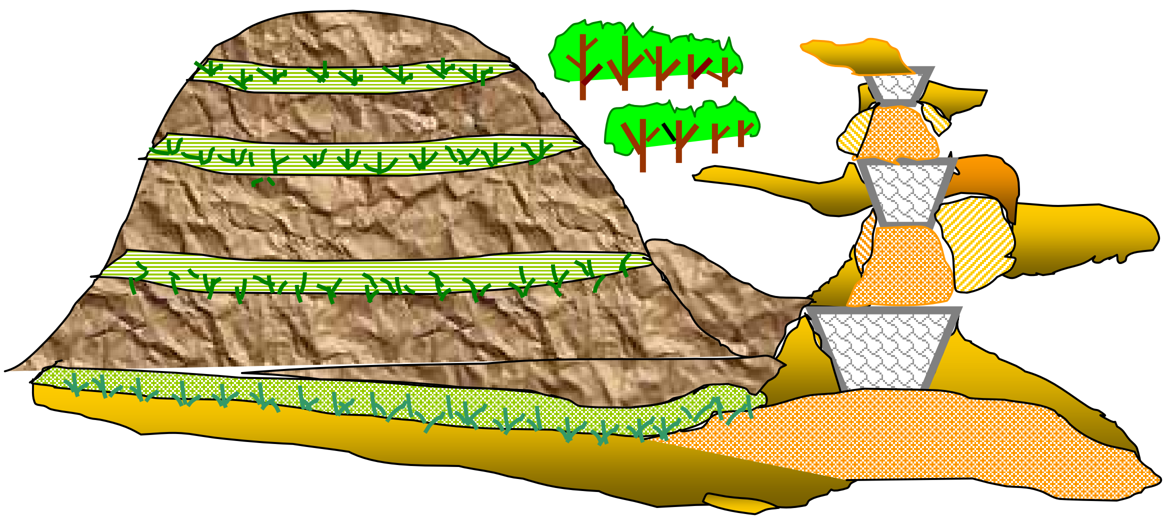
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF AGRICULTURE AND CO-OPERATIVES,
THE KINGDOM OF SWAZILAND



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1.1 Expected Users of the Guideline

This guideline has been prepared mainly for the use by the officers of the Ministry of Agriculture and Co-operatives who are in responsible position for guiding the community people properly and sustainably in their farming activities and livestock husbandry Also, this guideline has been prepared as the textbook for the agricultural extension officers of the Ministry of Agriculture and Co-operatives, with which, the officers of the Ministry of Agriculture and Co-operatives teach and train the agricultural extension officers until they have capability of appealing the necessity of soil conservation to the community people as well as until they have capability of proposing concrete soil conservation measures to the community people.

This guideline also includes many simplified illustrations as attached, which introduce several soil conservation methods to be applied depending on the conditions of the communities concerned. Accordingly, it is expected that this guideline will be useful as the textbook not only for the community people, but also for the teachers of primary and junior high schools who are expected to promote soil conservation in the communities as one of the environmental education to the school children.

Accordingly, it is hoped that this guideline will be widely used not only by the government officers concerned but also among the community people, teachers and school children as well.

1.2 Brief Introduction of the Contents of the Guideline

This guide consists of practical contents which will be useful for the field workers who actually participate in soil conservation works, avoiding too much theoretical description on the soil conservation. Therefore, this guideline provides with many illustrations which will help the field workers to understand and carry out the soil conservation works smoothly and easily. Main components of this guideline are; 1) descriptions of general planning method for soil conservation, 2) proposed implementing structures for soil conservation, and 3) proposed concrete soil conservation measures. It may be noted here that the concrete soil conservation measures have been proposed in the form of menus as much as possible, although the soil conservation measures largely differ depending on the nature of soil, topography and degree of land degradation etc.

2 Area covered by the Guideline

This guideline has been prepared for the Study Area (SA) covering the total area of 4,646 km^2 of Swazi National Land (SNL), which consists of Highveld of 2,979 km^2 and Upper Middleveld of 1,667 km^2. It is noted here that the Title Deed Land (TDL) included in the study area has been excluded from the target of this guideline.

3 Current Status and Recent Trend of Land Degradation in the Study Area

Land degradation has various profiles, such as soil erosion in sheet, rill and gully types, encroachment of alien plants, crop nutrient loss. Land degradation is a man-made disaster as an aftermath of improper land use, and it is globally observed that range-land has by far been affected as compared with arable land and forests or wood-lots, because the latter is protected by litter coverage and grass-strips covering over ground surface.

Similarly, drier area tends to get more degraded than humid zone with denser vegetative cover, because it takes more time for recovery of once disturbed vegetation cover due to shortage of rainfall. From this point of view, Highveld can take more advantage of vegetative regeneration than Upper Middleveld. Ravine type gullies represent extremity of degraded land, mainly distributed over grass-land where high density of cattle/goat herds have given lingered detrimental impact on vegetative cover for decade. In addition the results of soil erosion assessed by Dr. Remmelzwaal and Mr. McDermotlower as of 1997 through AELDA (Actual Erosion and Land Degradation Assessment, developed by FAO) method is shown in Table 3-1.

Table 3-1: Acreages of Land Use and Erosion Affected land Area against SNL Area

(Unit: percentage)

Area Division	Observed year	Land under communal grazing (A)	Out of (A), seriously eroded	Out of (A), moderately eroded
Highveld (2,979 km^2)	1997	57% (1,698 km^2)	31% (934 km^2)	23% (679 km^2)
Upper Middleveld (1,667km^2)	1997	67% (1,117 km^2)	54% (894 km^2)	10% (168 km^2)

Note 1 Seriously eroded: Formation of gullies is observed and vegetation covered area is less than 30%.
Moderately eroded: Occurrence of Rill erosion s is observed and vegetation covered area is within the range of 30% to 70%.

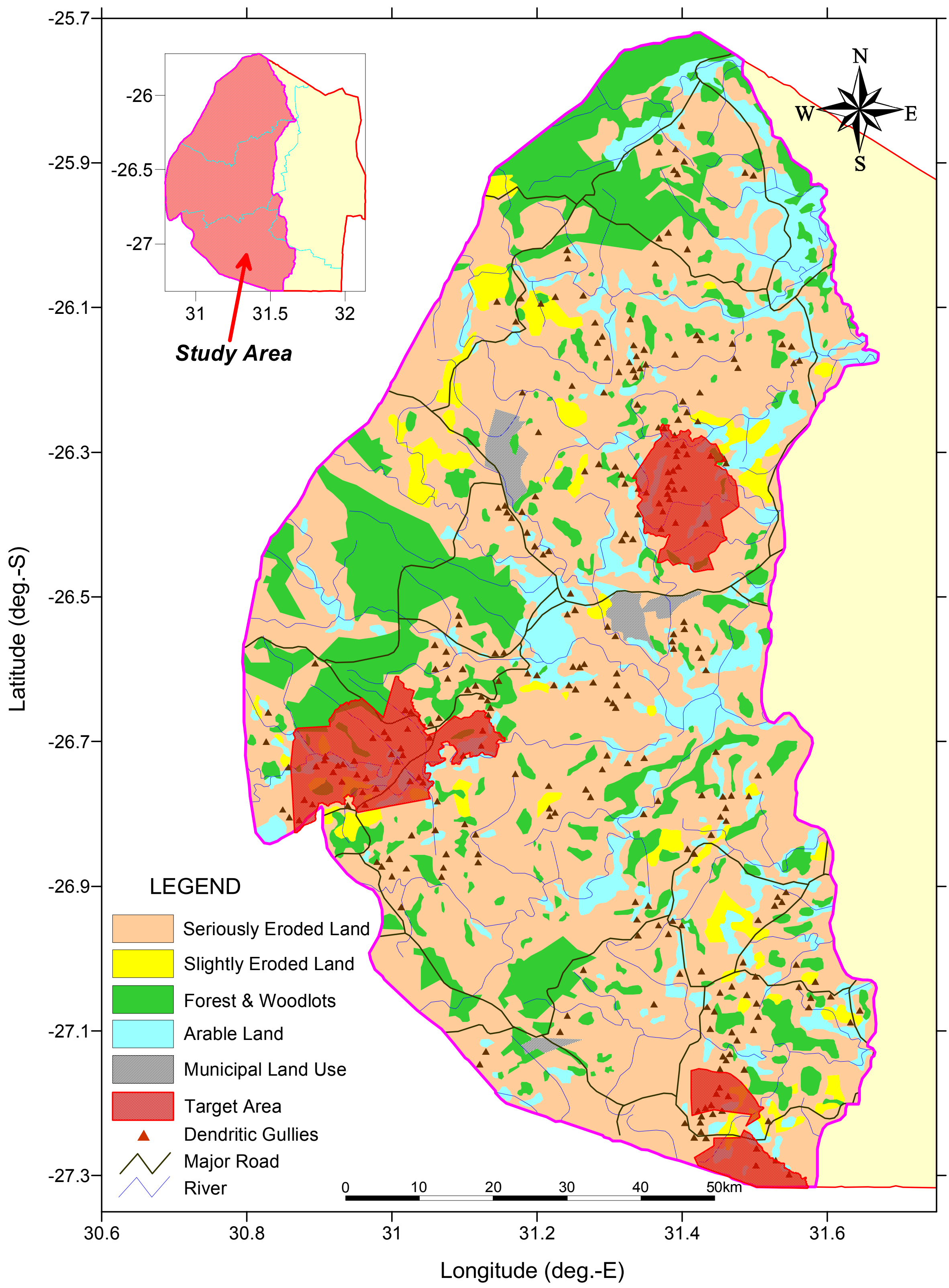


Figure 3-1: Existing Land Use and Degraded Land Condition in the Study Area

Table 3-2: Assessed Acreages of Land Use and Status of Degraded Land in the Study Area

(Unit: km^2 and %)

Land use & extent of erosion		Individual area in the study area	Grazing Land: Seriously eroded	Grazing Land: Ordinary eroded	Grazing Land: Unaffected area	Forests & wood-land	Arable Field	Others Area
SNL	Highveld	2,979	934 (31%)	679 (23%)	85 (3%)	149 (5%)	238 (8%)	894 (30%)
	Upper Middleveld	1,667	967 (58%)	33 (2%)	55 (3%)	95 (6%)	134 (8%)	383 (23%)
	Total	4,646	1,901 (41%)	712 (16%)	140 (3%)	244 (5%)	373 (8%)	1,276 (27%)
TDL	Highveld	1,849	527 (29%)	134 (7%)	49 (3%)	1,010 (55%)	55 (3%)	74 (4%)
	Upper Middleveld	987	543 (55%)	69 (7%)	53 (5%)	227 (23%)	99 (10%)	49 (5%)
	Total	2,836	1,018 (36%)	202 (8%)	92 (3%)	1,248 (44%)	142 (5%)	113 (4%)

Note: The figures are derived from planimeter reading of area on a classified map provided by the Study Team, Seriously eroded land corresponds to very seriously and seriously eroded area by AELDA classification, and Ordinary eroded land does to moderately and acceptably eroded area by the same classification. Distribution of land in this table is mapped in Figure 3-1.

As seen in the above table, grazing area in SNL not only accounts for major part of surface area but has high percentage of highly degraded land. Whereas, TDL has vastly extended forest and woodland area comparable to grazing field, and rate of degradation is not as high as that in SNL. Why has such a difference been brought about? A conceivable reason lies in historical aftermath of colonialism in which European colonists had occupied land with most favourable conditions.

However, these colonialists and current generation who manage TDL seem to have scientific knowledge to avoid land degradation and actually put it into practice. Also, because they are not poverty stricken, they can afford to take a due care for preventing land degradation.

In Swaziland, densest areas of gully occurrence coincide with Middleveld where alluvial and colluvial ridge type hills with highly weathered saprolite rocks are widely located. More than three quarters of these hills, mostly classified as SNL, has been used as range-land. Here, soil erosion particularly that of gully formation/development has markedly been accelerated since 1970s and 1980s during which highest cattle-herd population has been recorded in this country. The rate of gully erosion read from aerial photos during this period was reported as given in Table 3-3.

Table 3-3: Rate of Gully Development in Middleveld of Swaziland

Degree	Severe	High	Moderate	Low - None	Average
Gully density	1 / 3ha	1 / 5ha	1/ 12.5ha	< 1 / 12.5ha	1 / 8.5ha
1972 level	6.9 %	21.1 %	33.6 %	38.4 %	-
1990 level	13.6 %	26.7 %	28.2 %	31.5 %	-
Trend in 20years	+ 6.7 %	+ 5.6 %	- 5.4 %	- 6.9 %	-

Source: R.P.C. Morgan et al. Cranfield University, UK. Issued in Soil Technology 11 (1997)

As a current record of field observation as of 2002, the Study Team measured area percentages affected by various types of surface soil erosion. The results are given in Table 3-4.

Table 3-4: Estimated Extent of Surface Area affected by Erosion in the Target Areas

(Unit: % of surface area)

Erosion Type	Extent	Highveld	Upper Middleveld	Upper-Lower Middleveld	Total Target Areas
Sheet erosion	severe	4%	6%	7%	5%
	moderate	9%	20%	19%	14%
	slight	9%	1%	2%	6%
Sheet Erosion, Total		22%	27%	28%	25%
Rill erosion	severe	0.3%	0.3%	1%	0.3%
Terracette erosion	severe	0%	1%	0%	0.1%
	moderate	6%	10%	4%	6%
Terracette erosion, Total		6%	11%	4%	6%
Slip erosion	severe	0.1%	0.2%	0.1%	0.1%
	moderate	0.1%	1%	0%	0.3%
Slip Erosion, Total		0.2%	1%	0.1%	0.4%
Gully erosion (Ravine Type Gully)	extreme	2%	1%	3%	2%
	severe	0.5%	0.6%	1%	0.6%
Gully erosion, Total		3%	2%	4%	3%
Total affected area (%)	*	31%	41%	37%	38%

Source: Estimated by the Study Team based on the target area study.

Although ravine type gullies are outstanding in scenery views, the area incised by them occupies about 3 percent in the total acreage. Rather, agronomical and pastoral significance of soil erosion resides with sheet/terracette erosion compared to gully erosion, because these types of erosion foster loss of soil nutrient, leading to futile and degraded grass-land or crop-field. Besides, this erosion eventually forms naked or denuded land patches, by and by triggering gully occurrence given the sub-soil structure suits its development.

4 Mechanisms and Causes of Soil Erosion Including RTG (Ravine Type Gully)

Natural soil erosion without any artificial intervention exists as background phenomenon. However, man-made disturbance is by far greater that can accelerate erosion process. The major causes of soil erosion are tabulated as follows. Soil is eroded by runoff water during and after rainfall as well by wind in dry season. Surface vegetative cover provides maximum resistance against process of erosion because it not only attenuates raindrop energy that destroys surface soil clods but root system holds soil aggregates firmly against scouring by surface runoff or deepening of vertical cleavage. In order to rehabilitate eroded land, or to minimize rate of further erosion, it is essential to retrieve vegetative cover over denuded patches. Figure 4-1 shows how grass cover loss over ground surface affects sheet erosion.

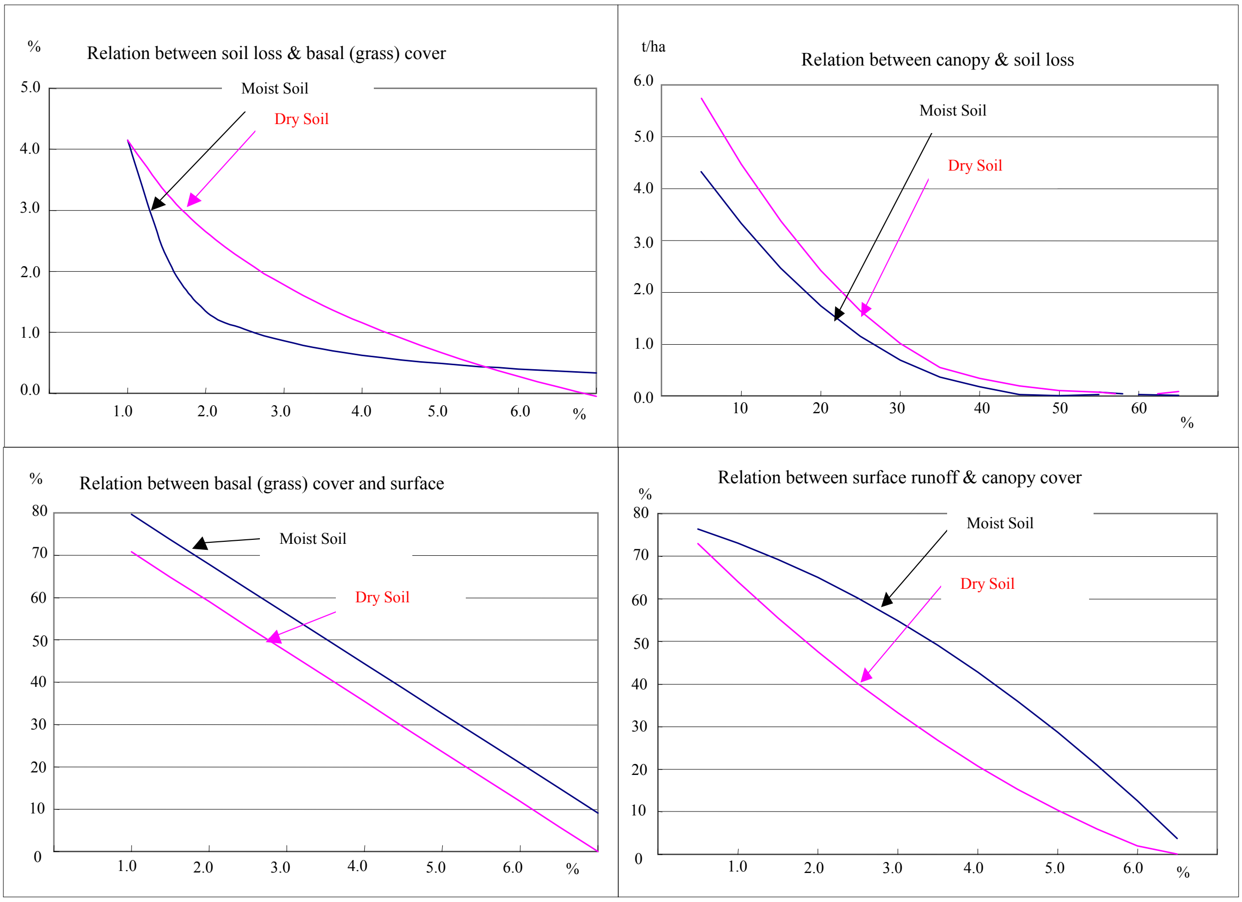


Figure 4-1: Relation between Basal Cover of Grazing Grasses, Soil Loss and Surface Runoff measured with a Rotating Rainfall Simulator on both Moist and Dry Soil

Table 4-1: Major Causes of Different Types of Erosion

Erosion Type	Susceptible Material	Major Causes
Sheet	all soil types over slope	overgrazing, field burning, deforestation, poor crop cover
Terracette	ditto on steep slope	A type of developed sheet erosion caused by cattle over-grazing over shallow rocky soils where exposed rock forms small terrace often in rhombic shape.
Slip/Slide	shallow soils on slope	cattle overgrazing over saprolites containing few rock/stone pieces where land slides over temporary impermeable layers
Rill	sandy soils/ stony soils	Runoff pathway often formed heavily sheet-eroded slope of cattle tracks, cart roads, borrowing areas or crop field.
Gully	all types of soils, with highly erodible clay mineral like kaolin	Rills are deepened to form gullies, or soil cleavage / holes can develop into gullies. starting from old termite mounds, borrow pits, scoured escarpment along stream banks etc.
Ravine Type Gully	deep layers of weathered saprolites with sub-soil containing readily water suspendable kaolin	With plural heads, often developing into dendritic form, starting often from denuded cattle tracks, local paths. Mostly accompanying with large loss of illuviated kaolin mass in lower saprolite layers melted into groundwater seepage.

Various hypotheses have so far been presented as to caustic factors influencing formation process of ravine type gullies (RTGs), but here the Study Team proposes these as cited and tabulated below, as a result of its observation for three years (Here, RTG doesn't include gullies with organ-pipe/flute wall typical in Lowveld colluvium) ;

1) RTGs can be encountered over wide range of altitude, soil type and surface geology though they are more found in elluvium (granitic/granodioritic saprolites) than in colluvium. Further, huge RTGs cluster along geological faults and areas of extremely weathered granite/ granodiorite and occurrence is more frequent along faults. The reason may relate to alluvial clay formation through repeated tectonic friction along faults.

2) As compared to range-land, arable plots are generally less affected by erosion, even if they are located over slope, possibly owing to grass strips along contour lines and thick maize leaf shading during rainy season.

3) Developing rate of gullies is regardless of annual precipitation, nor is there any interrelation between rate of growth and rainfall, possibly because earth structure exerts as a key factor. Slumping of gully walls tends to proceed towards upstream of groundwater.

4) RTGs by far more often take place on/along former cattle tracks or paths to dip-tanks and watering places that had carried a large herd every day, though they also occur along roadside drainage-ditches and around drain culverts, earth borrowing areas etc.

5) Heavily degraded areas with ravine type gullies are often found on range-land in SNL but much less found on that belonging to (formerly/currently) private ranches, where cattle herds have been raised at proper herd density (cattle have been grown rather for commodity purpose than as only household property).

6) Artificially caused RTGs very often develop on convex horse-back ridges than on the tips of concave valleys where natural geological incision occurs, because cattle herds seldom pass along valleys but take paths on the ridges by their instinctive behaviour (avoiding poisonous snakes and parasitic insects especially during rainy seasons).Also, ground along valleys has already been incised to impermeable bedrock without clay deposit where no room remains to form cavity or hollows.

7) Walls or isolated islands inside huge RTGs always have deposited clay-rich layers of lumps of illuviated kaolin. They are soft and friable, readily dissolving into water when they are seeped / dipped by groundwater/runoff, forming scoured hollows.

8) About 10% of observed gullies have perennial water flow/ponds at their bottom. Water flowing gully bottoms often are turbid with milky colour as it contains kaolinite colloid even in dry season. They often cease to deepen themselves above impermeable beds because no more clay remains in these beds. Some gullies have ponds inside them...

9) Illuviated clay is often deposited in an aquifer lying above a sparsely permeable layer (gneiss) where turbid spring water flows during rainy season. Illuviated pink coloured silty deposits found under remnant island-pillars inside RTGs or on the surface of gully walls have well-sorted particle size distribution and such low consistency or bearing capacity that even cattle urination can melt their matrices away instantly.

10) Cavities /hollows found in rills /gullies are wet even in dry season where layers with extremely friable silt/clay deposits are found containing groundwater that undergo continuous scouring especially during rainy seasons.

11) In most cases, development of gullies ceases at the top or flat part of hills, though rarely they still proceed on, cutting a hill into two parts. They develop either concave or convex parts of colluvial/remnant alluvial hills at the proximity of granitic mantles.

12) Some gullies particularly with high water table at their floor become stabilized by inner re-vegetation with bracken, shrubs or alien trees, but they can at times be rejuvenated into active ones.

13) Usually, U-shaped gullies have older age than those with V shaped ones without flat bottoms, though the section depends on the state of weathering of base rocks. Linear gullies grow into branched (dendritic) ones and finally circled depressions are resulted.

14) Generally, younger gullies can advance faster than older ones, but the latter may broaden their width or deepen, and in some cases aged ones formed a century ago are still active, continuing to grow. Development rate of gully-heads and widening rate of their walls tend to be faster in rainy to post rainy season than in dry season. Though saprolite commonly has little water porosity, it shows high hydraulic gradient and oozing seepage water springs are observed during rainy season at gully walls where relatively impermeable layers outcrop.

15) Outlets of ravine gullies form usually narrow ditches open to streams, or to heads of other gullies or even flat terrace of hill ridges etc. where bottom water flow disappears as latent seepage, or part of the gully floor already reaches dolerite sill... In alluvial terraces, often well-developed root-mat of thriving grasses limits further widening of gully mouths.

16) Almost all ravine gullies have lost enormous earth volume though slumping of saprolite walls with low clay content in rock-mass, possibly because of loss of illuviated kaolinite deposits. Material of gully wall contains smectite that shrinks and swells, forming vertical cleavage through drying to wetting hysterisis caused by rainy and dry season, and this fissures foster slumping down of hanging soil layers on wall surface.

17) Mechanism of branching of a linear gully into dendritic one is still controversial, though it may relates to shape of buried valley where impermeable layers lay beneath them, different hydraulic gradient or uneven distribution of illuviated clay lumps.

From these observations and hitherto records, it can be deduced that surface rainwater is very little to do with gully formation except for very initial triggering stage, implying that groundwater regime and underground clay deposits have more bearing to gully formation than surface runoff. It would be imperative to take gully-training measures taking full account of these basic mechanisms of gully formation/development so as to avoid wastes as well to make inputs for gully training efficient and worthwhile.

From an estimated cycle, gullies will be reduced to ordinary (geo-chronological) dissected valley as time elapses. Hydrated clay minerals (smectite) swell and the degree of clod-cohesion is gradually lost to allow hanging wall over bottom hollows to slump down. Length, depth and width of ravine gullies also depend on their age, volume and distribution of un-weathered rocks/weathered saprolites/illuviated clay lumps lain underneath and volume of illuviated and deposited kaolin (dissolvable into groundwater) in saprolite matrices. In this context, neither pedrogical nor geological data can contribute prediction of gully occurrence and development, but only location of running faults and 2:1 type clay content in alluvial/colluvial cover layers and presence of illuviated clay mass in underlain saprolite may be used as an indicator for predicting higher occurrences of RTGs.

Table 4-2: Process of Gully Formation

Stage	Causes	Solum	Initial Trigger: artificial land surface disruption by overgrazing etc
0	Faulting/ Clay formation and Illuviation	Through-out illu-vium of saprolites	Archaean tectonic movement induced frequent faulting inside granitic mass where claytization took place. Later, groundwater illuviated single-latticed clay mineral (kaolinite) to the layers with impermeable stratum. Illuviated layers lost finer particles, thus lowering their consistency.
I	Surface run-off	Surface horizons	Increased barren parts over ground surface by overgrazing, field burning for grass regeneration, road drainage works, tramped footpaths / tracks.
II	Formation of rill *	Lower soil horizons	Barren runoff waterways form rills over disrupted land surface (road drain /cart path) through vertical ground cleavages, scoring bottom hollows
III	Infiltration in t o s ubstrata	Corruvium ~ Saprolite	Water in rills percolates into weathered saprolite lain beneath them that has illuviated kaolin lumps susceptible to hydration and scouring erosion
IV	Intersolum Lateral flow	Ground-wat er gradient	Groundwater dissolves illuviated kaolinite deposits, hydrated talc etc. and carries away from argillized lumps through vertical cleavage/cracks in topsoil containing smectite or inside fossil veins in weathered saprolite
V	Intersolum Lateral flow	Hydraulic action	Cavities are formed and gradually truncated/scoured hollows develop in fossil soils / saprolite lying beneath alluvial soil layers. Rainwater laterally flows over gneiss and intrusive rocks that are relatively less permeable, through scoured hollows dissolving clay to silt from hollow
VI	Drying of walls and vertical separation	Developing into hollow	Cavities develop into hollows in the advanced stage of hydrated clay removal from clay-lumps and load-sustaining capacity rapidly weakens. Saprolite in the soil is rapidly air-oxidized and vertical cracks form as smectite shrinks in the ground surface, separating soil pillar from walls.
VII	Collapse of soil pillar from walls	Subsiding fossil layers	Overhanging soil layers thus separated above carved hollow or truncated cavities eventually fall down mainly during (post) rainy season as if land slaking occurs at the brink of vertical gully walls and heads
Developing process of Natural Gully			
I	Surface hole formation	B horizon (A lost)	Concave holes are formed on the ground surface by termites. Water dissolves dehydrated clay supplying water to upright saprolite layers
II	Occurrence of a fissure	All surface horizons	Narrow and vertical ground-surface fissure appears in a straight line by an action of geo-structural tension along upright saprolite fault/joint. Saprolite (sub-soil) is exposed, undergoing oxidation.

III	Widening of cleavage	Saprolites and others	Fissure develops into underlying fossil layers and saprolites, then rain water wash soil wall to widen until V section of a gully forms.
IV	Branching/ soil pillar	Above hard baserocks	A straight gully is gradually incised into branched form, and two adjacent branches merge again to form isolated soil pillar standing in the gully, but later falling down to the bottom, forming U-shaped section.

Note: * rill can even be developed through grass covered area, as the tail of ravine gullies, pouring into a stream. In this case width of rills remains narrow because grass / shrub root system protecting soil clods inhibits their widening.

Also, an important factor in these estimating instruments constitutes lateral and vertical water permeability, readily water-dissolving or swelling ~ shrinking clay minerals which fosters development of huge gullies through dissolution of clay/silt in saprolites into groundwater.

As early as 1970s, gullies and other erosions were mentioned in "The Conservation Ideal" by J.W. Rowland published in Pretoria, where gullies were considered originating in natural underground subsidence developing into subterranean channels, subsequent collapse of the upper horizons, then exposing the hideous gullies leaving permanent scars, which in the main are beyond repair but can at best be prevented from further extending.

Table 4-3: Example of Gully Development Process

Age	Period	Section	Shape	Depth (m)	Geology / Soil	Vegetation
I	few years	rectangular	flat plate	0.5 - 1	any bedrock	bare surface
II	10 years	V or rectang.	linear	1 - 2	Within soil depth	no, except grasses
III	10-20 years	V or U	branching	2 - 5	Saprolite	Some fern thrives
IV	20-30 years	U or still V	plural heads	5 - 20	If no hard stone at the gully	if not dark, some
V	30-50 years	U or W	brachiated	5 -20		trees grow lower part
VI	50-80 years	widened V	auto-burying	3 - 15	Gullies change to ordinary valley	trees grow gully head
VII	100 years	common valley	brachiated	2 - 10		trees cover whole

As concern development of huge dendritic gullies, their formation have been activated since the last half century, the numbers of which have reached 2,500 or more. In Highveld and Upper Middleveld, around 65% of them have been counted (about 0.2 gullies /km^2) as recent emergence. In three Target Areas, huge ravine type ones have been distributed over the sites as tabulated as follows (with a density of 0.9 -3.3 /km^2).

As mentioned above, risky areas of gully occurrence can roughly be predicted from present pattern of fault distribution. The distribution density of RTGs that exist in the area with a width of 5 km spreading from east to north along the faults running south to north is 2.3 times those in Highveld and Upper Middleveld (refer to Table 4-7).

It's needless to say that grazing land and unpaved roadsides account for over 90% of the total sites of active, incised and dendritic gullies, allowing no room for denying that artificial, man made land-use activities have triggered and accelerated huge gully formation and their development over geologically fractured veins.

Table 4-4 shows the observation on growth of natural grass by distance from a gully head. In addition, denuded patches too often take place around huge RTG. From this table, there seems a tendency that further from a gully denser grass thrives, and it implies how land degrades into futile surface, though in other cases brachiated gully heads proceed to grassed surface and gulf sod down to their bottoms.

Table 4-4: Relationship between Surface Vegetative Cover and Distance from Gullies

Item/ Target Area	Number of grasses (per 1.0 m^2)			Number of diverse grass species			Density of grass cover		
	Close to gully	50 meter ahead	100 meter	Close to gully	50 meter ahead	100 meter	Close to gully	50 meter ahead	100 meter
TA 1	43	41	83	4	4	5	40	50	75
TA 2	45	78	0	5	6	0	25	50	0
TA 3	65	47	49	8	7	9	40	20	30

Source: Observation by the Study Team in June 2002

As to trends of erosion development and future outlook, a study based on aerial photo-interpretation taken in 1972 and 1990 over the same area by R.P.C.Morgan et al. presented in Soil Technology 11 (1997). This study includes TA1 and part of TA3. The result showing trend of gully development is summarized in the table below and the trend in two decades is calculated in the last column. In order to apply AELDA (Actual Erosion and Land Degradation Assessment) criteria, the trend of gully development was converted into that of sheet erosion employing the mean rate of gully versus sheet erosion in the criteria of AELDA as shown in the last column of Table 4-5.

Table 4-5: Estimated Future Development of Soil Erosion

Degree	Severe	High	Moderate	Low-None	Average
Gully density	1 / 3ha	1 / 5ha	1/ 12.5ha	< 1 / 12.5ha	1 / 8.5ha
1972 level	6.9 %	21.1 %	33.6 %	38.4 %	-
1990 level	13.6 %	26.7 %	28.2 %	31.5 %	-
Trend in 20years	+ 7.0 %	+ 5.9 %	- 5.7 %	- 7.2 %	-
Sheet Erosion Equivalent	+ 35 %	+ 29 %	- 28 %	- 36 %	-

Carrying capacity on severely eroded grazing fields is estimated at less than a half of that of little eroded ones from the result of grass hill counting. The above table suggests us that 1.6% of national herds will disappear every year if no measures be made in future. This is equal to say that in 2060 almost no cattle will survive on grazing areas in SNL due to extreme dissection and soil loss. As identified in the following table, huge ravine type gullies seldom appear in man-made forests, and if the frequency of their appearance is compared between TDL (private land) and SNL, their density in SNL accounts for 2.7 times as much as that in TDL in Highveld, and 6.4 times as much as that in TDL in Upper Middleveld. This fact has significant bearing to the rate of seriously eroded part of grazing land, i.e., 95% in Highveld versus 97% in Upper middle vela in SNL and 79% in Highveld versus 88% in Upper Middleveld in TDL, respectively. This can alternatively be expressed; the more severely grazing land is affected by sheet erosion, the higher the rate of gully occurrence will follow.

Table 4-6: Observed Density of RTGs in Different Lad Use

Category	Land use Pattern	Surface area (ha)	Number of RTG observed	Density of RTG (area in ha per RTG)
Highveld	Plantation Forests	102,200	4	25,500
	Grazing land in TDL	71, 200	10	7,120
	Grazing land in SNL	280,100	106	2,642
Upper Middleveld	Grazing land in TDL	61,900	13	4,761
	Grazing land in SNL	100,500	134	750

Note: Density of RTGs indicates hectare where one huge ravine gully is found. In this table the number of gullies is those identified by the Study Team.

Table 4-7: Observed Density of RTGs along Major Faults

Location		Name of Fault	Length of fault (km)	Surface Area (km^2)	Number of RTG	Density of RTGs km^2 /gully
SNL	Highveld	Mahaleni	15	75	8	9
		Central *	120	600	3	200
		Empini	23	115	9	13
		Mahlangatsa	25	125	16	8
	Upper Middleveld	Zanzana (TA1)	23	115	26	5
		Markerns Depression	45	225	23	10
		Olwandle	8	40	8	5
		Kapunga-Hlathikuru	43	215	31	7
		Kamlotsa-Mahanga	60	300	12	25
		Ndlotane	4	20	13	2
	Total		366	1,830	149	**12**
SNL+TDL			-	7,482	267	**28**

As long as developing process of gullies (terminology: gullying) is chiefly governed by the presence and underground quantity of weathered saprolite mass with clay illuviation, they are caused only by surface disturbing like that over cattle tracks, road construction regardless of their environmental or location factors like climate, slope gradient and other topographic features, surface soils, surface geology, biotope etc. as indicated in the following table. RTGs are widely distributed throughout Highveld and Upper Middleveld except over long standing forest zones. People in Swaziland should recognise the fact that they live on such fragile earth ground just as population living on active volcanic ranges shouldn't forget the fact that they always face to risk of disastrous earthquakes.

As shown in the above table, RTGs are distributed along major faults running on saprolite layers derived from granites and granodiorites, where the density of occurrence falls on more than two times of the average density on High and Upper Middleveld. Only one exception is observed on the Central Fault where major part is covered with pulp forest standings.

Table 4-8: Physiographic, Geological and Pedological Characters of Gullies in 3 Target Areas

Character	TA1 (Upper Middleveld)	TA2 (Lower Middleveld)	TA3 (Highveld)
Physiography	Found over colluvial fans developed along foothill of remnant hills, dissected by Labandzi, Mhlambanyoni, Phowe, Mbuludzi Rivers	Found over colluvial fans or deposits along foothill of Hlobane Hill and piedmont / escarpment of plateaus called Sivule hills.	Found throughout the basin of Ngwempisi River, developed over stone-free alluvial fans (largest one in Nkhanyezini plain) and colluvial deposits
Geology	Developed along/ around a north-south fault running along Mhlambanyoni River, in the centre of hornblende granodioritic basin. No gully was observed on dolerite intruded into granodiorite. Few gullies were found over granodioritic gneiss.	Clustered on medium grained granites, also along escarpment with outcrop of clay stone at the boundary of dolerite cap and granite. No gully is found on the dolerite or gabbros cap over Sivule hills or Msila hills, because they are not much weathered into saprolite.	Found on most geologic formations except coarse and medium grained granite cap (less-weathered) over Mbeka and Ntabamphlophe Hills. They are scattered on vast tonalitic gneiss, hornblende biotite tonalitic gneiss, but few on serpentitic amphibolite
Pedology	By far aggregated on Rego- sols and deep Ferralsols, but also found on Acrisols, Cambisols and Gleisols.	Found on various soils like Regosols, Ferralsols, Acrisols, Lixisols, Vertisols and Cambisols.	Developed by far on Regosols but also Ferralsols, Vertisols, Cambisols, Acrisols, Pheozem and Lixisols.

Note: Fluted pipe-organ type gullies are not included because they dominantly occur in Lower Middleveld and Lowveld.

Caustic factors have so far identified or suggested as in the following table where all factors have possibility of affecting soil in such a way as weakening vegetative cover and spreading barren land.

Table 4-9: Major Causative Factors on RTG Occurrence

	Animal husbandry	Land use/ Cultivation	Construction works	Natural causes
Concrete causes 1	Cattle path, track	Field Burning	Drainage / Road	Fluvial dissection
Concrete causes 2	Overgrazing	Surface ploughing	Borrow-pit Excavation	Termite mounds

Based on the above listed observations, it is advised that caution must be paid to the future land use on hill-foot or piedmont areas with high erodibility. Typical formation area of gullies is observed over gentle sloped, stone free thick, weathered saprolite-layers, or outcrop often capped by colluvium derived from granitic gneiss and other acidic rocks. Schematic profile of saprolite layers are shown below.

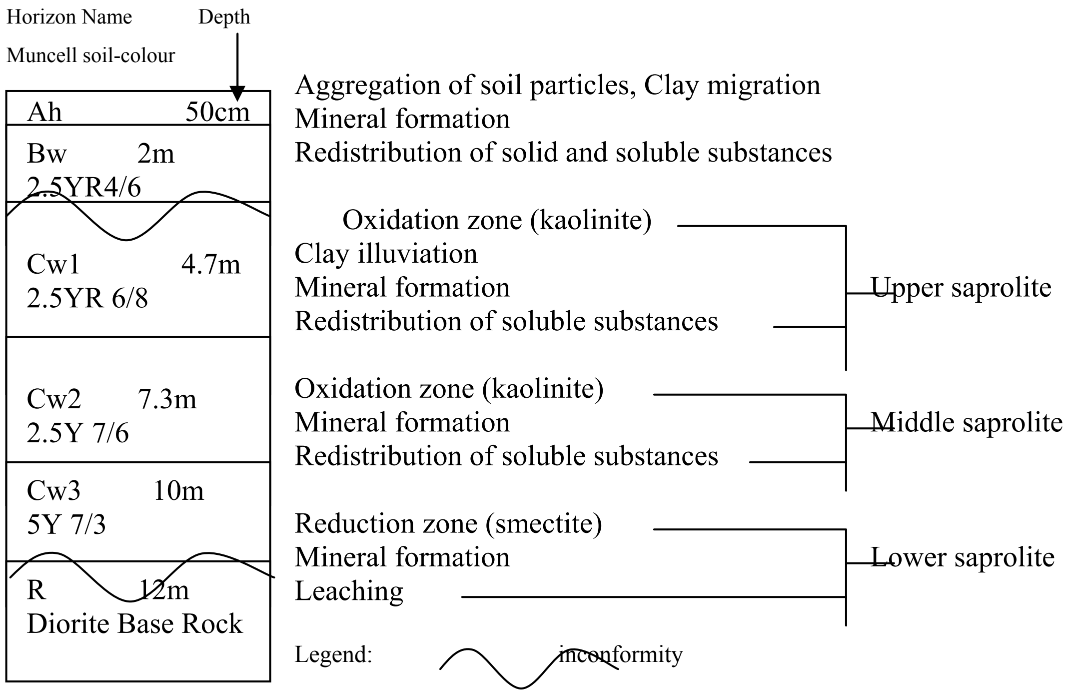


Figure 4-2: Zonation of Dioritic Saprolite with Overlying Ferralsol

Saprolite thus formed are found in the Target Areas and their proximities as tabulated following, suggesting that they are distributed almost everywhere over granodioritic, micrgranitic or dioritic bedrocks. In these saprolite layers, clays are formed and 1:1 type of these have been illuviated from upper layers to lower ones where kaolinitic patches are eventually deposited. Upon oxidation through exposure of illuviated layers to atmosphere, these deposits are gradually melted away into groundwater flow to form spherically shaped cavity hollows, inducing subsidence and slumping of above-hanging upper soil down to gully bottom. These surface layers above scoured hollows contain 2:1 type clay minerals that fissures into many vertical cracks, leading to loss of lateral cohesive force sustaining layers and eventual slumping down into the hollows/bottom. Where groundwater flows along underground valley with brachiated figures, dendritic gully shape appears as such scoured hollows form and develops.

After all, gullies develop irrespective of surface soil types or surface topographic gradient, where illuviated thick clay deposits have been formed. Gully formation can be triggered through deep crack formation or development of surface rills that can foster atmospheric exposure of illuviated clay deposits. Oxidized 1:1 type clays readily dissolve into groundwater forming colloid, and water flow in aquifers and gully bottom carries away huge clay mass from deposited layers until gigantic void space appears as gullies.

Table 4-10: Characteristic of Saproltic Properties at Different Slope Positions

Site	Position	Altitude(m)	Gradient°	Bedrock	Major soil type	Saprolite zone
Kukanyeni	Ridge top	825	0 - 2	granodiorite	Rhodic Ferralsols	Lower
	Upper slope	780 -820	8 -12	granodiorite	Rhodic Ferralsols	Middle-lower
	Middle slope	690 -780	5 - 9	granodiorite	Haplic Ferralsols	All
	Lower slope	675 - 690	6	granodiorite	G-Umbric Ferralsols	Lower
Mawelawela	Ridge top	1,225	0 - 3	microgranite	Umbric Leptosols	-
	Upper slope	1,050-1,200	24 - 37	microgranite	Umbric Leptosols	-
	Middle slope	900 -1,050	9 -15	Gabbro	Rhodic Ferralsols	Middle-lower
	Lower slope	800 -900	6 -11	diorite	Haplic Ferralsols	All
Ntondozi	Ridge top	920	0 - 6	quartz-diorite	Umbric Leptosols	-
	Upper slope	800-900	11 -15	quartz-diorite	U-Humic Cambisols	Middle-lower
	Middle slope	720 - 800	5 - 9	quartz-diorite	L-Rhodic Ferralsols	All
	Lower slope	695 - 720	4 - 7	quartz-diorite	M-Gleic Cambisols	Middle-lower

Note : G-; Gleyi, U-; Umbli, L-, Lixi. All sites are located around Manzini, Middleveld and Central Swaziland.

5 Dimension and Damage of Soil Erosion

The extent of cumulative soil loss can be visible or optically observed only if virgin soils free from erosion can be identified, though such undisturbed ground is rarely detected over grazing area and wood-lots. Figures in Table 5-1 show comparison between undisturbed soil-profile over hilltop covered with tree canopy and eroded range-land profile on slope near the sites of undisturbed soil in TA 1, TA 2 and TA 3.

Table 5-1: Estimated Maximum Annual Soil Loss by Sheet Erosion

Target Area	T A 1 (Upper Middleveld)	T A 2 (Lower Middleveld)	TA3 (Highveld)
Observed topsoil thickness	24 cm	16 cm	33 cm
Years under grazing	50 years	35 years	80 years
Specific density of soils	1.04	1.33	1.16
Equivalent annual loss	4.8 mm	4.6 mm	4.1 mm
Annual soil loss per ha*	50 ton / ha	61 ton / ha	48 ton / ha

Source: Estimated by the Study Team based on the site survey on soil and erosion, * Measured as the maximum because the difference becomes smaller if natural erosion (all the soils are subject to it) is taken into account.

The above Table calculated from the above figure suggests order of maximum annual soil amount lost from topsoil per hectare, because all the ground is subject to natural erosion unless it has been sheltered with thick canopy coverage. To compare this maximum level with various land use, the annual soil loss estimated by SLEMSA (Soil Loss Estimation Method in South Africa) , a prediction method using the coefficients applicable to the conditions in this country, is provided in Table 5-2. It can be found in this table that soil losses from steep rangeland give lower quantities as compared with the measured maximum losses shown in Table 5-1.

Unit: cm

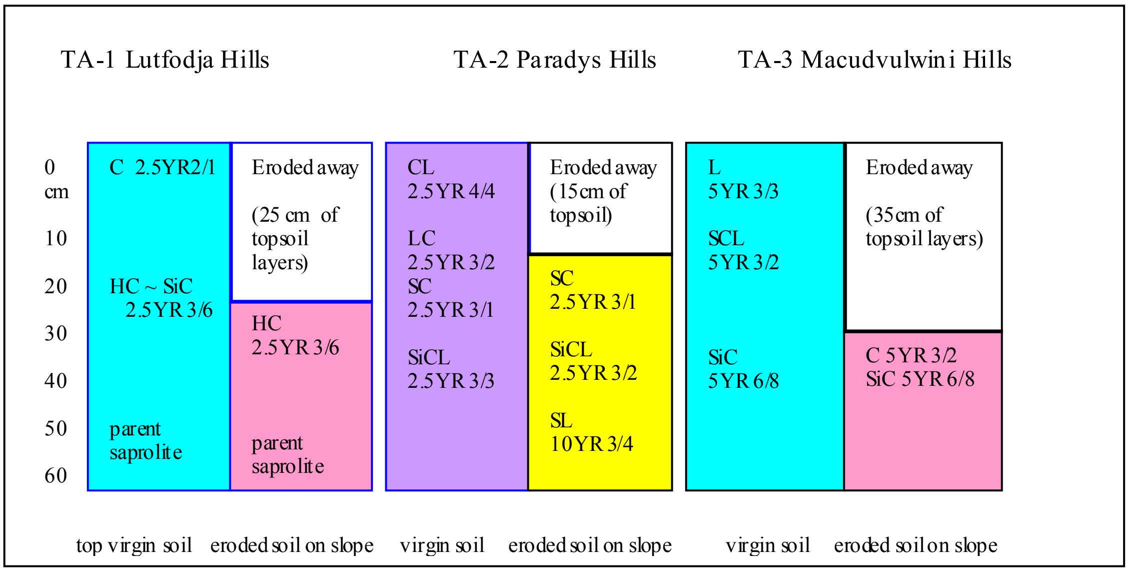


Figure 5-1: Topsoil Loss Observed in Three Target Areas

Table 5-2: Predicted Soil Loss by SLEMSA Method

Gradient	T A 1			TA 2			TA 3		
Land use	rangeland	arable	woodlot	rangeland	arable	woodlot	rangeland	arable	woodlot
flat	5.7	0.2	-	6.4	0.4	-	4.2	0.3	-
gentle	11.3	0.4	-	14.6	0.6	-	9.2	0.5	-
moderate	20.7	0.5	1.9	35.8	0.7	4.8	17.7	0.6	2.4
steep	36.3	-	4.8	54.2	-	9.5	32.0	-	5.6
average	18.50	0.28	3.35	27.75	0.43	7.15	15.78	0.35	4.00

Note: Unit; ton / ha. Slope Gradient; steep : 12%, moderate : 8%, gentle : 4%, flat : 0 ~ 2%

As runoff can transport soil particles up to 4,000 ppm, annual rainfall of 800 mm. can remove 64 ton of soil at maximum from a surface area of one hectare assuming that runoff velocity is 1 meter/sec and soil bulk density of the soil is 2, given 100% of run-off rate. This is equivalent to a loss of top soil layer by 0.3 cm/year. Thickness of top soil generally measures 20 cm or so, 70 year's naked exposure of soil surface to rainfall may cause a complete loss of top soil. In fact, many degraded range-land has gravel surface where trace of soil is barely visible in between exposed stone pieces, with innumerable barren patches. One thing to be emphasised here is that barren ground surface often consists of flat saprolite layers rather than soil layers for we can hardly distinguish rock from soil only by appearance. It is difficult to try to grow grass over rock surface, but tree sapling can self-establish even on rocks when planted during rains. The reason why tree planting on hillsides covered by gravel is recommended lies in this point.

As to damages caused by land degradation, people living in the affected area and local community authorities concerned have suffered from the following damages:

1) Destruction of local road networks by RTGs, incurring prohibitive cost for replacing affected roads with new ones. RTGs give inconvenience for pedestrians who passed through footpaths incised by RTGs to have to take detour to go to the destination.

2) Crop fields adjacent to active RTGs get faster drying and losing moisture since RTGs have evidently much larger relative surface area than flat ground surface.

3) RTGs have already lost aquifer layers, so they affect groundwater storage capacity.

4) Sheet erosion and rill/gully erosion in High and Upper Middleveld incur loss of surface soil at a rate 39,000 MT (metric ton) per annum, assuming 8 MT/ha from seriously eroded surface and 4 ton slightly eroded one as estimated by SLEMSA. This not only fosters loss of plant nutrients but also kill effective storage capacity of dam located down-stream of eroded catchment area.

6 Land Use and Area Susceptible to Ravine Type Gully (RTG) Development

Delineation of susceptible areas to RTGs can be made using surface geology map instead of soil classification map by the afore-mentioned reason (RTGs can be found over many soil types though Oxisols represent the area where they are distributed). Areas clustered with RTGs coincide with those covered by granites (accompanied with gneiss) including Lochel, Mswati and other types, and by granodiorite (Usutu suit and weathered rocks) except metamorphic types These rocks upon weathering form Oxisols, Inceptisols and many other types of soils but these never fail to contain kaolin as secondary mineral. Since kaolin is considered as major part of mass lost from RTGs, the areas where RTGs have been densely identified and those geologically covered ones with these rocks should be overlain with considerable accuracy. Whereas, RTGs are not found over basaltic and sedimentary rocks and rarely found over dolerite/diabase cover, presumably because these alkaline type rocks do not produce kaolin (acidic substance) when they are weathered.

However, hitherto provided map of RTG occurrence in Swaziland shows RTGs are found almost everywhere in High- and Upper Middleveld except areas covered by commercial forests regardless of surface soil or geology. Accepting this fact, risk of further occurring new RTGs can hardly be demarcated into specific areas characterized by geologic formation (much harder by pedologically classified groups). Nevertheless, the Study Team found that RTGs tend to cluster around major faults of granitic and dioritic rocks. One of conceivable reasons lies in the formation of secondary minerals, in particular so-called fault-clay, is outstanding on and around faults or fracture zones. In African Continent, streams incise along large faults and RTGs cluster banks of these streams. The examples include Mhlambanyoni River and Phowe River in TA1, Sibhowe River and Mtambe River in the west of TA3.

Highly weathered granodioritic elluvium and that affected with geological faults are shown in the following Figure (map). In these areas special caution is advised in order to avoid further land degradation, taking such measures as fencing-off of old cattle tracks affected with many rills, proper rill training before they grow into RTGs, reforestation on heavily sheet-eroded land and stony surface near ridges running at summit of hills etc.

As regards implication of land use, RTGs are seldom found inside commercial forests and arable land. This fact implies that either undisturbed soil surface or well-managed area with runoff control hardly allow emergence of RTGs. This is because thick litter has accumulated over man-made forests to prevent emergence of rills, and grass strips across arable land also prevent rill development, with maize leaf canopy curbing raindrop energy attacking surface soil aggregates. These facts may allow us to lead to a conclusion that only range-land has higher risk of TRG occurrence. Recently, however, arable field patches have been reclaimed in range-land in SNL. As RTGs often intrude into these arable patches from adjacent grazing areas, these can be interpreted as an exception.

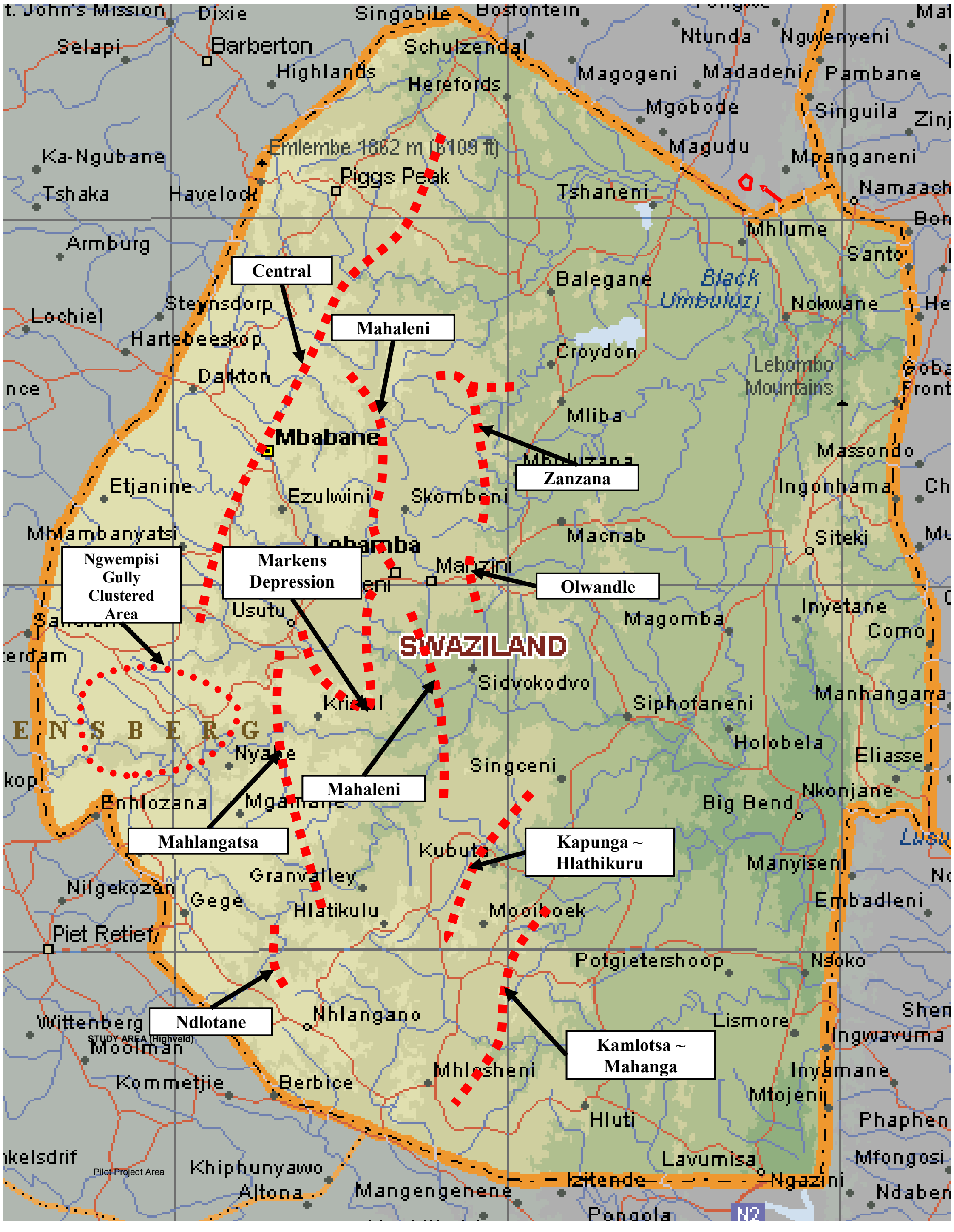


Figure 6-1: Major Faults with Clustered Gullies
(Refer to Table 4-7)

7 Necessity of Soil Conservation and General Consideration on Soil Conservation Measures

7.1 Necessity of Soil Conservation

Disadvantages and damages brought about by soil degradation are estimated in Table 7-1. As is seen from the Table, damages caused by soil erosion and land degradation are very big. It's needless to say that soils should be conserved in order to prevent from these damages. The losses do not remain constant, but may escalate year after year. Such loss will take place every year and continue forever unless proper soil conservation measures are taken.

Table 7-1: Estimated Damages Resulted from Soil Erosion and Land Degradation

Damages from sheet erosion	Annual loss	Damages from spot erosion*	Annual loss
Decline in carrying capacity	20,000head	Damage of road scouring	15km
Loss of plant nutrients	350,000 t	Damage of homestead	2cases /year
Loss of rainwater retention	1,500million t	Damage of livestock accident	150 head
Sediment damage in dams	4.3million t	Sediment damage in dams	11,000t
Alien plant encroachment	-	Damage of arable land	200 ha
Decline in carrying capacity	50million E	Damage of road destruction	3millionE
Loss of plant nutrients	70million E	Damage of houses/homestead	0.1millionE
Loss of rainwater retention	180millionE	Damage of livestock accident	0.3millionE
Sediment damage in dams	60millionE	Damage of arable land	1millionE
Estimated total annual damages caused by soil erosion			364millionE

Note: * Spot erosion includes rills, gullies, slips and land slides. Sheet erosion includes terracette erosion. Units used are; ton, head and kilometre. Source: Estimation in 2003 by the Study Team based on the observation results.

7.2 General Consideration on Soil Conservation Measures

Previously introduced book titled as "The Conservation Ideal" gives us many suggestions, when we consider soil conservation measures. The following sentences with brackets are the quotations from the book.

「*Soil conservation measures should be planned and implemented based on the clear understanding of the causes and mechanism of soil erosion and land degradation. Barren soil surfaces can trigger all evils relating to soil degradation, so inhabitants should make their all-out efforts not to create denuded patches, barren ground, and if such disturbed surface arises around them from inevitable economic activities, they should cover the barren parts (except arable plots) either with grass cover, planted plants or paved with gravel / asphalt. Inhabitants may venture risk of heavy land degradation when they graze cattle and other livestock beyond the carrying capacity of their grass-land. If a nation tries to eradicate seriously degraded land and rehabilitated it to an acceptable extent, a strong regime of land-use limitation should be imposed through effective legal control as observed in recent* *decades in China. Otherwise, if inhabitants of problem areas continue to use land as it is, all the efforts will sooner or later end up in vain even if proper advice were proposed therefore.*

First of all, inhabitants reserve usufruct right on degraded land, therefore any third person hardly intervene to handle it. Only awareness and relevant understanding of the land users / owners, followed by suitable actions to cope with currently-faced hazards can save the devastated state. These can be implanted through basic education, including science and civics, to younger generation. Areas affected with ravine gullies in Swazi-SNL are regarded so-to-speak a public place where nobody worries about its deterioration. Unless its users have common sense or social courtesy to try to keep their land as useful as possible, they can hardly overcome currently encountered soil hazards and degradation. Everybody should recognize the fact that over 70 years old gullies are still actively developing with further branching and deepening. 」

"The Conservation Ideal" referred above also suggests the following seven measures to be taken to improve soil erosion and to mitigate gully incision.

(1) Large scale afforestation in Usutu/Komati watershed,

(2) A stock redistribution system so that grass covers in overstocked areas can be re-established,

(3) Construction of heavy diversion works to encourage infiltration,

(4) Protection of stream banks,

(5) Observing "Grass Fires Proclamation" prohibiting grass-burning from 1st May to Sept. 30th, also forbidding burning more frequent than once in two ears,

(6) Construction of grass strips over all arable land and

(7) Refraining from cultivation on steep slope.

These are still valid even now, though only the item (6) has been observed by farmers at large. Likewise, USAID[1] warned adverse effect of overgrazing and recommended cattle herd adjustment in 1970s in its grazing improving projects although the advice could not reach local population.

Despite, number of national cattle herds reached the peak during 70s and 80s. Since 1980s, size of national cattle herds has traced a falling trend contrary to inhabitants' desire of holding as many cattle as possible. This is surely attributable to decreasing carrying capacity of range-land caused by land degradation thereon and global green-house effect. Grazing land has long been put under negative balance of plant nutrition as shown in the following table, as compared to arable land, leading to thinner grass cover and wider barren patches as a

[1] United States Agency for International Development

symptom of land degradation. Despite, cattle holders have never tried to feed their herds with cropped fodder, to offset declined natural grass supply, or with other means to share range-land burden. After all it may be said that, in the most African countries, rangelands have always been deprived and exploited.

Table 7-2: Plant Nutrient Balance of Arable and Rangeland

Land Use	Nutrient input	Nutrient output
Arable land	Manure collected from kraals has been applied to arable plot. Some plots have received chemical fertilizers as inputs.	Maize stover and other crop residues have been fed to livestock, part of this has been reduced to arable plots as natural dropping.
Rangeland	No particular input has been applied to replenish nutrient loss by grazing, other than natural dropping excreted by grazing herds.	Grass has been grazed, often excessively by overgrazing, or has been cut for thatching, causing heavy loss coupled with soil erosion

If we define soil conservation as an effort of keeping soil at its originally formed places, then various preventive measures against range-land erosion are conceivable as in Table 7-3.

Table 7-3: Soil Conservation Practices on Affected Rangeland

Function Type	Easier practice	Medium practice	Rather difficult practice
Minimizing surface runoff	contour terracing	check weirs in rills/gullies	soil property improvement
Improving surface cover	grass planting / sowing	fencing damaged tracks	planting shrub trees
Land use /grazing devices	fenced grazing rotation	feed-lot, fodder cropping	control grazing herd size

Community people should get rid of traditional grazing for creating sustainable, well-conserved eco system, but this seems to be far-reaching goal. For the time being, as a transitional process to shift to modern livestock husbandry with concentrate feeding, easiest and reliable soil conservation method includes keeping grass root-mat over ground surface, planting fast-growing shrub-trees along contour terraces at fixed intervals depending on slope, and as an indirect measure, to eradicate encroaching plants and to replace them with useful fodders and trees.

8 Recommendations for Planning the Soil Conservation Measures

8.1 Formulation of Soil Conservation Plan for Each Chiefdom based on "Inkhundla-Based Soil Conservation Plan"

It is recommended that, through the experiences obtained from the implementation of several soil conservation projects at pilot stage, future soil conservation plans should be formulated on Inkhundla basis. Because, the land degradation conditions, social and economic environment and natural environment etc, are largely differ from each other depending on the chiefdoms included in the respective Inkhundla. With this understanding, the following are proposed for formulation of soil conservation plans in the future.

(1) Ministry of Agriculture and Co-operatives shall formulate Inkhundla-basis soil conservation plan based on the survey, similar to the survey (inclusive of soil , social and economic survey etc.) that was conducted in the three pilot project areas .The plan is to be distributed to the Inkhundla concerned.

(2) Chiefs of the Chiefdoms belonging to an Inkhundla shall study the distributed plan, and whenever they consider it necessary they shall hold meetings with their Chiefdom development committee to convene the procedure and arrangement for establishing Chiefdom-basis Soil Conservation Plan.

(3) In the process of formulation, the committee members collect information from the "Rangeland Patrol Group" (refer to Clause 9.3 of Chapter 9) and others on the existence and extent of damages of soil erosion and land degradation within their Chiefdom and report the results to the committee so that the measures can be devised and proposed therein. If necessity arises, the committee can call for the attendance of an extension worker in charge of the Chiefdom to the committee workshops in order for people to consult him/her with the selection of possible and adequate measures to cope with confronting degradation problems.

(4) The extension worker in charge shall give the committee members pertinent advice on how to measure the size or area of affected land and how to find locally available material that can be used for rehabilitating the affect areas or to minimize damages of land degradation.

8.2 Necessity of Introducing the Concept of Environmental Conservation into Basic Curriculum in School Education

Soil is a property for common benefit. To conserve it in a sustainable way, school education by the Government of Swaziland should include significance of soil conservation and basic field observation as well as training for conservation measures. Higher class curricula should include soil conservation in the course of social study.

8.3 Formulation of Soil Conservation Plan in due Consideration of Introduction of Legislative Measures

The Swaziland governmental agencies concerned should work out practical soil conservation measures so that awareness, capacity building and action oriented attitude of stakeholders above all villagers can be enhanced.

There has so far been no exception but only compulsory imposition of rules to be observed by land users with legal penalty has brought success in rehabilitation of once seriously eroded areas. In this case spoiled environment by land exploitation is deemed as pollution, and the polluters should pay the rehabilitation costs or compensate for the damaged environment and its beneficiaries. For example, during the end of last century, China succeeded in resurrecting once heavily deteriorated land through toiled cultivation and overgrazing into stabilized land by compulsory, complete evacuation of cultivators and herdsmen from damaged tracts. However, such strong action required severe legislative decision makings. As such, introduction of legislative measures sometimes encounters the difficulty when they are put into operation; however, introduction of legislative measures is one of the important matters to be discussed in the course of formulation of future soul conservation plan.

In addition to the general discussions on soil conservation plan in the above, necessary technical considerations such as on 1) formulation of soil conservation plan in due consideration of measures for prevention of soil erosion and stabilization of RTGs, 2) delineation of the susceptible areas to RTGs and information on the land use to be referred, and 3) matters to be considered in the course of formulation of measures for the existing RTGs etc., are presented below.

8.4 Necessary Technical Considerations in Formulation of Soil Conservation Plan

8.4.1 Formulation of Soil Conservation Plan Aiming at Prevention of Soil Erosion and Stabilizing the Existing RTGs

Soil erosion tends to be severer in heavily sheet-eroded grazing land and denuded ground, the extent of which is readily visible from distant hill tops. Based on the observation, land users have to do self-diagnosis for their land in order to conserve it. Delineation of heavily eroded areas and densely gullied ones should be made on maps by the inhabitants with the technical support by the agricultural extension officers.

Then, the land users decide how to take measures to rehabilitate the delineated degraded land by consulting with the reference materials (for example, this guideline, and reports on the study of the land degradation in Swaziland prepared by FAO and UNDP, including the guidelines for soil conservation prepared by the same) as well as consulting with the agricultural extension offices. If they belong to a specified community/Inkhundla, the measures are submitted to community meeting where necessary debates and consultations are made to find final measures for soil conservation.

The best timing to take action for soil conservation lies in the stage of progressed sheet erosion but no rill or gully yet takes place. In this stage, preventive measures can easily be applied at cheaper costs and less efforts by land users. However, if rills and/or gullies have already appeared, the users will have to take relevant measures so as to avoid occurrence of rills/gullies or to conserve land fertility/productivity. According to the age, size and character of rills / gullies, feasibility and relevance of dealing with them should be considered for launching a concrete practices for conservation. When the erosions further develop into RTGs, economically feasible measures to cope with cannot be found easily.

8.4.2 Delineation of Susceptible Areas to RTGs and Necessary Considerations for the Land Use in the Specific Areas

The affected areas and potentially risky ones can be delineated on land-sat imagery maps with the help of geological maps and geo-electric surveys to detect decayed alluvium covered by thin colluvium. RTGs seldom develop over tracts under permanent cropping parcels owing to grass strips preventing rill formation even though they are located on susceptible, highly erodible soils. This may suggest the possible countermeasures for preventing or mitigating development of RTGs. General observation on existing measures already implemented or tried against RTGs can also give us guidelines on how to cope with RTGs. The major results of the observations on measures against RTGs are:

(1) Planting of drought resistant plants inside rills/gullies can stabilize existing RTGs. They are cactus, aloes, sisal, ferns, sisal, pasture grasses like Cynodon dactylon, indigenous trees like Diospyros lycioides, Syzygium coratum, Euhorbia ingens …

(2) Surface structures like sill construction, tree plantation to intercept runoff have little effect on their stabilization

(3) Vertical structures worked inside rills/RTGs at the initial stage can retard gullied rate, although they hardly provide a radical solution to control their development.

(4) Priority should be given on rill training in the area where many rills have taken place. Top priority must be given to old or currently passing cattle tracks, on which parallel rills are developing. It is the best way to enclose the damaged surface with fence, then, to start rill training works. Rills occurring in the exposed saprolite rocks in and around geological faults readily and quickly develop into huge dendritic gullies, so proper measures with earlier implementation is advised to villagers concerned.

Further, since it is observed that the same cattle tracks have been used for a long time, thus, this practice has become one of the main triggers of the occurrence of RTGs in the rangelands. Accordingly, it is proposed that other cattle tracks with gates should be provided to avoid the concentration of cattle pass on the same routes. This will help the disturbed grass cover on the cattle tracks, which have been used for a long time, to grow again. In addition to this, for example, construction of the fenced cropping field along the contour lines is also considered to be one of the effective measures to prevent the rangelands from the occurrence of RTGs.

The fact that many of private (title-deed) land and recently purchased SNL are apparently less degraded as stated above, but they will sooner or later be degraded if they are long exposed to heavy cattle and goat herds. Particular care should be practiced to prevent these lands from further erosion and degradation.

8.4.3 Necessary Considerations for Training the Existing RTGs

Two types of developing RTGs, namely on convex slope and on concave one are observed. The former one is evidently less influenced by surface runoff than the latter, so the measures are confined to training inside the gully. The latter is usually affected either by surface runoff or by perennial surface water flow over its bottom or seepage water flow beneath the bottom. This may need interceptive devices, for example a sill at the head against collected runoff or small check dam construction at its bottom. It's often observed that healing or stabilizing gullies have thicker vegetative cover inside them or at their bottoms. This fact suggests us to establish vegetative cover inside them rather than outside them. Usually, bottom soils of vegetated RTGs contain more water or have higher seepage (groundwater level) than those over open ground surface, and this year round available moisture sustains plants grown inside the gullies. Only if sunlight reaches inner part of them vegetative cover readily establishes inside them.

In this context, to foster the stabilisation of active gullies, it may be effective to place some check structures at their bottoms so that gullies can get shallow enough to receive sunlight through sedimentation in the gullies for easier floral establishment. Bundles of twigs or branches, bags filled with the materials consisting of the mixture rate of 9 to 1 (sand/cement) and/or stone checks on stony places can be used for this purpose. These inner gully structures should further be made higher by heaping additional material when they are filled with sediments. Transplanting trees/shrubs over the checked bottom can facilitate fast establishment of bottom vegetation. Measures for training well-developed, active RTGs will remain future task, to which more experimental trials should be added to finalize economically feasible methods therefore.

9 Recommendations for Soil Conservation Implementing Structure

To smoothly implement the soil conservation projects/plans discussed in Chapter 8, it is recommended that the Ministry of Agriculture and Co-operatives and communities concerned should take the following actions and approaches, aiming at further strengthening of the existing implementing structures of soil conservation.

9.1 Training for Agricultural Extension Officers and Community People

It is recommended that the agricultural extension officers in charge of livestock should be well educated and trained for soil conservation to strengthen their leading roles in soil conservation projects. Then, the trained agricultural officers will give the training to the community people until the community people recognize future disadvantage of exposing their land to degrading risks by their careless traditional practices (overgrazing, and grass burning etc.). In addition, the trained agricultural extension officers will train the community people until they can prepare by themselves a list with maps of soil erosion and alien plant encroachment within their communities for deploying appropriate measures to cope with.

9.2 Assignment of Soil Conservation Officer to Each RDA and Preparation for Soil Conservation Campaigns

As a national policy component, higher priority is now globally being attached to environment conservation. In this concern, Swaziland is not an exception free from environmental issue, because land degradation has recently been accelerated as a result of improper land use, to which relevant measures are acutely needed to remedy and rehabilitate severely affected land. However, at present no officer has been staffed to take charge of soil/water conservation in spite of growing importance or exigency on soil and water conservation. This would hamper sincere efforts of stakeholders who want to conserve and secure natural resources for coming generations. It is desirable that GOS takes action to assign a Soil Conservation Officer to each RDA as well as to provide campaigns to enhance awareness of, and to implant consciousness into local inhabitants until they all have a sense of crisis towards deteriorating nature around them, and voluntarily start actions to refrain from detrimental deeds that further foster to aggravate natural environment, to take actions to prevent growing land degradation and to make efforts to rehabilitate already degraded environment. Their daily roles include:

(1) To visit schools in order to instruct school children on environmental care and land conservation, to provide them with observation trips and training.

(2) To hold campaigns for educating young generations and adults by means of establishing demonstration sites where an existing gully is treated with inner check structures and a grazing slope is conserved with manual cutting of contour terraces.

(3) To diagnose together with community people and present status of soil erosion based on observation/measurement of run-off and soil loss from arable slopes, grazing land and other land use, as well to evaluate hitherto preventive efforts, works and performances of the community people.

(4) To establish soil conservation and land rehabilitation program/schedule together with community people, considering proper management of the implementing structures for soil conservation established by the community people. Such programs should include reforestation, fencing off of heavily incised cattle tracks, rill and gully training and clearing encroached alien weeds and trees.

In establishing the soil conservation and land rehabilitation program/schedule mentioned in (4) above, it is recommended that, for example, planning sheet as given in Table 9-1 should be prepared. Based on this, the soil conservation and rehabilitation program/schedule suitable to the specified area should be made in collaboration with the soil conservation officers and community people.

Table 9-1: Sample of Planning Sheet for Area-wise Soil Conservation and Land Rehabilitation Program to be prepared by the Soil Conservation Officers and Community People

Name of Community	Rangeland Area	Arable land area	No of cattle	Current grazing
○○○○○○	□□□. □(ha)	□□□. □(ha)	□□(head)	density

Check Items

Status of soil on SNL rangeland		Current conservation measures	Person of possession in Community people	Degree of degradation
Surface condition of rangeland	1. Gravels/ Stones are exposed on surface	1. Cattle head / Grazing Period control	1. 0-10 %	Grade: S1
	2. Soils are always wet.	2. Rotation fencing	2. 11-30 %	Grade: S2
	3. Soils are dry when no rain is observed.	3. Tethering cattle	3. 31-50 %	Grade: S3
	4. Occurrence of Terracettle / Slip type erosions.	4. Artificial feeding	4. 51-70 %	Grade: S4
	5. Complete grass cover	5. No grass burning	5. 71-100%	Grade: S5
Degradation condition of Rangland mainly with respect to gullies	1. Huge gully development	1. Fencing damaged part	1. 0-10 %	Grade: S1
	2. Young gully development	2. Inside the gully be trained	2. 11-30 %	Grade: S2
	3. Rills on cattle track	3. Outside the gully be fenced	3. 31-50 %	Grade: S3
	4. Bare surface on track	4. Rills filled with stone	4. 51-70 %	Grade: S4
	5. On liner erosion	5. Trees / Grass be planted	5. 71-100%	Grade: S5

Note: Grade S1: Degradation in grass covers
Grade S2: Degradation in vegetation on soil surface
Grade S3: Frequent occurrence of rill erosion
Grade S4: Occurrence of gully and it is developing
Grade S5: Occurrence of Ravine type gully, and it is developing

With respect to the check items in Table 9-1, 1) recommendable counter measures according to the soil condition in rangeland, 2) the meaning and necessity of each countermeasure, and 3) the necessity and meaning of grasping the present status of rangeland and extent of the land degradation etc. are summarized in Table 9-2, Table 9-3 and Table 9-4.

Table 9-2: Desirable Measures against the Associated Status of Soil

State of Soil on Rangeland in SNL (Swazi National Land)		Desirable measures against the associated conditions
State of Surface	1. Surface outcrop of stone pieces / gravel	No immediate measure necessary since top-soil had been lost. To foster soil formation by means of planting fodder trees.
	2. Soil hue remains at that of wet state	Since fast recovery is expected even if degradation proceeds on, planting readily spreading grass or vigorous grass species gives positive effect.
	3. Soil hue remains at that of dry state	Since deteriorated vegetative cover is hardly recovered, further soil loss must be prevented through contour terrace created over range-land slope.
	4. Terracette / slip erosion already appeared	This state proves lingered overgrazing, so it's necessary to ease it with such counter-measures as tethering and fencing for rotation grazing.
	5. Soil surface entirely covered with grasses	Herdsmen must be trained with proper grazing management in compliance with regenerative capacity otherwise overgrazing aggravates grass cover.
Land degradation level	1. Ravine type gullies already took place	Natural stabilisation must be fostered with check structures worked at gully bottom so that further soil loss from gully beds can be prevented.
	2. Young gullies are developing thereon	This state has higher priority for taking measures of installing checks at the bottom to foster sedimentation over gully bottom for stabilising them.
	3. Rills are developing over cattle tracks	This is highest priority state for installing check structures inside rills, desirably fencing out barren surface to keep cattle herds off.
	4. Bare surface patches developing on tracks	If highly erodent soils cover the range-land, substitute tracks must be provided to avoid a state subject to surface incision by cattle trampling.
	5. Linear type erosion not yet appearing	Vigilant monitoring and efforts to alleviate grazing pressure are essential in order to maintain top soils free from erosion damages

Table 9-3: Investigative Needs

Countermeasures	Reasons for the needs of considerations on the items listed on the left
1. Limitation of heads of cattle and grazing period	Overgrazing is main reason of land degradation. Therefore the information such as number of head and grazing period to be reflected to necessary actions.
2. Fencing for rotation grazing	Information on past and current use of fencing and its function and effect can be reflected in the formulation of effective measures to conserve rangeland.
3. Tethering of cattle	Study on past cases on tethering practices at nearby private land etc. and their methods of application, their effects can well be fed back to establish measures.
4. Artificial feeding	Study on past cases on methods and objectives of feedlot, sources of fodder, effect on fattening etc helps to formulate effective feeding plan to ease grazing pressure.
5. Range-field burning	Since field burning may cause land degradation, rehabilitation plan should reflect such information on the past area, frequency and damages of field burning.
1. Fencing protection at damaged sites	Past and current observation on fencing land protection practised in nearby areas, including methods, scale and effect thereof can be used as basis of the measures.
2. Inner-gully treatment	If this has been tried in nearby areas under government instruction or voluntary activity, its results, methods and scale can be referred to for taking measures.
3. Fencing outside gully	If the cases have been observed in nearby areas to prevent cattle loss by accident, information on their methods, scale and effect is informative for taking measures.
4. Stone check in rills	If this has been tried in nearby areas using stone checks or planting cactus, its results, methods and scale can be utilised for devising preventive measures.
5. Planting grass/ trees	If this has been tried in nearby areas under government instruction or by voluntary activities, its results, methods and scale can be referred to for taking measures.

Table 9-4: Reasons for the Needs of Grasping the Present Condition of Rangeland and Extent of Land Degradation

Status of possession of rangeland by community people	Reasons for the needs of the survey for the status listed on the left	Extent of Land degradation	Reasons for the needs of the survey for the status listed on the left
1. 0～10% of community population	The less occupancy of communal population is found on rangeland, the lower interest on degradation of rangeland is born by communal society, for example in rangeland where SISA system has long been practiced for absentee land users. Whereas, if the more communal people use range for their own cattle, interest on land degradation is naturally enhanced with more willingness to take measures for range conservation. Such facts must be taken into account in land conservation plan.	Degradation degree: S1	The extent of range land degradation can be judged by grazing grass cover over the surface. The less the degree of degradation remains, the measures will bring faster and effective result, and vice versa. The degree S3 indicates a break-even point, with the highest priority for taking measures. If the degree reaches S5, recovery is too dull even measures are properly taken.
2. 11 ～ 30 % of community population		Degradation degree: S2	
3. 31 ～ 50 % of community population		Degradation degree: S3	
4. 51 ～ 70 % of community population		Degradation degree: S4	
5. 71 ～ 100 % of community population		Degradation degree: S5	

It is noted here that cares have been taken so that the above-listed survey items can be handled by the extension officers of the Ministry of Agriculture and Co-operatives and by the community people as well, using simple instruments available with them. For reference, further survey items, which include a little bit higher technical standards, that should be taken care of by the Ministry of Agriculture and Co-operatives in the future are listed in Table 9-5, including necessary instruments for the survey. It is hoped that the Ministry of Agriculture and Co-operatives would make efforts to carry out the survey as early as possible.

Table 9-5: List of Comparatively High Standards Survey Items and Required Instruments

Survey Items	Survey Objective	Required Instruments	Expected Problems Encountered
1. Topographic gradient	Assessing erosion risk for plan / design	GPS and measuring tape, or hand-level, incline-compass	Insufficient of measuring instruments
2. Consistency of soils	Estimation of erodent soil	Laboratory measurement for sharing force	Insufficient of measuring instruments and / or shortage of budget.
3. Dispersing rate by Middleton	Estimation of erodent soil	Laboratory measurement for analysis	ditto
4. Liquidity limit by ATTERBERG	Estimation of erodent soil	Laboratory measurement for analysis	ditto
5. Other items listed in AELDA	Assessing erosion risk for plan / design	Measurement equipments	Insufficient measuring instruments at the extension office

Note：AELDA；(Criteria of Actual Erosion and Land Degradation Assessment) formulated byFAO in 1990

9.3 Organizing the Community-Based Rangeland Patrol Groups

Community-based rangeland patrol groups consisting of community people are advised to be organized in each community. These groups shall regularly patrol within their communities to identify soil erosion. And the patrol groups, where necessary, shall make temporary treatment of the gullies found during the patrol. Also, the members of the patrol groups shall establish countermeasures against soil erosion, and the groups shall bear the role of asking the local authorities to implement the countermeasures against soil erosion.

9.4 Distribution of Tools Necessary for Implementing the Participatory Soil Conservation Works

To support the participatory soil conservation works by community people, it is recommended that Ministry of Agriculture and Co-operatives should provide with patrol groups implements and tools necessary for the soil conservation works. The minimum requirement of tools needed for the soil conservation is given in Table 9-2.

Table 9-6: Minimum Requirement of Tools for Participatory Soil Conservation Works

Type of works	Tools to be officially supplied by the Ministry of Agriculture and Co-operatives (per patrol group)	Tools to be borrowed from RDA
Contour terracing	1 set of line-level. measuring tape 50m 3 shovels / hoes, 3 stone-picks per group	(If need arises, a tractor with ripper with operator and fuel)
Gully training	2 wheel barrows, empty bags, 4 shovels and hoes, 3 stone-picks, 1 hammer crusher	(If need arises, a tractor with ripper with operator and fuel)
Rill training	Necessary length of barbed wire, 4 hoes, 1 wheel barrow	(If need arises, a tractor with ripper with operator and fuel)

(Note: Above listed implements and tools are used mainly for treatment of the gullies at its initial development stage and for treatment of small size gullies.)

For additional information, the reasons why already developed gullies can hardly be filled with soils or other material like waste as a trial to treat them are mentioned below.

(1) In order to fill them, large amount of earth has to be borrowed/collected from other place. This would result in excavated/denuded pits, inducing another risk of gully occurrence.

(2) Because gullies develop through groundwater regime, there is possibility that filled earth will again be scoured and flown away by recurrent flood-storm even creating a water-tight dam at the downward section of gullies, through newly created gullies nearby treated one.

(3) Borrowed earth to fill existing gullies also contains water-dissolvable fine particles that will at least be lost through a strong leaching/scouring action exerting inside existing gullies.

9.5 Establishment of Soil Conservation Structure Taking the Benefits of Tethering of Cattle into Consideration

Serious problems on soil erosion are always and globally coincided with free and heavy grazing not only in Swaziland, but also in many other African, Asian, East European and Latin American countries. We can observe RTGs also in China, India, Turkey, Russia, South

Africa etc. In almost all developed countries, cattle have been kept in confined paddocks or roofed barns, partly because of limited land, partly of difficult health control and frequent accidents on grazing fields. Artificial feeding like tethering is indispensable to keep cattle worth for sale. The benefits of tethering cattle may be counted as follows.

(1) Tethered cattle never flock in a large herd that trample tracks and paths

(2) Tethered cattle have to be fed with cut grass or concentrates but it doesn't select only palatable species resulting in prevalence of unpalatable ones or alien encroachment.

(3) Herdsmen do not have to burn grass for regenerating field before grazing and this may minimize forest fires and surface soil degradation.

(4) Needs of hiring / paying for herdsmen can be dispensed.

(5) Potential crop damage by trespassed cattle during cropping season can be prevented.

(6) Less risk to get infected with FMD and other contagious diseases.

9.6 Establishment of Soil Conservation Structure in due Consideration of Desirable Long-term Policy for Grazing

Grazing over grassland belongs to a type of the most extensive way of land use, and obviously it is not suitable for such a land-scarce country as Swaziland. In 1980s, only 4-11% of the national herds had been slaughtered, in other words, even taking account of herd mortality, 80 - 85% of the herds had only been kept as farm property in the form of elder aged herds without contributing national economy, only deteriorating grazing land, except that they gave droppings to arable land. What to do in Swaziland in the future is to gradually convert the present farming practice into mechanized agriculture, with which, realizing the zero grazing cattle management with the cultivation of fodder crops and construction of improved grass lands by use of tractors with the functions of hay making as well as ensilaging. Current example of overstocking and desirable herd size is shown in Table 9-7.

Table 9-7: Desirable Carrying Capacity in Cattle Head (DCC) in 3 Target Areas

Area Name	Total Area (ha)	Range Land (ha)	Very (VSE) seriously eroded	Seriously eroded (SE)	Moderately eroded (ME)	Acceptable (A)
TA 1	19,700	12,489	3,621	2,623	3,872	2,373
TA 2	11,500	7,340	1,615	609	2,481	2,635
TA 3	30,600	19,151	2,681	2,681	9,959	3,830
Total	61,800	38,980	7,917	5,913	16,312	8,838
CCC	Actual Herds	Total DCC	DCC on VSE	DCC on SE	DCC on ME	DCC on A
TA 1	15,700	5,345	724	787	1,936	1,898
TA 2	11,900	3,855	323	183	1,241	2,108
TA 3	18,500	9,384	536	804	4,980	3,064
Total	46,100	18,584	1,583	1,774	8,157	7,070

[Note: DCC; Desirable Carrying Capacity, CCC; Current Carrying Capacity (Presently observed carrying capacity in 3 Target Areas, which is excessive.), SE; Seriously Eroded, ME; Moderately Eroded.]

By improving present status of free grazing and through introduction of keeping livestock in stables/barns/feedlot paddocks and tethering, there will be possibility of creating the lands where ravine type gullies (RTGs) do not occur.

To this end, current seventeen (17) Regional Agricultural Development Centres will have to be equipped with more sets of farming machinery, so that they can respond the farmers who make efforts to realize radical conversion of livestock husbandry mode. As of one of the steps towards realization of this proposal, it is proposed that the farming machine supplied by foreign donors should be rented out to the farmers with the condition that fuel cost should be borne by them, through which, farmers can convert the existing rangeland into fodder crop fields by proper management of mechanized feeding.

9.7 Administrative Measure to be introduced for Construction of Soil Conservation Structure

With respect to national measure concerning the treatment of the degraded lands in Swaziland, planning for soil conservation and decision on the areas where the soil conservation plans are to be implemented etc. belongs to the policy matter of the Government of Swaziland. Accordingly, JICA Study Team would like only to propose several administrative measures to be taken into account for construction of the soil conservation structure.

Proposed Administrative Measure-1

[The government/local administration can begin with compulsory/voluntary cattle and goat tethering in the areas where risk of unrectifiable erosion is higher than other areas. It can delineate areas with higher risk of RTG occurrence along fault valleys and fracture belts as the area under Priority A, where preventive measures of rill and young gully training should be introduced. Then, the government/local administration can recommend people to protect recently purchased SNL that has relatively less eroded area compared to original SNL with contour terracing and fencing off the damaged tracks.]

Proposed Administrative Measure-2

[The government/local administration can treat seriously eroded rangeland in old SNL by converting them into completely fenced fodder crop field. Next, the government/local administration can protect completely eroded out fields covered with stone pieces and gravel by converting it into fodder tree shrubs where seasonal grazing can be allowed in. Thirdly, the government/local administration can start actions for improving natural grass by eliminating encroaching and unpalatable species, also by sowing high yielding grass species and banning grass burning all the year round.]

To introduce these basic administrative measures, such considerations as 1) how to decide the priority areas where range management is to be officially promoted, and 2) overall concepts for sustainable grazing and its measures, may be required. To work out these, reference materials are provided in Table 9-8, Table 9-9, and Figure 9-1.

Table 9-8: Priority Areas Where Range Management is to be Officially Promoted

Priority	Locations and Conditions of Rangeland	Area in Highveld (%)	Area in Upper Middleveld (%)
A	Along fault valley & fractures	3 %	2 %
B	Recently purchased SNL	2 %	0 %
C	Seriously eroded surface	7 %	6 %
D	Pre-contemporary stone surface exposed over grazing land	1 %	0 %
E	Other eroded grazing land	1 %	1 %

Note: % accounts for percentage of total area of Highveld or Upper Middleveld. For C and D, 10% of the classified areas as seriously eroded land are chosen. Other eroded rangeland indicates RTGs are approaching towards homesteads. Sample priority areas where range management is to be officially promoted are given in Figure 9-1.

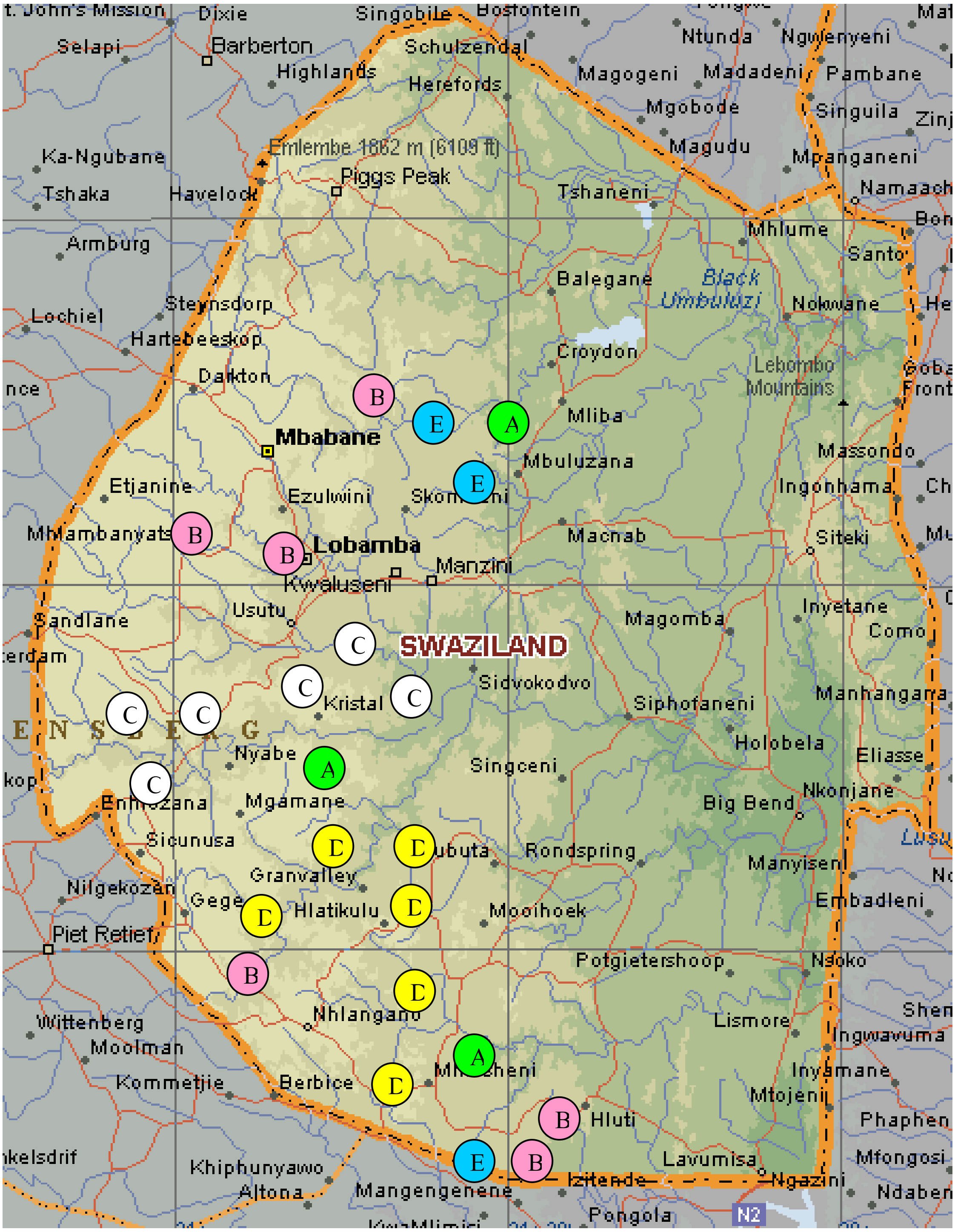


Figure 9-1: Sample Priority Areas where Range Management is to be Officially Promoted

Table 9-9: Overall Concepts for Sustainable Grazing

Order (Easy to Difficult)	Measures	Objective
Easy	Rotational fencing + Contour Terracing	To reduce grazing pressure
↓	Conversion of part of rangeland into fodder crop field	To sustain current herd size without damaging soil/ land
	Tethering a part of herds to feed fodder	ditto
	Further conversion into fodder crop field	To reduce grazing pressure
	Tethering more herds to feed fodder	Same as II
	Culling herds, selling culled heads for slaughtering and saving money in banks	To reduce grazing pressure
	Improving rangeland by sowing seed of good grass and encroached plant control	To sustain /resurrect damaged rangeland
Difficult	Planting fodder shrubs over rangeland	ditto

In addition to these administrative actions, it is recommended that the government/local administration should train agricultural extension officers so that they can properly instruct the community people concerned. At the same time, the government/local administration will have to consider introducing the environmental education into elementary school education curriculum so that next generation can accept the measures taken by the government smoothly. To facilitate the understanding by the community people, it is recommended that the government/local administration should arrange the study tours for community people to the sites where various types of soil conservation works were implemented. Proposed Implementing Period/Actions Required for the Measures to Realize Sustainable Grazing is provided in Table 9-10.

Table 9-10: Proposed Implementing Period/Actions Required for the Measures to Realize Sustainable Grazing

	Proposed period/Proposed actions	2004-2010	2011-2020	2021-2030	2031-2040
Enlightenment and diffusion to the community people	Putting the environmental education into elementary education and its practice.	↔			
	Training of the government officers	↔			
	Field trip and learning from the soil conservation activities carried out at the pilot projects.	↔			
	Control and tethering of cattle on all rangeland		↔	↔	↔
Treatment to the land	Priority A: Rill and young gully training	↔	↔		
	Priority B: Contour terracing on pastures	↔	↔		
	Priority C: Partial conversion of the lands into fodder crop fields	↔	↔	↔	
	Priority D: Planting fodder trees		↔	↔	↔
	Priority E: Wild grass improvement			↔	↔

Note:

(1) In Table 9-10, it is proposed the Ministry of Agriculture and Co-operatives should undertake the enlightenment and diffusion to the community people with respect to the education for soil conservation. Out of which, 1) to include the environmental education in the elementary education at schools, and 2) to visit the sites where various types of soil conservation works were implemented during the pilot project stage and to learn the actual environmental conservation activities, were not proposed in the proposed master plan. Instead, these two are proposed here in the Soil Conservation Guideline. The reasons for the above are that, 1) it has been found through the study that environmental education at an early stage for the young generation is necessary as well as useful, and 2) it has also been found through the study that the young generation can see the actual activities of soil conservation activities in the communities by visiting the sites where the soil conservation works were made and they can also learn the actual status of soil conservation activities, all of which will help to extend the soil conservation activities in wider areas of the communities. It may be mentioned here that the proposed master plan was basically proposed targeting mainly at the Ministry of Agriculture and Co-operatives, which is the main implementing body of the proposed soil conservation projects, and it does not basically concern much about the educational matter. With this understanding, the necessity of environmental education etc. have been highlighted here in the Soil Conservation Guideline, which is expected to be widely read and used among the people of different generation as well as of different origins.

(2) Implementation of the proposed actions given in Table 9-10 is subject to the conditions of each community.

10 Proposals for Soil conservation Measures Corresponding to Soil Erosion Conditions

Soil conservation measures change depending on the nature of soil, topography, rainfalls, groundwater, social and economic conditions of the local areas. Accordingly, it is difficult to show suitable soil conservation measures as simplified menus. However, summarizing the discussions in the pervious Chapters, recommendable precautionary and mitigative soil conservation measures according to the types of soil erosions are shown in Table 10-1.

Table 10-1: Recommendable Precautionary and Mitigative Soil Conservation Measures According to the Types of Soil Erosions

Type of Erosions	Causes and Natural Conditions	Locations	Proposed Measures
Sheet	Bare surface by too heavy grazing, slope, dry climate	All grazing field and shrub, road, gardens	Contour terracing, fencing for grazing rotation
Small size terracette	do., but on shallow soil and steep slope /grazing load	Steep, stony grazing field on hill ridges	do., tethering cattle coupled with feeding with feedlots
Slip / Slide	Shallow aquifer / loose soil on rock pans /grazing load	Steep, stony grazing field on land-slip zone	do., tethering cattle coupled with feeding with feedlots
Rill	Bare surface on cattle tracks, slope, erodible surface soils	Very often on cattle tracks, drain/culverts	Fencing off damaged cattle tracks, then training with structures
Gully	Developed from rills with highly erodible saprolites lain underneath rills	Road-side Drainage, dip-tanks, under culverts, borrow-pits, cattle paths	Inside stone structures or weirs to foster sedimentation, plant trees to stabilize/ deactivate it
Gully at heap covered by gravel	Slope fractures subject to overgrazing for decades, soil lost away by rain /wind	Grazing field exposed under heavy grazing for a long time	Difficult to find effective measures, but plant shrub fodder trees to restore vegetative cover for retrieving carrying capacity

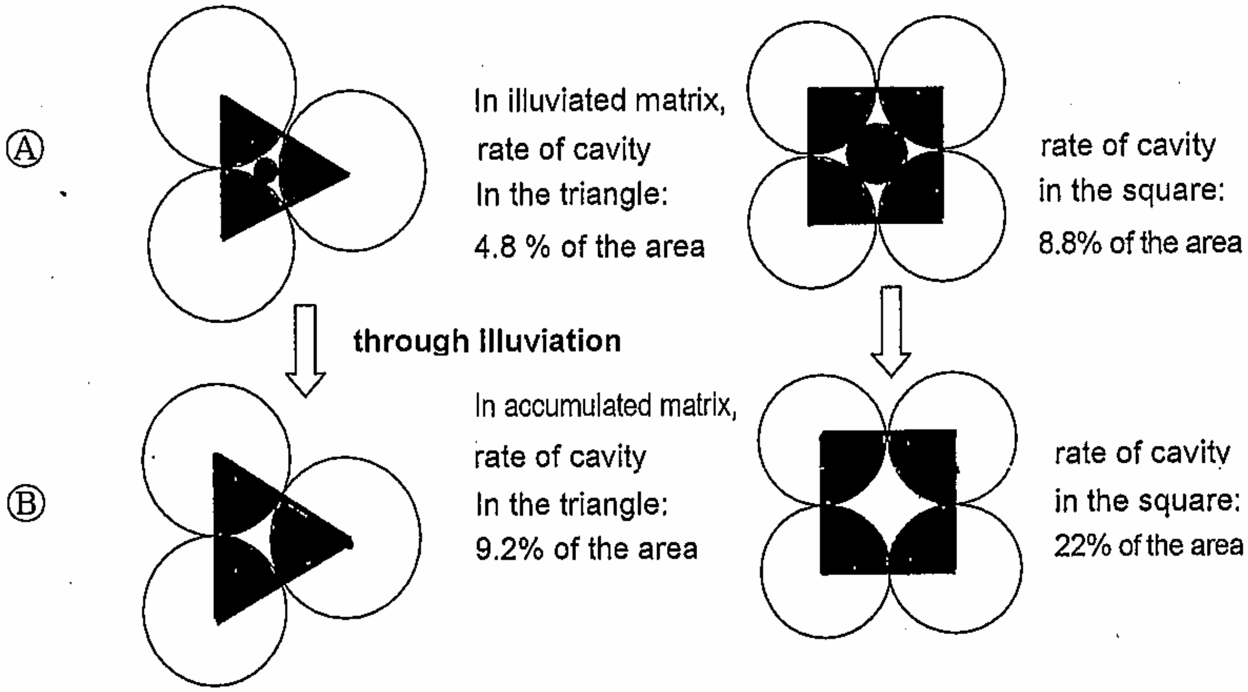
It may be mentioned here that most parts of this guideline include what have been pointed out and recommended by the international aid agencies and donor countries. In handling the soil conservation problems, no different conclusions and counter measures can be extracted from the same problems and behaviours that have traditionally been handed down from ancient generations. Thus, the solutions for soil conservation problems are found almost the same in almost every country where soil erosions are observed.

It is important to recognize that, neither the government officers nor NGOs and foreign donors can control land degradation process, but only the change of attitude and individual activities of community people can properly address the problems. Finally, it is hoped that this guideline will be widely utilized among the people concerned and contribute to the improvement of the degraded lands in the Kingdom of Swaziland.

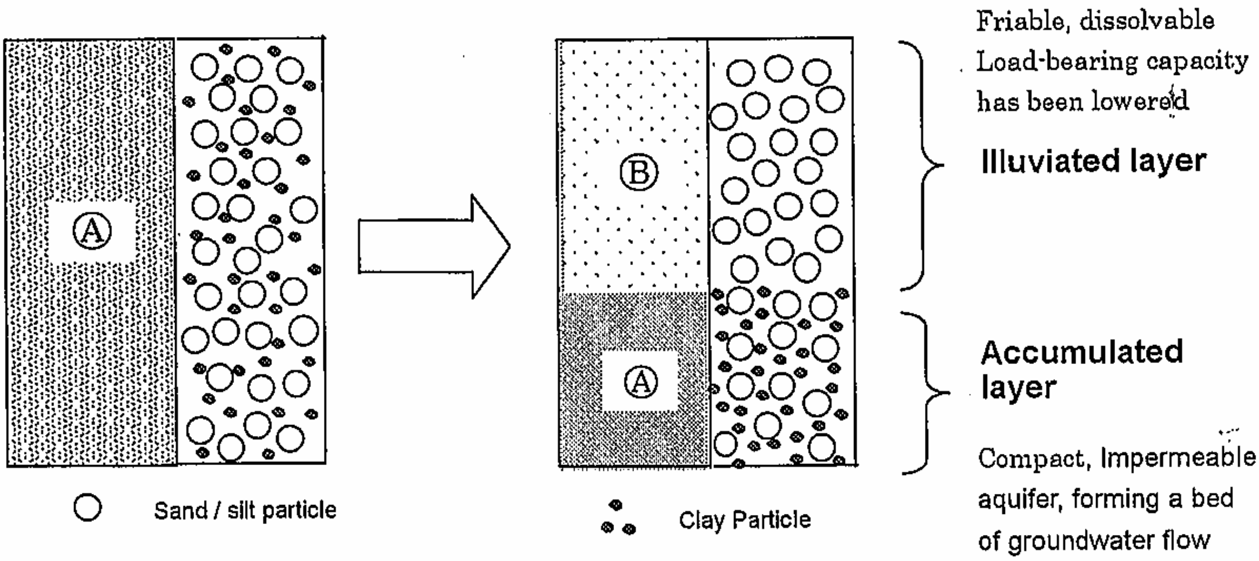
Annex

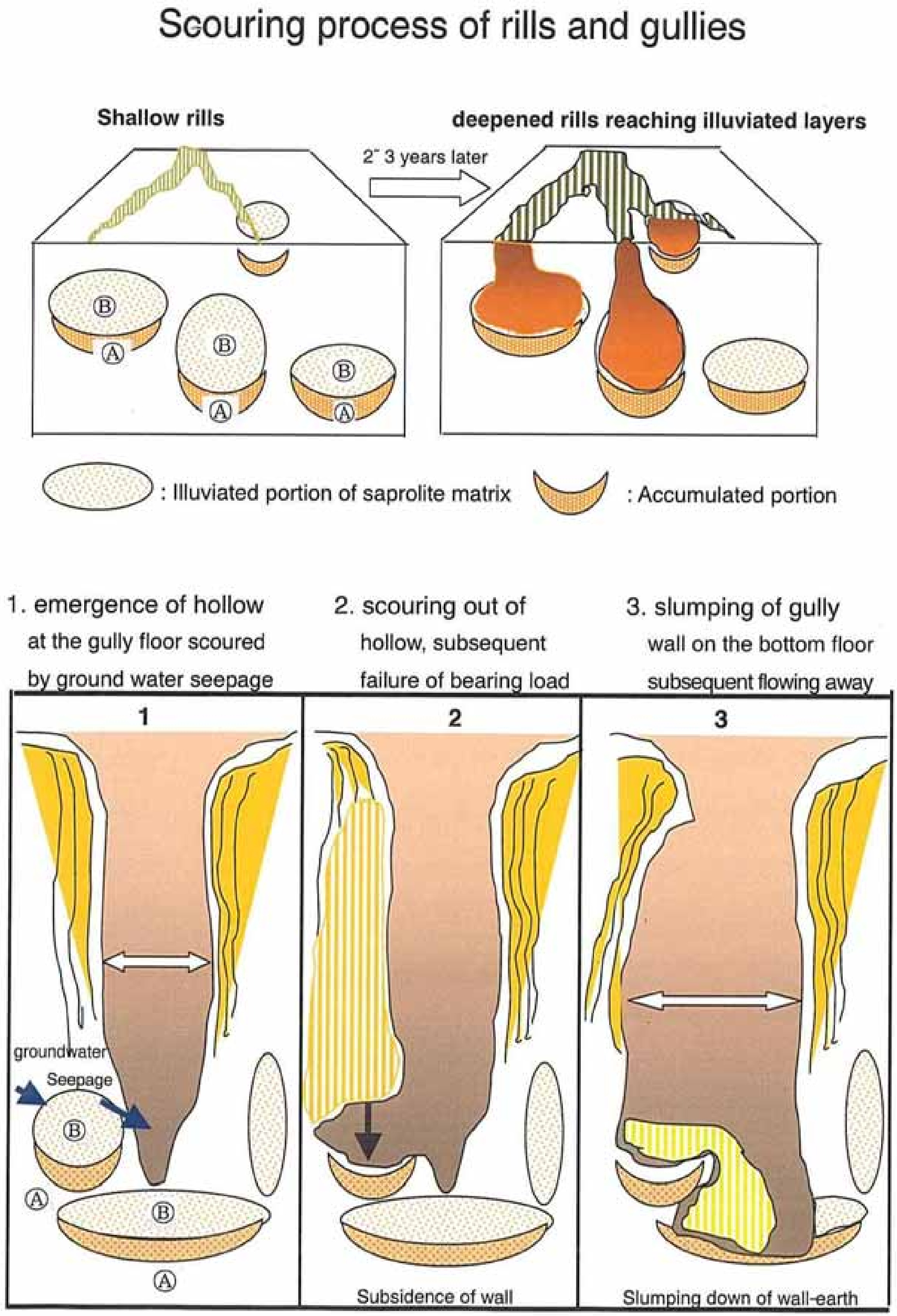
Property of Weathered Rock/Soil Inside Gullies / Rills

Cavity in soil / weathered rock matrix grows bigger when particle sizes are well-sorted, or consisting of similar sizes, often observed in highly weathered, illuviated saprolite matrix.



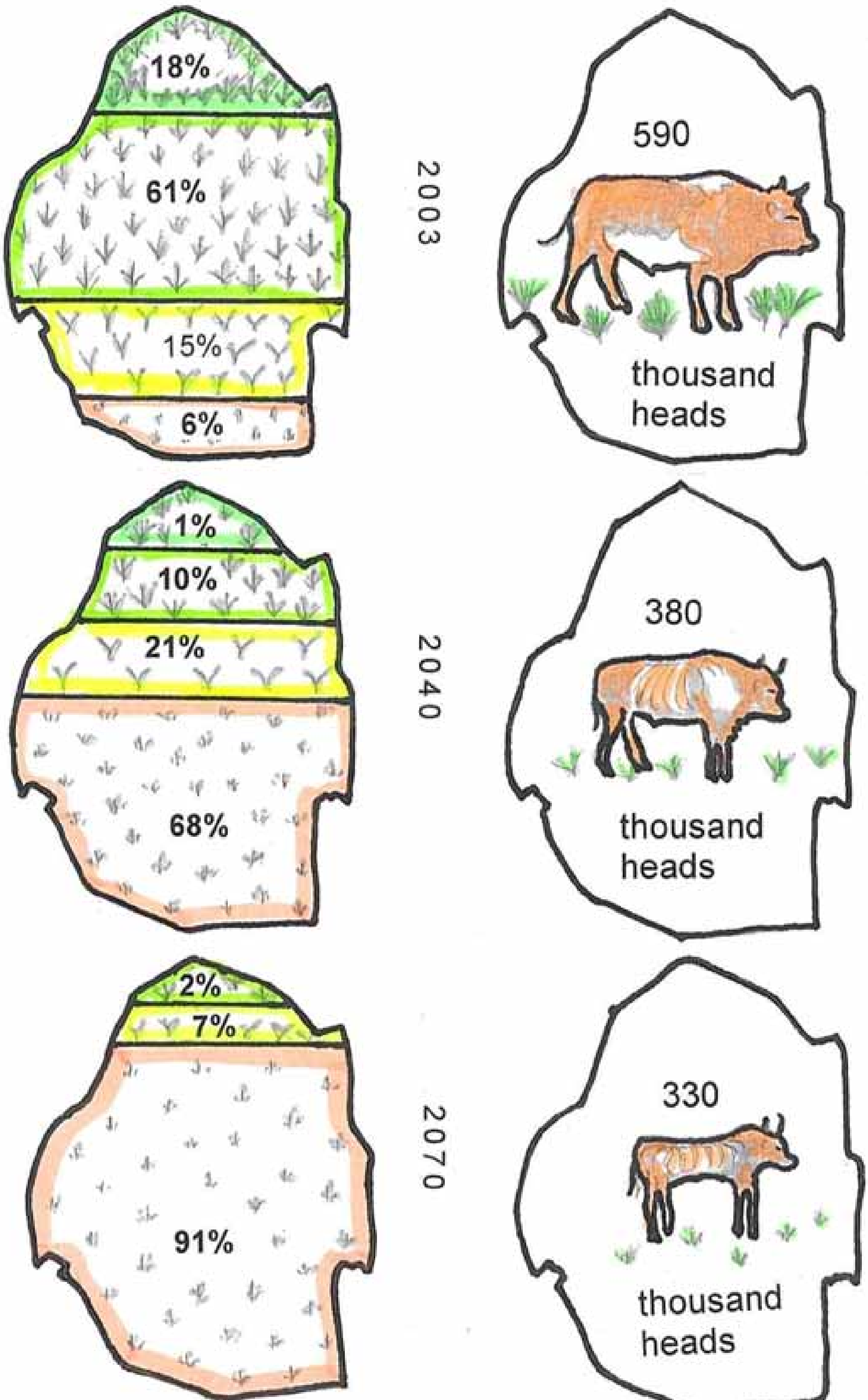
Therefore, if illuviation of clay particles from a horizon to lower lying one happened, the illuviated upper layers have higher water permeability and lower consistency.

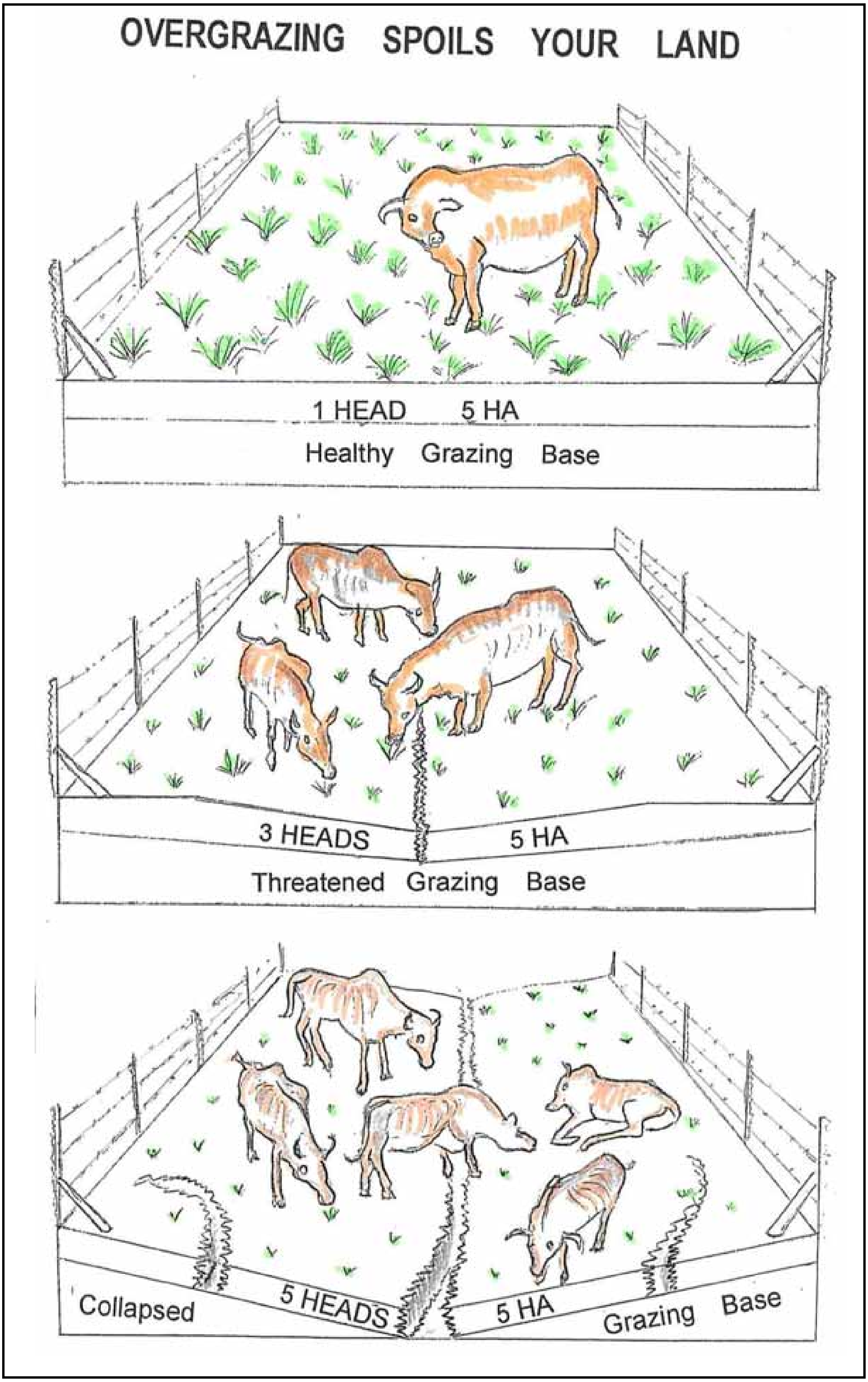



Scouring process of rills and gullies
Shallow rills
deepened rills reaching illuviated layers
2˜ 3 years later
B
A
: Illuviated portion of saprolite matrix
: Accumulated portion
1. emergence of hollow at the gully floor scoured by ground water seepage
2. scouring out of hollow, subsequent failure of bearing load
3. slumping of gully wall on the bottom floor subsequent flowing away
1
2
3
groundwater
Seepage
Subsidence of wall
Slumping down of wall-earth

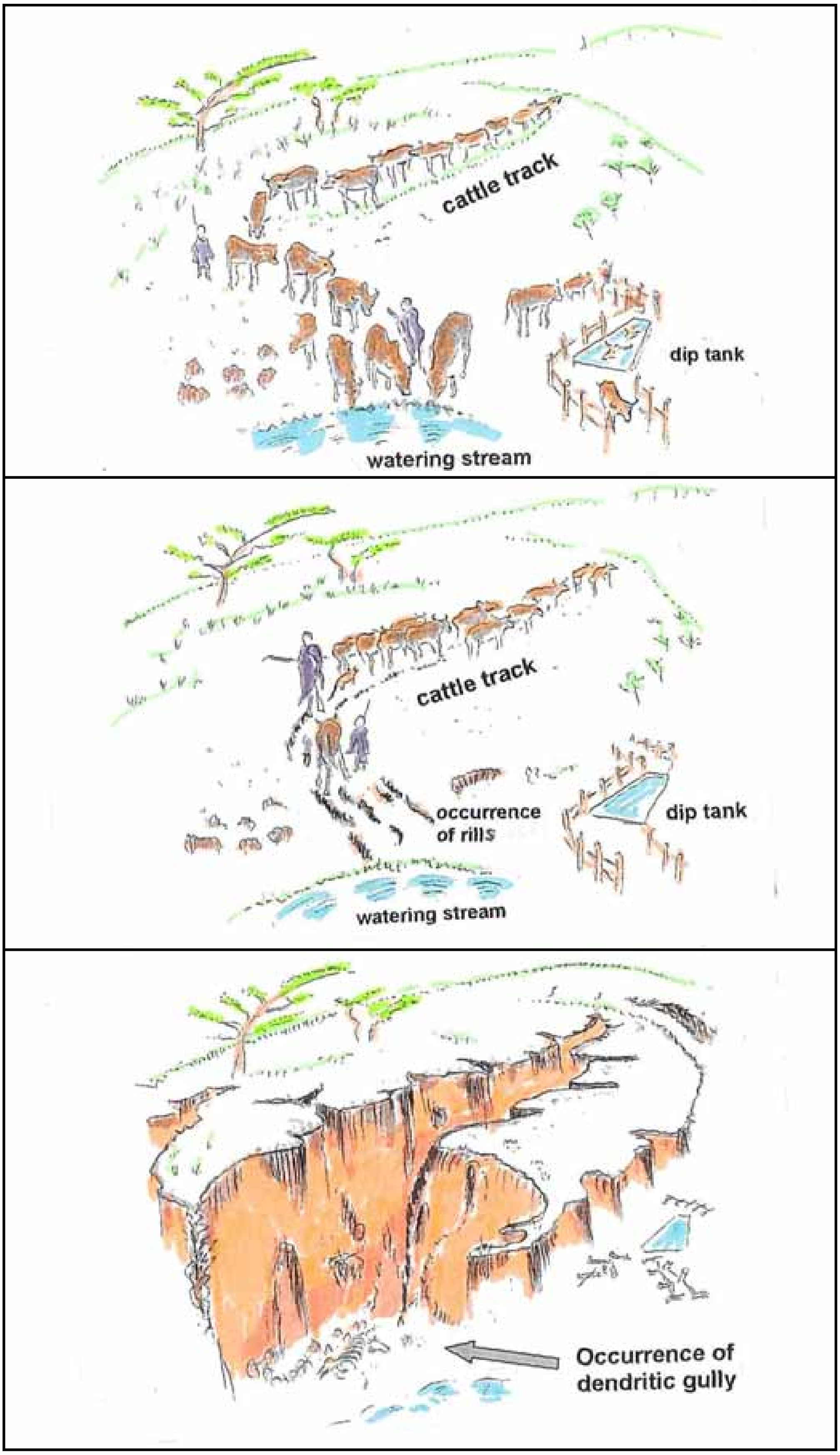
Your Grazing Land will be able to Sustain Less Cattle

Unless You Take Measures to Properly Conserve it




OVERGRAZING SPOILS YOUR LAND
1 HEAD 5 HA
Healthy Grazing Base
3 HEADS 5 HA
Threatened Grazing Base
Collapsed 5 HEADS 5 HA Grazing Base

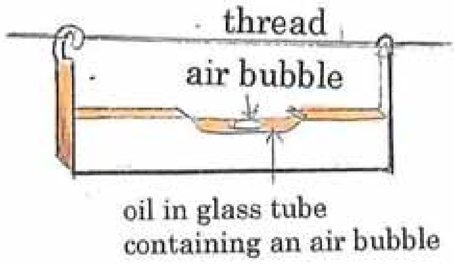
CATTLE TRACKS SPLIT INTO GULLIES

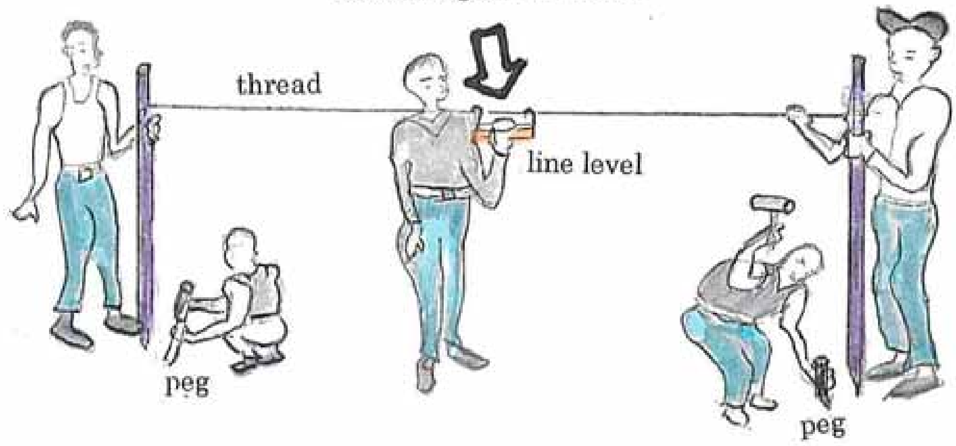


HOW TO MAKE CONTOUR TERRACES

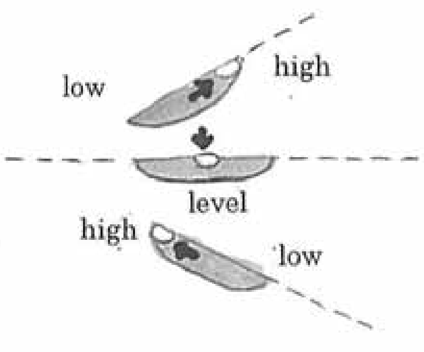
On your grazing field

① Use a " line level " to lay out horizontal terraces.



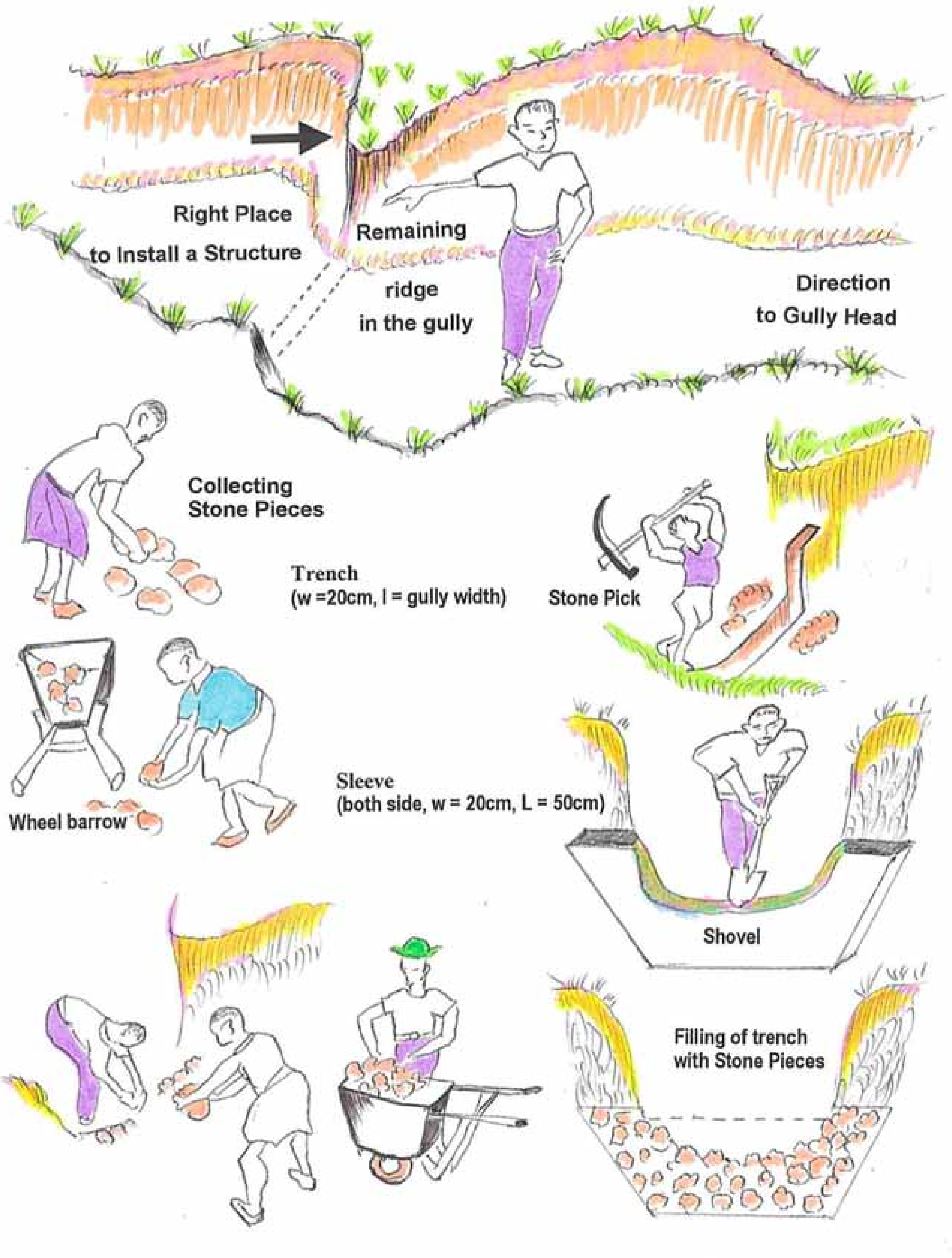


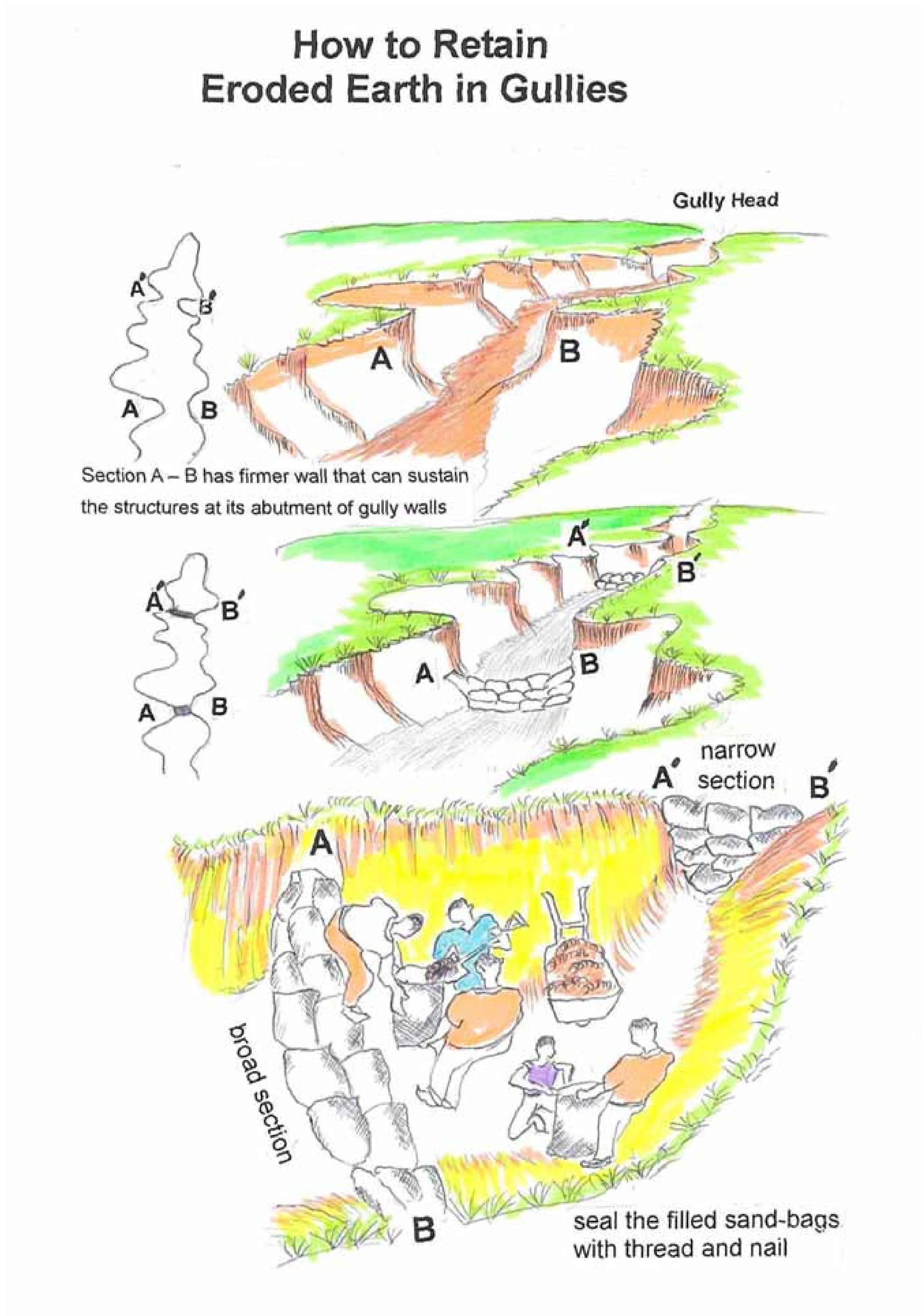
② Use " hoes " to cut terraces (better than machine cutting)



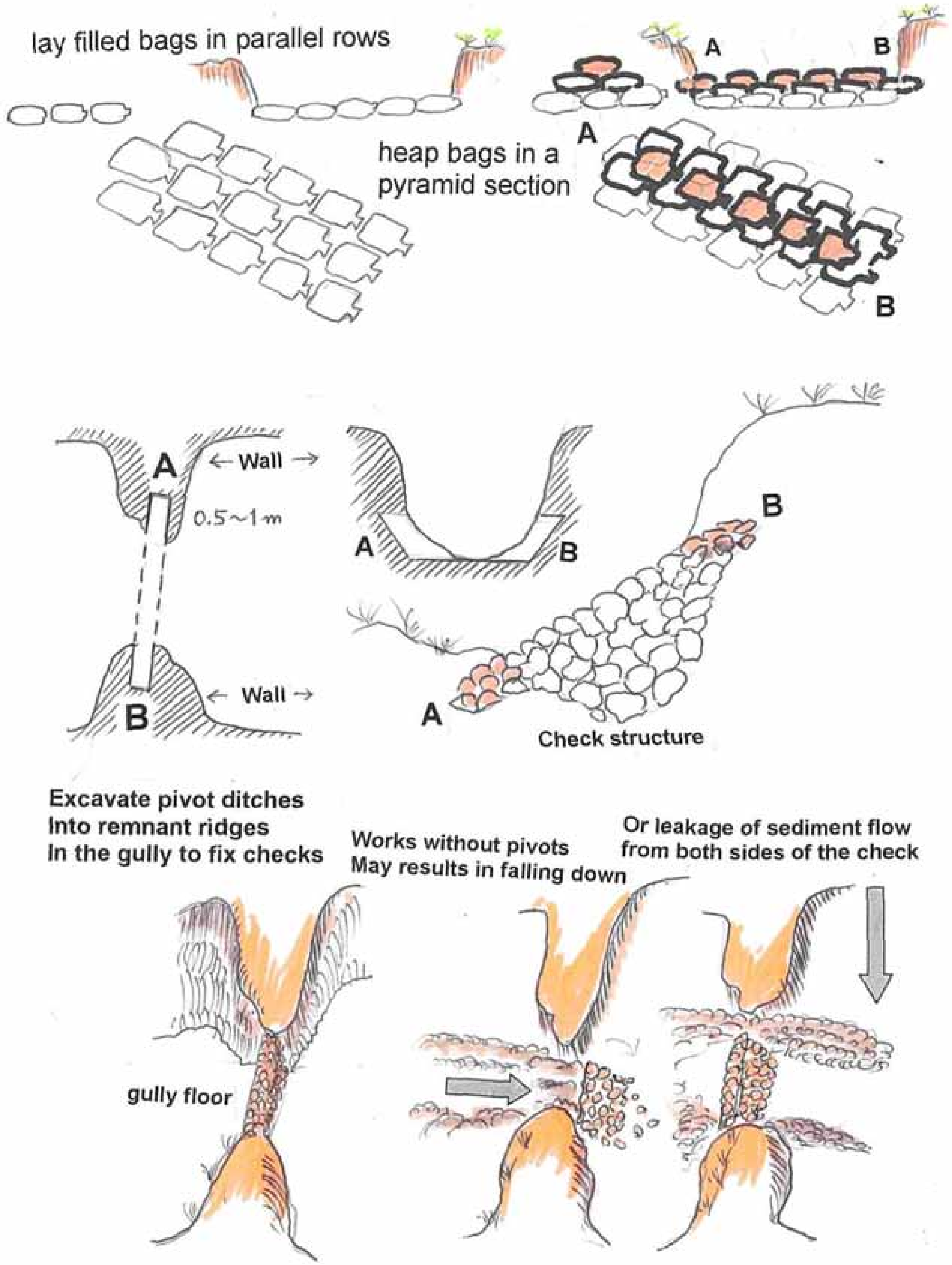
How to Make Inner Gully Structure

(with Stone Pieces)




How to Retain
Eroded Earth in Gullies
Gully Head
A'
B'
A
B
A
B
Section A – B has firmer wall that can sustain
the structures at its abutment of gully walls
A'
B'
A
B
A
B
A'
B'
narrow
section
A'
B'
A
broad section
B
seal the filled sand-bags
with thread and nail

How to Retain Eroded Earth in Gullies



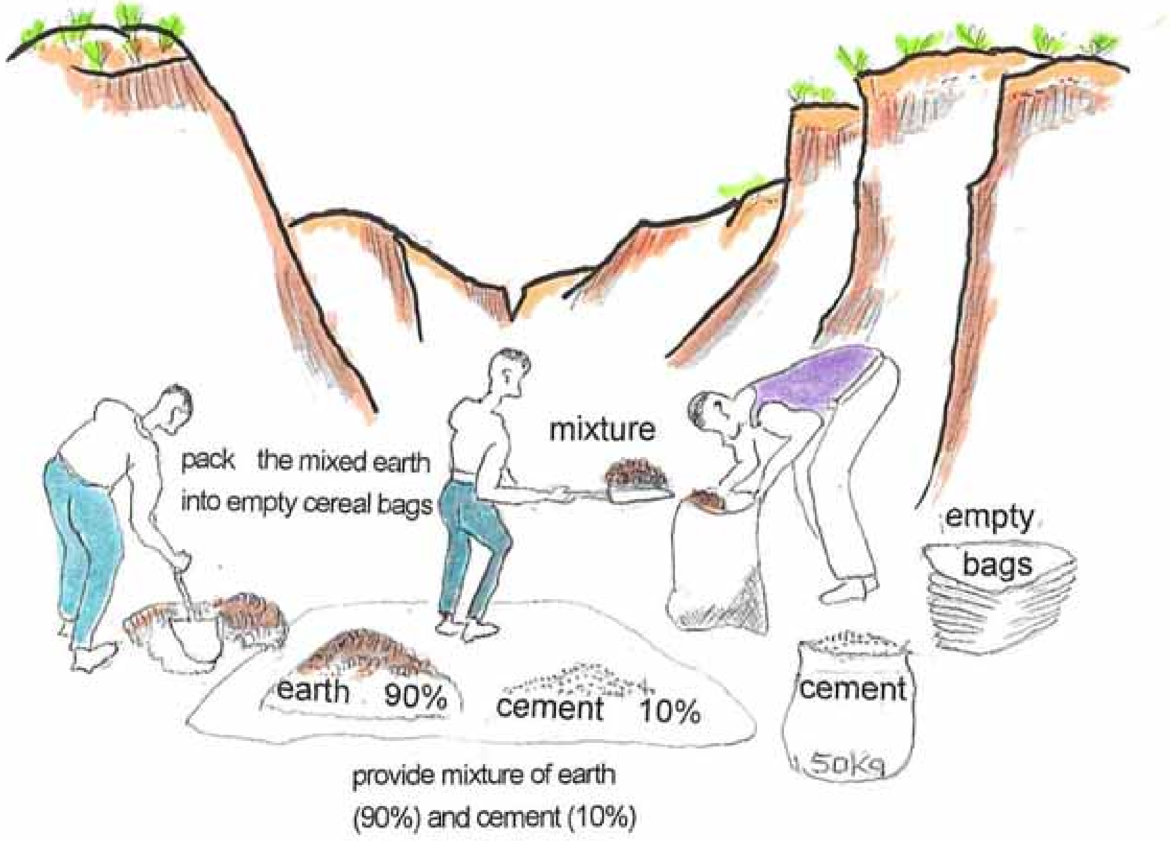
Use Readily Available Material for Training Gullies

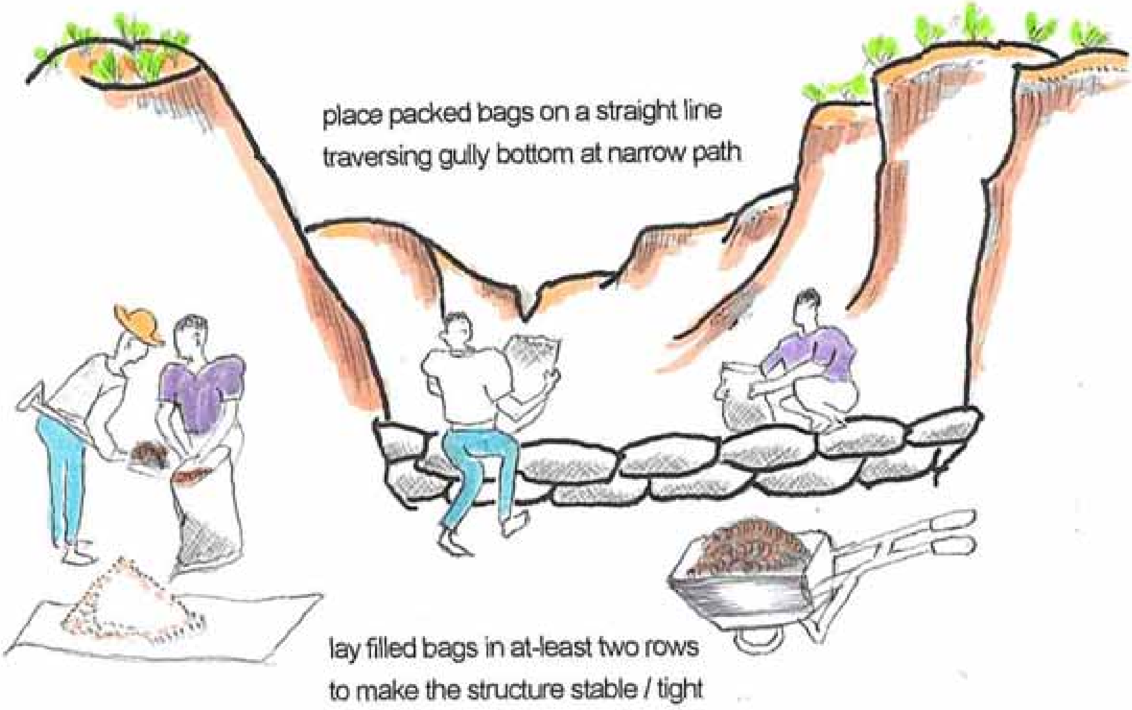
- Use stone pieces where a lot of stone pieces are found over the ground

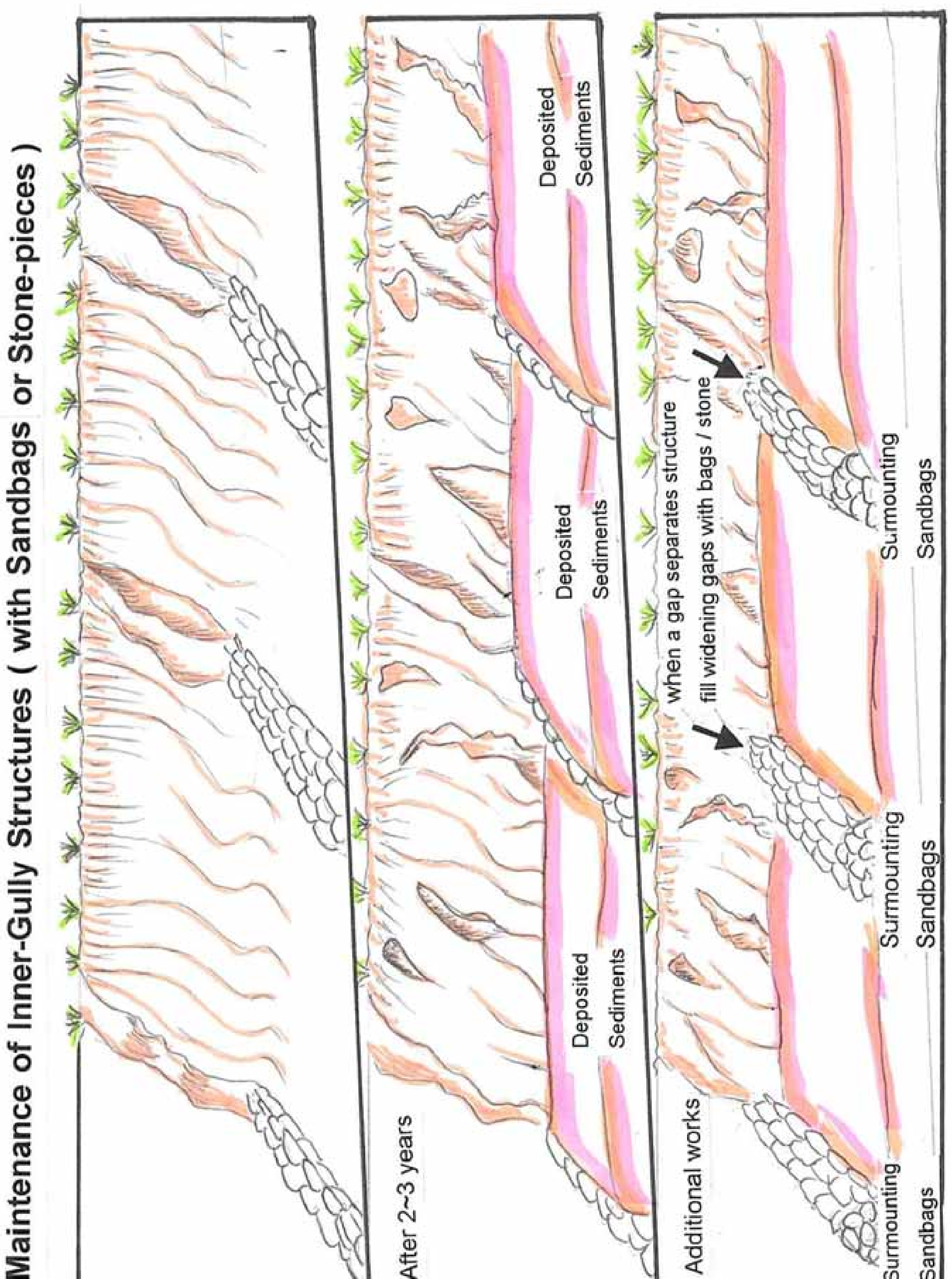
- Use branch bundles where there are many shrubs of alien tree species

- Use sandbags & cement where no bestowed resource is available

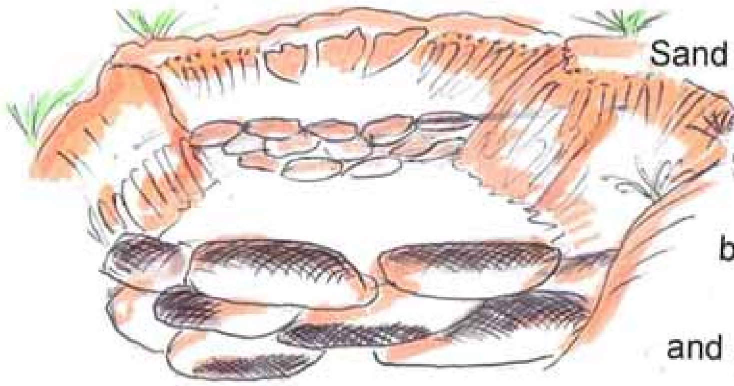
How to Train Gullies with Sandbags






Maintenance of Inner-Gully Structures (with Sandbags or Stone-pieces)
After 2~3 years
Deposited Sediments
Deposited Sediments
Deposited Sediments
Deposited Sediments
Additional works
when a gap separates structure
fill widening gaps with bags / stone
Surmounting Sandbags
Surmounting Sandbags
Surmounting Sandbags

Sand-bag Structure



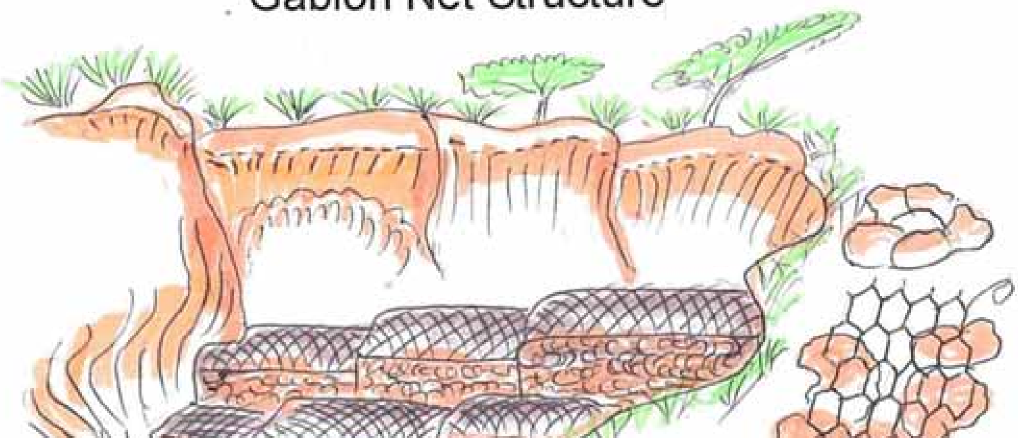
Sand bag structure has the same durability as gabion net one but the cost is much cheaper and material is readily available.

Cost Comparison of Gully Training with Empty Bags and Gabions

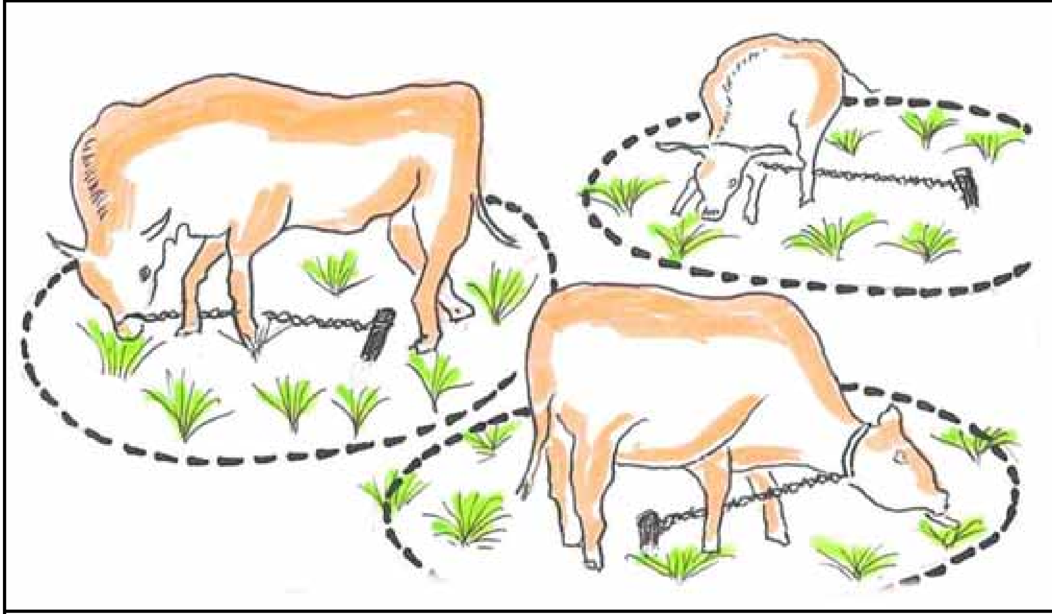
Unit work scale: section height 3m x width 10m

Item	spec/size	Quantity	Unit Cost	Amount(E)	US$ equiv.
empty bag	3m x 10m	120	18	2,160	297.9
cement	0.6ton	12	55	660	91.0
shovel	scew tip	3	80	240	33.1
stone-pick	10 kg	2	120	240	33.1
labor	2psn x 4d	8	25	200	27.6
wheel barrow	100kg	1	280	280	38.6
insurance		8	15	120	16.6
misceraneous	8%	15%		585	80.7
Works with sand-bags				4,485	618.6
Gabion baskets	2m x 1mx	30	174	5,220	720.0
weavier deprec.	0.02	1	160	160	22.1
Creosoted poles		6	26	156	21.5
shovel	scew tip	3	80	240	33.1
stone-pick	10 kg	2	120	240	33.1
labor	4psn x 6d	24	25	600	82.8
wheel barrow	100kg	2	280	560	77.2
misceraneous	8%	15%		992	136.9
Works with gabion-baskets				8,168	1,126.7
if a structure creates 10m x 15m = 150 m²,				cost to estore 1ha will	
amount to :	sandbags;	41,241	gabions :	75,112	US$ equiv.

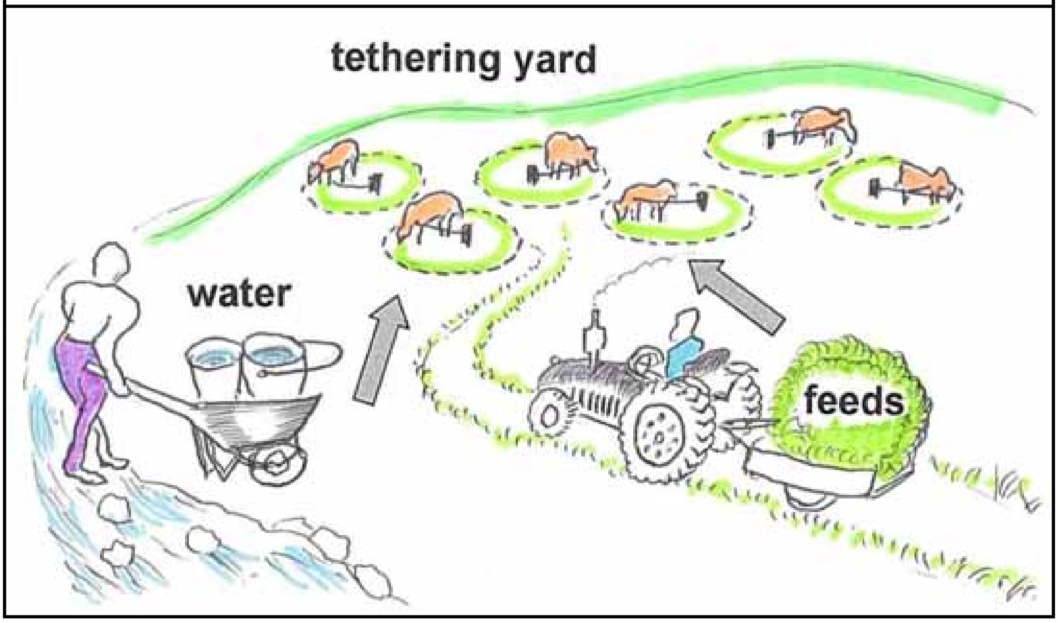
Gabion Net Structure



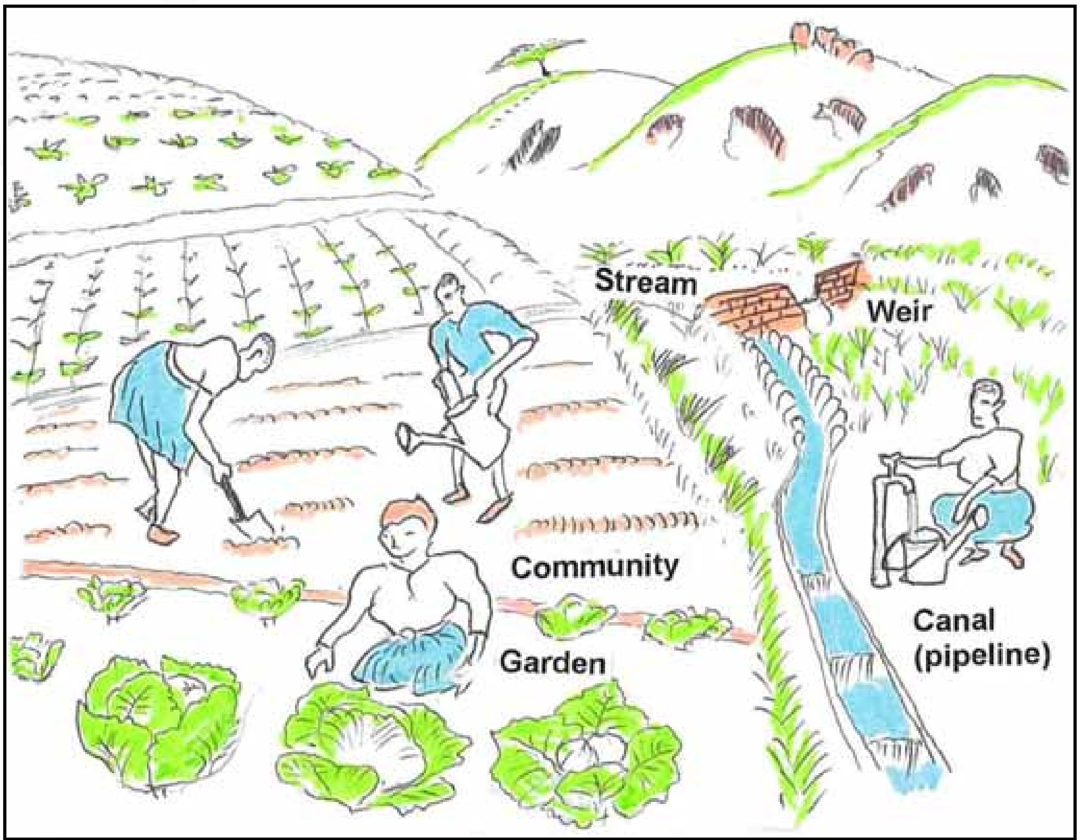
Tethering, a Final Solution to Stop Erosion

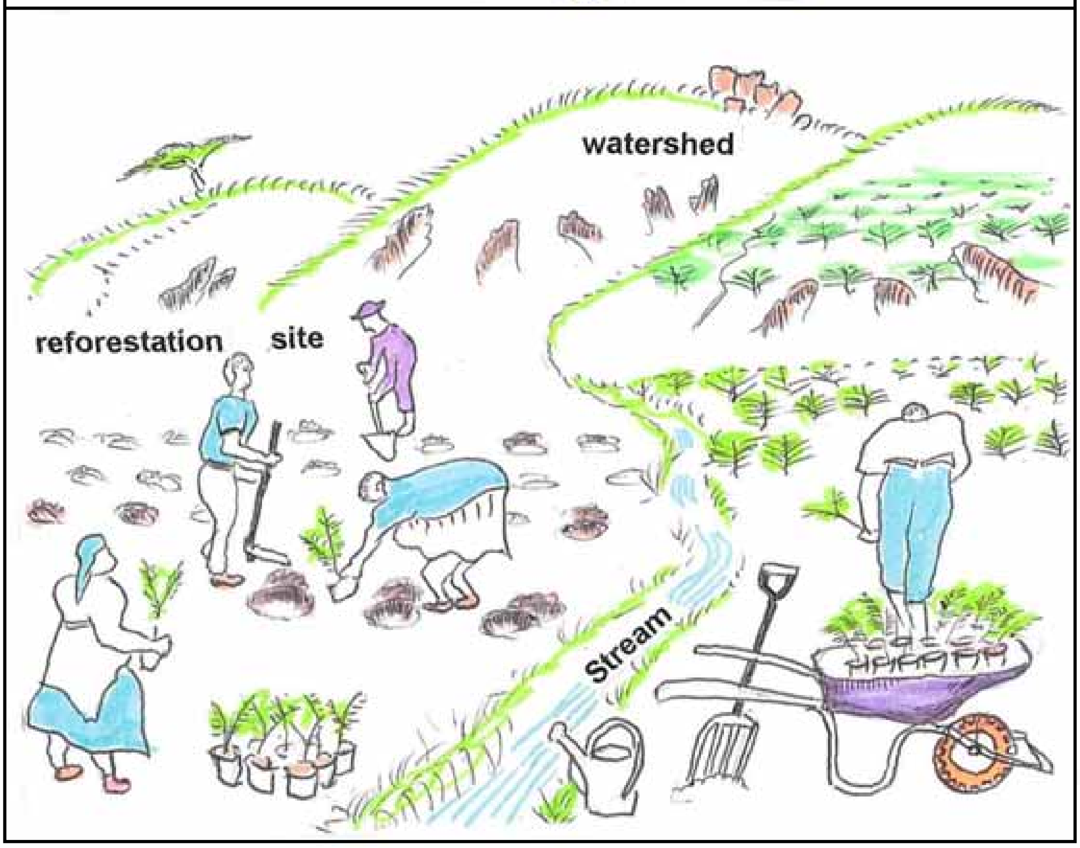


Tethering requires feeding by herd keepers, with cropped feeds.
Tethering doesn't allow cattle to flock, flocked herd harms ground
It can save cattle's energy to graze around grassless futile land.
All modern countries keep cattle by tethering or in barns/feedlots
Large cattle herds can only properly grazed by transhumancy.

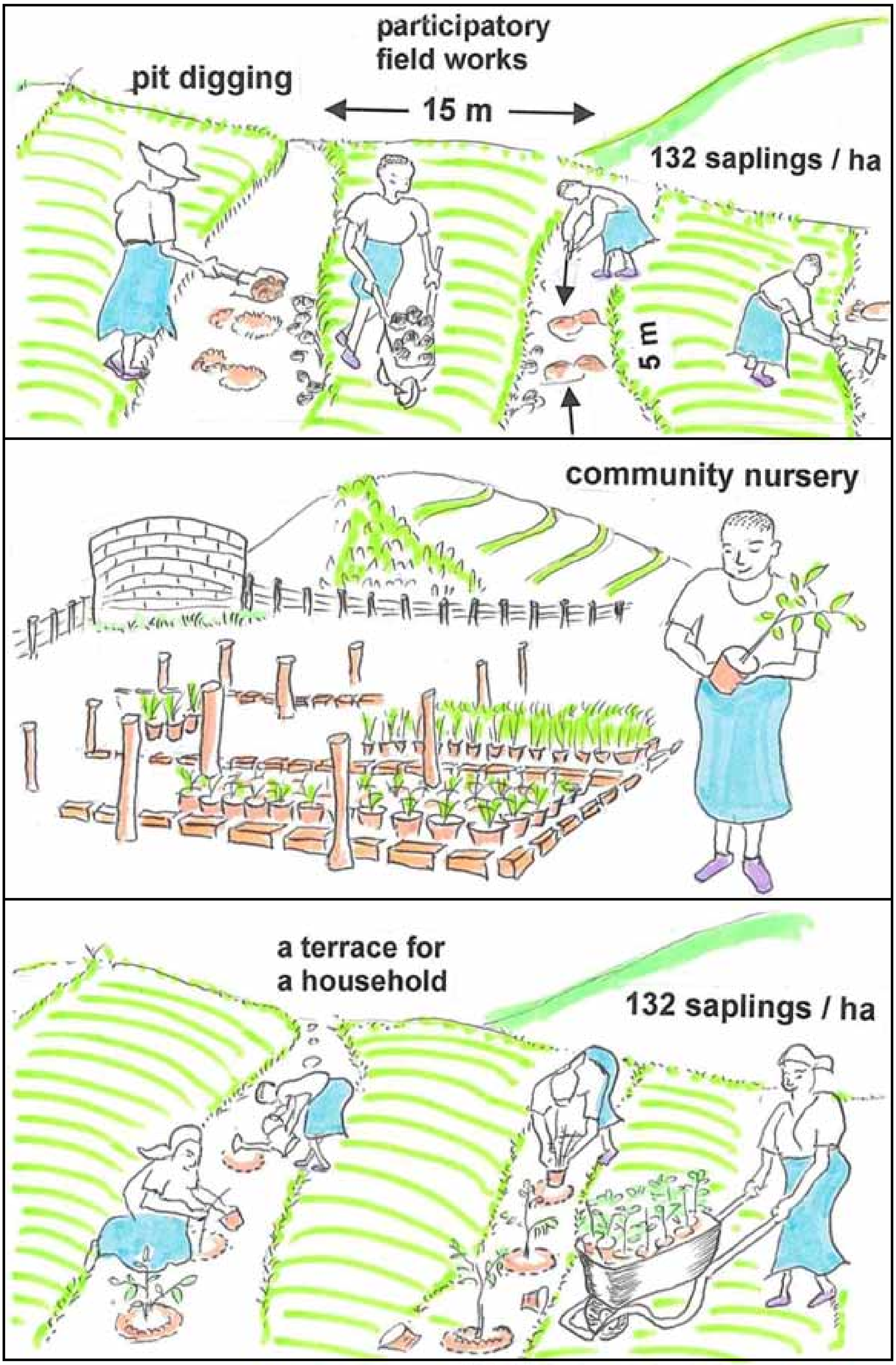


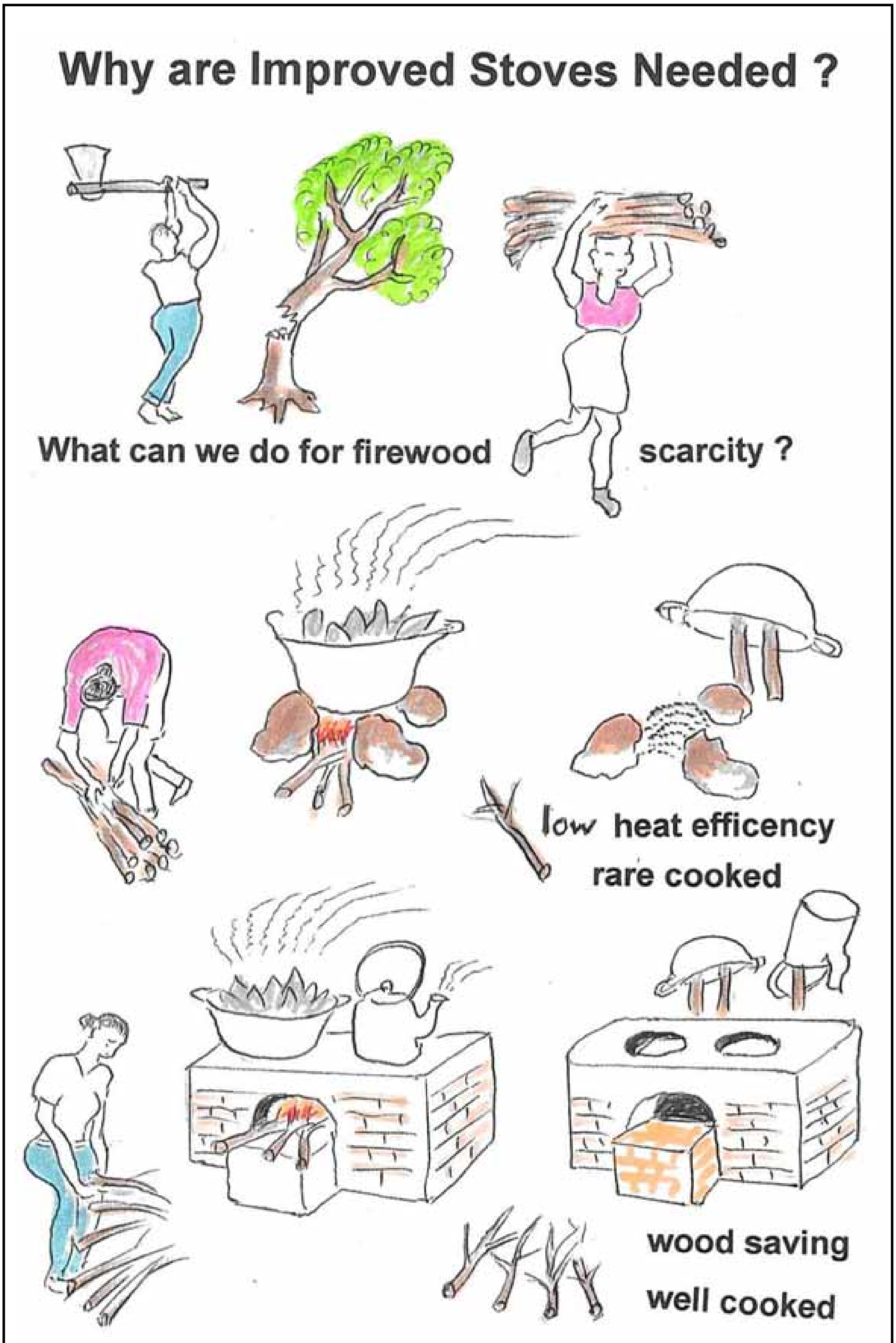
Keep Watershed Green by Reforestation Otherwise Water for Garden Depletes

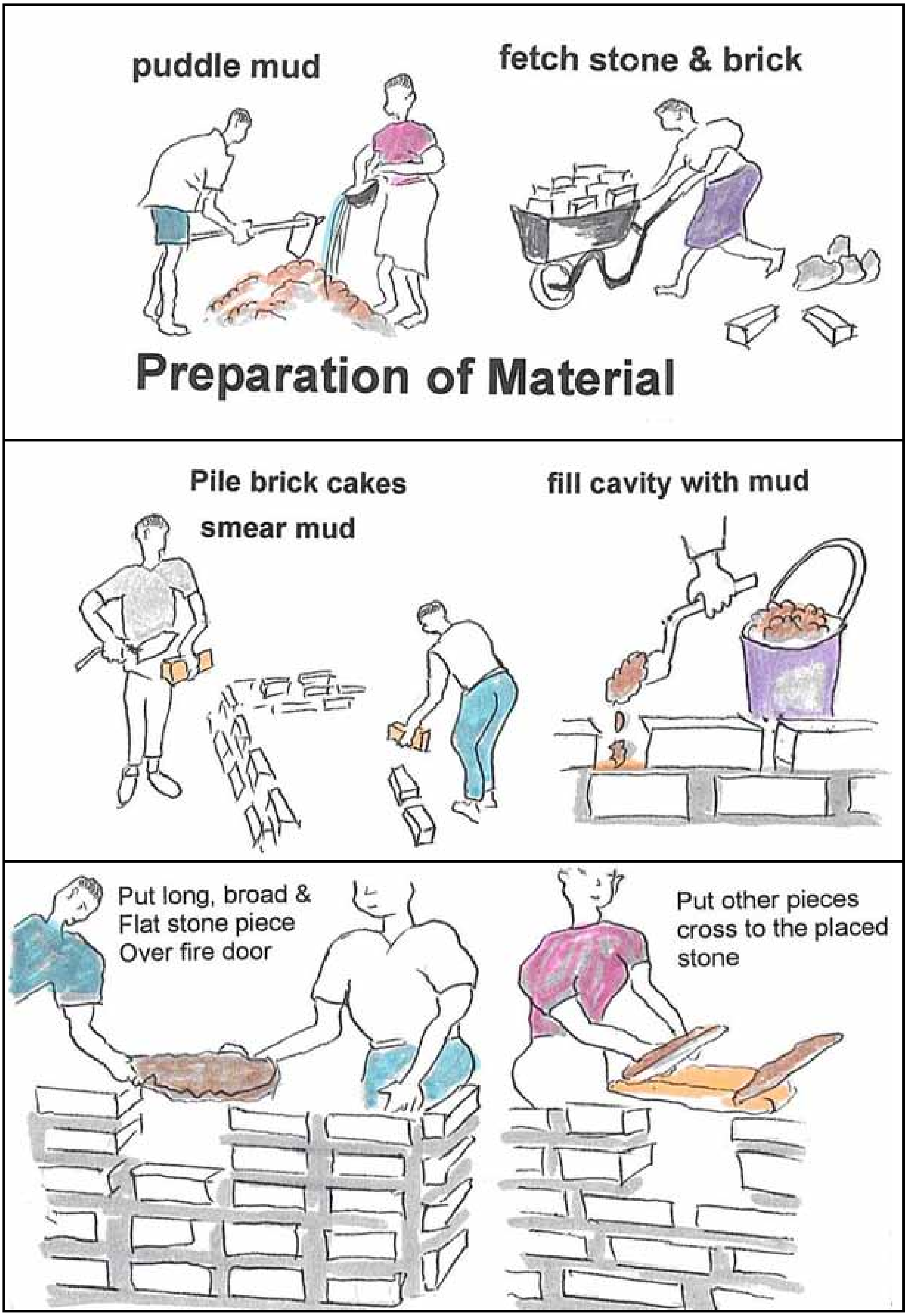


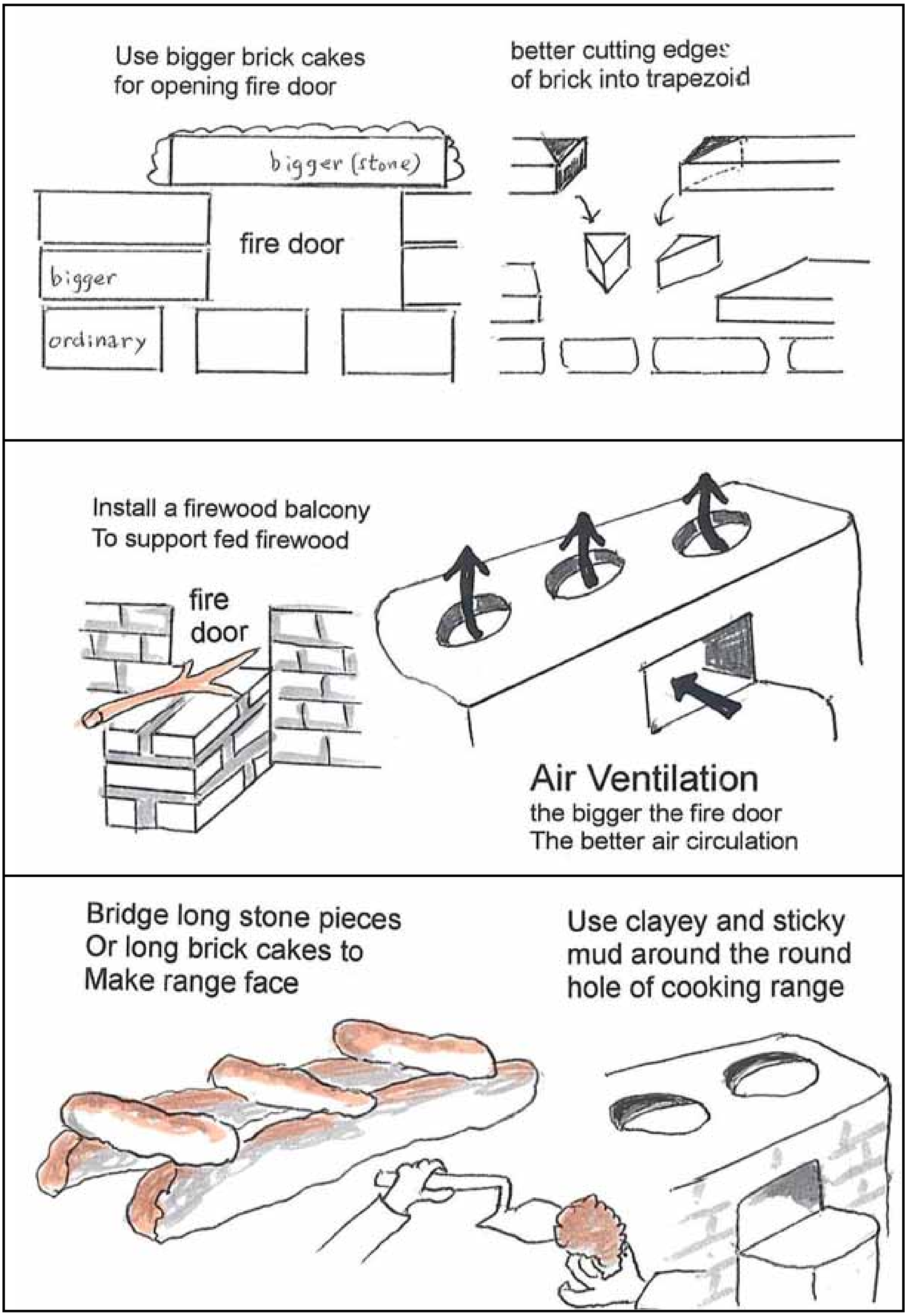


Let's Plant Fruit Trees on Contour Terraces




Why are Improved Stoves Needed ?
What can we do for firewood scarcity ?
low heat efficency
rare cooked
wood saving
well cooked


puddle mud
fetch stone & brick
Preparation of Material
Pile brick cakes
smear mud
fill cavity with mud
Put long, broad &
Flat stone piece
Over fire door
Put other pieces
cross to the placed
stone


Use bigger brick cakes
for opening fire door
bigger (stone)
fire door
bigger
ordinary
better cutting edges
of brick into trapezoid
Install a firewood balcony
To support fed firewood
fire
door
Air Ventilation
the bigger the fire door
The better air circulation
Bridge long stone pieces
Or long brick cakes to
Make range face
Use clayey and sticky
mud around the round
hole of cooking range