitation depends mainly on the land use type, and to a lesser extent on climate, topography and soil type. Degraded croplands with individual land use rights are normally treated with additional structural measures to retain soil moisture and trap sediment, and with agronomic measures to restore soil fertility. Open access grazing lands are closed for natural regeneration while partly treated with additional measures, and open access woodlands are simply closed. In the case study area 60% of the enclosed area is under treatment with additional conservation measures and 40% is under natural regeneration. First, the area to be closed is demarcated and protected with fencing, usually live fences, and a site guard may be assigned to further ensure protection. Structural measures such as micro-basins, trenches, and bunds that enhance water infiltration and soil moisture may be constructed to increase survival rate of vegetative material planted. Hillside terraces, spaced at a 1 m vertical interval with a width of 1 m are constructed on steep slopes (exceeding 20%). Nitrogen-fixing and multipurpose shrubs/trees (for fodder, fuel) such as *Acacia saligna, Sesbania sesban, Leucaena leucocephala* as well as local grass species such as napier *(Pennisetum purpureum)* and rhodes *(Chloris gayana)* are planted as additional measures for conservation.

The maintenance of area enclosures involves activities such as replanting, maintaining of fences, pruning of trees and weeding. After one year, cut-and-carry of grass for stall-feeding can be partly practiced – which is of economic benefit to the farmers. Rehabilitation normally takes about 7–10 years depending on the level of degradation and intensity of management. Land use is limited to selective cutting of trees, collection of dead wood and cut-and-carry of grass for livestock fodder. On individually owned enclosures land users start cutting trees after three years (for eucalyptus) and after 7–8 years (for other trees), while on communal land farmers are allowed to collect dead wood after 3–4 years, and the community decides about the use of trees.

Location: Bilate River Catchment (Rift Valley Lakes Basin), Alaba, South Ethiopia
Technology area: 20 km^2
SWC measure: management, vegetative, agronomic and structural
Land use: cropland and grazing land (before), mixed: silvo-pastoral (after)
Climate: subhumid, partly semi-arid
WOCAT database reference: QT ETH25
Related approach: Local level participatory planning approach (LLPPA), QA ETH25
Compiled by: Daniel Danano, Addis Abeba, Ethiopia
Date: July 2003, updated June 2004

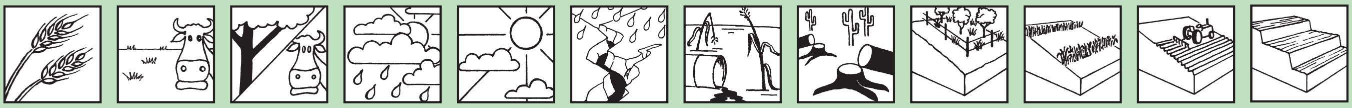
Editors' comments: Protecting degraded land against grazing is a common practice worldwide. In Ethiopia it is the second most important SWC practice after structural conservation measures. About 1.2 million hectares of degraded lands have been closed for rehabilitation in Ethiopia during the past three decades. As this case study shows, results are encouraging both in terms of effective protection and enhanced production.

Classification

Land use problems

Over 30% of the land in the study area is degraded, resulting in low crop yields and poor livestock production. Severe water erosion is the main cause of land degradation on all slopes, followed by fertility depletion due to intensive cultivation practices and overgrazing. Serious gully formation and a high sediment load in the Bilate River threaten Lake Abaya. Communal grazing lands, woodlands with open access, and cultivated lands on steep slopes without conservation measures are particularly affected. By tradition, land users in rural Ethiopia can own as many livestock as they wish, which encourages overstocking.

Land use | **Climate** | **Degradation** | **SWC measures**



Land use			Climate		Degradation			SWC measures			
annual crops: *Eragrostis tef*, barley, wheat (before)	extensive grazing (before)	silva-pastoral: cut-and-carry, trees (after)	subhumid	semi-arid	water erosion: topsoil/gully; off-site: sediment deposition	chemical: fertility decline (nutrient mining)	vegetation: reduced cover and quality (overgrazing)	management: land use change, enclosure, cut-and-carry	vegetative: dispersed trees/ shrubs, over-sowing grasses	agronomic: mulching	structural: micro-basins, terraces, bunds (opt.)

Technical function/impact

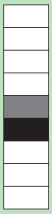
main:
- improvement of ground cover
- increase of infiltration
- control of dispersed runoff
- control of concentrated runoff
- increase in soil fertility

secondary:
- increase water stored in soil
- less sediment deportation

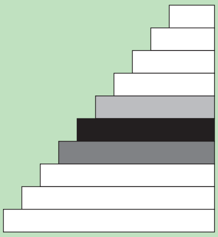
Environment

Natural environment

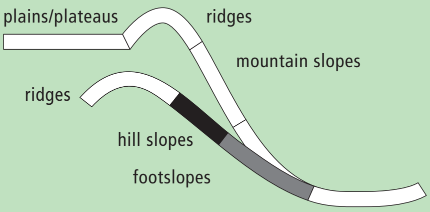
Average annual rainfall (mm)



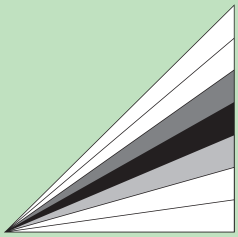
Altitude (m a.s.l.)



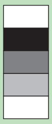
Landform



Slope (%)



Soil depth (cm)



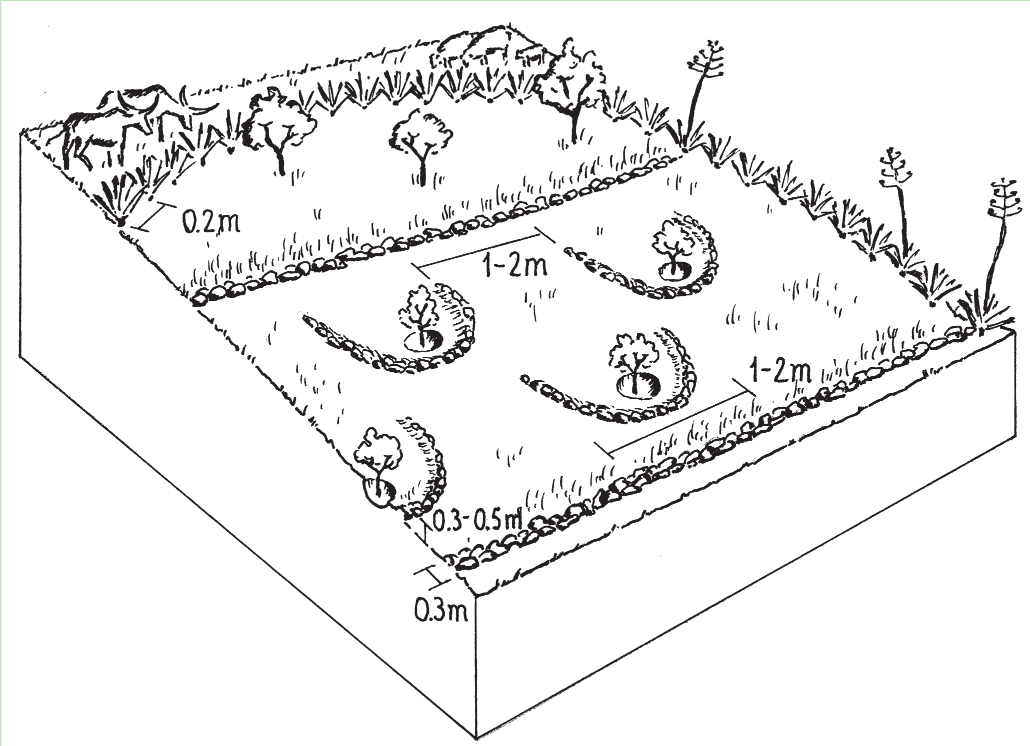
NB: soil properties before SWC

Growing season: 120 days (June to September)
Soil fertility: mostly very low
Soil texture: mostly medium (loam), partly coarse (sandy loam)
Surface stoniness: mostly no loose stone, partly some loose stone
Topsoil organic matter: mostly low (<1%), partly medium (1–3%) and high (>3%)
Soil drainage: good
Soil erodibility: very high

Human environment

Mixed land per household (ha)

Land use rights: open access on woodlands and grazing lands (communal land use rights), individual on cropland
Land ownership: state
Market orientation: cropland: 90% subsistence (self-supply) and 10% commercial (market), grazing land and woodland: subsistence
Level of technical knowledge required: field staff/extension worker: moderate, land user: moderate
Importance of off-farm income: <10% of all income: from petty trade, weaving, etc



Technical drawing
Rehabilitation of degraded land based on enclosure with live fence. Natural regeneration of vegetative cover is supported by water harvesting structures and planting of nitrogen-fixing/multipurpose shrubs and trees as well as local grass species. On steeper slopes hillside terraces may be established.

Implementation activities, inputs and costs

Establishment activities

1. Marking the boundary and establishment of live fences: digging pits and planting sisal *(Agave sisalana)*, early rainy season (before June).
2. Construction of structural measures such as micro- basins, trenches, bunds or hillside terraces before rains.
3. Planting of trees *(Eucalyptus spp.*, *Grevillea robusta)* as well as nitrogen fixing shrubs: *Acacia saligna*, *Sesbania sesban*, *Leucaena leucocephala* (early rainy season).
4. Oversowing/interplanting with local grass species: napier grass *(Pennisetum purpureum)*, rhodes grass *(Chloris gayana)* (early rainy season).
5. Mulching with tree leaves/grass around newly planted trees, before rains when there is less vegetative cover.

Duration of establishment: 2 months

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (250 person days)	175	50%
Equipment		
- Tools (local digging hoe, spade, shovel)	25	100%
Materials		
- Earth	0	
- Stones	0	
Agricultural		
- Seeds (grass, 100 kg)	40	0%
- Seedlings (2,000 trees)	150	0%
Others		
- Site guard (3kg grain/ha/year)	1	100%
TOTAL	**390**	**30%**

Maintenance/recurrent activities

1. Repairing breaks in structures before rains.
2. Replanting/gapping up live fence and trees during rains in the early establishment period.
3. Harvesting grass during rainy season.
4. Pruning of trees in the dry season.
5. Weeding after rains.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (50 person days)	35	100%
Equipment		
- Tools (local digging hoe, spade, shovel)	5	100%
Agricultural		
- Seeds (grass, 25 kg)	10	0%
- Seedlings (500 trees)	40	0%
Others		
- Site guard (3kg grain/ha/year)	1	100%
TOTAL	**90**	**45%**

Remarks: Labour for establishment activities: 250 person days per ha for structural measures and planting of trees, plus guarding. Labour for maintenance: 50 person days for replanting/weeding. A common daily wage is US$ 0.70 (= 6 Ethiopian Birr), however in this case the site guards were given 3 kg of grains per ha per year. They can control over 200 ha.

Assessment

Acceptance/adoption

- In the early stages of area closure implementation all land users accepted the technology with incentives (work tools and food). In the study area there were around 300 families.
- After a year, more than 90% of them continued activities without food-for-work support. At present almost all the beneficiary households accept the technology due to its benefits: fodder (grass, cut-and-carry), wood for fuel/construction.
- Food-for-work incentives were provided by the project for people participating in the initial establishment of structural measures (trenches, micro-basins), pitting and planting activities.
- Adoption rate has considerably increased owing to improved ownership feeling and immense benefits obtained through the practice. However, if labour-intensive structural measures are required people rely on food-for-work incentives.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	positive*	very positive
maintenance/recurrent	positive	very positive

*cut-and-carry

Impacts of the technology

Production and socio-economic benefits

- +++ fodder production/quality increase (cut-and-carry of grass)
- ++ wood production increase
- ++ farm income increase (selling grass/wood)

Socio-cultural benefits

- +++ community institution strengthening
- +++ improved knowledge SWC

Ecological benefits

- +++ soil cover improvement (>80%)
- +++ increase in soil moisture (>50%)
- +++ increase in soil fertility (increased organic matter, nitrogen fixing shrubs)
- +++ soil loss reduction (initially 50% reduction, after 2–3 years >90% reduction)
- +++ biodiversity enhancement (recovering disappearing local species)

Off-site benefits

- +++ ground water recharge and increased stream flow in dry season
- +++ reduced river pollution
- +++ reduced transported sediments and downstream siltation
- +++ reduced flood risk downslope

Production and socio-economic disadvantages

- – – – reduced grazing area/high pressure on remaining grazing areas
- – – increased labour constraints
- – increased input constraints

Socio-cultural disadvantages

- – unequal share of benefits (some illegal cutting of vegetation is involved)

Ecological disadvantages

- – soil erosion increase (locally)
- – waterlogging
- – competition between naturally regenerating and oversown (grass) species

Off-site disadvantages

- – – – increased pressure on other grazing lands which are not closed

Concluding statements

Strengths and ➜ how to sustain/improve

Reduction of on-site and off-site land degradation, reclamation of degraded non-productive land (regenerating fertility) ➜ Strengthen maintenance and protection to increase biomass production of enclosure.

Fodder shortage is reduced through cut-and-carry of grass in enclosures (after 1 year) ➜ Introduce more productive and nutritious grass/legume species.

Collection of dead wood from enclosures (after 3–4 years) mitigates fuelwood shortage ➜ Introduce alternative fast growing multi-purpose tree species such as *Grevillea robusta* (fodder for smallstock in very dry periods).

Cutting wood for construction of houses and wooden farm implements (after 7–8 years) ➜ Continue planting of multipurpose trees.

Increased honey production through increased bee activity in enclosures ➜ Improve beehives, 'bee feed' (bee-friendly plants), and access to market.

Emergence of springs, which have disappeared due to deforestation/land degradation ➜ Maintain proper ground cover to improve infiltration and percolation of rainwater.

Income generation: farmers sell grass/wood collected from area enclosures; they make profit despite seven years enclosure ➜ Better management of planted grass, making of hay, improve market systems.

Weaknesses and ➜ how to overcome

On highly eroded areas and in areas with low rainfall the survival rate of trees and shrubs is low and as a result the benefits only come after a very long period. This situation becomes unacceptable to the land users ➜ Select suitable local and exotic multipurpose tree/shrub species adapted to the local conditions (*Acacia spp.*, *Eucalyptus spp.*, *Grevillea robusta* etc). Construct water-harvesting structures (trenches, micro-basins). Raise awareness among land users through meetings and training.

Investment costs are rather high for land users ➜ Credits, loans, cooperatives.

Inequitable share of benefits ➜ Awareness should be increased through enhancing the LLPP approach (see related approach on the following pages).

Key reference(s): Chadokar PA (1985) *Multipurpose Plant Species for Soil and Water Conservation. Assistance to Soil and Water Conservation Programme.* ETH/81/003 ▪ Betru Nedassa (1995) *Biological Soil Conservation Measures.* Land Rehabilitation and Reforestation Project. Project 2488 MOA/WFP

Contact Person(s): Daniel Danano, Ministry of Agriculture, PO Box 62758, Addis Ababa, Ethiopia; ethiocat@ethionet.et

left: Participatory planning meeting underway in the community of Alaba, involving farmers and field technicians. (Daniel Danano)
right: Field activities for area closure in Alaba: women's participation in the implementation phase is more than 50%, however decisions are principally taken by men. (Daniel Danano)

Local level participatory planning approach

Ethiopia

An approach used by field staff to implement conservation activities, involving farmers in all stages of planning, implementation and evaluation.

The Local Level Participatory Planning Approach (LLPPA) starts with the selection of communities based on needs and problem assessment. Then development committees are formed, consisting of one or two technical staff and seven to eight farmers. They are elected by the community through a general assembly of land users.

The development committees plan and coordinate development activities. They first conduct a survey of the biophysical and socio-economic conditions of the area. Then problems are identified and prioritised with the community members through participatory rural appraisal (PRA). Land use analysis, followed by the definition of objectives, identification of development options and selection of appropriate SWC interventions, is carried out on a consultative basis. Targets for achievements are established, and resources and inputs are determined. Finally the development committee prepares a work plan. The plan for SWC activities is then submitted to the community leaders, and the approval of the plan is made by the general assembly of land users, in consultation with the technical field staff.

The development committee is given the responsibility for organising implementation. The beneficiaries actively participate in this implementation, in maintenance and in utilisation of the assets created, by contributing their labour and resources. Whenever required technical field staff give technical advice during implementation of development activities – area closure for rehabilitation in this case. Participatory monitoring and evaluation of activities is another important element of the approach.

The main purpose of LLPPA is to enhance farmers' involvement in all steps of the development process, from the initial stages of planning, to implementation of the activities, and in the evaluation of the achievements. A good relationship between land users and field workers, and acceptance as well as support of the development activities by the land users are fundamental prerequisites for fruitful implementation and maintenance of SWC measures.

Location: Alaba, South Ethiopia, Ethiopia
Approach area: 20 km^2
Land use: cropland, grazing land, forest
Climate: subhumid, partly semi-arid
WOCAT database reference: QA ETH25
Related technology: Area closure for rehabilitation QT ETH25, Improved grazing land management QT ETH26
Compiled by: Daniel Danano, Addis Ababa, Ethiopia
Date: December 2002, updated June 2004

Editors' comments: Having learned from past mistakes, where solutions were imposed, a participatory approach to conservation has emerged in Ethiopia and is supported by the Ministry of Agriculture in collaboration with the World Food Programme. The LLPPA is the planning tool used in the entire country – and is popular with both communities and development agents.

Problem, objectives and constraints

Problem

Difficulties in attaining sustainable development through area closures for rehabilitation are due to:

- lacking sense of ownership: land users feel that development attained in enclosures belongs to the government
- lack of awareness about land degradation problems, and the values of conservation measures
- reluctance to maintain activities and protect assets created
- shortage of livestock feed, fuelwood and construction material
- increasing land degradation problems (on- and off-site) due to improper land use and poor farming practices
- food insecurity and poverty

Objectives

- encourage the involvement of the beneficiary population and the technical personnel in the whole development process (ie initial planning, implementation, monitoring/evaluation) so that sustainable development, leading to improved living conditions is attained
- reduce land degradation (gully formation and landslides, sediment flow into downstream water harvesting and storage tanks) and enhance natural regeneration and fertility of soils in order to increase the productivity of degraded areas: provide livestock feed, fuel and construction wood, and higher crop yields

Constraints addressed

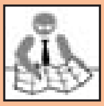
Major	Specification	Treatment
Lack of awareness	Lack of awareness about soil degradation and appropriate management practices.	Awareness raising through training and awareness creation seminars.
Technical	Cultivating steep slopes due to overpopulation and land subdivision (holdings of 0.25–0.5 ha/household).	Apply appropriate land use practices according to land potential and apply SWC practices. Alternative income generation.
Technical	Deforestation: illegal cutting of trees due to lack of fuel/ construction wood, letting livestock into closed areas. Lack of management plans for planted trees.	Training and awareness raising on how to assume responsibilities to protect the assets developed. Plant trees in woodlots and provide alternative energy sources (eg kerosene).
Technical	Overgrazing of sloping lands resulting in severe gullies (on >50% of the land) and landslides. No controlled grazing.	Practice zero grazing, cut-and-carry and/or controlled grazing.
Minor	**Specification**	**Treatment**
Financial	Lack of financial resources: >90% of the community members are poor.	Provision of hand tools by the project. Provide training to raise awareness about benefits.
Policy	Land tenure (land is state and public property).	Assure land user rights and provide certificates.

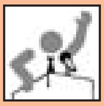
Participation and decision making

Target groups


Land users


SWC specialists/ extensionists


Planners regional/national


Politicians/ decision makers

Approach costs met by:

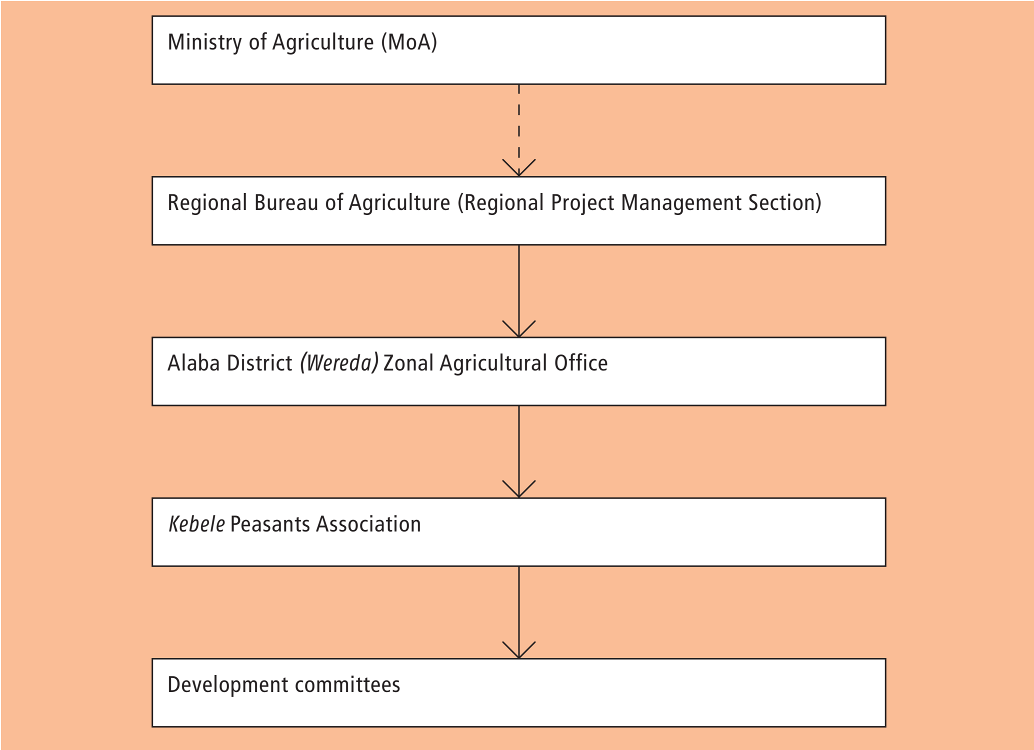
International agency (World Food Programme, WFP)	40%
National government	10%
Community/local	50%
	100%

Decisions on choice of the technology: Made by the community/land users in consultation with SWC specialists/extension workers.
Decisions on method of implementing the technology: Made by the community members based on the plan of action prepared by the development committee (comprising farmers and technical staff).
Approach designed by: National and international experts.

Community involvement

Phase	Involvement	Activities
Initiation	interactive	self-motivation: few farmers take the initiative
Planning	interactive	initiated by technical staff, motivated by the development committee: identify problems, prioritise them and seek solutions
Implementation	interactive and payment/incentives	community is responsible for implementation, some incentives are given for motivation: farmers are organised into working teams
Monitoring/evaluation	passive	initiated by extension agents, annual evaluation during community meeting
Research	none	none

Differences in participation of men and women: In the approach area women's participation is more than 50% (and this is increasing) in the implementation of SWC measures. However, women are still not playing a sufficient role in decision making, due to cultural norms/values.



Organogram
The **Regional Bureau of Agriculture** provides the technical support and coordinates the programme at the regional level. It is linked but not directly accountable to MoA.
The **Zonal office** participates in the monitoring and evaluation of the activities and also provides technical advice.
Kebele is the lowest administrative unit formed of different villages. Several *Kebeles* make a *Wereda*.
Development committees are assigned by the general assembly and comprise members from farmers/community and the development agents working in the area.

Extension and promotion

Training: Extension workers and *Wereda* district soil conservation specialists are given regular training on LLPPA and area closure management. Community leaders and the development committee are trained every year on the various techniques of soil conservation. Two to three day awareness creation seminars are held for the community in general. The awareness creation programme played a significant role in convincing beneficiaries to actively participate in the SWC programme. Training for community leaders has helped them to improve their leadership and coordinating capacities. The training given to field staff has improved their skills and hence enabled them to effectively implement the programme.
Extension: Key elements of the extension approach are: training, demonstration of the technology and provision of the necessary inputs for application. The extension has been very efficient, farmers have accepted the technology and the impact is visible. The extension service has been adequate, due to support by MoA and donor agencies such as the World Food Programme.
Research: Very little work is done with regard to research in area closure and LLPPA.
Importance of land use rights: Area closures would provide better opportunities and advantages to the beneficiaries if hillsides were distributed to individual farmers, and if they were provided with user right certificates for the plots developed by them. In that case each farmer would give more attention to the protection and maintenance of assets developed.

Incentives

Labour: Since farmers participating in the construction of structural measures are poor and the activities are labour intensive, they are given 3 kg of grain/person day as an incentive (food-for-work). Site guards protect large areas (from 200 ha to 1,000 ha They are often landless and hence are also rewarded with 3 kg of grain/ha/year. Nevertheless, voluntary labour contribution by the community for activities such as planting, weeding and other management activities is more than 50%.
Inputs: Seed and seedlings are provided free of charge.
Credit: No credit is provided.
Support to local institutions: There is considerable support to local institutions: they get more money through selling trees and grass from enclosures, which in turn strengthens the institutions financially and socially. The development committee continues to exist after the project phases out. The same committee could take up other development issues.
Long-term impact of incentives: Long-term impacts are uncertain. The beneficiaries need to be made better aware of the fact that incentives are merely to encourage their initial participation. Only then can dependency be avoided.

Monitoring and evaluation

Monitored aspects	Methods* and indicators
Bio-physical	change in slope, sediment trapped in ditch (behind the structures), soil depth, ground cover, amount of biomass, rate of regeneration of local trees and shrubs, productivity of livestock, spring water discharge, soil loss, runoff
Technical	quality of structural measures (determined by frequency of maintenance required), survival rate of planted trees
Socio-cultural	community participation in planning and implementation, trends in (a) the participation of poor and rich farmers, (b) women's participation, (c) decision making between men and women
Economic/production	amount of grass produced, household income from enclosures, availability and production of wood for fuel, increase in soil fertility
Area treated	area treated by structural and vegetative measures
No. of land users involved	land users participating in planning, implementation, decision making
Management of approach	number of land users participating in the implementation, land users participating in maintenance activities, type of activities undertaken on voluntary basis

* All indicators are measured once a year by the technical staff assigned to the sites in consultation with the farmers. The project undertakes such observations in order to evaluate the impact of the project interventions.

Impacts of the approach

Changes as result of monitoring and evaluation: As a result of monitoring and evaluation improvements in quality of micro-basins and/or trenches, for example, led to better attaining the standards of technology design initially proposed.
Improved soil and water management: Applied conservation measures in areas under closure considerably improve soil and water management, resulting in an increase in soil depth, ground cover, biomass, and in survival rates of planted trees and forage shrubs.
Adoption of the approach by other projects/land users: There has been a high adoption rate (both with and without project support) of the approach as well as the technology – as can be observed in nearby communities.
Sustainability: Land users can continue without support – and are actually doing so where the support for area closure has already stopped.

Concluding statements

Strengths and ➜ how to sustain/improve
Involvement of land users in decision making ➜ More work on empowerment/land use rights.
Encourages working in a team ➜ Further strengthen team organisation.
Application of appropriate land use practices contributing to sustainable development ➜ Further improvement of productivity by encouraging land users to make maximum use of development achievements.
Rapid benefits obtained: provision of livestock fodder (through cut-and-carry), fuel wood and construction material ➜ Expand use of improved planting materials.

Weaknesses and ➜ how to overcome
Dependence on incentives ➜ Improve the methods of using incentives: incentives should be understood as a means for promoting participation rather than as a payment.
Low sense of ownership ➜ Distribute the enclosures to individual land users.
The involvement of rich members of the community in the development committee is low ➜ Development committee needs to be represented by different target groups.
Site guards are given incentives by the project ➜ The community will have to assume this responsibility in future.

Key reference(s): Escobedo et al (1990) *The minimum planning procedures for soil and water conservation in Ethiopia. Assistance to Soil Conservation Project.* ETH016, FAO ▪ Voli C et al (1999) *The Local Level Participatory Planning Approach for the soil and water conservation programme in Ethiopia.* MOA/WFP
Contact person(s): Daniel Danano, Ministry of Agriculture, PO Box 62758, Addis Ababa, Ethiopia; ethiocat@ethionet.et

left: Drip irrigation systems considerably improve water use efficiency: The improved black *pepsee* pipes deliver water directly to the chilli pepper plants. (Shilp Verma)
right: Components of *pepsee* mirco-irrigation system: pipes and joints. (IDEI)

Pepsee micro-irrigation system

India – *Pepsee*

A grassroots innovation that offers most of the advantages of conventional micro-irrigation at a much lower establishment cost.

The continued expansion of irrigation in India is causing increasing water shortages. This may be compounded by the potential effects of climate change. Drip irrigation – delivering small amounts of water directly to the plants through pipes – is a technology that could help farmers deal with water constraints. It is considerably more efficient in terms of water use than the usual open furrows or flood irrigation.

In West Nimar, Madhya Pradesh, droughts, diminishing groundwater, limited and erratic power supply coupled with poverty, compelled farmers to look for a technology that would enable them to irrigate their crops (mainly cotton) within these constraints. They tried out several cost-saving options such as using old bicycle tubes instead of the conventional drip irrigation pipes. But nothing caught on – until about five years ago – when a local farmer experimented with thin poly-tubing normally used for frozen fruit-flavoured 'lollypops' called *pepsee.* It spread to neighbouring cotton farmers, and its popularity has meant that today pepsee has become widespread in the region. *Pepsee* micro-irrigation systems slowly and regularly apply water directly to the root zone of plants through a network of economically designed plastic pipes and low-discharge emitters. Technically speaking *pepsee* systems use low density polythene (65–130 microns) tubes which are locally assembled. Being a low pressure system the water source can be an overhead tank or a manually operated water pump to lift water from a shallow water table.

Such a system costs less than US$ 40 per hectare for establishment. But the tubes have a short life span of one (or two) year(s); an equivalent standard buried strip drip irrigation system amounts to between five and ten times the initial cost. The latter would, however, last for five to ten years. The critical factor is the low entry cost. *Pepsee* systems thus act as 'stepping stones' for poor farmers who are facing water stress but are short of capital and cannot afford to risk relatively large investment in a technology which is new to them, and whose returns are uncertain. The technology is today available in two variants: the original white *pepsee* and a recently introduced black *pepsee* which is of slightly better quality. Recently, a more durable and standardised version of *pepsee,* given the brand name 'Easy Drip', has been developed and promoted by a local NGO, IDEI (see corresponding approach). Easy Drip is one product within a set of affordable micro-irrigation technologies (AMIT) promoted by IDEI.

Location: West Nimar, Madhya Pradesh, India
Technology area: no information
SWC measure: structural and management
Land use: cropland
Climate: semi-arid
WOCAT database reference: QT IND15
Related approach: Market development and support, QA IND15
Compiled by: Shilp Verma, Vallabh Vidyanagar, Gujarat, India
Date: January 2005, updated March 2006

Editors' comments: In India, around a third of all cropland is irrigated, and water shortages threaten production. Here is a case of a low cost innovation which increases efficiency of water use. Irrigation is generally not covered by WOCAT, but this case study demonstrates that (a) water use efficiency and cost are crucial elements in irrigated systems and (b) irrigation can be described and evaluated in a similar way to rainfed systems through WOCAT.

Classification

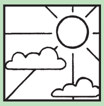
Land use problems

Acute groundwater stress associated with lowering of the groundwater table limits water for irrigation, coupled with poverty and reluctance to risk investing in relatively expensive – but efficient – drip irrigation systems.

Land use

annual crops: mainly cotton

Climate

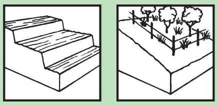


semi-arid

Degradation

water degradation: depletion of groundwater

SWC measures



structural: irrigation infrastructure

management: from furrow to drip irrigation

Technical function/impact

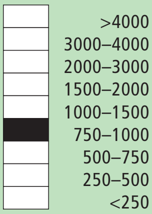
main:
- water supply
- improved water-use efficiency (reduced loss through evaporation), well directed, selective and targeted irrigation

secondary:
- ensures constant water supply in the crucial phase of germination, higher germination and establishment rate
- improvement of ground cover: better crop growth and greater area under irrigation

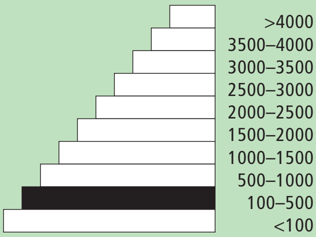
Environment

Natural environment

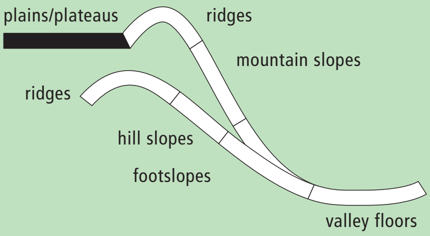
Average annual rainfall (mm)



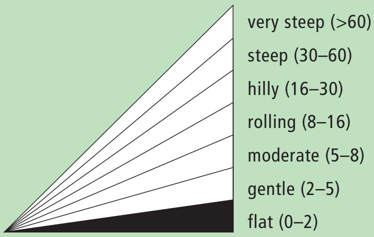
Altitude (m a.s.l.)



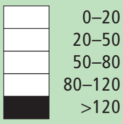
Landform



Slope (%)



Soil depth (cm)

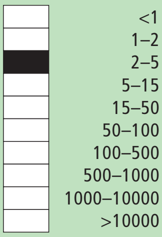


NB: soil properties before SWC

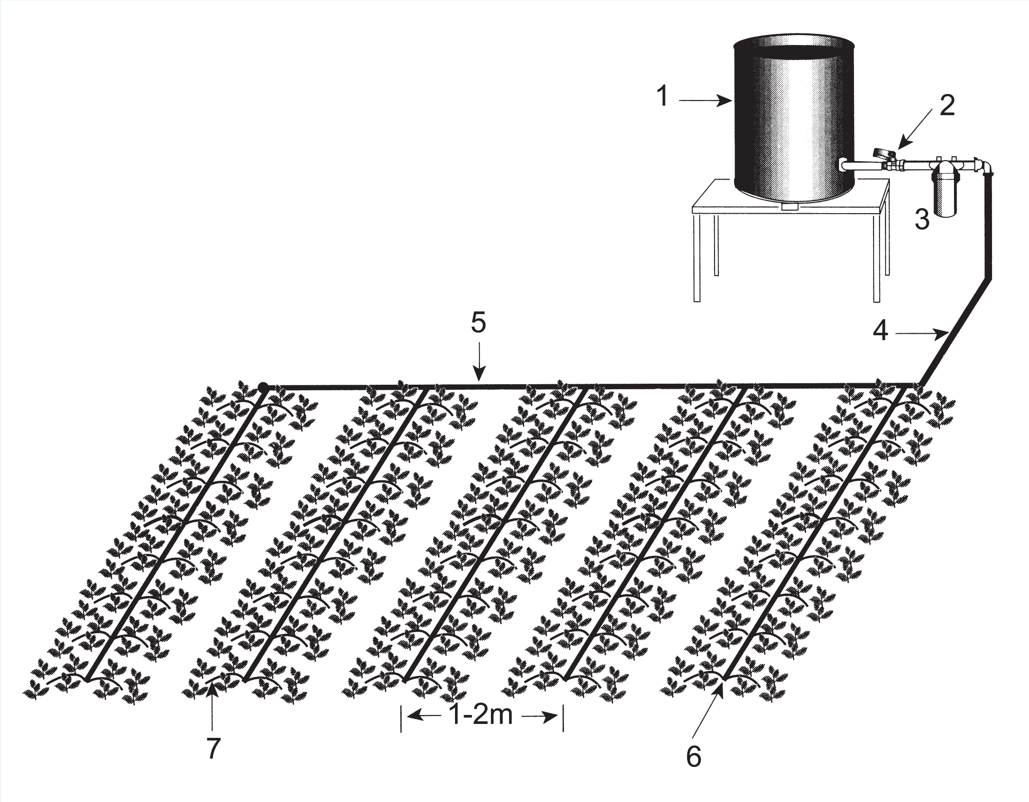
Growing season: 150 days (May to October) and120 (November to March)
Soil fertility: variable
Soil texture: mostly fine (clay): black cotton soil; mostly vertisols, partly inceptisols and entisols
Surface stoniness: some loose stone
Topsoil organic matter: medium (1–3%)
Soil drainage: poor
Soil erodibility: medium

Human environment

Cropland per household (ha)



Land use rights: individual
Land ownership: individually owned/ titled
Market orientation: mostly commercial farming
Level of technical knowledge required: land user: low – moderate
Importance of off-farm income: very low <10% of all income



Technical drawing
Components of *pepsee*/'Easy Drip' irrigation systems are described below.
Source: Sijali IV 2001, Drip irrigation, RELMA, Nairobi

1) Water source: For *pepsee*, commonly a water pump (in most cases electric) is used to lift water from a well and directly feed the irrigation system. Alternatively, an overhead tank (minimum of 1 m above ground level) can be used for smaller systems up to 400 m^2 area.
2) Control valve: valve made of plastic or metal to regulate pressure and flow of water into the system
3) Filter: Strainer filter to ensure that clean water enters into the system (optional in *pepsee* systems).
4) Mainline: 50 mm PVC (Polyvinyl chloride) or PE (Polyethylene) pipe to convey water from source to the sub-main.
5) Sub-main: PVC/PE pipe to supply water to the lateral pipes which are connected to the sub-main at regular intervals.
6) Lateral: PE pipes along the rows of the crops on which emitters are connected directly. Pipe size is 12–16 mm.
7) Emitters/micro-tubes: Device through which water is emitted at the root zone of the plant with required discharge. In *pepsee* farmers simply make pin holes in the plastic tube for water to pass. Easy Drip has inbuilt drippers/outlets along the lateral line which give a continuous wetting strip. It is mainly used for row crops.

Pepsee uses cheap, recycled plastic tubes instead of the rubber pipes used in conventional drip irrigation kits. Space between emitters is variable, for cotton cultivation it is commonly 1.2 m (between plants, within and between rows). There is (usually) one emitter for each plant. Different sizes of valves, mainlines, etc, are available, depending on flow rate of water in the system. Additional components are joints (connectors) and pegs (used to hold the lateral and micro-pipes in place).

Implementation activities, inputs and costs

Establishment activities

1. Installation of water pump, control valve, filter (optional) and PVC piping (main/sub-main and lateral pipes).

For details see technical drawing above.
All activities are carried during the dry season.
Duration of establishment: a few weeks

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (4 person days)	4	100%
Materials		
- Lateral piping (*Pepsee* tube)	17	100%
- Main/sub-main PVC piping	34	100%
- Other parts (valves, joints etc)	40	100%
TOTAL	**95**	**100%**

Maintenance/recurrent activities

1. Re-installation of lateral *pepsee* tubes (every 1–2 years).

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (4 person days)	4	100%
Materials		
- Lateral piping (*Pepsee* tube)	17	100%
TOTAL	**21**	**100%**

Assessment

Acceptance/adoption

No detailed information available regarding spread – though this is estimated to be several thousand farmers within West Nimar. All adoption has been spontaneous, without incentives, and the group which has adopted best comprises those who were previously using furrow irrigation. A large number of *pepsee* adopters are the resource poor farmers but rich farmers have also adopted *pepsee.*

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	positive	positive
maintenance/recurrent	positive	positive

Impacts of the technology

Note: compared with standard flood irrigation

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ greater irrigated area with same amount of water	−− higher labour requirement
++ higher yields	

Socio-cultural benefits	Socio-cultural disadvantages
++ poverty reduction	none
++ more farmers able to irrigate their land	
+ drip irrigation confers the image of a progressive farmer	

Ecological benefits	Ecological disadvantages
+++ improved water use efficiency	−− more land brought under irrigation

Off-site benefits	Off-site disadvantages
none	none

Concluding statements

Strengths and ➜ how to sustain/improve

- Low initial investment and recurrent costs: risk in adopting new system limited ➜ Keep costs of new variations of pepsee low.
- There are significant benefits in terms of reduced water use per unit of land, and in terms of yield per unit land area as well.
- Few extra skills required to implement and operate the system.
- An eventual shift to conventional drip system is feasible: pepsee acts as a 'stepping stone' ➜ Promote improved drip systems where pepsee has taken off.
- Higher yields, better quality, higher germination rate, lower incidence of pest attack; facilitates pre-monsoon sowing.

Weaknesses and ➜ how to overcome

- *Pepsee* is based on drip pipes which have a limited life: delicate and cannot withstand high pressure ➜ Develop/use stronger piping materials such as 'Easy Drip'.
- The increased water use efficiency has allowed an expansion in the area irrigated – which has used up the water 'saved'.
- *Pepsee* systems require replacement of lateral pipes each year and thus incur recurrent input and labour costs ➜ Develop/use stronger piping materials such as 'Easy Drip'.

Key reference(s): Verma S, Tsephal S. and Jose T (2004) *Pepsee* Systems: grassroots innovation under groundwater stress. *Water Policy,* 6, pp. 303–318. ■ http://www.iwaponline.com/wp/00604/wp006040303.htm
Contact person(s): Shilp Verma, IWMI-Tata Water Policy Program, International Water Management Institute, Elecon Complex, Anand Sojitra Road, Vallabh Vidyanagar, Gujarat 388120, India; s.verma@cgiar.org ■ Amitabha Sadangi, International Development Enterprises – India, C 5/43, Safdurjang Development Area (1st & 2nd Floor), New Delhi 110016, India; amitabha@ide-india.org

left: Demonstrating the technology: 'A satisfied customer is the best spokesperson for generating demand'. This is the basic philosophy of IDEI. (IDEI)
right: The assembler procures components from different manufacturers/suppliers and prepares a final product. (IDEI)

Market support and branding for input quality

India – *Krishak Bandhu*

Market development and support through use of a brand name – *Krishak Bandhu* ('the farmer's friend') – to help ensure quality amongst manufacturers and suppliers of drip irrigation equipment.

Poor smallholder farmers are generally slow in adopting new technologies, especially when such decisions require relatively large initial investments which only yield returns over a long period of time. Even when subsidies are made available, the high transaction costs act as a hindrance. After more than three decades of promotion by government, and despite subsidies as high as 90%, conventional drip irrigation technology remains exclusively popular amongst 'gentlemen' (better-off) farmers in India. Since it was first introduced in the 1970s, the total area under drip irrigation expanded sluggishly from 1,500 ha in 1985 to 225,000 ha in 1998, which is tiny compared to an estimated national potential of 10.5 million hectares.

IDE, India (IDEI) is an NGO dedicated to troubleshooting such problems through a unique market development approach. IDEI promotes simple, affordable, appropriate and environmentally sound technologies for poor smallholder farmers through private marketing channels, under the brand name *Krishak Bandhu.* Donor resources are accessed by IDEI to stimulate markets by creating demand for such technologies and by ensuring an efficient supply chain for the equipment. The key to the IDEI approach lies in its adoption and application of commercial business principles as well as in its path of socio-economic development as a tool to sustainability of programmes. IDEI seeks to create a strong and continuing demand by motivating and nurturing an effective supply chain (including manufacturers, dealers and assemblers of micro irrigation equipment). In West Nimar, Madhya Pradesh (as in the whole of India) IDEI supports the marketing of cheap, good quality equipment for so-called 'Affordable Micro-Irrigation Technologies' (AMIT) such as *pepsee* (see associated technology). The promoted technology in this case is based on a farmer's innovation, which then was promoted and spread by IDEI. IDEI has intervened in four major ways: (1) technically it has further developed the local innovation, *pepsee*, and come up with an improvement, aptly named 'Easy Drip'; (2) it has promoted small manufacturers of drip irrigation equipment and associated them with a brand name; (3) it has trained and supported private sector 'service providers' to assist farmers to install and adopt the systems; (4) on an *ad hoc* basis, IDEI commissions and supports studies on uptake and impact. Technologies promoted by IDEI provide returns on investment of at least 100% in one year which is crucial in explaining the success of *pepsee.* Within five years the projects supported by IDEI should become self-sustaining.

Location: West Nimar, Madhya Pradesh, India
Approach area: not specified
Land use: cropland
Climate: semi-arid
WOCAT database reference: QA IND15
Related technology: Pepsee micro-irrigation system, QT IND15
Compiled by: Shilp Verma, Vallabh Vidyanagar, Gujarat, India
Date: January 2005, updated March 2006

Editors' comments: Smallholder farmers in India, as elsewhere, are reluctant to invest in technologies that only repay their outlay over the long term. However, where they can be assured of good quality and low price, these misgivings can be allayed. Here is an example of the further technical development and market assistance, by an NGO, of a local technological innovation – low cost drip irrigation. This highlights the benefits of market support for pro-poor technologies that suit specific needs of smallholders.

Problem, objectives and constraints

Problem

An underlying problem of increasing growing groundwater scarcity combined with the high investment costs of conventional drip irrigation equipment. On top of this is the reluctance of smallholder farmers to take government subsidies because of the high transaction costs (not easy to access; long delays and the reluctance to adopt new technologies). Local and cheap technological options are available, but quality and marketing channels are not assured.

Objectives

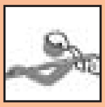
To bring affordable and appropriate water saving technologies to the rural poor through creating effective supply chains and developing markets, under a brand name associated with reliability.

Constraints addressed

Major	Specification	Treatment
Financial	Private business decisions are based on profit margins and volumes and the often fragmented and cash-starved customers do not constitute an attractive market on their own.	IDEI develops and nurtures the market for low-cost smallholder friendly technologies; thereby providing incentives to private businesses by encouraging growth in the size of the market.
Socio-cultural	Poor consumers are averse to risk and prefer to emulate the success of early-adopters. Hence, there's often a lag period between the introduction of the technology and its poverty impact.	Every project should become self-sustaining within five years. IDEI therefore establishes the supply chain for manufacturing, distributing and local network of components. It also undertakes mass marketing to create a sufficient demand for the supply chain to be viable and profitable.
Economic	Poor consumers cannot make large investments and may even be willing to pay a higher per unit price as long as the one-time investment is lowered.	IDEI identifies and develops appropriate technologies that have high poverty-alleviation potential, are produced locally; are environment friendly; and provide return on investment of at least 100% in one year.
Minor	**Specification**	**Treatment**
Socio-cultural	Certain technologies face socio-cultural barriers to adoption.	IDEI deals with such aspects at the design stage of the product itself thereby eliminating them. Additionally, it uses communication packages to facilitate adoption.

Participation and decision making

Target groups



Smallholder farmers

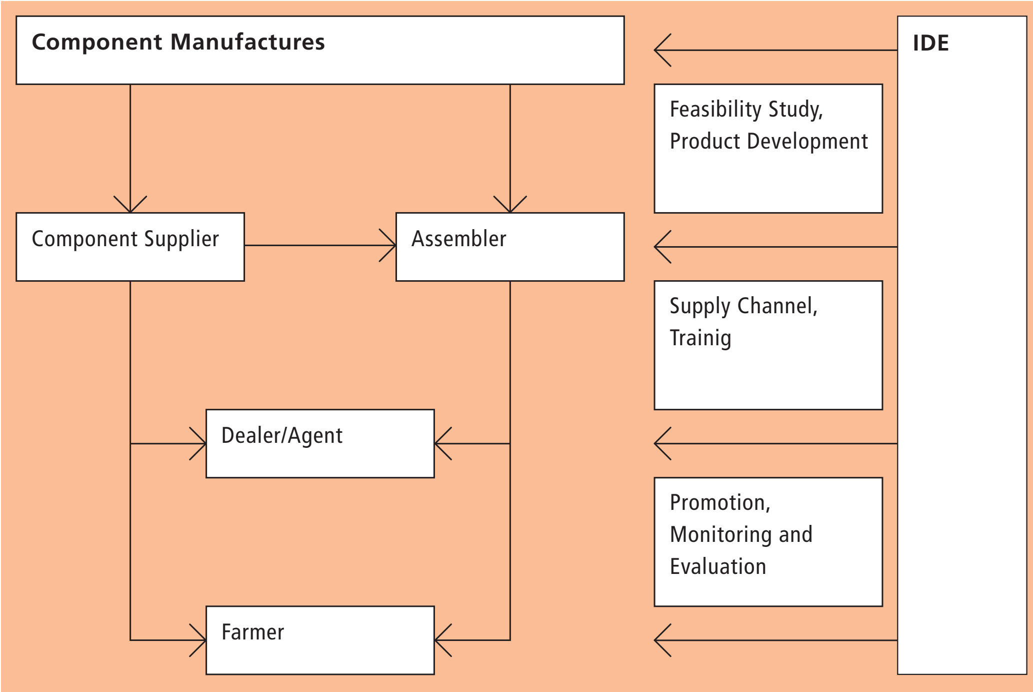
Approach costs met by:	
Donor agencies (international)	100%
	100%

Decisions on choice of the technology: Made by land users alone; on the basis of their specific requirements.
Decisions on method of implementing the technology: Mainly by land users supported by specialists/'service providers' (IDEI, the supporting NGO)
Approach designed by: national/international specialists

Community involvement

Phase	Involvement	Activities
Initiation	active	innovative development of *pepsee* technology, experimentation (farmers initiative)
Planning	passive	IDEI carrying out awareness creation etc
Implementation	passive	dealers, retailers marketing produce: technical backstopping provided by IDEI
Monitoring/evaluation	passive	market surveys, studies, assessments initiated and carried out by IDEI
Research	passive	planned and carried out by IDEI

Difference in participation between men and women: Traditionally, irrigation investments in particular, and farming in general, has been male-dominated. However, recent studies indicate that women play a critical role in the decision-making process, as these investments often compete with other household requirements.



Marketing strategy

- Market feasibility study
- Analysing customer profile (assessment of farmers needs)
- Technology/product development (adaptation)
- Setting the price (profitable for manufacturer and affordable for farmer)
- Test marketing
- Determination of market potential
- Territorial planning
- Development of supply channel (manufacturer, dealer and assembler)
- Training
- Promotion (demonstration)
- Quality assurance
- Monitoring and evaluation (impact assessment)

left: Supply channels of AMIT (Affordable Micro-Irrigation Technologies) systems and the role of IDEI (IDEI)
right: Key elements of the AMIT marketing strategy (IDEI)

Extension and promotion

Training: Training and extension are combined: while there are no dedicated training courses, through the network of service providers (who have been trained by IDEI), know-how on drip irrigation is spread among adopter and potential adopter farmers. Brochures and pamphlets (several in the local language) are circulated and there is an informative website.
Extension: (see training)
Research: Apart from research carried out by scientists (published in journals etc) IDEI has its own series of research reports which present the results of various studies on promotion and impact of low cost water saving technologies conducted (see references).
Importance of land use rights: Land is owned privately, thus there is no hindrance to investment in irrigation infrastructure.

Incentives

Labour: No incentives to support labour are given to land users.
Inputs: There are no material incentives given out to stimulate adoption. The necessary inputs are cheap and are fully paid for by the farmers.
Credit: No credit facility is provided.
Support to local institutions: Very important: this is the core of the approach. IDEI supports the whole chain from manufacturers and dealers to assemblers.
Long-term impact of incentives: Not applicable since there are no material incentives.

Monitoring and evaluation

Monitored aspects	Methods and indicators
Bio-physical	regular measurement of the improvement in water-use efficiency
Technical	regular measurement of the appropriateness of the technology to different crops and locations; also trying out technologies with new crops
Socio-cultural	regular assessments of impact on women and on the poor
Economic/production	regular measurements of returns vis-à-vis investments
Area treated	regular assessment of total scale of adoption; IDEI's estimates suggest that their technologies have so far reached 30,000 families

Impacts of the approach

Changes as a result of monitoring and evaluation: IDEI carries out a number of studies to investigate the impact of their technologies and the scale and dynamics of adoption. The results of these studies feed into their strategic and operational plans. For example, IDEI was the first to introduce drips in mulberry cultivation in Kolar. That became a huge success story.
Improved soil and water management: The widespread adoption of the *pepsee* and Easy Drip irrigation infrastructure has greatly improved water use efficiency
Adoption of the approach by other projects/land users: Several grassroots NGOs have recognised the potential of IDEI's low cost technologies and are promoting them in their respective regions. For instance, IWMI's own action research initiative in north Gujarat (called the North Gujarat Sustainable Groundwater Initiative) is actively partnering with IDEI (and other drip manufacturers) to try out various water saving technologies in Banaskantha District.
Sustainability: The entire approach relies on creation of markets which are initially promoted and supported by IDEI. It is perhaps too early to say whether the market would be sustained after IDEI withdraws but because of the fact that *pepsee* was a grassroots innovation and emerged spontaneously, there is a good chance of this happening. IDEI keeps a five year horizon for its intervention, and targets that the market should become self-sustaining by the end of this period.

Concluding statements

Strengths and ➜ how to sustain/improve

- IDEI believes in the essential dignity of people and their capacity to overcome social and economic pressures, problems and exploitations. It therefore treats poor farmers as customers and not recipients of charity. It applies business models to achieve development by tapping and developing small enterprises in the rural economy and creating markets.
- It applies business models to achieve development by tapping and developing small enterprises in the rural economy and creating markets ➜ Further promote market creation and then let the market forces take off on their own.
- The IDEI market creation approach to development ensures that there is awareness and availability of low-cost products that will have a high poverty alleviation impact ➜ Ditto.
- Growth in this approach will take place if the supply chain is performing and profitable. The early adopters may not be the poorest but if the product meets the needs of the farmers, the rural poor will follow suit and considerable market growth could result, creating a sustainable supply channel ➜ Ditto.

Weaknesses and ➜ how to overcome

- IDEI's reach is dependent on its ability to access donor funds. This might become a limitation at some stage.
- IDEI needs to work more closely with the government agencies. While market creation seems to be a very useful model, it needs to tap the government resources which are pumped every year in the business of promotion of drip irrigation.

Key reference(s): IDEI *Affordable Micro Irrigation Technologies: Marketing Manual.* International Development Enterprises, USA. ■ Phansalkar, S.J. (2003). *Appropriate Drip Irrigation Technologies Promoted by IDEI: A Socio-Economic Assessment.* International Development Enterprises, India (IDEI), New Delhi. ■ Shah, T. and Keller, J. (2002). Micro-irrigation and the poor: A marketing challenge in smallholder irrigation development. In Sally, H.; Abernethy, C. L. (Eds.), *Private irrigation in Sub-Saharan Africa: Regional Seminar on Private Sector Participation and Irrigation Expansion in Sub-Saharan Africa,* Accra, Ghana, 22–26 October 2001. Colombo, Sri Lanka: IWMI; FAO; ACP-EU Technical Centre for Agricultural and Rural Cooperation. pp.165–183. ■ Verma, S., Tsephal, S. and Jose, T. (2004). *Pepsee* Systems: Grassroots Innovation under Groundwater Stress. *Water Policy,* 6, pp. 303–318.
Contact person(s): Amitabha Sadangi, International Development Enterprises – India, C 5/43, Safdurjang Development Area (1st & 2nd Floor), New Delhi 110016, India; amitabha@ide-india.org ■ Shilp Verma, IWMI-Tata Water Policy Program, International Water Management Institute, Elecon Complex, Anand Sojitra Road, Vallabh Vidyanagar, Gujarat 388120, India; s.verma@cgiar.org; www.iwmi.org/iwmi-tata

left: Windbreak of millet stalks help stop dune encroachment. (Philippe Benguerel)
right: Bird's eye view of a stabilised sand dune. Clearly distinguishable is the enclosed area with improved vegetation cover and the chequerboard pattern of the millet stalk palisades. (Andreas Buerkert)

Sand dune stabilisation

Niger – *Fixation des dunes*

A combination of three measures to stabilise dunes: area closure, the use of palisades, and vegetative fixation through natural regeneration as well as planting.

In the Sahelian zone of Niger, sand dune encroachment can lead to loss of agricultural and pastoral land, and threatens villages. These dunes may form as a result of an increase in wind erosion, but more frequently originate from formerly stabilised dunes that have become mobile again following the disappearance of vegetation. Vegetation loss may occur through a combination of unfavourable climatic conditions and overexploitation by grazing and fuelwood gathering.

Sustainable dune fixation requires the regeneration of vegetation on the mobile parts of the dunes. For plants to establish, the dunes need to be protected by mechanical measures while being defended against any kind of use. Hence, the technique of dune stabilisation consists of a combination of three measures. These are as follows: (1) Area closure by wire fencing and guarding to prevent exploitation of the area during the rehabilitation phase until vegetation is sufficiently established (2–3 years). (2) Construction of millet stalk palisades arranged ideally in 'checker-board' squares, which act as windbreaks. These physical structures are a barrier to sand transport by wind, and thus are a prerequisite for revegetation. After two years the palisades fall apart and decompose – and the vegetation takes over the dune fixation function. Small erosion gullies can be controlled by check dams made from stone or millet stalks. (3) Natural regeneration, planting and seeding of annual and perennial plants (including *Acacia spp.* and *Prosopis spp.)* for soil stabilisation.

As soon as vegetation cover is established on the denuded surfaces the dunes can be used for grazing or for harvesting of herbs and fuelwood. Period and frequency of use should be determined in common agreement with all actors involved. In addition the pasture on the dune can be used as a 'reserve' for late dry-season grazing, depending on vegetation development and herd size. Between 1991 and 1995, just over 250 ha of sand dunes were stabilised in the case study area. Incentives were provided by the 'Projet de Développement Rural de Tahoua' (PDRT, see also 'Participatory land rehabilitation' approach). After 1995 no further dunes were stabilised due to the high cost of the wire fencing, which local communities simply could not afford themselves. However, as the objective of the fence is to keep out humans and animals during critical periods (the rainy season), the same effect could be obtained at no financial cost through 'social fencing', that is agreement between stakeholders on where there should be no grazing. Furthermore the technology itself – which works well – could be relevant to situations where higher investment can be justified for specific reasons.

Location: Niger, district of Tahoua
Technology area: 2 km^2
SWC measure: management, structural and vegetative
Land use: grazing land
Climate: semi-arid
WOCAT database reference: QT NIG15
Related approach: Participatory land rehabilitation, QA NIG01 (p 217)
Compiled by: Oudou Noufou Adamou, Tahoua, Niger; Eric Tielkes, Germany; Charles Bielders, Belgium
Date: August 1999, updated June 2004

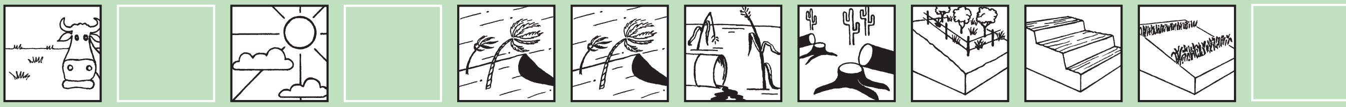
Editors' comments: In the Sahelian zone of Niger, wind erosion constitutes one of the major causes of land degradation. Measures to combat wind erosion and sand encroachment were developed through a rural development project. However in this case the cost was too high to justify continuation: nevertheless the technology itself may be applicable in other situations.

Classification

Land use problems

The area suffers from an imbalance between availability of natural resources (constrained by soil fertility and rainfall) and the rapid growth of the human and livestock populations. As a result, there is chronic food insufficiency and an associated overexploitation of the natural resource base. Accelerated wind and water erosion further enhance the degradation of the soil resources. From the farmers' perspective, the main problems are lack of grazing land, wood and drinking water (due to sinking water tables), insufficient and unevenly distributed rainfall. Sand dunes are fragile: when overexploited, they soon remain with only unpalatable plant species, eg *Panicum turgidum.* When the vegetation cover on dunes decreases even further, dunes start moving again, threatening fields, villages or depressions used for fruit and vegetable cropping.

Land use | **Climate** | **Degradation** | **SWC measures**



extensive grazing | semi-arid | wind erosion: loss of topsoil, | off-site: sand encroachment | chemical: reduced organic matter | vegetation: quality decline | management: area closure, controlled grazing | structural: millet stalk palisades, check dams (opt.) | vegetative: regenerated and seeded vegetative cover

Technical function/impact

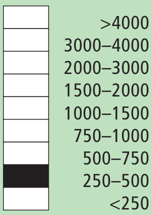
main:
- re-establish ground cover
- stabilise sand dune surface (control detachment of particles by wind)
- reduction in wind speed
- sediment harvesting

secondary: - increase in organic matter content

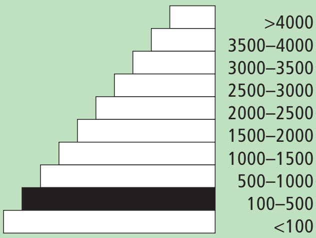
Environment

Natural environment

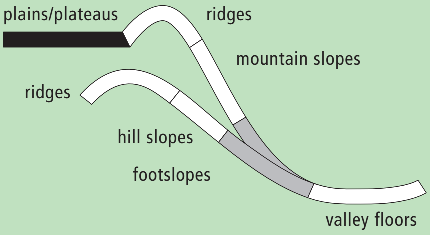
Average annual rainfall (mm)



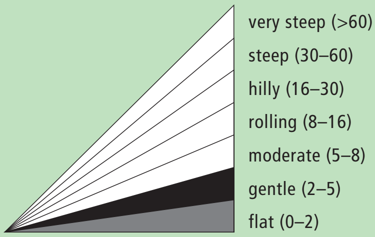
Altitude (m a.s.l.)



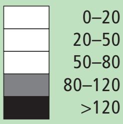
Landform



Slope (%)



Soil depth (cm)

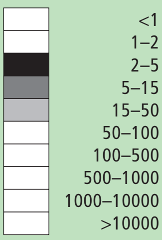


NB: soil properties before SWC

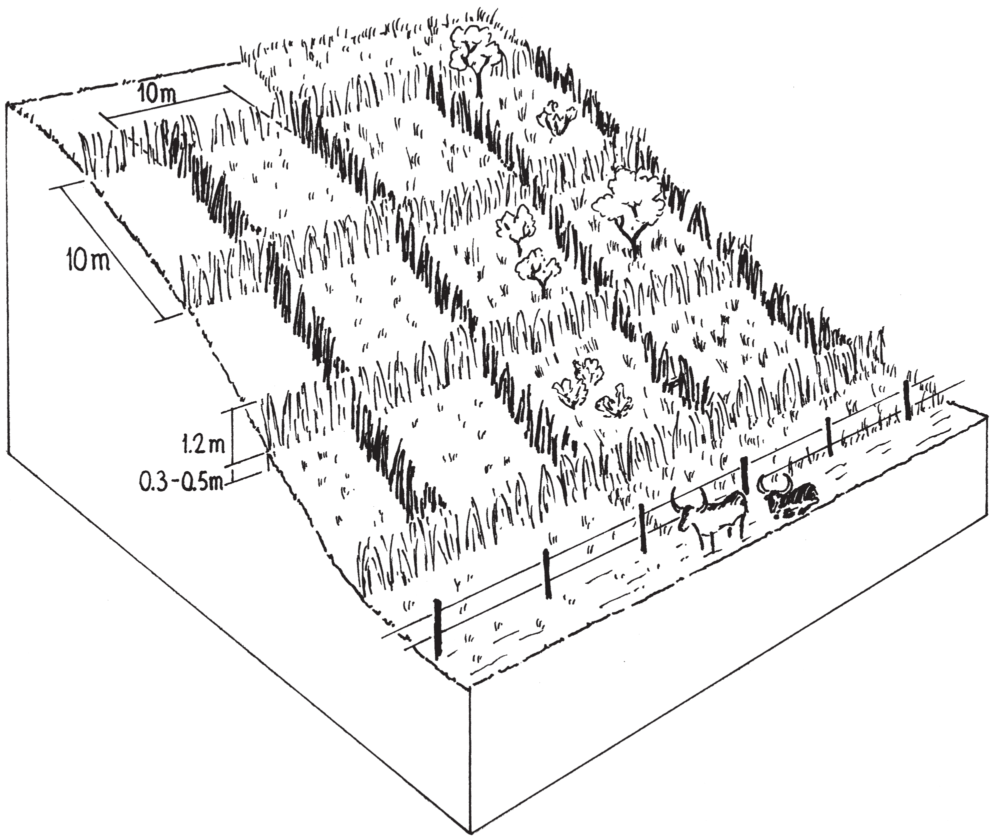
Growing season: 90 days (July to September)
Soil fertility: low
Soil texture: coarse (sandy)
Surface stoniness: no loose stone
Topsoil organic matter: low (<1%)
Soil drainage: good
Soil erodibility: very high to high

Human environment

Grazing land per household (ha)



Land use rights: open access (unorganised)
Land ownership: communal/village
Market orientation: grazing land: mixed (subsistence and commercial)
Level of technical knowledge required: field staff/extension worker: moderate, land user: low
Importance of off-farm income: >50% of all income, due to out-migration of labour, commerce and also arts and crafts



Technical drawing
Sand dunes in the process of stabilisation: millet stalk palisades hinder detachment and displacement of sand particles through wind, and help vegetative cover to re-establish. Fences exclude animals during the restoration process.

Implementation activities, inputs and costs

Establishment activities

1. Construction of wire fence around the dune (December to June).
2. Harvesting of millet stalks (October to February), 2,000 bundles/ha (1 bundle = 6–10 kg).
3. Palisade construction (December to June), 2000 m/ha.
4. Seeding of herbaceous plants (May, just before rainy season).
5. Transplanting of locally available trees reared in a tree nursery (June to July, early rainy season). Compost was mixed with soil for the planting bags. No fertilizers or biocides were used.
6. Guarding the fenced area (all year around).

Duration of establishment: 2–3 years (site specific)

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (200 person days)	300	100%
Equipment		
- Tools (hoe, donkey cart, machete)	10	0%
Materials		
- Wire fence	1,120	0%
- Millet stalks	0	
Agricultural		
- Herbaceous seeds (harvested by population)	0	
- Tree seedlings (300)	20	0%
- Compost/manure (farm yard manure)	0	
TOTAL	**1,450**	**20%**

Maintenance/recurrent activities

1. Guarding the area closure (all year around).
2. Replanting of dead tree/shrub seedlings (June to July, 20% replanting).
3. Controlled grazing once the dune has been stabilised: for periods of between 1 day and a week every 2 to 3 weeks – as determined by site and rainfall.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (30 person days)	45	100%
Equipment		
- Tools	0	
Agricultural		
- Seedlings (60 plants)	5	0%
- Compost/manure (farm yard manure)	0	
TOTAL	**50**	**90%**

Remarks: Labour (per ha, for establishment) includes installing wire fence (16 person days), collecting and transporting millet stalks and installing palisades (175 person days), sowing of herbaceous plants (2 person days), planting tree/shrub species (6 person days). Seedlings: under PDRT the tree nursery was financed by the project and the plants delivered to the 'village' – planting was done by the local population.

Assessment

Acceptance/adoption

All the families that accepted the technology did so with incentives: the whole village was involved. There is no spontaneous adoption as the technology is too expensive, labour intensive, and implemented on communal land.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	very negative	negative
maintenance/recurrent	negative	negative

Remark: off-site benefits are difficult to assess and do not necessarily accrue to the local land users

Impacts of the technology

Production and socio-economic benefits
- \+ + fodder production/quality increase
- \+ wood production increase

Production and socio-economic disadvantages
- – – – cost
- – – increased labour constraints
- – – increased input constraints (millet stalks are taken from the fields where they have a function as mulch and fodder)
- – temporary loss of land, reduced access to pastures

Socio-cultural benefits
- \+ + + improved knowledge SWC/erosion
- \+ + community institution strengthening

Socio-cultural disadvantages
- – – – requires concerted action from all land users during, but even more after, rehabilitation
- – socio-cultural conflicts between agriculturalists and pastoralists

Ecological benefits
- \+ + + soil cover improvement
- \+ + + soil loss reduction
- \+ + + reduction of wind velocity
- \+ + biodiversity enhancement
- \+ increase in soil moisture
- \+ increase in soil fertility

Ecological disadvantages
- – soil erosion increase (locally)

Off-site benefits
- \+ + + reduction in transported sediments
- \+ + + land or village protected from sand encroachment

Off-site disadvantages
- none

Concluding statements

Strengths and ➜ how to sustain/improve

Technically it is feasible to prevent dune encroachment and hence reduce the danger it exerts on arable/pastoral land and villages ➜ Prevent overexploitation, apply SWC measures that are technically and financially feasible (eg use cheaper fencing material or 'social fencing').

Decrease loss of arable/pastoral land ➜ Prevent overexploitation.

Additional income to the land user ➜ Planting multipurpose tree/shrub species on the protected dunes, encourage pasture management systems eg rotational grazing.

Weaknesses and ➜ how to overcome

Soil cover is very sensitive to overexploitation ➜ In order to increase acceptance, involve the whole community in the planning and management processes of the stabilised dune.

Social conflicts between farmers and herders due to area closure ➜ In order to increase acceptance, involve all actors, including pastoralists or their representatives, in the planning and management process of the stabilised dune.

Use materials for the palisades that do not have an alternative use as fodder (as millet stalks do) for example twigs of *Leptadenia pyrotechnica)*. Plastic nets exist for making palisades, but these are very expensive. Labour requirements difficult to circumvent.

Area closure to prevent exploitation of stabilised dunes means restricted access to potential grazing areas ➜ Initiate the establishment of sustainable management systems eg communally managed rotational grazing systems.

High costs for fencing ➜ Involved actors can agree upon a local convention that prohibits access during rehabilitation – 'social fencing' – and restricted exploitation after this phase. PDRT started to plant *Euphorbia balsamifera* within the fence with the idea of eventually removing and using it on another site.

Key reference(s): none.

Contact person(s): Charles L Bielders, Dept. of Environ. Sciences and Land Use Planning – Agric. Engineering Unit, The Faculty of Bio-engineering, Agronomy and Environment, Université catholique de Louvain, Croix du Sud 2, boite 2, B-1348 Louvain-la-Neuve, Belgium, bielders@geru.ucl.ac.be ■ Eric Tielkes, Centre for Agriculture in the Tropics and Subtropics, University of Hohenheim (790), 70593 Stuttgart, Germany; tielkes@uni-hohenheim.de; www.troz.de

left: A dam supplying irrigation water to a village, sited within a treated forest catchment. (William Critchley)
right: Enrichment planting of grasses and trees within the degraded forest land: note also contour trenches for infiltration. (Gudrun Schwilch)

Forest catchment treatment

India

Catchment treatment of degraded forest land including social fencing, infiltration trenches and enrichment planting with trees and grasses for production and dam protection.

Forest catchment treatment aims to achieve production and environmental benefits through a combination of structural, vegetative and management measures in badly degraded catchments above villages. These efforts are concentrated in the highly erodible Shiwalik Hills at the foot of the Himalayan range where soil erosion has ravaged the landscape, and the original forest has almost disappeared.

The purpose of forest catchment treatment is first to rehabilitate the forest through protection of the area by 'social fencing' (villagers agreeing amongst themselves to exclude livestock without using physical barriers), then construction of soil conservation measures (staggered contour trenches, check dams, graded stabilisation channels etc; see establishment activities), and 'enrichment planting' of trees and grasses within the existing forest stand to improve composition and cover. These species usually include trees such as *Acacia catechu* and *Dalbergia sissoo,* and fodder grasses – as well as *bhabbar* grass *(Eulaliopsis binata),* which is used for rope making. The combined measures are aimed at re-establishing the forest canopy, understorey and floor, thereby restoring the forest ecosystem together with its functions and services. Biodiversity is simultaneously enhanced.

The second main objective is to provide supplementary irrigation water to the village below through construction of one, or more, earth dams. The village community – organised into a Hill Resource Management Society – is the source of highly subsidised labour for forest catchment treatment. After catchment protection around the proposed dam site(s), the dam(s) and pipeline(s) are constructed. The dams are generally between 20,000 and 200,000 m^3 in capacity, and the pipelines usually one kilometre or less in length.

Apart from irrigation, the villagers benefit from communal use of non-timber forest resources. Forest catchment treatment (associated with the approach termed 'joint forest management' – JFM) has been developed from a pilot initiative in Sukhomajri village in 1976, and has spread very widely throughout India. This description focuses on Ambala and Yamunanagar Districts in Haryana State.

Location: Ambala and Yamunanagar Districts, Haryana State, India
Technology area: 198 km^2
SWC measure: structural, management and vegetative
Land use: forest
Climate: subhumid
WOCAT database reference: QT IND14
Related approach: Joint forest management, QA IND14
Compiled by: Chetan Kumar, TERI, Delhi, India
Date: September 2002, updated June 2004

Editors' comments: This integrated catchment treatment associated with 'joint forest management' is a well-known success story, especially in the degraded Shiwalik foothills of the Indian Himalayas. Forest land is rehabilitated and its ecological function restored through a series of conservation measures. It is often associated with dams for downstream irrigation.

Classification

Land use problems

The Shiwalik Hills are extremely prone to both surface erosion and landslides, and general degradation of vegetation due to over-exploitation. Some areas have become completely denuded because of overgrazing and woodcutting. Furthermore there is no, or inadequate, water for irrigation of crops.

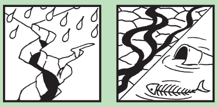
Land use

forest: rehabilitated natural forest

Climate

subhumid

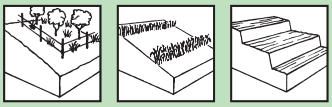
Degradation



water erosion: loss of topsoil, gully, landslides

water degradation: soil moisture problem

SWC measures



management: social fencing

vegetative: enrichment planting with trees/grasses

structural: dam, trenches, ditches, check dams

Technical function/impact

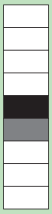
main:
- improvement of ground cover
- increase of infiltration
- water harvesting

secondary:
- control of dispersed runoff
- control of concentrated runoff

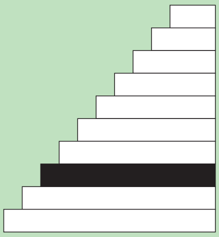
Environment

Natural environment

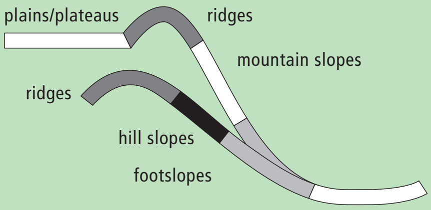
Average annual rainfall (mm)



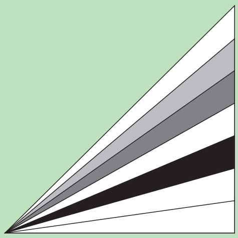
Altitude (m a.s.l.)



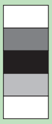
Landform



Slope (%)



Soil depth (cm)



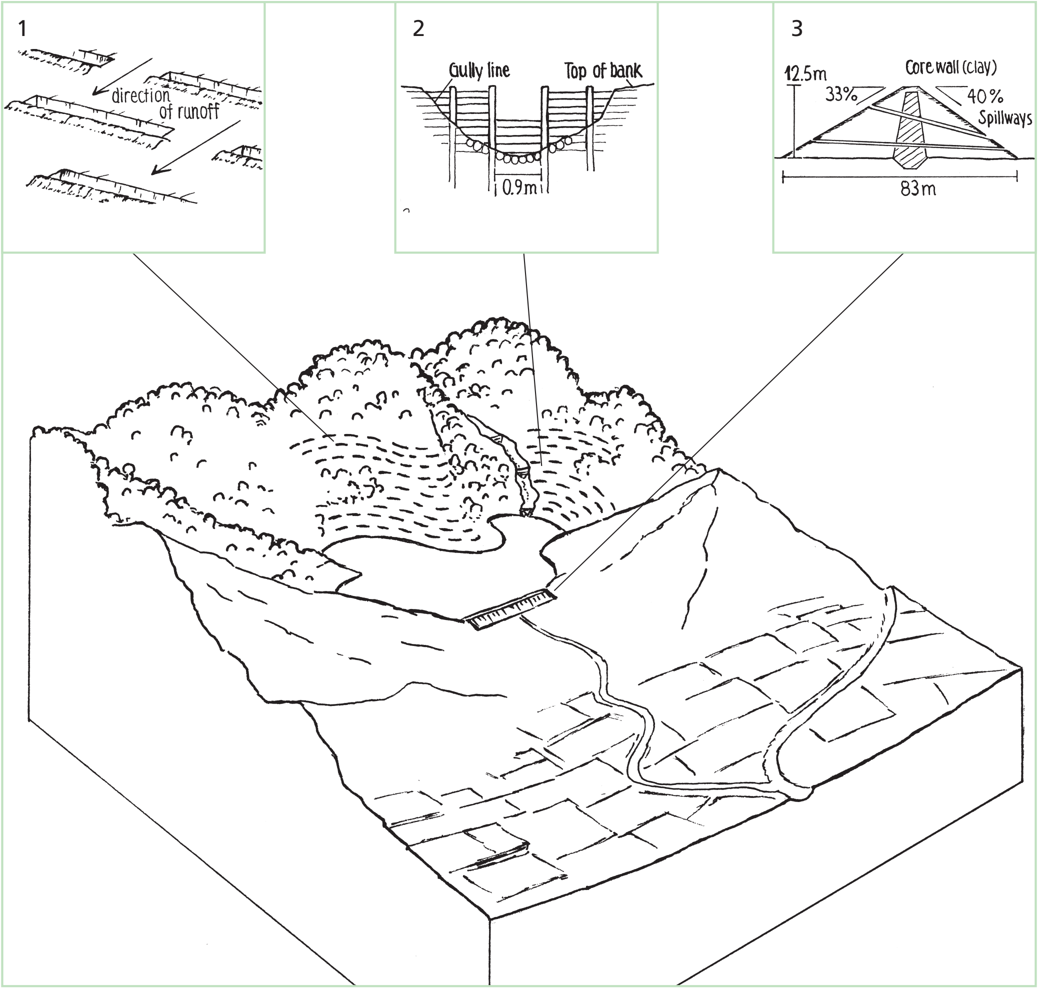
NB: soil properties before SWC

Growing season: 120 days (July to October)
Soil fertility: mostly medium
Soil texture: mostly coarse (sandy), partly medium (loam), some fine (clay)
Surface stoniness: some loose stone
Topsoil organic matter: mostly medium (1–3%), partly low (<1%)
Soil drainage: poor
Soil erodibility: high

Human environment

Forest land per household (ha)

Land use rights: communal (organised)
Land ownership: state
Market orientation: mixed (subsistence/commercial)
Level of technical knowledge required: field staff/extension worker: moderate, land user: moderate
Importance of off-farm income: 10–50% of all income comes from non-agricultural land activities: significant off-farm activity/income includes rope making from bhabbar grass. Sale of fodder grass from the forest provides additional income.



Technical drawing
Forest catchment treatment: an overview showing protected forest, dam and irrigated cropland below.
Insert 1: Staggered infiltration ditches; used for erosion control on steep slopes.
Insert 2: Front view of wooden check dam; used for gully control.
Insert 3: Cross-section of earth dam wall.

Implementation activities, inputs and costs

Establishment activities

1. Introduction of social fencing system through Hill Resource Management Societies.
2. Construction of a series of staggered contour trenches on slopes.
3. Construction of stone/earth/wood check dams in gullies.
4. Construction of graded stabilisation channels which capture runoff and discharge it safely.
5. Enrichment planting of tree seedlings *(Acacia catechu*, *Dalbergia sissoo* etc), grasses *(bhabbar* grass: *Eulaliopsis binata)* on bunds of earth and hill slopes, and Ipomea cornea in channels.
6. Construction of earth dam wall for water harvesting and concrete pipelines for irrigation.

All activities are carried out pre-monsoon, in the first six (dry) months of the year – except enrichment planting which takes place at the beginning of the monsoon rains.
Duration of establishment: 2 to 3 years

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (125 person days)	250	5%
Machines (bulldozer hours)	75	0%
Materials		
- for dam wall	25	0%
Agricultural		
- Seedlings	50	0%
TOTAL	**400**	**3%**

Maintenance/recurrent activities

Miscellaneous, including:
1. Desilting of water harvesting structures.
2. Repair of channels.
3. Maintenance of structures.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (25 person days)	50	95%
TOTAL	**50**	**95%**

Remarks: This information is indicative and is based on calculations derived from Thaska village (Yamunanagar District) where there are 3 dams – collecting the runoff from the total forest catchment of 75 ha. The cost range of treatments per hectare of rehabilitated forest is generally US$ 200–700 (where the main cost is that of the dam construction) and typically the area of supplementary irrigation (command area) is twice as large as the forest catchment treated (in this case the irrigated area is 150 ha).
Cost per unit: the treatment of a 25 ha unit of catchment including construction of a dam costs around US$ 10,000.

Assessment

Acceptance/adoption

- All land users in the 60 villages of the two districts accepted the technology with incentives.
- Incentives comprise an initial government/donor subsidy paying 95% of the labour and supplying machinery (bulldozers), dam wall materials/pipelines and planting materials.
- The spread of such forest treatment within Haryana (and outside) is happening steadily.
- Maintenance of the systems is increasingly left to the people themselves.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	very positive	very positive
maintenance/recurrent	very positive	very positive

Impacts of the technology

Production and socio-economic benefits

- +++ fodder production/quality increase
- +++ wood production increase
- +++ farm income increase

Production and socio-economic disadvantages

- – increased economic inequity (those with irrigation vs those without)

Socio-cultural benefits

- +++ community institution strengthening
- +++ improved knowledge SWC/erosion

Socio-cultural disadvantages

- – socio-cultural conflicts (see above)

Ecological benefits

- +++ soil cover improvement
- +++ soil loss reduction
- ++ efficiency of excess water drainage
- ++ increase in soil moisture
- ++ biodiversity enhancement

Ecological disadvantages

none

Other benefits

- +++ increased tree cover
- +++ increased grass
- +++ increased non-timber forest products

Other disadvantages

none

Off-site benefits

- +++ crop yield increases (from new irrigation water)
- ++ reduced downstream siltation
- + increased stream flow in dry season
- + reduced downstream flooding

Off-site disadvantages

- – – reduced runoff for filling dam (in some cases)

Concluding statements

Strengths and ➜ how to sustain/improve

Increased surface and groundwater help to fill the dam rather than running off and causing flooding and erosion lower down (but not always: see first off-site disadvantage) ➜ Ensure continuous protection/ regular maintenance.

Increased fodder and fuel from the renewed forest resources ➜ Ditto.

Reduction of runoff and erosion in the previously degraded catchment ➜ Ditto.

Improved forest conditions – both canopy and understorey delivering general ecosystem benefits ➜ Ditto.

Increased crop yield from irrigation made possible through irrigation from the dam ➜ Ditto.

Increased household income ➜ Ditto.

Increased community institution strength ➜ Strengthen Hill Resource Management Societies.

Weaknesses and ➜ how to overcome

In some cases reduction in runoff (because of increased vegetation) causes less water for irrigation ➜ Manipulate vegetative cover as required (selective cutting).

Conflicts in water distribution ➜ Conflict resolution may need to be carried out through Hill Resource Management Societies.

High labour input.

Key reference(s): Singh TP and Varalakshmi V (1998) *The Decade and Beyond: Evolving community-state partnership.* TERI, New Delhi ■ Poffenberger M and McGean B (eds) (1996) *Village Voices, Forest Choices. Joint Forest Management in India.* Oxford University Press, Delhi
Contact person(s): Chetan Kumar, TERI, Habitat Place, Lodhi Road, New Delhi 110 003, India; c.kumar@cgiar.org; www.teriin.org


left: Villagers at Thaska (in Yamunagar District) discuss their plans and problems with staff of TERI. (William Critchley)
right: The chair of the Hill Resource Management Society at Thaska Village, below the village dam. (William Critchley)

Joint forest management

India

Government and NGO supported community protection of forested catchments, through village-based Hill Resource Management Societies.

Joint forest management (JFM) in India emerged in the 1980s from community initiatives in forest protection. At that time, less than half of the official forest land had good tree cover. Forest protection groups took action, based on 'social fencing' of degraded forest land. JFM was adopted by support agencies – NGOs and Government (State Forest Department) – when its full potential was realised. It is an approach that leads to environmental and production benefits through community co-operation in natural resource management. State-supported JFM in Haryana began on a pilot basis in Sukhomajri village in 1976, and has built on the success of that initiative, spreading to a total of nearly 200 km^2, covering 60 villages in Ambala and Yamunagar Districts. The National Joint Forest Management Resolution of 1990 supported the rights of forest communities country-wide. In the same year, the Haryana State Government signed an agreement with The Energy and Resources Institute (formerly TERI: Tata Energy Research Institute) – underpinned by financial support from the Ford Foundation – to help establish Hill Resource Management Societies (HRMS). These state-sponsored, village level societies are key to the success of JFM, and their links to the State Forest Department are crucial. The founding principles of HRMS include appropriate social composition, accountability and conflict resolution. They are open to all members of the village communities – regardless of gender or caste – who pay membership fees, and are then officially registered. Management committees are elected, and each must include at least two women. The HRMS oversee forest catchment management activities by villagers, arrange distribution of irrigation water (where applicable) and liase with the State Forest Department and TERI. Hill Resource Management Societies derive income from non-timber forest products – particularly from sales of bhabbar grass (used for rope making) – and from water use charges. This income is managed by the HRMS and used for village development and community welfare. The HRMS plan activities together with the State Forest Department. Under the guidance of the HRMS, communities provide labour (for physical works in the catchment etc), which is partly paid, implement social fencing and share the multiple benefits. Where there is a water harvesting dam all members have the right to claim an equal share of the water, irrespective of whether they have land to irrigate or not.

Location: Ambala and Yamunanagar Districts, Haryana State, India
Approach area: 198 km^2
Land use: forest
Climate: subhumid
WOCAT database reference: QA IND14
Related technology: Forest catchment treatment, QT IND14
Compiled by: Sumana Datta, TERI, Delhi, India
Date: June 2002, updated June 2004

Editors' comments: Joint forest management (JFM) is one of the new community based participatory approaches to common property resources: up to 14 million hectares in India are cared for in this way. The Shiwalik hills in the northern part of Haryana State are home to some of the most successful JFM experiences in the world.

Problem, objectives and constraints

Problem

- the main basic problem to be confronted was lack of control over the degradation of forest in the Shiwalik Hills which was leading to erosion and siltation of water bodies, and a lack of forest products/grazing
- there was no community organisation established to address these issues on land that was handed over to the village for management by the Forest Department

Objectives

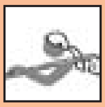
- develop democratic and powerful Hill Resource Management Societies
- protect the forest land, by means of local participatory governance, and thereby improve the flow of forest products
- boost agricultural productivity through irrigation in village fields from dams in the protected catchments

Constraints addressed

Major	Specification	Treatment
Social	Lack of local institution for natural resource management.	Set up Hill Resource Management Societies.
Financial	Inadequate budget from Forest Department for implementation.	Water charges help to provide finance – but the State Government should assist more.
Minor	**Specification**	**Treatment**
Technical	Inadequate appreciation/understanding of integrated soil and water conservation/production approach within Forest Department.	Build awareness in Forest Department.

Participation and decision making

Target groups



Land users: forest dependent families, users of irrigated land

Approach costs met by:

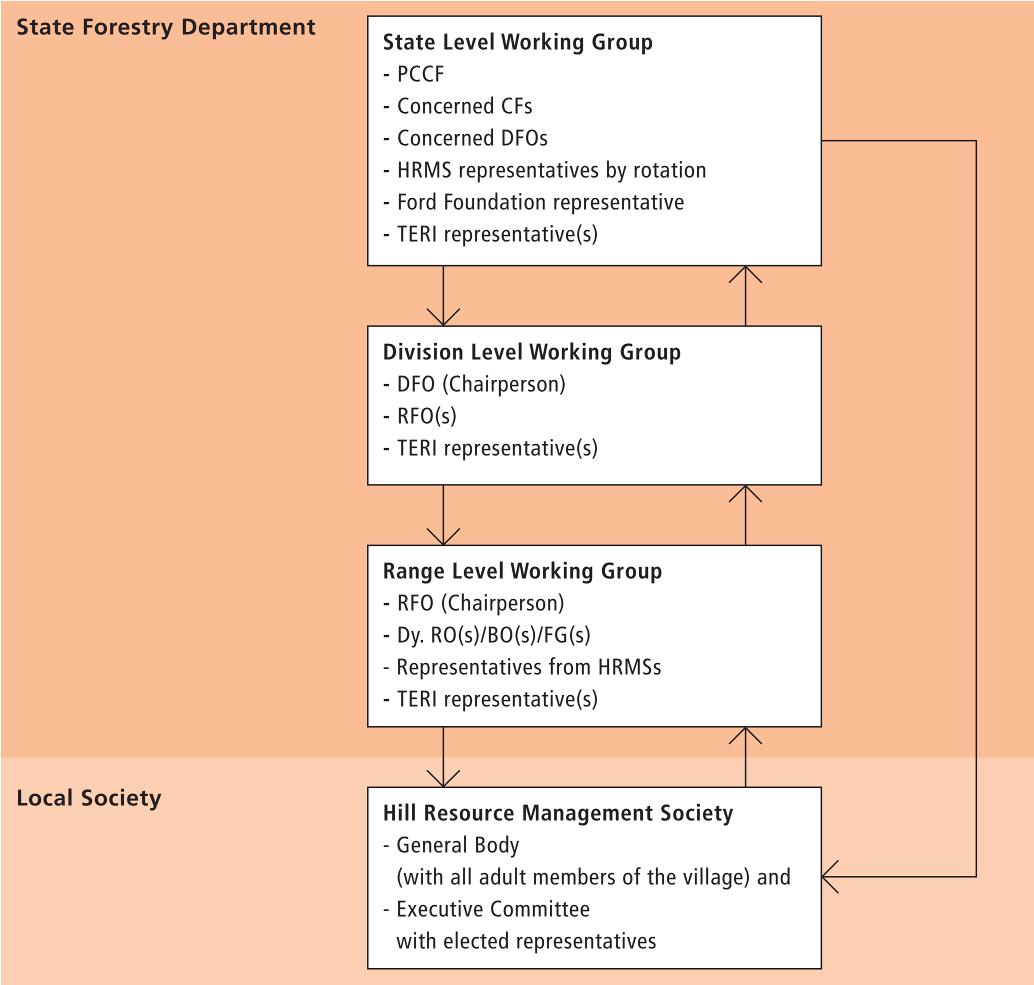
International NGO	50%
State government	25%
Community/local	25%
	100%

Decisions on choice of the technology: Mainly made by SWC specialists with consultation of land users.
Decisions on method of implementing the technology: Mainly made by SWC specialists with consultation of land users in the initial pilot scheme at Sukhomajri, but in other villages, later, land users have taken the lead role with SWC specialists' support.
Approach designed by: National specialists.

Community involvement

Phase	Involvement	Activities
Initiation	interactive	public meetings/Participatory Rural Appraisals
Planning	interactive	Participatory Rural Appraisals/meetings/workshops
Implementation	interactive	taking responsibility for organisation of casual labour
Monitoring/evaluation	interactive	public meetings/interviews/questionnaires
Research	interactive	trials with various varieties of crop seed

Differences in participation between men and women: There were moderate differences due to social and cultural practices. Women are active in only a few Hill Resource Management Societies, but at least two women must be on each management committee.



PCCF: Principal Chief Conservator of Forests
CF: Conservator of Forests
DFO: Divisional Forest Officer
RFO: Range Forest Officer
HRMS: Hill Resources Management Societies
Dy. RO(s): Deputy Range Officer
Dy. BO(s): Deputy Block Officer
FG(s): Forest Guard

Extension and promotion

Training: Training is given to land users by the Forest Department in conjunction with TERI on water harvesting structures and their maintenance. There are also workshops and meetings to evolve and maintain a water distribution system. Generally training is effective.
Extension: Extension, through the Forest Department's agents, covering forest management and irrigation is given to certain groups amongst the HRMS, but is not yet adequate. More is required from Government.
Research: Research is carried out by TERI, and covers various aspects (including both technical and social issues). Results are published in handbooks as well as having been compiled in 'The Decade and Beyond' (see references).
Importance of land use rights: Ownership rights affected the approach to a great extent and in a positive way: user rights to forest land are made available equally to all, to reduce potential conflict between unequal 'land owners'.

Incentives

Labour: For establishment of dams and infrastructure, labour is rewarded (up to 95%) with cash wages. Over the last few years there have been some contributions from HRMS funds (derived from water user charges etc), which go towards maintenance work.
Inputs: Machinery (bulldozers are used to construct dams etc), hand-tools (various), and some basic community infrastructure (buildings) are financed and provided.
Credit: No credit is provided.
Support to local institutions: The establishment and training of Hill Resource Management Societies is an important part of the approach.
Long-term impact of incentives: The impact is moderately negative: the prevailing culture of wages given for major works like dams makes it unlikely that these would ever be done by voluntary labour. However some general maintenance tasks are beginning to be carried out by the people themselves.

Monitoring and evaluation

Monitored aspects	Methods and indicators
Bio-physical	ad hoc measurements of change in vegetation
Technical	ad hoc observations of erosion status/siltation of water bodies
Socio-cultural	regular observations and measurements of level of participation
Economic/production	regular observations and measurements of change in income
Area treated	ad hoc observations
No. of land users involved	regular observations and measurements
Management of approach	regular observations

Impacts of the approach

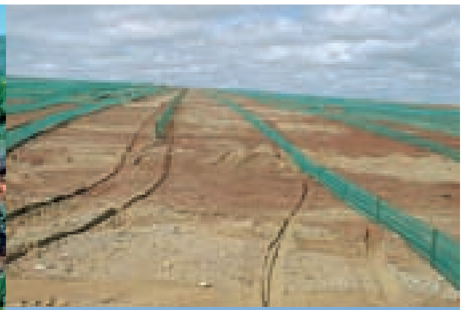
Changes as result of monitoring and evaluation: Internal reviews are carried out every one or two years: there have been several changes proposed and carried out as a result. These changes were in aspects of sharing water irrigation, and in methods of utilising income derived from forest products – especially *bhabbar* grass *(Eulaliopsis binata).*
Improved soil and water management: There has been a huge improvement in soil and water management – the forest canopy and its understorey have been restored with all associated benefits. Additionally, in fields below the forest area, levelling of land for irrigation reduces its vulnerability to erosion.
Adoption of the approach by other projects/land users: The original experiment in Sukhomajri has been replicated in 60 other villages within Ambala and Yamunagar Districts – and further afield in Haryana and India generally.
Sustainability: Land users can continue to maintain what infrastructure has been put in place (dams, irrigation pipelines etc) but technical guidance is required – and at least some budget from the Forestry Department. In terms of managing the forest resources itself, the existence of the HRMS should ensure that this will continue.

Concluding statements

Strengths and ➜ how to sustain/improve
Creation of strong people's self-help institutions – the Hill Resource Management Societies ➜ Create more awareness among women.
Cost-effective rehabilitation technologies ➜ Build more capacity amongst land users to implement and manage sustainably.
Emphasis on training and managerial capacity building ➜ Continue emphasis on/targeting of women.
Integrated approach of natural resource regeneration ➜ Policy required for encouraging interdepartmental development activities.
Equitable access to benefits ➜ New rules and by-laws needed to sustain this.
Opportunity to earn more from agriculture through irrigation ➜ Better access to improved seed and technology required.
Opportunity to earn more from livestock ➜ Better access to market, and thus value addition, needed.
The creation and efficient operation of Hill Resource Management Societies ➜ Continued outside support for HRMS required.

Weaknesses and ➜ how to overcome
Sustainability of SWC is dependent on regular maintenance ➜ Increased budgetary allocation through Forest Department required.
Weak market linkage ➜ Strengthen market linkages for agricultural, livestock and forest products.
Moderate participation of women ➜ Build better awareness among women.
Lack of credit for investment in agriculture and business ➜ Popularise micro-credit concept under women's self-help groups.
Lack of opportunity/knowledge for value addition to forest products ➜ Training programmes for micro-enterprise development are needed.

Key reference(s): Singh TP and Varalakshmi V (1998) *The decade and beyond: evolving community and state partnership.* The Energy and Resources Institute, Delhi, India
Contact person(s): Sumana Datta, Varghese Paul, TERI, Habitat Place, Lodhi Road, New Delhi 110 003, India; sumana@winrockindia.org, vpaul@teri.res.in; www.teriin.org



left: Post-rehabilitation phase: between the wind break nets a variety of indigenous succulents and other plants is growing. (Kirsten Mahood)
right: Large-scale strip mine rehabilitation at the establishment stage in 2000: topsoil is returned and spread by bulldozers (top); two years later dense vegetation cover protects the area (bottom). (Kirsten Mahood)

Strip mine rehabilitation

South Africa

Rehabilitation of areas degraded by strip mining, through returning stockpiled topsoil and transplanting of indigenous species, to promote revegetation.

In contrast to the land degradation commonly caused when 'strip mining' is carried out, a land rehabilitation technology, which was first developed experimentally, is now routinely applied by mining companies on the west coast of South Africa. Indeed it is now a legal requirement in South Africa for mining companies to rehabilitate mined areas to a condition and productivity equivalent to the pre-mining situation.

The primary purpose of the technology described here is to achieve this result – thus allowing the site to be used again for extensive grazing by sheep and wild animals. Revegetation also reduces wind erosion. The technology further contributes to increasing biodiversity, as particular attention is given to planting a range of locally endemic and other indigenous species.

The sequence of operations is as follows: during strip mining operations the topsoil is pushed to one side by bulldozer, and stockpiled. The substrata is then excavated mechanically, removed by tipper truck, and processed to extract the heavy metals. The tailings (waste materials) are returned by tipper truck to the area from which they were mined, and then levelled by bulldozer. The stockpiled topsoil is returned and spread by bulldozer over the levelled tailings. Indigenous succulents and other plant species are dug out by hand, with a spade, from either the surrounding areas of natural vegetation, or from the piles of topsoil (where plants may have naturally established) and transplanted manually into the newly spread topsoil. The planted areas are protected from wind erosion by erecting fine mesh nylon netting as windbreaks. These are 0.8 metre high and 5 metres apart. The nets are usually installed for a period of up to 2–3 years. Subsequently they are removed, once the vegetation has successfully become re-established, and they may be re-used at the next rehabilitation site. Maintenance activities continue for a few years – until the site is rehabilitated. An individual mine strip is usually about 1 km long and some 100 m wide.

This form of strip mine rehabilitation has been in operation since 1990, and costs on average just over US$ 200 per hectare, with all expenses met by the mining company. This particular approach was developed for the Anglo-American subsidiary – 'Namaqua Sands'. A similar approach was adopted by 'PBGypsum Mines' located further inland, where rehabilitation is also conducted on several hundreds hectares of mined land. Not all mining companies use the same technology, however.

Location: Brand-se-Baai, Western Cape, South Africa
Technology area: <10 km^2
SWC measure: vegetative and structural
Land use: mining (before), grazing land (after)
Climate: arid
WOCAT database reference: QT RSA47
Related approach: not documented
Compiled by: Kirsten Mahood, Stellenbosch, South Africa
Date: October 2001, updated June 2004

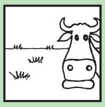
Editors' comments: In most parts of the world, industrial activities have – historically - resulted in significant land degradation through direct surface disturbance or dumping of waste. This is an example where a technology has been developed for the rehabilitation of areas degraded through mining, and then returned to productivity.

Classification

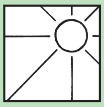
Land use problems
Land degraded and unproductive due to strip mining activities.

Land use

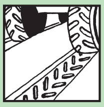

strip mining (before)


extensive grazing (after)

Climate


arid

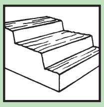
Degradation

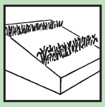

physical: loss of bio-productive function


water erosion: soil loss from the mine tailings (waste)


wind erosion: soil loss from the mine tailings (waste)

SWC measures


structural: land levelling, artificial wind-breaks


vegetative: translocation of indigenous plants

Technical function/impact

main:
- restoration of the bio-productive function of the land
- reduction in wind speed
- improved ground cover

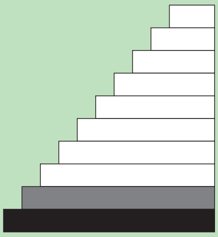
secondary:
- increase in organic matter
- increase in soil fertility
- improvement of soil structure
- increased infiltration

Environment

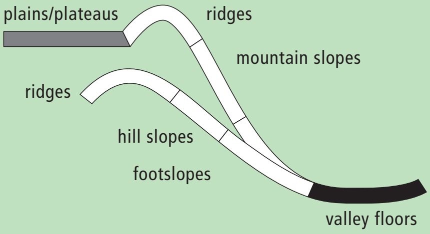
Natural environment

Average annual rainfall (mm)

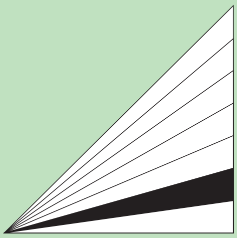
Altitude (m a.s.l.)



Landform



Slope (%)



Soil depth (cm)

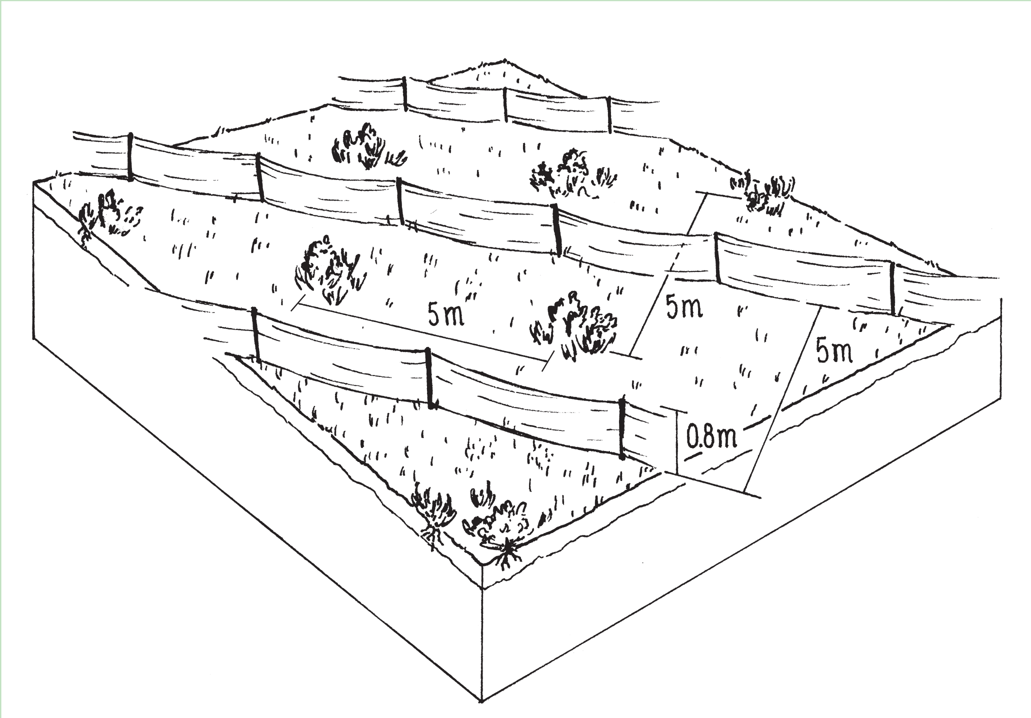
NB: soil properties before SWC

Growing season: 90 days (June to August)
Soil fertility: very low
Soil texture: coarse (sandy)
Surface stoniness: no loose stone
Topsoil organic matter: low (<1%)
Soil drainage: good
Soil erodibility: very high

Human environment

Grazing land per household (ha)
not applicable

Land use rights: mining concession, after rehabilitation the land rights fall back to the previous owners (herders).
Land ownership: state
Market orientation: commercial mining operation
Level of technical knowledge required: field staff/extension worker: moderate, land user/employee: moderate
Importance of off-farm income: not applicable



Technical drawing
Strip mine rehabilitation: after returning and levelling the removed topsoil, fine mesh nylon nets are established which act as windbreaks protecting regenerating, as well as transplanted, indigenous species.

Implementation activities, inputs and costs

Establishment activities

1. Removal and stockpiling of topsoil.
2. Excavation, removal and processing of substrata to extract heavy minerals.
3. Return and levelling of the mine tailings.
4. Return and spreading of topsoil (20–50 cm thick layer, 2000–5000 m^3; not massive earth moving).
5. Minimum tillage/land preparation
6. Collecting/digging up of indigenous plants and transplanting into returned topsoil (manually, transport by tractor/trailer).
7. Erection of fine mesh nylon net windbreaks (manually, transport by tractor/trailer).

Activities 1–4 are a continuous process associated with mining activities, using heavy earth moving machinery (bulldozers, front end loaders, tipper trucks). Activities 5 & 6 take place immediately prior to the onset of the rainy season. Activity 7 can take place at any time of the year.
Duration of establishment: 1 year

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (6 person days)	75	100%
Equipment		
- Machines (50 hours)	67	100%
Materials		
- Nylon netting	70	100%
Agricultural		
- Seedlings (‘wildlings’; 2,000)	0	
TOTAL	**212**	**100%**

Maintenance/recurrent activities

Maintenance activities restricted to:
1. Ensuring the nylon nets remain upright.
2. Supplementary watering during the winter months, when rainfall inadequate, to support plant growth.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (3 person days)	37	100%
TOTAL	**37**	**100%**

Remarks: Removal, stockpiling and returning topsoil (as well as processing substrata and returning mine tailings) are part of mining activities and thus not included in the calculation of rehabilitation costs. Rehabilitation costs include only spreading of topsoil, land preparation and collecting/transplanting native vegetation and installing nylon nets. The costs of the nets will be less than the amount quoted if they are re-used. Calculation of costs is difficult since mining companies do not keep separate accounts for rehabilitation work.

Assessment

Acceptance/adoption

It is a legal requirement for companies to rehabilitate areas they mine to a condition and productivity equivalent to pre-mining.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
establishment	slightly positive	very positive
maintenance/recurrent	positive	very positive

Impacts of the technology

Production and socio-economic benefits
- +++ fodder production/quality increase
- +++ land rehabilitation

Production and socio-economic disadvantages
- −− extra costs of rehabilitation

Socio-cultural benefits
- +++ improved knowledge of SWC/erosion

Socio-cultural disadvantages
- none

Ecological benefits
- +++ reduction of wind velocity
- +++ restoration of bio-productive function
- ++ soil cover improvement
- ++ biodiversity enhancement

Ecological disadvantages
- −− incomplete biodiversity restoration on site

Other benefits
- ++ land can be used again for extensive grazing after mining

Other disadvantages
- −− success of transplanting depends on rainfall which is unreliable and low

Off-site benefits
- ++ reduced wind transported sediments

Off-site disadvantages
- none

Concluding statements

Strengths and ➜ **how to sustain/improve**

Low establishment costs and very low maintenance costs ➜ Make use of whatever resources and potentials are naturally available (such as micro-catchments to trap rainwater and improve soil moisture conditions for plants) to lower establishment costs.

Costs are met by the mining company – no costs are transferred to those who subsequently use the land for grazing ➜ Regular monitoring of soil and vegetation conditions.

Land productivity is restored and biodiversity increased ➜ Seeding as well as transplanting.

Wind erosion minimised.

Weaknesses and ➜ **how to overcome**

Rehabilitation is an extra cost for the mining company ➜ Ensure mining company meets the costs through enforcing legislation.

Key reference(s): none available

Contact person(s): Andrei Rozanov, University of Stellenbosch, P/Bag XI Matieland, Stellenbosch 7602 Western Cape, Republic of South Africa; dar@sun.ac.za ■ Kirsten Mahood, Principal Technical Officer (Outreach), Centre for Invation Biology, Private Bax X1, Matieland 7602, South Africa; phone: ++27-21-8082833; fax: ++27-21-8082995; cell: ++27-82-7112154; kmahood@sun.ac.za

Annex

Dummy explanation pages of case studies
Pictograms
WOCAT categorisation system
List of organisations involved

Dummy explanation pages of case studies: SWC technologies

QT: refers to Questionnaire on Technologies and its related database

Two photographs are included here to provide – ideally – an overview and detail of the technology: from QT 2.1.3 or from the WOCAT photographic database

Name of Technology (QT 1.2.1)

Rehabilitation of ancient terraces

Peru – Andenes / Anchacas / Patapatas

Country – local name of technology (QT 1.2.2)

Repair of ancient stone wall bench terraces, and of an associated irrigation and drainage system.

A summarised definition of the technology in one sentence: from/based on QT 2.1.1

A concise description of the technology, based on QT 2.1.2, standardised by editors, usually including information on:

- the overall purpose
- establishment and maintenance procedures
- natural and human environment including land use, and land degradation problems
- costs (from QT 2.7)
- how long the technology has been practised
- `supportive technologies/measures' – those that add extra effectiveness or value to the main technology (where relevant; QT 2.8).

This section should give the reader a descriptive overview of the technology, which is then supplemented by data in the rest of the case study.

left: Photo caption and name of photographer(s)

right: Photo caption and name of photographer(s)

Location: location, district, country: from QT 1.3.1
Technology area: in km² indicating the particular site studied; from QT 1.3.1
SWC measure: agronomic/vegetative/structural/management or combination: from QT 2.2.2.2
Land use: cropland/grazing land/forest/woodlands/mixed/other: from QT 2.2.2.1
Climate: humid/subhumid/semi-arid/arid: from QT 2.5.2
WOCAT database reference: QT code
Related approach: name and code of approach: from QT 1.2.5
Compiled by: for original and updated versions (if these differ) name and address of main author QT 1.1
Date: of original data collection and update – month and year

Editors' comments: a short piece of text giving some information on the spread/ importance/ status/ representativeness of the technology. The idea is to put the technology into global context. This text is added by the editors.

Land use problems: This brief description of the major land use problems – without SWC – in the area is derived from the specialists' and the land users opinions combined, both of which questions fall under QT 2.2.1

Land use: Here there is a choice between cropland/ grazing land/ forest or woodland/ mixed and 'other' with various subcategories
Climate: The choice here is between humid/ subhumid/ semi-arid/ arid: taken from QT 2.5.2
Degradation: The types of soil degradation addressed by the technology are given here: water erosion/ wind erosion/ chemical deterioration/ physical deterioration/ water degradation/ vegetation degradation – with further specification where relevant: from QT 2.2.2.4
SWC measures: The relevant SWC category/ies is/are given; the choice is between agronomic/ vegetative/ structural/ management with possible combinations: from QT 2.2.2.2. There should be further specification of measures according to the SWC categorisation system given in Annex T4
Supportive measures **(supp.)** are desirable but not essential measures for the functioning of SWC.
Optional measures **(opt.)** indicate additional choices.
For definition of **pictograms** refer to page 359.

main: here the question was 'what are the main means by which the technology achieves its impact?': QT 2.2.2.5 gives multiple categories, and these have are ranked in terms of importance

secondary: from the same question (QT 2.2.2.5); those appearing lower down the rank are listed here

Avg. annual rainfall (mm): QT 2.5.1 / **Altitude (m):** QT 2.5.3 / **Landform:** QT 2.5.4 / **Slope:** QT 2.5.5

Natural environment ranked in the charts below: ■ very important/most common; ■ important; ■ less important. Note that within the technology area there can be a range of environments. In some cases, even where the area is small, the annual rainfall (for example) may be on the boundary between two categories – or not exactly known – thus both categories may be given a rank in that situation.

Soil depth before SWC applied
QT 2.5.6

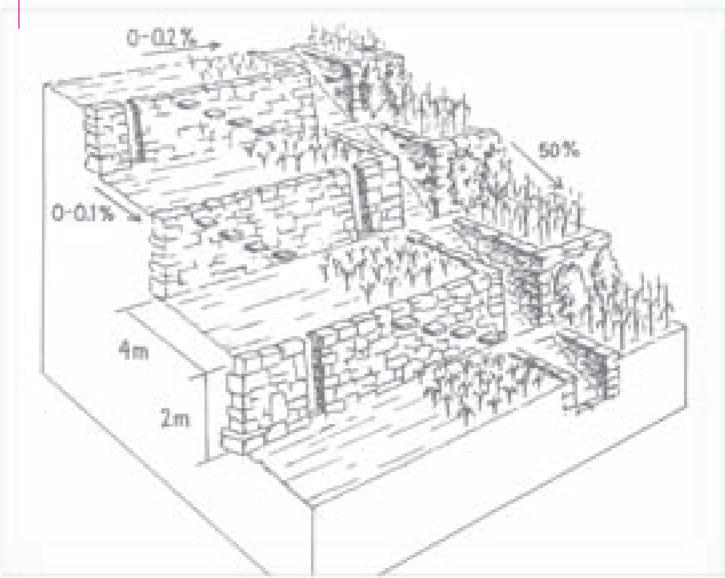
Growing period: how many seasons and the duration; from QT 2.5.15.4
Soil fertility: very high / high / medium / low / very low (QT 2.5.8)*
Soil texture: coarse (sandy) / medium (loam) / fine (clay) (QT 2.5.7)*
Surface stoniness: none / some / abundant loose stone (QT 2.5.9)*
Topsoil organic matter: high (> 3%) / medium (1–3%) / low (<1%) (QT 2.5.10)*
Soil drainage: good / medium / poor (QT 2.5.11) *
Soil erodibility: very high / high / medium / low / very low (QT 2.5.13)*
*if more than one category write 'mostly sandy, some loam' or 'mostly no stones, partly stony', etc.

Cropland (or grazing land, mixed land, forest land) per household*
Table (size of land per household in hectares): ranked ■ (very important/ most common): ■ (important): ■ (less important); dependent on what form of land use where the SWC is implemented: whether
QT 2.6.13.6 (cropland);
2.6.14.13 (grazing land);
2.6.15.6 (forest/ woodland)

*Note: title of this box will change depending on land use

Land use rights: open access (unorganised) / communal (organised) / leased / individual; QT 2.6.4
Land ownership: state / company / communal/village / group / individual – not titled / individual – titled; QT 2.6.4
Market orientation: QT 2.6.13.1/ QT 2.6.14.1/ QT 2.6.15.1
(answer chosen from list below depends on land use system)
subsistence (self-supply) / mixed / commercial (market)
Level of technical knowledge required: both from QT 2.6.11
field staff / extension worker: low / moderate / high
land user: low / moderate / high
Importance of off-farm income: from QT 2.6.10: <10% / 10–50% / >50% of all income
Comment regarding off-farm income: especially source of that income

Here a **technical drawing** of the technology (if available): originally from QT 2.4.1, but usually redrawn for consistency



Caption and artist

Establishment activities

The **establishment** activities for the SWC measures (whether agronomic, vegetative, structural and/ or management) are described here in sequence: 1. / 2./ 3./ 4.; etc.
Information is added on source of energy, equipment used, timing of operations etc.
Taken from the questions: QT 2.4.2.2; QT 2.4.3.2; QT 2.4.4.2 ; QT 2.4.5.2
The duration of the establishment phase is given (usually either within one year – or a number of years)

Establishment inputs and costs per ha

Input amounts and costs taken from QT 2.7.1: remarks may be added on specifications / how costs were calculated (e.g. for line structures: meter of gullies, etc)
Where inputs are 'free' to the land users (e.g. stone, manure etc) quantities are given, but no cost allocated unless there is a market value locally – in which case that value is quoted

Maintenance / recurrent activities

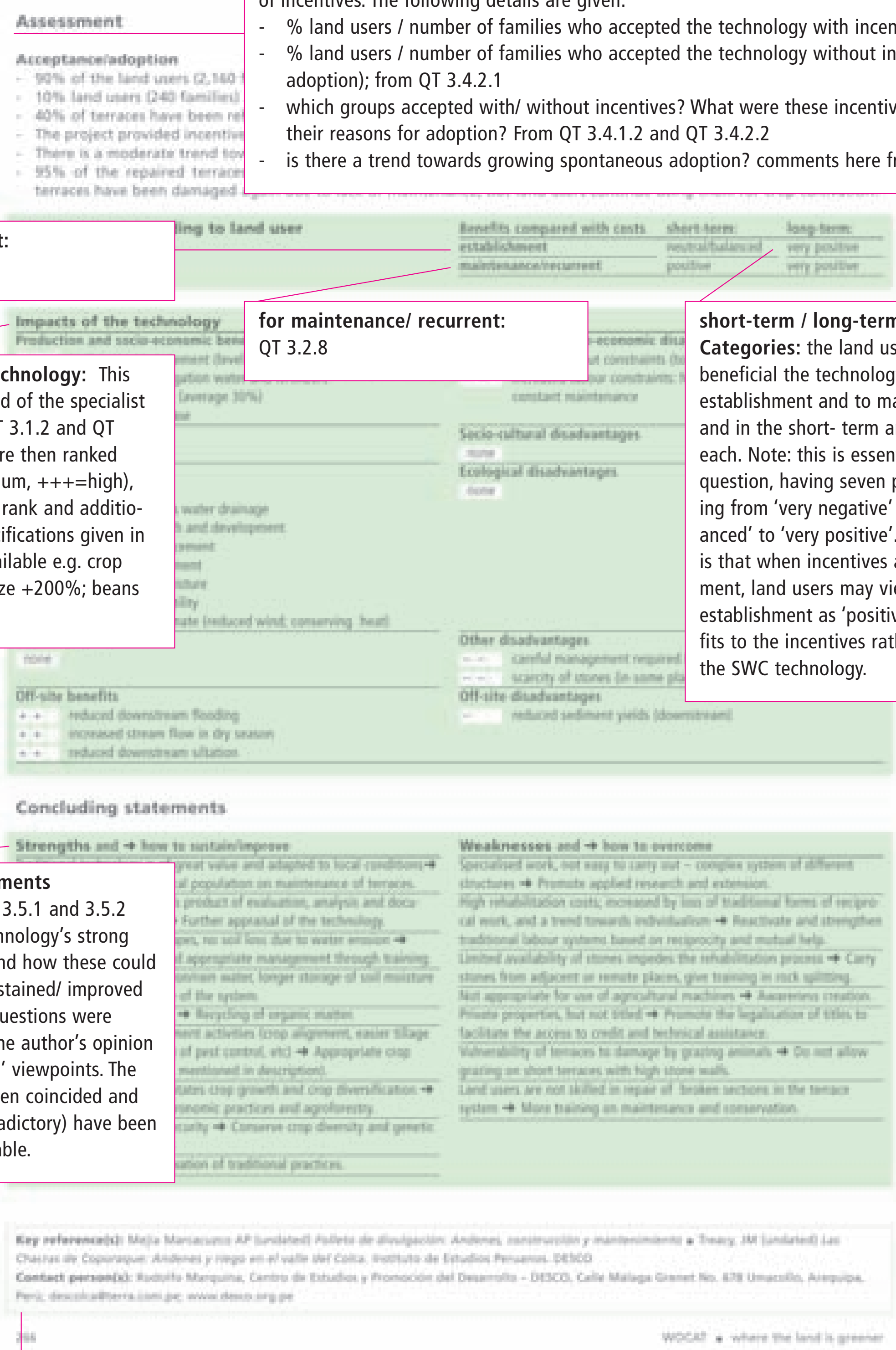
The annual **maintenance** (upkeep/ repair) or **recurrent** (regular annual operations) activities for the SWC measures (whether agronomic, vegetative, structural and/ or management) are described here in sequence:
1. / 2./ 3./ 4.; etc.
Information is added on source of energy, equipment used, timing of operations, frequency etc
Taken from the questions: QT 2.4.2.2; QT 2.4.3.2; QT 2.4.4.2; QT 2.4.5.2

Maintenance/ recurrent inputs and costs per ha per year

Annual input amounts and costs taken from QT 2.7.1:
Where inputs are 'free' to the land users (e.g. stone, manure etc) quantities are given, but no cost allocated unless there is a market value locally – in which case that value is quoted

Remarks

Here a comment is added on how, and for what situation, the inputs and costs were calculated. For example what was the original land slope? That can make a large difference to the costs of terraces or vegetative strips. What other assumptions have been made? Is it based on measurements or broad estimates? Any extra information that may be useful to shed light on the calculations is added here.
Taken from question 2.7.2



Acceptance / Adoption

The information below relates to the spread of the technology. Within the area covered by the case study (the 'technology area': see box on page one) we are considering only those people who have applied the technology (though often this means all/ nearly all the households). The infomation below refers to how the spread has occured/ is still occuring – with a special focus on the role of incentives. The following details are given:

- % land users / number of families who accepted the technology with incentives; from QT 3.4.1.1
- % land users / number of families who accepted the technology without incentives (spontaneous adoption); from QT 3.4.2.1
- which groups accepted with/ without incentives? What were these incentives and what were their reasons for adoption? From QT 3.4.1.2 and QT 3.4.2.2
- is there a trend towards growing spontaneous adoption? comments here from QT 3.4.2.4

for establishment:
QT 3.2.7

for maintenance/ recurrent:
QT 3.2.8

short-term / long-term
Categories: the land users' view of how beneficial the technology is with respect to establishment and to maintenance activities, and in the short- term and the longterm for each. Note: this is essentially a qualitative question, having seven possible answers ranging from 'very negative' through 'neutral/ balanced' to 'very positive'. Another consideration is that when incentives are used for establishment, land users may view the benefits for establishment as 'positive' relating the benefits to the incentives rather than the impact of the SWC technology.

Impacts of the technology: This information is asked of the specialist under questions QT 3.1.2 and QT 3.1.5. Categories are then ranked (+=little, ++=medium, +++=high), listed according to rank and additional comments/specifications given in brackets where available e.g. crop yield increase (maize +200%; beans +150%).

Concluding statements
The answers to QT 3.5.1 and 3.5.2 summarise the technology's strong and weak points and how these could be, respectively, sustained/ improved or overcome. The questions were divided into two: the author's opinion and the land user's' viewpoints. The answers (which often coincided and were seldom contradictory) have been combined in this table.

Key reference(s)
References to literature are specified here: not just taken from the questionnaire annex T1, but in some cases added to by the editors. Many technologies have not been documented before.

Contact person(s)
The name and contacts of the author(s) so that specific interests/ question from readers can be followed up, taken from annex T1.

Dummy explanation pages of case studies: SWC approaches

QA: refers to Questionnaire on Approaches and its related database

Two photographs of approach activities are included here: from QA 1.3.4 or from the WOCAT photographic database

Participatory catchment rehabilitation

Peru – *Participación comunitaria para la rehabilitación de cuencas*

Promoting the rehabilitation of ancient terrace systems based on a systematic watershed management approach.

Name of Approach (QA 1.2.1)

Country – local name of approach

A summarised definition of the approach in one sentence: from/ based on QA 2.1.1.1

This body of text constitutes a concise description of the approach, usually including the overall purpose, specific objectives, methods (including incentives), stages of implementation, role of participants, project description, donors, project dates (where relevant). It is based on the answer to QA 2.1.1.2: 'summary of approach with main characteristics'. The intention is that this section should give the reader a descriptive overview of the approach, which is then supplemented by data in the rest of the case study.

left: Photo caption and name of photographer(s)
right: Photo caption and name of photographer(s)

Location: location, district, country: from QA 1.3.1
Approach area: in km² indicating the particular site studied; from QA 1.3.1
Land use: same as in related QT
Climate: same as in related QT
WOCAT database reference: QA code
Related technology: name of related technology given in related QT
Compiled by: for original and updated versions (if these differ) name and address of main author
Date: of original data collection and update – month and year

Editors' Comments: here is a short piece of text giving some information on the spread/ importance/ status/ representativeness of the approach. The idea is to put the approach into global context. This text is added by the editors.

Problem
A list of the main problems addressed by the approach, in order of importance: from QA 2.1.3.1, intended to indicate what gaps the approach was intended to fill, so that the associated technologies could be effectively implemented.

Objectives
Description of the main objectives of the approach: text taken directly or summarised from QA 2.1.4.1

Constraints addressed
This is a list of the specific constraints 'hindering the implementation of the SWC technology' and an indication of 'the treatment offered by the approach' to overcome these. These are grouped under 'major' and 'minor' categories, such as 'social', 'financial' and 'legal': from QA 2.1.3.3. The intention here was to highlight those problems that arose, especially after the approach was put into practice, and how these were tackled.

Target groups
Meaning those identified to be addressed through the approach – from QA 2.2.1.1.
For definition of **pictograms** refer to page 360.

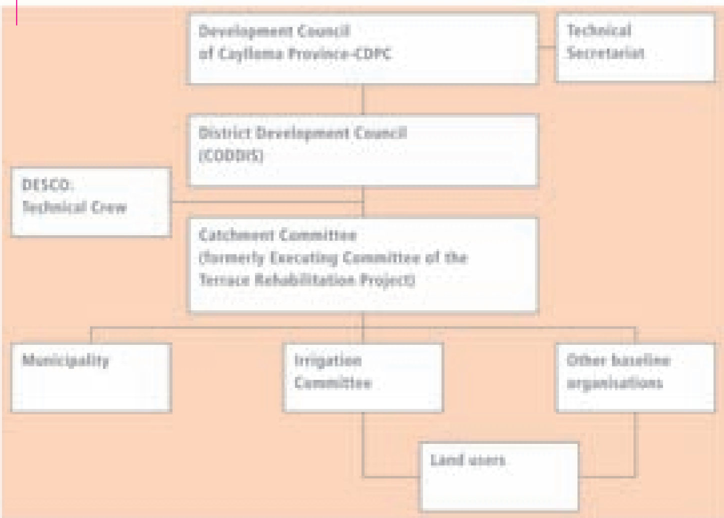
Approach costs met by
The various donors/ contributors listed in QA 2.3.1.1, based on figures or estimates

Decisions on choice of the technology: Categories here are specified in QA 2.1.5.1, and comments allowed
Decisions on method of implementing the technology: Categories here are specified in QA 2.1.5.2, and comments allowed
Approach designed by: Taken from QA 2.1.7.1: where the four options of 'national specialists', 'international specialist', 'land users' and 'others' are specified

Community involvement
This table below is based on a mix of answers to questions QA 2.2.3.1 and QA 2.2.3.2
phase / Involvement* / activities
* either 'none' 'passive' 'payment/ incentives' 'interactive' or 'self-mobilisation'

Differences in participation between men and women: Taken from question QA 2.2.3.3 this is a summary of the different roles played by women and men under the approach, with reasons for these differences explained where possible.

Here appears an organogram – if available from the answer to QA 2.1.2.6: where this is not the case, for example in an approach which is basically a tradition, a drawing or a photograph is included in its place



Caption

Extension and promotion

Training: A short piece of text, formulated from the answers to QA 2.4.1.2 and QA 2.4.1.3 (the subjects and form/ method of training) and from QA 3.2.4.1 where the effectiveness of training ('poor', 'fair', 'good' 'excellent') on different specified target groups is rated.

Extension: A similar piece of text here, formulated from QA 2.4.2.1 which asks for the 'name of extension approach' and its 'key elements' and a description of the adequacy of extension services to continue SWC activities in the future (QA 2.4.2.5) supplemented by a rating of effectiveness of extension ('poor', 'fair', 'good' 'excellent') on different target groups with an explanation – from QA 3.2.4.2

Research: Was applied research part of approach? QA 2.4.3.2 asks this basic question and requires an overall rating of 'not', 'low', 'moderate' or 'great'. It further asks for a list of topics researched. The text here goes on to describe and explain impact of the applied research on the effectiveness of the approach – taken from QA 3.2.4.3

Importance of land use rights: Did ownership rights affect (help/hinder) the implementation of SWC (QA 3.2.5.1)

Incentives

Labour: This section answers the question of whether labour for implementation was voluntary, or rewarded with incentives. If it was rewarded, specifications of those incentives for land user's labour input are given. It is taken from QA 2.5.1.1

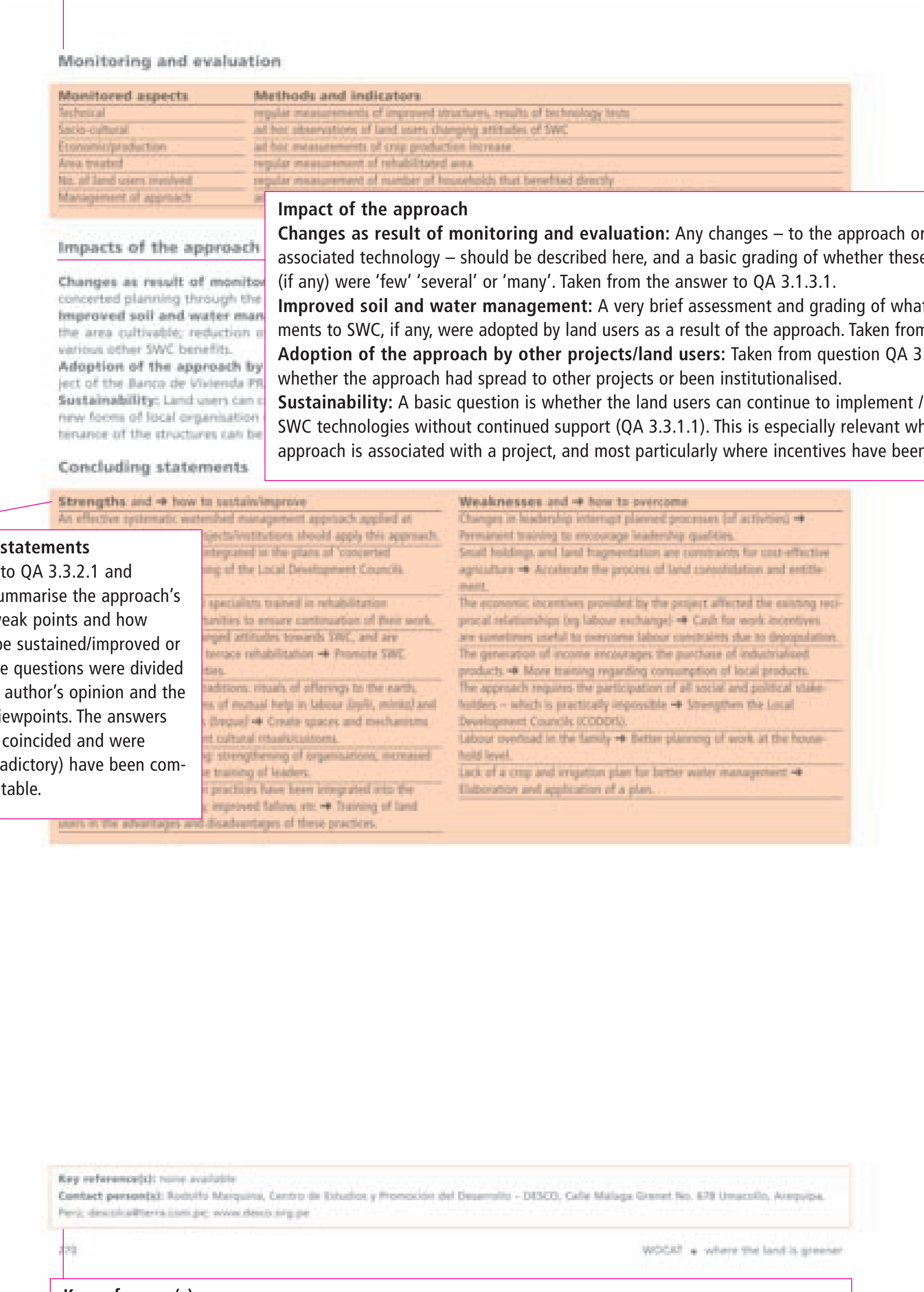
Inputs: Under this heading there is the answer to QA 2.5.1.2 which seeks to find out whether inputs were provided, and if so, what inputs and whether financed. And if financed, under what conditions and what terms?

Credit: The answer to QA 2.5.2.1 forms the basis for this information: whether credit was provided for activities under the approach, and if so whether the interest rate was equal to, or lower than, the commercial market rate.

Support to local institutions: Here is a sentence or two, taken from the answer from QA 2.5.1.3 which asks whether local institutions were specifically supported under the approach, to what extent and in what way. Naturally some projects or programmes focus strongly on institution-building, other not so.

Long-term impact of incentives: QA 3.2.6.3 asks the question of whether incentives – if used under the approach – were likely to have (or have had already) a long-term impact, whether negative or positive. The answer should be graded 'none', 'low', 'moderate' or 'great' and an explanation given.

Monitoring and Evaluation
Monitored aspects: Taken from QA 3.1.1.1 with aspects that had been monitored under the approach, including methods and indicators.



Impact of the approach
Changes as result of monitoring and evaluation: Any changes – to the approach or to the associated technology – should be described here, and a basic grading of whether these changes (if any) were 'few' 'several' or 'many'. Taken from the answer to QA 3.1.3.1.
Improved soil and water management: A very brief assessment and grading of what improvements to SWC, if any, were adopted by land users as a result of the approach. Taken from QA 3.2.1.1.
Adoption of the approach by other projects/land users: Taken from question QA 3.2.3.3: whether the approach had spread to other projects or been institutionalised.
Sustainability: A basic question is whether the land users can continue to implement / maintain SWC technologies without continued support (QA 3.3.1.1). This is especially relevant where the approach is associated with a project, and most particularly where incentives have been provided.

Concluding statements
The answers to QA 3.3.2.1 and QA 3.3.3.1 summarise the approach's strong and weak points and how these could be sustained/improved or overcome. The questions were divided into two: the author's opinion and the land users' viewpoints. The answers (which often coincided and were seldom contradictory) have been combined in this table.

Key reference(s)
References to literature are specified here: not just taken from the questionnaire annex A1, but in some cases added to by the editors. Many approaches have not been documented before.

Contact person(s)
The name and contacts of the author(s) so that specific interests/ question from readers can be followed up, taken from annex A1.

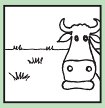
Pictograms SWC technology

Land use types

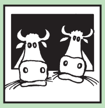
Annual cropping: land under temporary/ annual crops usually harvested within one, maximally within two years (eg maize, rice, wheat, vegetables)

Perennial (non-woody) cropping: land under permanent (not woody) crops that may be harvested after 2 or more years, or only part of the plants are harvested (eg sugar cane, banana, sisal, pineapple)

Tree and shrub cropping: permanent woody plants with crops harvested more than once after planting and usually lasting for more than 5 years (eg coffee, tea, grapevines, oil palm, cacao, coconut, fodder trees, fruit trees)

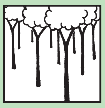


Extensive grazing land: grazing on natural or semi-natural grasslands, grasslands with trees/ shrubs (savannah vegetation) or open woodlands for livestock and wildlife



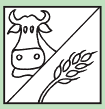
Intensive grazing land: grass production on improved or planted pastures, including cutting for fodder materials (for livestock production)

Natural forests: forests composed of indigenous trees, not planted by man

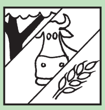


Plantations, afforestations: forest stands established by planting or/and seeding in the process of afforestation or reforestation

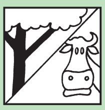
Agroforestry: crops and trees (mixed)



Agropastoral: cropland and grazing land (mixed)

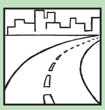


Agrosilvopastoral: cropland, grazing land and forest (mixed)



Silvopastoral: forest and grazing land (mixed)

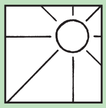
Mines and extractive industries



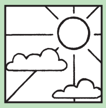
Settlements, infrastructure networks: roads, railways, pipe lines, power lines

Wastelands, deserts, glaciers, swamps, etc

Climate



Arid: length of growing period (LGP) 0–74 days



Semi-arid: LGP 75–179 days

Subhumid: LGP 180–269 days

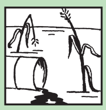
Humid: LGP >270 days

The length of growing period (LGP) is defined as the period when precipitation exceeds 50% of the potential evapotranspiration and the temperature is higher than 6.5° C.

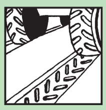
Degradation

Water erosion: loss of topsoil by water; gully erosion; mass movements; riverbank erosion / coastal erosion; offsite effects: deposition of sediments, downstream flooding, siltation of reservoirs and waterways, etc

Wind erosion: loss of topsoil by wind; deflation and deposition; offsite effects of wind erosion: Covering of the terrain with windborne sand particles from distant sources ('overblowing')



Chemical deterioration: fertility decline and reduced organic matter content; acidification; lowering of the soil pH; soil pollution; salinisation/alkalinisation



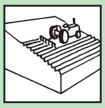
Physical deterioration: soil compaction; sealing and crusting; waterlogging; subsidence of organic soils; loss of bio-productive function due to other activities (eg construction, mining)

Water degradation: aridification/soil moisture problem; water quality decline (pollution of water bodies by chemicals and eroded sediments); water quantity decline (groundwater, surface water).

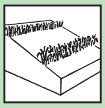
Vegetation degradation: reduction of vegetation cover; quality and species composition decline; quantity decline (loss of vegetative production)

Pictograms SWC technology continued

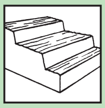
SWC measures



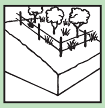
Agronomic measures: measures that improve soil cover (eg green cover, mulch); measures that enhance organic matter/ soil fertility (eg manuring); soil surface treatment (eg conservation tillage); subsurface treatment (eg deep ripping)



Vegetative measures: plantation/reseeding of tree and shrub species (eg live fences; tree rows), grasses and perennial herbaceous plants (eg grass strips)



Structural measures: terraces (bench, forward/ backward sloping); bunds, banks (level, graded); dams, pans; ditches (level, graded); walls, barriers, palisades

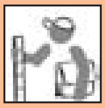


Management measures: change of land use type (eg area enclosure); change of management/intensity level: (eg from grazing to cut-and-carry); major change in timing of activities; control/ change of species composition

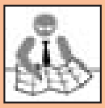
Pictograms SWC approach

Targed groups

Land users

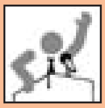


SWC specialists/extensionists



Planners

Teachers/students



Politicians/decision makers

WOCAT categorisation system

A hierarchical system is proposed to categorise SWC technologies. The hierarchical system combines 3 basic sets of information: first, on the land use where the technology is applied, secondly on the degradation type addressed and thirdly on the conservation measure. Each of these sets is subdivided into additional hierarchical levels. Each item on each hierarchical level has a predefined abbreviation. The combination of these letters makes up the code that fully describes a SWC technology, eg CaWtS1 for annual crops on bench terraces addressing loss of topsoil. See also www.wocat.net.

a) Land use

C: Cropland
- Ca: annual cropping
- Cp: perennial cropping
- Ct: tree and shrub cropping

G: Grazing land
- Ge: extensive grazing
- Gi: intensive grazing

F: Forest/woodland
- Fn: natural
- Fp: plantations, afforestation
- Fo: other (eg selective cutting of natural forests and incorporating planted species)

M: Mixed land
- Mf: agroforestry (cropland and forest)
- Mp: agro-pastoral (cropland and grazing land)
- Ma: agro-silvopastoral (cropland, grazing land and forest)
- Ms: silvo-pastoral (forest and grazing land)
- Mo: other

O: Other land
- Oi: mines and extractive industries
- Os: settlements, roads, infrastructure network
- Oo: others (wastelands, deserts, glaciers)

b) Degradation type addressed

W: Water erosion
- Wt: loss of topsoil (surface erosion)
- Wg: gullying (gully erosion)
- Wm: mass movement
- Wr: riverbank erosion
- Wc: coastal erosion
- Wo: off-site degradation (deposition of sediments, downstream flooding, siltation of reservoirs and waterways, and pollution of water bodies with eroded sediments)

E: Wind erosion
- Et: loss of topsoil (surface erosion)
- Ed: deflation and deposition
- Eo: off-site effects (covering of the terrain with windborne sand particles from distant sources ('overblowing'))

C: Chemical deterioration
- Cn: fertility decline and reduced organic matter content (not caused by erosion, eg leaching, fertility mining)
- Ca: acidification (lowering of the soil pH)
- Cp: soil pollution (contamination of the soil with toxic materials)
- Cs: salinisation/alkalinisation (a net increase of the salt content of the (top)soil leading to productivity decline)

P: Physical deterioration
- Pc: compaction (deterioration of soil structure by trampling or the weight and/or frequent use of machinery)
- Pk: sealing and crusting (clogging of pores with fine soil material and development of a thin impervious layer on the soil surface obstructing the infiltration of rainwater)
- Pw: waterlogging (effects of human induced hydromorphism)
- Ps: subsidence of organic soils, settling of soil
- Pu: loss of bio-productive function due to other activities (eg construction, mining)

V: Vegetation degradation
- Vr: reduction of vegetation cover
- Vs: quality and species composition decline
- Vq: quantity decline (loss of vegetative production)

H: Water degradation
- Ha: aridification/soil moisture problem
- Hp: water quality decline (pollution)
- Hq: water quantity decline (groundwater, surface water)

The degradation type that is mainly addressed by the SWC measure must be indicated under this system. In the case of several degradation types being more or less equally addressed by the same technology, this should be indicated as a combination of (two or more) categories eg CaWtV1+ CaCnV1, which means that the vegetative measure V1 (trees and shrubs cover) addresses both sheet erosion (Wt) and fertility decline (Cn). If subcategories are not specified, a '–' should be added instead of a letter.

c) Conservation measure

M: Overall management
- M1: Change of land use type:
  - enclosure/resting
  - protection
  - change from crop to grazing land, from forest to agroforestry, from grazing land to cropland, etc
- M2: Change of management/intensity level:
  - from grazing to cutting (for stall feeding)
  - farm enterprise selection: degree of mechanisation, inputs, commercialisation
  - from mono-cropping to rotational cropping
  - from continuous cropping to managed fallow
  - from 'laissez-faire' (unmanaged) to managed, from random (open access) to controlled access, from herding to fencing
  - adjusting stocking rates
  - staged use to minimise exposure (eg staged excavation)
- M3: Layout according to natural and human environment:
  - exclusion of natural waterways and hazardous areas
  - separation of grazing types
  - distribution of water points, salt-licks, livestock pens, dips (grazing land)
- M4: Major change in timing of activities:
  - land preparation

- planting
- cutting of vegetation

M5: Control/change of species composition (if annually or in a rotational sequence done eg on cropland -> A1)
- reduce invasive species
- selective clearing
- encourage desired species
- controlled burning/residue burning

A: Agronomic/soil management

A1: Vegetation/soil cover
- better soil cover by vegetation (selection of species, higher plant density)
- early planting (cropland)
- relay cropping
- mixed cropping/intercropping,
- contour planting/strip cropping
- cover cropping
- retaining more vegetation cover (removing less vegetation cover)
- mulching (actively adding vegetative/non-vegetative material or leaving it on the surface)
- temporary trash lines (and in A2 as 'mobile compost strips')
- others

A2: Organic matter/soil fertility
- legume inter-planting (crop and grazing land; induced fertility)
- green manure (cropland)
- applying manure/compost/residues (organic fertilizers), including 'mobile compost strips' (trash lines)
- applying mineral fertilizers (inorganic fertilizers)
- applying soil conditioners (eg use of lime or gypsum)
- rotations/fallows (associated with management measures)
- others

A3: Soil surface treatment
- conservation tillage: zero tillage, minimum tillage and other tillage with reduced disturbance of the top soil
- contour tillage
- contour ridging (crop and grazing land), done annually or in rotational sequence
- breaking compacted top soil: ripping, hoeing, ploughing, harrowing
- pits, redone annually or in rotational sequence
- others

A4: Subsurface treatment
- breaking compacted subsoil (hard pans): deep ripping, 'subsoiling'
- deep tillage/double digging
- others

V: Vegetative

V1: Tree and shrub cover
- dispersed (in annual crops or grazing land): eg *Faidherbia albida, Grevillea robusta, Sesbania sesban*
- aligned (in annual crops or grazing land): eg live fences, hedges, barrier hedgerows, alley cropping
  Subcategories:
  - on contour
  - graded
  - along boundary
  - linear
  - against wind
- in blocks
  Subcategories:
  - woodlots
  - perennial crops (tea, sugar cane, coffee, bananas)
  - perennial fodder and browse species
  Further subcategories for dispersed, aligned and in blocks:
    - natural reseeding
    - reseeding
    - planting

V2: Grasses and perennial herbaceous plants
- dispersed
- aligned (grass strips)
  Subcategories:
  - on contour
  - graded
  - along boundary
  - linear
  - against wind
- in blocks
  Further subcategories for dispersed, aligned and in blocks:
    - natural reseeding
    - reseeding
    - planting

S: Structural

Structures constructed with soil or soil enforced with other materials (S1–S7) or entirely from other materials eg stone, wood, cement, others (S8)

S1: bench terraces (bed <6%):
- level (incl. rice paddies)
- forward sloping/outward sloping
- backward sloping/back-sloping / reverse

S2: forward sloping terraces (bed >6%)

S3: bunds/banks
- level (tied/non-tied)
- graded (tied/non-tied)
- semi-circular
- v-shaped
- trapezoidal
- others

S4: graded ditches/waterways (to drain and convey water)
- cut-off drains,
- waterways

S5: level ditches/pits
- infiltration, retention
- sediment/sand traps

S6: dams/pans: store excessive water

S7: reshaping surface (reducing slope, etc)/top soil retention (eg in mining storing top soil and re-spreading)

S8: walls/barriers/palisades (constructed from wood, stone concrete, others, not combined with earth)

S9: others

Note: Often there are combinations: list them according to priorities: eg Ge/Wt/A3V2

Combinations

The measures described above are often combined where they are complementary and thus enhance each other eg: structural (terrace) with vegetative (grass and trees) with agronomic (ridges). Therefore the measures should be listed according to priorities eg GeWtA3 + GeWtV2 + …

List of organisations involved

ACT	African Conservation Tillage Network, Harare, Zimbabwe
ACW	Agroscope Changins-Wädenswil Research Station, Federal Department of Economic Affairs, Switzerland
ADB	Asian Development Bank, Manila, Philippines
ADDAC	Asociación para la Diversificación y Desarrollo Agrícola Comunal, Matagalpa, Nicaragua
AFZ	Association des Femmes Pag-La-Yiri de Zabré, Ouagadougou, Burkina Faso
AGRIDEA	Swiss Association for Agricultural Extension, Lindau, Switzerland
ARET	Allerton Research and Educational Trust, Loddington, Leicestershire, UK
ASC-UPLB	Agricultural Systems Cluster, University of the Philippines, Los Baños, Philippines
ASOCON	Asia Soil Conservation Network, Jakarta, Indonesia
AT&V	Asociación Tierra y Vida (AT&V), Nicaragua
BNU	Beijing Normal University, Department of Resources and Environmental Sciences, Bejing, PR China
BSWM	Bureau of Soils and Water Management, Department of Agriculture, Quezon City, Philippines
CAMP	Central Asia Mountain Programme, Bishkek, Kyrgyzstan
CDE	Centre for Development and Environment, University of Bern, Switzerland
CEAS	Centre Ecologique Albert Schweitzer, Neuchâtel, Switzerland
CETRAD	Centre for Training and Integrated Research in ASAL Development, Nanyuki, Kenya
CHTDB	Chittagong Hill Tracts Development Board, Bangladesh
CIB	Centre of Excellence of Invasion Biology, University of Stellenbosch, Matieland, South Africa
CIS	Centre for International Cooperation, Vrije Universiteit Amsterdam, The Netherlands
CISEC	Centro de Investigaciones y Servicios Comunitarios, Cali, Colombia
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
DANIDA	Danish International Development Assistance, Copenhagen, Denmark
DANWADEP	Danida's Watershed Development Programme, New Delhi, India
DEC	Dept. for Erosion Control, Faculty of Forestry, Belgrade University, Serbia & Montenegro
DED	Deutscher Entwicklungsdienst, Bonn, Germany
DESCO	Centro de Estudios y Promoción del Desarrollo, Lima, Peru
DoA	Department of Agriculture, Pretoria, South Africa
DSCOKTM	Department of Soil Conservation and Watershed Management, District Soil Conservation Office, Kathmandu, Nepal
DSCO	District Soil Conservation Office, Lalitpur, Nepal
FAO	Food and Agriculture Organisation of the United Nations, Rome, Italy
FAO-RAP	FAO Regional Office for Asia and the Pacific - (RAP), Bangkok, Thailand
FAO-SNEA	FAO Sub-Regional Office for North Africa - (SNEA), Tunis, Tunisia
FSWCC	Fujian Soil and Water Conservation Centre, Fuzhou, PR China
GDCRI	Gansu Desert Control Research Institute, PR China
GREAD	Group of Research, Studies and Actions for Development, Niamey, Niger
GTZ-CCD	Deutsche Gesellschaft für Technische Zusammenarbeit - UN Convention to Combat Desertification, Bonn, Germany
IAEA	International Atomic Energy Agency, Joint FAO / IAEA Division, Vienna, Austria
ICARDA	International Centre for Agricultural Research in the Dry Areas, Aleppo, Syria
ICIMOD	International Centre for Integrated Mountain Development, Kathmandu, Nepal
ICRAF	International Centre for Research in Agroforestry, Nairobi, Kenya
ICRAF-Claveria	ICRAF Claveria Research Site, MOSCAT Campus, Claveria, Misamis Oriental, Philippines
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, Niamey, Niger
IDEI	International Development Enterprises India, New Delhi, India
IFAD-GM	International Fund for Agricultural Development - Global Mechanism, Rome, Italy
IMNU	Inner Mongolia Normal University, College of Geographical Sciences, Inner Mongolia, PR China
INERA	Institut de l'Environnement et de Recherches Agricoles, Ouagadougou, Burkina Faso
InGeo	Institute of Geography, Ministry of Science, Almaty, Kazakhstan
INRA	Institut National de la Recherche Agronomique, Centre Aridoculture, Settat, Morocco
INSAH	Institut du Sahel, Bamako, Mali
IRHA	International Rainwater Harvesting Alliance, Geneva, Switzerland
ISCW/ARC	Institute for Soil, Climate and Water of the Agricultural Research Council, Pretoria, South Africa
ISRIC	World Soil Information, Wageningen, The Netherlands
IWMI	International Water Management Institute, Pretoria, South Africa (Headquarters: Colombo, Sri Lanka)
IWMI-TATA	IMWI-Tata Water Policy Research Program, Gujarat, India
KAU	Kyrgyz Agrarian University, Bishkek, Kyrgyzstan
KVL	The Royal Veterinary and Agricultural University, Denmark
LDD	Land Development Department, Ministry of Agriculture and Cooperatives, Bangkok, Thailand

MADRPM	Ministère de l’Agriculture du Développement Rural et des Pêches Maritime, Morocco
MAAIF	Ministry of Agriculture, Animal Industries and Fisheries, Entebbe, Uganda
MAFS-SCLUPU	Ministry of Agriculture and Food Security, Soil Conservation and Land Use Planning Unit, Dar el Salaam, Tanzania
MAG	Ministerio de Agricultura y Ganadería, Puriscal, Costa Rica
MoA-Ethiopia	Ministry of Agriculture, Addis Abeba, Ethiopia
MoA-Kenya	Ministry of Agriculture, Nairobi, Kenya
NCCR N-S	National Centre of Competence in Research North-South, Bern, Switzerland
NRW	Natural Resources and Water, Queensland Government, Brisbane, Australia
OSS	Observatoire du Sahara et du Sahel, Tunis, Tunisia
PARDYP	People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas
PASOLAC	Programa de Agricultura Sostenible en Laderas de América Central, Managua, Nicaragua
PRC-GEF	Gansu Project Management Office, PRC-GEF Partnership on Land Degradation in Dryland Ecosystems, PR China
PROMIC	Programa Manejo Integral de Cuencas, Cochabamba Bolivia
RELMA	Regional Land Management Unit, SIDA, Nairobi, Kenya
SDC	Swiss Agency for Development and Cooperation, Bern, Switzerland
SEARNET	Southern and Eastern Africa Rainwater Network
SOWAP	Soil and Water Protection project and its organisations, Europe
SWCB	Soil & Water Conservation Branch, Ministry of Agriculture, Nairobi, Kenya
SWCMC	Soil and Water Conservation Monitoring Centre, MWR, Beijing, PR China
SYNGENTA	Environmental Safety Assessments and Contracts, Jealott's Hill International Research Centre, Berks, UK
SYNGENTA FOUNDATION	Syngenta Foundation for Sustainable Agriculture, Basel, Switzerland
TERI	The Energy and Resources Institute, New Delhi, India
TROZ	Tropenzentrum – Centre for Agriculture in the Tropics and Subtropics, University of Hohenheim, Stuttgart, Germany
TSSRI	Tajik Soil Science Research Institute, Dushanbe, Tajikistan
TVN	The Vetiver Network, Maryland, USA
UCL	Université Catholique de Louvain, Agricultural Engineering Unit, Soil and Water Conservation, Louvain-la-Neuve, Belgium
UK-SMI	UK Soil Management Initiative, Loddington, Leicester, UK
UNEP	United Nations Environment Programme, Nairobi, Kenya
WASWC	World Association of Soil and Water Conservation, Beijing, PR China
WDCU	Watershed Development Coordination Unit, New Delhi, India
WORLP	Western Orissa Rural Livelihood Project, Bhubaneswar, India

Acronyms

GLASOD	Global Assessment of Soil Degradation
LADA	Land Degradation Assessment in Drylands
M&E	Monitoring and Evaluation
NGO	Non-Governmental Organisation
SLM	Sustainable Land Management
SWC	Soil and Water Conservation
UNCCD	United Nations Convention to Combat Desertification
WOCAT	World Overview of Conservation Approaches and Technologies

land users leading the way in making the land greener

where the land is greener

case studies and analysis of soil and water conservation initiatives worldwide

'where the land is greener' looks at soil and water conservation from a global perspective. In total, 42 soil and water conservation technologies and 28 approaches are described – each on four pages with photographs, graphs and line drawings – from more than 20 countries around the world. This unique presentation of case studies is drawn from WOCAT's extensive database. These and many other experiences deserve to be documented, analysed and used for decision support. The book is, furthermore, a prototype for national and regional compilations of sustainable land management practices.

Various land use categories are covered here – cropland, as well as forest and grazing land. The technologies range from terraces to agroforestry systems; from rehabilitation of common pastures to conservation agriculture; from vermiculture to water harvesting. Several are well established successes – others are innovative, relatively unknown and full of promise. The technologies are matched by studies of the 'approaches' that have underpinned their development and spread. Some of these approaches are descriptions of projects, but there are also fascinating explanations of how spontaneous development and spread has taken place. The book does not stop with case studies: there are two analytical sections, taking the technologies and approaches in turn. These uncover common elements of success, and offer hope for productive conservation at local level with simultaneous global environmental benefits. Finally there are policy pointers for decision makers and donors, who are challenged to invest further – to make the land greener.

Structure of the book

Part I: Analysis and policy implications
- Introduction – *from hot spots to green spots*
- Analysis of SWC technologies – *what works where, and why*
- Analysis of SWC approaches – *putting the practices into place*
- Conclusions and policy points – *support for descision makers*

Part II: Case studies
- Conservation agriculture (5 case studies)
- Manuring/ composting (3 case studies)
- Vegetative strips and/or cover (3 case studies)
- Agroforestry (8 case studies)
- Water harvesting (3 case studies)
- Gully rehabilitation (3 case studies)
- Terraces (9 case studies)
- Grazing land management (4 case studies)
- Other technologies (4 case studies)

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