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Land husbandry: an agro-ecological approach to land use and management Part 1: Considerations of landscape conditions

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Abstract

In this, the first of two papers, the roles of key features of any landscape in determining potentials for erosional losses of soil and water are considered from an agro-ecological viewpoint. In this light, the effectiveness of past commonly-accepted approaches to soil and water conservation are often found to have been inadequate. In many cases they have tackled symptoms of land degradation without appreciating fully the background causes, which often relate to inadequate matching of land-use/land-management with features of the landscape. A number of reasons for this mismatch are suggested. Understanding the ecological background to land husbandry (as defined below) will improve the effectiveness of attempts to tackle land degradation. In particular, an ecologically based approach to better land husbandry helps to foresee potential problems in some detail, so that appropriate forward planning can be undertaken to avoid them. This paper describes some practical ways of undertaking an appropriate survey of significant landscape features, enabling the definition and mapping of discrete areas of different land-use incapability classes. This is accompanied by an example of how the outcome was interpreted and used to guide the selection of appropriate areas which were apparently suitable for growing flue-cured tobacco within an area of ca. 140 km^2 in Malawi. This process relied on knowledge and experience in various disciplines (interpretation of air-photos, topographic survey, soil survey, vegetation analysis, hydrology, soil & water conservation, geology, agronomy) so as to ensure that the mapping process was based on the principles of better land husbandry.

Key Words: Agro-ecology, Soil & water conservation, Land-use incapability, Foresight

1 Introduction

The productive capacity of many areas of land now in use has already been compromised by damage to soils, following inappropriate matching of preferred systems of land use, and of their management, with the characteristics of the land on to which they have been imposed.

Is the present paradigm of "soil and water conservation" (SWC) still adequate to address the rising concerns about non-sustainability? Have we achieved all that we had expected or hoped? Are the positive results sustainable under the rising pressures being now being put onto land? (Shaxson, 1993, 2006). The answer is: it seems not. Mortimore (2013) notes that "*because development puts additional pressure on ecosystems, and rich populations continue to multiply destructive resource exploitation, the agenda for the planet is shifting from food supply constraints to sustainability themes*". This emerging realization implies that field-engineering approaches – on their own – to controlling soil erosion and strengthening sustainability of production systems are inadequate. An agro-ecological approach to land use and management which is effective in achieving conservation, as set out in this two-part paper, offers better opportunities for addressing both aspects simultaneously.

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1.1 *Land husbandry*

"*Good land husbandry is the active process of implementing and managing preferred systems of land use and production in such ways that there will be increase – or at worst, no loss – of productivity, of stability or of usefulness for the chosen purpose; also, in particular situations: existing uses or management may need to be changed so as to halt rapid degradation and to return the land to a condition where good husbandry can have fullest effect".* (Shaxson, Douglas and Downes, 2005) [after Downes (1982, 1971)]. This approach is described in two linked papers. The first (this paper) suggests that topographic catchments should be considered as key physical features onto which land uses are imposed. The second paper suggests that any land-management activities be based on considering soil as a living matrix from which yields of plants and water are derived.

2 A starting-point: the former paradigm

The sense of soil degradation as a problem of land use has long been acknowledged. It came to wide prominence with the wind- and water-erosion in the Mid-West of the USA in the 1930s, characterized in Bennett (1939). This perceptive and significant book set out many of the factors contributing to – and militating against – soil erosion. Many of these remain valid today. However, much subsequent anti-erosion action has commonly taken a mechanical – or "earthworks" – approach to reducing soil erosion, but this fails to ensure that soils remain sustainably productive. The long-held assumptions that mechanical land treatment methods would be automatically effective in halting erosion and maintaining productivity have proved illusory, and land damage continues, particularly where rising population-pressure on land results in the opening and tillage of land whose characteristics indicate it is at greater risk of suffering rapid loss of productivity.

2.1 *Processes*

In the past, levels of human populations and their constituent communities on the land tended to stay in relatively-stable equilibrium within the particular ecozones to which their inhabitants had adapted (e.g. Trapnell,1943; Makings 1966). Traditional local observations, experiences, knowledge and actions were able to maintain agro-ecosystems which were appropriate to, and sufficient for, their needs (e.g. Tenywa et al., 2013). However, these systems in turn imposed limits on increases of output over time when rates of soil degradation became faster than those (if any) of soil restoration. Ensuing decline in land-based ecosystem functions (notably those of sustained production of vegetation and water) resulted in net losses of plant-nutrients, soil particles, soil organic matter and soil moisture. With the ongoing increases in human populations and their rising density on potentially-productive land, expansion of "traditional" knowledge alone now often proves to be insufficient to confront, avoid or ameliorate problems of increasing degradation of their lands' productive capacities. Old "bush-fallow" systems for cropping-agriculture, and/or transhumance/grazing-rotation systems for "rangeland" management, are increasingly ineffective in countering the pressures imposed by rising populations and degrading land resources. Governments and aid-agencies' scientific knowledge has then been added into the mix, but the combined effects of "conventional" soil and water conservation measures − with or without local knowledge − have seldom proved sufficiently-effective always to halt and reverse the declining trends.

2.2 *Symptoms of land degradation*

There have been many past studies of soil erosion, but recent reports on fieldwork in western Kenya characterize some of the common processes and consequences of land degradation in small catchments after undisturbed forest has been cleared. On small farms under traditional tillage in the past - for up to 100 years - rapid initial rates of decline in soil organic carbon, soil nitrogen and crop-yields have been recorded. Over 35% of the declines during the first 50 years had evidently occurred within the first five years after clearing (see Solomon et al., 2007; Marenya and Barrett, 2007, 2009; Moebius-Clune et al., 2011).

As part of the cluster of inter-related studies in W. Kenya, on kaolinitic acrisols Recha et al. (2012) studied the effects of these declines in soil quality on stream discharge from four small catchments which were – at least in terms of changes in soil organic carbon and soil physical properties –*"broadly representative of the studied region and corroborate more rigorously replicated plot studies"* (item 4.1, p.10). Within an area of 6 km^2, they studied four plots: one had been maintained in original forest, and three more had formerly been forested but subsequently maintained under smallholder maize cultivation for 5, 10 and 50 years. These different lengths of cultivation provided a useful proxy for a time sequence of the changes that had occurred. They reported that, in considering the difference between the forested plot and the plot in cultivation for 50 years:

- soil bulk density in the 0 – 0.1 m surface-soil layer increased by 46%;
- soil organic carbon and total porosity decreased by 75% and 20% respectively;
- the annual catchment discharge expressed as a percentage of rainfall increased with increasing duration of cultivation, as did the average runoff due to stormflow;
- about half the total observed increase in runoff after conversion occurred in the first five years.

2.3 *Additional problems*

The search for effective solutions to ongoing land degradation problems is hindered by a variety of factors. These include: preconceptions, assumptions, inappropriate interpretation of evidence, misguided policies − but almost all pay insufficient attention to the agro-ecological basis on which the stability, productivity, and lasting usefulness of land depends. Approaches to land management based solely on "conventional" soil and water conservation − as has often been commonly accepted by many − have not automatically, or always, sufficiently addressed wider resource conservation issues such as:

- soil & water losses as consequences of other problems;
- loss of carbon from, and gain to, the agro-ecosystem;
- catching and retaining the curiosity and interest of land-users for adopting sustainable land-use practices;
- understanding the implications of anomalous field observations and/or research results;
- analyzing in detail the reasons for loss of productive capacity;
- the need to focus on sustainability of outcomes, so as to avoid repeats of past problems.

An improved approach to the husbandry of land, that seeks to address these broader issues, cannot be the same as "soil and water conservation" in any narrow sense. A land husbandry approach must also ensure an ongoing commitment and effectiveness into the next generation and beyond. Land husbandry is also broader than "land management", *"…which may be exploitative for short-term ends and profit only, without care to ensure continuity of productivity and sustained usefulness*" (Shaxson, 2005).

3 An improved paradigm

A more-effective paradigm – a formal "land husbandry" approach – should help us foresee the possible outcomes of different approaches, and facilitate rational planning and implementation of land management measures by adopting conservation-effective approaches when (a) opening new land, (b) restoring the productive capacities of already-damaged land, and (c) developing sustainable land-use systems that are simultaneously, and lastingly, productive of both plants and water and at the same time being protective of the land.

Adopting such a paradigm would also integrate crop husbandry, animal husbandry and land husbandry in several linked ways. It would begin by understanding the characteristics, potentials and limitations of different types of plants, animals and land. This would enable it to predict the likely positive or negative effects on their productivity from a given change in management, or severe but rare events such as disease or severe rainfall. As a result, it would be possible to work out how each might best be strengthened to resist the negative effects of such events and, simultaneously, to adopt systems of management of the underlying biological and physical systems in ways that maintained their productivity and usefulness. The net result would sustain lasting improvement in productivity of crop, animal and land, in terms of quality and quantity of output in a given time. Finally, it would emphasise the active and central role of the farmer as steward of the land (Shaxson et al., 1989).

3.1 *Five characteristics of land*

To begin, a land husbandry approach would identify the five key attributes of the landscape in question:

1. its spatial distribution/shape (x, y, z axes), which may be subjected to erosion or deposition of materials;
2. its physical characteristics, such as soil porosity, which is liable to suffer deformation or obliteration;
3. its hydrological characteristics, possibly diminished by damage such as loss of water-storage capacity;
4. its chemical characteristics, especially in terms of plant nutrients and pH, potentially damaged by deficit or excess;
5. its biological characteristics, both above and below the soil surface, subject to adverse changes in

quantity, species-composition, and/or activity.

These interact with each other under the influences of solar energy, gravity, climate and biological life, giving rise to different landforms and soil conditions. Across the globe, geological substrates have been widely etched by water over time (Hamblin, 1989), which, in most landscapes, has produced three-dimensional patterns of interlocking catchments and watersheds, colonized by plants and other organisms. Over time, the shapes of landscapes change: tectonic forces may raise the land surface while the effects of gravity (landslides, erosion), of climate (temperatures, rainwater, runoff, wind) and of life-forms (e.g. physical effects of roots, and chemical effects of solvents such as organic acids) tend towards flattening their land surfaces.

As for land's hydrological aspect, the nature and porosity of the geologic materials from which overlying soils have been derived affects the rate of downward movement of infiltrating water to aquifers from which streams derive, (e.g. Boorman et al., 1995). Conversely it can also affect the rate at which surface runoff may be generated from rainstorms, and hence – with slope – the rates of any erosion of the covering surface soil.

3.2 *Planning for the conservation-effective use of the land*

It is sometimes assumed by a would-be land-user that an unseen site – that is believed/assumed to have potential for production of crops, trees and/or or pastures – will be only gently-sloping, green and fertile; but this is often not the case. Planning for sustainable use of land means considering the risks – inherent in using the area – that need to be foreseen and either minimized or avoided by careful examination of the causes. The same *caveat* holds true – and even more strongly – for land that has already been damaged by misuse or neglect.

At any location, land's climatic and inherent characteristics may make it difficult to identify and maintain land uses which could be both lastingly productive and conservation-effective. These hazards may include:

Hazards of local climate such as:

- Rainfall: high intensities; drought; excess rainfall volumes;
- Temperature: maximum, minimum, fluctuations;
- Wind: velocity.

Hazards of landscape:

- Slope, as affecting velocity of any runoff;
- Past erosion effects as affecting quality of remaining topsoil;
- Inherent wetness, as limiting aeration in root-zone;
- Parent material(s)of soils: chemical limitations.

Limitations posed by "endemic" soil conditions:

- Effective rooting-depth;
- Surface hindrances – rocks, etc.;
- Topsoil texture (sand through to clay);
- Upper subsoil texture (sand through to clay);
- Subsoil permeability (excessively-free through to restricted);
- Material (if any) limiting rooting-depth: chemical, hydrologic or physical restrictions.

(See Tables 1 and 2 – below)

Land degradation may result from decline in biological, chemical, physical and/or hydrological attributes of the soil, such as in organic-matter content and/or organisms' activity, or acidification, loss of porosity, and/or the loss of soil particles, nutrients and water in runoff and erosion. Conversely, improvements to any, some, or all of these features will contribute to greater stability, conservation and sustainability of the affected land/soil system.

4 Harmonising land uses with land characteristics

"*It is a particularly serious handicap that the main practical requirement and opportunity for a concentrated point of synthesis of knowledge about the environment happens to coincide, in terms of organized studies, with a no-man's land between ecology, geography and landscape.*" (Nicholson, 1971).

As Nicholson pointed out over forty years ago, the search for a new paradigm for maintaining the environment is hampered by the lack of synthesis and interlinking between disciplines. However, there are other issues that will also need to be addressed for a land husbandry approach to be effectively adopted:

1. There are opposing views about how to select and appraise land for use. The work of resource-or soil-survey organizations in Governments are often dictated by urgent demands from politicians, planners, and

others to appraise land for development according to one of two main requirements:

- *"A specific area of land has been chosen for development – identify suitable and sustainable uses for it";*

  or

- *"A specific type of land use has been chosen for emphasis – identify the most suitable areas for this purpose and how they should be arranged and managed to assure sustainability of the proposed use".*

2. The need for speed. The instructions set out above on how to select land for appraisal are usually qualified by the following conditions, even though available resources are often insufficient for the task:

- *"The survey must be completed and results presented with great urgency",* and
- *"Every part of the survey area must be subjected to the same intensity of scrutiny".*

3. Two-dimensional maps and photographs are representations of only a limited proportion of the information needed to make a full evaluation of the different characteristics of any area of land. Plans are often envisaged in only two dimensions and drawn on flat paper: the locations of different types of land use – e.g. blocks for rotational cropping, forestry, pastures, other uses, buildings, access routes, etc. – may be decided only on the basis of a predetermined layout, or on the apparent characteristics of the different soil types across the area, differentiated by depth, surface hindrances (e.g. stoniness), texture of topsoil and subsoil, and other factors deemed significant by the farmer. Such maps provide pictures of proposed or actual land use across the farmland, but only in two dimensions. However, using only two-dimensional maps without including appropriate topographic information can lead to a significant mismatch between proposed uses and the likelihood of their stability over time in the face of potentially-damaging forces of rain, wind, farm equipment, or poor management. Two-dimensional maps do not produce a sufficiently-accurate assessment of what proportion of the land is suitable for – and capable of – supporting the proposed uses.

Time (often a limiting factor) is needed to study the characteristics of the area *in situ* so as to judge what proportion of it fits these criteria. The longer the time available, the greater the range and depth of detail that can be investigated. With limited time available, the pressure is then to produce the most-accurate assessment of the whole bounded area of the farm. It is more appropriate to identify and map the extent of the most-obvious limiting factors first and then – as time permits – add in less obvious (though perhaps equally-significant) factors in sequence. The next sections outline how this can be done.

4.1 *The advantage of using stereoscopic pairs of overhead air-photos*

The central role of the catchment as a reference unit in conservation-effective rural development has been emphasized by de Freitas (2000). But using only two-dimensional maps without including appropriate topographic information can lead to significant mismatch between land characteristics and proposed uses and their stability over time in the face of potentially-damaging forces of rain, wind and/or poor management.

For land-use planning purposes, accurate delineation of catchments requires analyzing the area in three spatial dimensions. This is best done by first using stereoscopic pairs of vertical overhead air-photos (Spurr, undated) at a convenient scale – often 1:20,000 to 1:30,000 – in conjunction with any satellite-imagery available. Stereoscopy enables visualization of the three-dimensional shapes of the landscape and its constituent catchments and sub-catchments, (through the identification and marking of streamlines and topographic divides/watersheds). When time permits, additional features visible in this imagery can be identified or confirmed with fieldwork. Airphotos also indicate areas of what may appear to be uniform surface characteristics, or "homogeneous areas" equivalent to Downes' *land husbandry units* (Downes, 1949, 1959), which will merit further investigation and characterization on the ground.

Practical techniques of using stereo-pairs of air photos, plus in-field checking of features for land-resource appraisal and planning for forestry and agricultural purposes, have been detailed in Shaxson et al. (1977). These were based on, and where appropriate, adapted from, earlier training courses run by the Dept. of Conservation & Extension (CONEX) in N. and S. Rhodesia (now Zambia and Zimbabwe) which were later described and illustrated separately in Carver (1981).

The most-recent stereoscopic photo-sets are of particular value in providing 3-D overhead views not only of topographic features (catchments), but also of land cover (vegetation types and their spatial distribution), as well as artifacts (roads, buildings, and other man-made structures). They help in design of on-the-ground surveys which can then verify and provide more detail of relevant features, which can be fed into any subsequent process of land-use planning.

4.2 *Determining erosion hazard and Land-Use Incapability*

A Land-Use Incapability Survey (Shaxson, 1981) provides a rapid means of assessing environmental risks to soils according to the severity of erosion hazard and other risks of degradation, as a means for foreseeing likely future problems to be minimized or avoided.

Land features are ranked in order of significance and each is assessed in the degree of detail possible within the time-frame for the whole area to be covered, and with the resources of staff, transport etc. available. At the outset, land quality is assumed to be optimum across the area for the proposed uses, and at each site is then, if necessary, downgraded, stepwise in sequence, according to the nature and severity of each limiting factor recorded. Evenness of coverage across the whole area in the time available is achieved by adjusting: (a) the number of observation-points per unit area, and (b) the amount of data collected at each point, according to a ranked hierarchy of features. Within this hierarchy, slope is probably the most significant because of the effect on runoff velocity and its potential for rilling/gullying and transporting eroded materials.

Land and soil features considered to be significant in determining land use incapability are ranked and grouped in order of the speed with which they can be appraised, both from readily-available maps and airphotos, and from ground surveys; as in Table 1:

Table 1 Ranking of land characteristics affecting soil erosion

Activity	Group	Item	Characteristics recorded
Interpret maps / air photos (very rapid overall view)	A	1	Slopes, catchments, patterns of vegetation, location of artifacts
		2	Apparent severity of past erosion
		3	Apparent surface wetness
In field: walk, stop, examine, record	B	4	Verify slope, erosion, wetness. Add surface hindrances
		5	Unfavourable surface conditions
		6	Texture of topsoil
Walk, auger/pit, examine, record	C	7	Effective depth to root-limiting layer
		8	Texture of subsoil
		9	Permeability of profile
		10	Other subsurface, e.g. nature and permeability of parent material

Preliminary (stereoscopic) air photo interpretation of the nature of the terrain and vegetation/soil patterns (which may indicate internally-homogeneous "land husbandry units") can guide the planning of least-frequency and optimum directions of traverses, as well as the number and placing of sampling points along them which will be sufficient to give a reasonably valid representation of the area. Survey design within the constraints of time, manpower and resources available then becomes a matter primarily of deciding how much data to record at each sample point: (in Table 1 above) Group A alone; Groups A + B; or Groups A +B + C. The greater the amount of relevant information that is recorded, the more it is possible accurately to delineate the boundaries of individual land husbandry units.

Features in Group A (= Items 1 – 3), if not already identified from maps and airphotos, can be checked and recorded almost as fast as one can traverse the terrain, at chosen sampling-points, along traverses pre-selected on the air-photos. Adding an examination of surface features (Group B = Items 4 – 6) will increase slightly the time spent at each sample point. Examining subsurface features in addition (Group C = Items 7 – 10) will necessitate even more time being spent at each sample point and slow down the whole survey considerably, though providing additional and potentially-significant information.

On each traverse of sampling-points within an investigation site, the degree of limitation afforded by each feature in Groups A, B and C is recorded, as indicated in Table 2. These code symbols are recorded in a standard sequence for characterizing each sampling site and for making comparisons between sites.

Interpreting the survey's results generates classes of Land Use Incapability which are defined and ranked according to increasing limitations to the proposed use. This is linked to the likely severity of water-induced erosion under bare-soil conditions, as in Table 3.

Table 2 Significant permanent features of land and soil, and their sub-divisions for in-field assessment and coding, to verify or amplify air-photo interpretation

(These code symbols are recorded in a standard sequence for characterising each sampling-site, and to facilitate making comparisons between sites)

(After Shaxson et al., 1977, pp. 530-542)

Group and features	Criteria and subdivisions	Coding symbols (CONEX/Malawi)
A		
Slope	Shallowest < +6 divisions > steepest	Numerical: 1 – 6
Severity of past erosion, e.g. gullies	None < +3 divisions > severe	Numerical: 1 – 4
Wetness at surface	None < +3 divisions > significant	Numerical: 0 – w3
B		
Surface hindrances, e.g. stones, etc	None < +3 divisions > many	Numerical: 0 – s3
Poor surface condition, e.g. crusting tendency	None < +3 divisions > significant	Numerical: 0 – t2
Texture of topsoil	Sand < +7 divisions > clay	Alphabetical: A – G
C		
Effective depth to root-limiting layer	Deep < +4 divisions > shallow	Numerical: 1 – 5
Texture of upper subsoil	Sand < +7 divisions > clay	Alphabetical: A – G
Permeability of upper subsoil	V. slow < +6 divisions > v. rapid	Numerical: 1 – 7
Nature of limiting material	If found: (waterlogging; rock, etc.)	Alphabetical: W, R, etc. (inc. geologic identificn. if appropriate)

Table 3 Land Use Incapability classification by erosion hazard

(After Shaxson et al., 1977)

Class designation (safest to least safe)	Hazard of soil erosion in excess of an average of 11 t ha^{-1} yr^{-1} if annually cultivated and kept free of cover [2]	Features which degrade the land use capability = increase the land use incapability
Ⅰ A-Arable[1]	Slight	Soil-structure stability
Ⅱ B-Arable	Moderate	As for ClassⅠ, plus: - slope of land, and/or - soil texture - soil depth - effects of prev. erosion[3]
Ⅲ C-Arable	Severe	As for ClassⅡ, plus: - poor profile permeability - temporary wetness - large particles at surface
Ⅳ D-Arable	Very severe	As for Class Ⅲ but more pronounced[4]
Ⅴ W-Wetland	Very severe	Overriding feature is permanent wetness. Unsuitable for arable
Non-arable Ⅵ A-Non-arable Ⅶ B-Non-arable Ⅷ C-Non-arable	Excessive	As for Class Ⅳ, but on interacting together, they facilitate excessive soil loss if put under arable–type use

Note:

1 "Arable" signifies tillage-agriculture. (On a very stable deep soil, but on slope steeper than for BA, in particular circumstances a "Special Arable Class –SA" may be justified.)

2 An average loss of 11 t ha^{-1} yr^{-1} is a commonly-assumed natural rate of soil formation (see for example Hudson, 1995, p.41); but it bears little predictable relation to the varied effects of such loss on the productivity of the land (Shaxson, 1997, p.7).

3 On very stable, deep, well-drained soils, a "Special Arable [SA]" category may be permissible on slopes steeper than the Class Ⅱ limit.

4 For mechanized agriculture, a 15% slope is generally considered the divide between "arable" and "non-arable" classes, because tractors following the level contour-lines of the land are in danger of rolling-over sideways on steeper slopes.

On this basis, each piece of land represented by a single sample point can be said to be "*no better than Class ... on the basis of the available information*". With minimal information, (from Table 2-Group A inclusion only) from a very rapid survey, it will only be possible to assign the least degree of downgrading from the best "No limitation" class.

The more detailed the survey, the more information can be used to refine the classifications. The stepwise method applied to the information from a particular sampling point is shown in Fig. 1.

GROUP (as in Table 2)	FEATURE	EXAMPLE Symbol recorded at sample-point	START Assume Class Ⅰ	Ⅱ	Ⅲ	Ⅳ	Wetland Ⅴ	Ⅵ	Max. permtted severity in Class Ⅶ
A	Slope ➢	0	0 √	0–1	0–2	0–3	0–4	0–5	5
A	Past erosion ➢	0	0 √	0	0–1	0–1	0–2	0–2	3
A	Surface wetness ➢	1	0 X	0 X	0–1 √	0–2	0–3	0–2	2
	Gp.A only	Cannot be better than Class Ⅲ							
B	Surface hindrances ➢	1	0	0	0 X	0–1 √	0–2	0–1	2
B	Surface unstable ➢	0	0	0–1	0–1	0–1	any	0–2	2
B	Topsoil texture ➢	2	0	0–1	0–1	0–1 X	any	0–3 √	4
	Gps.A+B	Cannot be better than Class Ⅳ							
C	Effective depth ➢	1	0	0	0–1	0–1	(0–2) √	0–3	4
C	Upp.subsoil texture ➢	4	0	0	0–1	0–2	any	0–4	4
C	Profile permeability ➢	4	0	0–1	0–2	0–3	(0–6)	0–5	6
	Gps.A+B+C	Cannot be better than Class Ⅵ							

Fig. 1 The more details recorded at a single sample-point, the more precise will be its allocation to a Class

The greater the number of sampling-points, the greater accuracy of classification (Fig. 2).

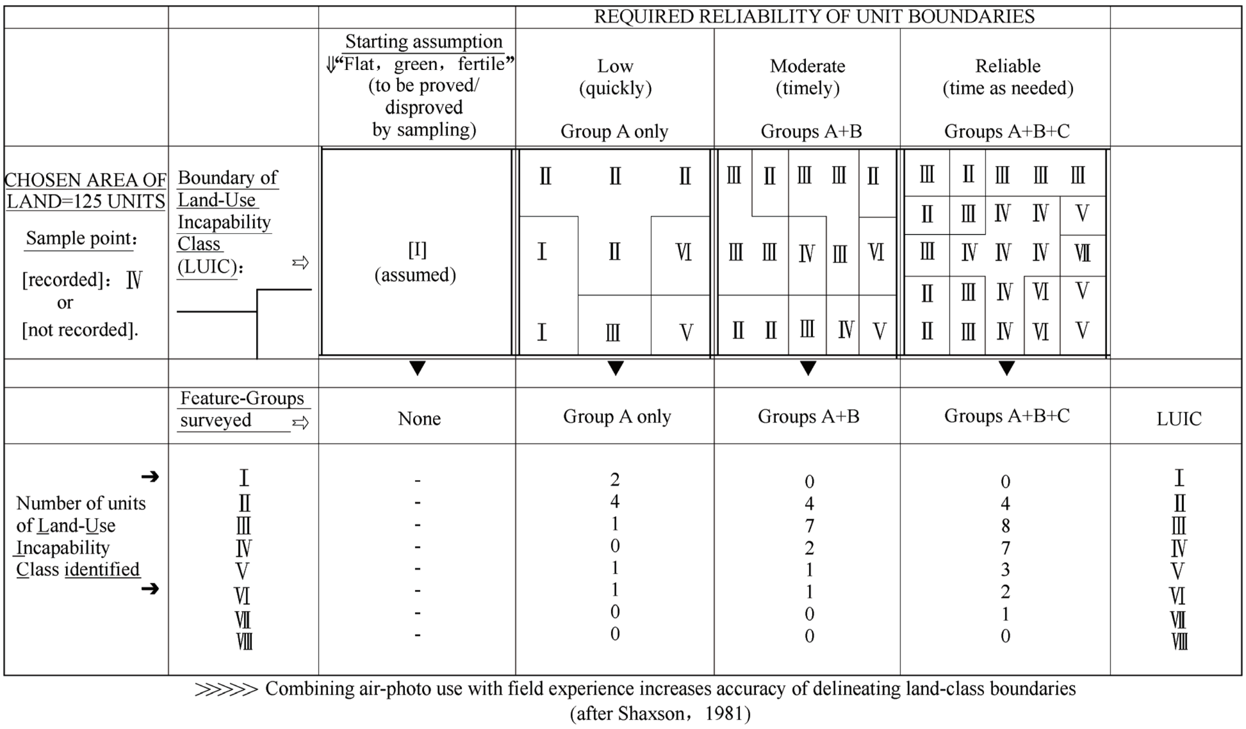

Fig. 2 Effect of increased survey intensity across a given area on the accuracy of land-use incapability mapping (Figs. 1 and 2 after Shaxson, 1981)

Definitions of land classes are meaningless for land-use planning purposes unless they can be separated on the basis of specific differences in the recommended intensities of practice and/or protection. This means that the determination of "best possible" class should automatically lead to guidelines for the maximum permissible intensity of use, governed by appropriate agronomic and physical means of erosion control, if excessive erosion is to be avoided.

This is shown in Fig.3, where "+" denotes acceptable land use for each class and "**o**" denotes unacceptable land use.

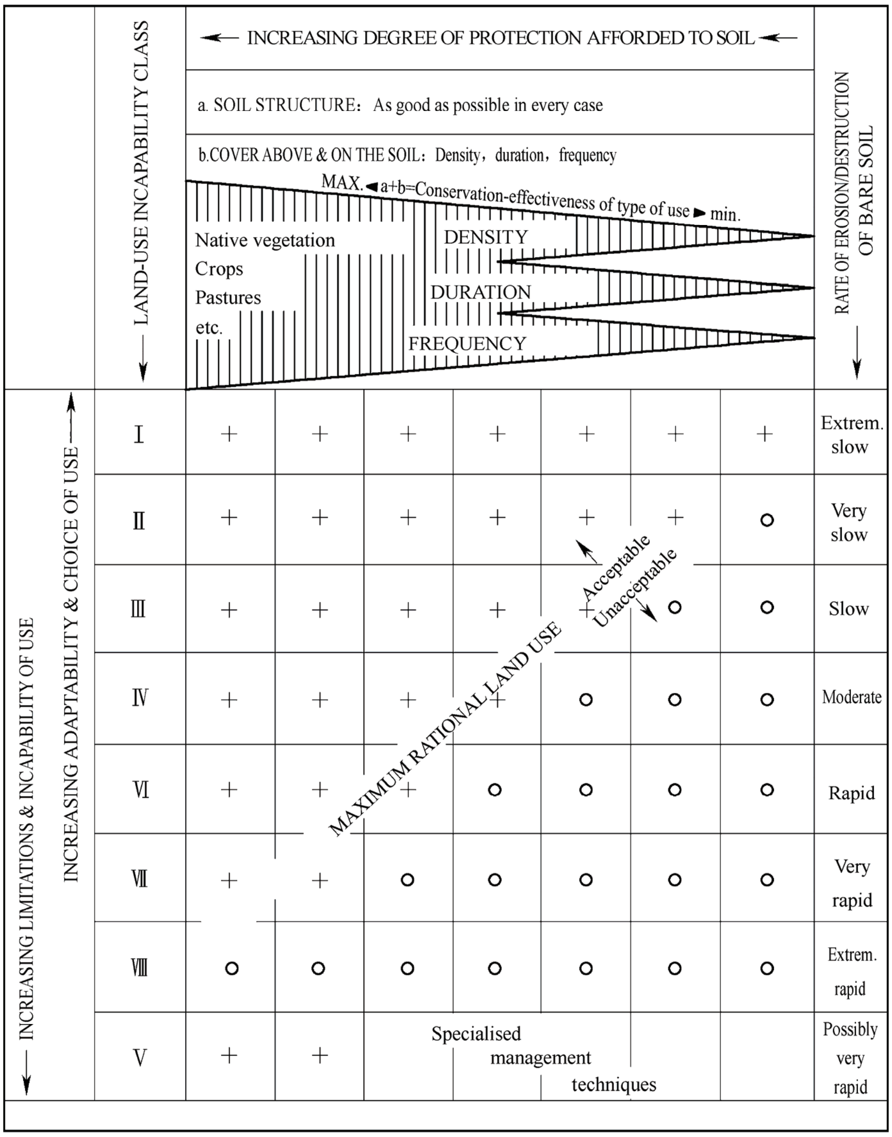

Fig. 3 Differentiating land use classes, land use and land management
(Derived from Shaxson et al., 1977)

The results of such surveys and classification provide basic reasoned guidelines for the future use, care, management and development of any particular piece of land, and the conservation of its sub-surface biodiversity. The results may be amplified by additional investigations as might be needed and/or appropriate, with reference to specific choices of proposed land uses.

These assessments are not static, but can be upgraded in both scope and detail, as needed and after appropriate land husbandry practices have been applied.

4.3 *Land-use Incapability Classification in practice – an example from Malawi*

The two maps below illustrate how the above techniques were used across a specific area of ca. 140 km^2 in Malawi, to determine how much of the area would NOT be suitable for growing flue-cured tobacco (the preferred use).

The starting assumption was that the whole of the specified area would be suitable for the proposed purpose. This assumption was tested using the method outlined in this paper.

Firstly, interpretation of the appropriate set of stereoscopic airphotos was undertaken to (i) map the land-forms, in terms of the natural catchments as delimited by crests and streamlines, and (ii) to locate obviously-limiting factors of steeplands and wetlands, (as visible on the airphotos). The results were recorded on a photo-mosaic covering the whole area, (summarised as the line-drawing – Fig.4) which was then used as a base-map for the ensuing in-field-survey along appropriate transect lines – using the criteria listed above – to identify apparently-homogeneous units of land.

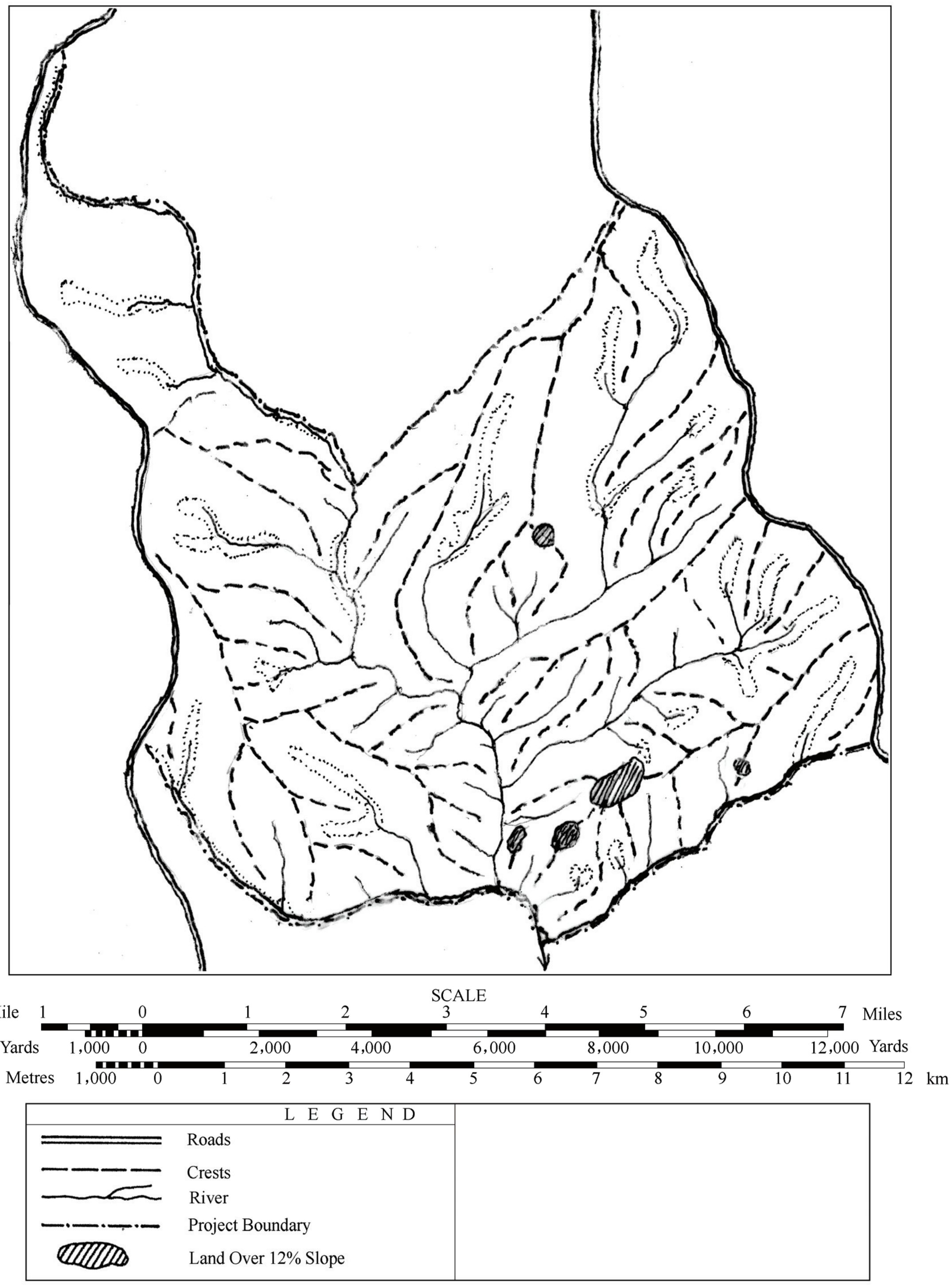

Fig. 4 Topography of the study-area (from air-photo interpretation)
(After Shaxson et al., 1977, p. 219)

(Interlinking crest-lines indicate possible well-drained access-routes; Points along drainage-lines where the ends of two crest-lines come close on opposite sides of a stream may indicate possible dam-sites)

The results of the subsequent in-field survey were then interpreted to produce – for this specific case – a specialized map of classification of land-use incapability with particular reference to the nature of types of land and soil suited/not-suited to the agronomic requirements of the proposed crop – flue-cured tobacco. The results shown in Fig. 5 show the areas possibly suitable for the proposed crop, which remained after rejection of those areas found to be either too light /too heavy of soil-texture, too hard when dry, too shallow for rooting, too wet, too rocky, or too steep.

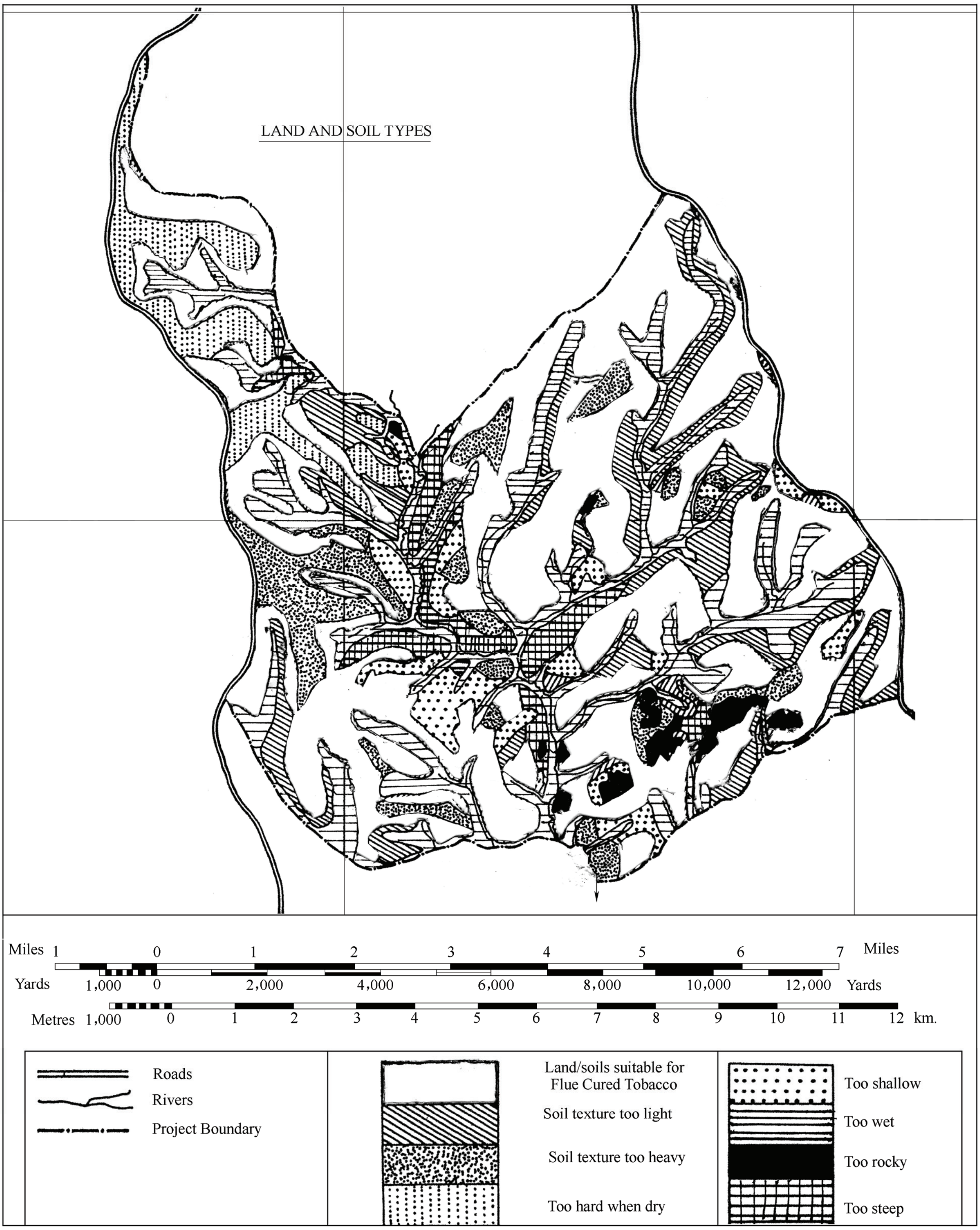

Fig. 5 Land-use incapability classification for FC Tobacco
(White areas = no apparent restrictions for F.C.Tobacco) (Derived from Shaxson et al., 1977, p. 218)

The information from the field survey was also used to define areas suitable for complementary land-uses, in particular tree-planting for provision of firewood for the “curing” of the tobacco, by allocating the steep, stony, “heavy” (= high clay-content) areas to the growing of trees for the firewood needed for curing the tobacco. The remaining wetland and the land which was too sandy for tobacco was allocated for cattle-raising activity.

The area’s pattern of catchments (Fig.4) shows crest-lines suitable for the development of the overall self-draining road-network necessary for the regular transport of the harvested tobacco-leaves. The pattern also suggests – by inference – the alignment of contours across the land surface which can provide guidance for a “ribbed” layout of cross-slope side-paths connecting to the main road-lines. When aligned at (calculated) slight gradients from crest to watercourse, these can serve (along their uphill sides) also as safe drainage-routes for excess surface-runoff. Using the topographic map, the detailed planning of layouts and optimum dimensions of roads, cross-slope structures and damsites can proceed in knowledge of the expected runoff from the (sub-) catchments they will serve. An example of a completed physical layout in an area (elsewhere) of similar characteristics to those shown in Figs. 4 and 5 is illustrated by Fig. 6.

Fig. 6 Vertical overhead view of part of a developed tobacco farm *(elsewhere, but on similar landscape to that in Figs. 4/5)*, showing crest-roads and contoured layout of fields on land-type suitable for tobacco production. The remaining areas, judged as unsuitable, being too wet/ too sandy/ too steep, were allocated as grazing-land for cattle. Black spots are termite-mounds. Note road-crossing over dam-wall at top (centre/right) (Photo: author)

5 Conclusion

Having considered the limitations of the “soil and water conservation’ paradigm, this paper set out the concept and practicable framework of an alternative paradigm, that of land husbandry based on agro-ecological principles. The main components of this paradigm were outlined: it considers land’s spatial distribution in three dimensions as well as (subsequently in Part Ⅱ) the range of its hydrological, chemical and biological characteristics. Planning this conservation-effective and sustainable approach to land husbandry is facilitated by a Land Use Incapability survey, which contributes to the work of planning the harmonisation of the potential uses of different units of land with their specific characteristics. The steps of such a survey were laid out, and an example given of how it was used to assess the suitability of a catchment area for growing flue-cured tobacco in an area of central Malawi.

Worldwide, there may no longer be many areas of land remaining uncultivated, to which such methods might still be applicable. Nevertheless, the ecological principles behind the purpose of such surveys remain valid, and may well be applied advantageously on lands already in use, whether damaged or not, with a view to achieving a better congruence between land use and land characteristics.

The methodology may also be used to advantage in investigation, characterization, and planning for the rehabilitation of land which has already been damaged by past misuse, and to its more-effective protective and sustainable use and management in the future.

The inherent land characteristics described during such a land-use incapability survey procedure will be relatively unchanging over time (unless wrecked by poor management). However, the interpretation of the suitability of the chosen area of land for different types of use (even for urban-type development) remains flexible according to different specific needs, but may need additional use-specific investigations to further refine the limitations/possibilities for the preferred use.

Part 2 of this paper will continue the ecological emphasis on land husbandry, and consider further aspects of soils and their management, in the context of concerns about sustainability of the land's capacities to yield plants and water (FAO, 2008). It will also consider implications for research and training activities.

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