ISSN 0309-023X

soil and water

JOURNAL OF THE SOIL AND WATER MANAGEMENT ASSOCIATION LIMITED

NATIONAL AGRICULTURAL CENTRE • STONELEIGH • WARWICKSHIRE CV8 2LZ

1979 VOL 7 NO 1 25p

SAWMA VIEWPOINT

At last the contribution of one man to the soil management aspects of farming has been recognised. Dr Norman Pizer, a long standing and invaluable member of the SAWMA Technical Committee, was awarded the Massey Ferguson National Award for Services to UK Agriculture 1978.

Dr Pizer, in his capacity as a soils consultant, has the happy knack of being able to identify in field soil problems after discussion and investigation, and plan a practical course of remedial action. This was clearly seen during a technical open day at Lord Rayleigh's Farms at Terling. His expertise in solving soil problems was well demonstrated on these difficult soils.

Dr. Pizer graduated at the University of Reading, moved to the School of Agriculture at Cambridge and then to Wye College. He was among the first to realise the extent to which factors other than soil chemistry affected soil fertility, and he developed simple new soil examination and assessment systems. Dr. Pizer joined NAAS in 1947. In 1970 he was released from his post as Head of Science Service to play a leading role in the study into modern farming methods and its effect on long term soil fertility and structure.

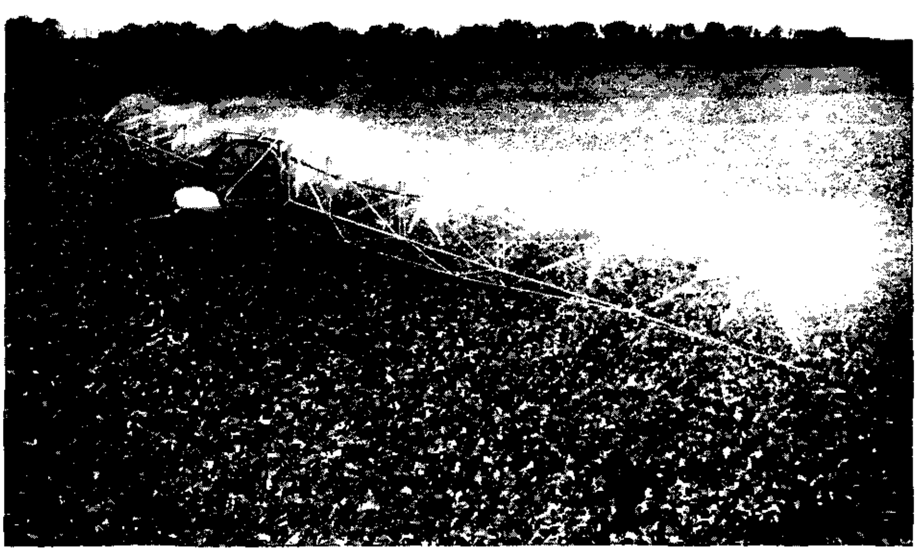
The Council's report 'Modern Farming and the Soil' was one of several reasons for the formation of SAWMA.

Drainage and Irrigation Courses

Once again these two courses which were held in one week just before Christmas at two venues, Rycotewood College and the National College of Agricultural Engineering, were most successful.

As SAWMA is gaining experience of organising courses on these two topics and they are filling a need in the industry, they will continue to be held. The next two courses will take place in December 1979 or early January 1980 and both will be at the NCAE, Silsoe. The reason for moving the Drainage Course is because we received considerable help from the ADAS Land Drainage Service Drainage School lecturers who are based at the NCAE.

The Technical Committee plan to extend the number of courses available by taking in the operator level in both irrigation and drainage. In addition to these a practical soil management course is also being considered for 1980.



Future Conferences

SPRING DRAINAGE CONFERENCE,
May 9th, 1979.

Details of this have already been circulated to members.

TILLAGE EQUIPMENT DESIGN AND POWER REQUIREMENTS IN THE 80's
October 9th 1979.

This is the first time that SAWMA has tackled this subject in a conference and it is doing so with the Institution of Agricultural Engineers as co-organisers.

The line up of speakers is exceptional with all of them fully conversant with all aspects of their own topics. By holding this Conference, SAWMA hopes to create a crossflow of information between farmer and engineer so that both parties know what the other is trying to achieve.

IRRIGATION — THE EFFECTIVE USE OF RESOURCES
March 4th 1980.

1975 and 1976 saw a vast increase in the number of applications for licences for spray irrigation. Many of these were granted but is the water and equipment being used as effectively?

Land and Water Consultancy

Land and Water Management, the Cambridge-based specialists in

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VIEWPOINT

agricultural development, agro-industry and fisheries consultancy, have been acquired by the W. S. Atkins Group of Epsom.

Atkins, with a professional and technical staff of more than 1,500 are one of the largest integrated planning, engineering and management consultancies in Europe. They are involved internationally on a wide variety of projects and the acquisition of Land and Water Management represents a significant strengthening of integrated planning, design, operation and associated consultancy services available from Britain for agricultural, rural and fisheries developments throughout the world.

Land and Water Management were established in 1966 by Dr. A. N. Ede, previously head of a government research unit, initially to serve clients in the U.K. Since 1973 they have also developed their overseas activities, offering a variety of services including feasibility studies and detailed planning, investment appraisal and project management consultancy.

Mr. J. C. Judson, a director of W. S. Atkins Group Consultants, has been appointed chairman of Land and Water Management: Dr. Ede is deputy chairman. The firm will continue operating from their Cambridge premises in Girton Road.

J. D. PETT & SONS LTD. from Boston in Lincolnshire have for some time built irrigation and slurry spreading equipment. The latest range of machines incorporate a turbine drive system for driving the cable drum which moves the machine forward. The SLURRYMATIC range, which is designed to spread liquid separated slurry does so through low height booms which reduce the wind effect, give more even application and help to minimise any possible odour problems.

Technical Meetings

In the course of the year, SAWMA holds several technical meetings to look at aspects of agriculture which are thought to be of interest to members. The level of support for these varies greatly, depending more on prevailing weather conditions than on the technical content of the visit. An example of this was the Soil Management Open Day at Leer Priory Farm in October, where we had good weather following several very wet weeks. We attracted several journalists, but relatively few farmers. This was unfortunate as the day was highly practical and would have benefited many others farming similar soils.

The Association's Technical Committee, who organise these days, would like your ideas and guidance in what topics, within the interests of the Association, should be considered for future meetings.

Please write to the Technical Secretary.

ASSOCIATION OF DRAINAGE AUTHORITIES

Demonstration 4th & 5th July, 1979

In view of the success and great interest shown in the previous two Weed Control Demonstrations, the above Association is planning a similar project near Spalding, Lincolnshire o" the 4th and 5th July, 1979.

The control of weeds in rivers and other land drainage channels is an important feature of the annual maintenance programme undertaken by Water Authorities and Internal Drainage Boards. Unfortunately traditional hand labour methods are nearing obsolescence and the need for suitable alternatives is becoming increasingly essential.

The aim of this National Demonstration is to exhibit a wide range of mechanical equipment under working conditions which will provide a useful focus for land drainage personnel in acquainting themselves with the latest machinery and ideas. Several lengths of watercourse have also been allocated for firms to display the effects of selective aquatic herbicides.

The format of this year's venture will be similar to the previous Demonstrations although other Authorities and private enterprises associated with the "Land Drainage World" will be participating on the static exhibition at Holbeach St. Johns. The working sites will be grouped along main water-courses accessible by roadway within a radius of six miles from the village. Further details from Mr. H. Price "Welland House", Roman Bank, Spalding, Lincolnshire PE11 2HW. ■

SAWMA AT THE ROYAI,

SAWMA will have an exhibit in the Cereals Marquee in the new Arable Centre at the Royal Show on July 2 – 5.

SERVICES

Each advertisement is 2½ in wide and in units of 1 in deep (59 × 25 mm). Cost of £5 for a quarterly insertion or f16 for four quarterly insertions invoiced in advance. For full details, write to Marketing Manager, Soil and Water Management Association, National Agricultural Centre, Kenilworth, Warwickshire, CV8 2LG.

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Irrigation Economics

IRRIGATION ECONOMICS

Dr. Richard Hey (Lecturer in Hydrology, University of East Anglia, Norwich) outlines how it is possible to assess the long term costs and benefits of irrigation and determine the optimum level of irrigation provision.

Irrigation Need

During the summer drought of 1976 potential soil water deficits in the UK were as high as 300 mm. Under such conditions irrigation may be the only means of maintaining the yield of many vegetable and fruit crops. The benefits of irrigation are undeniable in these circumstances and it is possible that the full capital costs of an irrigation system may be recouped in one season's operation. However droughts of this magnitude are extremelv rare, odds of more than two hundred to one, and in some years irrigation may not be required even in the drier parts of S.E. England.

Before investing in an irrigation system it is prudent to ascertain whether the potential benefits of irrigation provision exceed the capital and operational costs within the design life of the equipment.

Factors Affecting Irrigation Economics

I) ***Drought risk:***

In many parts of the UK summer rainfall is not sufficient to sustain the transpirational demand of many crops. Consequently soil moisture deficits increase and crop growth is retarded.

Clearly the benefits and to some extent the costs of irrigation are dependent on the sequence of droughts experienced at the farm after the system is installed. If a series of severe droughts are experienced immediately after installation of the irrieation system both the benefits and–costs will be greater than average. Conversely these will be considerably reduced if the soil water deficits are consistently low. Although it is not possible to forecast the magnitude of future drought events it is possible, using past climatic records, to determine the average number of years between droughts of varying magnitude~.This effectively averages all possible sequences of annual droughts and provides an objective basis for the calculation of the average annual benefits and costs of irrigation provision.

2) ***Soil and crop characteristics***

Soils vary considerably in their ability to hold water due to differences in texture, structure, organic matter content, stoniness and thickness. **A** measure of the soil's ability to store water is given by the available water capacity. This is defined as the difference between the soil water content at field capacity, measured at the end of the winter period, and wilting point. Peats and loams have much higher available water capacities (350 and 220 millimetres available water per metre of soil) than clays (150 mm/m) and coarse sands (65 mm/m).

To obtain moisture plants exert a suction or tension on the water held in the soil. As the soil dries out greater tensions have to be ε to extract water and eventually the plant wilts. For each crop there is a maximum soil water tension at which growth can be sustained. Potatoes, green vegetables and tomatoes are particularly sensitive to moisture stress at tensions above 0.5 bars at all stages of growth, while peas, beans and soft fruits have relatively short critical stages of growth. Consequently the amount of water that is readily available for vth is restricted and for most vegetable and soft fruit crops this is less than 80 mm/m for peat, 120 mm/m for loam, 60 mm/m for clay and 40 mm/m for coarse sand. This indicates that optimum irrigation practice is crop and soil specific. In general peats and loams will require less frequent irrigation than clays and sands.

Most irrigation systems enable up to 25 mm of water to be supplied every 10 days. This figure being based on the rate of water loss in the high summer (M.A.F.F. tech. bull. 138, 1977). If this volume of water is applied to a sandy soil much of it will drain away and be wasted. In addition the crop may suffer water stress within the ten day period. On loams and peats it would be possible to apply more than 25 mm per application and, thereby, increase the interval between irrigations and significantly reduce labour costs.

Crop development can also affect irrigation requirements. This is a significant factor after the crop cover becomes fully established. In these circumstances it is necessary to apply more water than is required to replenish the soil water deficit because a significant proportion of the water is trapped in the foliage and rapidly evaporated. Failure to allow for this factor in the calculation of water requirements will result in the crop suffering periods of moisture stress and, as a consequence, loss of yield.

3) ***Water supplies.***

The cost of developing water supplies is often more critical than water charges in the economic evaluation of irrigation projects. It is essential that the minimum rate of supply, and its reliability, are determined prior to the installation of an irrigation system. The failure of a water source during a critical period of crop growth could have a disastrous effect on yields.

4) ***Irrigation systems***

There is a considerable range of irrigation equipment available on the market with varying characteristics and capabilities. Choice of equipment depends on the type of crop and soil, acreage to be irrigated, and the capital and irrigation costs.

5) ***Farm management.***

Management decisions have a profound affect on the economics of irrigation. To maximise benefits and minimise costs it may benecessary to change farming policy with regard to the cropping pattern, the areas to be irrigated and the scheduling of irrigation.

It must be emphasised that irrigation alone will not ensure maximum potential yields. Many factors other than soil moisture conditions affect yields including pests and diseases, availability of plant nutrients, soil structure and the amount of sunshine. As the benefits of irrigation are dependent on the difference between irrigated and non-irrigated yields, these can be assessed on the basis of irrigation with existing management practices, or modified practices if these have the potential for producing higher yields.

6) ***Operational costs.***

The cost of applying the irrigation water is the major component of the operational costs and this is dependent on fuel, labour, water and tractor costs. Consideration also has to be given to the additional yields resulting from irrigation, as this will result in increased harvesting, packing and marketing costs.

Economic Assessment

Benefit-cost analysis can be applied to define the optimum level of irrigation provision bearing in mind all the factors outlined in the previous section.

A range of droughts are assumed to occur at the farm and for each one the non-irrigated yield is assessed for comparison with the potential irrigated yield for every crop in the rotation. The benefits of irrigation for any rotation system can then be determined given information on crop prices. During periods of drought, and hence crop scarcity, prices will be proportionately higher. However, as it is not possible to forecast these prices, the calculated benefits will be conservative estimates.

For each drought level irrigation requirements are also simulated given information on the crop, water retention characteristics of the soil, management practice, and type of equipment. Operational costs can then be determined for each drought level on the basis of the rotation system, fuel, labour, water and tractor costs and the increased marketing costs resulting from the additional yields. The fixed annual cost of the equipment, capital plus interest payable within the design life of the equipment or any prescribed period, has to be added to the operational costs to obtain the total costs for each level of drought protection.

Although it is not possible to forecast future droughts, local meteorological records can be used to establish their probability of occurrence in any one year. The benefits and costs associated with each level of drought protection can then be weighted according to their frequency of occurrence to obtain the average annual values. These values can then be compared and the optimum level of irrigation provision is defined by the one which maximises the benefit-cost ratio. It should be emphasised that this will he a conservative evaluation of optimum irrigation requirements because of the use of current crop prices in the assessment procedure. This introduces a factor of safety into the calculations which ensures even greater profitability provided irrigation is accurately scheduled (Dent, Hey and Scammell 1978).

If it is necessary to obtain the present value of the benefits and costs over a prescribed period for economic planning purposes, all future average annual benefits and costs have to be discounted. This arises because benefits are of more value if they are realised sooner rather than later, and the converse with respect to costs. As the benefits and costs will be similarly affected this will not alter the benefit-cost ratios.

A slightly different economic assessment can be carried out if capital is available to pay for the irrigation system in the first year of operation. The present value of the total costs are then determined by adding the discounted average annual operational costs to the capital costs, and the benefits are determined by discounting all future average annual values.

Conclusions

Many variables, such as soil type, crop characteristics, meteorological conditions, water supplies, Irrigation systems, farm management practices, irrigation and marketing costs affect the economics of irrigation. Failure to take all of these factors into account when determining the optimum level of irrigation provision can have serious economic consequences.

The analysis which has been briefly outlined in this paper indicates how explicit allowance can be made for all of these factors and this enables the following to be determined.

1) the optimum degree of drought protection and the expected profitability.
2) the area that can be irrigated,
3) the equipment required to maximise the return on capital,
4) whether yields are maximised by irrigating all the area suboptimally or part of the area optimally during droughts which exceed the capacity of the irrigation system,
5) whether costs are minimised by purchasing the equipment in the first year or spreading payments over any given period,
6) the minimum period between irrigation~,the volume applied per irrigation and the number of days equipment utilised for any prescribed drought condition.
7) the number of years irrigation is not required..

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Grassland soil problems

GRASSLAND SOIL PROBLEMS

Dr. T. Batey, Dept. of Soil Science, University of Aberdeen.

This is a reprint of a paper given by Dr. Batey at the Soil Structure and Drainage Conference, held at the National Agricultural Centre, on 14th March, 1978.

Introduction

Grassland covers about two thirds of the total agricultural area in the United Kingdom; output varies widely from intensive dairying to hill grazings. In the lowlands grass may be grown in rotation with arable crops, but most grassland is found where climate, topography or other features largely preclude regular cultivation.

In the lowland situation, grass has a well earned reputation for improving soil structure. The evidence is well documented; part of the benefit is due to the biological control of pests and diseases and part to the rest from disturbance by cultivations allowing soil structure to regenerate. Under grass organic matter, nitrogen, particle aggregation and structure stability all increase. Examination of the work done by the ARC, ADAS and others over a long period shows that almost all the research on soil structure and grassland has been in the lowland ley-arable situation. There appears to have been the tacit assumption that permanent grassland can take care of itself. However to make the most of grass as a structure improver requires careful soil management. Soil compaction induced at seedbed preparation can have adverse affects on grass growth and root development for some years. Generous fertilizer use cannot compensate for poor initial structure and the potential benefits of grass may be lost (ADAS 1972, Thomas & Evans 1975).

In many areas of permanent grassland high rainfall often prevents regular arable cropping. However it is not always rainfall alone which influences plant growth and soil properties. In wetter areas, summer temperatures are usually lower and humidity higher so that less water is extracted from the soil by plants. As a result soils do not dry out so extensively or so deeply as in drier warmer areas. This means that soil cracking is less, root growth shallow and soil structure is only weakly developed in the subsoil. Conversely, levels of organic matter in the topsoil are often high — not always an advantage in the grazing situation. The weak development of subsoil structure is not likely to affect plant growth directly, except in a drought. The main disadvantage is on clayey soils which rely heavily on soil cracking to dispose of excess water in wet weather. Surface waterlogging is therefore much more prevalent in cooler wetter areas and presents grazing problems of a different and difficult nature in comparison to most lowland grassland. Poaching, lack of soil aeration, denitrification and finding effective drainage techniques are thus well known problems in many grassland areas.

Modern Farming and the soil (1970)

While most of this report dealt with arable crops, the importance of structure under grassland was also discussed:

"We have been impressed by the difficulties of high stocking densities on grassland in areas of high rainfall. These too lead to structural damage and deterioration of the sward. This is a new problem requiring above all investigation and experiment . . ."

". . . more emphasis should be given to the problems of the wetter grasslands".

"The only answer to structural problems on some grassland is the provision of more housing for stock. . ."

"Research and experiment needs to be directed to the poaching problem in areas of high rainfall. Study is needed of the effects of different grass varieties on poaching susceptibility and into the development of cheap and efficient soil puncturing machines for remedial treatment; current investigations should be encouraged as a matter of urgency".

The results of recent research on grassland soil problems have been grouped into the sections which follow, on drainage, poaching, and grass-pulling. Several relevant reviews of research have been published since 1970: "Soil Physical Conditions and Crop Production" Technical Bulletin 29 (MAFF 1975), "Field Drainage" (Trafford 1970 & 1977), and "Improved Production from Drained Grassland" (Berryman 1975).

Drainage

The benefits of draining grassland should be many: increased grass growth, better utilization, reduced poaching, and more efficient use of nitrogen. With such a list of advantages one may ask why is all grassland not drained? The question centres on whether the costs of achieving efficient drainage can produce an adequate economic return. Furthermore there is still a lack of conclusive evidence on the best means of drainage in the typical grassland situation — often small fields, irregular slopes, high rainfall and soils of low conductivity. The ideal objective of draining grassland is to keep the water table below 80-100 cm for most of the year. In most situations it is simply not economic to place tiles or pipes at intervals close enough to do this effectively. The trend in drainage design is therefore to put in wide-spaced laterals with permeable back-fill, and to follow this with moling or subsoiling across the drains. Recent research is beginning to show useful results.

An experiment at Langabeare, Devon, was done 1961—1971 on poorly drained Culm Measures soils of the Tedburn Series, receiving about 1200 mm of rain a year. The early results showed that an economic benefit could be achieved by drainage (Trafford 1971 and 1972), and that mole drainage was successful on the silty clay subsoil. However a later assessment showed that the mole-tile system was effective in intercepting run off only in the summer period when the soil was cracked. Throughout much of the year there was considerable surface flow of water off the plots (Harris 1977). In other experiments on the same type of soil the effects of mini-moling 20 cm deep 50 cm apart with a 3 cm diameter bullet was assessed on 6 fields. Only a slight improvement was recorded and the comment was that "the technique does not appear promising on this soil" (ADAS 1973).

There are now several examples on soils of low permeability where drainage plus moling or subsoiling has given better results than drains alone, e.g. ADAS 1976, Trafford 1977. Preliminary results from current research on soils of low permeability in S.W. Scotland have also shown that water can be removed rapidly by wide spaced laterals with permeable fill and a secondary treatment involving moling or subsoiling (WOSCA 1977). However the problem in many grassland fields is that the soil is never or very rarely dry enough for effective moling or subsoiling to be done. This has led to experiments in several areas of difficult wet soils to test subsoiling or moling done even under wet soil conditions.

In Wales over 30 subsoiling trials have been done in grassland since 1965. Subsoiling was done in late summer usually at a depth of 30 – 40 cm, at intervals of half tractor width with the tractor wheel running over the previous cut to regain a level surface. Care was also taken to maintain a continuous shallow gradient. Most benefit from subsoiling was seen in wet periods when the surface at many sites was drier; on sites where yields were recorded substantial increases were found at several, particularly in the 1st cut in spring. (ADAS 1973, 1976; Evans, personal communication 1978). The trials also showed that surface drainage of many fields could be improved by subsoiling, even when there was no underdrainage.

Effective drainage is a key factor in making the most of grassland. The design needs to be matched to the soil, climate and proposed intensity of use. By collating the results of field experiments with practical experience on different soils, information on current drainage practice has been established. For example Thomasson (1975) identified 2 groups of soils, one which can be drained by pipe drainage alone and another which requires permeable fill with regular moling or subsoiling to improve hydraulic conductivity. In Eastern Scotland Spiers (1977) has also produced maps showing drainage solutions for different soils. The dominant drainage practice for some of the more commonly occurring soil series in England and Wales has been published by Armstrong and Smith (1977).

Poaching

This phenomenon occurs when a soil is so soft that it is compressed by the hooves of grazing livestock. Poaching may be seen as hoof depressions on the surface or as a compacted layer some 7 – 10 cm below the surface. Once it has formed, a poached soil tends to be self perpetuating because in wet weather water is held up in the topsoil making it liable to further damage. Subsequently grass growth is reduced by lack of aeration and the breakdown and loss of mineral nitrogen in the soil.

Poaching is an urgent problem in wetter areas of Britain. The Grassland Research Institute has prepared a map showing the extent of poaching (Annual Reports 1975, 1976); three susceptible classes have been identified, high, variable and low. The investigation showed that over 3 million ha of land was classified as highly susceptible to poaching.

Two experiments in Lancashire were designed to test whether damage by poaching could be minimised (Massey et alia 1974). Both sites had been underdrained in the 19th century with clay tiles at 7 m spacing and 1 m deep. At one site near Preston, shallow moling at 22 cm depth with a 3 cm diameter bullet was done under dry conditions in May 1971. The moles were drawn across the old tile system. The shallow moled plot remained consistently drier throughout the following year, 1972. At a second site in the Fylde on a similar soil derived from Triassic Boulder Clay, shallow moled plots were also consistently drier the following year. However there was no comparable improvement when spiking was done at monthly intervals in the summer of 1971. The latter treatment was done with a commercial device which made a regular system of spaced slits in the upper 10–15 cm of soil. Measurements of water table depths and penetrometer resistance at each site showed that under drainage was inadequate to minimize poaching, despite the promising effects of shallow moling. The authors suggest that to minimize poaching drainage needs to be designed to achieve a water table of at least 50 cm below ground level in wet weather and levels of the order of 100 cm at other times.

A subsoiling trial was also done on Bodmin Moor, (Hughes & Stokes 1976) 270 m above sea level with annual rainfall averaging 1650 mm. In July 1973 subsoiling was done at 1.5 m intervals, about 60 cm deep. Water levels were recorded the following winter and showed clear benefits by reducing water levels when compared with adjacent untreated land; grass yields were also increased by subsoiling. The surface condition of the subsoiled land was also much improved, it was much firmer in wet weather. The effects were shown in spectacular photographs of sinkage taken in March 1975.

Trials done on the Buckden Farm Unit at Great House EHF, Lancs, showed that, while shallow subsoiling produced a slightly drier soil in a situation where poaching occurred, there was no lessening of sward damage (Annual Reports 1972 & 1974/5). It was also considered that grazing management offered better control of poaching than mechanical treatment. While many subsoiling trials report increases in yield following treatment, both Great House (1972) and Trawscoed EHF (1973) report reduced yields. Clearly if progress is to be made careful soil examination must precede any subsoiling treatment to identify accurately the nature of the problem, and sound records made of any subsequent changes in soil, sward or water levels.

Grass-pulling

Pulling-out of grass by grazing cattle has been commonly encountered in the main grassland areas of

1 Typical upland problems caused by surface run-off nor being intercepted by ditches

2. Serious poaching occurs where run-off collects causing revertion of grass species

3. Ditch maintenance is vital to the productivity of reclaimed upland grazing

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Grassland soil problems

England and Wales (ADAS 1973, 1974. 1975. 1976). It is usually associated with high N usage, intensive stocking rates. and soil compaction. As a result the grass develops a shallow root system which is insecurely anchored' In an attempt to alleviate the condition, shallow subsoiling was done in an ADAS experiment in 1972; the sward was improved by treatment but pulling was not entirely eliminated. Not all cases are of pulling associated with soil compaction, in some fields it occurred on loose uncompacted soils.

While field examination has identified most of the causes of pulling, research does not yet seem to have provided the solution. However, because of the strong association between shallow rooting and pulling, every attempt should be made to encourage deeper rooting. This could involve careful preparation of a firm but uncompacted seedbed, allowing a longer initial period of growth before the-first grazing, giving at least one longer period of growth each season and avoiding poaching and surface compaction by keeping stock off in wet soil conditions.

Conclusions

Much research is still needed, particularly in wetter grassland where drainage techniques developed for drier arable areas are not suitable. It is all very well stating that moling or subsoiling is required but many of the current techniques present problems when applied in grassland. Sub-soils are rarely dry enough for effective secondary treatment and raising ridges along the slit and pulling up stones both make subsequent grass cutting hazardous. Nevertheless cutting a slot with either a subsoiler or mole drainer appears to be the only economic solution to drainage problems; using a disc to cut the turf and pressing the ridge down with the tractor wheel on the next pass may reduce surface damage. Where poaching is a serious problem, it can be reduced by drainage. However in many cases the techniques required may be too costly and not adequately effective.

The point must be made firmly that intensive utilization of grassland may not be viable in wetter areas. If high output is required in areas of high rainfall, the only long term solution is to house the stock for a longer period in winter and also at any other times when wet weather makes the soil too soft for grazing to be done without poaching.

More research is needed to determine the conditions under which subsoiling or moling may be used successfully. A single technique is never likely to be universally applicable. In each case the soil should be carefully examined to identify the nature of the problem and to decide on the most effective treatment.

Some improvement techniques have given apparently conflicting results; in many trials subsoiling has been effective in lowering water levels and increasing growth, in others no response has occurred and in a few there have been adverse effects. These results do not mean that such techniques have no value but that the effects are related to the particular problem at each site and to the conditions under which the treatments were applied.

Research on soil physical problems and field drainage is difficult and time consuming. Much is in progress in Britain but if best use is to he made of limited resources greater coordination is required. More encouragement should he given for sound measurements of climate, soil properties and grass production to be made and the results of all experiments and trials brought together for discussion, evalution and publication..

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Heavy soils of Essex

THE HEAVY SOILS OF ESSEX; THEIR PROBLEMS AND POTENTIALS.

R C Sturdy, Soil Survey of England and Wales, Rothamsted Experimental Station. Robin Sturdy has been at the Chelmsford office of the S Survev for the past ten years. This account of heavy soils, modified from the paper given at the Spring Drainage Conference at Writtle in May 1978, draws on that experience.

The Soil Survey classifies soils into units called soil series, defined as groups of soils showing similar profile development in similar geology. 'Permanent' properties of the profile are traditionally used to distinguish soil series as the basis of mapping units; these properties are; particle-size distribution (texture), organic matter content and the annual soil water regime and hydraulic properties particularly of the subsoil. Highly transient properties of the plough (cultivated) layer, and less transient physical properties below, also observed or inferred during soil surveys, play a major role, however, in assessing soil workability and in guiding tactical farming decisions (Thomasson 1977). Such properties do not define soil series as they can be more or less readily altered by the management of the land.

The aims of this paper, therefore, are threefold. Firstly, to give an account of the physical properties of the main soil series occurring in the heavy lands of Essex; secondly, to describe their distribution; and thirdly to briefly review the 'permanent' and transient properties of these soils which give rise to farming problems and which limit potential of the land. Emphasis is placed on drainage and soils in heavy London Clay, . the geological formation underlying this year's Farmers Weekly International Drainage Demonsiration site at Abberton, part of Wick Farm, Layer-de-la-Haye.

What are heavy soils?

In common parlance heavy land connotes ground which is difficult to cultivate and manage because of soil wetness, stickiness and poor trafficability. In order to discuss the problems and potential of such land it is important to have some understanding of the soil properties which contribute to these conditions. To do this it is helpful to think of a soil profile in terms of a topsoil layer (0-25cm), a subsurface layer (25-60cm) and the subsoil (60cm+). The thickness of these layers will vary from place to place and from soil to soil, but they are chosen to correspond with the layer in which normal cultivations and seed-bed preparation takes place (topsoil), the layer in which subsoiling tines and mole ploughs operate (subsurface) and the layer in which tile drains are laid or deep subsoiling takes place (subsoil). Crop roots penetrate all these layers.

Descriptions of the more extensive heavy soils of Essex are briefly summarised in Table 1. The properties, some or all of which characterise these heavy soils, and which determine their behaviour, are as follows:

'Permanent' properties.

(i) large clay content;

(ii) impermeable or slowly permeable subsoils;

(iii) impeded drainage in their unimproved state;

Transient properties.

(iv) large volume of water held at field capacity;

(v) small volume of air-filled pores at field capacity.

Clay Content

Typical clay contents of six of the soil series listed in Table 1, and representative of soil conditions in marine alluvium (coastal marshland), Boulder Clay and London Clay (see Fig.1), are shown in Table 2.

There is a large group of soils which are predominantly clayey, i.e. the soil contains 35 per cent or more clay-size particles in all layers. Marsh clays (Wallasea series) have about 50 per cent clay together with large silt content, whereas river alluvial clays (Fladbury series in Table 1) range from 50 to 80 per cent clay, and in both clay content is constant with depth. Clayey soils in Boulder Clay and London Clay (Ragdale and Windsor series respectively) tend to be lighter clay loams or silty clay loams in the topsoil, but can also be clays, and pass to heavy clays in the subsurface layers. Hanslope and Althorne series are less mottled (drier) analogues of Ragdale and Windsor with similar clay content. Ferrel series is intermediate between Windsor and Wallasea series, showing a slight increase in clay content with depth; it is also rather silty.

A second group of soils comprises those that are loamy over clayey. They are relatively lighter (between 20 and 35 per cent clay-size particles) in the topsoil and immediate subsurface layer down to about 45 – 60 cm, but rest on clay below. Oak and Wickham series are examples in loamy drift over Boulder Clay and London Clay respectively.

Impermeable subsoils

Impermeable soil layers are defined as those with saturated hydraulic conductivity of less than 10 cm (0.1m) per day, and as such characterise most of the clayey and loamy over clayey soils listed in Table 1, causing varying degrees of surface waterlogging in winter months. Once the soil has become saturated, the presence o' this impermeable layer at shallow depths (within 60 cm for Oak and Wickham, and immediately below the topsoil for Ragdale, Windsor and related soils) means there is negli downv ard movement of water so that the plough layer (topsoil) cannot begin to dry out until water is removed by direct evaporation or transpiration.

Impeded drainage

In :heir unimproved state most of the heavy soils in Boulder Clay and London Clay are waterlogged near the surface for long periods in winter, and their profiles show evidence of this impedance in the form of grey and rusty mottles in the subsurface layers above the impermeablesubsoil. Hanslope and Althorne show little or no mottling in the subsurface layer, associated with greater depth to and shorter duration of waterlogging. Fladbury and Wallasea soils in clayey alluvium have a different water regime in that both are affected by high ground-water tables and are slightly more permeable at depth than clayey soils affected only by surface wetness. In terms of drainage classes formerly used by the Soil Survey, these soils range from moderately well to poorly drained. It has, however, been appreciated for some time that mottling does not always reflect current amounts of waterlogging after underdrainage measures have becomeeffective, and that direct observation of water tables is needed to establish the water regime. Wetness classes defined by depth to and duration of waterlogging replace the former drainage classes, but, particularly for loamy over clayey and clayey soils with impeded drainage, there is approximate equivalence between the two systems (Thomasson 1975). This is shown for the first four wetness classes below:

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Wetness Class	Duration of waterlogging within 70 cm depth	Former Drain-age Class
I	<30 days (1 month)	Free
II	30–90 days 1 – 3 months)	Moderate
III	90–180 days 13 – 6 months)	Imperfect
IV	>180 days (6 months)	Poor

Duration of waterlogging above 40 cm can be up to 180 days in most years for wetness class IV (poorly drained), but is not specified for classes I – III.

Water and air content at field capacity

Soils consist of a matrix of solid mineral particles and organic matter within which there are spaces (pores) partly filled with water and partly with air. After saturation by rain, water drains from coarse pores (greater than 0.06 mm diameter) by gravity, but is retained in smaller pores by surface tension. When coarse pores have been emptied and water remains only in finer pores the soil is at field capacity. Most agricultural topsoils have between 25 and 50 per cent of their pore space filled with water at field capacity. This retained water content of heavy topsoils is large (more than 35 per cent) for long periods in winter, and since in this condition the soil is plastic and weak, surface compaction and structural deformation are a constant risk.

A well-aerated topsoil contains more than 10 per cent air by volume, but this degree of aeration is rarely achieved in clayey topsoils, or is reduced by compaction during seedbed preparation in arable soils. However, below the topsoil air capacity (the volume of fine pores filled with air at field capacity) is subject to less fluctuation and is very small in clayey subsoils. Very small air capacity (less than 5 per cent by volume) in the subsoil may be considered a permanent property of most heavy soils and is usually related to low hydraulic conductivity characteristic of impermeable layers. In clayey soils influenced by ground-water, aeration decreases only very slightly with depth and subsoil permeability is greater than that in otherwise similar soils with impedance to surface-water (e.g. Windsor series in London Clay).

Where are the heavy soils?

Soils identified in Table 1 occur in three zones (Fig.1): the low-lying coastal marshland, the undulating London Clay lowland of south and east Essex, and the Boulder Clay plateau of the central and northern parts of the county.

Within the London Clay landscape (Fig.2) there are a number of closely related soils the position of which has an important influence on their agronomic properties. The Farmers Weekly International Drainage Demonstration site at Abberton last year is typical, with Althorne and Windsor series in London Clay unaffected by drift occurring in mid-slope positions, Wickham series in the remnants of once more extensive and thicker drift on the crests of ridges and low hills, and Ferrel series in accumulations of roughly sorted drift at the foot of slopes. The two latter series are on nearly level sites with limited runoff; but water received on the plateau sites by Wickham soils is confined to precipitation, whereas

Geology	Soil series	Main soil properties
Chalky Boulder Clay	Hanslope	Calcareous clay loam topsoil over chalky yellowish brown mottled clay.
	Ragdale	Non-calcareous clay loam topsoil over strongly mottled clay; chalky below 60 cm.
Non-chalky boulder clay	Oak	Slightly stony clay loam topsoil and subsurface over orange mottled non-chalky clay to about 150 cm.
Drift aver London Clay	Wickham	Slightly stony clay loam topsoil and subsurface over brown London Clay below 60 cm.
	Landermere	Clay loam topsoil and subsurface over mottled clay; brown London Clay below 100 cm.
	Ferrel	Silty clay loam topsoil over mottled silty clay; brown London Clay below 100 cm.
London Clay	Windsor	clay loam topsoil over brown strongly mottled clay.
	Althorne	Clay or clay loam topsoil aver brown unmottled clay.
River alluvium	Fladbury	Grey and orange mottled heavy clay throughout; ground-water table influence.
Marine alluvium	Wallasea	Grey and brownish mottled silty clay throughout; ground-water table influence.

Table 1. *Main soil series in heavy land in Essex.*

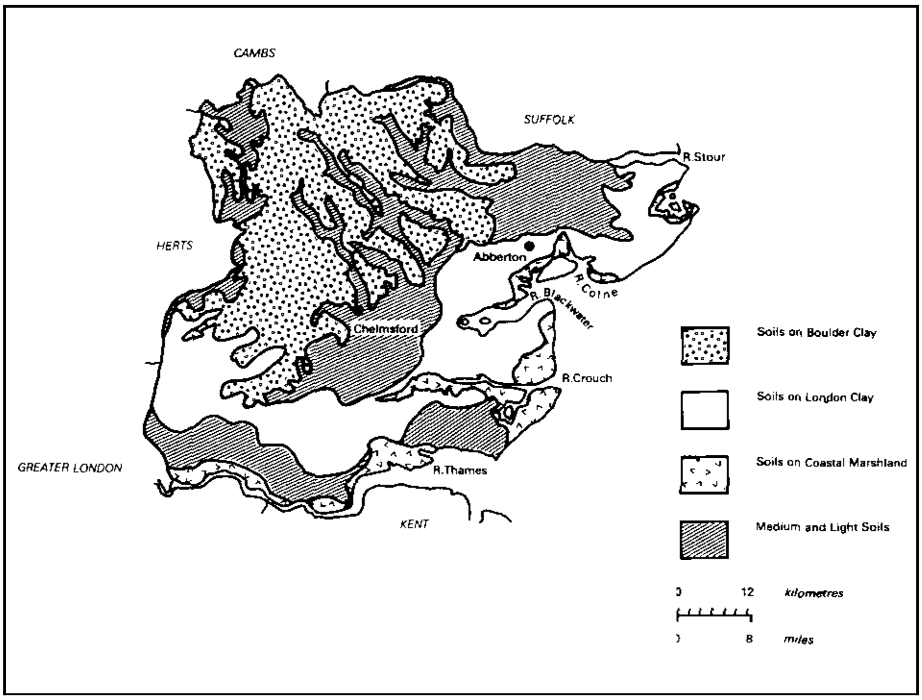

Fig. 1. Distribution of heavy soils in Essex

	Soil series:	Wallasea	Ragdale	Oak	Wickham	Windsor	Ferrel
Clay%	Topsoil 0 – 25 cm	50	35	20	25	35	40
	Subsurface 25 – 60 cm	50	45	30	30	60	46
	Subsoil 60 cm+	50	55	50	50	65	55

Table 2. *Typical clay contents* of *some heavy soil in Essex.*

Ferrel soils are in a receiving position for runoff from Windsor and Althorne soils upslope. Since these slopes are steep, and the clays virtually impermeable, runoff can be considerable. For example, dipwells in a drained Althorne soil on a 6" slope under grassland in similar landscape near Southminster showed waterlogging above 70 cm for only two months in February and March 1974, compared with six months waterlogging at a more gently sloping site below in the Windsor series. This suggests that most rainfall received by the Althorne soil was lost by runoff. At Layer Breton, the site of an experiment to investigate drainage of soils in London Clay, Windsor soils in the top half of the field are on gentler (1 – 2") slopes. Even so, when saturated, surface flow can cause severe waterlogging in the Landermere soils downslope (Davies and Kellett 1977). In this respect the water regime of Landermere series is very similar to that of Ferrel series.

The Boulder Clay landscape sequence of soils comprises Oak and Ragdale on level upper surfaces, giving way to Hanslope on the slopes, and Takeley series in colluvium at the foot of the slope. This simple pattern can vary: Hanslope can occur on rounded ridge tops as well as on slopes, and, in major valleys, Hanslope can be succeeded downslope by permeable soils in underlying glacial gravels. In general, because Chalky Boulder Clay is more permeable and slopes are less steep, more rain infiltrates into Hanslope subsoils and runoff is consequently less than for London Clay soils in corresponding positions.

The coastal marshland is level, but has pronounced natural microrelief. The problem here is to provide adequate standards of arterial drainage into which field drains can outfall. This entails sluicing or pumping schemes to discharge drainage water through sea walls.

Problems and potentials

The problem of farming heavy land in Essex can be summarised under three headings:

1. effectiveness of underdrainage measures;
2. difficulties in cultivations and harvesting;
3. position and slope.

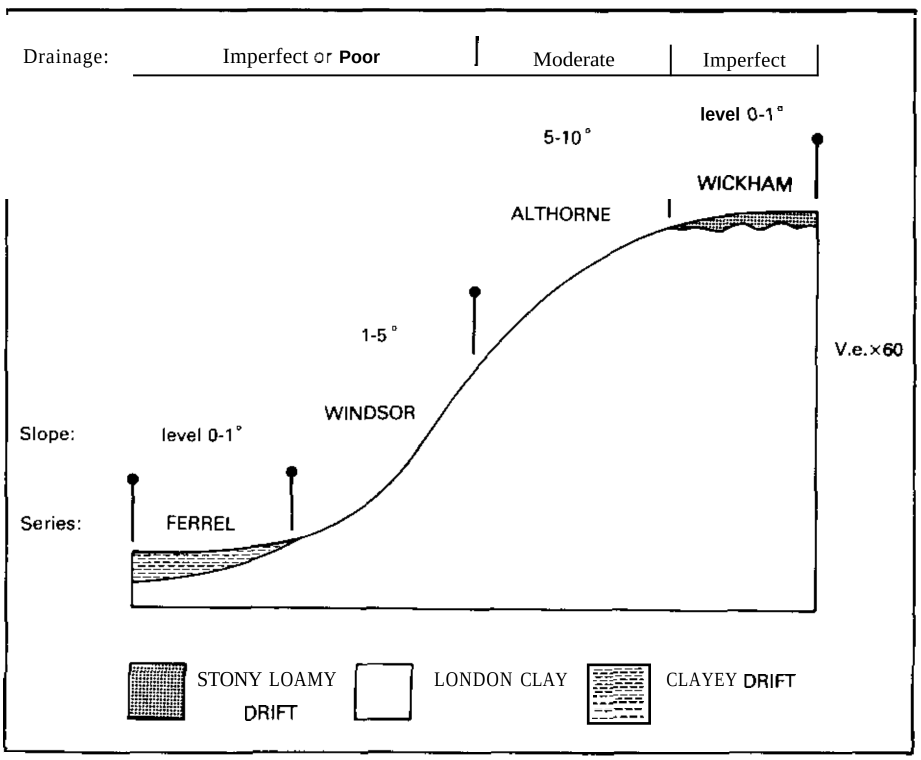

Fig. 2. Soil series in London Clay

1. Effective drainage at economic cost can be difficult. The subsoil clays are of such low permeability that, with normal drain depths, spacing of about 3 metres would be needed to lower the water table over a whole field to satisfactory levels. In practice mole drains can be drawn cheaply enough at this kind of spacing over a wide-spaced pipe main system to provide effective drainage of the upper 40–50 cm. Especially on level sites, the improvement is limited to this depth, and the subsoil may remain as waterlogged as that in nearby undrained sites of the same soil type. Problems arise because the right moisture conditions for moling, subsoiling and pipe laying do not always occur when work is scheduled, and also because supplementary treatments like moling may be short-lived due to instability of the soil around the mole channel. Loamy over clayey soils like Wickham and Oak series can be more responsive to drainage than heavier clay soils like Windsor series, and the benefit be more substantial.

2. Cultivation and harvesting operations are difficult in wet seasons because clayey topsoils quickly become and remain sticky and plastic for long periods even where adequate underdrainage systems are installed. Poor seed-beds can result if soils are cultivated at or near field capacity and structural damage done, or if the soil is dry and too hard to obtain a reasonable tilth in which to sow winter cereals. Wet harvesting conditions can lead to further structural damage or even crop loss e.g. when potatoes have to be abandoned in the ridge.

3. Position in the landscape and slope affect soil water regime as described earlier. In addition, some slopes are too steep for machinery to work effectively or safely, and the land may have to be left in grass. This is particularly true where isolated hills or ridges in London Clay are capped by loamy Claygate beds and landslipping occurs. Within-field soil variation, e.g. where Althorne and Windsor soils with clayey topsoils occur in small patches alongside lighter and easier working topsoils both upslope and downslope, poses tactical problems of when to work the land.

The major limitations to agricultural potential are summarised in Table 3. The system used is the Land Use Capability Classification (Bibby and Mackney 1969) which assumes a moderately high level of management, and aims to predict the cropping flexibility of land, as well as the level of yield. Subclasses identify particular physical limitations; soil (suffix s) and wetness (suffix w). Thus, although yields of cereals or grass can be high, cultivation difficulties, the limited degree to which drainage can be improved and the limited range of potential cropping combine to restrict much of the heavy land of Essex to class 3 in this system of classification.

Hanslope soils on Chalky Boulder Clay can be drained more effectively giving a slightly wider range of cropping and hence placed in subclass 2sw, whilst Fladbury soils are downgraded to subclass 4ws mainly because of flood risk. The divisions within subclass 3sw in Table 3 represent different drainage design and cultivation needs, and to some extent yield potential.

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LUC subclass	Soil series	Limitations
2sw	Hanslope	Relatively wide range of crops possible, but root crop harvesting is risky. Moderate cultivation and trafficability limitations.
3sw	Oak	Relatively easily cultivated but topsoils unstable.
	Wickham	Variable depth to clay can limit success of moling.
	Landermere	Root crop harvesting is risky.
3sw	Ragdale Windsor Ferrel Althorne	Underdrainage unable to radically alter water regime below 50 cm. Tendency to smear and compact. Seed-bed preparation difficult in most seasons. High poaching risk with grassland. Root crops should not be grown.
3sw	Wallasea	Easily damaged, unstable topsoil structure leading to top-panding. Variability after levelling. High poaching risk with grassland. Root crops should not be grown.
4sw	Fladbury	Very large clay content coupled with winter and spring flood risks restricts cultivation opportunities, grazing season and choice of crops to cereals and grass. Cereal yields may be very low.

Table 3. *Land Use Capability (LUC) of heavy soils.*

The Layer Breton experiment has demonstrated that cereal yields can be increased by installation of drainage. This is true of both the Windsor and Landermere series at this site, although dipwell monitoring established different patterns of waterlogging between them, especially in wet years. Yield increases need not be the only benefit from drainage, however, as field work days in autumn and spring can also be increased, leading to better timeliness for cultivations (Armstrong 1977).

Conclusions

Use of heavy land is difficult because of inherent soil limitations related to large clay content and slow permeability leading to prolonged surface wetness, and to poor cultivation and trafficability conditions. Marked improvement of water regime by underdrainage is limited in clayey soils except where slope aids runoff, but more can be achieved where topsoil and subsurface layers are loamy. Within-field variation of topsoil clay content can lead to difficulties of timing cultivations and to uneven seed-bed quality. These 'permanent' properties of the soil profile can scarcely be radically changed by existing techniques or at economic cost, but continued research and development may bring worthwhile improvements within reach. For instance, new break crops and direct drilling of cereals show some promise as means of partly avoiding the physical disadvantages of heavy soils, and draining and moling through standing crops could help to extend the periods when these operations are performed at the right moisture content.

Identification of the occurrence of different soils within landscape regions is an important aid to correct drainage design, as exemplified by the recent drainage demonstration at Abberton (Anon. 1978), and should influence both short term and long term management decisions.

Acknowledgements

I would like to express thanks to Mr. R. A. Walpole for helpful discussion on the presentation of the original conference paper, and to Mr. M. G. Jarvis for suggesting improvements..

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