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# CHAPTER 5.II
# *The Impact of Mechanization*

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## 5.II.1 INTRODUCTION

Agriculture is a series of organized processes carried out by man on his natural environment, particularly affecting the soil and vegetation, for the purpose of systematically producing foodstuffs for substenance and raw materials such as fibres. The only other activities competing with agriculture in this respect are the gathering of wild plants, fishing and hunting. From the Mesolithic era when the world's inhabitants numbered just a few millions, agriculture has developed the earth's potential to produce foodstuffs such that, despite localized endemic or episodic famine, the world's population has been able to reach its current level of 4.5 billion over the course of a dozen millennia supported by agricultural production. Continuing rapid and sweeping progress in agriculture will be required in most countries in order to cope with the demographic growth expected in the coming decades (a world population of 5.6–6 billion people forecast for the year 2000, and 10—15 billions for the second half of the first century).

Agriculture is, above all, a process of coordinating the preparation, care, maintenance and harvesting of crops, but it also involves considerable handling and transport operations. It is a difficult activity, for in place of natural equilibria, it substitutes others which, if long-term production is to be maintained, must not have irreversibly destructive effects upon the land.

Agriculture by definition involves the use of various implements (many of which must be mobile or transportable), and the application of directed force. Equipment must be suited to a particular treatment of the soil, crops and animals, in order to respect biological imperatives and protect the new equilibria that are essential to the entire agricultural environment.

Much progress in agriculture has only been made possible through improvements in implements and the means of propelling them. This has involved a change from primitive manual farming to farming using draught animals, the machines for which were perfected relatively slowly, followed by a rapid switch to mechanized farming.

In France, for example, it was only in 1850 that this latter stage began to be apparent; 130 years later 99% of farming is mechanized, involving the use of 1 400 000 tractors and 150 000 self-propelled machines. Agricultural production has more than doubled over the last 30 years, a result achieved over a slightly smaller surface area by a workforce only three-quarters its former strength. There has been consequently a significant shift of farm labour (5 to 6 millions out of a total of 20 millions) into non-agricultural occupations which, until the oil shortages of the early 1970s, allowed for exceptionally rapid growth in the overall wealth produced in the country, and consequently a very significant rise in the standard of living. These changes have also met the demands met by the concurrent improvements in the average Frenchman's diet, the demographic growth of the country, and have created agricultural surpluses that have made large-scale exporting possible. Precisely the same changes are evident in agriculture in the United States, as noted earlier.

Throughout the world, agriculture has followed broadly the same sequence of development and it is possible to recognize stages in the development and introduction of new agricultural implements (Table 5.II.1). At present there are, worldwide, somewhat over 20 million farm tractors in service on 1.5

Table 5.II.1 The development of farm equipment and changes in food supply

| Approximate dates | Era or essential characteristics of the era | 'Agricultural' implements[a] | Means of acquiring food supply |
|---|---|---|---|
| −1 000 000 | TERTIARY↑<br>QUARTERNARY↓ | No implements (in the sense of tools specifically chosen, and possibly adapted, crafted and saved for identical and repeated use) | Gathering (?) |
| −600 000 | Lower Paleolithic | Cut stones { blunt & handled (1 side) ↓ (2 sides) sharp & thrown | *Hunting*<br>*Fishing*<br>and more methods of acquiring food supply (fruits, grains, leaves, roots, etc.) |
| −150 000 | Middle Paleolithic | | |
| −40 000 | | | |
| −20 000 . . . | Upper Paleolithic | | |
| −12 000/ −10 000 | Mesolithic | Sickles, axes, pickaxes | Ditto, plus forest exploitation, gathering of wild cereals |
| −7000/−5000 | Neolithic | Digging sticks<br>Hoes, grippers, spades<br>Swing ploughs | |

Table 5.II.1 (*contd*)

| Approximate dates | Era or essential characteristics of the era | 'Agricultural' implements[a] | Means of acquiring food supply |
|---|---|---|---|
| −3000/−2500 | PREHISTORY↑ | | |
| | HISTORY↓ | Pickaxes, spades, hand-held hoes | Hunting |
| | | Wheels | |
| America | | Digging sticks/shovels | Fishing |
| | | Stone-faced clubs | *Extensive husbandry* |
| Sumer, India | | Two-handled swing plough with seeder | |
| Egypt, Greece Rome | | One-handled Mediterranean-type swing plough without seeder | *Crops* |
| Mesopotamia | Antiquity | Transport vehicles | |
| Mesopotamia | | Transport sleds | |
| Egypt | | Blocking hoes and forks | |
| | | Bill hooks, beating rods | |
| | | Harrows | |
| | | Water-mills | |
| Rome | | Screw presses | |
| | | Swinging yokes | |
| −270 | | Two-handled wheeled gallows | |
| | Founding of the Roman Empire | Plough | |
| Gaul | | Ear harvester (disappeared in the 5th century) | |
| Beginning of the Christian era 395 | Roman Empire | Disymmetrical use of the swing plough | *Crops* |
| | | Two-piece flails | Hunting |
| | Barbarian invasions | Advances in metallurgy | Husbandry |
| 8th century | | Beginning of the development of the plough | Fishing |
| | Middle Ages | Development of the water-mill | |
| | | Mounting coulters on swing ploughs and ploughs | |
| 10th century | | Harrows, rollers | |
| 1453 | | | |
| | Renaissance | Plough supports | *Crops* |
| | | Metal spades | Hunting |
| | | Windmills with rotating roofs | Husbandry |
| | | | Fishing |
| 1600 | | | |
| | Pre-industrial transition period | First prototypes of seeders | *Crops* |
| | | | Husbandry |
| | | | Hunting |
| | | | Fishing |
| 1789 | | | |
| | Political unrest | | *Crops* |
| 1800–1820 | | | |

Table 5.II.1 (*contd*)

| Approximate dates | Era or essential characteristics of the era | 'Agricultural' implements[a] | Means of acquiring food supply |
|---|---|---|---|
| | Development of transportation and communication<br><br>Industrial expansion | Widespread use of scythes<br>Numerous industrial inventions applied or specific to agriculture: cultivators, crossbill rollers, hay-makers, mowers, windrowing corn-mowers, binders, combined-harvesters, threshers, fixed-part cubing machines, seeders, fertilizer spreaders, reversible mouldboard ploughs, multiple ploughs, steam-powered ploughing, self-propelled threshers, horse-powered generators and inclined horse-powered generators<br>Progressive replacement of cast iron, iron, and steel for wood in the construction of existing soil working machines. | *Husbandry*<br>Fishing<br>Hunting |
| 1860–1890 | | First development of advanced animal-powered equipment for other than soil working | *Crops*<br>*Husbandry*<br>Fishing |
| 1914–1918 | 1st World War | | |
| | | Second development of advanced animal-powered machines. Beginning of motorization | *Crops*<br>*Husbandry*<br>Fishing |
| 1929 | Depression | First development of combine-harvesting | *Crops*<br>*Husbandry*<br>Fishing |
| 1939–1945–1950 | 2nd World War | | |
| | | Development of motorized machines and mechanized farming | *Crops*<br>*Husbandry*<br>(Fishing) |
| 1973 | 1st oil shortage | | |
| (1982) | | Application of data-processing techniques to some farm equipment | *Crops*<br>*Husbandry*<br>(Fishing) |

[a]Hunting and fishing have been considered as 'agricultural' activities, utilizing natural resources in prehistoric times; implements for these activities have therefore been included in the agricultural implements section for this period only.

billion hectares of farmland. This equipment is presently concentrated in the industrialized countries, where barely 10% of the world's active farm workers produce close to one-half the world's food on one-fifth of the world's usable farmland, thanks largely to the efficiency of the equipment and amendments at their disposal. It is almost inevitable that mechanization will in the future have as great an impact upon the land in the other four-fifths of the world if its growing population is to be fed and their rising expectations are to be met. That the area of fertile land cannot easily be extended, and that in most countries such land is also in demand for other purposes, will in the future necessitate increased agricultural productivity from less fertile lands, involving the extended use of farm machinery.

A change from the use of draught animals to tractors as the source of motive power in agriculture is brought about because of perceived economic and human benefits (Table 5.II.2), but there are consequent changes to the

Table 5.II.2 Technical comparison between draught animals and tractors

| Draught animals | Tractors |
|---|---|
| Must be cared for every day | Require maintenance only in terms of the amount of work they perform |
| Must be fed every day | Only consume energy when they work |
| Require large areas to be devoted to growing their food | Consume petroleum products which must be obtained outside the farm (and even the country) |
| Tire after 8–10 hours of work, including the breaks needed during the working day | Can work long, solid hours without breaks or interruptions if the operating personnel work in shifts |
| Work at one, slow speed—that of man | Work at a choice of several speeds, up to about 30 km/h |
| Leave discontinuous, shallow marks in the soil | Leave large, continuous tracks in which soil compaction may be deleterious |
| Can turn in place under certain circumstances (except with some types of hitches) | Have turning radii of several metres, causing wider furrows |
| Most often require the carter or ploughman to walk behind the hitch (10 km in single-share ploughing per workday) | Allow the driver to sit in increasingly comfortable seats on a heavy vehicle |
| Can be driven from a long distance but with a reaction time that is sometimes quite long | Require the driver to be in place, but execute his commands immediately |
| Can make major efforts, but for a short time | Can only get out of difficult spots if high-powered equipment is used |
| Produce manure | Do not provide manure but spread it quickly and efficiently, especially artificial fertilizers |

Table 5.II.2 (*contd*)

| Draught animals | Tractors |
|---|---|
| Are silent and non-polluting | Are noisy and polluting |
| Even when riding the hitch the carter is subjected to slow bumps; nevertheless, he is not subjected to high-frequency vibrations | Create high-frequency vibrations which the driver feels if they are not adequately absorbed |
| Are dangerous (fatal accidents possible) | Are dangerous (fatal accidents possible) |
| Replacements can be made relatively cheaply by breeding | Replacements involve high capital costs |
| When hauling, can only deliver low continuous effort (75 kg per draught horse) using conventional hitches of 1 to 4 horses (beyond that number, the animals are difficult to hitch and lead, and their output is worse still) | When hauling, can deliver high continuous effort (several tonnes, for example) without difficulty if the engine chosen is sufficiently powerful, if the work speed is not too great, and if traction is satisfactory |
| When the mechanism is in motion, it is necessary to have a drive wheel operating on the ground; the efficiency of this system is limited by the low traction of the hitch and its low flexibility (does not operate at rest, jerky starts, necessity of working over dry ground, etc.) | When the mechanism is in motion, all operations are possible thanks to the power take-off, and the power transmitted can be very high if tractor class and power are adequate; tractors have made total mechanization of farm work possible |
| Draught animals cannot work at night | The tractor has headlights |
| Draught animals can work over loose, wet earth | The tractor's efficiency is limited by its traction and it is inadvisable to insist upon working on earth where the modern tractor has no traction |
| Draught animals can supply energy in place by means of a rotary device; the energy is limited to the continuous effort of one or perhaps two animals which must take breaks | The tractor can provide energy when stationary without difficulty, with no other limitation than engine power, and without having to take breaks |
| In the fields, the working part of the machines can only be lowered by the force of gravity and raised again by means of a ratchet wheel | In the fields, lifting and hydraulic depth adjustment of the implements are possible; electric controls are also used |
| Cannot carry tools | Can carry heavy implements |
| Do not require special knowledge of mechanics | Require considerable mechanical knowledge, which is new for farmers |
| Correspond to a long agrarian tradition | Are new for farmers |
| Hardly allow for progress in work productivity, once animal-powered harvesting equipment, representing the second phase of the mechanization, has been acquired | Only require the use of new, more powerful mechanical equipment to offer new direct possibilities and substantial progress in the productivity of work |

soil itself which may or may not in the long run be beneficial. These fall into four main groups:

(1) factors which facilitate an extension of the area under cultivation;
(2) those which lead to compaction of the soil;
(3) factors enabling cultivation to greater depths;
(4) those which encourage changes in the chemical as well as the physical properties of the soil.

The principal items of equipment enabling this intensification of agriculture and consequent transformation are of five principal types. First there are multi-purpose tractors, increasingly of the heavier four-wheeled-drive kind. Secondly there are implements for working the soil—including the plough, still the most widely used of farm implements, but also including deep-working equipment such as chisels, spading machines and sub-soil ploughs as well as a wide selection of cultivators and harrows employed in the preparation of the seedbed. Thirdly there is a very wide range of machines involved in the spreading of wet and dry fertilizers and pest control chemicals. The fourth group of machines are those involved in the harvesting process: combine harvesters for grain crops, hay cutting and turning and silage equipment for grass. Root crops such as potatoes and sugar-beet can also be harvested using mechanical means, often self-propelled, as can vegetable crops such as peas and beans and even grapes and cotton. A fifth type comprises the multifarious pieces of farm machinery which use electricity as a direct source of power.

### 5.II.2 SOIL MANAGEMENT

Transformation of the land to create a good soil physical environment is a prime requirement for high levels of crop production, and this is synonymous with good soil structure and subsurface drainage. Such a condition provides an appropriate pore size distribution, optimizing available water and aeration status, and helps to provide adequate temperatures with minimum impedance to root development. Soil management through land transformation is concerned with maintaining and, it is hoped, improving this environment; but in the process, two opposing sets of forces are at work, one group tending to improve structure and the other causing deterioration.

Soil structure improvement arises largely through the related activities of plant roots, soil organisms and natural weathering. Roots, through their growth, exudate and breakdown products and coupled with organism activity, are responsible for the formation and the stabilization of the larger conducting pores and structural units throughout the soil profile. Mechanical operations can assist in exposing soils to the weathering agents and in the formation of the larger pores but can do little for their direct stabilization.

The forces causing soil structure deterioration, and thus increasing the negative aspects of transformation, are related to those activities which encourage the oxidation of organic matter, aggregate destruction through mechanical or chemical means, and restrictions to root development through impeding layers and general compaction. The deleterious activities are frequently associated with many farming operations, including soil tillage and harvesting, traffic, poor drainage and irrigation, as well as rainfall impact erosion of bared soil surfaces.

## 5.II.3 PAST AND CURRENT APPROACHES TO SOIL HANDLING

Experience in Britain exemplifies the changing influences of the mechanical management of soil and consequent soil transformation.

### 5.II.3.1 Soil Handling in Britain before 1960

The initial method of cultivation based on a digging stick or hoe was shallow, extremely precise, and limited in area, with soil only being disturbed where absolutely necessary—largely for the control of weeds. The introduction of animals as a source of power, and the mouldboard plough for weed burial, changed this precision tillage into a form of more extensive and complete tillage. Adequate burial could only be achieved through deeper working at 50–100 mm depth and complete soil surface inversion. The deeper tillage resulted in the formation of clods, and hence the need for subsequent operations for seedbed preparation.

The ideas and practices developed by Jethro Tull in the eighteenth century led to a considerable increase in the amount of complete tillage, based on the premise that production increased with increased soil working. Soil preparation came to take the form of ploughing and cross-ploughings, followed by multiple harrowing and often inter-row hoeing. These practices continued well into the twentieth century.

Interest in deeper tillage to depths of 500–600 mm, usually linked with subsurface drainage, increased in the nineteenth century, but the practice was never widespread and ceased abruptly as agriculture entered the depression at the end of the century. Protagonists of these practices attributed the improved crop response as much to better drainage as to greater rooting depth.

The introduction of the tractor in the twentieth century did not change soil handling methods, although ploughing depths tended to increase. Yield responses to deeper working were very variable and, where positive, were largely attributed to better weed control Russell (1956).

During the whole of this period, from the introduction of the mouldboard plough by the Romans to the late 1960s, a system of complete uniform tillage was practised with effectively random passes of animals, tractors and implements across the fields. Crops were established largely in the spring, allowing plenty of time for soil weathering following autumn ploughing. Although tillage was frequently excessive, the major benefits came from weed control, and weathering played a major role in conditioning and restructuring structurally damaged soil. The power available for soil movement was low, and hence soil conditions themselves played a large part in dictating whether soil working was possible. Soil loadings over the period were relatively low, and the results of studies of comparative tillage Russell (1956) and of compaction (Soane, 1970; Eriksson *et al*., 1974) show that most of the soil damage resulting from the farming operations was confined within the plough layer. This damage was alleviated annually through ploughing and weathering action.

### 5.II.3.2 Soil Handling in Britain after 1960

During the 1960s the rate of technological change started to increase rapidly, the changes being initiated by economic factors and research. The major changes which influenced soil handling practices were:

(1) large increases in yield potential of crop varieties;
(2) increased fertilizer, pesticide and herbicide usage;
(3) the introduction of paraquat;
(4) reduction in farm labour forces;
(5) the increased power available;
(6) a change from farmyard manure to slurry;
(7) closer links between producers and processors.

These changes stimulated a rapid increase in yield in many crops and in the quantity of materials to be handled. There were also increases in crop inputs (e.g. fertilizers and herbicides) and in the timeliness of their application; a move towards autumn-drilled crops and earlier and shorter establishment periods; and increased stocking rates and a longer grazing season. These changes in turn resulted in:

(1) harvesting times dictated increasingly by crop growth stage rather than soil condition;
(2) reductions in effective soil weathering time between crops;
(3) the increased importance of soil physical conditions influencing output as fertility levels increased.

The response of the farm machinery industry to all of these changing factors in the agricultural scene was to increase machine capacity and power further, which led to an increase in the weight of the equipment (Table 5.II.3). The tractive performance of power units was improved by making maximum use of weight, and the additional weight, particularly on implements, was supported on high-pressure, high-ply-rating, relatively small-diameter and narrow tyres. The industry also introduced specialist processor-inspired machines, frequently designed with little thought for soil conditions.

Table 5.II.3 Sizes of farm equipment

| | Power (kW) | Mass (tonnes) | |
|---|---|---|---|
| | | 1970 | 1983 |
| Wheeled tractors | 26 | 2 | |
| | 60 | 3 | |
| | 150 | | 10 |
| | 200 | | 12 |
| Combine-harvesters (full tank) | | 6 | 15 |
| Trailers | | 5 | 15 |
| Manure spreaders | | 4 | 10 |
| Potato harvesters (tankers) | | | 10 |
| Self-propelled slurry tankers | | | 25 |
| Ministry of Transport maximum allowable axle load (UK) | | 11 tonnes | |

The net effect of all these changes on the soil and its response can be most clearly seen by following the developments and experiences in the direct drilling of cereals on the well-suited soils which started in the early 1960s. Initially the results were very encouraging, with equivalent and sometimes higher yields than from traditional tillage systems (Davies and Cannell, 1975). Continuing improvements were noted in pore size distribution, organic matter levels, surface tilth, soil structure and soil support capacity (Russell *et al*., 1975). After a period, however, compaction symptoms started to appear, coinciding with significant increases in machine contact loads and pressures. The soil, even in its undisturbed state, was now no longer capable of supporting the surface loads without unfavourable deformation.

An increase in soil problems was also experienced over the same period in the root-crop growing areas, resulting in increasing abandonment of these crops on the heavier soils. Whilst soil damage was not the only reason for a cropping change, these soils were the first to suffer from the more punishing loads, with farmers finding increasing difficulty in rectifying the structural problems created. Similar compaction problems have also arisen in intensive grassland areas, where stocking densities, and the weights of forage- and slurry-handling equipment, have all increased.

This period has therefore seen a very large increase in soil loading and a move from initially satisfactory zero tillage to a situation where there is increasing interest at both farm and research level in the possibilities of deep tillage for the future.

Similar developments in tillage and machinery practices have taken place in many parts of the world, the major difference being the time scale, with certain areas still practising precision tillage and others strip tillage with animal-drawn equipment.

## 5.II.4 FUTURE SOIL MANAGEMENT OPTIONS

The brief review of past and current soil-handling practices highlights the emphasis placed on management measures to overcome problems, rather than attempt to prevent the problems arising in the first place. The options open for the future are therefore either to continue this reclamation management approach, or to move towards preventative management.

In the tillage/mechanization area the damaged soil zones have until recent years been confined within the top 300 mm of soil. This has allowed the annual reclamation process of tillage plus weathering to alleviate most problems. Any continuation, however, of the current machinery trends with increasing loads will increase the depth and degree of compaction damage, making reclamation increasingly more difficult and expensive. Figure 5.II.1, taken from Eriksson *et al*. (1974), shows the increase in vertical soil deformation at depth that can be expected from higher surface loadings, even at the same contact pressures. The situation has already arisen on many farms, as shown in Table 5.II.3, where the axle loadings on a material—namely soil—which the civil engineer removes immediately as being unsuitable for a road, exceed the permissible loads on a carefully prepared road pavement.

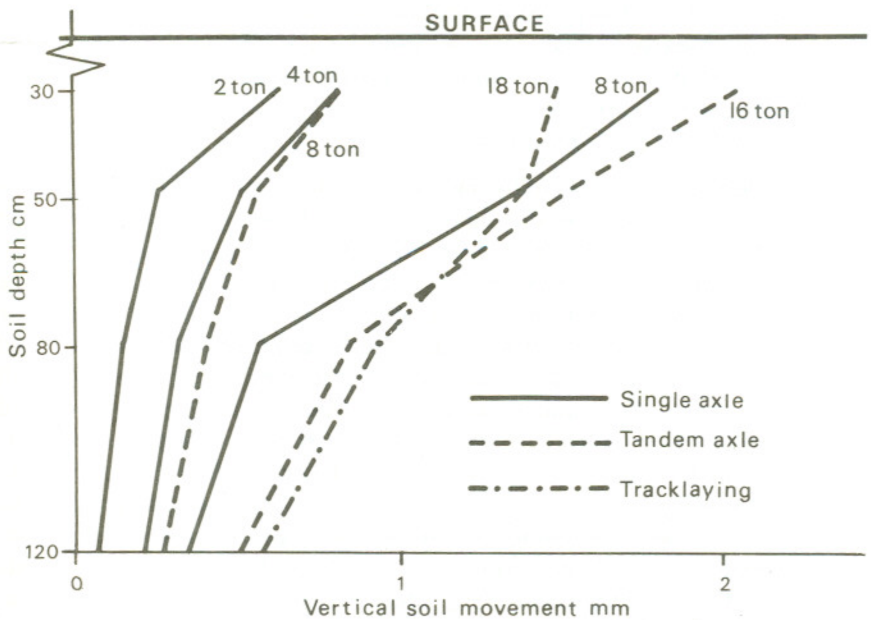


Figure 5.II.1 Vertical soil movement under loaded wheels and tracks (Danfors, 1974)

The results from continuing Swedish work (Hakansson, 1980) on the natural recovery of deeper compacted layers suggest that compaction effects could last for decades. Virtually no alleviation of compaction within a layer at 350–450 mm depth had occurred over a 2-year period, despite the soil freezing annually to depths well below this. The principles and techniques for satisfactory soil loosening at depth are established to enable deeper reclamation to be executed (see Spoor and Godwin, 1978), but loosening alone does not immediately rectify structural damage. The continuation, therefore, of this reclamation form of management in the future must be seriously questioned, for even without deep compaction problems, the annual ritual of loosening soil for the pleasure of recompacting it again makes little sense if it could be avoided. Any move towards a system of preventative management will require a reduction in the magnitude of the punishing loads and pressures applied to the soil. Such a change will almost certainly involve a cost, and hence it is worth while considering the potential benefits which may be achieved from preventative management to weigh against this cost.

## 5.II.5 POTENTIAL BENEFITS FROM PREVENTATIVE MANAGEMENT

The possible benefits arising from control over the level of soil compaction and traffic can be categorized as follows:

(1) avoidance of yield depressions resulting from incomplete reclamation;
(2) yield increases as a result of an improved soil environment;
(3) reduced establishment costs and increased system capacity;
(4) increased working period;
(5) opportunity for precision tillage.

The yield depression of the following crop resulting from incomplete reclamation can vary widely, depending upon the level of damage remaining and the subsequent weather conditions. Figure 5.II.2, taken from Hakansson (1980), shows equilibrium yield depressions resulting from medium-size farm vehicle compaction every autumn prior to ploughing over a 10-year period in Sweden. The compaction effect was mainly restricted to the plough layer, and an elapsed time of 5 years was required after the experiment to alleviate all the damage done. Continuing yield reductions are also being recorded following compaction damage to 500 mm depth created through one concentrated wheeling treatment with a 16 t tandem axle trailer (see Figure 5.II.3).

Whilst it is recognized that there is an optimum degree of compaction for crop production, deep loosening experiments without subsequent recompaction by wheels give some indication of the potential for yield improvements (see Table 5.II.4 and Stephens (1855), McEwen and Johnson (1979), Rowse and Stone (1980) and Gooderham (1976)).

Table 5.II.5, derived from Patterson *et al*. (1980), shows the influence of

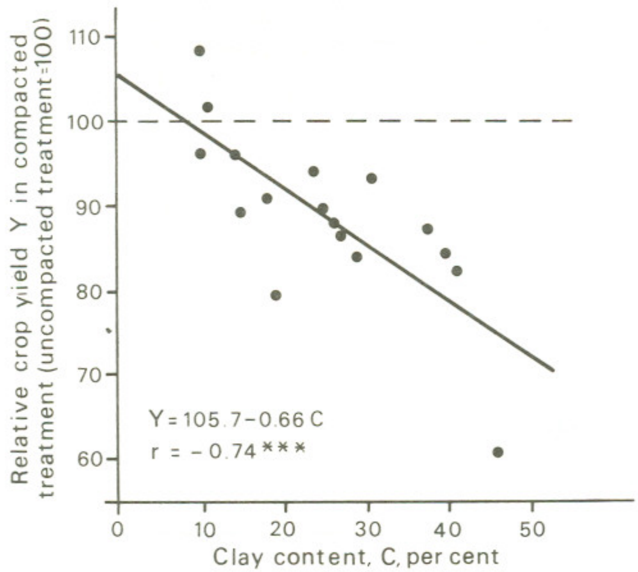


Figure 5.II.2 Yield depression from farm-vehicle compaction during previous harvest (Hakansson, 1980)

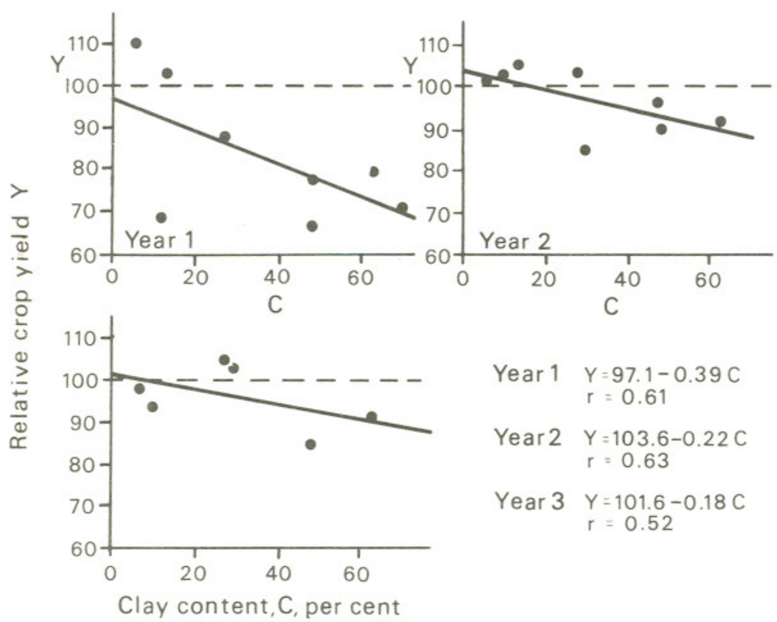


Figure 5.II.3 Yield reductions in successive years following compaction damage at 500 mm depth (Hakansson, 1980)

Table 5.II.4 Crop response to deep-soil loosening (% yield increase)

| | Drainage only | Drainage and deep loosening | Deep loosening |
|---|---|---|---|
| Yester 1850 (clay) | | | |
| cereals | 35 | 95 | |
| turnips | | 100 | |
| Rothamsted (sandy loam) | | | |
| cereals | | | 20–25 |
| sugar-beet | | | 11 |
| potatoes | | | 0 |
| Wye (silt loam) | | | |
| cereals | | | 15 |
| Wellesbourne (sandy loam) | | | |
| potatoes | | | 0 |
| broad-beans | | | 25–95 |
| red-beet | | | −3–20 |

working depth on the cost and system capacity when establishing winter cereals. The significant penalties from deeper soil working to overcome deeper compaction can be clearly seen.

Spoor and Godwin (1978, 1979) have shown that soils can be effectively loosened at moisture contents well in excess of those commonly considered as limiting, providing confining stresses are low. Table 5.II.6 shows brittle or loosening failure occurring in triaxial compression test samples at moisture contents well above the plastic limit. With traffic control, therefore, the opportunity exists for increasing work days and timeliness, extending crop growing seasons, and extending root-crop production to heavier soils.

The current approach to crop establishment executed with random tractor passes is completely dominated by the action of the wheels or tracks. The

Table 5.II.5 Relationship between cultivation working depth and cost of establishing cereals (Patterson *et al*., 1980)

| Cultivation depth (mm) | Relative cost | Relative output (time/unit area) |
|---|---|---|
| 0 | 1 | 1.0 |
| 100 | 0.9 | 2.0 |
| 150 | 1.3 | 3.5 |
| 200 | 1.8 | 4.0 |
| 400 | 2.8 | 7.0 |

Table 5.II.6 Effect of soil moisture on type of soil failure at low confining stress (% samples failing in brittle manner)

| Soil | Moisture tension (bars) | | | | Moisture tension at plastic limit |
|---|---|---|---|---|---|
| | 0.5 | 0.16 | 0.50 | 1.00 | |
| Wicken Series Clay | 0 | | 37 | 90 | 2 |
| Fladbury Series clay | 12 | 50 | 100 | 100 | 9 |

tractor wheels continually modify the soil condition produced by the implements, tending to increase the degree of compaction at each pass. This could well be a major reason for the lack of significant differences between implement and no-tillage treatments in many tillage experiments. Control over the dominating wheel opens up the possibility of returning to precision tillage. Particular attention can then be paid to providing optimum but different conditions in various parts of the field and the soil profile for the seed, the roots, wheel support and traction and the conservation of water and soil. Figure 5.II.4 illustrates, from the work of Prestt at Silsoe College, the

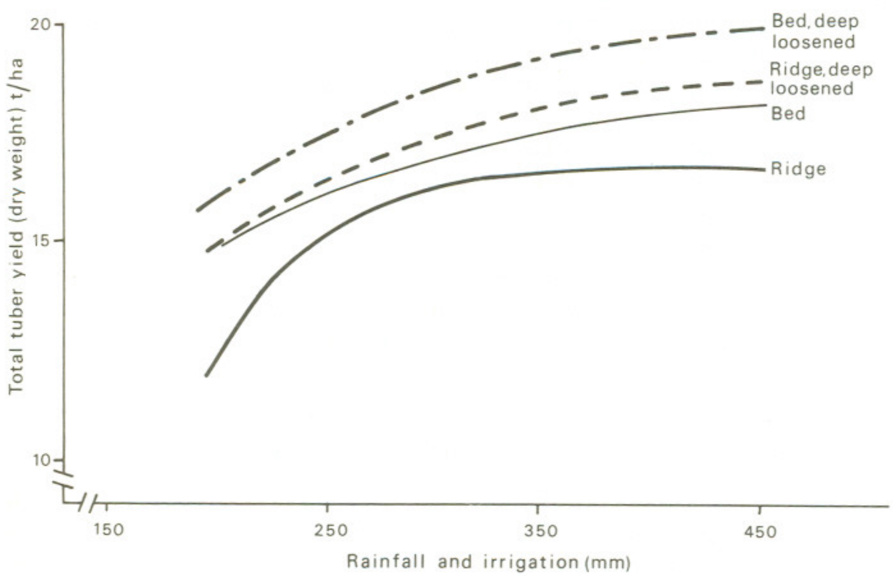


Figure 5.II.4 Influence of bed and ridge cultivation on potato yields (Prestt, 1983)

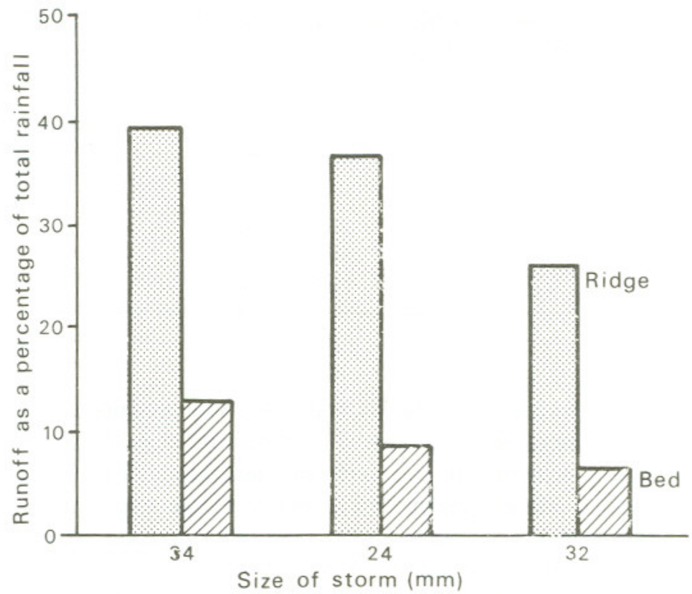


Figure 5.II.5 Influence of bed and ridge cultivation on rainfall runoff

type of yield improvement possible from providing a potato growing area within a bed system rather than in traditional ridges. The bed surface profile was formed to encourage water movement into the growing area, rather than runoff into the compacted traffic support area in the furrows. Differences in percentage runoff between the bed and ridge treatments are shown in Figure 5.II.5.

Larger-scale soil conservation measures rarely eliminate soil loss and are often not feasible in smallholder agriculture. Preventative management can, through significantly reducing soil loss, maintain soil fertility and hence production capacity.

These potential benefits, coupled with the increasing difficulty and cost of satisfactory deeper soil reclamation, force us into the situation where much more effort must be put into preventative rather than reclamation soil management.

## 5.II.6 A PREVENTATIVE MANAGEMENT APPROACH

In tillage mechanization, preventative management must involve a reduction in the damaging effects of traffic, the modification of husbandry techniques and greater attention to subsurface drainage. Similarly, drainage and husbandry methods must be given greater emphasis in irrigated and erosion prone areas. Interest is increasing in the possibilities of preventative management, but doubts exist as to its feasibility. Possible ways forward are considered under the following categories:

(1) reducing soil compaction potential of traffic;
(2) field control of wheels and tracks;
(3) soil preparation;
(4) drainage;
(5) cropping.

The two major factors influencing the compaction potential of traffic are the contact pressures and loads. Whilst it may be unrealistic to expect significant weight reductions in future, unnecessary weight can be shed and consideration given to restricting the magnitude of future increases. The suggestion made by Hakansson (1979) that axle loads of agricultural vehicles should be restricted to keep compaction damage within the top 400 mm must be considered very seriously.

The level to which farmers can reduce inflation pressures with current equipment and tyres is limited. Very low ground pressures (5–10 kPa) can be achieved on light, low traction vehicles using existing tyres. This is not possible, however, with the current very-high-pressure equipment such as trailers, combines and other harvesters, nor on vehicles with high traction requirements. The use of dual wheels can help, but their application is frequently limited by width restrictions and maximum allowable bending moment and torque levels in existing axles. Many of these problems can be resolved at acceptable cost at the design stage—hence the need for farmers to encourage manufacturers into action to minimize the compaction potential of their products. Crop transport operations are frequently the most punishing to the soil, and the continuing development of interlinked field and road container systems offer much promise for the future. In the meantime, farmers can benefit from making best use of the tyre equipment available, ensuring operation of their current units at maximum allowable tyre deflections and by achieving adequate traction through minimum rather than maximum added weight.

Tramline and bed systems for the control of through crop traffic after establishment and before harvest have proved very successful. Their full potential for complete traffic control through all operations has yet to be realized in most situations.

Situations requiring soil disturbance may be significantly reduced in future if good traffic control can be established. Where soil disturbance is still necessary, however, there are two major information gaps constraining the future development of soil preparation techniques. These are the lack of information on the actual soil environment required, and of objective tests to define the soil environment. These aspects were less important in the past when almost complete reliance was placed on the successful combined action of mouldboard ploughing and weathering to provide the required soil conditions. Future research programmes need to be directed towards providing this information in a form which would enable a more precise approach to be taken to tillage in the field. This requires a clear definition of the necessary environments for the seed, roots, and soil, and water conservation so that appropriate conditions can be produced between the controlled traffic zones.

In the immediate future in situations where traffic control cannot be achieved, a reversal in the sequence of tillage operations should be considered so that soil loosening, if required, becomes one of the last operations rather than the first, to minimize the risk of excessive recompaction. Great scope exists for the better use and selection of tillage equipment to avoid the creation of new problems when overcoming the original one. There is similar scope for maximizing the use of undisturbed soil strips during multi-pass operations, to maximize traction and minimize rolling resistance and compaction.

The long-term maintenance and improvement of soil structure is mainly dependent on root and organism activity together with natural weathering action. This improvement can be best achieved through minimum soil disturbance by cultivation and surface traffic, and good subsurface drainage below. Subsurface drainage is therefore one of the most effective and necessary aids to preventative soil management, contributing by increasing the soil resistance to compaction as well as through improved aeration and salinity control. Drainage problems are most severe and solutions most expensive in the finer textured soils, where close drain spacings are required. Appropriate soil loosening measures and mole drainage have much to offer in these situations, and possibilities should be explored for widening the use of these techniques in conjunction with other subsurface systems.

Soil erosion on erodible soils can only be prevented by protecting the surface soil layers and maximizing infiltration rates and minimizing runoff. Much more attention needs to be paid to the field conditions if soil losses are to be avoided, or reduced, in many areas. Field conditions more resistant to soil loss can be achieved through appropriate crop selection and zero or precision tillage, coupled where possible with the use of herbicides. Trends in recent years have been both towards reducing the number of farm enterprises and increasing farm size, with the demise of the crop rotation. In many situations farm size has now reached a point where more enterprises and crops could be contemplated and investigations into the possibilities of a return to the preventative management rotational systems would be well justified.

To summarize, the major research and development role for the farmer in any move towards preventative management lies in the area of field operation, organization and husbandry. The manufacturers' part is in providing equipment of appropriate width and performance to match the field systems and to reduce the compaction potential of their equipment. The major priority for the research and extension worker is the definition of soil environmental requirements and the development of objective tests, as well as the promotion of field drainage and preventative husbandry measures.

## 5.II.7 CONCLUSIONS

Changes in mechanization and soil-handling practices in recent years have placed increasing pressure on the soil environment, with soil structural problems tending to become more severe and deep-seated.

The previous approaches to soil management, based primarily on reclamation methods are rapidly becoming inappropriate; hence the need for a change towards more preventative management. Major benefits can be gained from following a preventative management approach, but they will only be attainable following a combined coordinated attack on the outstanding problems by farmers, manufacturers and researchers together. The slogan for the future must be 'prevention is better than cure'.

## 5.II.8 REFERENCES

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*Note*: A major portion of this chapter was previously published by Gordon Spoor in the Agricultural Engineer, 1983, Vol. 38, No. 4, pp. 95–100, entitled 'Soil management or reclamation?'.