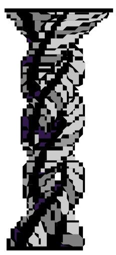
CHAPTER 6: COMBINING INDICATORS

6.1 Introduction

Single indicators give singular items of evidence for land degradation or its impact. They are susceptible to error, misinterpretation and chance. Especially in the case of field assessment where many of the measurements can only be described as 'rough-and-ready', the use of only one indicator – say, a tree mound – to conclude definitively that land degradation has occurred is problematic. It renders the field assessor open to criticism that much is being made of a little. Therefore, this chapter addresses how, by combining indicators, more robust conclusions can be entertained, even to the extent that quite different types of measure may be placed alongside each other to obtain a fuller understanding as to whether land degradation is happening.



This publication has throughout promoted the use of two or more indicators in combination, preferably with the active input of farmer experience. Just as a three-stranded rope is far stronger than the sum of the strengths of its individual strands, so is an assessment of land degradation based upon the combination of indicators that all trend towards the same conclusion. While each indicator has its own attributes and applications, several indicators together can piece together a far more comprehensive and consistent picture. Similarly, if indicators disagree in general trends, then the field assessor is led to further investigation to resolve the disparities. Disagreement in what the indicator suggests is one of the most powerful ways of picking up the difference in perspectives of the land user and the field professional.

Three particular areas of combining indicators are highlighted here:

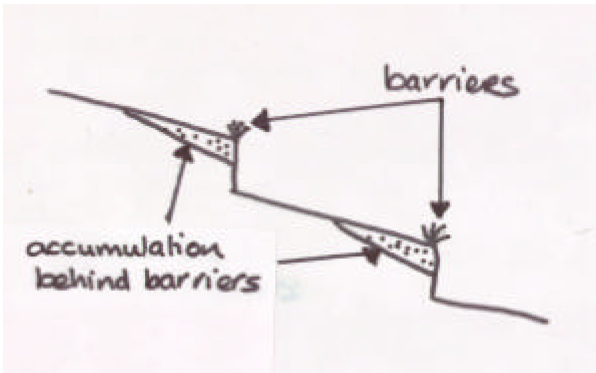
- combinations to show both the process and likely cause of land degradation through time
- combinations to provide corroborating evidence and a consistent view of land degradation
- methods to bring individual indicators together for comparative and overall assessment, including how to search for a suite of indicators and how to develop a semi-quantitative procedure for getting an overall picture.

However, before considering how indicator combinations can be constructed, why are they really necessary in all but the simplest of situations?

6.2 Why Single Indicators are Often Insufficient

An example is used here to illustrate how single indicators, especially when used with little reference to the farmer, may give erroneous conclusions.

Figure 6.1: Sketch of Bench Terraces



Accumulations of sediment behind barriers are a useful indication that soil movement has taken place in the field, and that, if it were not for the barrier, soil would have been irrecoverably lost. A typical example is shown in Figure 6.1, where the sediment trapped (shaded) by the constructed riser of the bench terrace can be measured to give an assessment of the minimum amount of soil that has been lost from the bench. The assumption here is that the material trapped has been eroded from the bench because of the land use and slope of the bench. Is this necessarily so?

Figure 6.2: Farmer planting *Gliricidia* Fence, Sri Lanka

In Sri Lanka, these types of bench terrace are common in the steep hill lands where a living plant is used to support the riser and maintain the benches. (See Section 7 for a fuller case study of this type of conservation). It is instructive to follow through with farmers how they construct the benches and what they think of the soil that is trapped behind the riser. The risers themselves usually consist of planted lines of a fast growing leguminous tree, *Gliricidia sepium*. A farmer will cultivate the field and then plant a new line of *G. sepium* sticks across the slope. At this stage there are no benches. Progressively, over a few seasons, the farmer then:

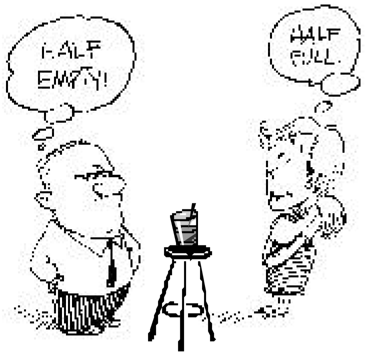
- manages the *Gliricidia* sticks so that they 'strike' and commence growing into trees;
- along the line, the farmer places sticks to form a more permanent barrier; weeds are also placed here, as it is a convenient close place and does not interfere with crop activities between the lines of sticks;
- with the hoe, the farmer scrapes soil downslope to cover the weed-fill and form benches; some soil is washed down naturally by rainwash but most is what is called 'plough erosion', that is, soil moved down by the action of cultivation.

Therefore, we have a situation where erosion has been 'encouraged' by the farmer. Is this land degradation? The field assessor must decide. However, it is useful to view the supposed eroded soil through the eyes of the farmer because:

- here is a useful site to get rid of weeds and other 'rubbish' – indeed, the fence line in the local language is called 'rubbish-things fence';
- after a few seasons when the benches are formed, the soil close to the fence is relatively rich in organic matter as well as being deep; hence the more valuable and demanding crops are planted here;
- meanwhile, the farmer harvests poles of *Gliricidia* for sale or use as bean-poles, while the leaves are left on the surface soil for a nitrogen-rich mulch;
- after six or seven years, when the *Gliricidia* starts to lose its vigour, the farmer uproots the fence line, and plants high value crops in the accumulated rich soil;
- at the same time, a new *Gliricidia* fence line is constructed mid-way across the old bench ….. and so the process continues.

Only with the farmer fully participating can this story of soil movement and farm production be told. So, again, is this land degradation? First, there is positive encouragement by the farmer for soil to move to fill in the upslope side of the fence. Secondly, there are interesting management and production opportunities opened up by the accumulation of soil. Thirdly, the farmer sees the accumulation as a longer-term production opportunity, while a new fence line in another part of the field is established. There has been a real and measurable movement of soil. But humans have done most of it for very specific reasons related to their livelihoods. The soil movement will have contributed to the deterioration of part of the slope for some six to seven years. But the farmers gain sufficient capital assets to implement a further cycle of soil restoration with the new fence lines, while fully utilising the 'eroded' soil for their benefit.

The answer as to whether this is land degradation must, therefore, depend upon the perspective through which the judgement is made. It is



like the alternative views on a glass of milk that has been half-consumed. The optimist will say, "Good – it is still half-full"; the pessimist will complain, "It is half-empty". The optimist will be the farmer. In field surveys in Sri Lanka, not a single farmer equated the soil movement with soil erosion – they saw it as part of the natural production cycle on steep hill slopes. The pessimist is the professional – soil is moving downslope, and what is worse is that farmers are even accelerating the process with their cultivation techniques!

The single indicator, with little reference to the farmer, could in this instance (and many others) present a simplistic and erroneous – from the farmer-perspective – understanding of the status of land degradation. The fuller picture is only available by, for example, examining plant growth on the eroded soil; the use of the *Gliricidia* branches and leaves; and, crucially, by observing what is done and talking with the farmer as to why things are done in this way. The single biophysical indicator needs supplementation by all these other observations before land degradation can even be considered as having occurred.

6.3 Assessment of Both Process and Cause

The example above has already illustrated how process and cause can be discerned in a complex field system of bench terraces. The field observation indicated that there had been a 'process' of erosion; the further enquiry found the 'cause', deliberate ploughing and entrapment of sediment by the farmer. Just as powerful conclusions may also be drawn in simpler situations where two indicators essentially agree but one is a measure of the process and the other a measure of how the process comes to have an impact on production.

Take the case of a flat-cultivated field where observation and measurement of 'armour layer' has shown that active current erosion is taking place under an extremely poor cover of maize. The coarse stones accumulating on the surface are evidence, not only of total erosion, but also that there is substantial selective removal of fine particles. However, the impact of this selective removal and how the erosion is causing a reduction in plant vigour (and presumably also of yield) have yet to be discovered.

Figure 6.3: Field Showing Poor Maize Growth

Examination of the growing maize plants and other field indicators for:

- nutrient deficiency symptoms – to discover if there is a causative effect through plant nutrient limitations: *yellowing, chlorotic leaves of the maize*
- differential crop growth characteristics between eroded and uneroded conditions to determine if it is the erosion that is reducing yield, and by how much: *a nearby site cultivated for only a few years has double the plant density and much larger plants*
- any sediments entrapped in field ditches, or hollows, for evidence of the degree of enrichment: *some coarse sands in a field ditch in the middle of the field; and some very fine clays and rich humus in a puddle at the bottom of the field …..*

all add to the understanding of how the obvious process of erosion under a poor standing crop affects current and future production from the field. In this case, the indicators are all in agreement in the sense that they all point to a consistent process (erosion-induced loss in soil productivity) and cause (selective removal of organic matter and clays and consequent nitrogen deficiencies for the maize)

Piecing together the separate strands of field evidence is one of the most exciting aspects of field assessment of land degradation, because they enable far more to be gained than with classical reductionist methods, where only the knowledge of a process may be gained. Here, an interesting inter-weaving of process, cause and effect may be gained, provided that the field observer is alert to the signs and is willing to put together evidence from a variety of sources.

6.4 Triangulation – Gaining a Robust View of Land Degradation

Mention has already been made in Section 1.3 that farmer-perspective, field assessments of land degradation may be criticised by some as being less reliable than standard measurement. The principal ways to overcome any possible lack of precision are a) to take as many individual assessments as possible, and b) to examine the general trends of several different types of measure to see if they are in agreement. This second means is known as **triangulation**, the gaining of a consensus view of overall trends from different types of assessment.

Example of triangulation using nine indicators

Take the example of a degraded catchment that has been largely deforested in order to plant annual crops of maize and beans with no obvious dedicated measures of soil and water conservation. There are some trees and field-plot boundaries. The maize is planted in rows up-and-down the slope. It is now two months since the rains started. A reconnaissance field survey with the farmer has revealed the following, with some preliminary measurements:

- In the furrows between the rows of maize, rainwash has concentrated and formed *rills within the planted beds of maize*. These rills

Figure 6.4: Maize Planted Up and Down Slope

are discontinuous and some contain the remains of organic matter. Closer field inspection shows there is an average length of rill of 4 m; cross-sections average 5 cm wide by 5 cm deep; and the average contributing catchment to each rill is one metre wide (the row width) and 5 metres long. So each rill has a space volume of 0.01 m^3 per 5 m^2 of field. The organic matter seems to come from grasses and small herbs. The farmer observes that these rills occur every year, and he finds them useful as narrow paths to get into his field for weeding, as well as places in which to put the weeds.
- The soil has a significant number of coarse quartz fragments some 2-3 mm across. Between the rows of growing maize, these fragments provide the capping material for *pedestals in-field*. A sample of pedestals gives a mean height of 2.5mm. The farmer confirms he last weeded with a hoe three weeks previously.
- There are several trees within and around the field that have been left for shade after a hot day's weeding and for their wild fruit. *Tree mounds* are apparent, indicating that the surface of the soil in the field has lowered because presumably topsoil has been washed off since the field was opened for cultivation. According to the farmer this was 20 years ago. The mounds average 15 cm in height above the surrounding soil surface, though there is some considerable variation between top (higher – up to 30 cm) and bottom (very little) of field.
- While at the downslope end of the field, our observer notes that there are *boundary accumulations* of soil that average 10 cm

deep against the grass path between this field and the one immediately downslope. Examining the accumulations more closely, a rough calculation indicates an average volume accumulation of 0.01 m^3 per metre length of boundary. Since the field is 10 metres long, the contributing area is 10 m^2, and the sediment therefore amounts to 10 m^3 per hectare. The farmer interjects at this stage that he only subdivided the field the previous year and sold the downslope part to his neighbour, and so the path has only been there for just over a year.

- Walking then to the middle of the field, the observer notes that the farmer has constructed a small drainage ditch across the slope to protect the lower field from runoff during heavy storms. There is *sediment in the within-field drainage ditch*, amounting on average to 0.001 m^3 per metre length of drain. The sediment is mainly medium to coarse sand – the fines have apparently been washed completely out of the field. Since each metre of drain has a contributing area of 5 m^2, this amounts to 2 m^3 of sediment per hectare. The farmer tells our observer that he has to dig this drain out each year as it fills up, and redistribute the sediment across the field, or else the drain will not work.
- While at the top of the field, our observer digs a small hole to examine the soil. *Soil depth* is very shallow, averaging only about 25 cm, with little differentiation in colour (a light yellow-brown) between subsoil and topsoil. The farmer says he is getting worried about this part of the field and has noticed the soil getting lighter and sandier. When he started cultivating there 20 years ago, it was 50 cm deep with 10-cm rich topsoil. At this stage, the farmer gets his hoe out and shows the field assessor how he cultivates: standing facing uphill, the farmer progressively brings soil downslope – this is an immediate explanation for the lack of soil depth here at the top of the field.
- Walking into the maize crop with the farmer, the observer notes that some parts of the field seem to be doing well, while other parts have suffered stunted growth. *Within-field variation of crop growth* is significant, with the upper parts generally poorest. Germination rate as evidenced by plant population density, however, seems to be relatively uniform.
- *Maize nutrient deficiencies* are also evident in the leaves of the growing crop. At the top of the plot, plants are stunted and yellow-looking. Towards the lower and middle parts of the field some of the plants have a purplish colour on new leaves, but those plants growing in the sediment accumulation along the boundary are sturdy, vigorous and deep green in colour.
- Then, finally, our observer walks with the farmer to the lower boundary of the field to see if there is any evidence of land degradation processes outside the immediate field. There, in a hollow is some fine mud and organic material, obviously collected after the last rainstorm from soil that had been completely washed out from the field. Here the *enrichment of sediment in the downstream hollow* can determine the quality of the material that has been entirely lost from the field. The clay and organic matter amount to 100 percent of the sediment in the hollow, whereas in the field clay is less than 20 percent. This indicates an approximate enrichment of the eroded sediment by a factor 5:1

In this example, the nine different types of measure all indicate that processes of land degradation are operating. They all show different parts or different aspects of degradation processes that have been set in train from when the land was originally opened up for cultivation. So there is a general consistency in trends, but the evidence is complex. Our field assessor can certainly conclude that there has been degradation and it is having a significant (and increasing) impact on crop growth in parts of the field. However, the simple calculations of the absolute levels of soil erosion from pedestals, rills, tree mounds, boundary wall accumulations and sediment in ditches do not agree. This is unsurprising because they represent different spatial and temporal scales, as well as different parts of the overall process of land degradation. Some measures give a view of the erosion for the last three weeks (pedestals). One shows what has happened since the field was last ploughed 2 or more months previously (rills); one from the last year (boundary wall accumulation); right up to one which integrates the situation of the field and its land use for the last 20 years (tree mounds). The spatial scales vary from being representative of a single point on the slope (tree mounds) to half the field (sediment in drainage ditch) and the whole field (Boundary accumulations), and even the whole slope (enrichment in downslope hollow). So, it is necessary to examine the different items more closely (Table 6.1) and piece together a comprehensive picture.

Table 6.1: Example – Field of Maize and Nine Indicators

(#Sub-Section) *Indicator*	*Quantitative Assessment*	*Interpretation*
(#4.1) Rills within planted beds of maize (0.01 m^3 per 5 m^2 of field)	Rill erosion of 26 t/ha since the last field cultivation to prepare ground prior to planting 2 months ago	This rill erosion has occurred in the current season: probably most of it in very early season storms before the crop has germinated. Rills act to channel excess water and sediment – so the soil loss represented by the volume of the rill will only be a fraction of total soil loss from the field [this observation is corroborated by the pedestals, suggesting an approximately 4:1 ratio between sheet soil loss and rills – about right for most fields]. Now, with weeds placed in the rills and the better cover from the maize, there will be little more additional rilling – maybe even some sedimentation.
(#4.3) Pedestals in-field. (2.5 mm high)	Sheet erosion of 32.5 t/ha in the last 3 weeks since weeding	This is a significant removal of soil during the middle growth period of the maize, indicating that the crop has given relatively poor cover to the soil. The erosion rate in the 3-4 weeks prior to weeding and after planting must have been just as high, if not higher, because of the poorer vegetation cover then. The observer needs to enquire whether there were large rains then. If there were, then this suggests an annual sheet erosion rate of the order of 70-100 t/ha.
(#4.8) Tree mounds (15 cm high)	Cumulative sheet erosion of 1950 t/ha over the last 20 years	If distributed evenly over the 20 years, there would have been nearly 100 t/ha/yr sheet erosion in this field. Erosion in the early years would likely have been less because the soil would have been in better condition. So this indicates a high long-term rate of erosion of 100 t/ha/yr since deforestation, and a current rate of erosion of possibly 120-150 t/ha/yr. These figures are slightly higher than those calculated from current sheet erosion (pedestal indicator) plus rill erosion – (70-100 + 26). The assumption of lower soil loss in early years may be incorrect – ask the farmer what was grown then and if the land had been kept bare or suffered major rainstorms.
(#4.9) Boundary accumulation (10 m^3 per hectare)	13 t/ha in the last year	This is a new grass path created just over a year ago. The grass has intercepted sediment and water from the field, and the accumulation has built up. But from these figures, it is apparent that about 90% of the sediment has gone through the boundary, probably in the larger storms. Nevertheless, the boundary has succeeded in 'saving' 10% of the loss, including some fine particles. Over time, the interceptive ability of this grassed path should get better, as the field slope reduces by the accumulation and the grass becomes more vigorous. Additionally, the deposited sediment will be fertile and so a better crop should grow - see next indicator
(#4.10) Sediment in within-field drainage ditch (0.001 m^3 per metre length of drain)	2.6 t/ha since preparation of land 2 months ago	These sediments represent only the coarsest fraction of the soil that has moved across the upper part of the field slope. Field observation of its texture (see #5.4) suggests that this fraction is only 10% of the whole soil. Hence, this is evidence that a minimum of 26 t/ha of soil was eroded to produce this material. It is a minimum because some of this same sand fraction may have remained in the field (and not caught in the drain), and some may have been washed out of the drain in very large storms. Because erosion selectively removes the fine particles, the actual amount of soil eroded in the 2 months must have been much larger than the 26 t/ha calculation, which is not inconsistent with the 70-100 t/ha from pedestals indicator.
(#4.13) Soil depth (25 cm deep at top of field; 50+ cm at bottom)	Sheet erosion loss of 25 cm in 20 years; or about 160 t/ha/yr	This reduction in soil depth, based upon farmer estimates as to original soil depth (but capable of corroboration by the field assessor on an adjacent site at same position on slope), occurred at the top of the field where maximum erosion has happened. However, some of this loss is 'cultivation erosion': i.e. the farmer has dug soil downslope. The field assessor needs to determine to what extent this direct intervention in land degradation by the farmer should be included. As there has been deposition at the base of the field (hence erosion is zero there), 160 t/ha/yr would give an average sheet erosion over the field of 80 t/ha/yr since the field was opened up.
(#5.1 & #5.2) Within-field variation of crop growth.	No quantitative assessment possible	Observations are consistent with soil having moved from the top part of the field to the bottom. This indicator is a measure of impact of land degradation, showing that crop growth on the 'eroded' soil at the top is significantly poorer than lower down the field where soil removal has been less, and very much poorer than on the lower boundary where there has been some deposition
(#5.3) Maize nutrient deficiencies	No quantitative assessment possible	The stunted, yellow plants at the top of the field are clear evidence of both poor growth because of lack of soil rooting volume and lack of sufficient nutrients and water. In that germination (as evidenced by plant density) was relatively uniform, the restricted growth only became evident once the plant had higher demands for nutrients and water. The purplish colours of the leaves in mid-slope is evidence of phosphorus deficiency. Phosphates are easily washed downslope by erosion; some may have accumulated in the deposited sediment (hence the good growth there) but most have been taken off in solution. The deep green of the plants at the lower end of the field indicates good water and nitrogen supply – much of this is accumulated from the higher parts of the field.
(#4.11 & #5.4) Enrichment of sediment in a downstream hollow. (5:1)	Five times as much clay in the hollow than in the soil from which it came.	The hollow will have trapped a representative sample of water and sediment exiting from the whole field. As the puddle in the hollow dried out, the clays and other fine material (e.g. humus) settles out. The 5:1 enrichment indicates that the impact of land degradation processes is a very significant influence on the fertility of the field. Most of the sands are redistributed in the field, but the main fertile fractions are almost (except for a small amount trapped behind the grass path boundary) completely removed from the field. Future production will be affected far more than in proportion to total amounts of soil lost – the factor 5 suggests a crash in yields after only a few more years unless remedial measures are taken.

The comprehensive picture

In the above example, triangulation has provided the field assessor with powerful conclusions that land degradation is currently active. Also, there is a substantial current effect on production and the loss of fine material is potentially serious to future yields. Previous land use probably also saw degradation but at a lower rate.

The evidence all indicates that the major influence on land degradation has been the opening up of this piece of land to annual arable crops without any form of protection or conservation, other than the field drainage ditch and the new grassed path acting as a lower field boundary. Overall current sheet erosion rates are at least 100 t/ha/yr, with possibly another 25% addition to account for rilling. Only a small percentage (c. 20%) of this sediment is caught in-field – 10% of coarse sands in the drainage ditch and 10% of more representative fractions of the whole soil against the field boundary. Erosion-induced loss in productivity is also serious, through a large reduction (50%) in plant-rooting volume at the top of the slope, which affects nutrient and water supply to growing plants. The erosion-induced limitation in mid-field is a reduction below critical threshold of available (soluble) phosphorus. At least two-thirds of the field is affected by serious land degradation, while the lower third has gained somewhat. However, still a very large percentage of fine particles and organic matter has been lost entirely from the field.

6.5 Guidelines for Combining Indicators

Finally, in this chapter, some guidance is given as to how to approach the challenge of combining indicators. It is a challenge because studies in land degradation have been bedevilled by reductionism. Approaches to measurement have usually been satisfied with single sets of observations rather than the approach advocated here. Yet, the example above demonstrates that a comprehensive view of the effect of the history of land use can be gained if the pieces of information are set side-by-side. The field assessor must, above all, have an open mind, observant eyes, and the qualities of a detective.

It is difficult to provide specific guidance for all situations – there are many permutations of possible land degradation and land use conditions, and hence many possible interpretations. Therefore, in the following two sub-sections, suggestions are made for a) the approach to adopt in the field, and b) how to put the indicators together in a semi-quantitative form for initial inspection.

A checklist for the field

It is important to make a careful reconnaissance of the field site to note all the pieces of evidence of both land degradation processes and their impact. The following checklist is for general guidance only. Like any good detective, the field assessor must follow-up any interesting leads, especially those initiated by comments from the farmer.

1. Map out the field slope as a sketch, noting the position of any obvious features such as gullies, rills, tree mounds, boundary walls.
2. Obtain the history of land use: when the plot of land started to be used, crops grown, any change in land use, subdivisions of the land, and similar important events that could have a bearing on land degradation. (These events should later be set alongside the field measurements to ascertain whether they correspond with observations.)
3. Determine any significant events: landslides, exceptionally heavy storms and soil wash, dates when trees were cut down.
4. Note any particular farming techniques that may have implications for land degradation (e.g. ridging practices across/down the slope; hand cultivation downslope)
5. Then, with the map in 1. Above, and preferably accompanied by the farmer, go through the indicators of the processes of land degradation:
   - soil losses from single places (e.g. tree mounds; pedestals; soil depth)

- soil losses from small parts of the field (e.g. rills, armour layer)
- soil losses from large parts or the whole of the field (e.g. gullies; differences in soil depth between degraded field and non-degraded; or averages over the field of previous items such as tree mounds)
- sediment accumulations and their enrichment/texture within the field (e.g. drainage ditches; against an in-field tree)
- sediment accumulations and their enrichment/texture at the base of the field (e.g. boundary accumulations)
- sediment accumulations and their enrichment/texture outside the field (e.g. clay enrichment in hollows)

6. Then, with the farmer (most important this time), determine the indicators of the impact of land degradation:
   - observation of current plant growth (e.g. within-field differences)
   - actual measurements of different sizes of plants
   - list known nutrient deficiencies observed
   - estimate, with farmer, likely yields from different parts of the field
   - obtain historical yields, and observations on how plant growth has changed.
7. Compile a comprehensive table of indicators and results, looking for trends, consistency and areas where there is broad agreement in the scale of degradation.
8. Return to the farmer with your account of the comprehensive picture, and get his/her evaluation of your diagnosis.

A semi-quantitative assessment

Assessment so far by combining indicators has attempted to use absolute (scale) levels of land degradation, such as tonnes soil per hectare. With the approximate nature of the techniques of assessment, this can be misleading unless careful precautions ('health warnings') are taken. To say that exactly 126 t/ha/yr of soil loss has occurred is folly, implying that it was more than 125 and less than 127. This degree of exactitude is unjustified. If it is suspected that someone may take these absolute figures (as has often happened) to use them as precise evidence of the level of degradation, then it may well be better not to give the figures in the first place. The alternative is a semi-quantitative assessment.

'Erosion Hazard Ratings - EHRs' (see Bibliography) are one example. The factors of erosion – slope, soil type, vegetation cover, and rainfall – are rated on a numeric scale, usually one to five in severity of likelihood to cause erosion. Then these individual factor ratings are combined, either through a scoring system or through a simple model, to give an overall hazard rating. This is not an actual measure of land degradation, but a prediction of potential land degradation according to the environmental factors that encourage it. Such assessments have been widely used for broad-scale planning purposes. They are simple to develop and easy to visualise since the results are usually presented in the form of a map. EHRs are not, however, particularly useful at the detailed field level, or for developing a farmer-perspective approach.

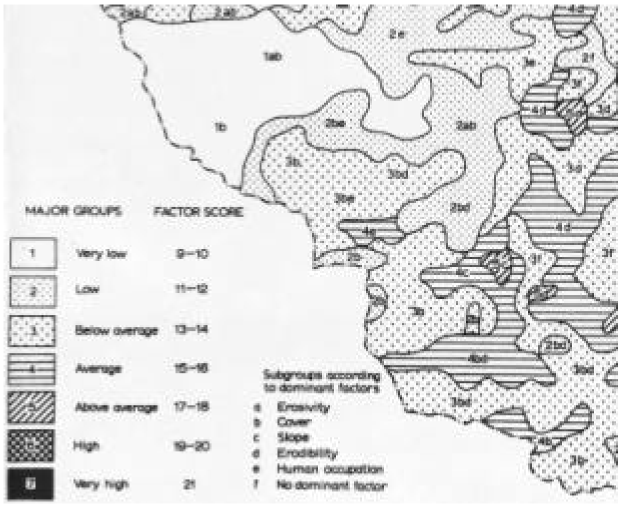


Figure 6.5: Extract from Erosion Hazard Assessment for Zimbabwe

Instead, Malcolm Douglas in his *Guidelines for the Monitoring and Evaluation of Better Land Husbandry* (see Bibliography) has suggested simple scoring techniques for seriousness of simple indicators of land degradation (and conservation effectiveness). The reader is referred to this 27-page publication for more details. However, it is perfectly appropriate to

Table 6.2: Sheet Erosion

Ranking	*Degree*	*Description*
X	Not apparent	No obvious signs of sheet erosion, but evidence of minor sheet erosion may have been masked, for instance by tillage.
0	No sheet erosion	No visual indicators of sheet erosion.
1	Slight	Some visual evidence of the movement of topsoil particles downslope through surface wash; no evidence of pedestal development' only a few superficial roots exposed.
2	Moderate	Clear signs of transportation and deposition of topsoil particles downslope through surface wash; some pedestalling but individual pedestals no more than 5cm high; some tree and crop roots exposed within the topsoil; evidence of topsoil removal but no subsoil horizons exposed.
3	Severe	Clear evidence of the wholesale transportation and deposition of topsoil particles downslope through surface wash; individual pedestals over 5cms high; extensive exposure of tree and crop roots; subsoil horizons exposed at or close to the soil surface.

Table 6.3: Rill Erosion

Ranking	*Degree*	*Description*
0	No rill erosion	No rills present within the field.
1	Slight	A few shallow (< 100mm depth) rills affecting no more than 5% of the surface area.
2	Moderate	Presence of shallow to moderately deep rills (< 200mm depth) and/or rills affecting up to 25% of the surface area.
3	Severe	Presence of deep rills (up to 300mm depth) and/or rills affecting more than 25% of the surface area.

develop one's own scoring system. Provided that it is consistently used, it can be a good way of combining indicators to get a more comprehensive view of land degradation.

The tables above give two of the more commonly used examples that combine observations of a number of separate indicators.

Douglas also suggests a three-point scale for the effectiveness of conservation for a) crop management, and b) soil management. The 'effectiveness of conservation' is essentially a composite view of both direct and indirect field interventions by the land user. They include how effectively crops protect the soil as well as the use of fertilizer and specific 'land husbandry' practices. Douglas' tables (adapted below for these *Guidelines*) give a very useful checklist of land user practices, as well as bringing together a diverse number of farmer-activities into a comprehensive picture of the land degradation potential.

Table 6.4: Crop Management Considerations

Crop management indicators	*Conservation effective Score 1*	*Conservation neutral Score 2*	*Conservation negative Score 3*
Change in percentage ground cover by the growing crop	At least 40% cover of soil achieved by crop within 30 days of the start of the rainy season	Little increase in ground cover provided by crop between fallow and growing crop	Decrease in ground cover – remains below 40% for most of the growing season
Intercropping/relay cropping	Cropping practices lead to improved ground cover and/or increase in the ratio of legumes (N-fixing) to non-legumes	No change in intercropping or relay cropping practices	Cropping practices lead to reduction in ground cover and/or decrease in the ratio of legumes (N-fixing) to non-legumes
Spacing/planting density	Ground cover improved through closer crop spacing and/or increased plant density	No change in plant spacing and density	Ground cover reduced through wider crop spacing and/or decreased plant density
Improved seed/planting material	Adoption of improved seed/planting material results in improved biomass production and better ground cover	No change in crop biomass and ground cover	Adoption of improved seed/planting material results in decreased biomass production and inferior ground cover
Fertilizer and/or organic manures	Increase in fertilizer and/or organic manures result in more biomass production and better ground cover	No change in quantity of fertilizer and/or organic manures used for crop production	Decrease in fertilizer and/or organic manures result in less biomass production and poorer ground cover
Crop residues	Crop residues incorporated into the soil or retained on surface as protective mulch	Not applicable	Crop residues burnt or fed to livestock

To gain a composite view of the influence of crop management on land degradation, the six crop management indicators are scored 1 to 3. The minimum score is 6, indicating almost no contribution of crop management to land degradation; the maximum is 18, indicating extreme danger of rapid degradation. To bring the composite view back to a 1-3 scoring scale, divide the sum of the scores by the number of indicators – in this case divide by 6. The 'conservation effectiveness' can then be interpreted comparing different crop management regimes in their likelihood to contribute to land degradation. So, a total score of 8 that gives an average score of 1.3 would be interpreted as "crop management practices are largely effective in limiting the danger of land degradation and could help to rehabilitate existing degraded land if implemented." Locally appropriate descriptions should be developed for ranges of scores, e.g.

1.00 – 1.49	No land degradation danger; good rehabilitation potential
1.50 – 1.99	Land degradation slight; good possibility of rehabilitation
2.00 – 2.49	Moderate danger of land degradation – particular practices have specific problems
2.50 – 3.00	Land degradation hazard high to very high – all practices contribute to danger

Table 6.5: Soil Management Considerations

Crop management indicators	*Conservation effective Score 1*	*Conservation neutral Score 2*	*Conservation negative Score 3*
Soil organic matter	Interventions enhance soil organic matter through, for example: a) Incorporation of crop residues; b) application of at least 3 t/ha/yr compost and/or animal manure c) application of at least 5 t/ha/yr of fresh green manure (e.g. *Leucaena*)	Interventions only maintain soil organic matter levels by: a) grazing livestock on crop residues *in situ*; b) application of compost and/or animal manure at rate below 3 t/ha/yr; c) application of fresh green manure at rate below 5 t/ha/yr	Interventions fail to maintain soil organic matter levels: a) removal or burning of all crop residues b) no application of compost and/or animal manures; c) no application of green manure – all biomass removed as fuel or fodder
Soil chemical properties	Interventions replace lost soil nutrients through: a) application of compost and/or animal manure b) use of N-fixing species in crop rotations and intercropping, or in N-rich green manures and hedgerows c) enriched fallows d) chemical fertilizer (as a supplement, not a substitute for organic manures)	Traditional low input fertility management practices capable of achieving low levels of nutrient replenishment, through: a) short bush fallow b) tethered grazing of livestock within farm plots on crop residues and weeds c) retention of a few scattered trees on the croplands	Poor practices that continue the depletion of soil nutrients through: a) continuous cultivation of cereal and root crops b) burning of crop residues c) little, if any, use of compost, organic manures or chemical fertilizer
Soil physical properties	Interventions maintain and enhance topsoil structure through: a) minimum tillage b) planted pasture and enriched fallows c) incorporation of crop residues, compost, animal manure, green manures and tree litter	Traditional low input practices neither combat nor promote physical degradation of the soil, through: a) partial tillage b) short bush fallow c) retention of a few scattered trees on the croplands	Poor practices continue physical degradation of the soil, through: a) excessive tillage b) continuous cultivation c) no incorporation of organic matter d) trampling by people and livestock

For soil management considerations in the above table, a minimum score of 3 and a maximum of 9 is possible against the three indicator variables. The same procedures apply to interpret these scores in terms of overall contribution to land degradation status.

Such tables should be adapted for the specific circumstances of each field and the different types of land use. Once developed for a local area, they can provide excellent ratings to determine the specific danger of different types of land use. Furthermore, they can be used to assess proposed interventions alongside existing practices to see if land degradation status will be unduly changed. Such semi-quantitative techniques, therefore, provide both a current view and a predictive means to monitor land degradation status.

6.6 Combining Indicators in the SRL Approach

Finally, in this chapter it is important to bring all the information together in a common framework that puts the farmer-perspective to the forefront. Chapter 3 and Table 3.1 gave a model for field assessment in terms of the 'capital assets' of land users. These assets, divided into natural, physical, human, social and financial capital, provide a useful means of assembling all relevant items of information that have been identified. An abbreviated example based on a field of maize (Table 6.1) and a farmer (Fig 6.4) is provided in Table 6.6

Table 6.6 Combining Indicators in the SRL Framework for a Field of Maize – How Land Degradation is Affected

(See Sustainable Rural Livelihood Model in Table 3.1 and field data example in Table 6.1 with added information from farmer interviews.)

Capital Asset	*Positive Effects of Change in Capital*	*Negative Effects of Change in Capital*
Natural	Farmers have planted field boundaries, against which some soil accumulates (13 t/ha in the last year). As these boundaries are enriched by planting of fruit trees and other economic species, their effectiveness in accumulating natural capital will increase	Deforestation has led to a substantial loss of natural capital. The soil is now eroded; its water-retaining properties are deficient; and the overall stocks of biomass and plant diversity are much reduced. Biophysical indicators (Table 6.1) summarise the effects
Physical	The farmer (Fig 6.4) has only a hoe for cultivation. This means he cannot extend his cultivation to larger areas. Instead, then, he has to intensify land use on small plots and use the benefits of multiple cropping to limit the need for more tools and equipment. This is good for conservation, but hard for the farmer.	Poverty means little opportunity to accumulate further means to manage the land resources. In effect the farmer is confined to cultivating simply with no means of physical conservation. In addition, distance from markets and physical infrastructure gives little opportunity to grow high-value crops for sale.
Human	The farmer has a wealth of indigenous knowledge, handed down from his father. This includes the small drainage ditch across the field to protect from runoff. He tells us about techniques he knows of composting and of building small terraces. These would be excellent to control land degradation. But in the pressure to grow the maximum amount of maize for home consumption, much of this knowledge is not applied	Old age and ill-health in the family (his wife is very sick) means that farming practices must be minimised if enough land is to be cultivated for sufficient food to be grown. Human capital limitations determine that the farmer's time-horizon is short, and that there can be little investment in the future – except those activities which demand least labour (planting field boundary) and those that are essential for survival (cultivating maize).
Social	Family and clan ties have enabled the farmer to call on relatives and clansmen to get the field ploughed early in the rainy season. This has enabled timely planting and minimising the risk of erosion because of poor vegetation cover. The maize crop is looking good (Fig 6.4) mainly because of this communal effort in planting the seed on time.	Family and clan ties also mean that part of the crop has to be given over to other members of the social network. To do this, the farmer has to take off-farm employment to supplement income. He cannot then devote time to carrying out protective measures such as managing the runoff safely, and to dealing with the maize nutrient deficiencies which manifest themselves in late season.
Financial	A rich uncle in the capital city remits enough money for the farmer to buy an ox-drawn ridger. Next year he can plough across the slope, with planting undertaken on conservation ridges that prevent further land degradation…… but……. ➔	No bullocks to pull the ridger. After negotiating with a neighbour, he gets enough cash to hire the animals for ploughing next season. However, it is now late in the new season because the neighbour wanted understandably to plough first. The animals are exhausted, and the crop planting is a failure. More land degradation.

Using the SRL framework in this way thus enables a balanced view of the complexities of real farming. Nothing is simple. Apparently simple solutions such as added financial capital assets from the rich uncle may mean ambivalent outcomes – a ridger good for preventing land degradation, but further demands in needing oxen in a timely fashion. These demands potentially exacerbate land degradation when they cannot be met – in this case by convincing the neighbour to let him have ploughing done first. It is important that this sort of 'balance sheet' of how the farming situation changes the assets of a farmer to gain a livelihood is built in a systematic way. Later in Chapter 8, a quantitative way (investment appraisal) will be used to bring this framework into an economic analysis. But for the moment, semi-quantitative and non-quantitative use of indicators provide a useful means of gaining a full impression of the land degradation situation.