CONSERVATION OF CARBON, WATER AND SOIL : A DIFFERENT PERSPECTIVE

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ABSTRACT

The paper suggests an alternative way of thinking about how to approach the conservation-effective management of carbon, water and soil for productive purposes, at the same time as enabling the ongoing sequestration of carbon dioxide, while simultaneously limiting its premature release back to the atmosphere and its loss as particulate organic matter in runoff.

At its beginning some commonly-stated assumptions about the erosion / conservation / soil-productivity complex are set out, together with some of the consequences of having acted on them.

A small number of unexpected results of erosion suggest an alternative viewpoint from which the problems can be seen with a different perspective. Some alternatives to the common assumptions are suggested.

Carbon in the soil - in both living and non-living organic forms - is considered with respect to sustainability of biomass production, and to soil porosity, water movement, and formation and erosion of soil. Coupled with the observation that it can form from the surface downwards, a biological definition of soil is suggested.

Needed improvements in land husbandry are indicated for improving the suitability of soils as rooting environments and maintaining their high organic contents so as to raise biological sequestration through increased biomass production.

In conclusion, it is suggested that if excessive rates of oxidative loss of carbon from within the organically-bound aggregates in the soil itself (Stage-1 loss) is not prevented by good management, the ensuing loss of soil porosity will inevitably result in a further (Stage-2) loss of particles of organic matter in increased runoff and erosion. Stated more positively, attention to increasing carbon sequestration through encouragement of more 'pro-biotic' systems of soil use are needed. These would lead to improved biomass production and to avoiding undue Stage-1 losses of carbon, which in turn will have more positive, far-reaching, and longer-lasting effects than those actions which only address Stage-2 losses through methods aimed primarily at erosion control.

Some implications of viewing the problems from this different perspective are considered.

Key words: Carbon, soil, formation, porosity, pro-biotic, husbandry.

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Introduction

"After seven decades of conservation programs that have consumed millions of dollars of economic resources and vast quantities of human resources, soil erosion and subsequent degradation of water resources remain serious environmental issues within the United States".
(Napier, 2001:279).

The same may also be said of other countries, in particular those covered by the Intertropical Convergence Zone in which high temperatures and unstable masses of moist air lead to heavy storms and high intensities of erosive rainfall (Pereira, 1989:12). In places where farmers' capacities to manage the soil are insufficient to maintain it, soil productivity is in decline, or its maintenance is increasingly costly and its use less profitable. If the USA - which has invested so much over so many years - has not solved the problem yet, it is perhaps not surprising that other countries, with less capacity to investigate them, also have not managed to do so.

Superimposed on this broad concern is the worry, being addressed at this Colloquium, that carbon selectively removed during erosion processes may somehow be contributing to carbon dioxide in the atmosphere and thus to global warming, adding urgency to the need to find solutions to ongoing degradation of soil and water resources.

The deliberately-provocative question is therefore implied: "Is erosion control the best approach for solving these problems?"

Some assumptions and actions

Pronouncements about accelerated erosion's effects on soil productivity seem to rest on some unquestioned but doubtful assumptions, leading to some more-or-less inadequate approaches to controlling it. Thus the problem of carbon loss through soil erosion by water may be more severe than it need be. The difficulty appears to arise from too-narrow an emphasis on soil erosion control and too limited an application of insights from other disciplines in the developing of better means of improving and sustaining the resilience and productivity of soils in the face of severely erosive climatic events.

As evidenced in the profuse literature on soil erosion and its control, common assumptions appear to include:

a. That soil erosion is some sort of a force in its own right, capable of destroying land: therefore it has to be combatted.
b. That runoff is the prime factor in erosion : therefore runoff must be controlled.

c. That productivity of soil depends largely on its chemical constituents, and these are selectively eroded attached to clay and organic materials: therefore fertilizers must be added to maintain/raise yields;
d. That productivity decline is commonly caused by soil erosion, and the relation between the two ought to be definable by knowing the quantities of soil lost: therefore measure soil loss and attempt to predict productivity changes under different scenarios.

This line of thinking is to an extent hallowed both by time and by repetition, and by respect for those who first paid serious attention to trying to solve the problems of land degradation on a large scale. Though it has led to much dedicated research and many kilos of reports, it has tended to 'tramline' thinking and action towards ever-more detailed investigation of the same parameters, and application of more refined forms of the same erosion-control technologies, more than to foster some lateral thinking about all aspects of the subject as a whole.

The common response has been to 'fight erosion' with 'soil conservation', which has often translated - through government policies, programmes and projects – into physical works to control and divert runoff and the soil it carries. Without (or often even with) financial inducements farmers have not adopted them very enthusiastically on the one hand, nor have physical works on their own improved the quality of the soil (though they may have slowed the rate of gross soil loss). The justifications for recommending such an approach are however diminished by the difficulty that the quantitative erosion-productivity relationship for most soils is not known (Sonneveld,2002:17; Eswaran et al., 2001:26).

A result has been that we conservation enthusiasts have tended in the past to assume we are correct in our analysis of land degradation, that farmers are resistant in not favouring our recommendations, and that the only way to improve the unsatisfactory situation is for governments to insist more strongly, and/or reward farmers more generously, until they readily comply. However, the problem of non-adoption by farmers is more likely to lie in the frustration they feel in not being able to get advice which is relevant to the problem of falling productivity, which can be seen to be effective, and which is both feasible and of nett benefit – or at least of no nett dis-benefit.

The danger is that, with continuing lack of evidence that the approach can rapidly solve the problem, governments could become disillusioned and reduce their support for their seemingly unproductive investments in 'SWC' (soil and water conservation).

Hannam (2001:8) points out that *"there is a need to re-think what we are doing, rather than re-fashioning dated concepts'*. This paper contributes to this necessary re-thinking.

From a different vantage-point

Some anomalous results

A small number of 'inconvenient' results of erosion's effects on productivity open a door to another perception: in some instances, in research plots and in farmers' fields, yields had actually risen rather than fallen after significant erosion has occurred (e.g. Morgan, (1995), Papua/New Guinea (Kerr, pers. comm.), and another in Australia (Sanders, pers. comm.).

Should we discard such apparently anomalous observations as mistakes, or consider them as a potentially-significant pointer to an unacknowledged but significant reality?

Observations of this sort indicate that the condition of a previously-subsurface layer was better for rooting than that of the former surface layer, and was exposed at the surface (before the next season's crop was sown) when the topmost layer had been stripped-off through erosion. Figure 1 shows visible differences within a multi-layered alluvium in Lesotho is where this could, possibly, give a similar result if significant erosion were subsequently to occur (in other soils such a difference in conditions for roots might be present but not easily perceived except by chemical analysis).

Figure 1. If erosion removed the light-coloured topsoil, the blackish subsoil band thus exposed might produce better yields than the complete soil did before the topsoil was lost. In other soils such a stratification might also be real but not visually distinguishable. *(Thabana Morena, Lesotho. T.F.Shaxson)*.

Different considerations

Re-arrangement and reassessment of some already-known facts allows some alternative interpretations of the assumptions a, b, c, d noted above:

a. Undue erosion is a foreseeable ecological consequence of changes (often man-induced) in relations between components of the natural environment both above and below ground - geology, topography, vegetation, hydrology, soil, fauna and flora, all under the influence of climate and the effects of people's actions.

   From soil not adequately protected from erosive raindrop impact the movement of eroded soil during a rainstorm is visible evidence that this adjustment is in actual process of happening. It may be occurring as a result of a detrimental change in condition of the surface soil, resulting in the ecosystem at that place changing from one level of meta-stable equilibrium to another, often (but not necessarily always) of lower productivity. (Downes,1982:6).

   If this is true, then soil erosion itself is not the first cause of destabilization and soil loss. The predisposing cause is here the disturbance to the balance among the several environmental factors, which is often provoked by people's damage to the soil's cover and three-dimensional architecture through inappropriate management.

b. Runoff control measures offer barriers/diversions in the *lateral* dimension, after water has begun to flow downslope. They have no effect on the prior impact of erosive raindrops falling in the *vertical* dimension, which cause splash of soil particles, hammering of the surface, and its interstitial sealing by filtered-out fine particles, with loss of infiltration capacity through the first few millimeters of the soil surface and their rapid saturation, thereby provoking runoff at the air/soil interface. If the porous condition of the surface can be maintained and improved by the interpolation of a permeable organic cover between rain and the soil surface, infiltration rates can remain surprisingly high, with little or no partition of the rainfall into runoff.

Physical cross-slope works against runoff are 'blunt instruments' and not-very-effective substitutes for (though useful complements to) adequate amounts of cover against damaging effects of rainfall.

c. Soil productivity, as expressed through plant growth, inheres in the dynamic interactions between its physical x chemical x biologic x hydric constituents which define the soil as a rooting environment, and not in its chemical component alone (Wild,1988; Squire, 1990:61). Both plant roots and soil moisture need to be explicitly identified as constituents, otherwise they tend to get overlooked when hidden within the 'biologic' and 'physical' segments.

Soil moisture at plant-available water potentials is a key component, because the effect of its deficiency on plant growth functions is almost immediate – within hours or days rather than weeks - once the transpiration rate is diminished by slowed water transfer from soil to roots, or as stressed plants are revived as rainwater enters the desiccated root-zone.

A range of pore-sizes enables water to be held in the soil at a range of water-potentials (in kPa) between Field Capacity and Wilting Point which is available to the transpiration stream of plants under the influence of evaporative demand (Allan and Greenwood, 1999). Pores large enough to allow free drainage to below the root-zone allow excess rainwater to pass downwards towards the groundwater.

Components of any strategy should therefore include (a) what is necessary to ensure that rainwater can enter the soil without avoidable hindrance, (b) that the soil is maintained in an appropriately-porous physical condition to retain high proportions, or all, of it at low tensions from which plants can retrieve it readily, and (c) that unproductive water loss by direct evaporation from the soil surface is minimized.

d. Difference between yields before and after soil erosion is more clearly related to differences between *in-situ* characteristics of the soil as a rooting environment before and after erosion than to the quantity of soil removed. (Shaxson,1997:7). The quantity and chemical quality of eroded soil provides an inadequate explanation of soil-productivity decline. Three-dimensional pore-spaces and interlinkages of soil particles, organic matter and soil micro-organisms are important for good root-growth and function in the surface soil, as also at sub-surface levels (Wild, 1988) (FAO,2001).

A more-effective strategy to maintain soil productivity should therefore emphasise protecting the soil surface and favouring the improvement of the complex integrity of the root-zone in good condition for root-growth and -function..

Soil porosity based on water-stable aggregates is of primary importance in joint consideration of soil productivity and soil erosion, because it moderates the movement of water, gases and roots within the soil.

Tillage provokes not only gross physical alteration to soil-architecture but also results in accelerated breakdown of dead organic matter by soil organisms, with untimely release of respired CO_2 back to the atmosphere (Stewart 2002, pers. comm.; Mrabet, 2001).

Exposure of unprotected soil to direct solar radiation also results in direct breakdown of the complex organic materials which give coherence and stability to soil aggregates, resulting in collapse of soil-architecture and loss of voids. Compaction damages soil architecture at the surface and below, resulting in quicker saturation of affected soil horizons and an increased likelihood of runoff.

Loss of voids (pore-spaces) from the soil, whether from compaction, collapse, pulverization, or interstitial sealing, represents loss of useful spaces in the soil matrix, hindering or even preventing exploration by root-hairs and root-tips, expansion of maturing roots, movements of water and gases, and, from the moist boundaries of these spaces, the absorption of nutrients (e.g.McGarry 2002:209). These are comparable to rooms in a building – all the important activities take place within the voids, not within the structural materials themselves. Their loss is comparable to the effects of demolishing a building: the mass of the rubble, glass, steel beams and other construction-materials is the same, but the value of those materials has disappeared because the useful spaces have disappeared. Loss of pore-space in the soil diminishes the value of the physical component of productivity.

In undisturbed conditions, both the physical processes of wetting, drying and weathering, and - under favourable conditions such as in the forest-floor, prairie grasslands, well-managed pastures, and other managed situations rich in organic materials – the effects of biological activity contribute significantly to the build-up and maintenance of soil porosity. This is a consequence of (a) the activities of micro-organisms such as bacteria and fungi in transforming organic materials into humic gums which cause soil particles to clump-together into irregularly-shaped aggregates, within and between which are the voids which form useful soil pores; (b) the expansion and subsequent decay of roots which leave tubes of various diameters in which organic materials have been disintegrated and transformed; (c) burrowing activities of meso- fauna such as termites, worms, and other soil-inhabiting fauna. Water acceptance is very high, a situation less-often found under conventional tillage systems.

Carbon's role in sustainability of biomass production

Prolonging the usefulness of resources: Throughout the history of agriculture, native vegetation and soil conditions have been modified by people's activities, and widely substituted by other plants capable of producing higher yields and/or different plant products of greater use to people. The chief requirement needs always to be that the substituted systems of use and management should be at least as stable and biologically sustainable in the face of the range of anticipated recurrent weather conditions as the native ecosystems they have supplanted.

The GAMMA Project of the universities in Montreal defined 'conservation' as "prolonging the usefulness of resources" (cited by Downes, 1978). In the context of this paper, resources of carbon, water and of life itself (expressed in the forms of e.g. soil-inhabiting plants and organisms) can properly be included in the development of this capacity.

Schrödinger indicated that, "metaphorically, the most amazing property and capacity of life is its ability to move upstream against the flow of time" (quoted by Lovelock,1988:23), with the capacity to assemble complex energy-rich materials against the otherwise opposite entropic tendency of breakdown to simpler units which is accompanied by dissipation of energy as time progresses.

This capacity of life itself provides a common thread which interconnects both concepts and dynamic aspects of 'ecosystems', 'soil health', 'resilience' (of both soils and plants), 'sequestration and combination of carbon', and 'self-recuperation capacity' (of ecosystems and their living components).

Significance of organic materials, populations and processes:

The literature abounds in references to soil organic matter, but the same seldom refer to the parallel necessity for the presence of active soil organisms which can effect its transformations. If the soil is inimical to their activity – too low in organic matter, too hot, too dry, too acid etc. - soil-benefitting transformations do not take place. In the author's experience, for instance, maize-stalks and leaves which had been ploughed-under three years previously re-appeared unaltered when the field was again ploughed because there was no biological activity in the soil.

The combination of sufficient organisms, organic materials, water, and nutrients, in soil provides continuing resurgence of biological activity from year to year. The transformation of organic materials provides humic gums which are key components of water-stable aggregates involved in recurrent re-formation of soil porosity, contributing to the soil's self-recuperation capacity, and thus to its resilience after physical damage.

Managing an *organic-rich* agriculture ensures the regular addition of organic materials to the soil surface, by crop residues and cover-crops, manures etc. It protects the soil surface, provides food for the soil organisms and raw materials for transformation by them, and keeps humic materials already within the soil in conditions which are opaque to ultra-violet radiation capable of breaking chemical bonds in organic molecules.

Carbon in terrestrial ecosystems is that captured by plants in photosynthesis. For there to be an abundance of this 'fixed' carbon per hectare there has to be a dense canopy of leaves over the soil surface, which itself depends on the soil being in good condition for their roots to grow and function effectively. For this to occur there has to be, among other necessities, sufficient plant-available water in the soil to maximise the duration of growth without the development of damaging water stress in the plants.

Sustainability of a good condition of soil-architecture depends on (a) not losing it in the first place, and (b) if it has become damaged, its rapid recuperation. This latter can only be achieved by microbially-induced transformations of organic matter which produce humic gums which 'glue' together soil particles to form more-or-less porous aggregates. On the one hand there must be self-perpetuating populations of living organisms to effect such transformations, and on the other there must be permanent or recurrent supplies of organic materials as a sufficient substrate for their activities. These may be variously provided by roots themselves, by the retention of residues from previous crops, and by transporting-in of organic materials from elsewhere as raw or composted additions. In the majority of agricultural situations (in crop-land, pasture-land, forest-land, range-land) the key factors for avoiding (rather than controlling) runoff and erosion are surface cover and soil porosity. Both depend on living organisms - plants and other soil inhabitants - and their proper husbandry thus contributes to extending the useful life of carbon in complexes within the ecosystem and to minimising its premature return back to the atmosphere.

These aspects of continuity of biological activity and of self-recuperation over time are fundamental to the sustainability of chosen land uses. These results were formerly achieved during fallow periods of maybe as long as 50 years in long rotational cycles with crops, pastures. Under today's pressures of population, declining farm-sizes, and many small-farmers' poverty of resources, a major challenge is to achieve the same sustainability by simulating fallows' restorative effects very much more quickly. Three options (preferably used together) for achieving this in a rotational cropping system can be outlined:

* Increase the soil's biological capability for recuperation – assist more organic activity;
* Reduce the time during which the soil suffers damage – rotate crops at shorter rather than longer intervals (Hudson, 1981:214).
* During the period of suffering damage, reduce the severity of its impact use equipment, pasture-management etc. which is least-damaging to soil in optimum root-favourable condition, in preference to those capable of causing adverse mechanical disturbance. (Shaxson,1993:112)

There are indications that some of the plant-growth benefits attributed to erosion control are in fact due to benefits of additional soil moisture due to the measures used, such as cross-slope conservation banks, where runoff may have accumulated locally along upslope sides of the banks, and thus had more time to soak in than where runoff had been diverted along a cross-slope shallow gradient (Hellin & Haigh, 2002).

Results from unirrigated residue-based ZT for a range of crops in Brazil (Landers, 1998:257), from mulching experiments in many situations – (e.g. on young tea in Malawi (Tea Research Stations,1963), and from ZT wheat in central Italy (Pisante, pers. comm.) and Morocco (Mrabet, 2002:238), in areas of annual rainfalls ranging from about 2000mm – 300mm), show that improved surface-cover conditions – by diminishing direct evaporation from the soil surface - prolong the usefulness of both rainwater and carbon in the soil. This enables longer duration of early growth of tea seedlings and of duration of grain-filling of durum wheat, by delaying the onset of growth-inhibiting moisture stress when rainless conditions set in during and at the end of a rainy season.

Soil as a renewable and self-renewing resource

Many consider soil to be virtually a non-renewable resource, (e.g. Eswaran et al, 2001:30) because of the slowness with which parent materials are weathered at depth to root-usable materials. This is not necessarily true, because in situations where organic matter increases on and in the upper horizons each year, the rooting-zone is thus enriched, and it is possible that organic acids moving down from the surface may raise the rate of 'weathering' of mineral particles within the root-zone.

Soil is formed top-down, almost independent of deep weathering. This is clearly achieved under well-managed residue-based zero-tillage systems, as in Brazil. Thus the thinning of soil-depth by erosion is capable of reversal under forms of improved land husbandry, accompanied by rising potentials for increased productivity (Shaxson, 1981:360; Haigh & Gentcheva-Kastadinova 2002:376).

A biological definition of soil
Should we properly call the shallow zone at the interface between rock and atmosphere 'soil' if it has no biotic component? Soil should be valued more for the dynamics and diversity of its living components which benefit plant-production than for the pedological characteristics of its arrangement of horizons.

We may take better care of soil if we consider it not primarily as an inorganic physical unit of mineral particles, air, water and nutrient ions which contains and is interpenetrated by organic matter and organisms in three spatial dimensions, but primarily *as a complex and dynamic subsurface ecosystem of diverse living organisms (including plant roots), non-living organic matter, and biologically-transformed organic/humic products, which inhabits, modifies and interpenetrates an inorganic mix of mineral particles, air, water and nutrient ions, and which changes dynamically over the fourth dimension of time.*

Land husbandry influences

Effects of good land husbandry
Principles of good land husbandry (e.g. Shaxson,1993:115) are well illustrated by an increasing number of Brazilian farmers, for instance, who on their farms have developed integrated residue-based farming systems with zero tillage whose total area has grown from around 0 to more than 14 million ha. in the last 30 years (Pieri et al, 2002:vii). These systems specifically pay attention to improving the protection and sustainability of soil productivity. They combine commercial crops, legumes, cover-crops with no-tillage and direct drilling in rotational systems of farming, extending the principles of soil protection and improvement to pasture-management systems also. Benefits include, among others: greater yields and their stability in the face of unpredictable vagaries of weather/rainfall; improved conditions of soil architecture accompanied by greater water-holding capacity; lowered costs of production; release of space and time for diversification of crops and of people's activities; much-reduced soil erosion and surface runoff; more-reliable and increased streamflow; reduced floods and related infrastructure damage; reduced costs of maintenance of rural roads and of water-treatment for urban consumption. (Landers,1998:252) (Mrabet et al., 2001:514).

Effects of poor land husbandry
Mis-managed systems - which by e.g. overgrazing, fire or excessive tillage allow or encourage breakdown of these essential compounds of carbon ('Stage-1 carbon-loss') in plant and soil – thus pre-dispose the land to lose yet more carbon in subsequent processes of erosion and runoff ('Stage-2 carbon-loss'). Concentrating attention only on the Stage-2 carbon-loss fails to take sufficient account of the effects of loss of the preceding Stage-1 carbon from the ecosystem. This sidelines the very serious and far-reaching consequences of its decline, which include the increasing exposure of the soil surface, decline in soil-structural stability, diminution of soil porosity, lowering of productivity, and consequent increases in occurrence and severity of runoff, erosion, and water stress in plants.

Better land husbandry
Improvements in land husbandry are necessary to move from the 'poor' condition (still all-too-common) to the 'good' condition, and then to sustain it. It should aim to assist the plants and other organisms of the chosen agro-ecosystem to optimize between themselves the dynamic relations

between the physical x biologic x hydric x chemical components of the soil's productivity, aided by farmers' decisions and actions.

Some implications

For research
Through reading potentially-relevant technical literature and re-interpreting the basic research data which is reported there, it may be found that much of the detail needed to fill-in the picture of sustainable organic-rich agriculture sketched above already exists.

Additional experimentation may be needed to disentangle the real effects of improved soil-moisture conditions in the three dimensions of space and in the fourth dimension of time from those of erosion control itself, with respect to their comparative effects on plant growth.

Research is needed to determine, in specific situations of cropland, pasture, rangeland, forest land, what proportion of declining production of biomass (at a constant, not rising, input-cost) is due to (a) insufficiency of plant nutrients (as commonly supposed) and/or to (b) root-impedance and soil-moisture deficiency following loss of soil porosity due to its compaction / pulverization / collapse following organic-matter decline / interstitial sealing / other cause.

The contention that difference between soil conditions before and after erosion provide a better explanation for yield-difference than the quantity of soil eroded needs investigation, with a view to resolve the uncertainty of the soil loss/yield loss relationship.

In view of the great need to extend plant growth into rainless periods and dry seasons, emphasis in plant-breeding may be directed to selection for root systems better capable of exploring soils for stored moisture which can freely enter the transpiration stream.

For training and advisory work
While the difficulties of implementing such an approach and strategy may be consideable in various socio-cultural and agro-climatic situations, notably in small-farmer and subhumid and dryland areas, the ecological principles remain valid in all situations. The challenge is to assist farmers devise appropriate means of putting them into harmonious practice, using the resources of rainwater, soil, organisms, organic materials, and the energy available to themselves as farmers, to better advantage and in ways which are simultaneously productive, sustainable and conservation-effective.

This implies the need for training advisory staff in the principles and practice of better land husbandry, in both its agro-ecological and socio-economic aspects, building on, expanding and, where necessary, re-moulding knowledge they already have so as better to fit those realities. It is important to appreciate and show the linkages between components at micro-scale (root hairs, soil pores, bacteria, etc.) and those at macro-scale (weather, landscape, institutions, etc.). A key need in such training is to match the ecology of agro-environmental situations being considered with an ecology of disciplines which teaching staff should employ in the training activities.

For policy
Within governments, relatively-independent departmental policies which at present are variously aimed at 'soil conservation', 'the environment', 'agriculture' etc. need an overarching agro-ecological policy framework which interconnects the concerns they have in common. These include

soil conditions, biomass production, erosion, sedimentation, and related matters, which are all linked through their common features of sustainability of organic potentials, soil porosity and water use efficiency. The basis for such a framework should be a concern to encourage, develop and support systems of land use and soil management which are actively 'pro-biotic' with respect to life in the soil, at the same time discouraging those approaches of the past which have allowed soils to degrade by default and inappropriate management, and which, in this sense, have turned out to be somewhat 'anti-biotic'.

Conclusions

Mitigating effects of floods and drought

Improved attention to prolonging the usefulness of carbon (in organisms and organic matter) on and in the soil has been shown by the Brazilian experiences with residue-based ZT systems to have positive effects - via benefits to soil porosity and water storage - on lessening the frequency and severity of floods following uncommon amounts of rainfall, and on diminishing the duration of, and damage to plant production by, infrequent but serious periods of drought. Observed positive improvements in water function may not, however, be adequately characterized by soil bulk-density measurements because soil under residue-based zero tillage systems are also penetrated by scattered large-diameter wormholes which may not adequately-sampled.

Improving erosion-hazard classes

Moving to organic-rich systems of agriculture with much-improved soil-water relations greatly reduces the hazard of soil erosion at a given place, because the soil is better protected against raindrop damage and is more porous and absorptive. Therefore the technical 'erosion-hazard' class of a particular land unit – commonly assigned I-VII from 'most safe' to 'least safe' – (e.g. Shaxson et al. 1977) can be down-graded (e.g. from IV to III, etc.), indicating greater flexibility of safe use and a wider range of suitable land-use types which could safely be allocated. By this means the 'marginality' of lands which are increasingly being brought under tillage by small resource-poor farmers can be modified by improving their organic quality and reducing their hazards of being eroded out of production.

Getting organic materials into the soil

The enrichment of soil by getting organic matter into the profile is much better achieved by soil-inhabiting organisms whose energy comes free of charge and whose actions tend, directly or indirectly, to improve the porosity of the soil, rather than by ploughs and discs, which have the opposite effects through their capacity to shatter aggregates, aerate the soil leading to high rates of organic-matter oxidation, and cause compaction. Heavy metal's physical effects cannot simulate biological effects in improving soil condition.

Carbon sequestration

Prolonging the usefulness of carbon in the soil through better land husbandry favours the sustaining of soil and of water supplies and can avoid most or all of the loss of organic-matter particulate fragments in erosional runoff.

A valid perspective

The perspective outlined in this paper appears valid for two main reasons:

* It suggests some credible alternatives to some doubtful assumptions;

* It offers a positive approach to enhancement of resources' value, agricultural sustainability, environmental improvement, and carbon sequestration, in contrast with the negative attitudes surrounding the difficulties of controlling erosion and the loss of carbon in runoff.

Prolonging the usefulness of carbon in living organisms and non-living residues in the soil also favours the formation, improvement and self-sustaining of its productivity as the rooting environment, as well as prolonging the usefulness of water within the soil and as streamflow. It thus contributes to the ongoing cyclical capability of plants to sequester carbon from the air.

References

Allan, R. and Greenwood T., 1999. Advanced Biology 2. Student Resource and Activity Manual. BIOZONE. Learning Media Ltd., Glasgow. First edn, 1999. Work Sheet on Transpiration, p.80. ISBN 0-909031-29-0, 336pp.

Downes R.G., 1982. Institution Building for Soil and Water Conservation in Brazil. Consultant's report to Project BRA/82/011. Rome: FAO (AGLS). pp.43.

Downes R.G., 1978. The use and management of resources : a philosophy and concept for decision-making. In: Proc. Symposium on Development of SW region [Western Australia]. Inst. Of Engineers, WA Divn.

Eswaran H., Lal R., Reich P.F., 2001. Land Degradation : An Overview. In: Response to Land Degradation. (eds. Bridges, Hannam, Oldeman, Penning de Vries, Scherr, Sombatpanit). Enfield (USA): Science Publrs. ISBN 1-57808-152-1. 20-35.

FAO, 2000. The Life in Soil. Agriculture 21 – Spotlight. www.fao.org/ag/magazine/0011sp1.htm.

Hannam I.D., 2001. Ecological Soil Standards. In: Response to Land Degradation. (eds. Bridges, Hannam, Oldeman, Penning de Vries, Scherr, Sombatpanit). Enfield (USA): Science Publrs. ISBN 1-57808-152-1. 8.

Hellin J. and & Haigh M.J., 2002. Impact of *Vetiveria zizanoides* (Vetiver grass) live barriers on maize production in Honduras. In: Sustainable Utilization of Global Soil and Water Resources. (eds. Wang L., Wu D., Tu X., Nie J. Proc. 12th International Soil Cons. Org. conf., Beijing, 26-31 May 2002 vol. 3, 277-281 (in press).

Hudson, N.W., 1981. Soil Conservation. London: Batsford. ISBN 0-7134-3521-6. 324pp.

Landers J.N., 1998. Zero tillage development in tropical Brazil. In: Conservation Tillage for Sustainable Agriculture. Proc. Intl. Wksp., Harare, June 1998.Pt. II – Annexes. (eds. Benites et al.) Eschborn (Ger.): GTZ. 247-262.

Lovelock J., 1988. The Ages of Gaia. A Biography of Our Living Earth. Oxford: OUP. ISBN 0-19-286090-9. 252pp.

McGarry D., 2002. Soil compaction – the unnecessary form of land degradation!. Development and Cooperation, no.3, May/\June, 2002.

Morgan, R.P.C., 1995. Soil Erosion and Conservation. Longman Group Ltd.

Mrabet R., 2002. Wheat yield and water-use efficiency under contrasting residue and tillage management systems in a semiarid area of Morocco. Expl. Agri. 38, 237-248.

Mrabet R., Saber N., El-Brahli A., Bessam F., 2001. Total, particulate organic matter and structural stability of a Calcixeroll under different wheat rotations and tillage systems in a semi-arid area of Morocco. Soil & Tillage Research 57, 225-235.

Mrabet R., Ibno-Namr K., Bessam F., Saber N., 2001. Soil chemical quality changes and implications for fertilizer management after 11 years of no-tillage wheat production systems in semi-arid Morocco. Land Degrad. Develop. 12:505-517.
Napier T.L., 2001. Soil and water conservation behaviours within the Mississippi River Basin.. J.Soil and Water Cons. (USA), Vol. 56, No.4, 279-285.
Pereira H.C., 1989. Policy and Practice in the Management of Tropical Watersheds. Boulder (USA): Westview Press. ISBN 1-85293-089-6.
Pieri C., Evers G., Landers J., O'Connell P., Terry, E., 2002. No-Till Farming for Sustainable Rural Development. Agriculture and Rural Development Working Paper. Washington: IBRD/World Bank. 65pp.
Shaxson T.F., 1997. Soil Erosion and Land Husbandry. Land Husbandry. vol. 2, no.1, 1-14.
Shaxson T.F., 1993. Conservation-effectiveness of farmers' actions – a criterion of good land husbandry. In: Topics in Applied Resource Management. Vol. 3 'Acceptance of Soil and Water Conservation – Strategies and Technologies'. (eds. Baum, Wolff, Zoebisch). Witzenhausen (Ger.): D.I.T.S.L. ISBN 3-9801686-4-6. 103-128.
Shaxson T.F., 1981. Developing concepts of land husbandry for the tropics. In: Soil Conservation : Problems and Prospects (ed. R.P.C.Morgan) Proc. Internatl. Conf. 'Conservation 80'. Chichester (UK): Wiley. 351-362.
Shaxson T.F., Hunter N.D., Jackson T.R., Alder J.R., 1977. A Land Husbandry Manual. Lilongwe (Malawi): Land Res. Cons. Dept. 627pp.
Sonneveld B.G.J.S., 2002. Land Under Pressure – The Impact of Water Erosion on Food Production in Ethhiopia. Ph.D thesis, Free University of Amsterdam. Maastricht: Shaker Publishing. ISBN 90-423-0192-9.
Squire G.R., 1990. The Physiology of Tropical Crop Production. Wallingford(UK): C.A.B. International. ISBN 0-85198-677-3.
Tea Research Stations, 1963. Planting experiments. Ann. Rept. 1962/63.Mulanje (Malawi): Tea Assoc. of C.Africa. Table 6.
Wild, A. (ed.), **1988.** Russell's Soil Conditions and Plant Growth. 11th edn. Harlow (UK): Longman Scientific and Technical. ISBN 0-582-44677-5. 991pp.

Shaxson, T. F. - Conservation of carbon, water and soil : a different perspective, pp. 28-40, Bulletin du RESEAU EROSION n° 23, 2004.