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EMERGING SOIL ISSUES AND THE ROLE OF PASTURES:

CAN YOU AFFORD TO KEEP YOUR SOIL?

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Abstract: *Soil degradation by erosion, structural decline, acidity and salinity is a major factor affecting the long-term sustainability of our agricultural systems and immediate farm profits. Loss of organic matter by erosion , or fire or by oxidation following ploughing results in soil structural decline and nutrient loss. Poor structure restricts soil water movement and poor plant nutrition limits productivity.*

Soil is one of the worlds most valuable assets and frequently it is the richness and fertility of this resource that determines a region's wealth (Murphy, 1991). Soil is the base for most agricultural activities and is essential for the broad scale agriculture that produces most of our food and fibre. Soil is the living system formed by the concentration of nutrients near the surface by plants. The recycling of these nutrients gives us a stable, sustainable system. Pastures can add sufficient organic matter to soil to improve soil structure but they cannot replace lost soil.

SOIL DEGRADATION

Soil is degraded when physical and chemical fertility are reduced, adversely affecting agricultural productivity. Degradation can occur by physical soil removal (erosion), nutrient depletion, decline in soil structure or the additions of toxins such as salt. Removal of soil by wind or water decreases the volume of soil available from which plants can extract nutrients and water. Nutrient depletion decreases nutrient availability, whereas structural decline restricts water entry to soil, reduces soil water holding capacity, and limits root growth. A high concentration of salt in soil limits the ability of plants to take up water and can have direct toxic effects on the plants.

SOIL LOSS RATES

Over thousands of years, nutrients are moved downslope by the transport of soil particles and solution. In a sustainable system the rate of loss is balanced by the rate of replacement. Weathering of rocks replaces nutrients lost in natural systems, whereas in agricultural systems, replacement is by fertiliser. Nutrients are also replaced by atmospheric accessions and by biological fixation in both systems.

To put soil loss rates from agricultural systems in context, geologic loss rates can be compared with current soil losses. For example, in the long term (tens of thousands of years) the Mooki Catchment, south of Gunnedah, has decreased in elevation (equated with lost soil) at the rate of 0.01 mm/yr (Gates, 1980) or 140 kg/ha/yr. In the shorter term, soil loss measured from cropped plots at Soil Conservation Research Centres in New South Wales averaged 2.4 t/ha/yr, standard deviation 3.25 (Edwards, 1991). There was a significant decline in yield with these rates of soil loss (Aveyard, 1983).

Ten tonnes per hectare per year is widely considered to be an acceptable rate of soil loss from fertile soils with depth >1.5 m, 5 t/ha/yr from fertile soils 1 to 1.5 m deep, and <1 t/ha/yr from infertile soils or soils <1 m deep (Rosewell and Edwards, 1988). The decline in yield with plot soil loss combined with the large difference between geologic erosion and the rate of soil loss experienced by cropping systems demonstrates that long term sustainability cannot be maintained by our current cropping systems.

In addition to broad acre soil movement, soil is also lost from drainage lines by gullying and stream bank erosion. In a study of rates of erosion from gullies and paddocks in a catchment near Uralla, northern NSW (Crouch, 1992), it was found that 70% of the eroded soil originated from gullies (5.0 t/ha/yr) and only 30% from the pasture/oats rotation paddocks (2.1 t/ha/yr). This is an extreme example in that some sections of the catchment were severely gullied. Nevertheless, soil loss from gullies can be a significant component of catchment sediment yield.

Rates of soil loss from sheet and rill erosion can be estimated using the Universal Soil Loss Equation (Wischmeier and Smith, 1978). This has been adapted for use in New South Wales by Rosewell and Edwards (1988) and is an ideal tool for comparing soil loss from various farming options.

NUTRIENT LOSS RATES

When soil is lost, preferential transport occurs, *ie.*, runoff is nutrient enriched. For example, the nitrogen content of sediment may be 50% higher than the original soils because the nitrogen rich organic matter is lighter and more erodible than soil particles. Also, the phosphorous content of sediment is increased because the clay particles to which the phosphorus is attached are more easily transported than sand (Stewart, 1975; Bargh, 1978). This has a direct effect on productivity and downstream water quality (Sweeton and Reddell, 1978).

Equations to estimate nutrient loss from catchments were proposed by McElroy *et al.*, (1976). Principally they consist of estimates of sediment yield multiplied by the concentration of the particular nutrient in the soil, multiplied by an appropriate enrichment factor.

SOIL STRUCTURE DECLINE

Soil structure is one of the major components affecting infiltration and water movement in soil, and the exploitation by plant roots of the water and nutrients stored in the soil. In Australia, successful dryland cropping relies on the efficiency of the soil as a catching and storing device for rain (Greacen, 1977). Maintaining the ability of the soil to: (1) catch water (infiltration); (2) transfer water within the soil (hydraulic conductivity); and, (3) store water (plant available water) are essential to the maintenance of soil productivity and viable agriculture. These are determined by soil structure and stability.

The removal of organic matter and clay by erosion also affects productivity by its effect on soil structure. This effect is compounded by the oxidation of organic matter induced by tillage.

SALINITY

Rising water tables and consequent salinisation are an increasing problem throughout New South Wales. Salinity is not a new problem, but in the last 10 years there has been a rapid increase in the effect of salt on crop and pasture production.

To maintain productivity, the soil not only has to be kept in place on the landscape, soil structure and nutrient content must also be maintained, and water managed to limit deep percolation.

THE CURRENT SITUATION

In NSW, most soils used for cropping have been in use for less than 100 years. The Soil Conservation Service of New South Wales recently conducted a survey to assess the extent of erosion and soil degradation (Graham *et al.*, 1989). This survey found that:

- Sheet and rill erosion currently affects 13% of the State, mainly on areas under cultivation;
- Gully erosion affects 23% of the State, mainly on the tablelands and western slopes;
- Wind erosion affects 25% of the State, mainly on cultivated areas of light sandy soil;
- Soil acidity affects 11% of the State, mainly on the tablelands and southern slopes under improved pastures;
- Soil structure decline affects 18% of the State, mainly on lands used regularly for cropping; and,
- Dryland salinity affects 1% of the State, mainly on the central and southern tablelands.

Cultivated areas are frequently associated with degradation by sheet, rill and wind erosion, and degradation by structural decline. Pastures are only significant in degradation due to increasing soil acidity.

CAUSES OF DEGRADATION AND SOIL LOSS

Over clearing of native vegetation, past land use, current farm management practices and the change from grazing to cropping are listed by Beal and Lothian (1989) as the major contributors to land degradation in the Murray-Darling Basin. These in turn lead to the more direct expression of soil loss, structural decline and salinity.

Soil loss causes can best be considered in terms of the Universal Soil Loss Equation (Wischmeier and Smith, 1978):

$$A = R * K * L * S * P * C$$

Where: A = soil loss per unit area
R = rainfall erosivity factor
K = soil erodibility factor
L = slope-length factor
S = slope steepness factor
P = support practice factor
C = cover and management factor

Anything that increases the value of these factors increases the risk of soil loss. For example, soil erodibility is a function of soil texture, structure, organic matter and permeability. A reduction in organic matter or soil permeability results in an increase in soil erodibility, "K", with a consequent increase in the risk of soil loss. Soil loss is inversely related to cover (soil protection from raindrop impact), and a decrease in cover increases "C", with a consequent increase in soil loss. Conversely, a reduction in these factors will reduce soil loss.

Soil degradation by structural decline is closely related to repeated cultivation and consequent reduction in organic matter (Harte, 1984; Clarke, 1986). The decline in organic matter reduces soil fertility through loss of nitrogen and organic phosphorus (Dalal and Mayer, 1986), decreases the strength of natural soil aggregates, and increases soil density (Harte, 1984; Quirk and Murray, 1991). Any increase in density has a direct detrimental effect on plant root growth (Passioura, 1991) by limiting the ability of plants to gather water and nutrients from a depleted soil supply.

Declining organic matter and degraded soil structure result in the collapse of large soil pores (1.5 mm diameter) and reduced infiltration and water movement (White, 1988). This results in a self perpetuating deteriorating spiral of low organic matter - low plant growth rates - lower organic matter - lower plant growth rates. Maintenance of soil organic matter is therefore essential for the maintenance of soil fertility.

Alternatively, salinity is the result of catchment mismanagement rather than the mismanagement of an individual area of land. Agricultural practices such as the replacement of trees with pastures and long fallow cropping systems have increased accessions to the water tables. This, in turn, has resulted in increased salinity, poor plant growth and soil degradation.

ON SITE COSTS OF SOIL DEGRADATION

In 1987, land degradation in the Murray-Darling Basin was estimated to be costing $215,000,000 per year in lost crop production (Beal and Lothian, 1989). This was itemised into losses that were irreversible and cumulative (wind erosion $0.1 M, water erosion $5.0 M), losses that were reversible but required expensive infrastructure (shallow water tables in irrigation areas $39.1 M, dryland salinity $0.4 M) and losses that were reversible through on farm management (soil acidification $27.8 M, soil structure decline $144.8 M).

At a local farm level, costs of degradation are variable, depending on the individual situation and seasonal conditions, particularly rainfall.

The effect of soil loss on yield of wheat was shown by Aveyard (1983) to depend on soil type. For a black earth, a loss of 220 tonnes of soil per hectare resulted in a 20% yield depression. On a red-brown earth, a loss of only 80 tonnes of soil per hectare halved the yield. The loss of A horizon material from the texture contrast soil depressed the yield much more than soil loss from a uniform profile. Similarly, the results of Hamilton (1970) show a much greater effect of soil removal on soils with shallow A horizons. Removal of the top 75 mm of soil from red texture contrast soils at Cowra, Wagga and Wellington depressed crop yields by 28%, 46% and 21%, while removal of a similar amount from black earths at Gunnedah and Inverell resulted in 10% and 6% yield reduction.

More recent studies using residual caesium-137 to estimate average net erosion from red-brown earths in northern N.S.W. have determined the effect of erosion on crop yield to be 0.35 percent per year per unit of log soil loss (Elliott *et al.*, 1988).

There is no doubt that soil degradation results in yield reduction. How much and under what conditions have yet to be well defined.

THE ROLE OF PASTURES

Pastures cannot replace lost soil, but pastures can replace lost organic matter, restore soil structure and use water whenever it is available. Further, pastures protect soil from the forces of raindrop impact and overland flow especially when correct management ensures that continuous cover is maintained throughout the year. Erosion of soil under pastures is therefore much less than soil under crop.

Well managed pastures can produce a significant improvement in soil structure (Greacen, 1958; Enright and Harte, 1984). In northern NSW, for example, three years of pasture was sufficient to significantly improve the aggregate stability of a degraded sandy clay loam. (Enright and Harte, 1984). The increase in stability was accompanied by an increase in organic matter. These studies also showed that grasses are more effective in improving soil structure than legumes, probably due to finer fibrous root systems.

The improvement in soil structure under pasture and its consequent effect on soil density has been related directly into the establishment of wheat seedlings (Millington, 1959). Soil that had been continually cropped had a density of 1.5 to 1.6 g/cm and a mean establishment of 5 plants per 25 cm of row. After 3 years of pasture, mean soil density was 1.3 g/cm and mean plant establishment was 7.5 plants per 25 cm of row. Results varied depending on seasonal conditions, particularly rainfall.

CONCLUSION

Cultivation of soils for cropping results in soil loss and structural decline. The impact on yield will vary depending on the soil type and seasonal conditions. Most current cropping systems are not sustainable in the long term.

Pastures have been shown to improve structure, fertility, infiltration and water holding capacity of soil. They therefore form an essential component in any long term cropping system.

The bottom line is, "Can you afford not to keep your soil?"

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