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Farewell SIAE
Welcome SCAE

The Institution of Agricultural Engineers

Journal and Proceedings

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Front cover:
The office block of the Scottish Centre of Agricultural Engineering (SCAE) at Penicuik, which is a constituent part of the East of Scotland College of Agriculture and the Scottish Colleges of Agriculture

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Guest editorial
Valediction to the Scottish Institute of Agricultural Engineering

David P Blight

THE following remarks were given to staff on the closure of the Scottish Institute of Agricultural Engineering and the transfer of its remaining staff and assets to the Scottish Centre of Agricultural Engineering.

"British Agriculture is passing through hard times. No single panacea will cure the ills from which it is suffering, but I have the best reason to think that the leaders of the industry would agree with me in looking hopefully to the development of research as a powerful agency of restoration". These are the published views of the Minister of Agriculture. Not, however, the current Minister, but Arthur Boscawen, writing in 1922.

There is currently much debate over the low level of civil research in the United Kingdom, but governments seem unable to get their timing right. We, as engineers, could say they seem to have an in-built 180° phase lag. SIAE is a casualty of the campaign to reduce public expenditure on research. Yet at the same time there is a growing realisation of a pressing need throughout the UK for more research and development, but the small unit size and depressed state of both the agricultural and the agricultural engineering industries in this country militates against substantial industrial funding; at the last survey, 80% of British agricultural engineering manufacturers employed fewer than 20 people.

With research we rightly couple development. Without adequate development, research can be a gift to our competitors. Many of us have long been advocating a greater emphasis on development, particularly in view of the small size and low capitalisation of most UK agricultural engineering firms. However, development can be very expensive, and our suggestion that more resources be directed towards the further development of new machines, particularly those originating at the Institute, has not been accepted.

David Blight was Director of the Scottish Institute of Agricultural Engineering at Penicuik, Midlothian from 1977–87.

Despite this, however, the Institute has a good record of successful innovation, and the results of our work, either as complete machines, or machine parts, can be seen at practically every public exhibition of farm machinery.

Reorganisation policy and structure

When the Green Paper of the Department of Agriculture and Fisheries for Scotland was issued the intentions for SIAE were apparent — practically all the research programme of the Institute, agreed only a short while before, was to cease; virtually only the soils work was to remain. We all pulled together to try to get this proposal dropped and many letters were written to the Secretary of State by firms with which we had worked, by other organisations, including a number of overseas laboratories, which recognised the quality and the importance of our work, by consultants and by professional and trade organisations. These letters all urged the Department to think again about its proposals for SIAE. The MP for Midlothian, Mr Alex Eadie, arranged an adjournment debate in the House of Commons; this is on public record in Hansard, indicating the value of much of the Institute's work, while a number of Parliamentary questions were asked. The Sixth report of the House of Commons Agriculture Committee expressed its disquiet over the proposals for SIAE and a debate in the House of Lords was being planned, but fell through because of more urgent business. Recognising the vulnerability of a small institute within the Agriculture and Food Research Service, particularly following the proposal for discontinuing SIAE, I suggested to the Scottish Committee of the Governing Body that the Institute might be taken out of the AFRS and made the Agricultural Engineering Research arm of the Scottish Agricultural Colleges. The Committee agreed with this proposal, and the Senior Staff of the Institute prepared proposals for a Scottish Centre of Agricultural Engineering, which were approved by the Scottish Committee and sent to DAFS. The Department welcomed the constructive approach to reorganisa-tion and showed itself sufficiently flexible and receptive to the views generally expressed to agree to the setting up of the centre with a budget of about twice the sum originally proposed. As a result of our strenuous fight, SCAE begins with a substantial dowry and becomes the Engineering Division of the East of Scotland School of Agriculture.

Achievements of SIAE

It is appropriate today to review the achievements of the Institute. Created in 1946, in the heady days after the war when, in the aftermath of fighting, the forging of a new and better world was seen not only as desirable, but also as possible, the Institute has a record of over forty years of progress before falling victim to the demand for savings — or, perhaps, the cynical view that a better world is unattainable.

Our achievements in the more recent past include a number of commercially adopted inventions including — the X-ray separator for potato/stone/clod mixtures — the strip seeder — the recording soil penetrometer — the soil density probe — the "Golden Slipper" crop deflectors — the semi-automatic separator being used very successfully for egg candilling — the plastic link grading screen — the straw incorporator, and many more. Others are licensed, or at an advanced stage of development.

Many of our efforts have been directed towards the general aim of aiding the machine designer through specifying the performance characteristics which equipment ought to meet. Examples of work of this type include — the frequency and amplitude of vibration of the picking fingers for raspberry harvesters — the limitations of low ground pressure on soil compaction where vehicle weight is high — the optimum shape of swath to be formed by mower conditioners — the effect of tank shape and position on the stability of liquid-carrying vehicles on slopes — the effect of the interaction of season, variety and drop height on damage to potatoes — the strategy for using near-ambient temperature grain driers.

The Institute has received international recognition for its work in four areas, methods of measuring the degree of soil compaction in the field, its effects on crops and the long term condition of the soil, together with means of ameliorating them; the mechanisation of all aspects of growing and handling the potato crop; the behaviour of tractors and machinery on slopes; and the mechanical harvesting of raspberries. I believe that very soon our work on the drying of forage in the swath, the modelling of forage production and harvesting, and the studies of energy usage, including the capture of solar energy for crop drying and other purposes will also achieve international acclaim. Not bad for an Institute which at its highest had a total complement of only 100, about half of whom were researchers! We have set a hot pace for other organisations to follow, and our thinking has often been so far in advance of the rate at which others have realised future needs, that it has taken years before the importance of our line of thought has dawned elsewhere.

The Institute bows out at the peak of its achievements. We have won the important battle to retain an agricultural engineering research capability in Scotland, in a framework which will be capable of expansion when the need becomes as apparent to others as it is clear to us. The Duke of Wellington once pointed out that next to a battle lost, the saddest sight was a battle won, and we have had casualties; some of us have to go.

The new Scottish Centre of Agricultural Engineering combining teaching, specialist advisory work and research has considerable potential and we wish it, and those of the staff transferring to it, success in the future.

Water hyacinth and soil fertility:

a review on an integrated approach to soil fertility with biogas production in the African rain forest

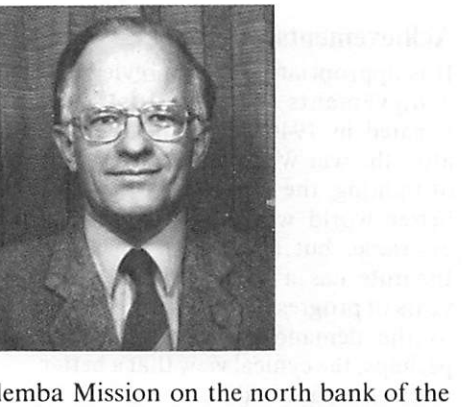
Alan Casebow

Summary

WATER HYACINTH (*Eichornea crassipes*) infects many tropical rivers and waterways and is virtually impossible to eradicate. Ideas are put forward in this paper to suggest that it can be turned into an economic asset, providing energy and fertiliser for the development of rain forest agriculture and to promote the conservation of soil fertility and forest cover in the rain-forest zone. This would help progress towards a stabilised permanent agriculture. After comments on the history of water hyacinth on the waterways of the Zaire basin, the relationship between the rain-forest and the soil in which it grows is outlined. Several methods for maintaining soil fertility are examined and proposals made for a possible development from shifting cultivation to a corridor or alley cropping system involving the use of the leguminous tree, *Leucaena leucocephala* to bring about areas of more permanent agriculture. The use of water hyacinth as a raw material for biogas plants in remote areas is examined before passing on to the anaerobic digestion processes, using the slurry as a fertiliser and providing gas as a source of energy. The designs of digesters, with comments from both Indian and Chinese experience, are discussed along with slurry distribution problems.

1 Introduction

Water hyacinth (*Eichornea crassipes*) is a tropical water weed which is well known around the world. Originating from the Orinoco River in Venezuela, man has spread water hyacinth into many countries throughout the tropics and it persists today in every country it has invaded. It was reported on the Congo first of all in 1952 and by 1955 had covered 1500 km of waterways, becoming a particular problem on the leeward side of banks and islands in the main river, and in small rivers and streams. The plant deoxygenates the water and increases surface evaporation by as much as four times the rate from open water (Casebow 1984). The banks and islands in some parts of the main river are infested to a width of 5–10 metres. The problem of this weed first occupied the author's mind in the early Sixties while



based at the Yalemba Mission on the north bank of the River Congo (now known as the Zaire) some 20 miles upstream from Basoko.

Zaire lies astride the equator and, occupying 13% of the African landmass, is a huge country. Its rain forest covers about 45% of the country. Many attempts have been made to control water hyacinth in the rivers, without success. If it cannot be controlled economically the author wonders if it can be kept in check and developed as an economic asset for the rural communities. In 1964 enquiries revealed a source (Hutchinson 1964) advocating methane digesters in Kenya to produce high quality manure and fuel gas from farm wastes. The conjunction of these two considerations formed the basis for the integrated approach to rural development which follows.

Over the years a file was kept of relevant material and this paper summarises and updates the suggestions for development which were presented more fully in an earlier monograph (Casebow 1983).

A study of water hyacinth as a possible source of good quality manure and biogas energy must be closely linked to an appreciation of soil fertility problems in rain-forest agriculture. For this reason the first considerations are aspects of soil fertility in rain-forest soils of the tropics, the vital role that forest trees play in the process and some ideas for a more permanent form of agro-forestry which may be used in place of traditional shifting cultivation. This is followed by suggestions for the use of anaerobically fermented water hyacinth to provide good quality manure and methane energy.

2 Soil fertility in rain forests

A period of fully developed forest tree cover — known as the forest climax — has been essential up until now to maintain the fertility of the soils. The necessity for this period of forest fallow needs to be understood. The natural agricultural value of these soils is generally low. The soils in the Zaire basin are variable but tend to be low in essential nutrients, acid, permeable and easily leached (see table 1). The upper layer of soil is usually sandy in nature, its fertility being linked to the very limited surface organic matter (rarely greater than 1.8% in the rain forest) that comes from the decayed matter of forest trees. Apart from the very thin surface layer of humus, the content of

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Table 1 Typical analysis of an 18 metre profile from an old rubber plantation on the Yangambi Plateau, Zaire (Tondeur 1957)

Depth, cm	Physical analysis					Chemical analysis								Remarks
	Granular composition, mm					Soil water								
	0 to 0.002	0.002 to 0.02	0.02 to 0.2	0.2 to 2	Porosity, % vol	Macrostructure, % vol	Water cap, % vol	Water cap, % weight	pH	C, %	N, mg/100g	P_2O_5 H_2SO_4 N/20, mg/100g	EB* HCl N/20, mg/100g	
5–50	29	0	16.8	54.2	37.3	9.7	27.6	16.6	4.4	0.6	64	1.1	0.5	Upper soil layer
50–150	31	8	15.9	52.3	40.7	7.1	33.6	21.5	4.7	0.2	22	0.9	0.9	Typical Yangambi type profile
150–750	37	6	17.7	44.7	40.0	5.4	34.6	22.3	4.4	0.1	18	1.0	1.0	Yellow soil
750–1250	41	9	22.7	35.4	40.7	3.4	37.3	23.8	5.2	tr	tr	1.8	1.4	Transition zone, red soil with yellow spots
1250–1800	41	7	18.5	39.8	41.7	2.3	39.4	25.4	5.4	tr	tr	2.2	1.4	Red soil

*Exchangeable bases. tr = trace.

plant nutrients tends to increase from the surface downwards to a point where the leaching effects are minimal; the forest trees, with their deep rooting systems, can reach down to these soil depths. The strong acidity of the soils favours decomposition by fungi, rather than by bacteria, and by the predominance of unstable organo-mineral complexes (Tondeur 1957). These facts must form the basic understanding of rain-forest fertility from which agricultural development is planned for these regions. Traditional shifting cultivation in the past (when land availability and the maintaining of the fertility of the soil were not a problem in the Zaire rain-forest) followed a pattern where a small patch of forest was cut and cleared, crops were grown for one or two years, then the cultivator moved on and allowed the patch to revert to forest. There was therefore in effect a forest fallow of indefinite length, allowing the rebuilding of the fertility of the soil.

The poor forest soils contrast strongly with the luxuriant aspect of the rain-forest itself, which was mistaken by early explorers as indicating an inexhaustible reserve of fertility. However, it is evident from the above remarks that rain-forest soils have almost no humus cover due to the rapid destruction of vegetable matter by internal microbial activity and high temperature. The speed of renewal of fertility in the soils after cropping is accomplished in proportion to the speed of regeneration of the forest cover. Practices which prolong the period dominated by shallow rooting grasses prolong the period of recovery of the soil. It is evident therefore that the primitive shifting cultivation practices did conserve the fertility of the soil through the long shallow periods given to the land in the rain-forest.

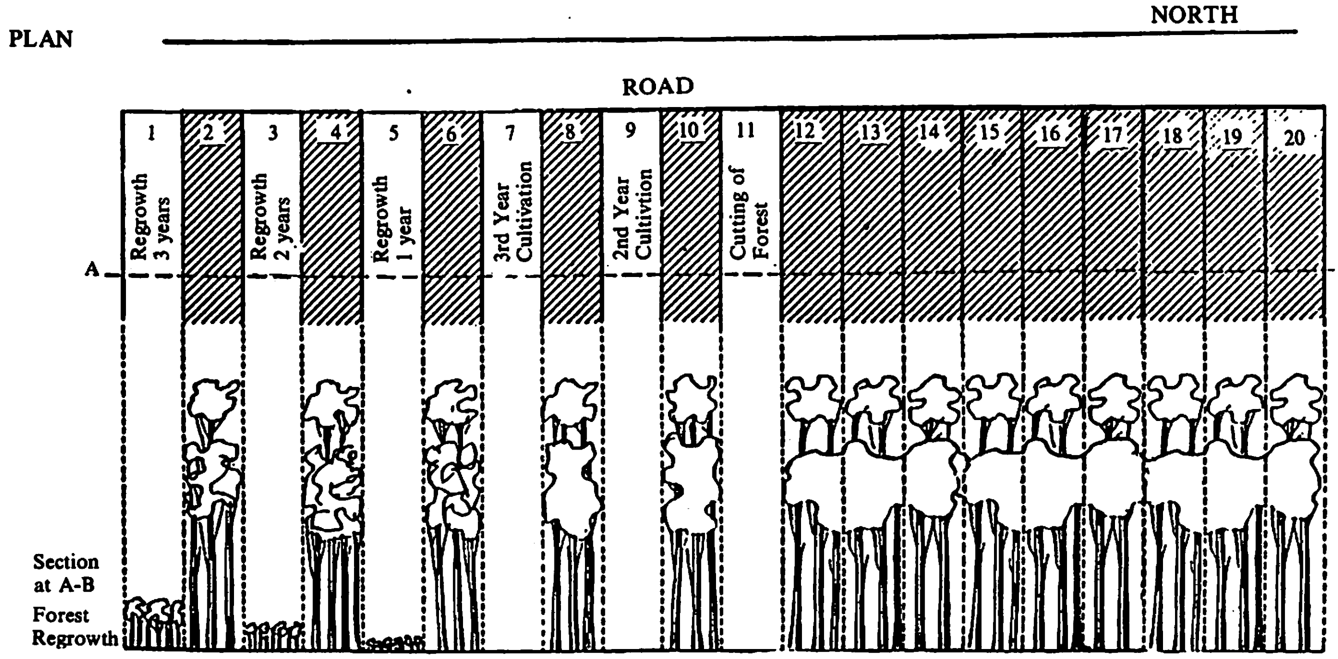
Today, the increase in cultivated areas resulting from higher population and stabilisation of migration, means that the effect of shifting cultivation on forest conservation and on soil fertility is much greater. Shorter and shorter fallow periods, caused by increasing pressure on cultivable land within the reach of expanding urban areas, result in a dangerous destruction of forests with a regression of permanent forest cover and of soil fertility in many places. There is a great need both to guard against the wholesale destruction of the forest with its resultant effect on soil fertility, and at the same time to provide settled areas of permanent agriculture for food production within the rain forest, which obey the natural laws for the maintenance of soil fertility by using the forest climax, or its equivalent. Modern trends towards urbanisation of the population mean that the practice of shifting cultivation with forest-fallow, which requires land to stay uncropped for a number of years, is becoming more and more unrealistic in those forest areas near to an expanding population.

3 The corridor system and soil regeneration using leguminous trees

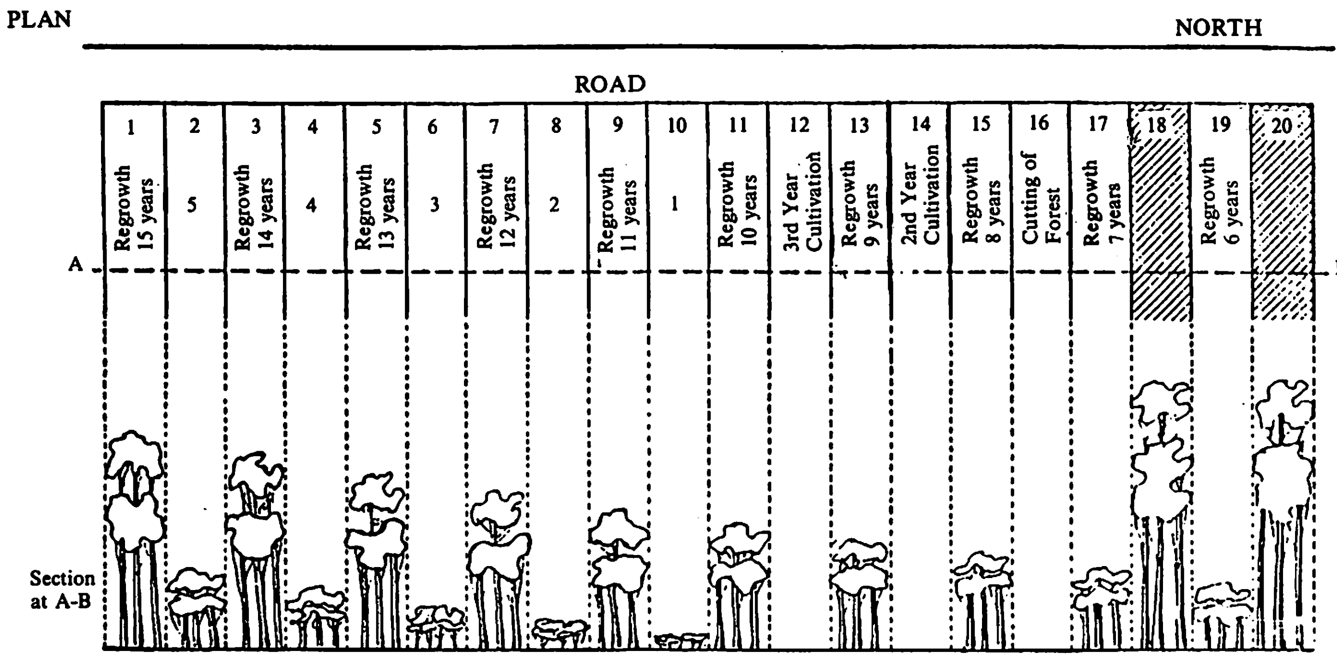
In the colonial era, the *Programme de Paysannat* was introduced as an attempt to systematise the shifting cultivation in the rain-forest of Zaire. It involved a 20 year rotation cycle of crops and forest and aimed to:

(a) control the time spent under crops and under forest-fallow;
(b) encourage a rapid regrowth of the forest, which favours in turn a rapid recovery of soil fertility. This rapid regrowth diminishes as the distance from the edge of the forest increases and is the reason for small subsistence plots quickly reverting back to forest. It follows that to ensure a quick regrowth for forest-fallow, the best shape of clearing for cropping is a long narrow band.

Therefore in this system the forest is cleared in strips or "corridors", cultivated for 2–3 years, before being



(a) *Clearing in alternate corridors or bands shown the sixth year after the initial opening of the forest.*



(b) *The same land in the 15th year after the initial opening of the forest.*

Figure 1 Plan and cross section showing method of cutting forest corridors in a 20 year forest rotation (adapted from G. Tondeur 1957).

allowed to revert back to forest, while the farmer moves to the next corridor (see fig 1).

The regrowth of the forest is hastened if a corridor of forest is left between cleared strips. This promotes quicker reseeding and re-establishment of the forest, but to avoid overshading of the crops in the strips alongside, a corridor of secondary forest is better than the full growth climax forest. The forest-fallow period was designed to last about 18 years (Tondeur 1957).

From reports received it is doubtful whether the corridor system, in spite of its obvious merits, is still in use. It was an excellent attempt to resolve a problem (which only gets progressively more acute) of replenishing soil fertility without other fertilisers being available. It was probably abandoned in the wake of the social disturbances following Independence (Carrington 1984). Projects involving land use should follow local customs and tenure systems closely, with people placed in family groups and not arbitrarily distributed. The forms of the corridor system evolved in the Turumbu and Ruzizi areas of the Congo in the colonial era were apparently a success because people appreciated the security, stability and protection given against abuses of tribal ownership and because the government could check the uncontrolled devastation caused by shifting cultivation (Tondeur 1957).

4 Maintaining the soil fertility

If the use of very long forest-fallows and shifting cultivation to give a slow, but sure recovery of fertility to the soil is impracticable, two other methods of soil improvement may be suggested:

(a) the addition of animal manure and compost to the soil;

(b) the use of leguminous plants with or without a fallow period.

To maintain fertility in the rain-forest, it is necessary to return humus to the soil at a far greater rate than in temperate climates. Cattle manure as a source of humus is not usually available, as these farm animals are rare in rain-forest regions and there are doubts about the wisdom of introducing them. Peasant farmers generally do not have the resources or the motivation to maintain and establish the necessary artificially introduced pastures whose inputs and production costs are very high (Rains 1983). It has been shown that the agricultural systems of these areas function as if animals did not exist (Gourou 1961). Where peasant pastoralism has been tried it is not very productive and does a good deal of damage. It seems as if any attempt to introduce a pastural system based on conventional grasses will probably result in ecological problems.

On the one hand therefore manure or compost is necessary in large quantities to maintain or to improve fertility in rain-forest soils where the forest has been cut for cropping; on the other hand any development of cattle husbandry here should be ecologically sound. If cattle husbandry is to be put into practice leguminous tree fodders are preferable to grasses as a replacement to the natural forest cover.

The best chance of succeeding with a soil improving forest-fallow may be by using a plant which regenerates the fertility of the soil and provides an economic return at the same time. Two recent research projects seem particularly relevant to the rain-forest: growing crops in living mulch, *the live mulch system*, and the planting of the leguminous tree *Leucaena leucocephala*.

The *live mulch system* uses a thick leguminous ground cover as a live mulch into which the crops are grown. The disadvantage is the need to control the vigour of the plant by herbicide spray so that the food crop can germinate without being choked by the cover crop. The use of chemicals can present difficulties in remote areas and for poor, subsistence farmers, but alternatives are being explored in current research at the International Institute of Tropical Agriculture, Ibadan, for management systems which will not depend on the use of any chemicals (Akobundu 1982 and 1984).

Leucaena leucoccephala is well known in the tropics as a shade tree. It is a soil improver, a good fixer of nitrogen in the soil, has a fodder value equal to Lucerne *Medicago sativa* and is also a quick growing source of firewood. It could be used to deliberately replace the natural forest regrowth.

A related species, *Leucaena glauca* has been identified as a very common small tree of this genus growing all over the Kisangani area of Zaire, which encourages the hope that *Leucaena leucocephala* may also do well in this area (Carrington 1984). *Leucaena leucocephala* may adapt to more acidic soils if the seed is initially inoculated with CB 81, an alkali producing rhizobium bacteria developed by CSIRO, Australia. It could be an ideal supplement, or replacement tree species for the period of secondary forest-fallow providing the forest regrowth of the corridor system mentioned earlier. It would enable the economic maintenance of the period of forest climax required by the environment, because an otherwise unproductive fallow period would return organic matter and fix nitrogen in the soil, as well as providing ruminants fodder of a feed value equivalent to lucerne, for an integrated system of permanent agriculture. It would also provide a large quantity of quick growing firewood, made available as each corridor in turn is cut for cultivation, and energy for cooking is one of the greatest human needs. (In many African countries the use of firewood energy for cooking may account for three quarters of all the energy used nationally).

Using this tree in the corridor system would enable a reduction to be made in width of the strips left for forest-fallow, thus allowing more land to be in productive cropping more of the time, with the strips coppiced for fodder. It should enable the reduction of the width of the 'corridor' to narrow strips, between rows of maize or other crop, which are continually cut to a hedge with the trimmings forming a mulch to the intercrop. Many *Leucaena leucocephala* varieties are useful for "Alley cropping" — as this form of agro-forestry is termed, and they have been used successfully in this way in Indonesia, the Philippines and Nigeria. In Nigeria it has been shown that *Leucaena leucocephala,* grown in the alley, produces 15–20 tonnes of fresh prunings per hectare with 5 prunings per year. The prunings in the trial gave more than 160kg N, 15kg P, 150kg K, 40kg Ca and 15kg Mg ha^{-1} yr^{-1}. In Hawaii a study is reported to have shown nitrogen fixation as high as 500–600kg ha^{-1} yr^{-1} (Taye Babalaye 1985). This is indication of the value of this plant when used for alley cropping techniques. Most *Leucaena leucocephala* of the tall type are suitable for timber production as well as forage and they all coppice readily (Fulloon 1984). Such use of this tree species can encourage a balanced mix of agricultural and soil conservation practices to replace the present shifting cultivation.

5 Anaerobically digested water hyacinth as a source of high quality manure and biogas fuel

Anaerobic fermentation of water hyacinth in specially constructed digesters produces gas, and the spent material is a manure-slurry which is rich in nutrients. This technique can be used where crops are grown near to rivers. If manure-slurry was available in large quantities it would enable a rotation based on the forest climax as described above, to be prolonged perhaps to the point where the forest-fallow could be dispensed with altogether. Tondeur (1957) reports that experiments in the forest zone have confirmed that this is possible, but the peasant does not at present have the means to handle the large quantities of material required. Water hyacinth manure-slurry would fit best into a system of permanent agriculture near waterways.

Riverine areas of the rain-forest will often tend to be the most populated as rivers are the natural access routes and form important areas for agricultural development. Water hyacinth multiplies along river banks, islands and the still water areas only to be broken loose in large rafts during storms, when they drift downstream in the current. Villagers in this situation may be able to use this weed by mixing it with goat or sheep manure and by processing it in a village biogas digester. The resultant slurry does not attract flies and would be a plentiful fertiliser for their plots of land. Large quantities of water hyacinth slurry will be needed to be effective, but enormous quantities of the weed are usually available and can be harvested with the help of a floating boom fixed from the bank out into the river to draw the weed in to the riverbank. Thus soil fertility may be maintained by using the anaerobically fermented manure-slurry in association with strips, or corridors, of leguminous tree or fodder crops.

If well established, water hyacinth is unlikely ever to be totally eradicated, its seeds remaining dormant for up to 20 years only to re-establish when conditions are suitable. A high nutrient and silt content in the water encourages growth. With suitable temperature and humidity, clumps of water hyacinth can double their size in about four days. The optimum pH of the water for its growth is pH7 (*World Water* 1980), but Berg (1959) established that where pH is less than 4.2, caused by humic acid, the plant cannot survive and the water is clear of this weed. Desiccation of the roots is fatal to the plant and this weakness can be exploited by turning stranded plants upside down to expose them to the sun (Druijff 1973).

One hectare of clear water hyacinth when decomposed under anaerobic conditions is reported to produce 70,000 m^3 gas containing about 60% methane. Under ideal conditions it recovers the following elements from water (*World Water* 1980):

Nitrogen	22–24 kg ha^{-1} day^{-1}
Phosphorous	8–17 kg ha^{-1} day^{-1}
Potassium	22–44 kg ha^{-1} day^{-1}
Calcium	11–22 kg ha^{-1} day^{-1}
Magnesium	2-*24* ha^{-1} day^{-1}
Sodium	18–34 kg ha^{-1} day^{-1}

It can therefore be useful as a water purifier and also as a concentrator of plant nutrients from water, which are released as it is broken down into manure. The value of raw waste is conserved through anaerobic digestion, giving valuable fertiliser and soil conditioner. Its organic content is reduced by 50 –70% and is well stabilised, having no offensive odour and not attracting flies.

Fresh water hyacinth on a dry weight basis is reported to have the value of a 10:14:18 fertiliser, but its high carbon/nitrogen ratio (giving it a high nitrogen demand before decomposition) means it cannot be safely used on crops before decomposition. While decomposing aerobically to a point where it can be safely used on crops, a lot of the nitrogenous element is lost. Anaerobic digestion will conserve a large part of this nitrogen within the slurry which is then available for use with the crops, making it a better fertiliser than the aerobically made compost. In addition biogas is produced as a possible bonus energy source.

Reliable data on results gained from crops fertilised with anaerobically digested waste (rather than empirical statements of observed improvement) have been difficult to find. An interesting example of results gained from anaerobically digested pig and cattle slurry as fertiliser for coffee, grown on marginal land 150 miles NW of Nairobi, Kenya, was reported in 1962 and is given here although the information is now rather old. The yields were obtained from three separate coffee plantations totalling 20 hectares:

Average yield coffee

— 7 years *BEFORE* installation of digesters (1948 –1954) 130kg

— for 7 years *AFTER* installation of digesters (1955 –1961) 301kg

Average yield for this farm during the 3 year period 1959 –1961 353kg

No organic fertilisers were applied during the 14 year period. The average yield for the District between 1956 and 1959 was 190.5kg (Hutchinson 1962).

To achieve a suitable carbon:nitrogen ratio in plant material for digestion, animal manure is usually needed. However, in the present virtual absence of cattle manure, digestion of water hyacinth is assumed to be in association with goat or sheep manure in this paper, the former being the most numerous domestic animal in Zaire.

6 Anaerobic digestion

The anaerobic digestion process consists of a series of reactions of a mixed culture of bacteria acting in turn on organic wastes. These bacteria are found on all decaying matter and excreta and become very active under suitable conditions. The by-products from the first bacteria form the food supply for the next. Acid-producing bacteria break down organic matter into simple compounds and volatile acids. Methane bacteria convert the volatile acids into methane gas, but are very sensitive to changes in environmental conditions. Successful digestion depends upon keeping the balance between acid-producing and methane-producing bacteria. The balance is achieved by regular feeding of sufficient liquid and by maintaining the right pH, temperature and mix of new materials in the digester. Greatest efficiency is achieved when the bacteria can work at a temperature of around 36°C (95°F).

An important factor in digestion is the carbon:nitrogen (C/N) ratio — carbon, as carbohydrates, and nitrogen are the chief foods of anaerobic bacteria. Organic matter when decomposed to humus has a C/N ratio of about 10/1, which indicates advanced decomposition, while a wide ratio of 35/1 or greater indicates that little decomposition has yet taken place. Anaerobic bacteria use up carbon 30 times faster than nitrogen and, although digestion takes place efficiently between C/N ratios of 20–30, preference should be given to material with the wider ratio nearer to 30 (Casebow 1984). The C/N ratio of vegetation will vary according to its stage of growth and tables indicating C/N values need to be used with care as they often refer to composted material. It is the ratio of *fresh,* non-composted material, which we need to know.

It should be possible to calculate the C/N ratio of commonly available local vegetation from feed analyses tables prepared by agricultural agencies throughout the world. As proteins are composed of 16% nitrogen, the nitrogen content of vegetable matter is used to calculate the crude protein value of a feed. Conversely, the nitrogen content of vegetable matter can be found from the crude protein value given in feed analyses tables. Carbon forms a part of most compounds which make up the nutritive value of the vegetation. To find the carbon content, the weight of the product must be divided by 1.95 for proteins and by 1.54 for fats. The amount in carbohydrates and fibre can be estimated as follows:

$$C \text{ content} = DM\% - (CP + F + A + IF)\%$$

where: DM = Dry matter
C = Carbon
CP = Crude protein
F = Fat
A = Ash
IF = Indigestible fibre (total crude fibre — digestible fibre).

Using tables in this manner gives a C/N ratio for water hyacinth of 22/1. However, to achieve a suitable C/N ratio in plant material for digestion, animal manure is usually needed. Fermenting a single material may give poorer results (in terms of methane produced) than a mixture of goat/sheep manure with the water hyacinth. A mixture of water hyacinth with an equal weight of sheep manure results in a calculated C/N ratio of 27/1, which is good for fermentation purposes.

Waste digestion will be more effective if vegetation is chopped before being fed to the digester and hand-powered chaff cutters would be effective to chop the water hyacinth. Scum formation also affects the process and digester material should ideally be agitated once or twice a day to prevent this. Provision for this needs to be incorporated into the digester design.

There are basically two types of digesters:

- *batch loading or compartment digesters,* where a battery of compartments is filled, sealed and emptied in rotation to provide a continuous supply of gas;
- *continuous load digesters,* where small amounts of material are fed daily, displacing an equal volume of digested slurry at the same time and producing gas continuously.

Batch loading digesters may not be as effective as the continuous load type because of fluctuations in the composition and supply of gas at each changeover of the compartments and the large quantities of bulky, awkward material which have to be handled at this time.

Continuous load digesters can again be divided into two types.

(i) Partially above ground plants with a moveable metal gas holder which rises in the slurry as gas accumulates underneath. This is popularised under the name of "Go-bar Gas Plant" in India.
Its disadvantages are:
- High cost of construction and maintenance.
- Heavy corrosion and deterioration of the metallic gas holder (which needs frequent painting).
- The farmer is often unable to solve repair problems himself and therefore expensive plant remains inactive. It is reported that at least half the biogas plants in India are lying unused mainly due to maintenance difficulties (Huisward 1982).

(ii) Chinese type plants are made of local materials, are totally below the ground surface and have no moving parts. The advantages for this design are quoted as:
- the slurry is underground and the temperature is comparatively higher than above ground plants.
- as there are no moving parts, wear and tear and maintenance are very low and there is no corrosion of the holder.
- the cost of this biogas plant is reported to be almost half that of the above ground design (Garg *et al* 1980).

Disadvantages are:
- Difficulty of constructing a gas leak-proof roof in a masonry structure. This has been overcome in Zimbabwe using bituminous paint (see below).
- The larger size of the inlet and outlet openings which can be dangerous as they are big enough for someone to fall into.
- The displacement distance from inlet to outlet may not be long enough to prevent accidental mixture of raw with spent slurry in the outlet. A remedy might be to increase the displacement distance using a baffle, so that all raw materials are effectively digested.
- The fixed size of gas holder means that pressure drops as gas is used — giving a lower and lower flame. This has been overcome in Zimbabwe using large vehicle inner-tubes. These are inflated by the gas pressure and as they contract, maintain gas pressure for long periods of time (MacGarry 1984).

The biogas digester was widely acclaimed in China in the 1970s and bold plans were outlined for 70 million digesters to be installed throughout the country by 1985, but reports indicate that of the 7 million digesters built in China by 1978 nearly half have been abandoned. The plan was far too ambitious. With digester plants built in a hurry, water and gas leaks abounded. Units gradually turned into waste pits and were abandoned (International Agricultural Development 1982). This seems to be a case where a well conceived idea was developed too rapidly, without time to appreciate difficulties and problems from controlled pilot projects and careful monitoring of construction. However, this does not invalidate the original concept. The simplicity of the below ground

Chinese design using locally available, low cost materials, makes it probably the best design for consideration in remote areas of Africa. The failures of the Chinese experiment emphasise that the quality of pit construction is crucial to efficient production of biogas. Care must be taken to see that the digester pit is absolutely watertight and airtight. Painting with two to three coats of bitumen has helped to render it leak-proof in Zimbabwe. The first coat of bitumen paint should be diluted with turpentine in the proportion 2:1 by volume, to help it adhere to the plaster.

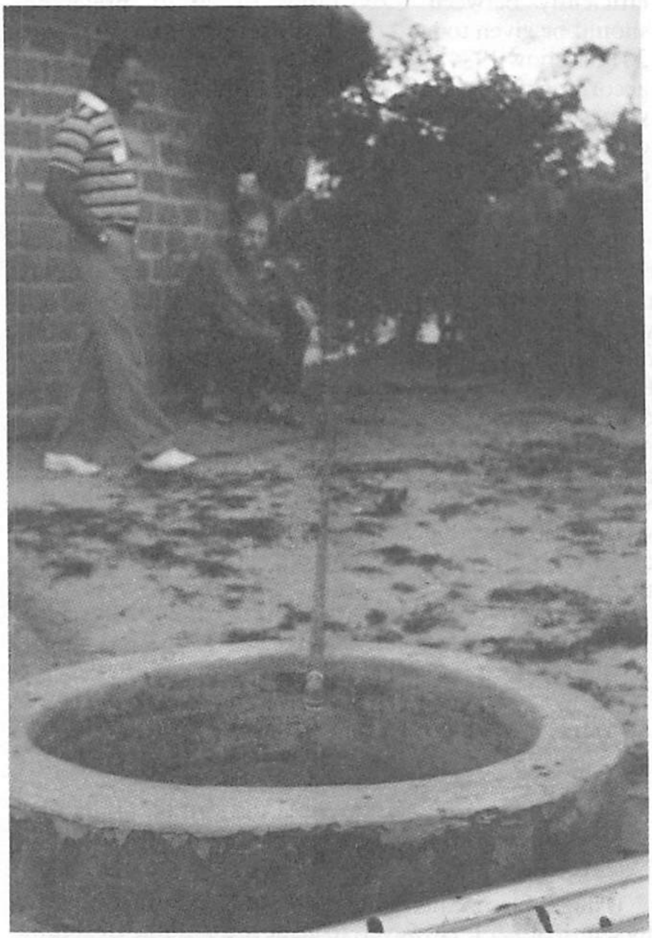
Liquid latex can be obtained from wild as well as cultivated rubber trees in rain-forest regions. A latex concrete lining for the digester may have advantages over bitumen due to its local availability, and also in gas/water impermeability since it should resist penetration and minor soil movement. Latex is used in the West to make a concrete having a greater plastic range and greater adhesion, with less porosity; such latex for addition to cements and concrete is a concentrated type having much less water and protein. Raw latex from the tree, known as 'Field' latex, contains about 40% rubber which, it is suggested, could be added to concrete and produce similar results to concentrated latex, although there is no direct knowledge of its use in this application. The use of locally obtainable field latex in concrete mixes in the forest village situation might incorporate the above qualities of the more concentrated latex used in the West and result in the easier construction of a water and gas tight digester. If this idea was tried for underground digesters it is suggested that the latex-concrete mix should be applied as a surface layer (25–50 mm thick) on a latex free brick or concrete base. The latex-concrete should contain, say, 10–15% of the dry concrete weight as rubber. The addition of a bactericide/antioxidant, such as zinc dibutyl-dithiocarbamate, is suggested to protect the rubber. As noted above, field latex has a large proportion of water. Excess water in the mix is often a major cause of weak, porous concrete and latex would allow a workable mix to be made with less water. The normal proportions of water for a concrete mix should be reduced to half water/half latex for a latex-concrete mix (Pendle 1985; Chubb 1985; Norwood 1985).

The Chinese type of design (fixed volume and below ground) appears to have been well accepted under African rural conditions in Zimbabwe where several Chinese type plants have been in use for a number of years in a project run by Fr MacGarry of Silveira House, Harare. The commitment and enthusiasm of the villagers is shown in that most small problems have been solved by them without reference to the Mission (MacGarry 1984) as shown in fig 2.

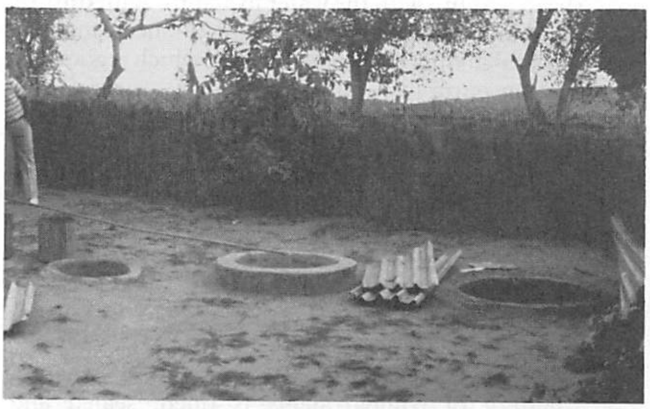
In design, the domed Chinese digester pit has a base diameter approximately the same as the height and is roughly spherical in shape. The highest part of the dome should be about 1m below ground level. For details reference should be made to such works as the Chinese Biogas Manual and other literature on the subject (Van Buren 1979). After construction water and air tightness must be strictly checked before allowing the pit to be filled.

Safety consciousness is very important. No smoking or naked flame should be allowed in the vicinity of the pit. Before maintenance work is permitted on an empty pit tests should be made for the presence of gas pockets. In rural Africa, a chicken lowered in a cage for a few minutes and checking it for abnormal behaviour would be a wise precaution. Always be conscious of the possibility of leaks and make a habit of daily checks.

Figure 2 Chinese design digester used successfully over several years on an African holding near Harare, Zimbabwe



(a) Cover access-pit with gas supply pipe to the farmer's dwelling.



(b) Below-ground digester: left to right – Inlet; pit-cover and gas outlet; digested slurry outlet.

7 Organisational aspects

Local social and legal aspects need to be carefully investigated; lack of understanding these result in the failure of an otherwise sound project. Health problems in biogas plants come from the sludge; batch, thermophilic digestion is reported to be the only process producing a guaranteed pathogen free sludge. There will always be ascaris ova and sometimes pathogenic bacteria present from other digestion processes and *Ascaris criteria* have apparently been adopted in China as a guide to pathogen content (Feacham *et al* 1980).

The type of project which suits the area will need to be considered carefully. Will it consist of many small domestic plants, or one or two large community plants with better supervision and full time operatives? Community plants should be easier to monitor and manage, but will demand a co-operative approach in the village community.

(i) *Family owned digesters.* Thought will need to be given to management services; education and advisory services; initial help in starting up. A pilot project, with an education programme and with demonstrations on the economic use of slurry on the farmers' own crops will be needed. As well as free lighting and cooking fuel, the incentive to better crops and less hard labour on annual ground clearance in the forest, needs to be stressed.

(ii) *Community type digester pits.* A pilot project and education programme should be mounted to show clearly the advantages of gas energy and compost slurry, as well as the clearing of water hyacinth from waterways. Emphasis could be given to compost production including demonstrations showing the effect it has upon their crops and land.

It may require a big incentive for farmers to see the advantages of this kind of development. Having been visually persuaded of the advantages of the compost to their crops, the next stage involves the energy from methane being regarded as the income generating part of the scheme — with an ample supply of compost for farmers regarded as the incentive generating part of the scheme. The gas energy will be used to power communal plant such as electric generators where the produce (electricity) is sold, or where gas is piped and sold to individual households.

The gas energy depends on a good supply of digestible material, which depends in turn on a continual supply of water hyacinth, and on a reliable supply of animal manure from the farmers. The supply of manure depends for its reliability on a strong incentive to farmers to keep up regular deliveries. For this reason the provision of an ample supply of good compost material should be regarded as the incentive generating part of the scheme, the farmers having the right to a free supply of a quantity of the digested effluent substantially greater than the quantity of raw manure supplied. It is thus:

(a) an incentive to the farmers for regular deliveries;
(b) a reimbursement in kind for his trouble in making regular deliveries;
(c) a means of maintaining/improving soil fertility and agricultural productivity;
(d) a means of controlling water hyacinth or other water weeds locally;
(e) a means of continuous generation of methane gas for sale as an energy source.

8 Slurry distribution

Transport of slurry to farmers' plots is a major question as it is an awkward material to handle. Western literature assumes the use of tanker lorries, but what is needed is a series of simple technology options which could be used according to the situation. There are three main possibilities: transport by land, by water, by pipe or lined canal.

8.1 Land transport

An illustration in the Chinese Biogas Manual (Van Buren 1979) clearly shows how slurry is extracted from the pits by long handled dipper and transported by yoke and buckets to the vegetable plots. This is extraction, haulage and spreading in its simplest form and is the method of choice for most small family units.

8.2 Water transport

Often the easiest access to fields may be by water using canoes. Quite large quantities of slurry might be transported by canoes joined together in the form of a catamaran or trimaran with a tank secured to the deck. Dippers could then be used to extract the slurry and transport it to nearby fields.

8.3 Gravity transport

Transport by pipe or canal would be possible with short distances, but the capital expenditure might limit it to large community schemes with high value market garden crops, grown near the digester.

9 Conclusion

Any scheme to improve agricultural production in the rain-forest must respect the soil and forest relationships. The ideas stated here are put forward to provoke discussion and experiment in the use of water hyacinth to assist in the conservation of soil fertility and forest cover in the rain-forest zone, which will help progress to a stabilised permanent agriculture.

The use of anaerobically digested water hyacinth (or other water weed) as a manure-slurry, in conjunction with leguminous trees could fit well into an integrated system of permanent agriculture near waterways in the rain-forest. It would provide:

(a) a large quantity of high quality manure-slurry for farmers' fields;
(b) clear waterways for navigation and fishing; and
(c) biogas as an important by-product.

The suggestions made in this paper need to be tested in a pilot project to develop a programme which could become an agro-forestry system of real benefit to rural communities in rain-forest situations.

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A survey of the incidence and control of soil over-compaction problems on Scottish farms

B D Soane and C D Kershaw

Summary

A postal survey was conducted among 1421 farmers in Scotland (excluding the Highlands and Islands) to establish the incidence of soil over-compaction problems and the extent to which precautionary measures of different types were adopted by farmers.

A stratified method of sampling was adopted on the basis of the three Agricultural College regions (North, East and West), three farm types (stock farms, arable farms and dairy farms) and three farm economic size groups (small, medium, large). A response was obtained from 893 farmers which represents about 10% of the selected population and 63% of the sample.

There was a high degree of awareness of over-compaction problems among farmers in the sample. Although 61% thought such problems to be of only occasional frequency, 25% thought that they occurred in most years or every year. Precautions were taken against over-compaction problems by 82% overall and by 91%, 82% and 72% on arable, stock and dairy farms respectively. Keeping off the land when it was wet was widely believed to be an important factor in avoiding over-compaction problems. The most damaging operations were thought to be the harvesting of potatoes and root crops and the distribution of slurry and dung.

The most sensitive crops, in terms of the perceived prevalence of large yield reductions on compacted soils, were oil-seed rape, peas/beans and other vegetables, but few farmers grow these crops these crops in Scotland and, hence, the number of responses concerning them was small. Approximately 50% of farmers considered that compaction problems result in some yield reductions of both spring and winter cereals.

In many cases the responses show considerable differences among regions, farm economic sizes and farm types and these factors are clearly important in influencing policy concerning the alleviation of over-compaction problems. There was a tendency for the awareness of over-compaction problems and the perceived damage from many field operations to increase appreciably with increasing farm economic size. On farms having no heavy soil fewer farmers took precautions against over-compaction than on farms having appreciable heavy soil.

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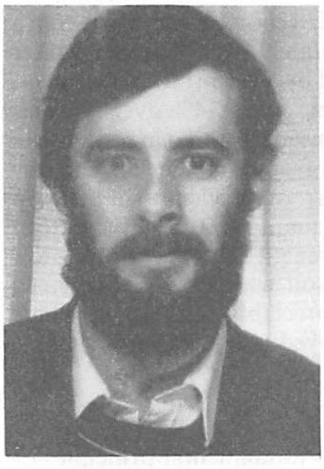


Chris Kershaw

Brennan Soane

1 Introduction

1.1 The importance of soil compaction problems

It is increasingly recognised that soil physical conditions must be maintained at an optimum level if maximum crop yields are to be obtained. Crop growth and yield will decline if the level of soil compaction lies either above or below a variable optimum value. There has been particular concern that over-compaction of soils as a result of agricultural vehicle traffic is restricting the profitability of crop production with accompanying enhanced risks of soil erosion. This concern has extended to many agricultural and forest crops in many countries (Soane 1985). The incidence of such problems is likely to be influenced by the design and management of field vehicles, soil type, weather conditions and the type of crop and it is therefore important to establish the role of these factors.

An extensive series of experiments on crop responses to different levels of compaction has been conducted by the Soil Engineering Section of the Scottish Institute of Agricultural Engineering (SIAE) over the past 20 years. It has been established that on certain Scottish soil types, crop production is particularly prone to over-compaction problems resulting from vehicle traffic (Cambell *et al* 1984) because the clay minerals generally present do not lead to self-structuring and the soils are often wet at the time of Autumn and Spring seedbed operations. In addition, the early onset of Autumn and Winter rains means that soils are commonly wet during the harvesting operations of all arable crops and the same problem is frequently encountered during the Summer harvesting of grass crops.

The potential benefits to be obtained from the elimination of over-compaction in cereals can be studied in experiments in which a zero traffic regime is compared with different levels of wheel traffic, but the results obtained are likely to vary for different soil types and in different seasons. Campbell *et al* (1986) working on Winton series near Edinburgh, reported that when even a single tractor wheel pass treatment over ploughed winter barley seedbeds was replaced by a zero-traffic treatment, the average grain yield increase was 14% over a 4-year period, but there was pronounced variation in response in each of the four years. Apart from increases in yield, the elimination of vehicle traffic from the vicinity of the crop may result in improved crop quality and an earlier date of maturity. An additional benefit is that the power requirement for cultivating soil which has not received vehicle traffic can be appreciably less than where conventional traffic is employed (Chamen *et al* 1985).

1.2 Background to the survey

Field experiments permit the fundamental principles of wheel/soil/crop interactions to be established under carefully controlled conditions. However, it is also desirable to establish the extent to which commercial crop production over extended areas is rendered less efficient or less profitable as a result of over-compaction problems. It is difficult to obtain this information in formal experiments because research resources are limited so that experiments are necessarily few in number, small in area and of limited duration. Inevitably the applied treatments and crop management may differ somewhat from normal farming practice. To obtain wide ranging information on the extent and distribution of over-compaction problems, it was decided to undertake a postal survey of farmers throughout Scotland. The survey (Soane and Kershaw 1986a, 1986b) attempted to discover the extent to which over-compaction problems were experienced on land used for a wide range of crops including temporary and permanent grassland.

Stratified sampling was employed to ensure that reasonable numbers were sampled from each category of interest (farm type, size, location). The farms that were selected were chosen from a list of holdings for which separate responses were made in replies to a census made in 1983.

Bias in the responses may arise if there is a greater tendency for those farmers who recognise compaction problems on their land, to take time to fill up and return the questionnaire than is the case for farmers who have not encountered these problems. The risk of this bias will be greatest if the response rate is low. An attempt was made to reduce such bias by stressing in the letter explaining the survey, and in the reminder to prompt a reply, that a completed questionnaire was wanted even if no compaction problems were experienced. The stratification of the sample allowed the correction of bias because of the different response rates within the strata.

2 Survey technique and analysis

Greater details of the survey technique and analysis than are given here can be obtained from Soane and Kershaw (1986a).

2.1 The questionnaire

The primary questions were concerned with the following topics:

a) the frequency of occurrence of problems which the farmer attributed to over-compaction of soils,
b) the nature of the field operations thought to be the cause of the observed problems,
c) the effects of over-compaction on crops,
d) the type of precautions taken to avoid over-compaction problems.

Information about location of farm, farm type and farm economic size was already available but in addition it was thought desirable to seek information on other aspects. In particular, predominant soil type and altitude were considered important since the incidence of compaction problems might be related to climate, with wetter soils tending to be more readily damaged than drier ones and rainfall tending to be positively correlated to altitude. Farmers were asked to indicate whether the average altitude of their land lay within 0–31, 31–62, 62–123, 123–185 or above 185 m (0–100, 100–200, 200–400, 400–600 or above 600 ft). Farmers were also asked to estimate the proportion of their land which they would describe as light, medium or heavy texture. The result was subjective since no definition of light, medium or heavy texture was provided.

To augment the information given in the answers to the questionnaire farmers were invited to comment informally on other aspects of soil compaction problems. The questionnaires etc. were posted in mid-November 1984.

2.2 The composition of the sample

The sample of farmers was stratified according to the following characteristics:

Region: North, East and West Scotland (corresponding to the areas of the three Scottish Agricultural Colleges but excluding the Highlands and Islands).

Farm type: Six types of farm, identified by the Department of Agriculture and Fisheries for Scotland by Codes 4 (least favoured area with arable), 5 (lowland cattle and sheep), 61 (specialist cereals), 62 (general cropping), 71 (specialist dairy) and 72 (general dairy), were sent questionnaires. The data from these six types have been pooled into three groups which are termed stock farms, arable farms and dairy farms.

Farm economic size: Farms were selected to be within one of three groups defined in terms of Economic Standard Unit (ESU) values where 1 ESU = £2000 standard gross margin (averaged for period 1979-1981). The groups were 8-16 ESU, 16-40 ESU, 40-100 ESU, thus the terms small, medium and large allocated to these groups refer to economic size and not to land area. The average areas of crops and fallow on specialist cereal farms varied from 145 ha (large) to 54 ha (small), whereas on general cropping farms the corresponding figures were 116 ha (large) and 22 ha (small). The information on farm type and size were relevant to March 1984.

2.3 Sampling strategy

The technique of sampling in proportion to the total number in a category (ie using a fixed sampling fraction) was rejected because the large disparities between numbers in categories would result in most of the sample being drawn from a small number of categories. The sampling scheme adopted was a compromise aimed at ensuring that the categories with smaller numbers of farmers were reasonably well represented. Details of how the sample was drawn are given by Soane and Kershaw (1986a).

The actual number of farms, within the selected categories to which questionnaires were sent, was 1421 out of a population of 8920 farms, a sampling fraction of 16%, with a higher fraction in the smaller categories.

2.4 Method of analysis

When combining results from different farms, it is important to make some adjustment for the wide range of farm economic size to prevent the smaller farms from contributing disproportionately to estimates; hence, responses from farms were weighed in proportion to their ESU value. The proportions giving different responses to questions were estimated by combined ratio estimates (Cochran 1977, pages 165-167) as described by Soane and Kershaw (1986a).

An estimate for proportions across farm types within economic size groups, was obtained by making summations over farm types rather than economic size categories. A further estimate, where results were summarised over economic size and a combination of farm type, was obtained by extending summation over economic size and type.

Estimates for regions and for Scotland were obtained by combining proportions for the different farm types in proportion to the aggregate ESU values for types and standard errors of proportions were also estimated.

Some estimates based on altitude and soil type categories were calculated by ratio estimation with summation across region group as well as across farm economic size and farm type groups.

As there was a proportion of non-respondents, care had to be taken in interpreting variance and standard error estimates. There is always the possibility that some bias due to non-response will still exist. The standard errors, reported by Soane and Kershaw (1986a), indicate how much reliance can, at best, be placed upon estimates.

3 Response characteristics

Out of the total of 1421 questionnaires distributed, 893 were returned completed, representing a return of 63% and corresponding to 10% of all farms in Scotland within the selected criteria.

The percentage of returns varied with region (North 63%, East 67%, West 58%) and with farm size (small 52%, medium 61%, large 74%). Among the sub-groups, the highest percentage return was from large farms in the East region (78%, 146 returns) and the lowest was small farms in the West region (46%, 50 returns). Of all questionnaires returned, 63% were received within three weeks of the original posting (mid November) and 95% within nine weeks. A reminder letter was sent to farmers who had not returned the questionnnaire within three weeks. The file was closed after 13 weeks and the few responses subsequently received were excluded from the analysis.

4 Presentation of results

4.1 Statistical interpretation

The sizes of differences in response relative to standard errors are indicated in tables 1-4 and 7 only, by marking columns or rows by an asterisk if the difference between the highest and lowest proportions in the column or row exceed twice the estimated standard error of the difference. The asterisk indicates that a paired t test on these two proportions would show that there is a significant difference at roughly the 95% level of probability and that one can reasonably judge that real differences in proportions exist.

4.2 Relevance of ESU basis of proportion

The results of this survey are expressed not in terms of the proportions of the number of farmers who responded in certain ways but rather in terms of the equivalent proportions of the economic size of each farm expressed on an ESU basis. This latter technique avoids the opinions of the more numerous farmers on smaller farms being given undue emphasis. Thus in the following interpretations of the results the expressions "the proportion" or "the percentage" refer to the proportion of farmers on an ESU basis.

4.3 Treatment of non-responses

Some farmers did not respond to all questions so the percentages for multiple response questions do not generally sum to 100%. Where answers relate to the effects of over-compaction on different crops, the responses have been adjusted so that they apply only to those farmers who grow the crop. In this case, non-respondents include those farmers who never grow particular crops. Similar adjusted values have been calculated for the proportions of farmers experiencing problems arising from the conduct of different field operations.

Table 1 Frequency of perceived occurrence of over-compaction problems

Sample component	*Frequency of occurrence of over-compaction problems, % of farmers*			
	Each year	*Most years*	*Occasional years*	*Never*
Overall:	5.1	19.7	60.7	13.2
Region:				
North	5.0	15.8	64.0	13.0
East	3.7	23.3	61.3	10.0
West	6.8	18.2	58.0	15.2
		*		
Farm economic size:				
Small	3.0	6.1	58.5	28.7
Medium	5.1	16.5	63.9	12.0
Large	5.5	23.8	58.9	10.7
		*		*
Farm type:				
Stock farms	2.6	18.6	65.3	12.2
Arable farms	5.6	22.3	59.1	10.7
Dairy farms	6.2	17.8	59.6	14.8

In this table and in tables 2, 3, 4 and 7 only, an asterisk indicates that the smallest and largest values differ by more than twice the associated standard error for the difference (see text).

5 Results

5.1 Frequency of occurrence of over-compaction problems

Over-compaction was considered to be a problem in every year by only 5% of the farmers (table 1) but 20% encountered it in most years. While 61% considered that it occurred only in occasional years, 13% never encountered it. The proportion considering that over-compaction problems occurred frequently was higher in the east than in the west or the north, very much higher on large farms than on small farms and higher on arable farms than on stock or dairy farms.

The majority of farmers (58%) did not consider (table 2) that compaction problems had become more prevalent during the last five years (1979-1984), whereas 20% thought there had been an increase during this period with a greater proportion holding this view in the East (23%) than in the North (18%) or West (19%). The proportions considering that compaction had become more prevalent during this period was appreciably higher on large farms (23%) than on small farms (10%) and was higher on arable farms (23%) than on stock (17%) or dairy farms (17%).

5.2 Whether precautions are taken to cure, reduce or avoid over compaction problems

The majority of farmers (82%) reported that they did take precautions to overcome over-compaction problems (table 3). The proportion taking action was appreciably higher in the East (89%) than in the West (72%), and higher on large farms (85%) than on small farms (71%). On arable farms 91% took precautions compared with 72% on dairy farms, while stock farms were intermediate (82%).

5.3 Types of precautions taken

Farmers were invited to indicate which of 15 possible types of precautions they undertook to overcome over-compaction problems. For convenience their responses are considered in three groups related respectively to ameliorative cultivation, reduced ground pressure and reduced vehicle traffic (table 4).

(a) Group A: Ameliorative cultivation. The most frequently employed cultivation practices were deeper ploughing (43%) and subsoiling (46%). Both these practices were very much more prevalent in the East (54% and 67% respectively) than in the North where 42% and 31% respectively used deeper ploughing and subsoiling as a means of reducing over-compaction, whereas about 32% employed both practices in the West. Deeper ploughing and subsoiling were practised to a much greater extent on large farms than on small farms (table 4 and fig 1), and similarly were more prevalent on arable farms than on dairy farms.

(b) Group B: Reduced ground pressure. By far the most widely employed technique was the use of dual tyres (52%), while wider than standard tyres were used by 36%. There was thus a preference for those options which were relatively cheap and easy to fit. Dual tyres were used by 71% in the East, but only 24% in the West. Several of the opportunities to reduce ground pressure were noticeably more popular on large farms than on medium or small farms. For instance dual tyres were used on 60% of larger farms but only 30% of small farms (fig 1).

Dual tyres were used on 72% of arable farms, 56% of stock farms and 27% of dairy farms. While dual wheels are now widely available for the drive wheels of tractors (fig 2) they are generally not recommended for fitting to combine drive wheels because the added axle and bearing loads have not been allowed for in the design and transmission failures may result (Anon 1985).

(c) Group C: Reduced or controlled vehicle traffic. A common practice was the avoidance of traffic on wet soil (68%) which was more widely adopted in the North (76%) than the East or West (both 66%). The proportion of farmers using reduced vehicle traffic as a means of reducing compaction was 33%, with a higher proportion using this technique in the East (39%) and North (36%) than in the West (26%). Over all regions the use of

Table 2 Changes in perceived incidence of problems caused by over-compaction over the last five years

Sample component	*Incidence of problems, % of farmers*		
	Not worse	*Worse*	*Don't know*
Overall:	57.9	20.2	21.7
Region:			
North	59.4	18.0	22.6
East	56.5	22.7	20.8
West	58.5	18.8	22.7
Farm economic size:			
Small	65.9	9.6	24.4
Medium	59.1	17.7	23.1
Large	55.9	23.3	20.7
	*	*	
Farm type:			
Stock farms	61.9	17.3	20.8
Arable farms	54.7	23.5	21.8
Dairy farms	61.9	17.3	20.8

Table 3 Proportion of farmers taking precautions to cure, reduce or avoid over-compaction problems

Sample component	*Precautions taken, % of farmers*	
	NO	*YES*
Overall:	16.9	81.6
Region:		
North	15.5	83.2
East	9.2	89.5
West	26.3	71.8
	*	*
Farm economic size:		
Small	28.7	71.3
Medium	20.0	78.5
Large	13.0	85.2
	*	*
Farm type:		
Stock farms	16.8	82.0
Arable farms	7.8	90.7
Dairy farms	26.5	71.8
	*	*

Table 4 Proportion of farmers taking various precautions against over-compaction problems

Types of precaution	Proportion of farmers taking precautions, %									
		Region			Farm economic size			Farm type		
	Overall	North	East	West	Small	Medium	Large	Stock farms	Arable farms	Dairy farms
Group A Ameliorative cultivation										
Deeper ploughing	43.3	42.3	53.9	32.3*	33.0	40.5	46.8*	41.4	58.1	28.9*
Subsoiling	45.9	31.1	66.6	32.6*	21.5	35.3	56.7*	34.9	63.7	34.1*
Extra or deeper cultivations	10.4	12.4	9.5	10.1	11.5	9.2	11.0	11.1	10.6	9.7
Group B Reduced ground pressure										
Wider than standard tyres	36.1	32.3	37.0	37.7	22.2	35.1	38.9*	29.9	38.1	38.1
Low pressure tyres	6.7	6.0	7.9	5.9	6.7	5.6	7.6	6.2	7.7	6.1
Low ground pressure vehicle	4.3	3.7	7.7	1.0*	1.6	4.1	4.9*	3.7	6.8	2.1*
Dual tyres	51.8	61.5	70.8	24.2*	30.0	43.9	60.1*	56.2	72.2	27.3*
Cage wheels	10.8	2.3	15.1	11.6*	7.0	10.7	11.5	7.5	13.3	10.3*
Tracklayer	2.0	0.9	3.9	0.5*	0.3	0.7	2.9*	1.8	3.4	0.4*
Group C Reduced or controlled vehicle traffic										
Reduced vehicle traffic	33.4	35.7	38.6	26.1*	28.1	32.3	35.1	31.3	42.1	25.7*
Uncropped headlands	1.1	0.2	0.5	2.4	1.7	1.4	0.8	0.6	0.6	2.0
Tramlines	29.3	46.3	41.0	5.1*	13.1	20.5	37.4*	28.7	49.7	8.0*
Traffic-free beds	2.4	1.7	4.6	0.5*	1.0	1.6	3.1	1.6	4.6	0.6*
Stock control	23.7	14.9	15.1	39.0*	19.0	25.5	23.2	20.6	10.8	39.3*
Avoid traffic on wet soil	68.1	75.7	65.7	65.9*	68.9	67.1	68.7	74.8	67.4	64.8

tramlines was 29%, the highest use being reported for the North (46%), closely followed by the East (41%) but tramlines were used to only a very small extent in the West region (5%). The use of tramlines was much more prevalent on large farms (37%) than small farms (13%). On arable farms tramlines were used by 50% but their use is very much lower on stock farms (29%) and dairy farms (8%).

Fig 1 The effect of farm economic size (ESU) on the adoption of dual tyres, subsoiling and tramlines as precautions against over-compaction

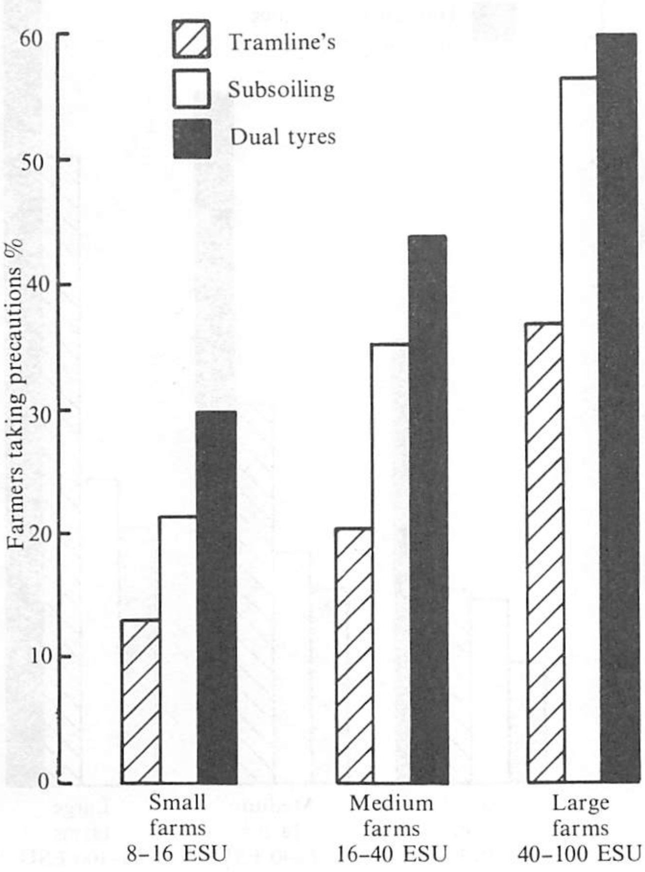


Fig 2 The use of dual tyres on tractors was about 70% on large arable farms in the East of Scotland and only 13% on specialist dairy farms in the West of Scotland

While the use of traffic-free beds were reported for only 2% overall, the proportion rose to 5% for the east region and 5% for arable farms. Their use was higher on large farms (3%) than on small farms (1%) and is probably mainly confined to vegetable and fruit production.

5.4 Types of field machine operations thought to cause over-compaction problems

(a) Effect of region. The extent to which specific types of field machine operations were thought to cause over-compaction problems was based on the proportion of farmers who both undertook each operation and considered it to be damaging (table 5). The harvesting of potatoes and root crops was thought to be damaging by 61% overall with large regional differences; 73% considered these operations to be damaging in the East compared with 49% and 45% in the North and West respectively. These differences are likely to be associated

Table 5 The influence of regional differences, farm economic size and farm type on the proportion of farmers who undertake certain field machine operations which they consider cause over-compaction problems

Operation	Proportion of farms, %									
		Region			Farm economic size			Farm type		
	Overall	North	East	West	Small	Medium	Large	Stock farms	Arable farms	Dairy farms
Harvesting grain crops	18.3	12.5	23.7	16.1	10.5	16.4	21.0	14.5	24.2	13.6
Harvesting potatoes and roots crops	60.7	48.6	72.9	44.7	35.6	56.5	67.6	39.6	74.8	56.2
Silage making	22.8	15.0	23.1	27.2	15.0	19.5	25.5	14.8	20.6	27.9
Haymaking	3.8	2.6	6.3	1.9	2.6	5.4	2.7	6.2	5.4	0.8
Seedbed cultivation	22.4	24.0	25.0	16.6	19.0	20.3	22.8	19.9	28.4	16.0
Spraying	21.5	25.4	33.2	5.9	7.5	16.7	26.3	15.2	37.4	8.5
Slurry and dung spreading	41.0	30.4	38.6	49.6	16.3	30.8	51.3	26.2	34.8	55.1
Lime spreading	23.2	23.9	28.9	17.3	15.4	21.6	25.4	20.2	30.9	17.8

with the different role of the potato crop in the three regions, with large areas and large machines being employed in the East, whereas in the West lighter machines are used for the early crop, and in the North potatoes tend to be restricted to smaller areas on better drained soils.

Slurry and dung spreading was thought to be damaging by 41% of farmers overall. The proportions for the North, East and West regions (30, 39 and 50% respectively) showed pronounced regional effects, perhaps reflecting the generally wetter conditions of soils in dairying areas of the West when these operations are carried out. Spraying operations were thought to be damaging by 21% overall with the highest value (33%) in the East compared with only 6% in the West.

Responses for harvesting grain crops, seedbed cultivations and lime spreading showed similar overall values (18%, 22% and 23%) with a tendency for the values in the East to be higher than in other regions.

The perceived incidence of damage from silage making was only marginally higher in the West (27%) than in the East (23%) but was appreciably lower in the North (15%). The overall value for haymaking, (4%), was considerably lower than the corresponding value for silage making (23%).

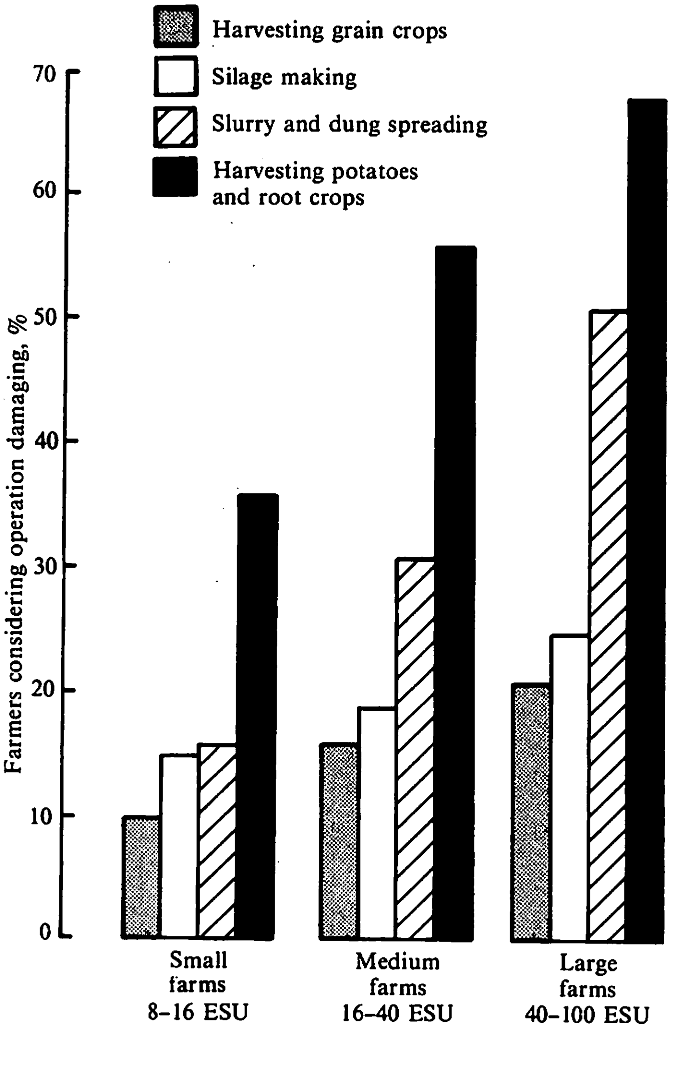
(b) Effect of farm economic size. The perceived influence of harvesting grain crops, harvesting potatoes and root crops, silage making, and slurry and dung spreading in causing compaction markedly increased as farm economic size increased (fig 3). A similar effect was found for spraying and lime spreading. On large farms all these operations are likely to involve much heavier machines than on small farms and there may be less opportunity than on small farms to avoid compaction risks by keeping off the land when it is too wet.

(c) Effect of farm type. The reported differences were perhaps less than would be expected because the terms 'stock farms', 'arable farms' and 'dairy farms' refer to broad ranges of farm type rather than specialised examples for which differences in machinery use would be more extreme. Damage from harvesting grain crops, harvesting potatoes and root crops, spraying and lime spreading was perceived to be appreciably greater on arable farms than on stock or dairy farms, perhaps due to arable farmers tending to employ larger machines for these operations than do farmers on predominantly stock or dairy farms. Slurry and dung spreading was thought to be very more damaging on dairy farms (55%) than on stock (26%) or arable farms (35%). This may be due to the much greater volume of slurry spread on dairy farms or the need to carry out the operations when soils are wet in a more compactible condition.

5.5 Crop yield reductions attributed to over-compaction

A large proportion of Scottish farmers reported that they were already taking precautions to relieve the effects of over-compaction. If their efforts are generally successful

Fig 3 The effect of farm economic size (ESU) on the extent to which farmers considered some field operations to cause the over-compaction of soils



then large crop yield depressions will not be observed.

In table 6, the results are expressed as a percentage of those responding for each crop. In this way all the crop groups are given equal weighting. The crops which were considered to show the most frequent large yield depression, attibutable to over-compaction, were oilseed rape, peas/beans and other vegetables. There are however relatively few farmers growing these crops in Scotland and hence the number of responses concerning them was small. Among winter and spring cereal growers, 50% considered that these crops showed small yield depressions attributable to compaction, compared to 22-30% for the other crops.

The observed frequency of small yield depressions for permanent and temporary grass, attributable to compaction, did not differ appreciably from that for other non-cereal crops (permanent grass 22%, temporary grass 29%), which supports the view that the alleviation of compaction in grassland soils may be no less important than in arable soils.

5.6 Influence of dominant soil type and altitude

Calculations were made to see whether the predominant soil type or altitude had an influence on farmers' responses. For those farmers having no heavy soil there were consistent lower proportions saying they took precautions (table 7), than was the case for farmers having appreciable heavy soil, but these differences were restricted to deeper ploughing, subsoiling, reducing vehicle traffic and avoiding traffic on wet soil.

Although, in general, altitude did not influence the precautions taken, on farms with no land above 62 m (200 ft) there was a lower proportion of farmers saying they avoided traffic on wet soil than for farms with appreciable areas above 62 m (200 ft).

Table 6 Proportion of farmers growing specified crops who consider that over-compaction influences yield in an average year

Crop	*Proportion of farmers, %* — *Perceived effect on crop yield,* *Large effect*	*Small effect*	*No effect*	*Don't know*	*Response rate, %*
Winter cereals	4.6	50.9	20.8	23.7	52
Spring cereals	5.7	49.2	21.8	23.2	84
Potatoes	5.6	29.6	34.1	30.6	41
Oil seed rape	13.8	27.5	23.3	35.3	17
Turnips/swedes	5.2	22.9	39.2	32.6	44
Peas/beans	12.4	29.2	19.5	38.9	11
Vegetable crops	14.0	25.6	25.6	34.9	4
Permanent grass	1.4	22.2	38.0	38.3	70
Temporary grass	1.8	29.3	34.0	34.9	73

Table 7 Effect of farm type and soil type on the proportion of farmers taking precautions to reduce or avoid over-compaction

Farm type	*Perceived soil class*	*Precautions taken, % of farmers* *No*	*Yes*
Stock farms	No heavy soil	20.6	78.1
	Heavy soil <25%	10.3	89.7
	Heavy soil >25%	15.1	82.5
Arable farms	No heavy soil	18.3	79.4
	Heavy soil <25%	1.8	97.9
	Heavy soil >25%	1.6	97.2
		*	*
Dairy farms	No heavy soil	41.8	55.8
	Heavy soil <25%	23.4	76.6
	Heavy soil >25%	16.9	81.2
		*	*

6 Discussion

6.1 Additional comments by farmers

The fact that 334 farmers (representing 37% of those returning questionnaires) took the trouble to make additional comments indicates the widespread concern with over-compaction problems. The proportion of farmers in the East (58%) who made additional comments was more than twice that in the North (27%) and West (25%), suggesting that there was a very much greater interest in the East. In some cases the comments consisted of merely a single sentence emphasising an answer already given in the questionnaire. In others a lengthy description was given of soil management on the farm in question, sometimes summarising several decades of experience (Soane and Kershaw 1986b).

6.2 Association of farm type, region and economic size

The type of farming practised and the economic size of farms varies greatly among the three regions used in the survey (table 8). Stock farms are concentrated mainly in the North, arable farms in the East and dairy farms are especially dominant in the West. Thus any differences obtained in the survey which were associated with region may be partially attributable to differences between predominant farm types as well as to soils and climates; indeed these factors are so intimately related as to make it impossible to draw a clear distinction between them. For instance, the very much higher popularity of subsoiling and deep ploughing as a means of overcoming compaction problems in the East than in the North or West may be attributable, either to the drier soil conditions in the east which will enhance the effectiveness of these operations, or to the prevelance of large farms in the East. Since large farms are likely to use very much heavier machinery than is the case on small farms, this may partially explain the much greater awareness of over-compaction problems in the East.

6.3 Value and implications of survey

The authors are not aware of any previous surveys among farmers on over-compaction problems. The information clearly demonstrates the widespread concern about such problems and the need for changes in the management of agricultural vehicles.

The number of farms in this survey (893) was relatively large compared with that in many other surveys, eg Church and Leech (1985) — a survey of fertiliser use on 250 Scottish farms; Elliott *et al* (1983) — a corrosion survey on 232 UK farmers; Chaney and Kershaw (1986) — a survey of sulphur on 147 farms in South East Scotland. However, the relevance of the results of the survey must depend on the personal and subjective observations and opinions of the farmers who responded. Decisions on the farm regarding over-compaction

Table 8 Proportion of total economic value of Scottish farms (ESU) for farms of different type and economic size within the three regions and overall

	Proportion of farmers, %			
	North	*East*	*West*	*Overall*
Farm type:				
Stock farms	48	21	10	23
Arable farms	40	69	6	40
Dairy farms	12	10	84	37
Total	100	100	100	100
Farm economic size (ESU):				
Small 8–16	16	5	6	8
Medium 16–40	43	29	43	37
Large 40–100	41	66	51	55
Total	100	100	100	100

These results are based on the distribution of economic standard units (ESU) within the sample (893 farms)

problems still depend largely on a complex interaction of factors in which cost/benefit information is largely lacking or based on guesswork.

A recognition of the importance of region, farm type and farm economic size on the perceived incidence of over-compaction problems should assist advisers and research workers to adopt a better approach to the solution of over-compaction problems.

7 Conclusions

1 In general, there was a large measure of awareness of the problems of over-compaction. The incidence of such problems was seen by most farmers as being of only occasional frequency although 25% thought that they occurred in most years or every year. Variation in rainfall was likely to be the primary reason for the fluctuation in intensity of over-compaction problems. While the majority thought that these problems had not increased during the past five years, 20% thought that they had.

2 A very large proportion of farmers reported that precautions were taken against over-compaction problems and the proportion was higher on arable farms than on stock or dairy farms. Deeper ploughing and subsoiling were widely used, especially on large and arable farms and in the East where the proportion employing subsoiling was 67% compared with only 31% and 33% in the North and West respectively. Dual tyres were much more widely used in the North (62%) and East (71%), than in the West (24%). Keeping off the land when wet was very widely adopted (68%) as a means of controlling compaction with very little variation according to farm economic size or farm type, but it was more prevalent in the North than elsewhere. Both reduction in vehicle traffic and tramlines were widely used on arable farms but much less so on stock and dairy farms.

3 The most damaging operations with respect to over-compaction were thought to be the harvesting of potatoes and roots and slurry and dung spreading. There was a tendency for the perceived damage from many field operations to increase appreciably with increasing farm economic size.

4 The most sensitive crops, in terms of prevalence of large effects of over-compaction on yield, were believed to be oil-seed rape, peas/beans and other vegetables. Over-compaction was thought by an appreciable proportion of farmers to be responsible for small yield reductions in spring cereals and in winter cereals. For other crops, including permanent and temporary grass, the proportion considering that over-compaction caused small yield reductions varied between 22% and 30%.

5 Large differences in the opinions and actions of farmers with respect to over-compaction problems were related to region, farm economic size, farm type and to a lesser extent soil type. These factors are clearly important in influencing policy concerning the alleviation of these problems.

8 Acknowledgements

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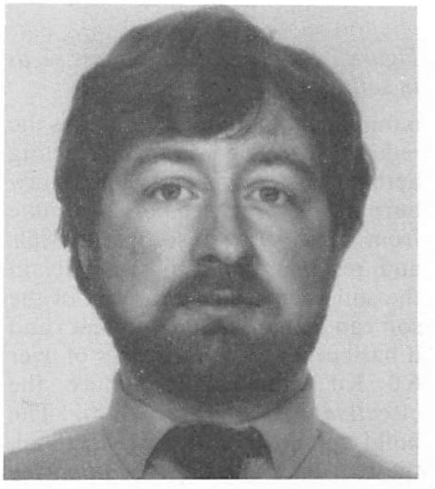
Re-examining the role of the plough

T J M Brassington

Summary

THIS paper considers the role of the mouldboard plough in arable farming in Britain today. The adoption of straw incorporation, the need to control weeds and volunteer cereals, and the problems of ash and herbicide accumulation in the soil, have focused attention on the plough in the last five years, and led to an increased acreage under the plough. During this period, a number of developments to design, and to accessories have taken place, and these are discussed in relation to the farmers' requirements of optimum workrate and performance.

The plough is a high draught implement, and the cost of ploughing in relation to minimal cultivation systems are discussed in the paper.



1. Introduction

The plough has always been the basic tillage implement on the farm; it will totally invert the soil, burying surface growth and crop residues to leave a clear surface for subsequent cultivation, or to be weathered into a seedbed. The principle of the soil engaging components have been refined through the ages with the development of construction materials and engineering techniques.

The plough frame design has also undergone considerable change, particularly in the last 130 years with the development of mechanical power. Pioneers of steam ploughing in the 1850s developed many forms with the cable drawn reversing balance plough having up to eight furrows becoming the preferred method. A fact often overlooked, however, is that the single furrow, horse drawn plough dominated the scene until the internal combustion engine tractor made its impact on agriculture in the early part of this century. The development of tractor hydraulic linkage systems and the increase in tractor power, has given engineers the opportunity to develop a number of designs, with mounted and semi-mounted ploughs, 180° turnover ploughs, and, more recently, front mounted ploughs.

The introduction of chemical weed control in the 1950s had a dramatic impact on British Agriculture. With this method of weed control and the need for faster seedbed preparation for autumn sowing, minimal cultivation techniques began to substitute the plough. Whilst straw burning is still practised, this situation will remain, but the plough has still a role to play on today's arable farm. Recently, increased interest in the plough is indicated by increased sales as between 1980 and 1985 the number of new reversible ploughs over 4 furrows increased by 50%.

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2. The Role of the Plough

There are three main reasons for the return to the plough:-

2.1 Weed Control

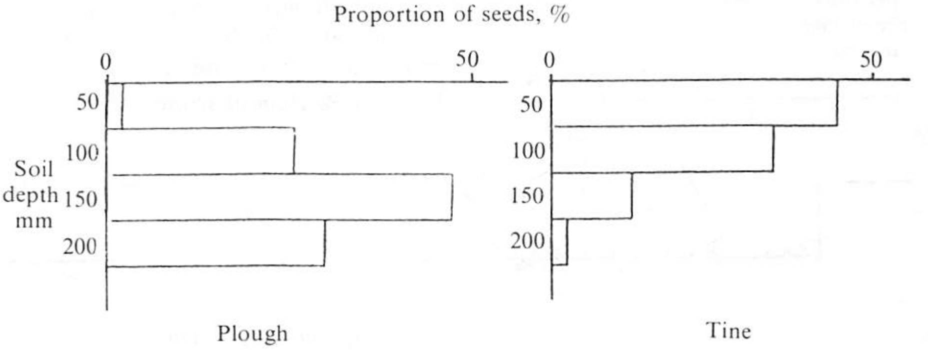
Blackgrass is a problem weed of importance to the cereal farmer. It has been shown that 90% of blackgrass plants emerge from the upper 50 mm of soil, and that the plough is effective at burying seeds below this level (fig 1).

Good burial will render most seeds non-viable. Some survive however and trials show a 3% survival after three years and 1% after four years; these still represent a considerable infestation (fig 2). The plough is good at burial, but it will also return old weed seeds back to the surface. The role of the plough is, therefore, an aid to weed control which may allow growers to reduce their chemical inputs. Trials have shown that the annual percentage kill needed to maintain a static population on a burnt stubble is 50% for ploughing and 88% for direct drilling. On a minimum tillage system, where two applications of a pre-emergent plus a post-emergent spray are made, these can be reduced to a single application when ploughing.

Sterile Brome has become another problem weed, encroaching from hedgerows, and is promoted by minimal cultivations. The current range of chemicals cannot control the weed adequately. The seed requires shade and moisture to encourage germination, but ploughing the seed to below a depth of 125 mm can sharply reduce infestation. At this depth the seed will germinate and die within a few months.

A further problem associated with

Figure 1 The effect of cultivation implement on burial of blackgrass seed



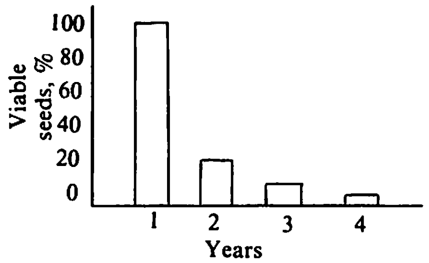


Figure 2 Survival of blackgrass seeds in soil

minimal cultivation techniques is the reduced effectiveness of soil acting herbicides, especially where straw burning is practised. Ash residue from burnt straw absorbs chemicals and residues build-up gradually in the soil. The absorption level of the soil can be measured (Kd value) and it has been found that values of over 6.0 Kd dramatically reduce the effectiveness of herbicides. The build-up of ash in the soil is gradual, the rate of which depends upon the dilution effect of the soil. Direct drilled crops are most affected, but ploughing will rectify most situations by mixing the ash with the soil (table 1).

Table 1 Effect of cultivation on herbicide absorption Kd (AFRC-LARS)

Ploughed	*Direct drilled*	
1980	1981	1982
2.7	4.6	6.7

2.2 Straw incorporation

The practice of straw incorporation has increased due to the proximity of some fields to public roads and buildings and preference by some farmers of non-burning methods of straw disposal (see table 2).

Table 2 Area of straw ploughed or cultivated (MAFF Straw Survey)

Year	1983	1984	1985
Area, '000 hectares	58.6	243	354
Proportion of area, %	1.6	7.1	10.4

In ADAS trials, the preferred method of incorporation on most soils, apart from the very shallow and very heavy; is the plough. Ploughing offers the advantages of leaving the surface free of trash, which will minimise problems with following operations in adverse conditions and is less likely to give a yield reduction in subsequent crops. ADAS trials show an average yield loss of 1%–2% which can be expected with tine and disc straw incorporation. Ploughing must be effective, and subsequent operations for preparing an autumn seedbed must be carefully planned; these points will be discussed in relation to plough design.

2.3 Fire breaks

It is well recorded at Long Ashton Research Station (LARS), that burning will kill a significant proportion of blackgrass, wild oat, and other weeds, and promote germination of remaining weeds. Ploughing the fire breaks around fields is often preferred to the alternative tined cultivation, as a totally trash-free fire break is achieved, the headland is in a more consistent condition to the remaining field and it gives better control of weeds encroaching from the hedgerows.

The area of ground cultivated in a fire break is often under estimated. With the present Burning Code fields are burnt in blocks of up to a maximum of 10 ha with a 5 m ploughed strip. This ploughed strip accounts for 6.5% of the total acreage, with more for smaller fields.

3. Plough developments

3.1 Plough frame dimensions

Ploughs with increased underbeam clearance and interbody dimensions are available. In normal dry conditions, and provided straw has been chopped and spread evenly, standard plough clearances of 675 mm and 850 mm respectively have been found adequate. It would be prudent, however, to plan for the occasional difficult year where laid crops are left in the field, or wet conditions at ploughing inhibit flow through the plough. In these situations additional underbeam, clearance is preferable to increased plough length because of extra strain on the tractor linkage due to the greater overhung weight. In lighter soils, it is often the ability of a tractor to lift the plough, rather than the draught force, which limits the size of plough.

3.2 Skimmers and their alternatives

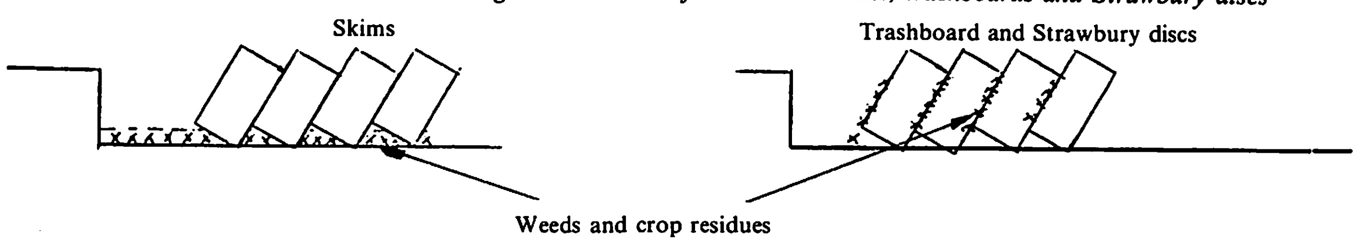
For effective burial of weeds and crop residues, the top edge of the furrow must be removed and placed in the furrow bottom. Standard skims should be set to remove the top 50 mm of soil, operating to best effect in undisturbed soil; loosened soil, particularly if wet, will not scour cleanly and therefore, will lead to blockages.

Trash boards were made popular by straw incorporation practices on the continent. The action could be described as a 'delayed' skim, spreading the skimmed top edge of the furrow down the side of the previous furrow to leave a sandwich effect (fig 3). It is argued that this improves air entry to the soil to promote rotting; however, trials have shown no differences due to the position and concentration of straw in the furrow. Good burial of weeds is not as effective when using trash boards, so some of the advantage of ploughing is lost.

Fitting trash boards in place of skims increases clearances and improves flow through the plough. Whilst skims should always be selected as the first option, trashboards do have a place where blocking is a problem. They function best on a loose surface but, while operating well on light soils, heavy land must be pre-cultivated if maximum burial is to be achieved.

In ADAS trials conducted in conjunction with Ransomes, a slight reduction in draught forces between trashboards and skims were obtained of between 1%–4%. This is considered relatively insignificant

Figure 3 Position of straw with skims, trashboards and Strawbury discs



and should not influence the decision on selection (table 3).

Table 3 Draught forces of trashboards relative to skims

Treatment	*Draught of trash-boards relative to skim coulters, %*
Ploughing 225 mm	98
Ploughing 225 mm + *pre-mixing*	96
Ploughing 150 mm	Not recorded
Ploughing 150 mm + *pre-mixing*	99

A further alternative to the standard skim, is the concave 'Strawbury' disc which freely rotates and is set at an angle to the vertical. This operates in a similar manner to a trashboard, spreading the skimmed material down the face of the previous furrow. Being virtually unblockable, it is particularly suited to conditions where large amounts of surface material are present. In heavy soils, the plough tends to ride on the discs making depth control difficult and side forces on the discs have a steering influence on the plough; hence its attachment is more suited to lighter soils.

3.3 Furrow width

Experience on heavy land favours a 300 mm wide plough body, to leave the surface more level and broken, with less hollows between furrows, when compared to 350 mm and 400 mm wide bodies. Its use will reduce subsequent cultivations and prevent drying of the soil at depth. Lighter land has different requirements, as soil breaks readily as the furrow is turned, a wider body can be used. This not only reduces the number of wearing parts per unit width, but the resultant draught per unit width will be lower as a high proportion of the draught forces are developed at the share point.

Most arable farmers operate on a variety of soil types and this is catered for by variable width ploughs having hydraulic furrow width adjustment. Optimum performance in terms of surface tilth, and work output can be selected according to conditions. There is also greater scope for interchanging tractors of different power outputs, e.g. a 100 kW tractor can develop a 30 kN draught force and operate a six furrow plough at 400 mm furrow width, and an 80 kW tractor, developing 24 kN, can operate with the same plough at 300 mm. It is anticipated that sales of variable width ploughs will increase significantly.

3.4 Furrow swept distance

The swept distance of the furrow is often confused with the furrow width, and the two are totally unrelated. The furrow width is the width of the slice; the furrow swept distance is the distance the slice is moved across the ploughing. The swept distance is often inadequate for the larger tractors which are necessary to achieve the timeliness for autumn crops. Many general purpose mouldboards leave a furrow which will comfortably accommodate a 400 mm (16 in) and even a 450 mm (18 in) tyre; however, 500 mm (20 in) tyres will cause compaction on the furrow side. Many larger tractors, of up to 100 kW, fit standard 500 mm (18 in) tyres. Using the traction formula developed at AFRC Engineering Silsoe it can be shown that tyres are under sized for most tractors (see table 4).

Table 4 Tyre size and pressures for a 99 kW tractor ploughing at 6.5 km/h

	Rear	*Front*
Axle weight required	5940 kg	3960 kg
(1) Standard tyres	18.4 x 38	16.9 x 28
recommended pressure	1.5 bar	1.2 bar
(2) Optional tyres	20.8 x 38	16.9 x 30
recommended pressure	1.1 bar	0.8 bar

It can be predicted that the standard tyres will develop enough pull (38 kN) for a six, 450 mm (16 in) furrow plough in the worst conditions. Inflation pressures are too high with the standard tyres, and the wider tyre section can be operated at a lower inflation, provided a plough is selected to give an adequately wide furrow.

3.5 Ploughing depth

The draught power required for a plough is proportional to the depth of ploughing within the normal working range. Measurements taken at recent ADAS/Ransomes trials, showed that a 30% reduction in depth from 225 to 150 mm gave a 25%–35% reduction in draught. It is difficult to plough shallower than 150 mm with a standard plough due to the near negative vertical forces on the tractor lift arms making it difficult to maintain an even depth.

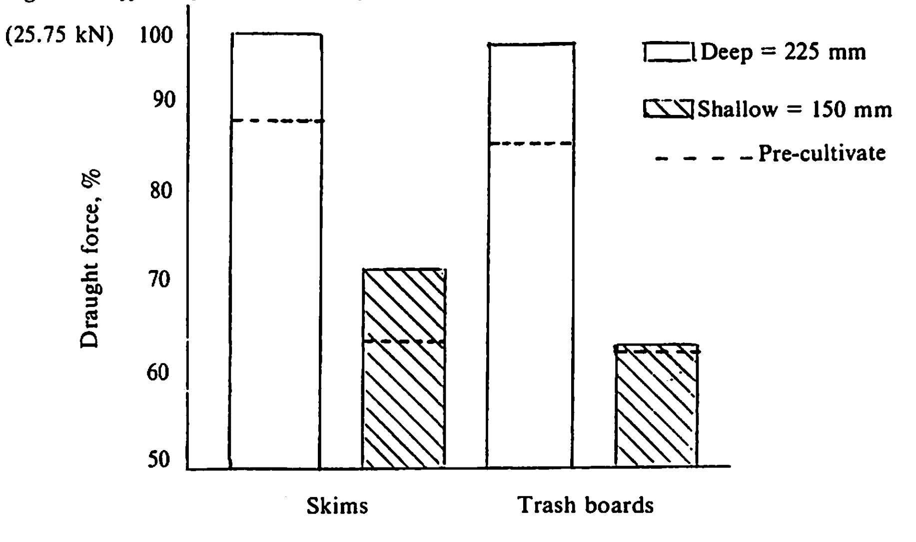
The depth of ploughing will also influence the efficiency of burying surface material. On shallow work, material is left close to the surface, and there is a tendency for skims and trashboards to bunch material which leads to difficulties in subsequent operations. Ploughs should, therefore, be operated as shallow as possible to maximise output, but quality of ploughing should not suffer as a result.

3.6 Pre-cultivation for ploughs

Pre-cultivation of land, where straw is incorporated is considered a necessary pre-requisite for ploughing on the Continent. Trials in the UK have proved this to be unnecessary and it can be detrimental to subsequent operations. In wet conditions, a plough fitted with skim coulters will tend to block when operating on a loose surface.

In some conditions pre-cultivation with heavy discs may be necessary to cut surface trash, — if for example

Figure 4 Effect of draught at 2 plough depths



the previous crop has been badly lodged leaving long straw on the surface. In these situations trashboards are more suitable.

It is interesting to note that the reduction in draught force, when pre-cultivating to half the plough depth, can be between 11% and 16%. This is, however, more than offset by the energy required for the additional operation, which could be up to 50% that of ploughing where two passes of pre-cultivation takes place (table 5).

Table 5 Effect of pre-cultivation on draught forces of a 3 furrow plough (heavy load)

	Mean draught force, kN	*Draught reduction %*	*Specific energy consumption kwh/ha*
Deep plough	25.8	Not applicable	78.0
Deep plough after pre-cultivation	23.0	11	69.5
Shallow plough	18.9	Not applicable	57.5
Shallow plough after pre-cultivation	16.2	16	49.0

3.7 Front mounted ploughs

The recent development of front linkages on tractors has led to the introduction of forward mounted ploughs. For tractors in the 120–130 kW power range, with the ability to develop a pull of up to 43 kN, six furrows can be used on heavy land and up to 10 furrows on lighter land (see table 6).

Table 6 Plough draught forces, kN/m width (Davies *et al*)

Heavy land	*Medium*	*Light*
18	12.5	6

A single rear mounted six furrow reversible plough is a good match for modern high horsepower tractors, however, anything larger would exceed the lift capacity of the hydraulics. Semi-mounted ploughs overcome this problem but are: long for road transport, need large headlands and do not make maximum use of weight transfer to the tractor. Fitting a front plough to the tractor improves manoeuvrability and utilises the implement weight to greater advantage. Weight from the front plough, when in operation, is not fully transferred to the tractor because the front linkage is operated in the fully float position with a front wheel controlling depth of work. Front linkages therefore need further development before the front mounted plough can be fully utilised. The concept is not very popular, possibly due to the increased complexity of operating and setting the plough combinations.

3.8 Implement combinations

Retention of moisture in the soil is very important particularly where autumn cropping follows ploughing.

(a) Using a furrow press with the plough on light to medium soils will consolidate the ground immediately, often leaving the soil in a suitable state for drilling with no additional tillage required, with the added advantage of a reduction in wheelings. The saving of an operation justifies the increase in power required which in ADAS trials has been measured at 3–5 kW for a four furrow press and accounts for 10%–20% of total draught. The power requirement and the cultivation effect are influenced both by soil type and by press design (table 7). Points to consider are ring profile, spacing, diameter, and weight.

Table 7 Power requirement (kW) of presses on different soil types (ADAS 1985)

	Sandy loam (Norfolk Ag Stn)	*Medium/ heavy silt (Terrington EHF)*	*Loamy sand (Gleadthorpe EHF)*
1. Single axle, 8 x 70 cm rings	3.3	3.0	3.9
2. Double axle, 16 x 70 cm rings	3.2	3.5	4.8
3. Double axle, spiral ring	2.9	2.8	4.1

A practice, gaining popularity in certain areas, is drilling in combination with a plough and press enabling a crop to be established from the stubble of a previous crop in a single pass. The output of the plough must be high as all the ploughing has to be completed within a much shorter period, although the overall output is reduced by approximately 20% for filling the drill with seed. Above average horsepower per hectare will be needed therefore, to achieve this. Physical characteristics of the land must also be considered; trees, pylons and other obstructions in the field will complicate the operation. Undulating or sloping ground will affect tracking and, therefore, drill matching on successive bouts. Headlands are normally drilled as a separate operation with a standard seed drill.

(b) Heavier land has to be treated in a different manner. The soil may be in a friable condition when first ploughed, but more often it is in a plastics state. In these situations, it should be left to partially dry before levelling with a separate implement such as discs or a land packer. The object is to crush the clods, fill in the hollows and level the ground and to achieve this objective, the weight of the press must be in the region of 90–100 kg/wheel, compared to 40–50 kg/wheel on light land presses. Heavy land that is untreated and left in an open condition after ploughing, can become very cloddy, and difficult to prepare into a seedbed.

3.7 The cost of ploughing

Minimal cultivation with straw burning has enabled cereal farmers to prepare autumn seedbeds quickly and at low cost using minimal labour and power. Ploughing is a high draught operation resulting in the cost of higher tractor power requirements and in pressure on timeliness, which need to be considered against its benefits.

The relative costs of three cultivation systems, (up to drilling), are given in fig 5a. On light land, the differences are small, and ploughing may be practised for other reasons as a necessary loosening operation. On heavy land the differences are significant. If straw incorporation is practised, the additional cost of a predictable 3% yield loss and the possibility of having to apply an extra herbicide treatment must be considered when comparing tine/disc incorporation to ploughing. A predictable 3% yield will cost £21/ha, and an extra autumn herbicide charge of £33/ha on top of the cost of the cultivation. However when these additional costs are considered, the expense of ploughing can sometimes be justified.

A second point to consider is the workrate of a ploughing system of tillage (fig 5b). Workrates are not a problem on light land, but on heavier land, there is considerable pressure on labour to achieve the required target dates unless tractor power is sufficient.

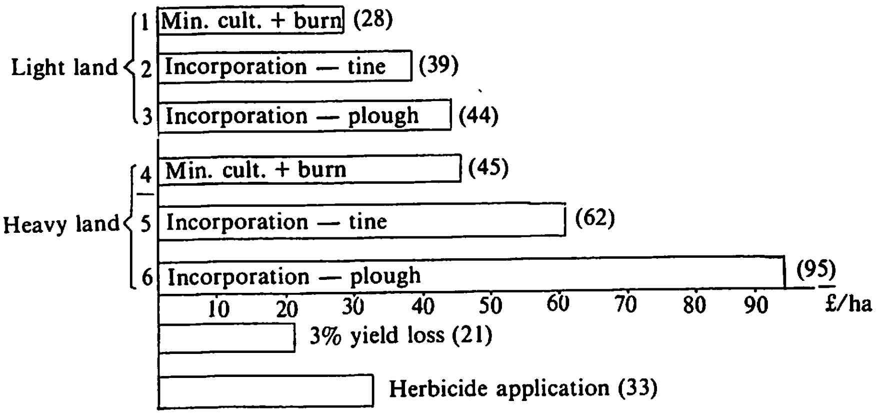


Figure 5a Comparative costs of autumn cultivation systems

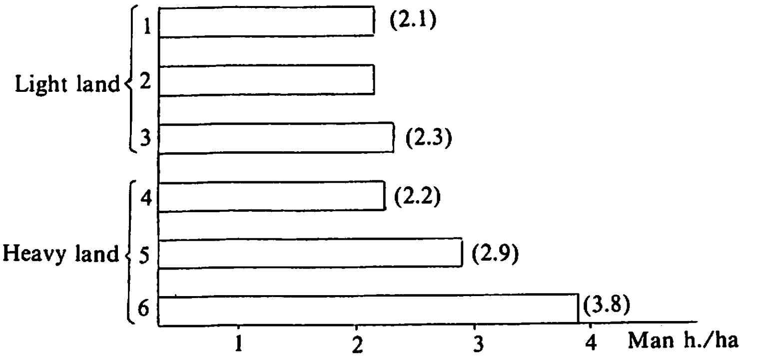


Figure 5b Comparative labour required for autumn cultivation system

4. Conclusion

While the plough is not considered the primary implement for cultivation on most arable farms, it does have an important role to play preparing fire breaks, incorporating crop residues, where straw is not burnt, and as an aid to weed control.

The future of the plough is assured as there is increasing environmental pressure on farmers to reduce the area of burning. The plough will regain its position as a primary cultivator, being the preferred method of straw incorporation on most soils. The development of new technology in cereal harvesting methods will influence subsequent cultivation techniques. For instance, the stripper header on combines is designed to remove only the ears of corn from the standing crop, leaving the straw standing in the field and ploughing, with suitable attachments, may prove to be the preferred method of disposal of the long straw.

The industry is under increasing financial pressure, resulting in the need for fixed costs of machinery to be kept to a minimum. Ploughing, as illustrated, is a high cost operation and the further development of materials, such as plastics, for soil engaging components to reduce draught forces and wear rates, will be required to lower these costs. There is limited time available for autumn cultivations, ploughs designed with quick methods of adjustment, as on the variable width plough, and front mounted ploughs will give the operators greater opportunity to maximise the output of their equipment. Presses have become well established on medium to light land as a method of combining operations, reducing overall costs and wheeling on seedbeds. This concept is likely to develop with the attachment of drills to plough-presses for land that is suitable.

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Transmission assembly using automatic guided vehicles

Alan Boad

1 Introduction

AT the start of the '80s, Massey Ferguson started their strategic plan for upgrading the assembly facilities at Banner Lane to be capable of taking them through into the '90s. The aims of the plan were two-fold, to boost efficiency by reducing inventory to enable the plant to progress to a Kanban (just in time) method of operation, and to put into place modern and flexible assembly facilities, which would be capable of responding to the many different build configuration and volume demands required by the market place.

The first installation of the £11 million investment was the Automatic Guided Vehicle (AGV) system for transmission (gearbox) assembly. This was commissioned in February, 1985. New rear axle and chassis facilities followed, being commissioned in April and August 1985 respectively. The final-build lines will complete the plan in August 1986.

2 The transmission AGV facility

2.1 History

The old transmission assembly facility comprised of a 24 station floor-mounted slat-conveyor surrounded on both sides by the associated sub-assembly areas, equipment and component storage. At that time, produced on the conveyor were 6-speed and 8-speed crash transmissions, an 8-speed synchromesh transmission and a multi-power hydraulically selected hi-lo ratio 12-speed transmission. Planned output was 30 units/h. In an area adjacent to the main conveyor on static build stands, a manual shuttle (6 forward and 6 reverse speed) transmission was assembled at low volumes.

The problem area was extremely congested. The proposed transfer from our French factory to Coventry of the assembly of 12-speed synchromesh and 12-speed multi-power synchromesh transmissions, together with an increase in the build of manual shuttle transmissions, meant that we had to do something, but what?

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2.2 The solution

Due to the increasing complexity of the transmission types and the quantity of different variable builds (some 170 currently) it was decided to implement a system of kit issue in which all the components and sub-assemblies are collected together and presented to the assembly line for each transmission build as required.

For this purpose, the transmissions were divided up into six different sub-assembly kits, viz shift rails and forks, retainer and input pinions, countershaft (lay shaft), mainshaft, planetary units, transmission case, etc. Each kit is built in a separate sub-assembly area, which is completely self-contained with respect to components, tooling and equipment. The completed sub-assembly is then placed into a plastics kit box ready for selection for the main build. This gives the advantages of a reduced likelihood of wrong builds, due to wrong component selection, and a greater flexibility in the introduction of new configurations or transmission types, as usually only two or three sub-assemblies are affected.

Two options were considered for the final assembly operation; a floor conveyor with separate overhead kit collection and feed conveyor or the use of AGVs to collect the kits and to act as mobile work platforms.

The former was rejected on the basis of:

- Lack of flexibility to accommodate future change. The floor conveyor in particular would have had permanency in location, length and layout when established.
- The need to commit the total funds for the maximum planned capacity at one time. There was no possibility of the facility being progressively built up in phases as demand for output increased and necessitated expansion.
- The ability to continue to improve and modify the assembly process as different techniques were developed or changes in demand arose.

AGVs have none of these problems and have many additional advantages. For example:

- The ability to be routed wherever required as the process necessitates the shape or size of the available floor space.
- The ease and speed with which the route can be modified or changed to accommodate changes in production or product requirements.
- The ability to vary the routeing of some or all the AGVs within one layout.
- Variable banking to accommodate cycle time imbalance.
- The capacity of the system to be expanded by the addition of AGVs and, if required, additional guide paths to suit production needs. AGVs can be removed from the system without any interruption to production.
- A quiet and clean operation with a totally free floor area having no obstructions except control panels and battery charge stations.

2.3 What is an Automatic Guided Vehicle (AGV) and how does it work?

Most AGVs comprise of a steel fabricated body which has mounting plates incorporated into the structure to enable build heads or fixtures to be attached to the vehicle for carrying the work piece. It also incorporates a platform for carrying the kits of parts and two passenger platforms to enable the operator to be carried along by the vehicle as it progresses down the main build line. The vehicle in use at Massey Ferguson was designed and manufactured in France by CFC.

The AGV is powered by four starter batteries (as fitted to our tractors) having a capacity of 180 Ah at 24V dc, these supply power for all the systems on the vehicle, the main energy consumption being the motive power and steering unit. The power unit is mounted at the front of the vehicle and is built into a frame which can be readily removed from the vehicle in the event of a breakdown by simply unplugging the electrical supplies and removing eight bolts.

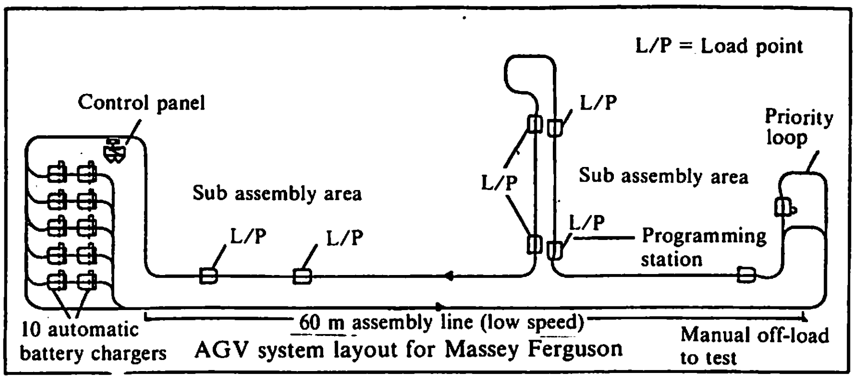
The AGV follows a path which is pre-determined by frequencies carried in a cable which is slotted into the floor. It is informed which ones to follow by a switch (normal or priority) on its control panel.

The steering is controlled by sensors mounted in front of the drive wheel. They act as arms of a Wheatstone bridge circuit and sense the frequency in the guide cable, which generates a current in each sensor. The balance in the Wheatstone bridge is maintained by a motor which rotates the drive unit to centralise the sensors relative to the guide cable and, thus, the AGV will follow the cable.

The vehicle incorporates two safety devices which protect both the operators and the vehicle. The first is an ultrasonic sensor, similar to that used on Polaroid Auto Focus Cameras. This can be set to slow and stop the vehicle at a pre-determined distance from an obstruction. At MF it is set to give a minimum gap between the AGVs of 450 mm. The second device is a collapsible bumper which, when it contacts an obstruction, is designed to stop the AGV with its maximum load (650 kg) and maximum speed (30 m/min) within the bumper's collapse length.

2.4 The AGV circuit and how it operates

The circuit was designed to allow the AGVs to travel between the kit sub-assembly areas, stopping at each one to allow manual loading of the kits to suit the required build (fig 1). At the first kit area (rails & forks), a build card is attached to the vehicle. This card identifies the transmission type and the appropriate kits required for the assembly (fig 2) which have to be loaded onto the AGV. At each kit loading position, the AGV stops automatically as it senses the presence of a stop beacon in the floor.



CIRCUIT	AGV TECHNICAL DATA	
Length: 240 metres	NUMBER OF AGVS	: 40
P.L.C.	DIMENSIONS — Length	: 1490 mm
TELEMECANIQUE TSX 47	Width	- 1420 mm
	Height	: 930 mm
CHLORIDE SPEGEL	WEIGHT (WITH BATTERIES)	: 600 kg
Battery Chargers:	CARRYING CAPACITY	: 650 kg
10 + 1 on Priority loop	BATTERIES	: 4 off - 12 VOLT STARTING BATTERY
	SPEEDS	: 28 m/m and 1 m/m
	SAFETY	: BUMPER & ULTRASONIC CELL

Figure 1 AGV system layout and technical data

The operator identifies from the build card, the correct kit which is then exchanged for the returning empty kit box. A start button on the vehicle is then pressed and the vehicle automatically starts and moves to the next kit area, where the process is repeated.

The bends in the circuit are protected by a system of blocking loops which prevent more than one vehicle from entering a bend at a time. This is necessary due to the very tight 90° bends which render the ultrasonic sensor ineffective and would cause the AGVs to clash and stop nose to tail as they progressed round the bends.

At the last kit loading position, the transmission case is loaded into the build fixture on the AGV. This enables the transmission to be

Figure 2 Transmission build card

MASSEY FERGUSON MFG. LTD.
TRANSMISSION TALLY BUILD AUTHORITY
*********************************** 03/19/86

TRANSMISSION SEQUENCE NUMBER 842 DESCRIPTION - MK2 SYNCHRO 12 SPEED
SPECIFICATION - 5965
DESTINATION - PAKISTAN C COMMENTS -

\- - 2990404 - 290 4 - BROCK SPACER -
\- - - -

To be built in accordance with the following specification;-

SYNCHROMESH	- MK2SY	CONSTANT MESH	- 1.14	CM-L RANGE	- 1.45
C.O. P.T.O.	- 1.90	EPICYCLIC	- HD	CREEP BOX	-
HYD. PIPES	- PIPES	P.T.O.	-		

***** KITS *****

F	R	C	M	P	T
10	35	34	14	4	42

TRACK SEQ. 5115 SPEC. 5965

TRANSMISSION SERIAL NUMBER
STICK HERE !

!! Remember .. Quality sells our product. !!

rotated through 360° in both the horizontal and vertical planes, to provide good access for the operator on final assembly.

After being loaded with the complete set of kits, the AGV enters one of five lanes of battery chargers, where the vehicle automatically receives a charge on demand. The sequence by which AGVs enter the area is maintained throughout the charging process, ie first in — first out.

AGVs are called out of the chargers when an AGV clears the timer release position at the start of the main build run. The time release is controlled by the system PLC (Telemechanique TSX 47) and can be regulated in 0.1s increments, to suit the build rate required.

The main assembly section, where the AGV travels at 1 m/min, is 60 m long. The build rate is controlled by the timer release, which in effect, controls the pitch of the vehicles (unlike a conventional conveyor, where the pitch is constant and the speed is varied). This has the advantage of being able to have the overhead tooling in fixed positions, which are suitable for all build rates.

The transmission is assembled completely on this section from the kits on the AGV. The work ranges from bushing the transmission case, fitting the gears and shafts through to fitting the shift rails and selectors. Quality checks are carried out on the line, eg concentricity of input pinions, pressure testing input seals and rotation, etc. Each operator is responsible for fitting a specific section of the transmission, such as the mainshaft or input pinions. This was decided rather than the complete build, due to the high variables, problems of training inexperienced operators to cover for absentees and the reduced number of operators required on the main build. Space is available for on-line rectification as required. At the end of the section, the completed transmission is unloaded manually to the test area, CKD packing or to the next stage in the tractor assembly process, as required. The AGV then continues on the circuit to restart the whole process once again. As the AGVs are re-charged on every circuit, the system has the capacity to run continuously for successive 24 hour periods if required.

3 One year on

The system although having minor teething problems, eg slow AGVs and frequency problems within the battery charging area, has not caused any losses in production. It has proven to be reliable, reasonably easy to maintain and very easy to modify. As an example, the PLC was changed from a Telemechanique TSX 21 to a TSX 47 over a two day period (including testing), assembly restarted on time with no problems or loss of production.

The change in method of working and the use of AGVs has been readily accepted by the shop floor workers after initial reaction to the "strangeness" of operator isolation, (previously they worked shoulder to shoulder, now they can be 2–3 m apart!). The introduction of the new transmission types has given few problems. Inventory of both built-up transmissions and components is under greater control and stockholding has reduced significantly. We now keep only a maximum of 4 hours stock of built-up transmissions, as all our assembly operations are linked together with minimum stocks held between each stage of the process.

The Engineering Council — Five years of Progress

J C Levy

1 Introduction

THE birth of The Engineering Council took place some five years ago at the initiative of the government and with the active co-operation of the professional engineering institutions.

The intention was to create a body with a wider remit than that of the old Council of Engineering Institutions (CEI) and the continued commitment of the institutions has been a vital factor in the progress made towards fulfilling The Engineering Council's objectives which, stated broadly, are:—

* to promote and develop the science and practice of engineering in the United Kingdom.
* to ensure the supply and best use of engineers
* to co-ordinate the activities of the engineering profession.

Because it is a chartered body, rather than the statutory authority which the Finniston Report recommended, The Engineering Council has to work by persuasion rather than by edict.

But persuasion works, as our record will show, although anyone who expects a sudden change in national attitudes towards industry, towards the profession and towards the individual engineer, is likely to be disappointed because of deeply ingrained social and cultural attitudes. The fundamental change of attitude for which the Engineering Council is pressing does not come easily. It is a long hard, unremitting task for all concerned. And the arguments and action have to be sustained with determination, patience, reasoning and good humour.

The Engineering Council has many audiences which it seeks to influence and the diagram (fig 1) illustrates the four principal directions in which the Council looks out at the world. However, in its

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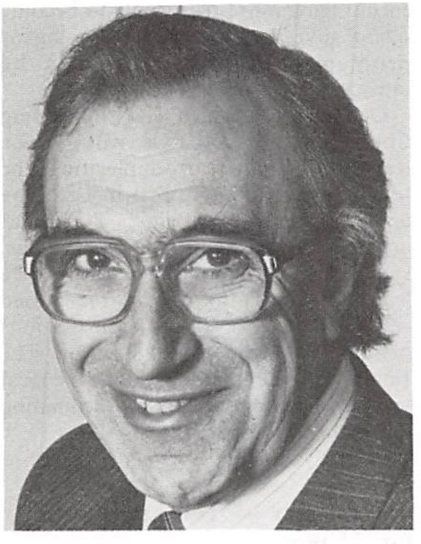
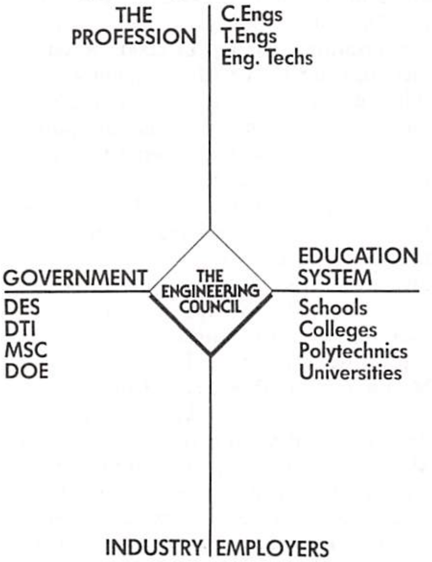


public affairs activities there is a further direction, the nation itself.

2 Public Affairs

The Council has set itself the task of bringing about a significant improvement

Fig 1 Relationship of outside bodies in the Engineering Council



in public awareness of the profession and of the role of qualified engineers. An unremitting campaign has been conducted under the leadership of the Director — Public Affairs, Ron Kirby to cure such persistent problems as the public confusion of engineer with mechanic, of engineer with scientist and of the many misconceptions relating to the importance of manufacture and commerce in relation to the economy as a whole.

In a sample period of eight months there were found to be 1208 newscuttings and media mentions of engineering including TV, radio and press. Of these, 534 referred specifically to The Engineering Council. While many of these efforts are simply like trying to hurry-up a glacier, there are occasionally tangible results. For example, after repeated requests to the Home Office, the notes accompanying passport application forms giving examples of 'persons of standing' fit to countersign applications now include engineers in the phrase ... doctors, engineers, lawyers..., a fortunate alphabetical chance putting us between our companion professions.

The wider public is reached several times a year via the Council's responsibility for the 'Prince of Wales Award for Industrial Innovation and Production' and via its 'Young Engineers for Britain' contest. Media coverage of such events can be very extensive indeed. Just one example must suffice, though many could be given. The 1986 "Young Engineers for Britain" awards were made by HRH Princess of Wales at the Wembley Conference Centre and not only did the quality papers carry the story but there was also coverage in the *Daily Express* and the *Daily Mail* and a front page picture of the Princess with the winner and mention of the competition in the *Today* newspaper. The competition was also mentioned in the *Sun, Mirror* and *Star*. In addition it featured on the influential BBC Radio 4 "Today" programme and there were excellent stories on mainline BBC TV programmes; a feature solely on the competition itself on BBC TV Breakfast Time and other features on BBC TV Superstore and BBC TV Blue Peter. The latter two programmes alone went out to more than 7,000,000 youngsters. The subsequent enquiries fully occupied the full attention of four members of staff for several days.

Behind this public affairs frontage a vast amount of solid work and pressure is maintained resulting in the issue of Council policy statements or discussion documents or sometimes in changes in which the Council has played a leading part but which cannot be attributed. The Engineering Council employs less than 60 people of whom about a dozen are exclusively engaged in maintaining the Register and in running The Engineering Council examinations which cater for more than 5000 students a year in 50 centres world-wide. The other staff run the qualifications function of the Council together with its engineering education and training activities, maintain contact with the Engineering Institutions and 170 industrial affiliate organisations, service the Annual Engineering Assembly and encourage its role, look after the 19 regional committees and maintain contact with a large number of national organisations each representing substantial interests in industry, education, training and government.

From time to time too the Chairman, Sir Francis Tombs, and Director General, Dr Kenneth Miller, penetrate to higher levels of government at ministerial level. This involvement may even include the Prime Minister who, in fact opened the first meeting of the elected Engineering Assemby in Birmingham in 1985, being followed in 1986 by the Secretary of State for Wales at the Swansea meeting.

3 The Register, The Engineering Assembly and the Regions

The Register contains the names and particulars of 280,000 Chartered Engineers, Technician Engineers and Engineering Technicians. The designations CEng, TEng and EngTech are continuing to establish themselves as recognised hallmarks of competence and there is some evidence that this is now showing on the salaries front. Each registrant receives The Engineering Council's newsletter twice a year and can vote in elections to The Engineering Assembly, giving all the opportunity to influence policy.

The country has been divided into 19 regions, each of which elects four Chartered Engineers and two Technician Engineers or Engineering Technicians to the Assembly. The 114 Assembly members may discuss any matter within the responsibility of The Engineering Council and may pass resolutions which the Council is required to consider.

The Council aims to expand considerably its activities in the regions through The Engineering Council Regional Organisation (ECRO) committees on which local institution branches are represented. Activity centres on contacts with the schools, local industry, local government, local press and local radio. In particular the immediate plan is to expand the 'Opening Windows on Engineering' scheme from about 5% of schools to 80% in the next five years.

Already the Council's initiatives on correcting the shortage of maths and physics teachers is having an effect at the highest levels; we are working with the Manpower Services Commission on "career breaks" to enable women to return to the profession; we are encouraging more registrants to become school governors; and we are pressing for problem-solving methods to be introduced at primary school level.

One task with which The Engineering Council and its ECROs will *not* be concerned is that of duplicating the learned society function of the engineering institutions. Technical activities by means of papers, meetings, symposia, conferences and distance learning programmes is the recognised responsibility of each of the institutions in their own fields of engineering. The Engineering Council at national and local levels will concentrate on a co-ordinating and public relations role.

4 Industry — The Engine for Change

If the views of the Engineering Assembly provides one essential input in forming the policy of The Engineering Council, the views of industry provide another equally important channel. There are now some 170 employers of engineers who have become Industrial Affiliates of The Engineering Council. They each pay an annual sum depending on their number of employees, the largest organisations paying £10,000. Regular meetings are held with the members of this industrial forum, each meeting having a set theme such as continuing education and training, school education, registration of engineers.

To assist industry The Engineering Council is encouraging managements to take a critical and positive look at various engineering activities. This is accomplished by means of easily assimilated but authoritative texts including 'Technical Reviews for Manufacturing, Process and Construction Companies' and 'Appraising the Technical and Commercial Aspects of a Manufacturing Company' both of which have been distributed widely and have been well received. They have been followed recently by a joint venture with The Design Council 'Managing Design for Competitive Advantage'.

Involvement with industry in these ways and emphasising the desirability of industrial support for the registration system will form a continuing theme in the policy of The Engineering Council.

5 The Engineering Institutions

So what of the institution front itself? The professional institutions stand in a very special relationship to The Engineering Council in their role of Nominated Bodies able to certify the attainment of individuals for registration and, in some cases, as Authorised Bodies for the accreditation of academic courses and training programmes. They alone may appoint representatives to the Council's five Executive Group Committees which in turn nominate to the Board for Engineers' Registration. Their involvement has been wholehearted and characterised by tremendous collaboration with the Council and with each other in overhauling standards of engineering education and training for Chartered Engineers, Technician Engineers and Engineering Technicians. The effort culminated in 1984 with the publication of 'Standards and Routes to Registration' familiarly known in the education and training world as SARTOR.

This policy statement has had a profound effect upon the development of engineering degree and BTEC courses for the 1990s and, with its companion statement 'Resources for Engineering Education' has been instrumental in convincing the government of the need to provide extra finance to the tune of £43M for more student places in subjects linked to Information Technology and, more recently an additional £54M for the polytechnics to restore their unit of resource and to support new initiatives in areas of advanced technology.

To aid the continuing collaboration with the engineering institutions, Engineering Council senior staff hold regular meetings with the secretaries of the institutions who are consulted about a wide range of administrative and policy matters before decisions are taken. The smooth working of the registration system is a tribute to their goodwill and helpful attitude.

The Engineering Council would like to promote even more joint-working between the engineering institutions and has not been slow to encourage mergers amongst them. At present negotiations are at an advanced state for mergers or federations involving nine institutions.

6 The International Dimension

A further area of common interest and joint efforts between the engineering institutions and The Engineering Council lies in the area of international relations for the profession.

The most important and active overseas link is through the European Federation of Engineering Institutions (FEANI) which consists of 20 European countries including all those in the European Economic Community. Each country, has a National Committee which is responsible for its participation, the British National Committee consisting of representatives of the Chartered Engineering Institutions, the Fellowship of Engineering and of The Engineering Council which also provides the administrative back-up. There is in addition a Technician Engineer representative.

The importance of FEANI deliberations lies in the mutual recognition of engineering qualifications within the countries of Europe and lately there has been a breakthrough which could be of the utmost importance for United Kingdom engineers. For many years the continental countries have refused to acknowledge Chartered Engineers on an equal basis to their own professionals because the length of continental degree courses is generally longer than those in the United Kingdom. Now, due to a new initiative taken by the British National Committee, this deadlock has been broken and all 20 National Committees of FEANI have agreed to recognise a seven-year package of education, training and experience which strongly resembles that of the Chartered Engineer requirement in the United Kingdom. In 1987 this agreement will be used to launch the new title Euro-Engineer which may perhaps be used as a pan-European prefix such as Euro Ing Jack Levy. All Chartered Engineers would then be able to use the new title on personal application and, would receive a FEANI 'passport'. A similar provision for Technician Engineers would follow.

7 The Future

So what else is on the stocks for the future? While it is not the policy of The Engineering Council to press for widespread licensing of engineers, it intends to examine the areas where licensing exists and to consider whether any extensions to those areas should be sought. To lift the veil slightly on this kind of issue, work is commencing to examine the practicability of defining the type and level of responsibility which, it may be recommended, should be reserved for registered engineers. This would fall short of a full licensing arrangement but would indicate to employers and Government the views of The Engineering Council on this important matter.

On the education and training front, emphasis will swing to continuing education and training following the Council's publication a few months ago of its statement 'A Call to Action' which showed the need for an urgent approach to up-dating and for improved facilities to be made available. Providers include colleges, polytechnics, universities and the engineering institutions as well as industry itself which provides a large amount of in-house re-education and training. The institutions, will also be responsible, through the Council's Board for Engineers' Registration, for establishing a truly national system of monitoring which will include a personal record compiled by each registrant and which will act as evidence of their effort to maintain awareness and keep up-to-date in their chosen field.

Although the initial government grant-in-aid terminated after the first three years of the Council's existence, government support is still forthcoming for various individually planned projects particularly in the education and training field. In 1987 this includes support from the Manpower Services Commission the Department of Education and Science and the Department of Trade and Industry.

Because there is no further automatic government grant-in-aid, The Engineering Council can now claim to be fully independent. It derives about 50% of its income from Registration fees, the other 50% coming from the specific supported projects (10%), examination fees (20%) and fees from the industrial affiliates (20%).

By the end of its first five years of existence it can fairly be stated that The Engineering Council has established its place in the national scene by acting in an independent, forthright manner which nevertheless takes account of the many and varied interests and opinions among its external contacts.

The next five years will probably be even more challenging than the last. The priorities will be to continue to establish the Council permanently and prominently at the core of national strategic thinking for industry, for the profession and for the role and importance of qualified engineers. Great care has been taken, in a proper engineering approach, to build sound foundations which will serve the profession well in the long run.

The Board for Engineer's Registration

The Mature Candidate Scheme for Chartered Engineer status

THE Engineering Council regards due recognition of engineering talent, at whatever stage it can be identified, as an important contribution to the profession and to the nation, and is anxious that individuals who achieve a high standard of professional competence in the course of their careers should not be handicapped by lack of early educational opportunities.

It has, therefore, adopted a Mature Candidate Scheme to provide a route to registration for candidates who, although they do not have formal academic qualifications at the right level, are able to demonstrate that in later life they have achieved a standard of technical competence comparable to that of their contemporaries who become Chartered Engineers by a normal route. A conventional examination would not be an appropriate method of testing such individuals.

The Mature Candidate Scheme does not offer an easy option; the burden of proof upon candidates is stringent. They are required to complete a technical paper (or papers) at the appropriate level which will be submitted for examination by assessors appointed by the sponsoring Institution and the Engineering Council. If the assessors agree that the standard of the submission is adequate they will proceed to examine the candidate orally on it and any other matters they may consider relevant.

The purpose of the submission is to give candidates the opportunity to offer an ordered and critical exposition of some aspect or aspects of engineering practice, defining the problems or development aims involved and demonstrating their resolution or achievement by the application of engineering principles and knowledge. In some cases the submission will consist of reports or design studies with a commentary or connecting dialogue setting the material into the appropriate perspective. Alternatively it may take the form of a single speciality paper which might be based on a design project or on a report of original work.

A candidate whose submission is deemed by the assessors to be adequate for further consideration will be required to attend an interview, normally in the UK, to be examined orally on the subject of the submission, etc.

Candidates who are at least 35 years of age and wish to be accorded permission to satisfy the academic requirements for Chartered Engineer status through the Mature Candidate Scheme should apply (to the Institution) for full details.

The title 'Chartered Engineer' and the designatory letters 'CEng' are reserved for those who are registered at Stage 3 of the Engineering Council's Register for professional engineers and are members of a nominated Chartered Engineering Institution or institution-affiliated body.

Book reviews

Farm building construction — the farmers guide

Maurice Barnes and Clive Mander

Publisher: Farming Press Ltd, Wharfedale Road, Ipswich, Suffolk IP1 4LG, 1986. ISBN 0-85236-159-9. £11.95.

THIS is a very informative and useful book for those contemplating construction or modification of a farm building, service road or liquid storage receptacle. It is aimed primarily at helping the farmer to decide whether to undertake a DIY approach on some, or possibly all of the constructional aspects related to his project. For the enquiring individual who does not wish to undertake DIY 'entrepreneurialism, the book is still of value since it briefs the reader well on fundamental planning and layout and on good constructional practices, including many related technical matters and terminology. It thus enables the reader, firstly to make an informed decision on which project best meets his needs and secondly, to make considered appraisals of the work of his appointed contractor.

The book is attractively laid out, containing many helpful figures, photographs, tables and charts and is consequently easy to digest. It contains information drawn from publications by many recognised establishments in the field such as the Ministry of Agriculture, Fisheries and Food, the Cement and Concrete Association, the Timber Research and Development Association, and the Agricultural Construction Industry Federation. This information is knitted together into a coherent whole by the two authors, both of whom have considerable practical experience in the farm buildings industry. The book contains general information and guidance on the entire building operation covering legislation, planning, measurements, levelling, excavation, drainage, framed buildings, cladding, foundations, walling, rendering, floors, services, ventilation and insulation. The areas of foundations, walling and floors receive greatest attention.

The book cannot, however, be considered as a comprehensive manual to enable any reader to construct a farm building. Indeed, the need for safe erection of the main framework of a large building, particularly if it is of steel or concrete, is something which should not be undertaken lightly since it has potentially fatal consequences if done incompetently (Health and Safety Executive and British Standard Institution documents provide important guidance on the safe erection of structures). It is however a good reference work which will help the discerning individual to make a considered judgement of which aspects he might sensibly do himself, rather than contract out, and how properly to set about doing those parts. In this way it will also appeal to the novice considering a DIY domestic garage, home extension or wall rendering project!

Adam Robertson

Surface irrigation systems and practice

Melvyn Kay

Publisher: Cranfield Press, Cranfield Institute of Technology, Cranfield, Bedford MK43 0AL. 1986. ISBN 0 947767 26 6. £8.50.

THIS book is stated by its author to have been written for "those involved in irrigation at a vocational level in developing countries".

The book gives basic information on

the layout, operation, and maintenance of basin, strip, and furrow irrigation systems. Some information is also given on piped irrigation systems and the final chapter discusses health problems associated with irrigation in general. On the whole the information is well presented and clear, with many of the tables giving data that could be used in the field as initial guidelines for setting up and operating farm/estate level irrigation systems.

My conclusion on reading the book is that it provides a broad overview of surface irrigation systems for people working in developing countries. This could be useful in updating or training technical field officers or students not directly involved with irrigation advisory work, (eg people specialising in agricultural/mechanisation extension), but who need a good appreciation of commonly used irrigation systems.

Jim Meredith

Housing of Animals

A Maton; J Daelemans; J Lambrecht

(English Text by F Lunn)

Publisher: Elsevier Science Publishers B.V., PO Box 211, 1000 AE Amsterdam, The Netherlands, 1985. ISBN 0-444-42528-4. £57.

THE English edition of *Housing of Animals*, according to the preface, takes into account recent scientific research and includes information of an international nature. The majority of the text is based on the latest edition in Dutch which was published in 1983.

The book opens with a brief history of the housing of animals and this is followed by a chapter on housing in relation to present day society. This inevitably includes a discussion on the welfare of intensively housed livestock.

Chapter 3 is concerned with the building structure and materials. The work presented relates to design procedures in continental Europe and does not specifically refer to the British scene. Indeed, the British Standard (BS 5502) is not discussed, or even mentioned. Fundamental information such as the thermal properties of structures are well dealt with and much of this chapter is good reference material.

The remaining chapters, 4 to 10, are species specific, with, naturally, greater emphasis on cattle (124 pp), pigs (98 pp) and poultry (72 pp).

The last four relatively short chapters cover horses, sheep, rabbits and furred animals (eg mink) respectively.

Each chapter gives examples of buildings and equipment used in the husbandry of the different species and is very detailed. These chapters are fully illustrated with photographs and very good line drawings, all of which cover well the very diverse material. The different stages of rearing are described in detail and examples of the relevant housing discussed fully. At the end of each chapter there is a long list of references, it is a pity that these are not also translated for the English reader. All three authors are well known in the agricultural engineering industry and they have drawn together a great deal of relevant information under a single cover. Many researchers and students will be in their debt.

Inevitably with a work of this nature there are a few minor quibbles on the content, but nothing can detract from the wealth of information, relevant to the housing of animals on the farm, that is presented. However, it must be mentioned that the translation, when combined with the type face employed, made the book very difficult to use for the reader, it is hard going. Perhaps more importantly, if this book was produced as a standard reference work, the lack of an index prevents easy access to the information contained therein. This is a shame because this should be a very important source of information.

Chris Boon

Soil cutting and tillage

E McKyes

Publisher: Elsevier Science Publishers, PO Box 211, 1000 AE Amsterdam, The Netherlands. (USA/Canada from Elsevier Science Publishing Co Inc, PO Box 1663, Grand Central Station, New York NY 10163) 1985. ISBN 0 444 425489. £36.

THERE is a shortage of text books on soil mechanics related to compressible agricultural topsoils and so this text is welcome. Of the few texts that are available the "landmark" is Gill and Vanden Berg's "Soil dynamics in tillage and traction" against which other texts may be compared. "Soil cutting and tillage" is easy to read with a good mix of texts, diagrams and analysis. There is also a good selection of problems presented at the end of most chapters.

The first chapter is an introduction to tillage and earthmoving equipment which is covered in a rather perfunctory manner — the review of earthmoving is particularly brief. The second chapter covers basic soil mechanics as may be found in any standard civil engineering text. Coverage of the important concept of critical state soil mechanics is very brief but there is a good selection of problems provided at the end of the chapter.

Chapter 3 on soil cutting forces contains the primary material of the book and gives good coverage of the various two-dimensional and three-dimensional mechanical models of soil cutting that have been proposed in the literature. Similitude methods are also described and there is a useful comparison between different models. The authors only give consideration to soil cutting where major shear planes are created; they do not consider plastic or flow failure of soils. Dynamic effects in implement/soil interaction are covered very briefly and there is no mention of recent work on the effect of strain rate on soil strength. There are useful applications of the models to various implement geometries.

The complementary chapter on soil loosening and manipulation concentrates mainly on implement efficiency in terms of specific draught. As it is being increasingly recognised that the effect of an implement on the soil is of greater importance than the forces generated on the implement by the soil, it is a pity that the authors pay such little attention to the quality of work by an implement. There is no discussion of the way in which soil fails or of the different types of failure that may be induced by an implement under different conditions. The effect of implement speed on soil condition is touched on but is poorly covered. There are useful sections on soil mixing and inversion and on the effect of tool spacing on soil disturbance.

The chapter on soil physical properties and plant growth concentrates on compaction with particular reference to the studies undertaken by the author and his colleagues. There is a useful section on influence of soil compaction on root penetration and on final crop yield. A good, but brief description of the traction characteristics of wheeled tractors, is provided and a review of some models of wheel performance.

The author has been responsible for many useful studies in the area of soil cutting and tillage and, together with his published papers, this book provides a useful contribution to agricultural soil mechanics. However, some sections do not add much to Gill and Vanden Berg's book of 20 years ago and, in general, the list of references to published papers is rather brief. It has notable omissions and contains a number of dated references. The book would appear to be more appropriate to the needs of researchers than as a student course text.

John Stafford