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Alternative enterprises for agriculture in the UK

CAS Report 11

Alternative enterprises for agriculture in the UK

Edited by S P Carruthers

Centre for Agricultural Strategy
University of Reading
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Reading RG6 2AT

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Centre for Agricultural Strategy

Originally established by the Nuffield Foundation in 1975, the Centre for Agricultural Strategy is a self-financing unit within the Faculty of Agriculture and Food at the University of Reading.

Its function is to identify important issues in agriculture – worldwide, to ensure that they are subjected to informed debate and to publish its findings in reports designed to influence decision makers.

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Preface

The Centre for Agricultural Strategy exists primarily to identify important issues and to ensure that they are subjected to informed debate.

At the present time, it would be hard to find a more important topic, for Agriculture in the UK, than the alternatives available to the farmer who is currently producing commodities that are in surplus.

This Report (and its summarised form, Report 12) is the result of a study, sponsored by MAFF, aimed at exploring all those enterprises – crop, animal, and non-agricultural – that are, or might become, useful alternative ways of using agricultural land.

C. R. W. Spedding

Foreword

This document is one of two reports resulting from a study sponsored by the Chief Scientist's Group of the Ministry of Agriculture, Fisheries and Food. This report presents a detailed account of the study; its essential findings are summarized in CAS Report 12, *Land-use alternatives for UK agriculture.*

The following members of the University of Reading contributed to the study and to the compilation of the reports: Professor C R W Spedding, Dr S P Carruthers, Mr J L Jollans, Mr J H C McClintock, Mr A Korbey and Mr R B Tranter of the Centre for Agricultural Strategy; and Mr R S Tayler of the Department of Agriculture and Horticulture.

Many people were consulted during the course of the study and are listed in the Appendix of this Report; their assistance is gratefully acknowledged. Particular thanks are due to Dr G H O Burgess, Dr D J White and Miss H Ainsworth of MAFF, and to the following who participated in two workshops to discuss draft versions of the Reports: Lord Belstead; Professor J Barber; Professor R L Bell; Sir Kenneth Blaxter FRS; Sir Leslie Fowden FRS; Professor J L Harper FRS; Dr A T James FRS; Mr R W Patrick; Professor L Roche; Dr M H Unsworth; Professor P N Wilson; Professor H W Woolhouse.

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Abbreviations

ABRO	Animal Breeding Research Organisation
ADAS	Agricultural Development and Advisory Service
BDFA	British Deer Farmers' Association
CAS	Centre for Agricultural Strategy
DART	Dartington Amenity Research Trust
DM	Dry matter
EC	European Community
GPA	Goat Producers' Association of Great Britain
HLCA	Hill Livestock Compensatory Amount
ICARDA	International Centre for Agricultural Research in Dry Areas
IVITA	Centro de Investigaçion Instituto Veterinario de Investigaçiones Tropicales y de Altura
MAFF	Ministry of Agriculture, Fisheries and Food
ME	Metabolizable energy
MII	Management and investment income
MLC	Meat and Livestock Commission
NAC	National Agricultural Centre
NCC	Nature Conservancy Council
NPK	Nitrogen, phosphorus and potassium
PYO	Pick-your-own
R&D	Research and development
RD&D	Research, development and demonstration
RSPB	Royal Society for the Protection of Birds
SEPASAT	Survey of Economic Plants for Arid and Semi-arid Areas
THC	Tetrahydrocannabinol
UK	United Kingdom
USA	United States of America
USSR	Union of Soviet Socialist Republics

Weights and measures

ha	hectare = 2.4711 acres
J	joule = 0.239 calories (thermochemical)
t	tonne = 0.9842 tons

Multiples

k	kilo 10^3 = thousand
M	mega 10^6 = million
G	giga 10^9 = thousand million

Conclusions and recommendations

Overproduction of a number of major commodities in the EC is, at present, substantial, and there is a clear need for farmers, and all those concerned with agriculture, to examine alternative uses of the resources currently producing surpluses. Such alternatives could produce commodities to replace current imports or could open up new export opportunities or indigenous markets. The study reported here examined a range of possibilities including alternative crops and animals, forestry and various agriculturally-related and non-agricultural enterprises that are possible on farms and consistent with farming.

GENERAL CONCLUSIONS

It seems clear that there are unlikely to be any new enterprises of a sufficiently major character that they could be regarded as panaceas for the problems of overproduction. This is particularly so in relation to the use of land. Some individual enterprises might conceivably replace the revenue currently generated on a farm by cereals or milk, but they appear unlikely to use the same areas of land.

It follows that individual farmers may have to increase the number and variety of enterprises. Whilst this may appear less efficient, being smaller-scale and making the farm as a whole less specialised, it may be advantageous in terms of adaptability to rapidly changing economic circumstances. Those enterprises that might make use of large areas will be either relatively large-scale crops or animals fed on home-grown feedstuffs. The enterprises currently offering most promise are listed below under *Specific Conclusions.*

There would be great merit in establishing an on-going assessment of alternative enterprises. This could be updated continually and absorb new ideas as they emerged; it would also provide continuing guidance on research and development needs in relation to clarifying the choices available at any one time. Linked to this could be a loose network of contacts with Research Institutes and University Biology Departments encouraging the identification of novel production possibilities. Special studies, to examine such initial possibilities further or to carry out cost/benefit analyses on well-developed projects, would then arise naturally when they appeared justified.

SPECIFIC CONCLUSIONS

Identification, exploration and development of alternatives
Alternative enterprises need to be kept under continual review, rather than periodically going over the same ground. Such a procedure could usefully maintain contact with a network of biological research workers (eg. in Universities and Research Institutes) to encourage the flow of new ideas, and be used to maintain a data bank giving easy access to the information collected.

There would also be enormous value in ensuring that an interface between research and industry was encouraged in order to establish what industry needed in the way of products and what research had to offer that might lead to new products.

When possible new enterprises, or new markets for existing enterprises, are identified, it has to be recognised that many will not be developed by private or commercial funds. The reasons for this include the early, exploration phase when the potential is not clear, the development of enterprises with no clear financial advantage to the developer and the fact that the development of many new products will involve a high risk.

There is thus a need for a group to serve as an identified focus, for the identification and exploration of new enterprises, funded by Government. There is also a need for mechanisms for developing new enterprises and this would best be done by the establishment of consortia, involving industry, research and Government (and jointly funded). Such consortia would also need to give considerable attention to marketing.

It is clear that scientific progress could transform the prospects for the future. For example, the development of both genetic engineering and tissue culture techniques will bring benefits which cannot all be foreseen at present. It is also possible that industrial use of existing cereals for the production of biofuels would become economic at some point in the future.

Implementation of alternatives

Changes in land use have to be considered with the above in mind, especially in relation to major transfers of land to purposes, such as forestry, from which they are not easily recoverable.

For many farms, there may be no large-scale alternative and a greater diversification of enterprises will be required. This will not be without advantages, of flexibility in adapting to rapid changes in the economic climate. Such diversification may include agriculturally-related or non-agricultural enterprises and this may require the relaxation of current planning restrictions on the development of such activities on agricultural holdings.

Even where large-scale developments appear possible or even promising (eg forestry, finer-wool production), it will be essential to ensure integrated use of the land, for economic and ecological reasons, taking full account of public concerns about appearance, access and conservation.

Government interest therefore needs to embrace not only Agriculture, Fisheries and Food but also Environment, Energy, Industry and Health. Integrated thinking about alternatives needs to be supported by integrated advice to those involved in practical application.

Government contributions to land-use change could assist farmers to move into new enterprises as well as out of those that lead to over-production. This is particularly relevant to new enterprises with high initial costs and long pay-back periods, such as forestry.

Alternative crops

There is no single alternative crop enterprise which will use a substantial area of land, but there is a range of possibilities whose contributions will depend on the extent of market development or the availability of suitable cultivars. These include flax, linseed, herbs, medicinals, essential oil crops, chickpea, lentil and salad crops. The development of export markets for established UK crops such as brassicas may also be feasible.

Alternative animal enterprises

The main alternative animal enterprises that could use substantial areas of land are the production of finer wool and milk (for cheese) from sheep, goat production and horses. In the last case it would be helpful for the horse to be recognised (again) as an agricultural animal. In addition, reduced intensification of existing animal enterprises could well lead to substantial areas being devoted to free-range poultry (for meat and eggs) and to outdoor pig-keeping (on light land).

Forestry

Forestry appears a promising alternative land use, judged in terms of the need for the products and technical potential. Potential productivity, in terms of increased growth rate and reduced crop duration, is capable of substantial and rapid improvement. The economic feasibility on different classes of land still needs further assessment and it is important to arrive at agreed figures for this. Potential developments include:

(i) regeneration and extension of existing broad-leaved woodlands on lowland farms;

(ii) the planting of new woodland on farms, particularly on land in the west of the country that is currently growing barley;

(iii) the planting of trees on pasture land.

The future of forestry on farms depends strongly on improved financial arrangements, information dissemination and the development of markets for non-conventional products.

Agriculturally-related and non-agricultural enterprises

Many alternative enterprises may be important in sustaining farmers' incomes even if they do not, by themselves, occupy significant areas of land. Amongst the agriculturally-related and non-agricultural enterprises, those concerned with management for conservation and the feeding of horses offer the greatest land-using potential.

Other considerations

It seems unlikely that lower-input farming will offer a major alternative in terms of large-scale movements from one form of land-use to another. Organic farming is increasing, but involves a substantial transition period and seems unlikely ever to occupy more than a small percentage of the agricultural area.

Lower input that does not lead to lower output cannot influence the area of land required, but represents a wholly-desirable increase in efficiency. If lower input leads to lower output, it would certainly involve larger areas, but would only be feasible if profit was at least sustained in relation to whatever was currently possible by other means.

Thus a high level of technical and economic efficiency will continue to be needed and this means that it is probable that we shall be able to produce our food needs on a reducing area of land.

This means that land will be available for other purposes – but at a cost. If these areas are used for amenity, recreation and conservation, these represent products (just as much as cut flowers, for example) and can be paid for. If the land is used for the production of raw materials for industry, the products must pay for the resources used. Their competitiveness as raw materials will be determined primarily by their costs of production.

RECOMMENDATIONS

The main recommendations of this study are as follows.

(i) It is highly desirable that alternative enterprises should be kept under continual review. It is recommended that a focal point be established with responsibility for this.

(ii) It is recommended that such a focal point should maintain contact with a network of biological research workers to encourage the flow of new ideas.

(iii) The same centre should also have responsibility for ensuring exploration of new enterprises and for their development. It is recommended that consortia involving industry, research and Government be established as a mechanism for the development of new enterprises assessed as promising.

1 Introduction

BACKGROUND

Currently, in the EC, there is substantial overproduction of major commodities, notably wheat, milk, sugar and wine. This is expected to continue: the technical capacity to produce even more exists now, and there is no reason to suppose that the limits to production per ha have been reached.

Controls on milk production have already been introduced and it is widely assumed that, in time, controls will be imposed on the production of cereals and other commodities or that price reduction will be used to achieve the same effects.

Farmers currently engaged in the production of commodities so affected will therefore have to redeploy resources, including land, to enterprises that will not themselves then result in surpluses. There is therefore a clear need for farmers, and others concerned with agriculture, to examine alternative uses for the resources that would then be released.

In fact, of course, since it takes time for new enterprises to become a significant part of farm practice, it is desirable that this process of examining alternatives should be continuous, so that, at any time, it would be possible to re-assess the state of knowledge and what might be needed, in terms of R & D or demonstration, to improve the prospects for application or increase the range of effective choice.

Since the relevant circumstances can change quite rapidly, sometimes affected by monetary exchange rates, for example, it is hard to predict when such knowledge might be needed. When a need is identified, there may not be time for R & D programmes to be launched and brought to fruition. On the other hand, it is simply not feasible to maintain research on all fronts all the time, so that we are ready, whatever happens.

There does therefore appear to be a strong case for someone to take a continuing responsibility for keeping the alternatives under review, adding novel possibilities to the list as they arise, deleting those that are demonstrably inappropriate and re-assessing the need for research and development, with the aim of improving the basis on which sensible choices could be made.

This is so, and would be in the interests of the agricultural industry, whether or not overproduction was a problem, but it is the current surpluses that have imparted urgency to the need.

As stated earlier, the argument, based on overproduction, is quite straightforward. This does not mean, however, that it should be accepted without question. Indeed, it is probably a good principle to challenge precisely those propositions which seem self-evident and to test very carefully the assumptions on which they are based.

The first thing to recognise is that, whilst technical advances have made very high levels of production possible, they have not been the sole cause of overproduction. Actual production has been a response mainly to economic incentives. Furthermore, whilst the economic argument for producing cereals (or milk) has been so strong, alternative enterprises could not easily be developed. Every hectare diverted from the main enterprises would have represented less than optimum use of resources.

It follows that changes in the economic framework can change the level of output and do so quite quickly – so quickly, of course, that social problems may be a major part of the result. The point is that, just because the relevant technology has not yet reached its limits, there is no reason to suppose that further increases in output are an inevitable consequence of this. After all, the technology already exists to grow pineapples in Aberdeen, but this does not make it very likely to happen.

The second point is that large sectors of farming are still very environment-dependent, much affected by the weather and often-related pest or disease problems. Such dependence has been reduced in recent years but it has not been eliminated. Thus the UK output of wheat in 1984 was greater than that of the previous year by 25–30% – for no obvious reasons. It followed, as a very few pointed out at the time, that the opposite could happen if the weather/disease conditions changed adversely.

The general judgement is that, even so, the upward trend in yields is likely to continue: but it is just worth recognising that this judgement could be wrong. For example, we cannot predict what changes in disease organisms might be combined with unavailability of a chemical spray due to health risks as yet unsuspected.

Thirdly, there is at least a possibility that export prospects could improve and, related to this, there is likely to be a substantial need for food aid to developing countries for some time. The complexity of this latter question is well recognised and the disadvantages of food aid have been well publicised; nevertheless, it is clear that the current starvation crises are not likely to be of short duration.

Finally, there are many pressures for a move towards lower-input farming systems, some of which might be expected to result in lower yields per ha. These pressures stem from a positive wish to devote existing agricultural land to non-agricultural purposes (conservation, recreation etc), beliefs that current agricultural practices are damaging to the environment or that they are unsustainable, and concerns that the products of intensive agriculture do not provide a healthy diet.

It is therefore possible that the problems of overproduction might be reduced by the diversion of land out of agriculture altogether and it is worth noting that some alternative uses, including building and forestry, may render the land virtually irrecoverable for farming.

It is salutary to recall that when the Centre published its Report on Land for Agriculture (CAS, 1976), it came to the (then) reassuring conclusion that increases in agricultural productivity could easily compensate for the transfer of land out of agriculture, running at a rate of 0.20% of the total land area per year for the UK (from 1960–1970).

Now the concern is not how to maintain food output, but how to decrease it and the current loss of some 15 kha per annum may be seen as a minor help rather than a disadvantage.

Whether overproduction continues or not, however, there is everything to be gained by an assessment of alternative forms of land use.

ALTERNATIVE USES FOR LAND

Many organisations favour the use of increasing amounts of land for non-agricultural purposes and would argue that we do not need all the land currently used for farming. These arguments often ignore the role of farming in managing the countryside and the costs of managing land taken out of farming. They also tend to focus on the commodities subject to overproduction and ignore those that we currently import and could produce ourselves.

It surely needs to be questioned as to whether we are so wealthy as a nation that we can afford to import fine wool, rabbit meat and fur, honey and a host of other products, whilst deliberately not employing resources of land and labour that could produce them here. This is not to say that they should be produced here, and certainly not without regard to the cost of doing so; but the possibilities should be examined.

This report, then, examines what alternative *agricultural* uses of land are available – or might become so – and also considers briefly those agriculturally-related and non-agricultural enterprises that are possible on farms and consistent with farming. The major part of the report deals with alternative crop and animal enterprises and assesses – insofar as this is currently possible – whether they are feasible, sensible and profitable, or might become so.

We have endeavoured to consider all the options, without pre-judging at too early a stage those that hold out little promise. Enterprises that show small prospects of success at the present time might look quite different in a few years time.

Finally, it should be stressed that alternative uses for agricultural land are not just of concern to the farmer. It is true that the farmer is in greatest need of information about alternatives, but farming in the UK is an integral part of a complex agricultural industry, many parts of which are affected by changes in farm enterprises. Indeed, the feasibility and profitability of a new enterprise may be quite as dependent upon input and service industries, on processors and on marketers, as on the activities of the producer.

Nothing will be produced for which there is no demand and a key element in launching a new farm enterprise is to ensure that there is a market to which the farmers can sell. Frequently this will not be the ultimate consumer and very often there may be little demand for new products that are limited in quantity and perhaps seasonal in supply. Very often, new home produce may have to compete with well-established, reliable and large-scale sources of supply from outside the country. In establishing prospects for new enterprises, therefore, it is very important to consult all parts of the industry.

2 Alternative crops

This chapter first examines the characteristics required of a new crop and considers different methods of classifying them, before proceeding to review the individual crops themselves. Many have been considered, some to be discarded immediately, though comment about these has been retained in the text. No large-scale solution to the problem of existing surpluses has been identified, not surprisingly for if one were available, it would probably have been introduced already.

GENERAL CONSIDERATIONS

A potential new crop for the UK must eventually meet the following requirements.

(i) It must be suitable for at least some of the soils and climates of the UK;

(ii) The crop must be capable of incorporation into existing farming systems, or of being the basis or a component of a new system;

(iii) It should provide a product or service which meets an existing or potential need of the community;

(iv) The crop must achieve this in competition with any alternative, perhaps an industrial product, on economic, quality or aesthetic grounds;

(v) It should provide a yield and/or confer benefits in general or on other components in the farming system so that its contribution represents an appropriate return to the community or the farmer.

At this stage, less detailed criteria have been adopted, as follows. There must be some reason to expect that the crop will be suitable for cultivation in at least some parts of the UK, or it must be potentially capable of genetic adaptation to make it suitable. There must also be some reason to suppose that it could provide a product or service which will find a market or use. Because most new crops will be in competition with an alternative product, for example natural fibres *versus* synthetics, this implies some consideration of economics. However, economic factors have not been given undue weight; economic circumstances can change and, in any case, the pressure to reduce imports or the area of crops currently grown could create circumstances which encourage financial supports for alternative production.

A key factor in identifying alternative crops for the UK is an appreciation of the important characteristics of the British climate. There are of course considerable regional variations, but some features are more or less common to all. The occurrence of winter frosts means that winter annuals, biennials or perennials must be cold tolerant, and it also prevents year-round production of successional annuals unless some form of protected cropping is employed. The largely maritime climate provides a long growing season, but one of relatively low temperatures. Thus annual crops whose duration is at least partly temperature-dependent occupy the land for longer than when grown in a more continental climate. This can be an advantage, for example in giving a longer grain-fill period, but it can be a disadvantage if delayed ripening pushes maturity too far into the autumn. Another feature is the UK's relatively reliable rainfall and the limited occurrence of severe water deficits. On the other hand, high humidities can exacerbate disease problems, for examples *Botrytis,* which may be less serious in continental and Mediterranean climates.

Experience from other countries suggests that there can be one particularly useful feature of introducing a crop to an area where the species has not previously been present. Provided suitable phytosanitary measures are taken, it can be kept free of many of the pests and diseases which will have developed with the crop in its centre of origin. Equally though, for a seed crop it is necessary to ensure that appropriate pollinators are available, for example if it is insect pollinated.

The need to seek crops adapted to UK conditions emphasises the importance of considering alternative uses for the crops we already grow. Their performance is proven, their yields have in many cases been dramatically improved by the plant breeder, their management is understood and their output is considerably greater than in most other parts of the world. It is therefore a significant part of this study to examine the possibility of diverting their production to novel uses.

It is also important to consider the development of by-products, both from existing crops and from alternative crops. These may range from the development of better uses of straw from cereal crops to the combined production of oil and a protein feed, or the extraction of a chemical constituent from a crop previously grown for another purpose.

CLASSIFICATION OF ALTERNATIVES

Later in this chapter, possible alternative crops have been considered in a grouping based largely on product use. There are other systems of classification which might have been used, and because the various methods stimulate different ways of thinking about new crops and their characteristics, some other methods are presented here together with consideration of their implications.

Characteristics of the crop

The characteristics of the crop, in terms of its agricultural requirements, may affect its suitability. These characteristics include:

(i) whether it is an annual, biennial or perennial;

(ii) whether the useful yield is the result of vegetative growth, or a part of the vegetative growth (tuber, leaf, axilliary bud, phloem fibre, etc) or of reproductive growth (seed, fruit) or is a chemical extract from the plant;

(iii) its climatic and soil requirements;

(iv) its input requirements;

(v) whether harvesting is a single episode towards the end of the season or at the end of the crop's useful life, or whether a succession of harvests is required.

Factors such as these will determine the type of farming system for which the crop is suited and whether it fits easily into existing systems, particularly as affected by time of sowing and crop duration. Crop duration and the nature of the yield will largely govern the type of management and whether existing equipment will be suitable for cultivation and harvest. Input costs are mainly determined by fertilizer and pesticide requirements, but occasionally there can be costly specialist requirements, as in the retting of Flax. The legumes tend to have the lowest input costs because they need no nitrogenous fertilizer.

Novelty of the crop

The extent and location of any previous production can be of consequence. It may be:

(i) a new use of an existing crop, or the development of a new byproduct from it;

(ii) a reintroduction of a crop previously grown in the UK;

(iii) introduction of a crop from elsewhere in the world;

(iv) a plant not previously grown as a crop.

Information about suitability for UK conditions and the type of management the crop requires will already by available if it is currently grown here or has previously been grown here. To that extent, confidence in its development can be greater, not only in terms of its adaptability to soil and climate but also in relation to potential pest and disease problems. Where the proposed crop is being introduced from another area, climatic adaptability must be considered and tested. Even though the general temperature levels may be satisfactory, crops introduced from climates only slightly warmer may not have a long enough growing season because of the delay in phasic development. If flowering is necessary to the production of the crop, the ability of the UK climate to satisfy the crop's photoperiodic requirements will be another important aspect of adaptation.

Quite different factors apply to plants which have not previously been grown as crops. They may lack the structure to perform well in monoculture or in mechanised farming, and they may lack a suitable synchronisation of yield development. New crop plants often shatter and shed their seed yield too easily, may exhibit too much dormancy, or alternatively can display an absence of seed dormancy which in a wet season can result in germination before harvest has been completed. Experience suggests that these and other undesirable features can be bred out of wild plants during their development as crop plants, but it can be a slow process.

Williams (1978) points out that no crop introduced into northern Europe in the last three centuries (Potatoes, Clover, Turnip, Swede, Oilseed Rape and Sugar Beet) has been truly new. However, it is notable that success as a weed has often been an indication of crop potential. Weed status signifies adaptation to soil and climate, and suggests synchrony of development with existing crops, eliminating the impediment of late ripening. Weed status as an annual is also a clear indicator of satisfactory seed production and of establishment from seed.

Many plants introduced into cultivation were successful fodder crops before genetic selection and processing technology developed their potential for human food; Rape and Beet were grown for fodder before being used for oil and sugar, and Soyabean was a minor fodder crop in the USA for almost a century before being used for grain production (Williams, 1978).

Novelty of the use

Novelty of use may affect marketing characteristics. The crop may be:

(i) similar to, or an alternative to, an existing agricultural product;
(ii) similar to, or an alternative to, an existing industrial product;
(iii) a crop with a novel use, not previously satisfied or, perhaps, recognised.

Where a crop product is in competition with an industrial product, comparative economic evaluation can be affected by industrial factors considerably removed from the agricultural scene. In addition, the industrial competitor can have two particular advantages. First, it is produced under controlled conditions, which means that output is much more predictable, and quality characteristics will usually be more dependable and repeatable from batch to batch.

Second, the industrial product may be able to gain advantage from large-scale production at a single site, whereas crop products will often be produced on a smaller scale at many different locations. Marketing and any processing necessary for the crop may have to be preceded by collection at a central point; for bulky crops this can be an appreciable expense.

The ability of a crop product to compete with an industrial product is poorer today than it was a century or more ago. At that time, many forms of manufacture were conducted in small units, for example the village blacksmith, the local carpenter, and many types of cottage industry. Today the number of units has fallen and the scale of operation of those that remain has greatly increased. Similar increases in scale of activity have taken place in UK farming, but not to the same extent. Apart from these considerations, the ability of a crop plant to compete with an industrial alternative will be much affected by the energy cost of the industrial product and the extent to which solar energy can replace this in the crop without incurring additional non-renewable energy requirements, for example to evaporate excess moisture.

A current trend which may favour crop enterprises is an increasing interest in 'natural' products. It may take a suitable advertising campaign to exploit this tendency and it is questionable how resilient it would be in the face of any substantial price differential.

To date, this study has not identified a novel use not previously satisfied, so it is difficult to comment sensibly on this category. It is however likely that such a product would require considerable development and perhaps market promotion before it was established.

Post-harvest management

In terms of processing, the crop may require:

(i) little or no processing;

(ii) processing on the farm;

(iii) processing off the farm, either on a small scale and with little investment, or requiring a large scale of operation, perhaps with considerable investment.

Crops which require little processing are those most likely to be capable of rapid development to meet a market need. If processing is needed, it may have to occur on the farm in order to avoid early deterioration, for example the drying of grains, or to allow easy transport, for example densification of straw. It may also be necessary for those crops which are used on the farm, for example the processing of short-rotation Willow chips for farm fuel requirements.

The cost of processing, and the investment needed in it, can be an important factor in determining whether an enterprise is economic and the rate at which it might develop. It can also greatly affect the competitive ability of the crop enterprise. For example, Flax, once it is grown, still requires considerable processing to provide the fibre for thread making and then weaving, whilst synthetic fibres need little further processing once they have been manufactured. The importance of scale of operation for processing investment is also illustrated by Flax. One of its difficulties in competing with Cotton is the enormous size of the Cotton industry at all stages from field to fabric and the difficulty Flax will have in competing from its present low level of operation except in specialist uses.

FIBRE CROPS

The fibres used by the textiles and cordage industry are of three types. Synthetics such as nylon come from an oil base; regenerated fibres are manufactured from cellulose, usually a timber source; and natural fibres are of direct plant origin. Synthetic and regenerated fibres make up half the world's textile fibre production, cotton accounts for most of the remainder (Neenan, 1983).

The natural fibres are favoured for their hard-wearing characteristics, their absorbency and their ability to take dyes, but they are more expensive and do not have the 'easy care' properties of the synthetics. However, these properties can increasingly be incorporated by treatment of the fabrics, for example with a resin finish. The natural fibre from Flax is the most suitable for UK production and it will be considered later in this review.

The regenerated fibres, for viscose rayon or acetate rayon, are weaker than synthetic fibres, do not wear as well but take dyestuffs more easily. They are often used in conjunction with either natural fibres or synthetics. The usual raw material is wood with a high cellulose content: Spruce, which is also fast growing, is favoured. The main UK manufacturer uses imported supplies of raw material, mostly Eucalyptus and Acacia from South Africa, because of a special relationship with the supplier. Rayon production in the UK is under pressure from other fibres and from third world rayon output, but were production to increase here, a local source of Spruce would be apppropriate.

Filling of upholstery used to be done with horsehair, moss and plant fibres, but foam materials and waste synthetics have replaced them. The latter are superior to natural fibres because of their greater resilience, an important property for this purpose, but natural fibres produce less toxic fumes when they catch fire, and if resilience could be incorporated during manufacture, any vegetable fibre might be useable. Species previously used include Cotton Grass *(Eriophorum* spp) for its seed hairs, and the Bog Moss *(Sphagnum acutifolium).*

Though not a fibre crop itself, Teasel *(Dipsacus fullonum)* has been used in the carding of cloth, usually woollens. It is the stiff hooked bracts of the mature inflorescence which can be used for this purpose. Production of Teasel occurred in Somerset at least until the early 1950s and still continues on a few holdings in other parts of the country.

Amongst the natural fibres, a very tentative suggestion is that *Phormium tenax,* sometimes called New Zealand Flax, could in the long term contribute to UK fibre production. It is a perennial and produces a leaf fibre which can be used for 'fine linen-like clothing' (Kirby, 1963). It has been grown in the UK as far north as the Orkneys (Mueller, 1888) and is resistant to frost, but the development of its use is likely to be too costly to justify attention at present. Hemp *(Cannabis sativa)* is an annual fibre-producing plant suitable for cultivation in temperate regions. It produces a stem fibre which lacks the flexibility of Flax because it is somewhat lignified, but it can be used for cordage, twine, sacks, sail cloth and carpets. Synthetic fibres probably have an advantage for cordage and netting, particularly in marine use, because their products are rot-proof and have great buoyancy. They also have greater resilience which reduces the risk of a rope breaking. It is currently illegal to grow Hemp in the UK because it also produces marijuana, a stimulant resin compound. However, a monoecious variety has now been produced in which THC, the psycho-active ingredient of marijuana, has been reduced to 'virtual insignificance' (Malyon & Henman, 1980).

Both the common Stinging Nettle *(Urtica dioica)* and the Small Nettle *(U. urens)* have been used in the past for fibre production. The fibres are retted and beaten from the stem, much as for Flax, and are fine enough to be used for muslin. Production was common in Scotland during the eighteenth century (Edlin, 1951), but in current circumstances extraction costs would be too great in relation to the value of the fibre.

Flax

The most promising fibre crop for re-introduction and expansion is Flax

(Linum usitatissimum). Linen from Flax can be used for both clothing and furnishing fabrics but it probably has fewer applications than Cotton and it is more expensive partly because of the high cost of retting and scutching. Retting is a partial decay process to loosen the fibres in the stem and is done on the farm. Traditional methods were by soaking the stems in tanks or ponds, or 'dew' retting by lying damp in the swathe. Scutching is a factory process in which the retted fibres are beaten free of the stems. Improved technology could well reduce the retting cost: one method is to initiate the process before harvest through an application of glyphosate during flowering.

Linen lends itself well to the current fashion for the 'crumpled look', and there is in any case an increasing tendency to turn away from synthetics and return to natural fibres. Developments in imparting easy care characteristics to linen may help its ability to share in this trend. Furthermore, linen fibre is increasingly being used for mixing with other fibres if only because a textile which can include the word *linen* on its label tends to have a greater sales attraction.

The EC grows about 58 kha of Flax. Most of the fibre currently used in Great Britain and Northern Ireland is imported, amounting to about 13 kt per year for both textile and paper production. About 400 ha were grown in Northern Ireland in 1985 and the industry there appears poised for expansion, both to reduce current imports of Flax and because Flax should increase its share of the textile market. All the existing mills are re-equipping and two new mills have been established within the last year. In Scotland, where 290 ha of flax were grown in 1985, a scutching mill is in process of construction, but has encountered loan-servicing problems. The Industrial Development Board for Northern Ireland (1985) has recently reviewed the spinning, weaving and marketing position. It has not been able to make any estimate of the future of the Flax market but it is broadly optimistic about the prospects for linen, and emphasises that expansion will need a significant input of capital. It is also worth noting that, in an enquiry in 1911 into the continued decline of the Irish Flax industry, lack of co-operation between the interests concerned was *perhaps the only substantially responsible cause brought to light* (Hunter, 1931). This is a lesson which is probably well learnt by now because it applies not only to Flax but to most other farm products.

Flax: further studies

The development of Flax will have to depend on the development of its markets except to the extent that we can replace continental Flax imports. The promotional activities of organisations such as International Linen, which has units in London, Europe and New York, will therefore be significant. It may be necessary for the potential role of UK production to be assessed by a joint group which could be sponsored by MAFF and the Department for Trade and Industry, but on which textile producers and some farming interests should be well represented. Having determined the likely development of market needs, and therefore of mill and factory capacity, farming implications can be considered.

Much is already known about the management of Flax, but trials which have already started in Scotland could be extended to northern England. Some years of work have been done in Northern Ireland, including variety evaluation trials at the Plant Breeding Station, Loughgall. Management features which require attention are weed control, and the manipulation of glyphosate for retting.

PAPER

In 1984, the UK consumed 7.5 Mt of paper and exported 0.4 Mt. A total of 3.6 Mt was produced at home, only 0.1 Mt (3%) from UK wood pulp, the remainder from waste paper (53%) and imported pulp (44%). However, UK pulp production has recently doubled, to more than 0.2 Mt. Many plant materials can be used for paper making; those chiefly used are shown in Table 2.1.

Table 2.1
Amounts of the chief constituents of paper-making fibres (%)

Material	Alphacellulose	Hemicelluloses and other non-cellulosic polysaccharides	Lignin
Wood	40–50	12–34	20–30
Raw Cotton	88–96	Up to 6	None
Linen Rags	92–96	1–3	3–5
Flax	65–70	15–21	2–5
Esparto Grass	44–50	26–30	16–19
Cereal Straw	31–40	35–48	15–25

Source: Adapted from Bolam, 1965

The ideal material for paper making is pure cellulose; hemicelluloses may be beneficial to some extent, but lignin is detrimental and must be removed. The cellulose content is highest in Cotton and high in Flax.

Cotton and Flax also have long elongated cells which have a high length/breadth ratio and these properties make them particularly valuable for paper making as well as for textile purposes. The highes quality papers are therefore produced from Cotton or Cotton rag, Fla or Linen rag, and also from Manila and Hemp (Bolam, 1965).

Bulk paper-making developed considerably in the UK from the 1920s to the 1960s with the help of high protective tariffs, but after the tariffs were abolished in 1967 the UK producers were unable to compete with those from Sweden and Finland with their ready and large-scale supplie of wood pulp. Imports are now taking about 50–60% of the UK pape market and the large, long-established, paper makers have been badly affected, with some ceasing production entirely. At the same time, however, a number of small entrepreneurial paper makers have becom established in the UK and are tending to specialise in high-quality, high-value papers. Products include tea-bags, sausage skins, filter ar other absorbent papers, stencils and banknotes. New processing techniques have also been developed recently which allow economi production in smaller-scale mills than previously.

Paper: future studies

Timber for wood pulp and Flax for fibre production are the paper-producing materials of greatest potential for UK expansion. Ther is also the possibility of greater use of straw, which is considered in later section.

The commercial viability of an increase in wood pulp output is regarded as doubtful because of the difficulty of competing with low-cost Scandinavian production which has considerable advantag in cheap hydro-electric power and fewer problems of effluent disposal. Considerable investment would be needed; the capital cost of a plar producing 300 kt per year could be £350 million. The two main physical factors affecting viability are mill-size, which determines the extent t which the benefits of large-scale operation can be achieved, and transport costs, which are largely determined by the size of the catchment area necessary to provide a sufficient and continuing supply of timber.

However, a preliminary study is probably justified to determine whether recent technical developments, and the distribution and age-distribution of UK timber, can allow the viable development of one or more additional mills. The study should take account of new technology, especially the production of chemi-thermomechanical pulps which can give a yield of 90–95% compared with 35–50% for the older processes. Long-term planning of forestry development shoulc consider not only landscape and land-use factors, but also the need to be able to supply pulp mills on a sufficient scale and within appropriate transport distances.

In the past, the textile market has provided a better return from Flax fibre than has paper production, and paper-makers have relied mainly on linen tow, waste and rags. However, given the recent innovations in small-scale, high-quality paper making, it would be worth investigating the feasibility of producing Flax for the paper industry as well as for textiles. This would require an assessment of the home and export markets, and their likely trends, the extent to which Flax products might be expected to contribute to different products and markets, and the price at which it would compete with alternative materials. These studies would indicate whether the size of the potential market and the likely return per hectare make Flax a suitable crop for development for paper production, either on its own or in conjunction with the textile market. An auxiliary source of fibre, which should be reviewed at the same time, is the use of Linseed straw. Its fibre is more difficult to extract and is less suitable for linen, but may be appropriate for paper production.

Agronomic trials should accompany or follow the market and processing studies, to determine the varieties and management most appropriate to the end use, the potential for meeting textile and paper needs in combination, and perhaps also the most suitable areas for Flax production. These may be the cooler and wetter parts of the country, but the choice may also be affected by the current or future location of the processors and the need, for a bulky product, to keep transport distances to a minimum.

RUBBER

Latex is a sticky white liquid present in latex vessels, which ramify through most parts of those species in which latex occurs. Its significance to the plant is obscure, but it can be of value in the healing of wounds. Lettuce and Dandelion are two of the many species that contain latex.

Latex is a mixture of many different substances, and in some species one or more of these constituents may be commercially useful. Rubber and gutta-percha (a non-elastic rubber) are examples.

Rubber is known to be present in about 1000 different species, in nearly 80 different plant families, but often in very small quantities (Minshall, 1957; Polhamus, 1962). Many of the species are plants of the tropics and sub-tropics; the major world source is *Hevea brasiliensis*, a tree which originated in South America but is now a major feature of the agriculture of South East Asia. It would be very valuable if an economic source of rubber could be found in a species adapted to UK conditions, but it is by no means certain that any exists.

Taraxacum kok-saghyz, the Russian Dandelion also called Kok-saghyz, is one possibility which is reputed to have been an important source of rubber for the USSR during the last war. In greenhouse trials it performed better at around 13°C than at 25°C, and in American studies, in 41 states of the USA, and in Canada, it was found to do best in northern USA and southern Canada. It is sown in spring and the rubber-bearing roots are harvested early the following spring. Rubber tends to continue accumulating in them over the winter, but the majority is contained in the root 'bark' which is shed soon after growth is resumed in the spring. The roots can be damaged by very cold weather, but this appears to be ascribed more to frost-induced soil heaving than to the direct effect of low temperature. It therefore seems possible that Kok-sahgyz could be adapted or adaptable to UK conditions. Root yields in the USSR have been reported as 3.5–4.5 t per ha, thought to be fresh weight; performance in the USA trials was very variable but, in general, lower than this. Despite reported concentrations of up to 6–8% rubber in the dried roots, rubber yields of no more than 70-110 kg per ha per year are quoted (Polhamus, 1962). It is therefore not surprising that Kok-saghyz is described as *one of the most costly of our rubber crops* and that the USA wartime trials were discontinued after the war was over.

Scorzonera tan-saghyz (rubber-bearing Salsify) and *S. acanthoclada* are, like Kok-saghyz, members of the family *Compositae.* Both grow at higher elevations than Kok-saghyz and might be better adapted to the UK, but yields are probably similar.

The figure of 6–8% rubber in the root dry matter quoted above can be compared with the 1.5% reported for the rubber concentration in the dried bark of *Hevea brasiliensis.* Yet the latter can give a rubber yield of 2000–3000 kg per ha per year. The reason for the difference is probably that in *Hevea* the latex and rubber is tapped continually from the growing plant which is therefore stimulated to produce more to replace what is removed. Similar behaviour might occur in Kok-saghyz if it could be treated in the same way, but the nature of the plant is such that once-over harvesting is the only feasible method. It seems unlikely that breeding and selection could do enough to increase rubber concentration to a practicable level. A woody perennial like *Hevea* is probably the only economic type of rubber producer. It has been suggested that the family *Euphorbia* is most likely to be the source of a suitable temperate example, but none has been identified.

DYES

Until the middle of the nineteenth century, most dyes were extracted from plant tissues. They were then largely supplanted by aniline and other synthetic products, mainly derived from coal-tar, and giving brighter, more consistent and permanent results. Natural dyes provide a range of colours which can be increased by appropriate mixing. It has been said that their warm shades and soft lustres can never be exactly imitated by synthetics.

A number of UK plant species can produce dyes of various colours, including red, yellow, blue, green, brown and black. Plants providing these dyes include the following.

Red dyes

(i) Madder *(Rubia tinctorum),* various shades of red, red-brown and purple-brown can be obtained from the peeled, dried and powdered root;

(ii) Our Lady's Bedstraw *(Galium verum),* from the root;

(iii) St. John's Wort *(Hypericum* spp.), from the flowers after acidification;

(iv) Spindle Tree *(Euonymus europaeus),* pink from the fruit case, orange from the seeds.

Yellow dyes

(i) Yellow-wort *(Blackstonia perfoliata);*

(ii) Marsh Marigold *(Caltha palustris);*

(iii) Golden Rod *(Solidago virgaurea);*

(iv) Yellow Camomile *(Anthemis tinctoria);*

(v) Saffron Crocus *(Crocus sativus),* from the stigmas and styles, a highly labour intensive product;

(vi) Dyer's Broom *(Genista tinctoria),* a perennial plant treated as a biennial, the whole plant is used in the preparation of the dye;

(vii) Dyers Rocket *(Reseda luteola),* boiled from the whole plant.

Blue dyes

(i) Woad *(Isatis tinctoria)* fermented from the foliage;

(ii) Whortleberry *(Vaccinium myrtillus),* from the berries.

Green dyes

(i) Bracken *(Pteridium aquilinum),* from the young fronds;

(ii) Other green shades can be produced by mixing woad with a yellow dye.

Brown dyes

(i) Dandelion *(Taraxacum officinale),* a magenta brown from the roots;

(ii) Onion *(Allium capa),* a yellow brown boiled from the skins;

(iii) Yellow Iris *(Iris pseudacorus),* from the roots;

(iv) Meadow-sweet *(Spiraea ulmaria),* from the roots.

There is considerable interest in natural dyes amongst certain sections of the community and in those parts of the textile industry which specialise in cottage-style production, particularly for the tourist trade. However, it is very uncertain whether there is any substantial prospect for an introduction of dye crops.

FLAVOUR, PERFUMERY AND MEDICINAL PLANTS

This group of crops is an extremely diverse one, but they are so interconnected that it is sensible at this stage to deal with them together. Their value and use is usually dependent on the presence of some biochemical constituent. This is often an essential oil, but it may be a resin (oxidation product of an essential oil), an oleo-resin (a mixture of the two), an alkaloid (possibly a protein decomposition product), a glucoside (carbohydrate-derived) or some other material.

Essential oils are also called volatile oils and often have a pleasant taste and strong aromatic odour, for example Mint, Jasmine, Camphor. Most of the herbs, spice and perfumery materials owe their characteristic to a content of essential oil which may be present in any part of the plant. The content varies with species, it can be as low as 0.4% and it may vary from time to time and in different seasons.

The early pharmaceutical industry relied almost entirely on plant materials and substances extracted or infused from plants. Today the main sources of pharmaceuticals in decreasing order of importance are: chemical synthesis, fermentation, animal extracts, and plant extracts. The pharmaceutical industry produces a wide diversity of products in relatively small amounts; the area cultivated of any particular plant is not therefore likely to be large (Reubens & Burstall, 1973). However, to these can be added a wide range of plant materials used in alternative medicine including the traditional medicine of ethnic communities. It is not easy to draw a dividing line between conventional medicine and alternative medicine, but in total some hundreds of plant species are used. Some of the pharmaceuticals used in conventional medicine are derived from plants unsuited to a temperate climate. For example Cascara (from the bark of *Rhamnus purshiana),* Quinine (from the bark of *Chinchona* spp) and Senna (from the leaves and pods of *Cassia spp).* Others, such as Eucalyptus oil with UK imports in 1983 valued at £31.2 million, are produced from tropical species which might be replaced by a species adapted to the UK climate. A further group of plant sources, for example, Fenugreek, are well-adapted to UK conditions.

The whole range of materials for culinary, perfumery and medicinal uses may be processed in a variety of different ways. The whole plant or particular parts of it may be used fresh or dried, or in powdered or tablet form. Active ingredients may be extracted in pure form or in mixture by aqueous extraction, steam distillation or using organic solvents, to supply a product which may be used directly or as the precursor of some other substance.

Few statistics are available to assess the size of the market or the contribution that imports make to materials used or processed in the UK, or the proportion of UK processing which is subsequently exported. Greenhalgh (1979) considered that there was scope for increased world production of herbs, particularly Peppermint, Sweet Marjoram, Oregano, Parsley, Savory and Tarragon, and that demand for herbs and their products was increasing in the 1970s at about 10% per year. Recent trade opinion suggests that it is continuing at about the same rate, though with considerable variation between different products. Imports probably supply over 70% of home market needs. It has also been privately estimated that the demand in the UK for plant products for medicinal and health uses has increased by about 25% per year over the last seven years and is continuing to increase at this sort of rate. For this type of product it is estimated that imports account for 90–95% of the materials used. The total UK market for herbs and medicinal plants of all types must amount to many hundreds of millions of pounds. The statistics allow a very few imports to be identified separately (Table 2.2). All of those shown could be produced in the UK, and they represent only a small proportion of the total range of imported products. Liquorice *(Glycyrrhiza glabra)* used to be grown in the UK, particularly around Pontefract, but production here is now virtually non-existent. The many imported herbs include a number like Parsley and Sage which are well-adapted to UK conditions.

Table 2.2
Miscellaneous imports into the UK, 1983

Product	Quantity t	Value £thousand
Peppermint oil	754	10 000
Jasmine oil	0.2	137
Lavender oil	136	854
Rose oil	17	298
Thyme (dried)	119	118
Liquorice	570	1 000

Source: Adapted from Department of Trade and Industry (1984)

Some of the common herbs are natives of Mediterranean climates, but many of these are foliage crops, or combined foliage and inflorescence, and are not necessarily lower yielding in temperate conditions. It is not clear what effect environment may have on the concentration of essential oil; it has been claimed for both Oregano and Sage that plants grown in northern Europe are less pungent in odour and taste, but this is not universally accepted.

Peppermint oil is one essential oil which is imported in quantity; some 750 t in 1983, valued at over £10 million. Most of this comes from the USA and at an average yield of about 60 kg per ha, this represents the produce of over 12 kha. Peppermint *(Mentha piperita)* is a perennial plant native to the temperate parts of Europe and is already grown on a few holdings in the UK. Its yield is reported to be lower in the UK, perhaps 40 kg per ha, and if this is so the current price of about £20 per kg means a gross return of about £800 per ha which would have to cover both growing and distillation costs. However, it is a possibility which is worth further study.

The major contribution made by imports is the result of a number of different factors. In the case of Peppermint it is probably because the large demands of the United States chewing-gum and tooth-paste industry have allowed the develoment of large-scale low-cost production. Many other crops are produced on a small scale by labour-intensive methods and have kept a place in farming systems less mechanised than those in the UK. Many medicinal plants are still gathered rather than cultivated and are produced from areas where the tradition and opportunity for gathering has persisted, particularly in eastern Europe. For one reason or another, manufacturers and brokers in the UK have found imported supplies more reliable, and often only a telephone call away. It was reported that one large hotel chain which was seeking substantial and regular supplies of a particular temperate herb, turned to a continental broker because of uncertainties about the reliability of UK production.

Production in the UK

Several factors suggest that a substantial increase in UK production may be possible. Indeed, comment by farmers and professional agriculturalists suggest that herb growing has already increased, but firm information on its extent and the species used is lacking; farmers are less willing than previously to discuss the innovations they find profitable. Amongst the medicinal plants, control of quality is becoming more rigorous at the same time as quality in the gathered crops of eastern Europe is declining; much of the material is gathered near to urban areas and industrialisation is leading to an increase in heavy metal content. Controlled cultivation in rural areas of the UK could avoid this, and some at least of the brokers and processors would welcome an increase in reliable UK production because it would allow them greater control over both supply and quality.

Farmers who have grown trial areas of herbs and other novel crops in recent years have often given up after one or two years because the crops were of similar or lower profitability compared with cereals, and more trouble to manage. However, there is more appreciation now of the need to gain the skills of producing alternative crops in preparation for a possible decline in the profitability of existing crops.

World and domestic prices for herbs and similar crops fluctuate widely. For example, prices on the UK parsley market commonly double and then halve again in the space of a fortnight more than once in a season, and show numerous lesser fluctuations. Average prices also vary widely between years. A grower would need to be involved in a range of products or in other enterprises, in order to cope with such fluctuations. On the other hand, it is necessary to be producing individual crops on a scale large enough to be mechanised, and to consider the size of enterprise needed if steam distillation is to be done on the farm. These crops may never occupy a large area of the UK, but it is likely that they could make a much bigger contribution to farm output than occurs at present. A much greater development of their cultivation would be possible if the UK share of the extensive and lucrative overseas market, particularly for medicinals, could be increased.

One small market which has developed in this way is the production of flower petals for pot-pourri. The reputation of the English Rose and English Lavender is such that pot-pourri production might be further developed into a larger export market.

Amongst other crops currently grown in the UK, both Caraway *(Carum carvi)* and Coriander *(Coriandrum sativum)* may be capable of greater production to reduce imports.

One or two new UK crops have been in process of development in recent years. There has been considerable publicity about them although the area required for their production is still small. Evening Primrose *(Oenothera biennis)* and Borage *(Borago officinalis)* are both sources of gamma linolenic acid, a precursor of prostaglandins which have a regulatory role in human metabolism. It was estimated that some 240 ha of borage was grown in 1985 and that it could be in excess of 10 000 ha within 7–10 years. Average seed yields vary between 0.35 and 0.60 t per ha which at a price of £2800 per tonne gives a gross return of £1000 to £1700 per ha. The seed contains about 30% oil of which approximately one fifth is gamma linolenic oil.

Another specialised oil requirement is for certain types of long-chain fatty acid oils for industrial and cosmetic purposes. Sperm whale oil and the arid zone shrub Jojoba are current sources of a product for which the demand is likely to increase. A similar oil is produced by the annual Meadowfoam *(Limnanthes alba)*. It is native to the cooler areas of the Pacific coast of North America and is presently grown on a few hundred hectares in Oregon. The crop is probably adaptable to the UK, but low yield and uncertain price suggest that the economics of cultivation are doubtful. The price currently available in the United States is considerably greater than can be obtained in Europe and is probably the result of temporary and very specialised market conditions.

An annual herb coming into cultivation is Fenugreek *(Trigonella foenum-greacum)*, which was previously used as a flavouring but which also contains diosgenin, a chemical used in the preparation of steroid drugs and oral contraceptives (Lees, 1981).

Despite these developments, it is likely that chemical and biochemical synthesis of many drugs will continue to be more economic than the use of plant sources. For example, rye ergot used to be produced by artificial infection of rye crops for subsequent hand harvesting. This laborious process has now been replaced by synthetic production. It should also be mentioned that there is work in progress to develop systems of essential oil production in tissue culture. This is likely to be some years away, but confidentiality shrouds activities in this area and progress cannot easily be assessed. On the other hand, there is increasing use of plant products (Table 2.3) in alternative and ethnic medicine, including herbalism, for treatment of a wide range of disorders and for general health care. This interest and active use comes not only from the general public, but also from within the medical profession. It is a market with considerable export potential which is worth many millions of pounds.

A much longer-term development is the possible production of crop protection chemicals from plant materials. There are several important examples from the past which are still in some use, notably Pyrethrum, Derris and Nicotine as insecticides, and Red Squill as a raticide. None of these can be produced in the UK. There is considerable, and probably increasing, public pressure to reduce dependence on synthetic pesticides, and conversely, a much readier acceptance of naturally produced products. A programme to identify possible materials would be worthwhile if a preview suggested that there was some chance of success, but the present study cannot give much encouragement. Perhaps the

Table 2.3

Some of the herbs currently used in medicinal preparations (British/European)

Aesculus hippocastum L.	Horse chestnut
Allium sativum L.	Garlic
Anethum graveolens L.	Dill
Apium graveolens L.	Celery
Arctium lappa L.	Burdock
Arctostaphylos uva-ursi (L) Spreng	Bearberry
Atropa belladona L.	Deadly nightshade
Capsicum annum L.	Chilli peppers
Capsicum frutescens L.	Tabasco pepper
Caum carvi L.	Caraway
Caulophyllum thalictroides (L) Michx.	Blue cohosh
Cimicifuga racemosa (L) Nutt.	Black cohosh
Cinnamamum zeylanicum nees.	Cinnamon
Corindrum sativum L.	Coriander
Crocus sativus L.	Saffron crocus
Digitalis purpurea	Foxglove
Elettaria cardamonum var. miniscula maton	Cardamon
Equisetum arvense L.	Horsetail
Foeniculum vulgare mill.	Fennel
Guiacum officinale L.	Guiacum
Humulus lupulus L.	Hops
Hypericum perforatum L.	Common St John's Wort
Lavandula stoechas L.	French lavender
Lavandula dentata L.	Fringed lavender
Lobelia inflata L.	Lobelia
Matricaria recutita L.	German chamomile
Melissa officinalis L.	Balm
Mentha spicata L.	Spearmint
Mentha x piperita L.	Peppermint
Menyanthes trifoliata L.	Buckbean
Myristica fragrans Houtt.	Nutmeg
Papaver rhoeas L.	Corn poppy
Papaver somniferum L.	Opium poppy
Phytolacca americana L.	Poke weed
Pimpinella anisum L.	Anise
Rosmarinus officinalis L.	Rosemary
Syzygiun aromaticum (L) Merr & Perry	Clove
Taraxacum officinale Weber	Dandelion
Urtica dioica L.	Common nettle
Valeriana officinalis L.	Valerian
Viscum album L.	Mistletoe
Zanthoxylum americanum Mill.	Prickly ash
Zingiber officinale Rosce	Ginger

Source: Adapted from Svoboda (1984)

most promising category is that of chemicals repellent to birds and insects. The saponins contained in Quinoa (see the following grain crops section) have repellent properties and are difficult to synthesise. Other plants too suffer less from pest attack because of some constituent of their tissues, and their possible commercial development could be considered.

Flavour, perfumery and medicinal plants: future studies

An increase in the UK share of the market, for both home and overseas sales, is dependent on two requirements. First, buyers must be convinced that home production can be advantageous to them both for existing markets and for entry into new ones. The main needs will be reliability of supply, easy access to it, and the maintenance of a suitable quality. Secondly, farmers must be reasonably certain of an adequate return for their investment and efforts, in comparison with other types of land use.

These requirements can only be met by an integration of effort by buyers and growers together. Because marketing is the crucial factor, the initiative may have to come initially from the buyers. This has been a major feature of some of the crops already in development, for example Borage.

Evaluation of prospects in this area would be greatly helped by more information on the size and requirements of the market, including the extent of imports. It may not be easily obtainable because national statistics are not available and individual firms dealing in herbs and *botanicals,* a general term used for medicinal plants, may be loathe to reveal the size and nature of their activities. Nevertheless, some information on the scale of the market could help to convince growers of the value of participating in it.

The development of production, and of an association between buyers and growers, might possibly be organised or promoted by a small national body, but for the more specialised products is probably more likely to be successfully achieved through the efforts of individual buying firms, perhaps in conjunction with a farming cooperative. Even so, there could usefully be a series of national studies to develop awareness generally, to determine the yield and quality of major herbs and medicinals and to examine the potential for increasing quality by breeding and selection. It will also be necessary to examine the farming system implications of planting and harvesting dates, and of the optimum balance between scale of operation of individual crops and an adequate diversity of crops to cope with fluctuating prices. The development of mechanised systems may be important, although the significance of labour-intensive cropping should not be neglected in an era of high unemployment if economic methods of labour-intensive production can be devised.

It would be unrealistic to expect rapid development of a wide range of crops in a short space of time. The process will, in any case, be much affected by the rate of any decline in the profitability of cereal production or by how rapidly such a decline is perceived by farmers to be likely. A start could be made in increasing the home share of crops already grown here, for example Parsley and Lavender, or developing the medicinal uses of existing crops, for example Lucerne for the production of alfalfa tablets. Fennel, Lemon Balsam, Valerian, Verbena, Buckwheat leaf, Camomile flowers are a few of possibly hundreds of products, where UK cultivation could be gradually introduced. Buyers may find it easier to proceed with a limited range first, to test the development process; their confidence in the feasibility of home production will be essential to its success.

A few members of ADAS currently have a considerable knowledge of herb production and marketing, and an appreciation of the possible role of medicinals in UK production. Perhaps a start could best be made through the combined promotional activities of an ADAS officer working in conjuction with an enthusiastic buyer having a knowledge of the present and potential markets at home and overseas.

GRAIN CROPS

There seems no strong case to seek alternatives to cereals unless types can be found which are adapted to difficult soil types, show better nutrient utilisation, have a greater protein content, or which meet particular culinary needs. No entirely novel species can be suggested, but four are worthy of brief mention.

Durum Wheat is primarily used for pasta products, the UK market for which is increasing at 7% per year. UK use of Durum is currently about 50 kt per year, partly imported. In 1984 about 6 kha were grown, the 1985 crop is estimated at 8 kha; total home needs can be met from some 12 kha. Views differ on the export opportunities. On the one hand it is suggested that, if quality can be maintained, some exports to the continent are feasible and a total crop of 20 kha (about 100 kt) should be sustainable. Others maintain that the increasing area grown in other EC countries will severely reduce the export opportunities. Until now, Durum wheat has commanded a price appreciably greater than Wheat and can achieve greater gross margins, but future price movements are uncertain.

Triticale (Wheat x Rye) has been around for some while but it is only recently that it has been seen to have any substantial place in UK farming; about 6 kha were grown in the UK in 1985 compared with 100 kha in France. The main use of Triticale is in feed compounding and pet food production and its main place is as a winter cereal of lighter and drier soils or after a second or third Wheat crop, to exploit its greater resistance to take-all. It presently also shows better resistance than Wheat to yellow rust, brown rust and *Septoria* and it is resistant to mildew. Gross margins are similar to those of winter wheat and may well be greater than other cereals on light soil.

Buckwheat *(Fagopyrum esculentum)* is a member of the *Polyganaceae* and was once grown as a grain crop in Britain. Its seeds produce a coarse flour for biscuits, porridge and poor bread. It can be used as a livestock feed, usually dehusked, or as a poultry food. Its particular merit is that some types can produce a yield in 100 days from sowing, and that it does well on poor, sandy and acid soils. It has also in the past been a source of a glucoside, Rutin, used to treat high blood pressure. Its disadvantages are a lack of frost resistance (so that late spring planting is necessary) weak stems, very uneven ripening, and a low yield. At the present time it does not seem to have merits as a grain crop which it would be useful to exploit in the UK.

Quinoa *(Chenopodium quinoa)* is related to Fat Hen and is an Andean grain crop. It appears well adapted to spring sowing and September harvesting in the UK; small-plot yields for different cultivars have ranged from 2 to 6 t per ha. Grain composition is similar to that of cereals but with a rather higher protein content, around 14%, and a greater proportion of lysine and arginine than in Wheat or Barley but negligible cystine. Its main use would be in animal feeds though a breakfast cereal and specialist flour market might also be developed for it. Its main value in UK rotations is that on light land it may eventually outyield conventional cereals, and that because it is genetically distinct from cereals, it is unlikely to be susceptible to the same pests and diseases.

A major problem is the presence of bitter-tasting saponins in the outer layers of the grain. Partial or complete removal can be achieved by washing, by alcohol extraction or by scarification, but the development of saponin-free genotypes also seems feasible. The absence of saponins makes the crop more susceptible to bird damage. Alternatively, extracted saponins might be usable as a bird repellent on other crops, such as Oilseed Rape, or used as a feedstock for the synthesis of pharmaceuticals and other compounds. Some of the saponins are terpenoid compounds containing 4-carbon rings which are believed to be difficult to synthesise (NW Galwey, personal communication). The literature on Quinoa, and a related crop, *C. pallidicante,* has been reviewed by Risi & Galwey (1984).

Future studies: grain crops

Durum wheat and Triticale can both fit usefully into some cereal growing systems; their potential in UK farming is determined by the size of the market they can command. similarly, the place of Buckwheat is primarily determined by whether a market can be developed for it. Therefore, the major need is for market research and promotion and, for all three crops, the opportunities may be greater abroad than at home.

If a market for Buckwheat can be developed, it will be necessary also to examine its agronomic management and perhaps to develop more determinate varieties of better structure, but work on any scale cannot be justified at the present time. Development of Triticale and Durum Wheat varieties is continuing, the main area which requires further research is the identification of suitable post-emergence herbicides for use in Durum.

GRAIN LEGUMES AND OILSEEDS

The grain legumes can be harvested as green vegetables, processed (canned or frozed) or eaten directly, or as pulses (ie harvested when the seeds are mature) and have other useful and unique characteristics. They produce seeds with large protein concentrations (typically greater than 25%) and their ability to fix and use atmospheric nitrogen means that when effectively nodulated they have little or no requirement for nitrogenous fertilizers. Furthermore, providing that the amount of nitrogen fixed by the nodules exceeds that removed by harvest then they can leave a residue of fixed nitrogen in the soil, which reduces the fertilizer requirement of the subsequent crop. Peas *(Pisum sativum)* and Faba Beans *(Vicia faba)* are the traditional and major grain legumes grown in the UK, and some expansion of these crops will be possible, using improved types which are in the pipeline. This particularly applies to Peas. However, there are other grain legume crops which could also have a significant place; some to meet a specific food requirement for the population in general or for various and large ethnic groups in particular, others to help supply the animal feed requirements of the UK and EC. Some of these crops have a greater concentration of protein in the seed than have Peas and Faba Beans. This does not necessarily mean that they will give greater yields of seed protein per unit area of land, but the characteristic could have some advantages in feeding. Both Chickpeas *(Cicer arietinum)* and Lentils *(Lens culinaris)* are temperate food legumes though they are not always recognised as such. In fact, their temperature requirements for germination are colder than for Peas and Faba Beans. Grown in the UK, Lentils mature in about the same period as Peas, and Chickpeas have a similar duration to Faba Beans. There is an increasing demand for both crops, harvested as a pulse, by ethnic communities, as health foods, and from the population in general as public awareness increases. Imports of Chickpeas into the UK cannot be separated from those of Peas, but 11 kt of Lentils were imported in 1984. Some Lentils, especially those traditional types cultivated in North Africa and the Mediterranean region, are not well adapted to mechanical harvesting, but those improved cultivars grown in Canada and the USA, for example, are combine-harvested with few problems. Chickpea seeds can be susceptible to damage in mechanical handling because of their 'rams-head' shape and prominent radicle, but cultivars differ in their relative robustness. Both crops deserve more attention.

Navy Beans *(Phaseolus vulgaris)* require only brief mention here. They have been the subject of considerable study nationally in order to develop types suitable for UK conditions and which will satisfy the needs of UK processors. About 120 kt were imported in 1984 so there is considerable scope for import-saving, but reliable UK varieties are not yet available.

Interest in Lupins *(Lupinus* spp) has been stimulated in recent years and they are currently receiving some attention from commercial breeders in the UK. The limited area grown to date is mostly of the White Lupin *(Lupinus albus)*, a crop which has considerable disadvantages in the UK climate. It has a vernalisation requirement which makes flowering date and growth habit unpredictable, and maturity is delayed by 25 days compared with spring-sown Faba Beans because of delayed seed growth and maturation of fleshy pods. By contrast, the Pearl Lupin *(Lupinus mutabilis)* is in most respects much better adapted; it does not have a vernalisation requirement and so development is more predictable, seeds grow more rapidly and thinner pods mature earlier. Sweet (alkaloid-free) varieties are available for both species. The protein concentration of Pearl Lupin seeds is 34–40%, slightly greater than the White Lupin and considerably better than in Peas or Faba Beans. However, the Pearl Lupin, or Tarwi as it is also known, has until now been a third-world smallholder crop and the structure and growth habit needed for exploitation as a mechanised farm crop have not yet been fully developed. This process is comparable to the development of Field Peas from traditional, taller garden types and should prove no more difficult to achieve.

Oilseeds

An important attribute of Pearl Lupin seeds is their oil concentration; values of 18% are typical, similar to that in Soyabeans. The oil is of good edible quality, so that the crop has considerable potential as a combined protein and oil producer, better adapted to the UK than Soyabeans and without the glucosinolate problems and nitrogenous fertilizer requirements of oilseed rape. It can also be noted that genetic manipulation during the next 10–15 years may allow the production of an oil-rich Pea which could itself replace Soya.

There are other oilseed crops which may also be adaptable to UK conditions. Sunflower *(Helianthus annus)* has been under study for some years in Europe and the success in developing cold tolerance and earlier ripening has resulted in its gradual progress northwards through France. Further improvements in earliness may be possible, though probably more slowly than those achieved to date. The most promising variety at present is a North American hybrid, Interstate 7000. If UK production can be developed, the British climate would confer the advantages of less risk of mid-season drought and a better concentration of unsaturated fatty acids induced by the slower ripening in our cooler climate. A spring-sown crop will divert some work away from the autumn peak. UK demand for Sunflower is about 100 kt per year (perhaps 50 kha) and though lower yielding than oilseed rape, the seed fetches a substantially greater price. Control of seed-head infection by *Botrytis cinerea* is likely to continue to be a problem; there appears to be very limited prospect of improving resistance genetically.

Another possible oilseed crop is *Brassica carinata* (Texel Greens). This has a large erucic acid concentration and probably has no special advantages over Oilseed Rape. It does, however, merit consideration as a salad and vegetable crop and is considered again under Horticulture. Crambe *(Crambe Abyssinica)* is another Crucifer which produces a high erucic oil and is adaptable to at least the warmer UK climates. It does not appear to have any major advantages over Rape Oil.

The Poppy *(Papaver somniferum)* is notoriously sensitive to establishment conditions, but can be grown in the UK. Whilst it is probably better adapted to warmer climates, seeds have ripened as far north as latitude 69°N in Norway. This crop is grown for its edible oil and also for morphine production, one of several alkaloids contained in the latex which is normally tapped from the wall of the seed capsule.

The Linseed crop *(Linum usitatissimum)* was formerly grown in Britain and has enjoyed some recent revival, reaching 1 kha in 1984 (Richards, 1984) and about 4 kha in 1985. Its seeds contain 38–40% oil, the residue providing a protein-rich livestock feed. The oil is used for specialised industrial purposes, mainly paints and varnishes. In 1984, some 60 kt of Linseed were crushed in the UK and a further 10 kt of oil were imported. Oil from the home-grown crop would have been equivalent to only about 10–15% of that imported, so there appears to be considerable scope for an increase in domestic production.

Grain legumes and oilseeds: future studies

Chickpeas, Lentils, Pearl Lupin and Linseed are the main crops in this group having potential for UK production, with Sunflower and Navy Bean as longer term prospects if adequate cold tolerance can be developed. UK consumption of chickpeas, lentils and linseed suggests that they could occupy at least 60 kha of arable land in the UK. The potential for Sunflower and Navy Beans is probably for a further similar area. The EC is only about 20–30% self-sufficient for both feed protein and edible oil so there is some potential for additional production in both categories which the Pearl Lupin could provide.

The development of Chickpeas and Lentils is dependent on the identification of the most suitable cultivars for UK use and the development of appropriate systems of management. This will require a series of agronomic trials which can also determine suitable areas of production in the UK. There may not be any need for a breeding programme because a wide diversity of types is already available and is accessible through ICARDA, the international institute in Syria. At the same time, importers and large-scale users should be approached to determine their quality requirements and to encourage them to consider taking UK production.

A continuing increase in the area devoted to Linseed is likely to occur without specific promotion, perhaps to as much as 40 kha, and no development work other than variety trials is suggested at this stage.

The introduction of Pearl Lupin is dependent on a programme to breed types with suitable growth habit. This could be undertaken by either commercial plant breeders or a plant breeding institute. The latter may be necessary if commercial plant breeders are unconvinced of whether crushers will accept Pearl Lupin. It has been suggested that they may be disinclined to make provision for a seed which has only half the oil content of rape-seed, even though it is similar in many respects to soya bean.

ROOT AND TUBER CROPS

There are no very obvious competitors for the commonly grown root crops, but a number of local plants have been used to some extent in the past and have useful attributes. Most of them would require breeding work to allow selection of types with root or tuber better developed.

Jerusalem Artichoke *(Helianthus tuberosus)* is a tuber crop which produces a not very popular vegetable. Its particular merit is a capacity to accumulate very large yields, a result of its perennial habit, long growing season and the high photosynthetic rate of the individual leaves. Together with the Dahlia *(Dahlia pinnata)* and some other plants, Jerusalem Artichoke tubers are a source of the polysaccharide inulin from which fructose can be prepared. Apart from this and its minor use as a vegetable, Jerusalem Artichoke is possibly of most interest as a biomass producer.

Salsify *(Tragopogon porrifolius)* is related to the common Goat's Beard *(T. pratensis)* but has blue flowers. It is a plant of damp lowlands and produces succulent roots which were commonly prepared by boiling and have a characteristic flavour which earned it the name 'vegetable oyster'; Meadow-sweet *(Spiraea ulmaria)*, a plant of heavier soils, and Dropwort *(S. filipendula)* found in chalk grassland both yield roots which once were roasted for food. The Tiger-nut *(Cyperus esculentus)* used to be grown in Europe and is presently cultivated in China. The small tubers have been used as a source of flour. They contain 22% starch, 15–20% sugar, and also 20–30% oil which can be expressed and used in cooking.

Other species which have been used to yield roots or tubers are *Althea officinalis, Campanula rapunculus, Lathyrus montanus* (a legume), *Potentilla anserina, Eryngium maritinum, Conopodium majus, Orchis mascula* and *Arum maculatum.*

There are many other plants with swollen roots, indigenous to other parts of the temperate world, which have been used for food and which could be grown in the UK. It is very likely that some have a sufficiently distinctive and attractive flavour that a market could be developed for them, if the investment in identifying, testing and promoting them were considered worthwhile.

Three Andean tuber crops are currently being examined in this country (N W Galwey, personal communication). They are Ulluco *(Ulluco tubersum)*, Oca *(Oxalis tuberosa)* and Mashun *(Tropaeolum tuberosum).* They illustrate one of the difficulties in introducing plants from the tropical and sub-tropical highlands. Temperature conditions in the UK may be suitable for them but, if there is any photoperiodic (day length) control of plant development, the long days of a temperate summer may be inappropriate. Flowering is the most common feature of plant development which may be photoperiodically controlled, but tuberization is another, and the three crops under study do not tuberize in UK conditions, nor has sufficient genetic variability in their response to photoperiod yet been identified to suggest that adapted types might be found. The potato originated from the same region and suffered similar problems when first introduced into Europe in about 1570. Tubers were produced only in the short days of late autumn, but presumably sufficient variation existed for the crop to become genetically adapted.

The most likely development of roots crops on any scale is as sugar, starch or biomass producers for industrial uses. The existing root crops are the ones most likely to be used for this purpose, perhaps also including Jerusalem Artichoke, because of its high yield. Chicory *(Cichorium intybus)* is also a large biomass producer and could probably be harvested with sugar beet equipment.

HORTICULTURE

It is often difficult to know where the dividing line between agriculture and horticulture lies. It is a boundary which farmers should increasingly ignore but a number of topics can usefully be grouped together under this heading.

Horticultural imports

The importation of many fresh vegetables has increased in recent years (Table 2.4). In 1983, the total value of these imports was £42 million. Of course, some of the imports relate to seasonal needs which UK production cannot meet. Others may be *loss-leaders* with which we cannot compete. However some others are probably due to the difficulties that big buyers encounter in seeking large quantities of reliable, good quality, home-grown supplies. It is recognised that continental producers are well-organised and provide first-class competition for the available market; perhaps UK marketing does not always achieve the same standard.

Table 2.4
Imports of fresh vegetables into the UK (kt)

	1975	1979	1982	1983
Cauliflower, fresh or chilled	24.7	19.1	49.2	100.3
Lettuce and Endive	6.8	9.0	17.6	20.6
Carrots and Turnips	24.2	34.9	74.9	34.7
Celery	13.6	12.6	21.3	18.2

Source: Adapted from MAFF (1984).

There is also a large importation of ornamental pot plants and container plants into the UK, for example pot Azaleas for the Christmas trade from Belgium. In 1984 the UK imported pot plants worth £30 million from other European countries, particularly the Netherlands, and the estimate for 1985 is £35 million. These imports satisfy about 40% of domestic demand.

Some costings have been compiled by ADAS (1983) for UK grown chrysanthemums, the most important pot plant in volume. The highest gross margins of £148 000 per ha (labour excluded) were obtained with 4.5 crops per year and a yield of 53 000 pots per ha per year. Less intensive systems grow plants during the natural season only and give gross margins of £10 000–£40 000 per ha. Turner (1985) estimated capital costs in the order of £600 000 per ha for intensive systems and a need for about 25 staff per ha.

It is technically possible to grow all our pot plant requirements in the UK. However, Dutch producers are highly efficient and have a well-developed marketing system which is geared to supply export markets. They used to benefit from subsidised gas for glasshouse heating, but these subsidies have now been removed. However, it now appears that thermal screens are subsidised by the Dutch government and this issue has become highly controversial within the EC. The Dutch industry also has access to long-term loans at low and fixed interest rates, so that borrowing to develop a pot plant enterprise does not carry uncertainty about the burden of future interest payments. There is also likely to be an increase in competition from plastic tunnel production of ornamentals in Southern Europe.

The high organic matter soils in the high rainfall areas of the UK can be very suitable for soft fruit production. Fruits such as Cranberry *(Vaccinium oxycoccus),* Blueberry *(V. corymbosum* and *V. angustifolium),* and Cloudberry *(Rubus chamaemorus)* as well as various Raspberry and Blackberry crosses could be produced to supply a created market, or to substitute for imported jams and processed fruit. Other bush fruits, which are of interest to the Scottish Crop Research Institute and which are being studied in Scandinavia, are used for juice production and include *Rosa* and *Hippophae* spp. For example *H. rhamnoides* (Sea-buckthorn) has a yellow-fruited hybrid with a high vitamin and carotenoid content in a juice of attractive aroma. *Aronia macrocarpa* (Chokeberry) has an anthocyanin content in the juice which can be used as a natural colourant for other fruit juices and health preparations. The berries of *Lonicera* and *Viburnum* spp may have a similar use.

Export opportunities

Problems of import competition prompt an examination of the potential for exports of UK vegetables. The main climatic advantage of the UK, compared with continental conditions, is the open winter conditions that we normally experience. By market promotion it may be feasible to develop exports of winter Brassicas and of Parsnips; both are crops which do well in the UK and whose management is well understood. At present, exports of Brussels Sprouts amount only to 500–600 t per year, about 0.2–0.4% of total production.

The main reason for this limited export activity appears to be the traditional nature of the British horticultural industry which is not used to meeting the quality and price specifications of the export market. Younger growers, however, are conscious that they have to operate in an open market and traditional attitudes are gradually changing.

There have been several attempts to export brassicas to the Continent, but often those pioneers have had to contend with considerable difficulties with agents and wholesalers, and feel that the returns do not justify the effort expended. However, whilst some effort has been made to stimulate demand for British vegetables on the Continent, through the 'Food from Britain' organisation, without a sustained marketing campaign it is only to be expected that exporters will confront resistance.

A further factor that complicates the export of vegetables is the lack of any central marketing agency for horticultural produce. Vegetable growers do not benefit from an equivalent of the Milk Marketing Board, and it is left to a few large horticultural concerns to make the first steps towards the continental markets. It is possible that even these large concerns are not large enough to carry the risks involved.

Novel vegetable crops

A crop which may be appropriate for development in the UK is Texel Greens *(Brassica carinata)*. It produces large leaves which can be used as a salad vegetable or as spinach. It has an adequate, but not lengthy, shelf life and can also be canned or frozen. Its particular merit is that it can produce a yield quickly and at relatively low temperatures. Sown initially into a cold frame in February, and then planted in the field, it can produce a crop in May. Cultivation in polythene tunnels will allow several cuttings in autumn and spring. It could therefore find a useful niche in the supply of vegetables, but as with so many products the demand must be found, or developed, to justify production.

Guenault (1985) mentions Swiss work on Winter Purslane or Miner's Lettuce *(Claytonia perfoliata)*, a North American annual used as a salad or spinach crop. He reports that it can be grown under glass without additional heat. Other possible salad plants include Corn Salad or Lamb's Lettuce *(Valerinnella locusta)*, Japanese Parsley *(Cryptotaenia japonica)* and Iceplant *(Mesembryanthemum crystalinum)*. Production of Watercress *(Nasturtium officinale)* is limited by the need for running water. Research may be able to develop a land cress which would have potential for wider cultivation.

Cold tolerance

A crop which has been increasing its sales is Chinese Cabbage. Its potential market would be increased if types better adapted to UK conditions could be produced, particularly greater cold tolerance to reduce the risk of bolting in the spring and perhaps also to increase its ability to stand in the field in early winter. These aims are likely to be achievable.

Improved cold tolerance is also desirable for Green Beans *(Phaseolus vulgaris)* to develop earlier production. Any improvement obtained will be transferable to the Navy Bean, referred to previously.

Considerable improvements have been made in breeding cold tolerance into some crops. For example, Tomato varieties are now available from eastern Europe in which the threshold temperature for flowering and fruit set is as low as 7°C compared with 11-13°C in earlier types, and temperature requirements for other stages of growth are similarly lower. There is now the potential for field production of Tomatoes, particularly if plastic film is used to allow early planting. They may be suitable for a PYO (pick-your-own) trade, but the possibility of production for processing is limited because of competition from Italian crops. Calabrian growers benefit from EC regional aid so that tinned Tomatoes can reach the UK at prices which severely undercut what could be achieved here.

The use of plastic film is allowing earlier production of many field crops, including Carrots, Early Potatoes, Sweet Corn, Lettuce, Runner Beans and even Melons. The area in England probably exceeded 3 kha in 1985. It is said to be a more common practice in eastern counties, and an extension of its use to milder areas, which is already occurring, will improve our ability to compete with warmer parts of the EC. The use of plastic tunnels can give greater benefits and may allow an increase in the production of more exotic vegetables, though experience to date has not been entirely successful.

Production of seed

Seed production of many flower and vegetable crops is done overseas in more favourable climatic conditions. However, for some at least, it is also because hybrids are being produced and the labour required for emasculation by hand can be obtained more cheaply in other countries. Breeders are finding it increasingly possible to produce male sterility genetically, and chemical sterilisation is also becoming feasible. Both developments can avoid the need for hand emasculation and might allow appropriate species to be grown for seed in the UK.

The problem of climatic suitability in the UK can be overcome for some species by the use of polythene tunnels. This is already done for breeders seed, but might be extended to commercial production for a few crops. Large yields, high quality and high percentage germination are possible, offsetting to some extent the greater costs of production.

Other enterprises

In vegetatively propagated crops an important feature is the need to ensure that new plants are free from disease. This can be done more easily if the propagation industry is sited in an area away from the main centres of normal production. It might be considered whether the UK could be a propagating centre for crops grown elsewhere; vine propagation for the European vineyards has been quoted as an example.

Alternatively, wine production could be expanded; although wine is over-produced in the EC, specialised or quality wines are in increasing demand. There were 431 ha of vines in England and Wales in 1984, an increase of 120% over the area present in 1975.

The garden rose bush industry is very substantial, some millions of rooting stocks are imported each year for grafting, but could equally well be grown in this country. This could be a simple and attractive development but it may be overtaken within a few years by 'tip' culture, propagation from the meristem and first two leaf primordia of buds. Tip culture will avoid the need for grafting and eliminates the requirement for root stocks, but it may prove to be too expensive for the normal run of commercial production.

Horticultural crops: future studies

Two key factors emerge from this brief survey: the development of cold tolerance, and the need for market research and promotion.

Progress in developing cold tolerance has been slow in the past, and in many of the species of current interest it may have reached close to the limit of existing techniques. However, new methods may become available in the next 10–15 years and are discussed in the final section of this chapter.

The importance of marketing skills is apparent at many points in this report, but perhaps particularly for the horticultural crops. A major opportunity lies in seeking and developing export markets, for crops like Brassicas that we grow well, but it is less clear how this can most easily be achieved. Perhaps a group of growers, wholesalers and ADAS should examine ways of developing export activity, making use of a professional market promotion company or Food from Britain. Initial development work will be appreciable but will probably be small compared with the cost of biological research and would be a legitimate and worthwhile charge on public funds. The same group might also consider the challenge of overseas competition for large-scale home markets of crops that are well-adapted to the UK.

Another marketing activity is the development and promotion of novel salad, vegetable and soft fruit crops. Because of the greater diversity of races now in the UK, and because of the increasing preoccupation with a 'healthy diet', the community is probably more receptive than previously to the development of new foods of this type. It will not be a rapid process, but it need not be expensive, and if the UK does not make use of the opportunity, overseas growers will. The activity is rather different from the market promotion of export crops and import savers, because it will involve both test growing and consumer studies of relatively untried material. The crop introductions unit referred to in the final section of this chapter may be a suitable starting point.

CROPS FOR ANIMAL FEED

Compared to grass and the cereal grains Barley and Wheat, the major sources of feed for ruminants and non-ruminants respectively, alternative crops for animal feed often play a tactical rather than a strategic role in agricultural land use. Hence the catch crops Peas, Kale, Stubble Turnips and Rape, are commonly used to generate useful feed at a time when the land would be unproductive following the ploughing out of grass or the failure of a cereal crop.

There are situations in which alternative crops are produced strategically for animal feed, notably in areas where livestock are present on arable farms. There are also instances on all-grass farms where an area of land is either permanently devoted to alternative crops such as Rye, Maize, Swedes, Fodder Beet or leafy Brassica crops, or where leys are systematically sown in rotation and a forage crop is grown as an entry to the new ley.

Alternative feed grains

There is increased interest in alternative crops which are of high protein content and which can replace imported Soyabean meal in the diet.

Support from the EC for such crops has led to an expansion in the production of Rape, and also the various grain legumes mentioned previously.

Recent reports that *Agrobacterium tumefaciens* may be a suitable vector for the transfer of genes in monocotyledonous species in addition to dictyledonous plants, opens up the possibility of rapid improvement in the nutritional composition of cereal grain crops which are commonly used as animal feeds. Specifically, the identification of the major limiting amino acids for lean tissue growth and for milk production, coupled with the identification, transfer and expression of genes for their production will enable plant breeders to produce improved cultivars which ultimately may be balanced feeds in themselves. This will reduce demand for protein-rich feeds.

In the shorter term, however, home-produced protein-rich crops will continue to replace imported protein until EC support is reduced. In this context there is need to develop higher-yielding varieties of Rape which are low in both erucic acid and glucosinolates.

Incidentally, as production increases to the point at which demand for vegetable oil is fully supplied, the whole seed will be used in animal feeds, rather than the residues from oil extraction, since the content of metabolisable energy (ME) is high in addition to that of protein. Thus in least-cost ration formulations Rape seed will replace cereal grains of lower energy and substantially lower protein content.

Alternative forage feeds

Cereal grains contain relatively low contents of protein relative to energy; thus grass, with its relatively high content of rumen degradable protein (particularly in silage), is a suitable complementary feed.

There may be opportunities to add value to cereal crops, and at the same time avoid the need to burn, bale or incorporate straw, by harvesting and ensiling the whole crop. Yields of ME per ha are likely to be comparable to that from grass in areas of relatively low summer rainfall, and the crop is only harvested once a year.

There is increased interest in Fodder Beet as a high-energy forage feed. Yields of ME per ha are substantially higher than those of other forages and in favourable areas may be more than 50% higher than those of grass.

Selection of forage Maize varieties for earlier maturity is now coming to fruition, with the introduction each year in the UK of new high-yielding cultivars which can also be harvested at 30% dry matter in September.

Forage legumes offer both opportunities and problems as alternative crops. They are sources of relatively low-cost protein in the diet of ruminants and are complementary to the high-energy forages discussed previously. They have high intake characteristics compared to grasses. The deep-rooting legumes such as Lucerne reduce the need for subsoiling. Residual nitrogen from the legume can reduce the need for fertiliser–N in the subsequent crop. Grass/White Clover swards may form a useful part of the cropping strategy on all-grass farms where particularly suitable fields may be designated for clover production and managed accordingly.

Research into somatic cell fusion and gene transfer may produce improved cultivars which combine agronomic with nutritional advantages. Thus hybrids are being sought between Sainfoin (low yield but no bloat) and Lucerne (higher yield but bloatagenic).

There may be opportunities for inter-cropping alternative crops to reduce costs of production and improve either yield or feed value or both. Thus Forage Peas are often sown with Barley as a catch crop in spring. The presence of Barley reduces lodging in the Peas and increases total crop yield, though the concentration of both ME and protein in the mixture is reduced. The Pea/Barley mixture may itself be undersown to Ryegrass or Lucerne so that the forage acts as a nurse crop for the next perennial crop.

Red Clover may be sown with Italian Ryegrass to increase the protein content of the mixture. Rye may also be sown with Italian Ryegrass to provide even earlier spring growth.

Ideally, crop combinations should seek to maximise yield and redress nutrient imbalances. For example, if Runner Beans were to be grown with Forage Maize, both total yield and the protein content of the mixture may be increased. Research into such novel crop combinations may be worth encouragement.

FUEL CROPS

Fuel crops, in this context, are field crops grown specifically for use as fuel, either directly or *via* one of a number of biomass conversion processes. The practice of fuel cropping could also include the use of residues of existing crops and areas of unexploited herbaceous natural vegetation for similar purposes, and the growing of multi-purpose crops of which fuel is one of a number of components.

Fuel cropping needs to be seen in the wider context of biofuel production and utilization as the future adoption of fuel crops depends very strongly on the development of biofuels as a whole. On-the-farm biofuel production also includes the anaerobic digestion of animal wastes to generate biogas and various types of energy forestry; the latter are considered in Chapter 4.

Technical considerations

Biofuels and conversion processes

Dry crop materials, such as cereal straw, provide a solid fuel suitable for direct combustion or conversion to various fuels *via* gasification, pyrolysis, direct liquefaction, strong hydrolysis and yeast fermentation or bacterial fermentation (see Chapter 4). A combined drying and burning process could also be used to provide low-grade heat from 'wet' green crop materials; such a system has been developed for animal wastes by Have (1982, 1984) who estimated its overall thermal efficiency to be 60 – 65%.

Low-grade heat could also be produced from green crop materials *via* aerobic decomposition. Thermal efficiencies for animal wastes range from 15–35% (Schuchardt, 1983); higher efficiencies may be attainable using plant substrates, but the process is likely to be very limited in application.

'Wet' crop materials provide a suitable feedstock for anaerobic digestion to produce biogas, although the process has largely been developed as a treatment for livestock or human wastes. Efficiencies depend on the feedstock, the type of anaerobic digestion process, retention time and the digester temperature; efficiencies of 40 – 60% may be obtained (Lawson *et al*, 1984). Anaerobic digestion would seem to be most suited to farm-scale operation as transport of the low energy density feedstocks is unlikely to be economic.

Conventional mechanical and solvent extraction processes may be used to extract vegetable oils from oilseed crops for use as fuels. On-farm mechanical expellers could be used to produce oil, but their extraction efficiency is substantially lower than industrial plants. The energy efficiency of extraction is high (c 90%) (Tragarth, 1983). Vegetable oils can be used in diesel engines, but the use of additives or chemical treatment may be necessary to achieve satisfactory combustion in unmodified engines.

Ethanol is most efficiently produced from fermentation of crops with a high sugar content. Starchy crops, such as cereals and potatoes, may be fermented after mild hydrolysis, while strong hydrolysis, using acid or enzymes, is necessary to create a fermentable feedstock from cellulosic biomass. Energy-intensive distillation of the dilute 'beer' produced by fermentation is then needed. Farm-scale ethanol production plants have been developed in the US, but these are usually less efficient than large-scale plants, which can use more sophisticated techniques and achieve more efficient use of process energy.

An alternative to yeast fermentation for the fermentation of cellulosic feedstocks may lie in the use of bacteria, such as certain strains of *Clostridium thermocellum,* which are capable of directly converting cellulose to ethanol; however, at present the process is at a very early stage of development.

The current status of the various biomass conversion technologies is indicated in Table 2.5.

Table 2.5

Biomass conversion technologies for UK feedstocks

Product	Process	Feedstock quality	Typical feedstock	Status*
Heat	direct combustion	dry	wood	1
	aerobic decomposition	moist	wood chips	2
Gaseous fuels†	anaerobic digestion	wet	green crop	2
	gasification	dry	wood	2
Liquid	pyrolysis	dry	wood	2
	direct liquefaction	wet	wood	3
	oil extraction	high oil content	Oilseed Rape	2
	fermentation	high sugar content	Sugar Beet	2
	fermentation + hydrolysis	starchy	Potatoes/ grain	2
	fermentation + strong hydrolysis	cellulosic	wood	3
	cellulosic fermentation	cellulosic	wood	3

Source: Adapted from Jones (1984).

* 1=proven technology, economically viable.
2=proven technolcgy, not economically viable in the UK.
3=experimental technology.

† May be converted to liquid fuels.

Fuel-crop species and productivities

Some potential non-woody, plant-based, feedstock resources for the above processes are listed in Table 2.6. These include crop residues, natural vegetation (Callaghan *et al,* 1984) and purpose-grown fuel crops. Examples of multi-purpose crops include oilseed rape, producing fuel (oil and straw) and animal feed, sugar beet and Jerusalem artichoke (Carruthers & Jones, 1983). The choice of species for growing as a fuel crop will depend on the quality and duration of availability of the land and on the fuel required. The duration of land availability will determine whether a catch crop (Carruthers, 1985), annual or perennial can be grown. Where land is available for a long-term commitment to fuel production then trees will also be considered. In addition to conventional agricultural crops a number of high-yielding, naturalized, exotic species have been identified by Callaghan *et al* (1984) as possible fuel crops; examples of some of these appear in Table 2.6.

Some indication of the annual productivity of various fuel crops appears in Table 2.7. These data should, however, be treated with some caution. The figures quoted are estimates from experiments, results of trials or averages from a number of sources, and thus may not be an accurate guide to the sustainable yields which may be obtained under practical management systems.

Table 2.6
Possible non-woody, plant-based feedstocks for biofuel production in the UK

Process	Feedstock resource
Direct combustion	Dry crop residues (eg cereal, rape, pea and bean straw)
Gasification, Pyrolysis	Natural vegetation (eg bracken, heather)
Anaerobic digestion	Wet crop residues (eg sugar beet tops, potato haulm)
Aerobic decomposition	Natural vegetation (eg bracken, cord grass)
	Catch crops (eg fodder radish, mustard. rape, stubble turnip)
	Annuals (fodder beet, forage rye, Policeman's helmet, red clover, sugar beet)
	Perennials (giant hogweed, Japanese knotweed, lucerne, ryegrass)
Oil extraction	Oil seed crops (eg castor oil plant, oilseed rape, poppy, sunflower)
Fermentation	Sugar crops (eg sugar beet)
	Starch crops (eg potatoes, cereals)
	Inulin crops (eg Jerusalem artichokes)
	Cellulosic crops (examples as for anaerobic digestion)

Source: Adapted from Carruthers (1985)

Table 2.7

Annual production of various fuel crops in the UK.

Crop	Fuel	Yield		Source
		t DM per ha	GJ per ha	
Agricultural crops				
Sunflower	Biogas[1]	18.5	180	a
Italian ryegrass	Biogas[1]	16.9	165	a
Perennial rygrass	Biogas[1]	14.6	142	a
Rye (green)	Biogas[1]	13.5	270	a
Rye (grain)	Ethanol[2]	2.5	16	a,c
Meadow fescue	Biogas[1]	13.3	130	a
Sorghum (green)	Biogas[1]	13.0	127	a
Cocksfoot	Biogas[1]	12.2	119	a
Timothy	Biogas[1]	12.1	118	a
Oats (green)	Biogas[1]	12.4	121	a
Wheat (green)	Biogas[1]	12.1	118	a
Winter wheat (grain)	Ethanol[2]	5.1	32	a,c
Spring wheat (grain)	Ethanol[2]	3.9	25	a,c
Barley (green)	Biogas[1]	10.1	98	a
Winter barley (grain)	Ethanol[2]	4.0	25	a,c
Spring barley (grain)	Ethanol[2]	4.2	26	a,c
Maize (green)	Biogas[1]	11.7	114	a
Kale	Biogas[1]	7.3	71	a
Comfrey	Biogas[1]	7.1	69	a
Fodder radish	Biogas[1]	5.2	51	a
Rape	Biogas[1]	4.7	46	a
Lucerne	Biogas[1]	14.7	143	a
Red clover	Biogas[1]	13.7	134	a
Lupins	Biogas[1]	13.0	127	a
Sainfoin	Biogas[1]	10.7	104	a
Fenugreek	Biogas[1]	9.0	88	a
Fodder beet (total)	Biogas[1]	15.4	150	a
Sugar beet (total)	Biogas[1]	15.7	153	a
Sugar beet (roots)	Ethonal[3]	9.9	86	a,c
Potatoes (roots)	Ethanol[4]	10.7	54	a
Jerusalem artichoke	Biogas[1]	14.7	143	a
Oilseed rape	Oil[5]	0.9	35	a
Naturalized species				
Japanese knotweed[1]	Biogas[1]	9.80–37.50	96–366	d
Japanese knotweed[3]	Biogas[1]	0.23–2.59	2–25	d
Giant knotweed[3]	Biogas[1]	1.28–5.41	12–53	d
Policeman's helmet[1]	Biogas[1]	11.4	111	b

Sources: (a) Spedding *et al* (1979b), (b) Callaghan *et al* (1981), (c) Rothman *et al* (1983), (d) Callaghan *et al* (1984)

Notes:

[1] Assuming 9.75 GJ per t DM.
[2] Assuming 6.3 GJ per t DM.
[3] Assuming 8.7 GJ per t DM.
[4] Assuming 5.0 GJ per t DM.
[5] Assuming 39 GJ per t oil.

The economics of biofuel production

At present, the cost of biofuels is generally greater than conventional fuels, as Table 2.8 shows. Thus the production of biofuels is unlikely to be profitable unless particular local conditions make fuel prices higher than normal, or subsidies are available. In addition, in the UK where

Table 2.8

Estimates of costs of biofuels relative to conventional fuels.

Fuel	Feedstock	Country	Date	Conventional fuel	Relative price of biofuel
Biogas	crop	New Zealand	1979	petrol	1.29–1.48
Biogas	bracken	UK	1981	propane	2.00
Biogas	catch crop	UK	1981	propane	0.92
Biogas	pig waste	UK	1981	propane	0.75
Biogas	green crops	West Germany	1982	oil	1.5–3.8
Electricity	biogas	West Germany	1980	electricity	1.7
Electricity	biogas	US	1982	electricity	0.33–1.12
Ethanol	sugar beet	New Zealand	1977	petrol	1.3–1.6
Ethanol	wheat	Australia	1979	petrol	2.03–3.33
Ethanol	sugar beet	Australia	1979	petrol	1.41–2.70
Ethanol	wheat	Australia	1979	petrol	2.20
Ethanol	beet	New Zealand	1979	petrol	1.48–2.24
Ethanol	maize	New Zealand	1979	petrol	1.71–2.52
Ethanol	wood	New Zealand	1979	petrol	1.71–2.29
Ethanol	na	Sweden	1980	petrol	2.5
Ethanol	maize	US	1980	petrol	0.84–1.12
Ethanol	maize	US	1980	petrol	2–5
Ethanol	beet	Australia	1981	petrol	1.63–1.97
Ethanol	wheat	Australia	1981	petrol	1.97–2.07
Ethanol	na	West Germany	1981	petrol	1.79
Methanol	wood	New Zealand	1979	petrol	0.95–1.67
Methanol	bracken	UK	1981	fuel oil	1.63
Vegetable oil	oilseed rape	West Germany	1979	diesel	1.8–2.4
Vegetable oil	na	Sweden	1980	diesel	1.7
Vegetable oil	oilseed rape	Australia	1981	diesel	1.21–2.73
Vegetable oil	sunflower	Australia	1981	diesel	1.80–2.58
Vegetable oil	soya bean	West Germany	1982	diesel	1.8
Bracken	N/A	UK	1981	fuel oil	0.44
Crop residues	N/A	US	1980	coal	1.11–1.36
Straw	N/A	Sweden	1980	oil	0.53–1.00
Straw	N/A	UK	1981	fuel oil	0.31
Straw	N/A	France	1982	oil	0.21–0.51
Straw	N/A	UK	1982	oil	0.51
Willow	N/A	UK	1982	oil	0.13
Willow	N/A	UK	1982	coal	0.21
Willow	N/A	France	1982	oil	0.16–0.32

Source: Reproduced from Carruthers & Jones (1983).

crop prices are higher than in some of the countries shown, the cost of biofuels is likely to be even greater.

The probability of biofuel production is a function of three factors: feedstock production costs; feedstock conversion costs; and the value of the fuel produced. Feedstock production costs for biofuel production systems which are based on existing crop species are unlikely to fall substantially unless higher-yielding production systems are developed, or their use as biofuel feedstocks permits changes to a management system which reduces costs. For example, a reduction in herbicide spray costs may be possible if maximum biomass yield is the objective rather than economic yield. With new crop species grown for fuel there may be expected to be some reduction in costs of production as improved production systems are developed.

Reduction in conversion costs, as a result of development and commercialisation of currently experimental technologies, offers some potential for improving biofuel production economics. However, as feedstock costs form a major proportion of total costs of most biofuel production systems (Hall, 1982), the impact of reductions in conversion costs may be limited.

After the substantial fuel price rises of the 1970s, world oil prices have been falling in real terms in recent years. Further real price increases in conventional fuel prices cannot be ruled out though, and would improve the profitability of biofuel production systems, as their output value would increase more rapidly than their input costs. However, there may be other alternative sources of fuels, such as methanol and methane from coal, which may be cheaper than biofuel and thus may restrain fuel prices to levels below those at which biofuels are competitive.

At the farm level, the decision as to whether to introduce biofuel production systems will depend primarily on the relative profitability of fuel cropping and existing cropping systems. This will be true whether the biofuel feedstock is to be produced for on- or off-farm conversion. Biofuel production systems will have to compete with other enterprises for the land, labour and capital resources of the farm. Only where the opportunity cost of these resources is low, therefore, would biofuel production systems seem likely to be competitive at present.

The Department of Energy's *Land Availability Study* for wood energy plantations (Price & Mitchell, 1985) identified large areas of upland Britain where wood energy plantations would be more profitable than existing extensive livestock systems. In other areas of the country, however, wood energy plantations were always less profitable than existing cropping systems.

In modelling studies Jones (1984) also found that only where biofuel production systems were not in direct competition with cropping systems were they likely to be adopted. For example, catch crop fuel production, though profitable, was unable to compete with cereal production for labour or land. Wood energy plantations in the uplands were the only competitive fuel cropping systems, though it was apparent that capital availability would be an important constraint on their development.

Impact of biofuel production on the farm scale
The use of conventional food crops as feedstocks for off-farm processing should not require any substantial modification of existing farming practices, unless existing techniques aimed at ensuring product quality were relaxed to achieve greater biomass yields. For a new fuel crop for off-farm processing, the problems of adoption should not be any different from those of any new food crop. Where a biofuel crop with on-farm conversion is to be adopted, however, a number of other factors need to be considered.

Jones (1984) found that the viability of on-farm conversion was substantially affected by the on-farm energy demand. For example, a high demand for heat, which can be met relatively efficiently from biofuels at the farm scale, is likely to be more attractive than a high demand for liquid fuels. The seasonal pattern of energy demand on a farm will also be important as it will determine the need for feedstock storage and the matching of biofuel supply to energy demand.

On modern UK farms with intensive production systems a high premium is also likely to be placed on the reliability of fuel supplies. The problems of new technologies, when recently introduced would seem likely to deter farmers from adopting biofuel production systems where their unreliability might adversely affect other enterprises.

Other factors which would seem likely to affect the adoption of biofuel production systems on a farm, include the ease with which the biofuel production system can be integrated into the farm system, and the attitudes of farmers. This may benefit the adoption of biofuel production systems if farmers are keen to achieve a degree of energy self-sufficiency, but may discourage the adoption of tree-based biofuel production systems if farmers are opposed to afforestation.

National impact of fuel crops
As Carruthers & Jones (1983) indicated, the limited feedstock resource for production of biofuels in the UK means that they are unlikely to make a major contribution to UK fuel supplies at the national scale, though they may be locally important in some regions. The major source

of biofuel feedstocks is likely to be urban and agricultural residues and wastes which have low production costs. Fuel crops which must cover their full production costs and compete with conventional food crops for farm resources are likely to be restricted to locations where the opportunity cost of these resources is low.

The most attractive fuel crops at present, therefore, appear to be tree species planted on low quality land. These could be used for direct combustion or gasification to methanol or methane depending on the demand for particular fuels. Management of farm woodland and natural vegetation, such as bracken, may also be attractive if there is no competition for the land (Jones, 1984). Wood energy plantations and the management of farm woodland are discussed in more detail in Chapter 4.

More information on the appropriate management systems, for use of the annual and perennial species shown in Table 2.7 as fuel crops, is required before their potential can be satisfactorily assessed. Their adoption as fuel crop species, however, would seem unlikely in the short term. It is extremely difficult to predict their long term potential for biofuel production as this will depend on the relative movement of fuel and food prices. However, it would seem unlikely that the substantial price rises necessary to make biofuel from food crop systems profitable will occur for quite some time. For example, the cost of ethanol at the 1982 prices and yields given in Nix (1981) would be £0.4 per litre for Wheat, £0.4 for Potatoes and £0.3 for Sugar Beet based on feedstock costs alone. This may be compared with pre-tax value for four-star petrol of £0.2 per litre and the post-tax cost of about £0.4 per litre.

The potential use of ethanol as an additive to petrol is considered in the section dealing with alternative uses of existing crops.

ALTERNATIVE USES OF EXISTING CROPS

The major crops for which alternative uses would be most desirable are the cereals, especially Wheat and also Potatoes and Sugar Beet. They are predominantly producers of starch, from cereals and Potatoes, and sugar from Sugar Beet. Processing can readily convert starch to sugar and *vice versa*, so to some extent the crops are inter-changeable as the basis of industrial processing. However, cereals have the advantage of easy storability and therefore easy ability to supply a process operating throughout the year. Cereals are also less bulky for transport, are grown more widely and are in greater surplus, so whilst the following paragraphs are applicable to all three crops they are more particularly directed at cereal grains. Currently only 4% of EC cereals are used for industrial purposes.

World starch extraction is currently of the order of 16Mt, 20% produced in the EC. Some 75% of world production is derived from Maize, so is 72% of EC production (Table 2.9). Low-protein starch is more easily produced from Maize than from Wheat, but there are applications which do not require pure starch. There is also scope for improving the process of Wheat starch extraction which has not received as much attention as Maize processing. The development of improved extraction procedures may also require the selection of cultivars which are better adapted to starch extraction. Alternatively, the relatively pure A-starch can be extracted and the remaining starch fermented to ethanol. It seems likely that home-grown Wheat could replace at least some of the imported Maize which is used for starch production in the EC.

Table 2.9
Raw materials for the production of starch in the EC (1981–82).

Raw material	Consumption of raw material Mt/year	Production of starch Mt/year	No of plants	Output per plant. Mt starch /year
Maize	4.1	2.5	19	0.1
Potatoes	4.6	0.8	17	0.05
Wheat	0.4	0.2	16	0.01

Source: Adapted from Rexen & Munck (1984)

The market for industrial starch is likely to increase, but the rate of increase is uncertain, mainly because of uncertainties about process development (Rexen & Munck, 1984). Starch is used in paper and board production, the textile industry, in the production of synthetic polymers and a number of other chemicals. It is also used in the food industry as a thickener and filler in both modified and unmodified form. The food industry is keen to develop a bland nondegradable carbohydrate for use as a filler which does not contribute to the calorie intake. If developed, it will have considerable use, but to the extent that it may replace more conventional carbohydrates in the diet, it may not provide much of ar advantage in terms of cereal marketing.

An area of much greater potential is the production of synthetic polymers, broadly speaking the *plastics* industry. At present, petroleum products are the major and more efficient feedstock, but changing price relationships between oil and cereals have made starch a more attractive source than previously. Any increase in starch use would require considerable industrial investment and would be largely a substitution because no dramatic increase in the demand for synthetic polymers is expected. But it would allow greater dependence on a surplus renewable resource and some reduction in the rundown of a non-renewable one.

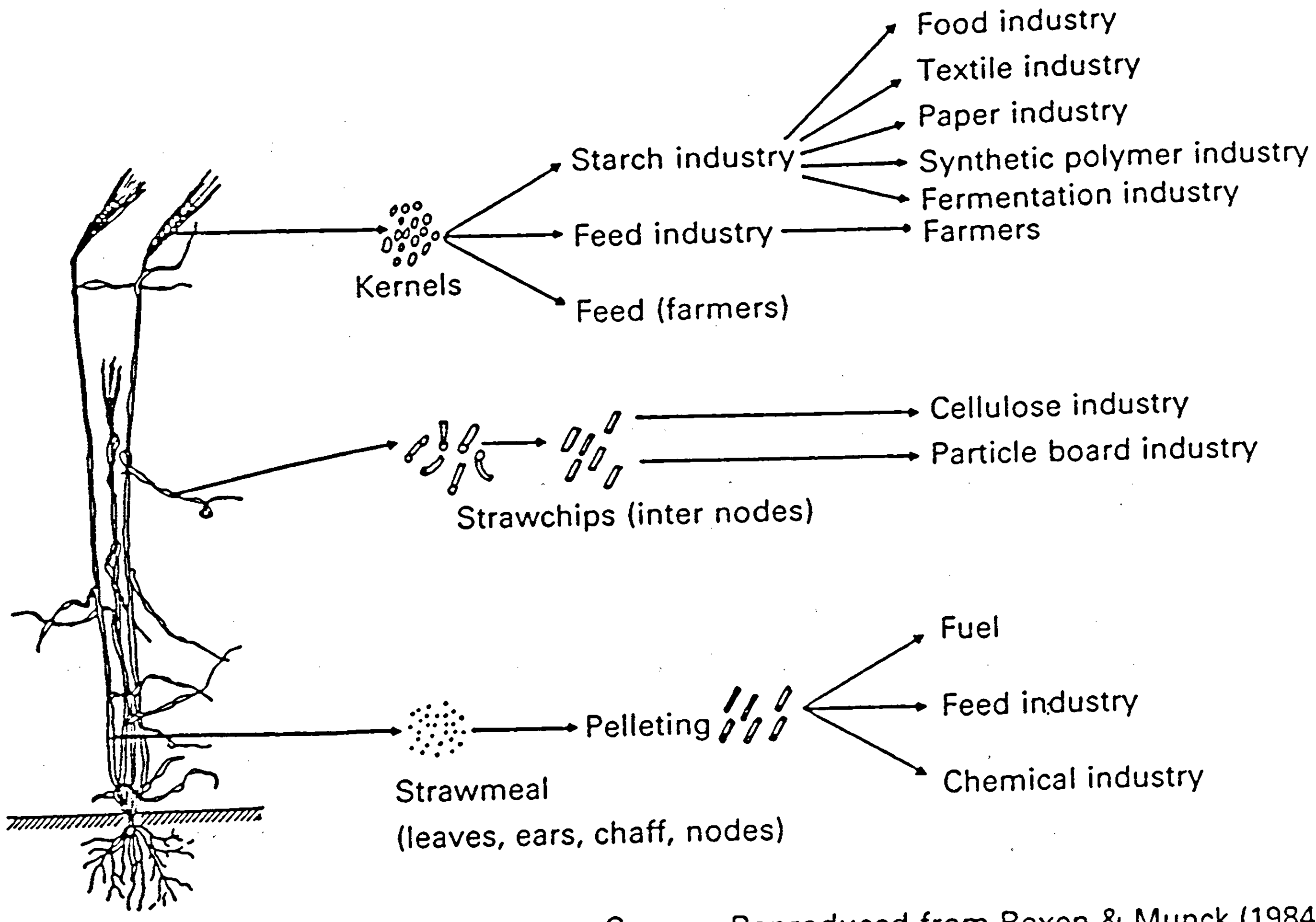
In all these industrial applications, the amount of change is highly dependent on price and price differentials. EC regulations also have many influences: for example they limit the amount of sugar which can be processed from cereals in order to limit competition with the sugar industry.

The earlier discussion of biofuels has shown that the use of crops to produce ethanol as a petrol replacement is not cost effective at present prices. However, the potential market is enormous, much greater than the market for starch-derived chemicals or durables, and particular interest lies in the possibility of using ethanol as an octane enhancer. This is stimulated by the pressures to develop lead-free petrol. Ethanol has an energy value only 60% that of petrol, but it is claimed that the 10% addition of ethanol to petrol gives a fuel comparable to pure petrol with lead additive. Used in this way, ethanol is therefore considered by some to be comparable in energy value to petrol. The EC uses 80 Mt of petrol per year, and a 10% ethanol admixture derived from cereals could use 30 Mt of cereals per year (Rexen & Munck, 1984). This is about 25% of EC output and contrasts with the 4.5 Mt of Maize and Wheat currently used in starch production.

It is possible therefore that the anti-knock properties of ethanol can justify a premium price, and even if some financial support is needed, the fact that one process could both relieve the cost of intervention and also hasten an anti-pollution development might seem to many a popular and sensible use of public money. Although cereal grain may be the most readily available substance for this purpose, it should be mentioned that, because ethanol is a wet fermentation product from sugar, Sugar Beet could also be a suitable source.

Perhaps the ultimate aim in developing the cereal crop should be to recognise that both grain and straw (see the following section on straw utilisation) can produce a number of different materials, each with a different use or uses. This is illustrated in Figure 2.1. In order to utilise the various fractions efficiently, and to increase the efficiency of machinery use, Rexen & Munck (1984) have proposed a system of regional agricultural refineries, operating in conjunction with a whole-crop harvesting system. The refinery would receive, and perhaps even harvest and transport, the bulk grain and straw of cereal crops from farms in the area, and similar bulked material of other crops. It

Figure 2.1
Transformation of a cereal crop into intermediates for use in various industries.



Source: Reproduced from Rexen & Munck (1984)

would separate the crops into their required fractions and then send bulk supplies to grain stores and to appropriate industrial plants. Some grain and treated straw would be returned to the farm as animal feed (Figure 2.2).

This would be a radical step which may only be justified if industrial outlets can be substantially increased, but it is a logical move forward in the development of co-operation between groups of farmers, and their integration with the users of farm products. It also emphasises once again that many of the potential alternative uses of existing crops are industrial in application, for which close integration of farm production and subsequent processing will be necessary.

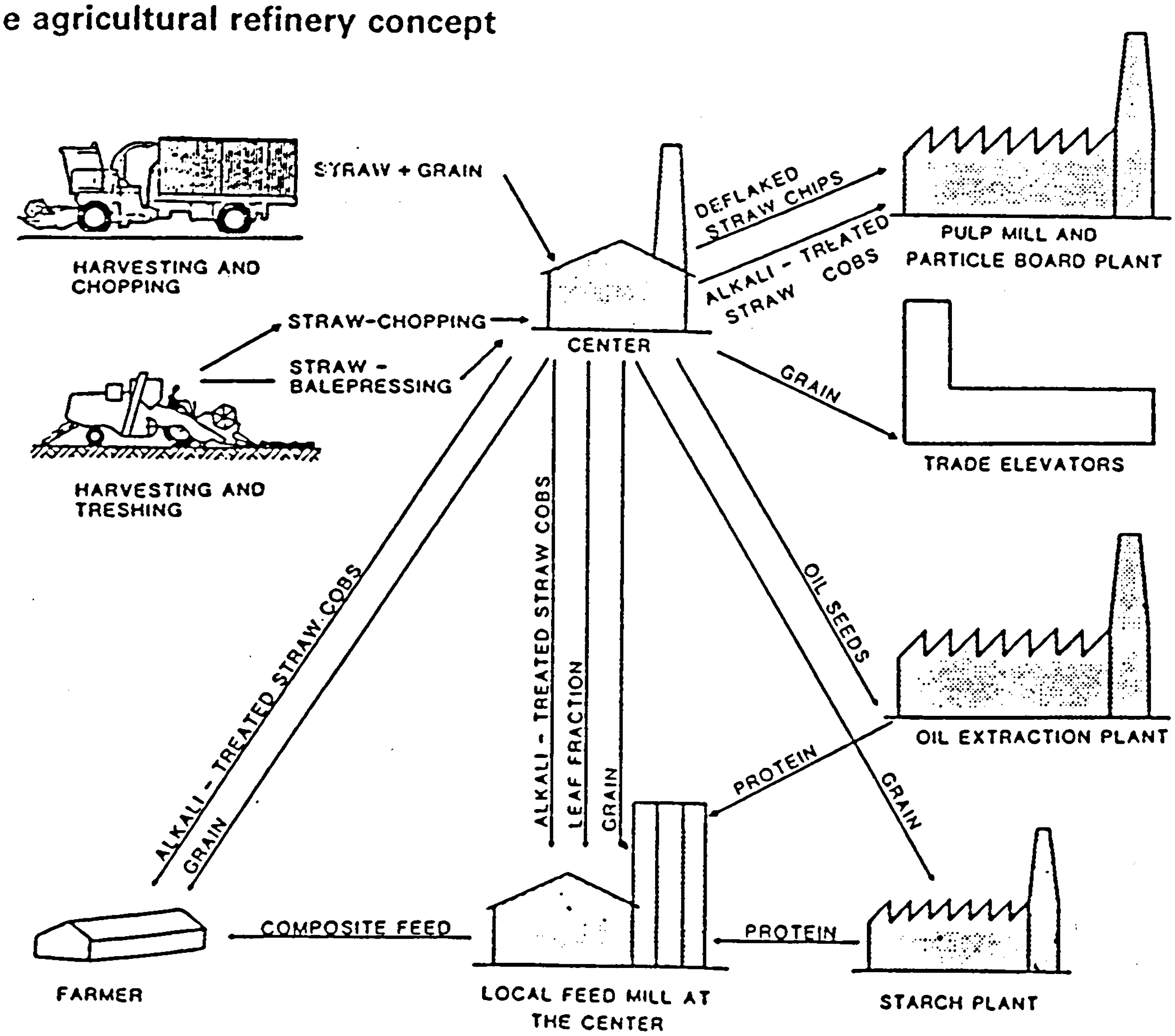
Future studies: cereals

There are two main areas of possible development in the markets for UK cereals: greater use of wheat as a source of industrial starch, and an increase in the market for industrial starch. The latter includes the production of ethanol as a petrol additive and could dwarf all other industrial uses.

Substitution of wheat for maize in starch production will require investment in process development, a study of the suitability of existing cultivars and also of the feasibility of selecting and introducing wheat cultivars better adapted to starch extraction. It will also be desirable to consider the implications for wheat gluten sales. At present, gluten use is confined to the limited and specialised markets of the baking and petfood industries and an expansion in the production of wheat starch could lead to problems in gluten marketing. If an increase in the use of wheat for starch production is feasible, it could be developed over a ten-year period and would then be in a good position to be further extended to help meet any increases in demand for starch.

There are many possibilities for the increased use of starch in industry

Figure 2.2
The agricultural refinery concept



Source: Reproduced from Rexen & Munck (1984) and a number of commercial and non-commercial organisations in Europe and elsewhere are engaged in research, development and feasibility studies. Predictions about them are impossible to make, but the problems caused by massive cereal surpluses suggest that the EC and its member governments should continue to encourage such studies. The development of starch use for synthetic polymers is an area of considerable potential where it has been suggested that *a reduction in cereal raw material prices in relation to petroleum feedstock prices, coupled with increased investment in R & D, could change the picture completely* (Rexen & Munck, 1984).

The production of ethanol from fermented cereals, and its use as an additive in petrol is primarily dependent on policy decisions about the distribution of price support and the weight given to anti-pollution measures. Studies are also needed on the grain alcohol process; it uses considerable amounts of energy, and although process efficiency has been greatly improved in recent years, further economies are considered possible.

USES OF STRAW

Production of recoverable straw in England and Wales has been estimated at 11–13.5 Mt per year, though some calculations suggest it may be 30–50% greater. Of the more conservative estimate, it is thought that 5–6 Mt per year are burnt and 5.0–7.5 Mt are baled. The estimated uses of baled straw in 1982 are given in Table 2.10.

The development of straw use has been the subject of considerable research for the last decade. This research has recently been reviewed (MAFF, 1984). It is not appropriate to re-examine it here in detail but some likely developments are outlined.

Straw can be used cost effectively as fuel on farms, for farmhouse heating and for glasshouses and other small units. Larger scale use is presently limited by the energy costs of handling, hauling and processing. Even so, there is at least one instance, in Denmark, where a centralised straw-burning furnace provides the heat and hot water for a town of 20 000 people (Anderson, 1985), reportedly 20% to 30% cheaper than using oil or gas.

Chemical treatment for livestock feed includes both caustic soda and ammonia treatment. Financial benefits are variable, but the process can be cost effective and is likely to be increasingly used, especially in those areas which combine substantial amounts of both cereals and livestock production.

Table 2.10

Estimates of baled straw utilisation in England and Wales, 1982 (kt)

On-farm straw uses	Fuel	166
	Chemically treated livestock feed	125
	Potato storage	70
	Sugar beet storage	50
	Horticultural uses	71
	Livestock bedding and feed (plus wastage)	4 266
	Total (on-farm)	4 748
Off-farm straw uses	Stables and mushroom production	300
	Livestock feed (processed off-farm)	150
	Thatching	15
	Building board	16
	Briquettes for fuel	1
	Total (off-farm)	482
TOTAL (all uses)		5 230

Source: Adapted from Larkin (1984)

Straw is used in horticulture as a growing medium or compost for a variety of crops and as mulching for both summer and winter use. Of these uses, composting is the one most likely to increase because of developments which accelerate straw decomposition and provide gains in both nitrogen fixation and in soil aggregating gums (Lynch, 1984). There may also be some opportunity to use the carbon dioxide evolved from composting to enrich the atmosphere of glasshouses.

Straw can be used either as a filler in wood particle board, or to produce excellent straw board or particle board from straw alone. This is a use which is developing gradually but could in time be a major market for straw and at the same time reduce to some extent the demand for forest products. Two processes currently operating in the UK are *Compak* and *Stramit*. They can produce building materials, horticultural boxes, crates and pallets.

The cellulose and some other constituents of straw can be converted by hydrolysis to glucose. It can be the starting point for a number of chemical processes which were considered in the previous section. This might be a valuable use of straw if it had no other uses, but at the present time glucose can be produced more cheaply from other readily available starchy materials.

The paper-making industry can also use cellulose from straw; one of the reports examined during the course of this study indicated that the paper on which it was printed contained 40% of straw cellulose. Greater use of straw for paper making in the UK would reduce the need for imported wood pulp but will require considerable capital investment by the paper-making industry, at a time when it has been subject to increasing financial pressures (MAFF, 1984).

Other uses for straw include thatching, straw mat production, wreath bases, straw rope and corn dollies, but they are unlikely to make any substantial demand on the supply. However, the other larger uses which have been outlined, especially animal feeding, straw board and possibly paper making, are likely to take gradually increasing quantities.

FUTURE STUDIES

The future development of alternative crops falls into two parts. There is firstly the identification of possible new crops, and secondly the more detailed assessment and development of those which have been identified. These will be dealt with in turn.

Identifying potential alternative crops

The present study would have been easier, and perhaps more productive, if information about economic plants had been available in a more organised manner. Examination of the numerous encyclopaedias, books and journals shows that there are hundreds, and probably thousands, of plants which will grow in the UK and produce something useful. It is impossible to review them all and so to a large extent selection from them is based on subjective judgement and without always having the confidence that the full range for a particular type of production has been reviewed.

The Royal Botanic Gardens at Kew has been developing, for some years, a computerised data bank on a *Survey of Economic Plants for Arid and Semi-Arid Tropics* (SEPASAT). This now records some 6 000 species with details of a number of different characteristics, including some 550 categories of different uses. There appears to be no similar body of knowledge for the temperate zones and assembly and recording of this information would require considerable time and investment. It would not be sensible to consider it for the UK alone, but a service to meet UK needs could equally serve much of the rest of Europe and much of the North American continent too: indeed all the temperate and cool temperature parts of the world. A wide ranging service could perhaps justify EC or international funding.

The availability of a bank of information can then allow extraction of lists of species with common characteristics. The questions which can be asked will depend on the data collected and how it is recorded, but the following sample questions illustrate the intention.

(i) What temperate species produce fibres suitable for weaving?
(ii) What species produce a starchy grain and are suited to acid soils?
(iii) What semi-drying oils are grown in Canada?

Once produced, the data bank would be of lasting value to a large area of the world. New information can be continually added to increase the coverage. It is in the temperate area that crop yields are increasing most rapidly and it is therefore in these areas that problems of over-production, the need to diversify and the need to find products with industrial applications are most likely to arise.

In these circumstances, it is perhaps surprising that the UK has no formal crop introductions unit. Such a unit could be used to keep possible new crops continually under review and could conduct preliminary trials on any for which the production and marketing potential gave adequate justification. The unit could also have a remit to identify marketing opportunities, particularly for food crops, where signs of a new or adventurous demand suggest that novel crops might be acceptable. The unit might have one or two full-time appointments but could otherwise be more of a working party. It would not require substantial resources exclusive to its activities but it would need to have access to land and laboratories for trials work. It should certainly work closely with any private enterprise activities of a similar type.

Developing alternative crops

Assuming that resources for crop development are limited, it will be necessary to determine how to allocate them between elaborating alternative uses for existing crops and developing alternative crops. For the reasons outlined in an earlier section, new uses for existing crops should probably take priority, though this will be partly dependent on the importance of the new crop use and how close it is to implementation. Another area of study which may be competing for the same resources is the development of low-cost, low-output systems of producing existing crops.

The development of alternative crops will require information on a number of features. The following list is designed for a seed crop and will require modification for other types.

(i) Information on its ecological needs, including soil factors but especially the temperature requirements for, and duration of: germination and establishment, leaf canopy development, flowering, seed growth, and maturation. Time to first flower, total crop duration and likely harvest date would emerge from these studies. Information on photoperiodic requirements, uniformity of ripening, incidence of shattering, and seed dormancy will also be needed. Collection of these data would provide an economical means of determining the UK suitability of a crop, and for which regions, because it would greatly reduce the need for multi-location trials conducted over a run of years to sample climatic variation.

(ii) If required, an assessment of the variability present in the population to determine the feasibility of genetic adaptation.

(iii) Field trials to determine the agronomic management and likely yields.

(iv) Identification of potential pest and disease problems through information from its centres of origin and/or previous cultivation, and by observation of UK trials.

(v) Development of methods of processing and assessment of the economic effects of scale of operation.

(vi) Market and marketing studies.

During the collection of material for this study, it was often claimed that other countries, particularly the Netherlands, are more organised and successful in identifying home and export marketing opportunities and then generating production to meet them. It is difficult to know whether the UK is less active in these areas and there are notable British examples of new market-oriented production, such as the development of the flower-bulb industry. Nevertheless, there is probably greater scope for active market development. Medicinals have already been mentioned as one area, and the increasing interest in salad and vegetable crops suggests that, in addition to identifying market needs, there are probably opportunities to create them by active promotion of novel products.

Market studies and promotion, and crop and farming systems development can require considerable investment even after a potential new crop has been identified. Public funds may be needed where the potential is not clear; where the risk, though justified, is great; or for areas with special problems. Farming co-operatives and individual entrepreneurial activity can deal with other innovations, particularly direct-marketed products. It is likely that progressive farmers will be active in developing those crops for which the agronomy is the only area needing elucidation. Similarly, the merchant companies will be keen to develop those crops for which they perceive a useful demand for inputs or profitable business in crop marketing.

Many of the alternative crops and alternative uses which might be introduced are for industrial purposes. Successful development, indeed any development, will depend upon co-operation between producer and processor at all stages of development and implementation. This is not an area where formal links have been very strong in recent years and much will depend on how these links are formed and used.

It has been shown that the development of cold tolerance is a requirement for many crops which could usefully be grown in the UK. Breeding crops with improved tolerance to low temperature is a difficult task for several reasons. The exploitable genetic variability may be limited, genetic control of low temperature tolerance is extremely complex, and the available selection methods do not always accurately reflect the conditions for which tolerance is sought (Marshall, 1982; Stushnoff *et al,* 1984). Success seems to have been greater in woody than in herbaceous species.

In many countries, especially for autumn-sown crops, cold tolerance is primarily a need to survive low temperatures. But whilst this is one component of cold tolerance for spring-sown crops, their adaptation to a temperate climate also requires the ability to germinate rapidly, photosynthesise, develop a canopy and produce a yield, all within a limited period and at temperatures lower than they commonly experience. Response of these and other attributes to temperature is primarily governed by biochemical reactions within the cell which are under complex genetic control. In the absence of a full understanding of both cell biochemistry and the genetic mechanisms, past progress in developing cold tolerance has mostly been based on selection from large segregating populations by exposing them to appropriate environmental conditions. Much of the plant breeder's skill depended upon an inspired ability to select suitable parents. In many crops we are now close to the limits of improvement which this kind of technique can achieve. However, two current developments may alter this. Firstly, progress in cell biology, from work such as that of the John Innes Institute, is giving a detailed understanding of the molecular determinants of low temperature response. Secondly, genetic engineering techniques may soon allow manipulation of those determinants. As a result there may be a more rapid development of the type of cold tolerance we seek, perhaps in the next 10–15 years.

Over the same period, genetic engineering may allow even more dramatic changes. For example, and merely to illustrate the nature of possible developments, a modified Sugar Beet plant may accumulate protein or an essential oil instead of sugar; or Lettuce might be produced as axillary buds on a plant with the general structure of a Brussels Sprout plant. Changes such as these are likely to be much less complicated than the manipulation of low temperature response and may therefore precede substantial improvement in cold tolerance.

Another major biological innovation is the development of tissue culture, the production of whole plants, or of plant tissue systems, from individual protoplasts, cells or calluses. It may have several applications to, and implications for, agriculture. The most important is large-scale, low-cost propagation of plants, for example in the rapid expansion of forestry, but it may also be used for continuous industrial production of plant substances such as essential oils. These techniques are likely to become widely available in the next 5–10 years, but some of the applications will take longer than that to implement.

Genetic engineering and tissue culture will greatly alter the options available to the farming industry. They will eliminate the need for some cropping enterprises, but widen the opportunities in other directions. It is therefore important that, along with the more traditional development studies and marketing activities which have been proposed, adequate public and private funds should be available for the development of these new techniques.

3 Alternative animal enterprises

This chapter is a brief review of possible future livestock enterprises, including those based on unconventional animal species (eg Llama) and non-traditional methods of rearing conventional animal species (eg Barn Hens, Outdoor Pigs). Low-input forms of existing livestock systems, such as extensive dairy production, are not considered, since these require only adjustments in existing production methods rather than fundamental changes in livestock management.

Almost all animal species can survive in the UK. The large number of tropical mammalian species kept under more or less natural climatic conditions in zoos throughout the UK attests to the climatic adaptability of most animals. The UK winter is therefore sufficiently mild to allow species from some of the most torrid regions of the world to survive in the UK without the need for expensive housing.

In addition to survivability, however, two further criteria have to be satisfied.

(i) The species need to be sufficiently productive.

(ii) The products need to command farm-gate prices which provide adequate remuneration to the producer.

In the case of many unconventional species, one inevitably enters the realm of conjecture when assessing the extent to which they fulfil these two criteria. Often there is no information available on their performance under UK conditions, and it is necessary to infer efficiency rates from foreign reports.

Reference to the official trade statistics indicates that some forty different animal products are imported by the UK, either for consumption or for re-sale. Some of these items are products from conventional species (eg bovine leather and chicken eggs), but most of them are derived from unconventional species. Thus, the import statistics provide a primary listing of products from alternative species which are already in demand. Table 3.1 shows the value of these imports which, in 1983, totalled £431 million.

To this list of imports are added a further 10 species. These species produce commodities which, although not currently imported, may satisfy a demand (or a higher level of demand) in the future, either from UK consumers or from abroad. Thus, the following species and products are included in this study: Chinchilla (for fur and as a pet), Goats (for meat and milk), Horses (for meat and work), Kangaroo and Wallaby (for leather and meat), Muskrat (for fur), Nutria (for fur), Reindeer (for meat), Sheep (for milk) and Earthworms (for fishing bait, livestock feed and as waste processors).

In addition, alternative ways of rearing conventional species are considered, including Free-range Egg and Broiler production, Outdoor Pigs and Outdoor Rabbits.

CHINCHILLA

The Chinchilla *(Chinchilla laniger)* is a South American rodent that can be easily tamed and handled. For several decades it has been reared for fur in this country, the pelts being sold to dealers in Denmark. The largest UK ranchers have up to 400 animals.

Chinchillas are herbivorous and reach 32 cm in length with an 11 cm tail. They weigh up to 700 g.

The gestation period is 111 days and it is unusual for females to produce more than two litters a year. Litter size varies from one to three; occasionally litters of up to six are born.

Young Chinchillas are fully developed at birth, their eyes are open and they are fully furred. They nurse for about six weeks and may attempt to eat adult food when only a week old. Nine months are required to produce a pelt. Breeding females generally live from five to eight years.

One unusual feature of this animal is that it can release tufts of fur when startled or frightened. This means that careful handling is essential. Once the pelt has been dressed, however, the fur becomes cemented to the leather and does not slip free.

Some ten years ago, annual output from the UK was in the region of 1500 pelts. At the present time output is a fraction of this, possibly only a few hundred pelts per year (Wadsworth, C–personal communication). This drastic reduction in pelt output has been due to the activities of the animal welfare lobby.

The Chinchilla industry, however, appears to be thriving – since the animals are now in strong demand as pets. Almost all Chinchilla producers are now targeting their output at this new market.

Chinchillas for pets are more profitable than for pelts. Producers can

Table 3.1

Value of UK imports of some animal products, 1983.

	Valve £	% of value of animal product imports
Ruminant products		
Bovine leather, prepared	72 695 000	17
Sheep and lamb leather, prepared	23 035 000	5
Merino wool (Ryder's estimate for 1984)	70 000 000	16
Goat and kid leather, prepared	8 451 000	2
Mohair, not carded or combed	36 343 000	8
Cashmere, not carded or combed	21 196 000	5
Alpaca, vicuna and llama hair, not carded or combed	109 000	*
Fabric of speciality fibre	2 510 000	1
Camel hair, not carded or combed	623 000	*
Non-ruminant products		
Angora rabbit hair, not carded or combed	6 231 000	1
Rabbit fur, raw, tanned and made-up	9 085 000	2
Rabbit meat	5 618 000	1
Mink fur, raw and tanned only	100 115 000	23
Products from birds		
Duck meat	1 249 000	*
Goose meat	54 000	*
Goose and duck liver	676 000	*
Guinea fowl meat	275 000	*
Turkey meat	14 155 000	3
Turkey and goose chicks	129 000	*
Turkey and goose eggs	15 000	*
Invertebrate products		
Honey	12 667 000	3
Silk, raw, yarn, fabric and made-up	45 090 000	10
Snails	89 000	*
Other products		
Chemicals for cosmetics	1 033 000	*
	431 446 000	99

*less than 1%

Source: Adapted from HMSO (1983) Overseas Trade Statistics of the UK.

expect to receive £20–£40 for a pelt, whereas they receive £25–£50 for a pet Chinchilla, with prices reaching more than £100 for show animals of unusual colour. Moreover, producers receive payment immediately when selling pets, whereas payment for pelts may take up to 18 months.

When reared in captivity, Chinchillas eat specially prepared pellets and hay. They eat only 30g of pellets a day and are thus cheap to rear. Wadsworth, C (personal communication) reported that feeding costs per animal amounted to 6p per day.

It should be noted that demand for pelts has not fallen off. Indeed it appears that demand for pelts may itself be expanding, although no factual information on this has yet been found.

DEER

Deer belong to the family *Cervidae.* Throughout the world there are about 16 genera and 40 species of Deer. Nine species are found in the UK: Chinese Water Deer, Fallow Deer, Muntjac, Père David's Deer, Red Deer, Reindeer, Roe Deer, Sika and Wapiti.

In the UK, there are two main methods of venison production: sport shooting and Deer farming. Only a very small proportion of the country's venison is produced by Deer parks.

Sport shooting is, by far, the most important method of venison production. MLC (1985) estimate that, in Scotland, there are some 270 000 Red Deer and about 25 000 Roe Deer. These Deer range over some 3 Mha of "Deer forest" and the annual culls produce about 2 000 t of venison. This is 75% of UK output.

In contrast, the population of farmed Deer in the UK is between 5 000 (MLC, 1985) and 10 000 (Spedding, 1983). Assuming a mean stocking rate of 6 hinds per ha, and that hinds account for 40% of the population, then commercial Deer farming uses 500 to 1 000 ha. At the present time, therefore, Deer farming is not an important user of land.

The two methods of Deer production are briefly described below in terms of production parameters. The section continues with a consideration of the economics of Deer production before concluding with a discussion of the future prospects for this activity.

Sport shooting

In 1979, the Red Deer Commission estimated that in Scotland there were more than 500 estates keeping Deer. Of these, 55 kept more than 1 000 Deer and 10 kept more than 2 000 (Middleton, 1979).

The best Deer forests produce around 1 kg of venison per ha per annum (Hamilton, 1976). Stag shooting rentals vary from £50 to £900 per stag, depending on the quality of the stag, judged on its antler form and development and on the cuisine offered by the shooting lodge or hotel.

For every 100 hinds approximately 60 calves are born: only 50% of these survive the winter. Stocking rates vary from one animal per 10 ha to one per 20 ha. Rutting (mating) takes place in October and November and calves are born in June or July, the gestation period being about 233 days (Hamilton, 1975)

The shot Deer are retained by the estates and sold to game dealers. Most of the venison is then exported, although some is sold to local hotels, restaurants and butchers. In 1985 game dealers in Scotland were offering around £2.05 per kg carcase weight for Red Deer and £2.30 for Roe Deer.

Deer farming

The most commonly farmed species is Red Deer, with Sika accounting for less than 10% of farmed output. Fallow Deer, which are more timid than Red Deer or Sika, are farmed on a very small scale. Sika and Wapiti bucks are sometimes used to produce hybrid progeny form Red Deer hinds.

Deer farms have been established in both the uplands and lowlands of the UK during the last 15 years. Much of the pioneering research was undertaken by the Rowett Research Institute and the Hill Farming Research Organisation at their joint experimental unit set up in 1970, at Glensaugh in Kincardineshire. Both upland systems and lowland systems are described below.

Upland systems

In these systems, the Deer are enclosed by 1.8 m high fences and pastures may be improved. Stocking rates are 3–8 hinds per ha and calf growth rates average some 350 g per day during July (Beer, 1985).

It was this type of system that was developed by the Rowett Research Institute and the Hill Farming Research Organisation, and its subsequent commercial feasibility prompted considerable speculation that Deer farming was about to replace Sheep farming in at least some of upland Britain. Deer have two advantages over Sheep: their appetite is better synchronised with the growth of pasture, and venison has a lower fat content than lamb. Upland Deer farming has stimulated great interest amongst farmers and landowners over the last 10 years, and in 1983 the British Deer Farmers Association (BDFA) was established which has a current membership of over 100.

Lowland systems
These systems appear to have been established by entrepreneurial farmers or commercial companies with little technical experience in Deer production and before the national authorities had conducted any research.

They originated from the tradition of estate owners to run Deer in lowland parks primarily for amenity purposes, and all research seems to have been conducted by the farmers themselves, independent of government research organisations.

Stocking rates in lowland systems are considerably higher than in upland systems – at 6 to 13 hinds per ha (Beer, 1985). Calf growth rates average some 400 g per day in July – the month of fastest growth.

Economics of deer production
Producer prices for venison have varied dramatically over the last 13 years. Middleton (1979) reports that UK average carcase prices reached 100 p per kg in 1973, falling to 30 p per kg in 1975, before increasing to 150 p per kg in 1978. Drescher (1984) states that the British Deer Producers Society price for prime quality venison in 1984 was 300 p per kg. Unfortunately, the causes of these fluctuations have not yet been analysed.

Any calculation of gross margins for Deer production is, therefore, highly dependent on the assumed price for venison, and should thus be regarded as tentative. A recent estimate of gross margins for Deer production on upland grass was made by the Hill Farming Research Organisation, and is reproduced in Table 3.2 only in order to give readers an idea of orders of magnitude.

During recent years, velvet – derived from Deer antlers – has commanded high prices on SE Asian markets where it is purchased as an aphrodisiac, as a condiment and as an ingredient in medicines. Clutton-Brock (1983) states that mature Red Deer stags can produce up to 2.5 kg of velvet per annum, which, at £50 per kg, represents an important component of Deer farming profits. However, world market prices for velvet have not been stable in recent years: Loudon & Fletcher (1983) state that New Zealand velvet sold at more than $US 200 per kg in 1979, before becoming virtually unsaleable the following year – due to a glut – and reaching only $US 120 per kg in 1981. The financial viability of Deer farming, therefore, can be strongly influenced by the world market price of velvet.

Whilst market prices for venison and velvet influence the profitability of Deer production, the relative profitability of Deer production *vis-a-vis* Sheep production will determine the extent to which Deer replace Sheep

Table 3.2

Tentative gross margin for upland deer production (£ per hind).

Output:		
Calves	79.20	
Cull hinds	5.50	
Cull stags	0.70	
Total output		85.40
Variable costs:		
Concentrate feed	16.50	
Forage costs	10.00	
Veterninary and medical costs	2.00	
Haulage, etc	2.00	
Sundries	3.00	
Total variable costs		33.50
Gross margin per hind		£51.90
Gross margin per ha	£519.00	

Note: the above estimate assumes a stocking rate of 10 hinds per ha, that 90% calves are weaned and that the deer are provided with a hill outrun. Fixed costs – such as fencing – are, of course, not included in gross margin calculations.

in hill and upland Britain. Bryden (1978) developed a preliminary model for analysing the comparative value of Deer and Sheep farming. He concluded that relative profitability depended on three technical variables and one economic variable. The technical variables were the relative efficiency of Deer and Sheep in utilising hill pasture, the cost of farming and the practicality of managing Deer on a commercial farming scale. The economic variable that was found to be critical was the rate of interest on borrowed funds. Since 1978, further biological research has been performed which would go some way to specifying these technological variables, and the model could be re-run with updated values for these variables to examine the relative profitability of Deer *vis-a-vis* Sheep production at the present time.

The majority of UK venison is exported to West Germany, the world's major market, where the world price is set. West Germany often requires only the higher quality cuts, such as saddle and haunch, and UK exports to other countries, for instance the US, are therefore important. Consumption of venison in West Germany, in relation to other meats, is very low – being 0.4% of all meat consumption (MLC, 1985).

No data exist on UK consumption of venison. However, given the amount of venison produced (perhaps 2.5 kt) and knowing the volume exported, it seems likely that consumption could be 600 to 700 t per annum, which is equivalent to less than 13 g per person per annum.

Future prospects

According to Middleton (1979) the following factors are inhibiting domestic demand for venison.

(i) Irregular supply – housewives are apparently reluctant to buy, and retailers to sell, a product whose supply is not guaranteed.
(ii) High price – the housewife is reluctant to pay best beef prices for venison.
(iii) Strong flavour – flavour of farmed venison is however milder than venison from feral Deer.
(iv) Dark appearance.
(v) Lack of culinary knowledge – this is problematic since the flavour of venison cannot be appreciated unless it is properly cooked. The meat has a low fat content (Britain *et al*, 1981), giving it a dry consistency unless care is taken during preparation.
(vi) Variation – in quality, texture and flavour.
(vii) Small supply.

Of these constraints, the high cost of venison is the most important. In November 1985, *Farmers Weekly* (1985b) stated that farmed venison steaks cost about £6.60 per kg. The number of British housewives able to purchase venison regularly is therefore small. Domestic demand for venison is likely to remain relatively low.

Of greater potential significance, however, is Deer farming for export of venison. German consumers prefer Scottish venison as this has a *gamey* flavour and this preference would therefore restrict exports of farmed venison. However, the *gamey* taste has been attributed to putrefaction, a process that could be hygenically controlled and manipulated to satisfy a known demand (Beer, 1985). At present all processing is carried out in Germany.

Any assessment of the future prospects for UK Deer farming must take account of the New Zealand industry which is generally regarded as being 10 years ahead of the UK industry. The ability of UK producers to compete on price with New Zealand Deer farmers will have to be investigated carefully and the fact that Waitrose imported 500 kg of New Zealand venison in 1983 may perhaps be a bad omen for UK Deer farmers.

GOATS

Goat production for milk

The number of Goats in the UK is not known for certain but has been estimated at 100 000 – 150 000 (Mowlem, A–personal communication). The Goat population is increasing dramatically; the number on registered farms alone almost doubled in the seven years to 1983. If it is assumed that 70% of the Goat population are in milk and that the mean annual yield (after consumption by kids) is 700 l, then some 62 Ml, of Goats' milk is produced in the UK each year. This compares with an annual output of cows' milk of 15 Gl. The Dairy Goat industry is therefore still extremely small, but its significance derives from its very high growth rate.

If a mean stocking rate of 6 milking goats per ha is assumed, then the Goat industry currently uses 15 kha of land.

The rise of the Dairy Goat industry from obscurity over the last decade can largely be explained by the increased awareness of the importance of a healthy diet. Some sections of the public are wary of consuming products that may contain artificial additives, and the strength of the Dairy Goat producer lies in his (or more commonly her) ability to promote Goats' milk as a 'natural' product. However, the industry was accorded an important measure of establishment approval when the medical profession began to prescribe Goat's milk to consumers found to be allergic to Cows' milk.

It is estimated that 50% of the output of Goats' milk is processed into yoghurt and cheese, while the other 50% is consumed as liquid milk. A very small amount has apparently been used successfully in ice cream production.

Liquid Goats' milk currently commands a retail price of 63p per litre, compared to the price of Cows' milk at 38p per litre. Goats' milk yoghurt sells at 26p per 150g, whilst Cows' milk yoghurt retails at 16p per 150g (Waitrose–personal communication). Differentials are highest, however, with cheeses: Goats' cheese is a luxury commodity, used for both specialist culinary dishes and as an item on a cheese board, and usually retails at £6–11 per kg. In contrast, the cheapest English cheeses cost £2 per kg with the dearest fetching £4 per kg. Continental cheeses command retail prices of £3–8 per kg (Waitrose–personal communication).

At the present time (September 1985), UK producers are exporting frozen curds to France. The size and stability of this export outlet is, however, not clear. French cheese makers currently dominate the international market but some UK cheese makers see no insuperable obstacles preventing a share of the market being won by them.

Finally, it should be noted that British Dairy Goat stock is held in high repute in international Goat circles and that a UK breeder is currently negotiating a major export order with the People's Republic of China.

Hard data on the Goat industry do not exist, but it is generally felt that there are three types of Goat keeper.

(i) The enthusiastic breeder;

(ii) The amateur milk producer with several goats;

(iii) The commercial keeper whose livelihood is derived from herds of up to 200; it is this class of keeper that has increased spectacularly over the last decade.

Some producers sell their milk wholesale to yoghurt and cheese manufacturers, who tend to operate fairly small processing businesses usually employing only themselves. One of the reasons that milk producers relinquish the added-value of Goat cheese and yoghurt to a processor is the difficulty of simultaneously managing a herd, manufacturing yoghurt and cheese and marketing these products. A characteristic of the Goat industry is the geographical separation of supply and demand; local demand is often insufficient to allow a livelihood from Goat dairying. Reliable financial data for Dairy Goat enterprises are rare but records published for two enterprises indicate that commerical Goat dairying can be highly profitable. Table 3.3 gives some summary financial results for two enterprises. In their study for the Chief Scientists' Group of MAFF, Wilkinson & Stark (1982) estimated a gross margin per breeding female of £140. This assumed a milk yield of 800 l per goat per annum, and a farm-gate price per buck of £25.

Table 3.3

Gross margins of two Goat enterprises in 1983.

Location	Number of head in milk	Mean milk yield (l)	Gross margin per head (£)	Gross margin per ha (£)
Yorkshire	81	850	203	3200
Avon	80	700	169	615

Source: Adapted from GPA (1984 & 1985).

Goat production for fibre

It was reported (McKenzie, 1970) that Goat fibre has been found to provide effective screening from radio-active fall-out. Further information on this possible attribute has not been found. The two principal Goat fibres are cashmere and mohair, which are briefly discussed below.

Cashmere
Cashmere is the undercoat of Goats raised by Mongolian peasants and is one of the finest natural wools known to man. In 1983, the UK imported £21 million worth of uncombed cashmere. Further imports of semi-processed or made-up cashmere occur, but it is not possible to ascertain the value of such imports from the official statistics.

Cashmere Goats have never been selectively bred. Raw cashmere wool commands some £50 per kg on world markets. Pure cashmere wool is not used in knitting since it is too soft and tends to pill. It is, however, woven, and jacketing material fetches approximately £1 700 per kg in Central London (one metre costs £420 and weighs 280 g). Overcoating and suiting material command somewhat lower prices.

Mohair
Mohair is the product of Angora Goats which are farmed commercially in Argentina, Australia, Botswana, France, Lesotho, New Zealand, South Africa, Turkey and the USA. Current world output has been estimated at 16.3 kt from a population of 6.4 million Angora Goats. The bulk of production derives from South Africa, most of which is exported to the UK and processed in Bradford. In 1983, the UK imported mohair, in an uncombed form, to the value of £36 million. The value of imports of semi-processed and processed mohair is not known.

There are an estimated 200–300 pure-bred Angora Goats in the UK (Mowlem, A–personal communication). A flock kept in Hampshire apparently produced mohair of a quality comparable to the second and third grade of imported mohair and superior to that produced in the eastern Mediterranean. The same source states that fleece quality deteriorates where the annual rainfall exceeds 500 mm, but it is not know to what extent this is an impression or a verified fact.

Mowlem, A (personal communication) considers that there is a future for mohair production in the UK, and the British Angora Goat Society has been established to further this objective.

The world price for raw mohair is £9–10 per kg, and the retail price for 'mohair' wool in the UK ranges from £40–150 per kg depending on the quality and proportion of mohair in the wool. Pure mohair retails at £500 per kg. Mohair combined with wool and woven into suiting fabric commands a retail price in Central London of £75 per metre, equivalent to £300 per kg.

Goat production for meat
The current consumption of Goat meat in the UK is so small that it is

not identified in the National Food Survey (Spedding, 1983). However, Mowlem, A (personal communication) states that, in the UK, there are a number of Goat meat producers supplying several hundred carcases per annum. These meet the demand of three different groups.

(i) Ethnic groups – Pakistanis, Indians, Italians and Cypriots;
(ii) French restaurants;
(iii) A very small number of UK households.

Goat meat has the advantage of a low fat content, compared to lamb, and domestic demand might increase if a promotional campaign was undertaken. There may be a large potential export market to Italy which is presently supplied by intensive French producers. Moreover, it is of interest that the Food Research Institute at Bristol has found Goat meat to be particularly suited for processing into meat products such as sausages and pâtés.

Very little research appears to have been conducted in the UK on Goat meat production, and Spedding (1983) has commented that a direct comparison of the potential output of Goat meat from grassland, against that of other meat-producing species, appears to be overdue.

Goat production for meat and hair

Russell *et al* (1983) have experimented with the integration of Goats and Sheep, and have found that the two species complement each other in feeding habits. The Department of Agriculture and Fisheries for Scotland has supported this research using feral Goats, and there would appear to be potential for rearing these two species in mixed systems in upland Britain and using the Goats to produce hair and meat.

Constraints on the Goat industry

There are three principal constraints which hamper the expansion of the Goat industry:

(i) There is a severe shortage of Goats, and keepers launching a Goat enterprise now have to begin with kids. Weaned kids fetch £40–50; mature females, when available, cost £100–120.

(ii) The lack of controls on Goats' milk marketing attracts criticism. The veterinary profession is anxious that problems arising from amateur Goat keepers retailing contaminated milk should be avoided by including Goats' milk within the umbrella of the Milk and Dairy Regulations.

(iii) In the future, the principal retail markets will be the supermarkets. But supermarkets are not willing to retail Goats' milk as a major product until the industry is seen to produce a steady and substantial supply. At the same time, producers are not willing to expand their enterprises before a guaranteed market is assured.

Goat research

A certain amount of research on Goat production has been conducted by the Rowett and Hannah Research Institutes. However, the bulk of UK research has been performed at what was formerly the National Institute for Research in Dairying.

Despite this research, many basic questions remain unanswered. For instance, it is still not clear how Goats should be fed for maximum milk output at lowest possible cost. Since Goats are seasonal breeders, is it possible to manipulate breeding to obtain a steady milk supply during the year? Further, it is not known to what extent Goats and Cattle are complementary or competitive. Wilkinson & Stark (1982) observe that few studies have been designed specifically to compare Goats with other ruminants in terms of efficiency of production. They state that Goats appear to have a higher voluntary feed intake per unit of liveweight than Sheep or Cattle, but their requirement of energy for maintenance may be higher than that of Sheep. There would thus appear to be a growing demand for more basic and applied research into Goat production for all three products – milk, meat and fibre.

Future studies

Prospects for milk appear good. It was reported that 5% of babies are allergic to Cows' milk and if this proportion is true of the general population, then potential demand for Goat's milk is substantial. Annual Cows' milk consumption per head in 1982 was 125 l (MacCarthy, 1984). If 5% of the UK population consumed the same level of liquid Goats' milk, the demand would amount to 300 Ml. The Goat industry would have to use some 70 kha for liquid milk sales alone. Prospects for fibre and meat also appear promising. The most useful and up-to-date study on Goat production in the UK is that of Wilkinson & Stark (1982) commissioned by the Chief Scientists' Group of MAFF and potential Goat-keepers are referred to this study for futher details. There would thus appear to be a growing demand for more basic and applied research into Goat production for all three products – milk, meat and fibre.

HORSES

Meat production

In Europe, France is the main consumer of Horsemeat. Italy, Belgium, Luxembourg and the Netherlands are also important consumers. In none of these countries does per capita consumption of Horsemeat approach that of beef and poultry, but the potential significance of these countries to UK agriculture lies in their being major importers of Horsemeat.

The Meat and Livestock Commission (MLC) have examined trends in European Horsemeat consumption and production from statistics provided by *Eurostat.* France and Italy are the major producers, each producing about 17 kt of carcase weight equivalent per annum. The UK produces about 6 kt per annum (MLC–personal communication).

Despite their relatively high levels of domestic production, both France and Italy are major importers of Horsemeat. In 1980 France imported 75 kt of carcase weight equivalent while the corresponding figure for Italy was 46 kt. France is estimated to be 20% self-sufficient, whilst Italy is slightly more self-sufficient at 26% (MLC–personal communication).

The UK trade to continental Europe is unimportant in relation to their requirements. Exports from the UK vary between years, but in the six years preceding 1984, exports were never greater than 8 kt per year.

At the present time only 15% of French Horsemeat imports are from within the EC, with most being supplied by the USA and Argentina (MLC–personal communication).

Naturally, producers of Horsemeat have to contend with considerable public disapproval. Chivers, K (personal communication) cites a plan for a Horse fattening centre and slaughter house at Portsmouth which had to be abandoned following public outcry. The Shire Horse Society is particularly aware of the possibility of increasing Horsemeat exports, but at the same time realises the emotions that are associated with this activity. It has therefore appointed a sub-committee to consider the matter.

In August 1985, the Shire Horse Society ascertained that producers received prices as shown in Table 3.4 for Horses on a deadweight basis.

The UK is the only EC member which does not accord *agricultural status* to the Horse. Consequently, Horse owners and producers do not enjoy exemption from VAT and rates, and are subject to stricter planning regulations.

Table 3.4
Producer prices for horsemeat, deadweight, August 1985.

Carcase weight (kg)	Pence per kg
less than 75	40
75–150	54– 56
150–250	70– 84
250–300	94– 96
more than 300	100–108

Source: Adapted from Shire Horse Society – personal communication.

Working horses

In 1920 there were 650 000 agricultural Horses in England and Wales and a further 360 000 Horses were used in business and commerce (Chivers, K–personal communication). In other words, less than 70 years ago more than a million Horses were at work in our towns and countryside.

Today, only heavy Horses are significant as working horses. There are four breeds of heavy Horse: the Shire, Clydesdale, Suffolk Punch and Percheron. Of these, the Shire is the largest with a mature stallion standing 17 hands high and weighing 850–1000 kg. It is also the most important breed numerically: the Shire Horse Society estimates that there are some 7 000 Shire Horses in the UK, of which 2 500 are used for breeding (Gibson, T–personal communication). Most of the non-breeding Shire Horses are owned for promotion purposes and are displayed at agricultural and county shows. Only a handful, perhaps 12–20 according to Bush, B (personal communication), are used by breweries for beer deliveries. The number employed on farms in the UK is probably less than 200.

The efficiency of Horse draught was examined by Brody (1945). He estimated that, when efficiency is defined as the ratio of energy equivalent of work performed divided by the energy expended in achieving that work, Horses are 28% efficient. The theoretical maximum efficiency for a contracting muscle is approximately 40%, the remaining 60% is expended in overcoming internal resistance of the body colloids (Brody, 1945). When the maintenance requirements of draught animals are taken into account, their efficiency decreases. Thus if energy furnished by animals and available for work is divided by the gross energy contained in the ration over a sustained working period, efficiency for Horses is in the region of 10–12% (FAO, 1972). Their efficiency drops further if account is taken of energy consumed in non-working time since Horses require feed in non-working periods. Thus the more they are worked, the higher their overall efficiency becomes.

Despite these low energetic efficiencies, it has been shown that draught Horses are financially attractive in certain situations. The Shire Horse Society (1985) showed that draught Horses were more cost-effective relative to motor vehicles in making deliveries within a radius of 4 miles from a central depot. Some breweries make deliveries to a large number of public houses within this circumscribed zone, and thus continue to use their draught Horses. Since a pair of 4-year old trained geldings presently costs £7 000–£8 000, a dray up to £2 000 and the associated equipment a further £2 000, it can be seen that the capital outlay is substantial. Furthermore, stabling has to be provided close to the primary distribution point and if this is near to a town centre, the high cost of land further reduces the financial attractiveness of Horse draught for businesses which do not already own stables and Horses.

For financial reasons, then, it is extremely unlikely that Horse draught for deliveries will expand in the near future in the UK.

Concerning the use of Horses on farms, the same conclusion is reached. At present price ratios, heavy Horses cannot compete financially with tractors. One Yorkshire farmer, who has 30 heavy Horses, states that a team of six horses can plough an acre per hour, but it has to be borne in mind that this farm is sited on fairly light land (Morton, G–personal communication). In certain situations, however, Horses have advantages of manoeuvrability. This makes them useful in forestry work and 30 000 heavy Horses are reputedly working in the forests of Sweden (Morton, G–personal communication).

One future for heavy Horses in this country lies in exploiting them as show animals. Heavy Horses attract very high levels of interest at county shows and publicity is undoubtedly an important inducement to those breweries who deliver by Horse draught to continue to do so. There are other possibilities; the use of Horses in amenity woodland and cultivation in vineyards: but such developments are at a very early stage and may be greatly affected by whether Horses are again recognised officially as agricultural animals.

The potential of Horses for leisure purposes is covered in Chapter 5 of this report.

KANGAROO AND WALLABY

The family *Macropodidae* comprises some 47 species of Australasian marsupial mammals. All the larger species of this family, together with some of the smaller species are known as Kangaroos. Wallabies are those species of medium size.

Kangaroos are hunted in Australasia principally because they are considered to compete for forage with livestock (Sinclair, 1983). However, they are also killed for meat and leather.

Kangaroos are generally terrestrial and all species are herbivorous. In their natural habitat, they occupy the ecological niche held by grazing and browsing animals. They typically have long, thin and powerful hindlegs for jumping, and long tails, thickened at the base, for balancing. The largest species are the Grey Kangaroo *(Macropus canguru)*, the Red Kangaroo *(Megaleia rufa)* and the Wallaroo *(Macropus robustus)*. A adult Grey Kangaroo can clear more than 9 metres at a bound and attain a speed of nearly 80 mph. Similar abilities are characteristic of the Red Kangaroo.

In the female Grey Kangaroo, the gestation period is variable (29–38 days). The young remain in the pouch for about 10 months, and then suckle for a further 6 months. The Red Kangaroo gestates for about 33 days.

There are four different genera of Wallaby: the Brush Wallaby (genus *Wallabia)*, the Rock Wallaby (genus *Petrogale)*, the Hare Wallaby (genus *Lagorchester)* and the Scrub Wallaby (genus *Thylogale)*. Of these, only Scrub Wallabies are of commercial importance, being hunted for their meat and fur in New Guinea, the Bismarck Islands and Tasmania. They are often known as padmelons and are small and stocky, with short hind limbs and pointed noses. Despite their name, they use scrub vegetation only for resting during the day, feeding on open grassland during the night.

Both Kangaroos and Wallabies have powerful jaw muscles and sharp incisors used for shearing, which allow them to make use of low quality, tough roughage. In the UK, hay would be suitable roughage during winter, and a horse or pony ration would be more suitable than a cattle ration owing to the Kangaroo's dental configuration (Frappe, D–personal communication).

In a study on both Grey and Red Kangaroo, it was found that carcase muscle comprised 52% of the liveweight. Kangaroos had more muscle than domestic livestock of similar weight (Tribe & Peel, 1963).

A later study found that muscle mass is concentrated in the region of the loin, rump and thigh, thus giving Kangaroos a high proportion of valuable muscle in the carcase (Hopwood *et al*, 1976).

In the 1950's, a gourmet market for Kangaroo meat existed in New York, Paris and Frankfurt, according to Poole (1978). The Singapore Sunday Times (1982) reported that Kangaroo meat had been passed off as fillet of beef in Western Europe. Exports of Kangaroo meat from Australia in the twelve months after June 1981 totalled 1.5 kt, which was destined for Japan, Holland and Germany. The value of these exports was over $ A 2M, (Sinclair, 1983). Kangaroo meat contains polyunsaturated and saturated fatty acids in the ratio of 1:1 and the total lipid content of Kangaroo meat appears remarkably low (12.3 mg/g net weight) (Redgrave & Vickery, 1973). Thus Kangaroo (and Wallaby) meat may be attractive to the growing number of consumers who are looking for a low fat diet.

Kangaroo leather is noted for its high tensile strength and is used in the manufacture of fine gloves, quality footwear, garments and novelties for the souvenir trade (Poole, 1978). In Australia, many Kangaroos are harvested for their skins alone, the supply of which is currently restricted by culling quota (Sinclair, 1983).

The ability of the Kangaroo to jump fences gives the Wallaby a distinct advantage from the perspective of domestication. Furthermore, the UK press has reported cases of Wallabies surviving without any evident problems outside captivity in the UK (Daily Telegraph, 1985). If the Kangaroo's attributes of low fat meat with a balanced ratio of fatty acids, and high quality leather are also found in the Wallaby, then the latter may hold promise as an agricultural animal in the UK, particularly as imports of bovine and ovine leather total some £96 million per year (HMSO, 1984).

LAMOIDS

Llama, Alpaca, Guanaco and Vicuna are all South American members of the Camel family *(Camelidae),* and are collectively known as lamoids. Lamoids are included in this study as potential producers of speciality fibres.

Lamoids do not have the characteristic Camel hump; they are slender-bodied animals and have long legs and necks, short tails, small heads and large, pointed ears. They are gregarious animals, grazing on grass and similar plants in the altiplanos of Argentina, Bolivia, Chile, Ecuador and Peru. The Llama and the Alpaca are domestic animals not known to exist in the wild state. They appear to have been domesticated before or during the Inca civilisation.

Llama

The Llama *(Lama glama)* is primarily a pack animal in South America but is also valuable as a source of food, wool, hide, tallow for candles and dung for fuel. There are about 3 million Llama in the Andean countries. It is the largest of the lamoids, averaging 120 cm at the shoulder. When annoyed, Llama spit cud into the faces of their attendants, a feature that is common to the other three members of this group. Llama are usually white, but may be black or brown, or may be white with black or brown markings.

Llama fibre belongs to the group of textile fibres known as speciality fibres. In South America, Llama are normally sheared every two years, each yielding a fleece of 3.2–3.6 kg. Llama fleece consists of the coarse hairs of the protective outer coat, comprising about 20%, and the short, crimped (wavy) fibre of the insulatory undercoat. Cleaning reduces the final yields of fleece to about 66–84% of the original weight.

Staple length varies from 8 to 25 cm, with the coarse hairs being longest. Diameter ranges from about 10 to 150 microns, with the diameter of undercoat fibre usually 10 to 20 microns. All but the finest fibres are likely to possess a hollow central medulla resulting in low density that makes the fibre fairly light in weight.

Llama fibre is used, alone or in blends, for knitwear and for woven fabrics made into outerwear, dresses and suits.

In the UK, Llama survive well, but are subject to Sheep diseases and have to be wormed. Nutritional requirements are very similar to those of Cattle, although Llama like a small amount of browse (Kitchenside, C–personal communication). One informant consulted during the course of this study reported a stocking rate of 7 Llama per ha: this included land set aside for hay for winter feeding (Skinner, S–personal communication). Llama can survive cold temperatures, but have evolved in dry climates. Thus, in the UK, Llama fibre can freeze to the ground after a wet, freezing night. Shelters with a bed of straw litter are thus necessary.

Yields of fibre in the UK are highly variable. One owner maintained that his Llama produced 3.6 kg of fibre annually which would be sold locally for £35 per kg, resulting in a gross revenue from fibre alone of £126 per animal per year. At a stocking rate of 7 per ha, this implies a gross revenue of nearly £900 per ha per year. This compares favourably with Sheep production, for which gross revenue per ha per year is around £700 (Nix, 1984).

However, it has to be noted that few owners report fibre yields as high as 3.6 kg per year.

At present, a buoyant export market exists for Llama and other lamoids in the US where they are in a high demand as pets. One American company is currently offering prices of £750–800 for breeding female Llama (Skinner, S–personal communication).

It is not known for certain how many Llama are kept on farms and in zoos in the UK, but they probably number several hundred. Generally, single Llama or small flocks are kept; flocks of more than 6 animals are rare.

A producers' association – the Llama Owners' Association – was established in January 1983, but folded up in 1985 owing to insufficient support.

Alpaca

There are about 3 million Alpaca *(Lama pacos)* in South America, the majority being kept in herds of 200–300 in Peru. They are reared for their fibre and two types are recognised: the *Suri*, characterised by long, straight hair, and the *Huacaya* which has shorter, curly hair.

Alpaca stand 90 cm at the shoulder and are thus smaller than Llama.

In Peru, male and female Alpaca reach puberty at about 12 months, but usually age of breeding is delayed until two years in females and three years in males. Females show continuous oestrus and ovulation is induced by copulation. Females return to oestrus within 18 days after sterile copulation. Multiple ovulations occur in about 10% of the cases; however, multiple births have never been reported.

The gestation length is about 342 days. There is a high incidence of embryonic mortality within the first 30 days of gestation. Artificial insemination can be performed; semen is collected by electro-ejaculation and ovulation induced by service with vasectomised males or chorionic gonadotrophin injections.

Alpaca are either sheared, like Llama, every two years or are sheared each year (IVITA, 1971). Fibre yield varies from 2 kg to 4 kg, with the suri type giving a heavier, more compact fleece than the huacaya type. Individual fibres within the fleece range from 20 to 40 cm in length. Although the fibre contains some coarse hairs, Alpaca do not have a protective outer coat. Fibre diameter is about 22–30 microns. Colour includes shades of brown ranging form tan to dark, and grey, white, black and piebald. Alpaca fibre is stiffer than wool and has greater strength than wools of medium diameter, with fibre from the huacaya type being stronger than that from the suri. The fibres have felting properties, and resemble wool in their ability to absorb and retain moisture.

Alpaca fibre, sometimes blended with other fibres, is made into dress and lightweight suit fabrics, and is also worn as a pile fabric used both for coating and as a lining, adding warmth to outerwear.

Bleaching of dark Alpaca fibre is frequent because of the price differential between white and coloured fibre. However, bleaching often damages the fibres and reduces their tensile strength when wet.

Alpaca appear to be rare in the UK, and a breeding female currently costs £6 000–10 000. Males cost £500–1 000 (Isaac, P–personal communication).

Alpaca wool is considerably more valuable than Llama fibre, and in the UK sells locally at £105–140 per kg. An annual yield of 3.6 kg was reported by one owner, giving a gross revenue from fibre alone of around £430 per animal per year (Isaac, P–personal communication).

Guanaco

Unlike Llama and Alpaca, Guanaco *(Lama guanaco)* are wild lamoids that live in small bands of females, usually led by a male. Their grazing area ranges from sea level to the snowline throughout the Andean region, southward to Tierra del Fuego. They are larger than Alpaca, standing 110 cm at the shoulder. Of all lamoids, they are the swiftest and when kept in captivity have to be enclosed by 2.5 m high fences.

The Guanaco is pale brown above and white below, with a greyish head. The soft, downy fibre is interspersed with coarser hairs comprising about 10–20% of the fleece. Very young Guanaco, known as guanaquito, are hunted for their pelts, which resemble those of the red fox and are used by the fur industry.

Guanaco fibre is finer than Alpaca, with a diameter of 18–24 microns and an average staple of 5 cm. It is highly valued for its rarity and soft texture.

The number of Guanaco in the UK is probably between 100 and 200. Like Llama they are kept either in zoos, or in small flocks on farms, principally as pets. Owners shear them, but yields tend to be low at around 1 kg per year. The fibre contains no lanolin and is thus difficult to spin by hand. The price of breeding stock in 1985 was £400 for a female and £100 for a male.

Owners report that Guanaco tend to be nervous and nosey, and two strong men are required for any handling (eg drenching and shearing). They suffer the same diseases as Sheep. During the winter, hay and a compounded Sheep ration are regarded as satisfactory feed (Dawes, U F–personal communciation).

Males exhibit territoriality and when two or more are kept in captivity, males fight each other viciously. Defaecation always occurs in the same spot and thus pastures can become damaged over time.

Vicuna

Like Guanaco, Vicuna *(Lama vicugna)* are generally wild lamoids living in small bands of females, although a small number of domesticated flocks exist in Peru. Of all the lamoids, Vicuna are the most valued for their fibre. Vicuna are swift, graceful animals, inhabiting the semi-arid grasslands in the Central Andes at altitudes of 3600–4800 m. They are the smallest of the lamoids, standing 80 cm at the shoulder. The Vicuna has been hunted for centuries and is listed as rare in the Red Data Book and is protected in several South American countries. Protection has, however, been highly effective and now Vicuna are no longer considered to be an endangered species.

Vicuna fibre is fine, shading from light cinnamon colour (called *vicuna)* to a pale white. Coarser hairs comprise 10% of the fleece. In South America the annual yield of fleece sheared from domesticated animals shows a wide range from 85 to 550 g per animal. Fine fibres have diameters of 13–14 microns and are 1–6 cm in length. Vicuna fibre is renowned for being strong, resilient, lustrous and soft. However, it is highly sensitive to chemicals and resistant to dyes. Thus, it is normally used in its natural colour.

Lamoid hybrids

Lamoids are able to interbreed and to produce fertile offspring. Hybrids of Llama and Alpaca frequently occur and are called *huarizo* with a Llama sire, and *misti* when sired by an Alpaca. Fleeces of these hybrids are not as fine in quality as that of the Alpaca.

One owner in the UK has attempted to cross Llama and Alpaca for four years, but without success (Isaac, P–personal communication).

Crosses of Alpaca with Vicuna dams apparently occur frequently. They are known as *paca-vicuna* (IVITA, 1971) and such hybrids are fertile. Because of their extreme timidity, however, Vicuna males will not mate with Alpaca females.

Lamoids – an appraisal

Of the four species and two hybrids discussed above, the Alpaca would seem to merit further consideration because of the high value of its fibre. Llama fibre is coarse and therefore does not command high enough prices to warrant further research and development. Vicuna are still so rare that they would be difficult to obtain. Guanaco have to be fenced, unlike Alpaca. It would appear, therefore, that Alpaca may be the most sensible choice of lamoid for further R & D. They are suited to rough climates and poor pasture and are thus well adapted to hill and upland areas in the UK.

The first question to be examined is whether adaptation to a UK ecosystem — in particular nutritional and climatic factors – would alter the character of the fibre.

Secondly, it would be necessary to observe reproductive performance under different management systems. Since ovulation is induced by coitus, traditional AI methods would not be appropriate. The high level of embryonic mortality, reported above, is probably due to nutritional stress and could be overcome in the UK.

MUSKRAT

The muskrat *(Ondatra zibethica)* is a semi-aquatic rodent found over most of North America and introduced into parts of Europe. Its fur is a basic commodity of the fur industry and is medium to dark blackish brown.

The muskrat is a compact, heavy-bodied rodent about 30 cm in length. The musky secretion to which the animal owes its name, comes from musk sacs in the anal region.

It lives in marshes or streams, sheltering either in burrows or reed mounds constructed in the water. Its diet consists of a wide variety of water plants and occasionally freshwater animals.

Two to five litters of one to 11 young are produced each year after three or four weeks, gestation.

In the United States the muskrat has been known to damage cereal crops, and its flesh is sold as *marsh rabbit* for human consumption.

It is not known to what extent Muskrat is farmed in the UK. The scale of future production will most probably be determined by the animal welfare lobby. Unless acceptable production methods are devised, then it is unlikely that production will be a significant activity in the UK.

MUSTELIDS

Of all families, the family *Mustelidae* contains the greatest variety of mammals utilised by the fur trade. Fur coats that command the highest prices are usually those made from Mink, Ermine (short-tailed Weasel) and Sable (a name applied by the fur trade to several species of Marten). Excellent skins are also produced by the Fisher, Skunk, Otter and other species of Marten. In fact, the durability of all furs, including those from other mammalian families, is based on that of the River Otter, which has been given the top rank of 100.

Almost all mustelids are active both day and night, although most of their activitiy is nocturnal. The majority are solitary in habit, except when travelling with young in a family group. In general, mustelids are terrestrial, living in forested or brushy areas, and most species are able to survive a variety of habitat from forest to desert. The Marten and Fisher, however, are strongly arboreal whilst the Otter is largely aquatic.

Delayed implantation is a characteristic of all mustelids, with the exception of the Skunk. Gestation periods are highly variable within the family, being as little as 36–42 days for Ferrets and as much as 220–337 days in the case of the Long-tailed Weasel. Those with exceptionally long gestation periods breed soon after the litter is born or in the following year. Some females have two litters a year, but in most only one is produced. Average litter size varies from one to 18, depending on the species, with most species having between three and five young per litter. Generally, young are weaned when between six and ten weeks of age.

Being carnivorous, mustelids sometimes become pests, especially around poultry. Those that are proficient diggers sometimes become a hazard to Horses (and riders) which can stumble when stepping into a burrow. Some mustelids are carriers of rabies.

The obnoxious scent glands of mustelids discourage humans from eating most of these animals. In the past, however, the scent from these glands was used as a base for perfumes. Grisons and the Ferrets have been trained to drive animals out of their burrows: the Grison to flush out Chinchillas, and the Ferret to drive out Rabbits and Rats.

Fisher

The Fisher *(Martes pennanti)* is a rare mustelid found in North American forests. It has a weasel-like body, bushy tail and low rounded ears. Adults are usually 50–63 cm long, excluding the 33–42 cm tail. The Fisher hunts both on the the ground and in trees, attacking various rodents, including porcupines, and other animals. Its diet also includes fruit and sometimes nuts. A litter consists of one to five young, born after a gestation period of 338–358 days, including a delay before implantation of the fertilised egg in the wall of the uterus.

The fur of the Fisher consists of dark brown ground hair and long black lustrous guard hair. It has good wearing qualities and fur from females is especially fine.

Kolinsky

Little is known of the reproductive features of the Kolinsky *(Mustela siberica)* which is found in East Asia and which produces a yellow brown fur with short fine ground hair and long silky guard hair. It is light weight and has fair to good wearing qualities. Chinese artists value the hairs for paints brushes.

Marten

Three species of Marten produce fur: the American Marten *(Martes americana)*, the Pine Marten *(Martes martes)* and the Stone Marten *(Martes foina)*.

Martens are forest dwelling, they climb easily and feed rapaciously on animals, fruit and carrion. A litter contains one to five young: the gestation period may last 290 days or more because of delayed implantation.

Fur of the American Marten ranges in colour from blue–black through various brown shades to a pale yellow that is usually dyed. Fur from this species is sometimes sold as American, or Hudson Bay, Sable. The Pine Marten produces a yellow-brown fur, whilst Stone Marten's fur consists of greyish-white ground hair with dark brown guard hairs.

Mink

There are two species of Mink – *Mustela vison,* New World Mink of the forests of North America and *Mustela lutreola,* Old World Mink of

Eurasia. Both species have a pelage which is deep, rich brown and consists of a dense soft underfur overlaid with dark glossy, almost stiff, guard hairs.

Mink are nocturnal and semi-aquatic, swimming, fishing and foraging for various animals. A litter of up to ten kits follows the gestation period of 39–76 days. Crossbreeding has led to the production of many mutant colours of fur. Except for the rarer mutant colours, however, the fur of wild mink is more valuable than that of *Ranch Mink*. Mink has good wearing qualities and is fairly lightweight.

Mink were not produced in captivity until about 1930 and since then have grown steadily in popularity, their pelts now accounting for about 75% of the value of the fur trade. Much of the increased popularity of Mink fur has resulted from the development of mutant colours. The pelts of new mutations are usually the most costly, since the number of skins available is quite low until sufficient offspring can be bred to meet the demand.

In the UK, 70 farms are involved in the production of Mink and the majority of skins produced are sold on the London market for export. Indeed the vast bulk of the Mink skins imported (the total value of which is £100 million per year) are auctioned in London for export.

Commercial Mink farming is a skilled operation and requires considerable financial investment. The animals depend on a diet of poultry, meat and fish offals which have to be carefully prepared and combined with pre-cooked cereal.

In the UK in recent years, Mink growers have had to contend with the views and actions of the animal welfare lobby, with the result that many Mink have been set free and now constitute a serious agricultural pest. Many ranches have relocated their operations to the Republic of Ireland.

Otter

There are fourteen species of Otter belonging to four genera. They are found throughout the world and have the same proportions as the Weasel – a lithe slender body, short legs and small ears. Otters swim easily with webbed feet and can travel underwater for 0.4 km without surfacing for air. They prefer to travel by water but their short legs notwithstanding, can travel on land faster than a man can run. Their diet consists of all manner of small aquatic animals, including fish, which they sometimes catch by team work.

Otters are intelligent, friendly and inquisitive. When obtained young they can be readily trained. A litter of one to five young is born after a gestation of 61–63 days.

Few other animals produce a fur so highly valued by man and so durable – the darker furs of northern Otters are the most prized.

Sable

The Sable *(Marten zibellina)* is a graceful mustelid found in the forests of northern Asia mainly in the USSR (the common name is sometimes also applied to the related European and Asian species and to the American Marten). Its body colour varies from brown to almost black.

The Sable is solitary and arboreal in habit, feeding on small animals and eggs. The gestation period is 250–300 days, and the litter numbers from one to four young.

The finest Sable fur is known as *crown sable.*

Skunk

There are 11 species of Skunk, which is also known as Polecat. They are noted for the offensive odour produced by glands on either side of the anal opening. If the animal feels severely threatened, it will turn its hind-quarters toward the target and eject a fine spray of yellow odoriferous liquid as far as 3.7 metres. Deodorised Skunks readily tame as pets. Their gestation lasts about 42-72 days and litters contain two to ten young.

Skunk pelts have commercial value, particularly when plucked and dyed to simulate more precious furs. They have good wearing qualities and are of heavy weight.

Stoat

Also callled the short-tailed Weasel, the Stoat *(Mustela ermina)* is found from the Artic to northern North America, in Eurasia and in North Africa.

In summer the Stoat is brown, with a whitish throat, chest and belly. In colder climates the winter coat is white, except for the black tail tip; the animal in this colour phase is popularly known as Ermine, as are other winter-white Weasels. In moderately cold climates, the fur becomes only partly white.

Stoats feed on small mammals, birds, eggs, frogs and occasionally invertebrates. The litter contains three to 13 young born after a gestation of as long as 10 months.

The winter-taken pelts, prized for fineness and pure colour, are among the most valuable of commercial furs and are obtained mainly in northern Eurasia.

Weasel

There exist some ten species of Weasel distributed between several genera. They are found in the Americas and in Eurasia. They are usually reddish brown with white or yellowish underparts; in winter the coats of those living in cold regions turn white and their pelts, like those of the Stoat, above, are known as Ermine in the fur trade.

They are active predators, feeding principally on rodents, fish, frogs and birds' eggs. They are valuable rodent controls, and can pursue their prey through holes and crevices, under dense herbage, up trees and into water.

Depending on the species, one or two litters of three to 13 young are born after a gestation period of 35 to 337 days.

Weasel fur is short and thick, with fair to good wearing qualities.

Wolverine

The Wolverine *(Gulo gulo)* lives in cold northern latitudes, especially in timbered areas around the world. It resembles a small Bear some 65-90 cm long, with a shoulder height of 36–45 cm.

The Wolverine is noted for its bad disposition, strength, cunning, fearlesssness and voracity. It is a solitary, nocturnal hunter preying on all kinds of game.

Litters contain one to five young, but the gestation period is unknown.

The course, long haired coat is blackish brown with a light brown stripe extending from each side of the neck along the body to the base of the tail. It has good wearing qualities and is valued for trimming parkas, as frost and frozen breath can easily be brushed off the smooth hairs.

Appraisal of Mustelids

The animal welfare lobby has proved itself effective in disrupting the farming of fur animals and in discouraging the demand for fur garments. The various pressure groups involved are highly motivated and still active. Unless fur producers can devise farming methods which are seen by the general public as being more humane, then it is likely that they will have to continue to contend with this lobby.

NUTRIA

Also known as the Coypu, the Nutria *(Myocastor coypus)* is a semi-aquatic rodent, originally from South America. Its fur is short and dense with fair wearing qualities. In South America the meat is widely eaten. Nutria are about 1 m long and may weigh up to 8 kg. They live in shallow burrows along rivers and feed mainly on aquatic plants.

Females produce up to three litters of two to eight young per year, with a gestation period of about 135 days.

In the UK, Nutria have been bred in captivity for their fur. Some have escaped, or have been set loose by members of the animal welfare lobby, and have become agricultural pests. In some areas, Nutria compete with other wildlife for food.

The future of Nutria production will depend on whether producers can devise farming methods which are acceptable to the animal welfare lobby.

OUTDOOR PIGS

Since feed accounts for 70% of the costs of Pig production, outdoor systems are suitable for breeding sows only. In the UK at present there are some 850 000 breeding sows.

Boddington (1971) studied the economics of outdoor Pig systems in the late 1960's and concluded that Pigs kept out of doors were in no way less profitable than those kept intensively. Outdoor systems performed badly on productivity indices, the number of litters and reared piglets per sow per year being less than in indoor systems. Lower prolificacy, however, was more than compensated for by a reduced labour requirement and by lower housing and other costs.

It is not altogether clear if, nowadays, outdoor systems actually do demand less labour. The evidence on this point is inconclusive. Ridgeon (1984) reported that labour costs per Pig were almost identical for both systems, this finding being based on a comparison of nine outdoor herds and 111 indoor herds in East Anglia. On the other hand, surveys performed in the West Country suggest that outdoor systems require only 66% of the labour input per Pig required in indoor systems (Burnside & Sheppard, 1985).

The latter surveys indicate that outdoor herds out-perform indoor herds in terms of revenue per sow per year after deduction of direct costs. Revenue per sow per year was £143 for outdoor systems, compared to £100 for indoor systems for the year 1983–84.

Evidence from East Anglia corroborates this conclusion. In outdoor herds, margin after total costs, excluding interest charges, was found to be £12 per £100 output for the year 1983/4. This is some 16% greater than the same index for indoor systems (Ridgeon, 1985).

Stocking rates of nine sows and litters per ha were the most common in Boddington's survey, although this was found to go up to 25 per ha in some cases.

The advantages of outdoor production are as follows (Boddington, 1971).

(i) Profitability compares favourably with the indoor herd.

(ii) Strong, healthy store pigs are produced for which there is a good demand.
(iii) Labour costs are lower than for the indoor herd.
(iv) There is no slurry problem.
(v) Capital outlay is low.

The same author listed the following disadvantages of keeping pigs outside.

(i) Productivity tends to be low.
(ii) It is hard to manage individual animals and controlling pigs is not easy.
(iii) Barren sows and sterile boars may be carried for some time before their infertility is evident.
(iv) The enterprise is generally restricted to light land.
(v) Fencing requirements may be heavy and sows may not respect the fences.
(vi) Mud can become a major problem in winter.
(vii) Visiting the herd on outlying land, especially in winter, may be a difficult task.
(viii) Foxes may take young pigs and birds will almost certainly steal food.

RABBITS

Rabbits reared in indoor systems

Fibre production

Both Angora and Common Rabbits produce fibre that is used commercially. Angora Rabbit hair is a speciality fibre used for luxury fabrics, whilst fibre from the Common Rabbit is generally used for making felt. These two different types of Rabbit fibre are discussed separately below.

The hair of the Angora Rabbit is prized for its fineness, soft texture and lustre. It is used mainly for high quality woven fabrics, knitted goods and knitting yarns.

Angora Rabbits are reared specially for their fibre and are usually sheared, clipped or plucked four times a year, allowing the hair to grow to some 8–9 cm. Each Rabbit yields 200–400 g of hair per year, with a low percentage of course guard hair.

It appears that no Angora Rabbit hair is currently produced in this country. Our imports are substantial: in 1983 they totalled £6.2 M (HMSO, 1984) rising to £6.9 M in 1984, this representing nearly 500 t (Confederation of British Wool Textiles Ltd–personal communication).

Unspun Angora Rabbit hair retails in the UK for about £60 per kg and is thus in the same price bracket as Cashmere and Camel hair, which retail at £80 per kg and £70 per kg respectively (Gough, A–personal communication).

Common Rabbit fibre is used for felted fabrics and also for knitted goods. Manufacturers favour fibre from the domesticated White Rabbit, but do use a certain amount of fibre from Grey Rabbits.

Much Common Rabbit fibre is supplied to the textile industry as a by-product of the manufacture of fur hats and garments. Some of the fibre so supplied is known as *boiled fur* since it is obtained by boiling waste pieces of pelts in a sulphuric acid solution, which frees the fibre. Another source of fibre is pelt shearings.

Unlike wool, Rabbit hair requires special processing for felt manufacture. Its ability to absorb and retain moisure is slightly less than that of wool. Alkalis and hot water tend to damage the fibres.

It is difficult to know the quantity of Common Rabbit hair consumed by the UK. It appears, however, that the UK imports all its requirements from China. Common Rabbit hair retails, unspun, at £20 per kg (Gough, A–personal communication).

Meat production

With a level of output of 15 kt of Rabbit carcase per year, the UK ranks as a small Rabbit producer. The major European producers are France, Italy and Spain, all of which produce about ten times the output of the UK (Commercial Rabbit, 1984). It is estimated that there are some 300 000 breeding does in the UK.

UK consumption of Rabbit meat is low for three reasons:

(i) the retail price of Rabbit (180 p per kg) is approximately twice that of Chicken (90–100 p per kg);

(ii) many potential consumers tend to regard Rabbits as pets and are therefore reluctant to purchase Rabbit for eating;

(iii) in the past, Rabbit was regarded as *poor man's* meat and this stigma is still prevalent amongst some older people. In the future, this source of consumer resistance is likely to disappear.

Rabbit meat, however, does have the important advantages of having a low content of both fat and cholesterol.

A proportion of UK output is exported to France, Italy and Spain. The size and stability of this market is, at the moment, unclear. Of greater significance, perhaps, is the fact that the UK regularly imports Rabbit carcases from China and Poland. These imports comprise smaller Rabbits which are more boney than those produced by domestic suppliers.

Also of significance is the importation by the UK of Rabbit feed from France. The extent to which this occurs and the reasons for its are not clear at present.

The Rabbit industry is characterised by a small number of comparatively efficient and large-scale producers and a plethora of small-scale producers. The former type of producer is often able to take advantage of economies of scale – particularly by forward contracting his output – and may well have bred superior lines.

In contrast, the small-scale producer is likely to be inexperienced, short of capital and at the mercy of the market in terms of both feed costs and the price for his produce. Many such producers regard Rabbit production as a way in to *proper* farming. However, intensive Rabbit production is a precarious undertaking and it is difficult to get reliable advice on husbandry techniques. It is not surprising, therefore, that many such producers become disenchanted and then leave the industry. Commercial Rabbit production has thus acquired the sobriquet: *the 18-month industry.*

A handful of companies service Rabbit producers. The major feed companies supply compounded rations. Packers process and market the Rabbits, often entering into contractual relations with the producers for a fixed supply at a predetermined price. Several companies, which may also operate as packers, supply housing and breeding stock to newcomers to the industry. It is reported that it is these latter firms who make the money out of Rabbit production, there always being a small stream of potential producers requiring training and the materials to set up a Rabbit enterprise.

It has recently been calculated by one of the trade magazines that the gross margin over feed in a 100-doe enterprises would be £45 per doe per year. However, this estimate is highly dependent on a number of parameters, particularly the farmgate price of meat, the price of feed and average litter mortality. Moreover, no allowance is made for interest on capital, depreciation of capital equipment or the cost of labour.

In contrast to the Cattle, Sheep, Pig and Poultry industries, the Rabbit industry has never been the recipient of large-scale research funding. Rabbit producers themselves tend to operate on a small scale and in a risky environment and are therefore reluctant to undertake experiments on what may often be their only source of income. Thus there is a relative dearth of objective technical knowledge of husbandry techniques.

Concerning the technology of Rabbit production, there are four areas where greater technical understanding may well have a significant effect on financial performance.

(i) Bronchial and enteric disorders are important causes of post-parturition mortality, incidence of which is estimated to be 12% nationally. The enteric disorders are likely to be caused by a disease – diet interaction, and are poorly understood at present.
(ii) The manner in which feed is presented, type of housing and method of waste disposal are examples of just some of the many husbandry aspects which have received very little, if any, attention by researchers.
(iii) Comparatively little breeding work has been conducted. High quality genetic material exists but has yet to be exploited. Improved feed conversion ratios (ratio of weight of feed dry matter to wet weight of carcase) – currently in excess of 3:1 – would be one important benefit of selection.
(iv) Sudden and inexplicable depressions in doe fertility are often noted by producers. Whilst the physiological basis of such depressions may be known, it is not clear which factors in a production context are responsible.

Concerning the marketing of Rabbits, it has proved impossible to introduce any price agreements between the fragmented small-scale producers on the one hand and the small number of packers on the other. A structured price system was set up, through the British Rabbit Federation, to provide high quality producers with a floor price for their product, but this scheme collapsed after one year when one of the packers withdrew its support.

Another difficulty concerning the marketing system appears to arise from the dispersed nature of production, with packers incurring high haulage charges relative to the quantities collected. These costs are passed back to the producers, thus squeezing margins.

Feed conversion ratios for commercial Rabbits are generally greater than 3:1 compared to 1.6:1 for broiler production. The future of the Rabbit industry thus depends to a large extent on lowering this ratio. Given the fast reproductive cycle of Rabbits, more efficient lines could be generated fairly rapidly.

A second important factor is the value of Rabbit pelts. At present demand for pelts is very low and producers currently receive nothing for their pelts. If lines were bred giving higher quality pelts, then the financial attractiveness of Rabbit production might well be improved.

The extent to which domestic producers can compete with the smaller-sized Chinese imports should be examined. The extent to which a stable and remunerative export market exists should also be determined.

The larger European producers have conducted substantial research on intensive Rabbit production and it is suggested that the extent to which UK producers can benefit from this research should be determined. This should precede any cost-benefit studies of research projects sponsored by the UK authorities, farmers' organisations or consortia of farmers.

Outdoor Rabbits

It is a somewhat curious feature of the British psychology that more use is not made of the Common Grey Rabbit which over several centuries has adapted itself very successfully to much of the country's grassland. The Rabbit is considered by most farmers as a serious agricultural pest and is thus the target for eradication schemes. Its abilities, however, to convert food efficiently, to survive myxomatosis, to build its own shelters, to furnish man with a low-fat meat at very little financial cost, and above all, to reproduce itself at a notorious rate have all been overlooked. This is paradoxical, especially when one realises that, in the past, wild Rabbits were of great importance as purveyors of protein to the large metropolis and to the country's industrial centres (Humphreys, 1985).

One factor that may account for the Rabbit's demise as a food item, is myxomatosis which broke out first in the 1950's. Prior to this, in the 1930's, about 1.36 kg per caput of Rabbit and game were consumed in the UK each year. But since the advent of myxomatosis, annual consumption has fallen to around 84g per capita (Walsingham, 1972).

Wild Rabbit populations are about 20% of their pre-myxomatosis levels and are rising steadily. The increase has resulted mainly from the reduced effect of the disease, due to the spread of less virulent strains and, more recently, the development of inheritable resistance in the rabbit (MAFF, 1984).

A full-grown adult Rabbit weighs between 1.1. and 2.2 kg and eats about 0.5 kg of green feed a day. The breeding season lasts from late January to July or August, although some sporadic breeding occurs throughout the year. Does generally produce about 22 young per year although the potential is 80 young per year. An adult female will produce four to six litters annually and females born early in the year may start to breed later in the same season. Wild Rabbits usually conceive within 24 hours of giving birth; a doe is continuously in oestrus during the breeding season, except when pregnant, and ovulation is induced by mating.

Gestation lasts 28 to 30 days, and most litters contain three to seven young. In the wild, however, most young Rabbits (about 90%) die from a variety of causes before the end of the year (MAFF, 1985).

A number of institutes in the UK have conducted research on Rabbit production, the most important of these being the former Grassland Research Institute.

It is unlikely, however, that wild Rabbit production would be as straightforward as it may at first appear. No warren would be safe from myxomatosis unless a vaccine was developed or a biological control agent was found. Neo-natal mortality rates are high and research would be required to reduce them. Grazing areas would have to be well fenced, not only to retain the Rabbits, but also to prevent the entry of predators. Present legislation prohibits the artificial spreading of Rabbits.

Lastly, it is doubtful whether wild Rabbit farming would compete financially with store Cattle or Sheep production, and thus it would be limited to areas such as moorland and heathland. But there may be scope to integrate Rabbit production with Cattle production, since the latter do not graze pastures closely, as Rabbits do.

REINDEER

Reindeer *(Genus Rangifer)* belong to the family *Cervidae* and are domesticated in some polar regions. In North America they are known as Caribou. The Lapps of northern Scandinavia keep Reindeer as a draft and pack animal, for meat and milk, and for hide, used in making tents, boots and clothing. Reindeer milk is reported to have a protein content of 10%, compared to that of Cows' milk at 3.5% and a fat content of 22% (cf fat content of Cows' milk of 3.7%).

Reindeer stand 0.7–1.4 m at the shoulder and can weigh up to 300 kg. Small, domesticated races are about the size of donkeys. They are stockily built, and have lateral hooves that allow the feet to spread on snow or soft ground. Reindeer are strong swimmers and are always found in herds, some of which are famous for their seasonal migration between summer and winter ranges. Males fight fiercely for harems, and breeding is during the autumn. Gestation is seven and half months after which one or two calves are born.

The staple winter food of Reindeer is a lichen *(Cladonia)* popularly called Reindeer moss, which the animals reach by scraping the snow away with their feet. In summer, the diet also includes grasses and saplings.

In Scandinavia, Reindeer meat is consumed as a luxury item outside the Lapp economy and plays the same role for Scandinavian consumers as venison plays for British gastronomes. No information on Reindeer performance in the UK has been found, but there may be a role for Reindeer in the harsher environments in Scotland.

Sheep production for fine wool

Ryder has estimated that the UK imports some £70 M of fine wool each year (Ryder, ML–personal communication).

The finest Sheep wool in the world is obtained from the Merino breed which originated in Spain. Over the last 200 years breed improvement has occurred in Western Europe, particularly in France and Germany, but the greatest advances have been made in Australia.

At present, there exists only a handful of Merino flocks in the UK and several of these are used for experimental purposes rather than for the production of wool.

There are four reasons which probably explain the reluctance of the UK Sheep industry to exploit the potential offered by the Merino. First, Merino are reputed to have irredeemably low prolificacy. In Australia, lambing percentages are certainly low at an average of 70% for the breed. However, selective breeding has cured this in the Soviet Union, for instance, where lambing percentages for Merinos are reported to be 135% on average (Chaffey, 1985). Furthermore, it should be noted that the Booroola strain, developed in New Zealand, on average produces 0.6 more lambs per ewe than any other Merino (Ryder, in press).

Secondly, it is often held that Merino Sheep produce carcases of very poor conformation. This is certainly true in the arid lands of Australia where wether flocks are run exclusively for wool production. However, the belief that poor carcase quality is immutable is refuted by the development of, amongst other strains, the German Mutton Merino. This strain has a 6-month body weight of 40 kg (Ryder, 1975), while mature ewes weigh 70–80 kg (Chaffey, 1985).

A third reason that has discouraged research and development of the Merino breed is the belief that the introduction of genes for fine wool into British breeds would cause a deterioration of other characteristics. However, there is no evidence of any absolute genetic antagonism between fine wool and other characteristics. The Southdown, which is one of the best meat breeds in this country, and which also has the finest British wool, illustrates the point that genetic antagonism need not necessarily occur.

The fourth reason is that UK Sheep farmers derive only a small proportion of their income from wool. Chaffey (1985) has calculated that the proportion of total income derived from wool for lowland and upland sheep farmers is 10% while the corresponding figure for hill producers is 18%. Farmers, therefore, appear to have little incentive to concentrate on improving the quantity or quality of fleeces. Such calculations, however, are greatly affected by both fleece weight and price per kg.

The first trial with Merino Sheep in the UK in recent times was undertaken in Cumberland during the 1950s and involved crossing Merinos from New Zealand with Herdwick Sheep. Burns (1955) reported on this study and concluded that in the crossbred progeny there had been considerable improvement in the fleece, with little loss of carcase quality and no evident loss of hardiness.

In 1955, the Animal Breeding Research Organisation (ABRO) imported a number of Tasmanian Merinos with very high quality wool. The ABRO's experience has demonstrated that Merino Sheep can survive in the UK with no deterioration in wool quality. Fleece rot has not proved to be a problem.

A number of cross-breeding programmes have since been initiated. ABRO found that Merino-Cheviot crossbreds yielded wool with Merino characteristics. In Scotland, Merino and Blackface crossbreds were found to yield 43% more wool than purebred Blackface; furthermore the wool was of higher quality (ABRO, quoted in Chaffey, 1985).

Tempest & Boaz (1977) investigated growth rates of different Merino crosses, and found that liveweight gain increased as percentage of Merino blood fell. However, when growth rate was related to mature body size, it was revealed that rate of mature weight gain was the same across all genotypes. The implication is that acceptable growth rates could be obtained from Merino-cross lambs if a large-bodied Merino strain was used.

Wool fineness does not appear to be affected by high levels of nutrition. One flock of UK Merinos is kept in an area of 600 mm rainfall and the *cauliflower* closeness of the fleece has been found to turn rain well. However, leg and belly wool can become soiled when Merino are kept on heavy land and this lowers the price received for the wool (Chaffey, 1985).

Regarding carcase quality of crossbred lambs, Chaffey (1985) reported that Merino-Suffolk cross lambs at seven months gave a carcase weight of 18–20 kg. Merinos are a slow-maturing breed and thus there is little benefit to be gained in feeding concentrates to lambs. However, they do have the advantage of leanness in the carcase; an attribute that is important in a country where consumers are becoming increasingly conscious of the health hazards of high-fat diets.

Chaffey (1985) has made some preliminary estimates of gross margins of Merino production in the UK. He concluded that, in most cases, when compared with gross margins for non-Merino Sheep systems, Merino systems are more profitable. Only in the instance of a lowland system with frequent lambing (ie 2.5 lambs reared per ewe) do non-Merino systems appear more remunerative than Merino systems.

There would thus appear to be a strong case for examining the feasibility of finer wool production in the UK, particularly as Sheep utilise substantial areas of land in a fashion consistent with amenity use. There is already extensive experience of Merino-British breed lamb production under Australian and New Zealand conditions.

Imports of fine wool to the UK total 30 kt per year. European Merino crosses yield fleeces of 4.5 kg, which is equivalent to 3 kg clean wool. 10 million fleeces per year would therefore substitute for the nation's imports of fine wool. At a stocking rate of 12 ewes per ha, the area of land required would therefore total 800 kha.

In addition, it is important to recognise the scope for increasing home-production of wool that is finer than the average UK clip, but produced from existing British breeds, without further crossing. There are prospects for substituting for imports and increasing exports of these finer wools, including their use as mixtures (eg with Mohair). Some price incentive might be necessary to encourage such production, but it could be achieved quite rapidly.

Sheep production for milk

During the Middle Ages many Sheep were kept for their milk. Hunt (1985) reports that, in the 14th century, Canterbury Cathedral estates were milking 6 000 ewes. Wensleydale cheese was originally made from Sheep's milk. However, the cow rose in popularity and this led to the demise of sheep dairying. Now, in terms of gross agricultural product, Sheep dairying is almost insignificant. However, it is expanding dramatically. No official data exist and it is not clear how precise the available estimates are regarding current expansion rates. In 1982, it was estimated that there were 20 milking flocks in the UK (McAleer, 1982). In 1985, Mills estimated that this number had risen to 150, and that the population of milking ewes was about 5000. Flocks of up to 300 ewes exist in the UK (Mills, O–personal communication) although the majority appear to be much smaller.

The dramatic growth of this industry has been due to the high prices offered by consumers for fresh Sheep's milk, yoghurt and cheese, and the relative ease with which smallholders and farmers can start a Sheep's milk enterprise.

Sheep's milk has a total solids content twice that of cows' milk. Like Goats' milk, it meets a specialist demand from consumers who are allergic to Cows' milk. In France, milk from the Lacaune breed is used to make Roquefort cheese, and it appears that UK Sheep's cheese benefits from this *gourmet* connection. Only 4 l of Sheeps milk are required to make 1 kg of hard cheese, compared to 10 l of Cow's or Goats' milk for the same weight of cheese.

The premium that consumers are willing to pay for Sheep's milk products is reflected in supermarket prices. In August 1985, Waitrose in Reading was retailing Sheep's milk yoghurt (imported from Greece) at about £2 per kg in comparison to Goats' milk yoghurt at £1.73 per kg and Cow's milk yoghurt at £1.06 per kg. Roquefort was retailing at about £9 per kg and was twice the price of Camembert and the most expensive English cheese (Waitrose–personal communication). Fresh Sheep's milk retails at about 97p per l (Mills, O–personal communication). This compares with 39p per l for Cows' milk and 63p per l for Goats' milk (Waitrose–personal communication).

Sheep dairying is a novel activity in the UK and thus relatively little research has been done on breeding, nutrition and management. Most dairy ewes are of the East Friesland breed (also known as British Friesland) which originated in Germany. Ewes of this breed yield at least 3.5 l per day for the first eight weeks of lactation and, over a seven month lactation, will produce 400 l (Treacher 1981). The British Friesland Society claims that yields of 9 l per day have been obtained from some ewes, and 600 l in a lactation, giving some 120 kg of hard cheese (McAleer, 1982). British Milksheep have risen in popularity over the last few years, but their numbers are small relative to the East Friesland breed.

Other breeds which may have potential as milk producers are the Colbred, the Cambridge, the Texel and the Dorset Horn, amongst other possibilities (Mills, 1982). One important advantage of the East Friesland breed is its prolificacy, as it is able to breed out of season. Ewes kept at the Animal Breeding Research Organisation have recorded lambing percentages of over 200 (McAleer, 1982). One UK flock of British Milksheep, however, has recorded a lambing percentage of 300% with quadruplets and quintuplets apparently quite common (Hunt, 1985).

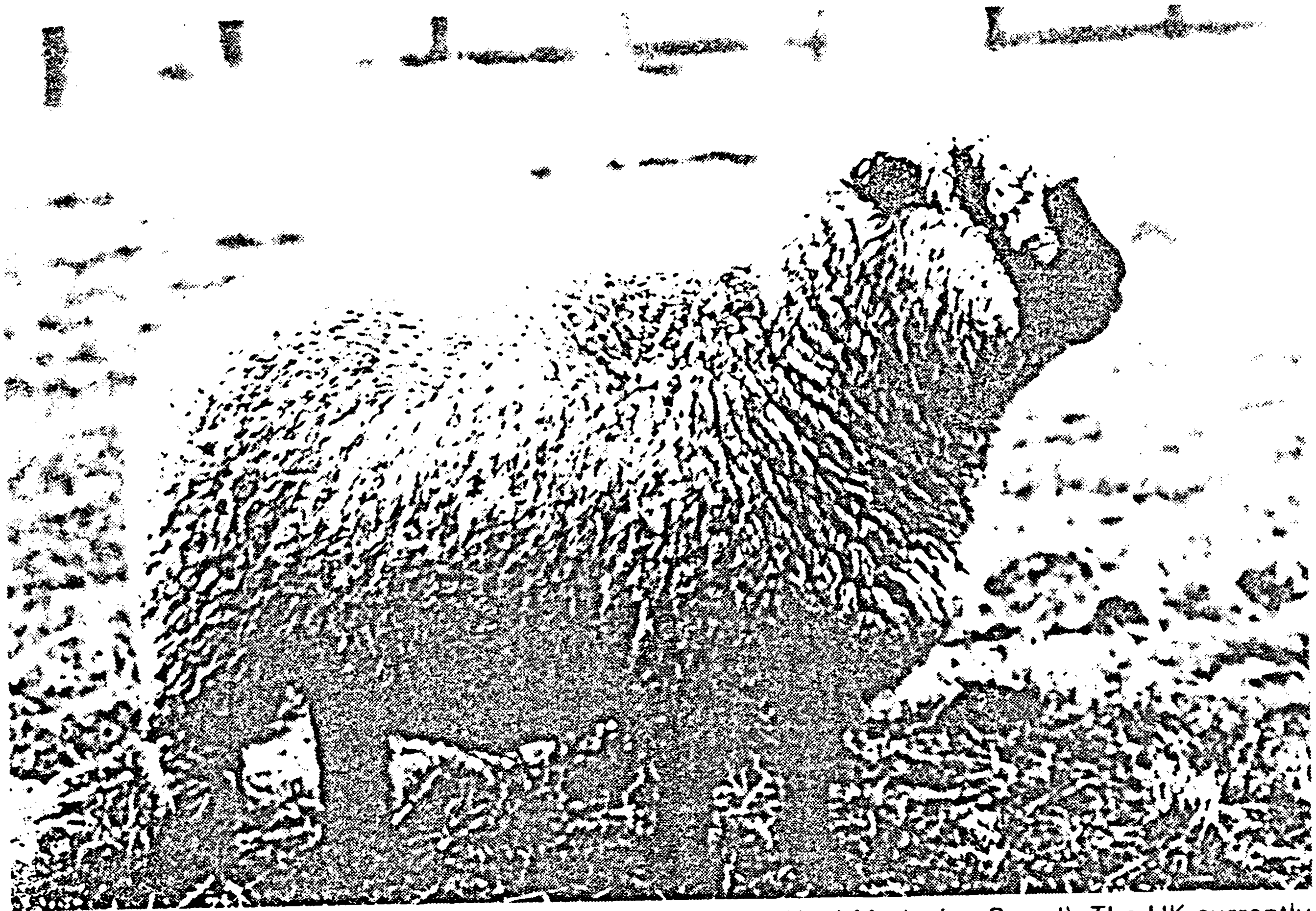
Some flocks in the UK are milked once a day, the lambs being allowed to suckle for restricted periods. However, the high opportunity cost of milk means that practically all flocks are milked twice a day, either by hand of by machine.

Lactation milk yields are highest from the third to the sixth lactation, after which yields fall rapidly, due possibly to dental failure (McAleer, 1982).

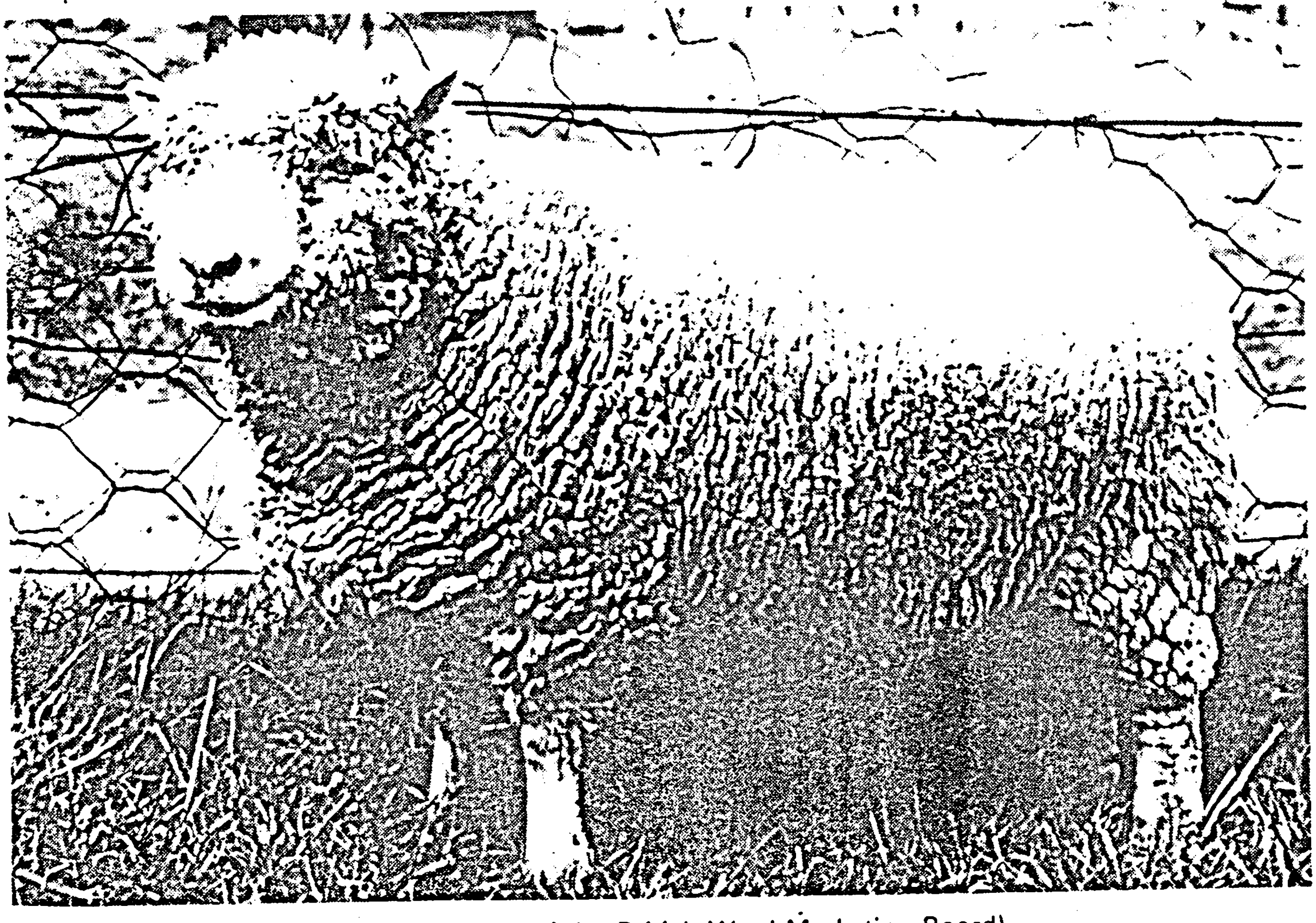
A particular problem encountered with dairy Sheep is their inability to ovulate during lactation; this means that ewes have to be dried off before re-conception. It is not clear, however, what causes this

Ripening bolls of a Linseed crop. Linseed does well in cool humid conditions on soils which are near-neutral. (Photograph courtesy of MAFF).

Inflorescence of Borage. This spring-sown crop is grown for its seed oil which contains a high content of gamma linolenic acid and is used in the pharmaceutical industry. (Photograph courtesy of MAFF).



The Hampshire Down. (Photograph courtesy of the British Wool Marketing Board). The UK currently imports some £70 M worth of fine wool each year. Although the Merino breed produces the finest sheepwool, the breeds shown here (and others) produce wool that is finer than the average UK clip.

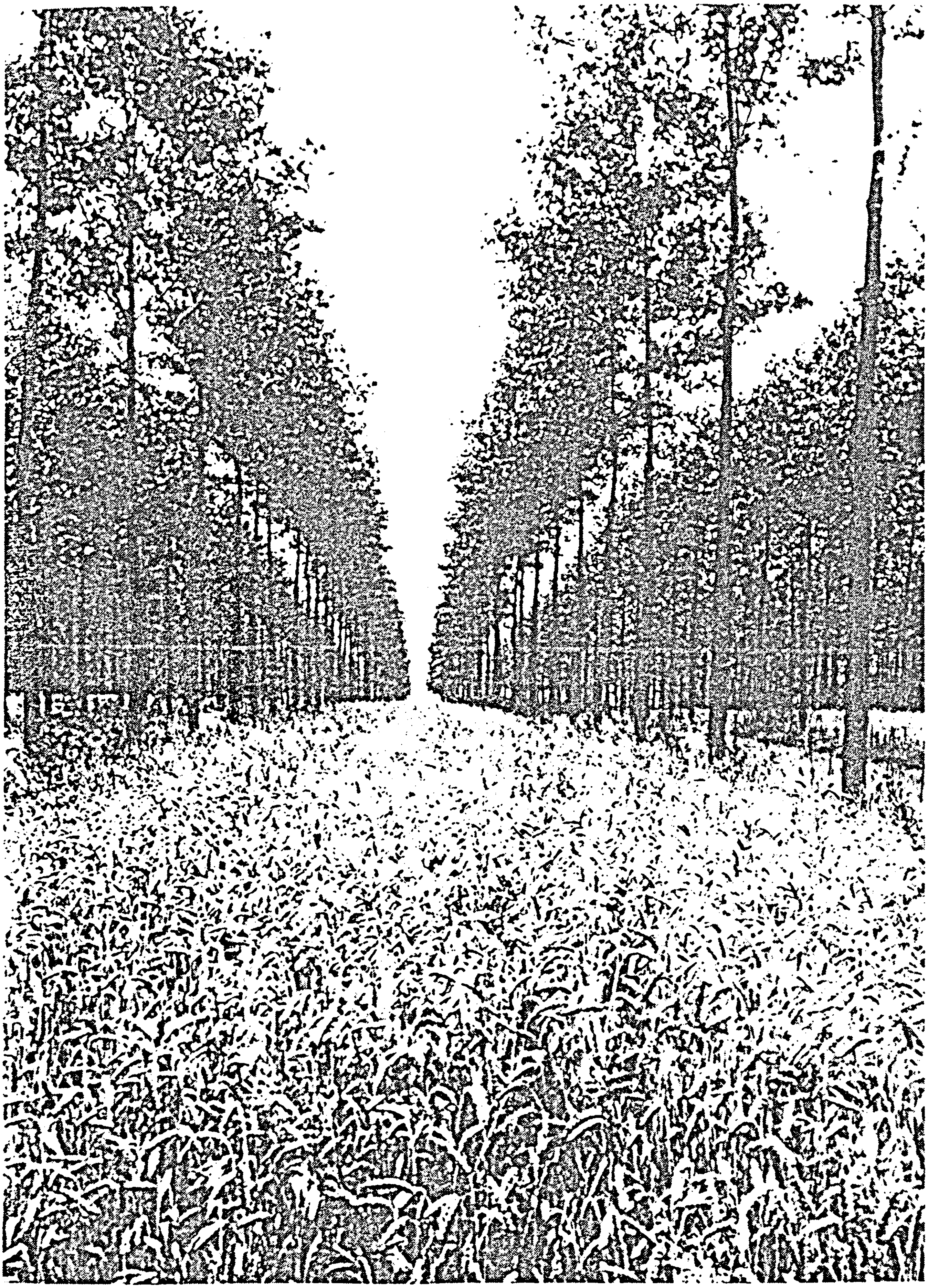


The South Down. (Photograph courtesy of the British Wool Marketing Board).

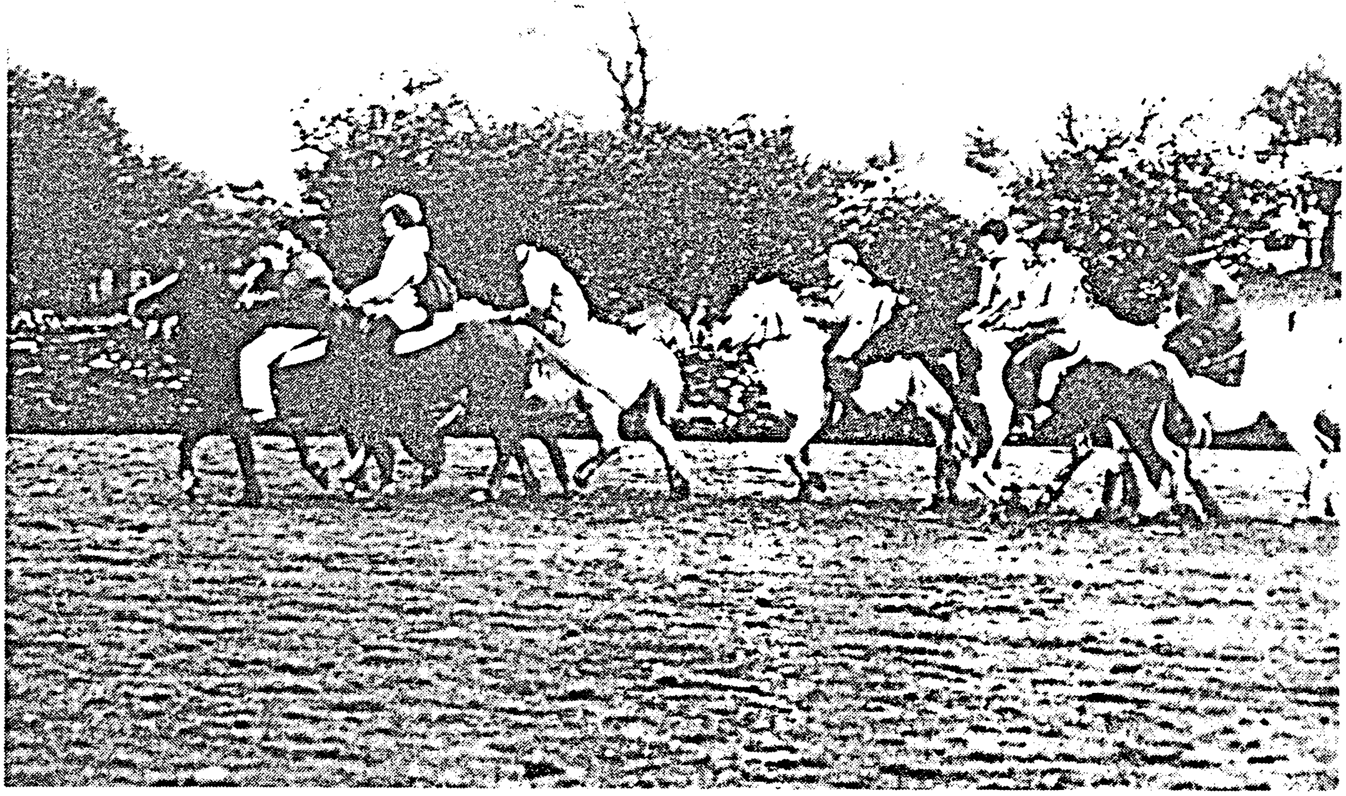
Prototype coppice harvester developed at Loughry College of Agriculture and Food Technology, Northern Ireland. Short rotation coppice yielding up to 15 t DM per ha per year could be used for large-scale wood energy plantations. (Photograph courtesy of C P Mitchell).

Cattle grazing amongst 3 year old Radiata pines in New Zealand. Experience in New Zealand suggest that, in some circumstances, agroforestry can be more profitable than either agriculture or forestry alone. (Photograph courtesy of the Forest Research Institute, New Zealand).

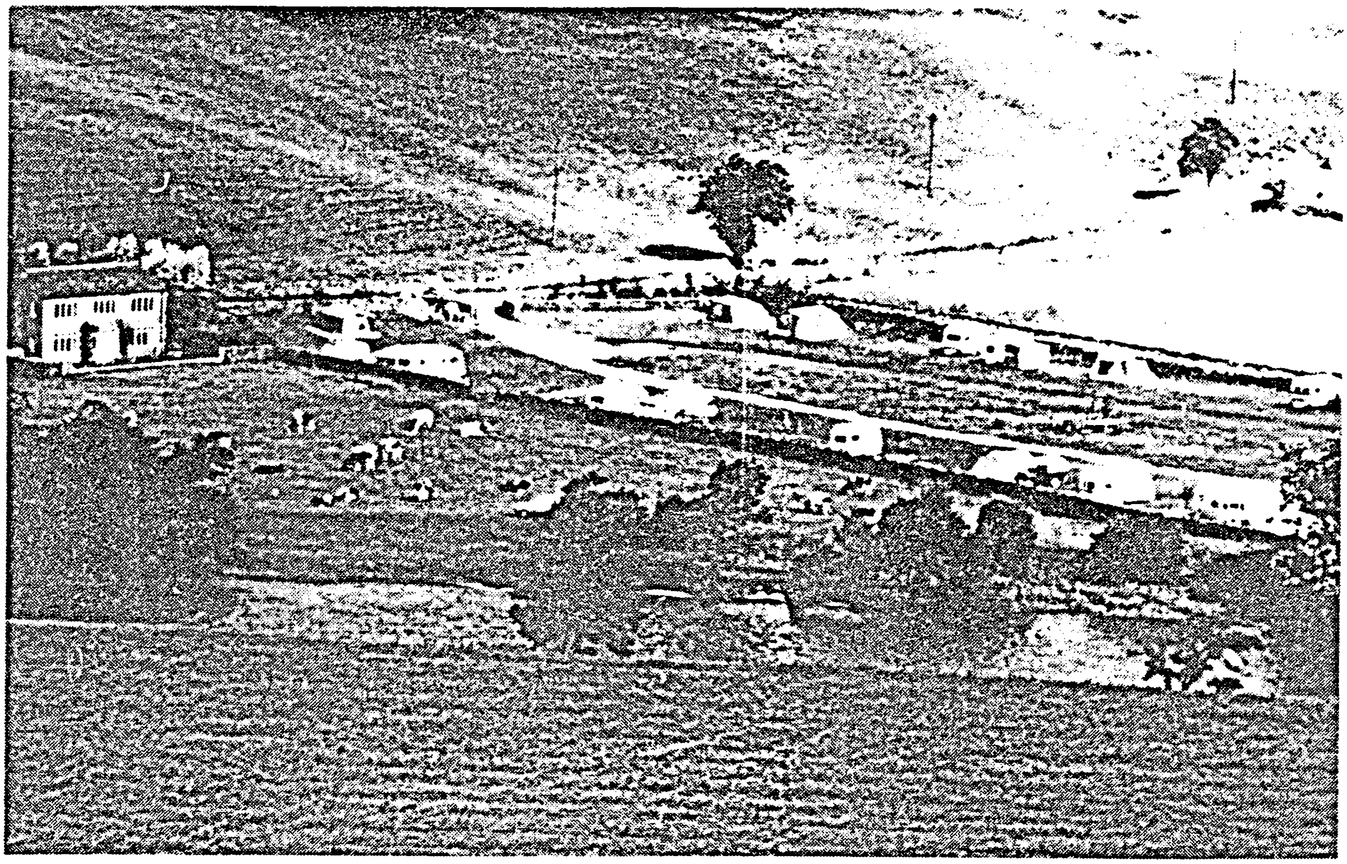
Sheep grazing between 16 year old Radiata pines thinned to 200 stems per ha. Agroforestry systems of this type, but adapted for UK conditions, could prove a viable alternative land use in both the uplands and lowlands. (Photograph courtesy of the Forest Research Institute, New Zealand).



Mixed cropping of Wheat and Poplars at Bryant and May, Risbury, Hereford. In this system Poplars were planted at 185 stems per ha and intercropped with wheat for 7–9 years followed by grazing. (Photograph courtesy of TV Callaghan).



Pony trekking in the Black Mountains near Hay-on-Wye. Such a farm-based enterprise, whilst not using much land, can provide useful additional income for the farm business. (Photograph courtesy of W Seabrooke).



Multiple land use in the Yorkshire Dales National Park. An integrated business like this one which has a dairy enterprise, lets fishing by the day and provides camp and caravan pitches is able to obtain a higher income than a pure farm business on similar land. (Photograph courtesy of W Seabrooke).

lactational anoestrus; Hunter (1968) suggests that the metabolic load of milking is the cause. Rhind *et al* (1980) consider prolactin released during lactation is the reason, and other theories have been offered.

With those Sheep breeds that ovulate seasonally, milk output from the flock obviously fluctuates throughout the year, and this may cause marketing problems. Indeed, in France the factories that produce Roquefort cheese close for the winter months when milk production is low. Some UK producers have overcome this problem of seasonality, however, by forming summer and winter flocks.

Mills (1982) states that most of the nutrition research concerning dairy ewes has focused on housed animals, and is thus of limited assistance to most producers. Furthermore, no concentrate feeds have been formulated for dairy ewes.

McAleer (1982) calculated gross margins for an early lambing enterprise and a milking Sheep enterprise. For the former, gross margin per ewe was £25.50 per year, whilst for milking Sheep it was £274.00 per year. In the milking Sheep enterprise milk output of 675 l per ewe was valued at 40 p per l to give a return per ewe from milk alone of £270. In the system examined, milking was by hand. In his calculation no charges were made for labour. For smallholders and farmers with spare family labour, therefore, Sheep dairying may be a very attractive proposition.

The British Sheep Dairying Association has been formed and has a current membership of about 200. The Association is optimistic about the future of Sheep dairying in the UK.

At present, there is no specific health legislation pertaining to Sheep's milk production and there have been instances of food poisoning from UK Sheep's cheese. There may thus be a role for a measure of health control, although some producers fear that if controls are too rigorous then the expansion of Sheep dairying may be severely curtailed.

YAK

The Yak *(Bos grunniens)* is large, massively built and inhabits some of the most inhospitable regions of the earth. 12 million Yak, being 85% of the world Yak population, are found in China (Zhang Rong-Chang, 1985) where they survive on the Tibetan plateaux at altitudes between 4 300 and 6 100 m. The remainder are found in Afghanistan, Pakistan, Nepal, Bhutan, Sikkim, Northern India and the Soviet Union. There are an unknown number of wild Yak, mainly in Northern Tibet and these are classed in the Red Data Book as an endangered species.

Domestic Yak are the basis of the economy in many of these harsh environments. They are used as pack and saddle animals, and in those areas where cultivation can be practised, they are used for ploughing and threshing. Milk (particularly for butter making) and beef are important products. Their fibre is used for making tents, ropes and carpets and their hides provide leather. Their dried dung is the only obtainable fuel in these treeless regions. Yak are reported to be docile and easy to manage.

In China, Zhang Rong-Chang, (1985) reported that Yak cows lactate for 100-180 days and yield 450-600 kg during a lactation and that the milk has a fat content of 6.85%. The National Research Council (1983), however, reports that yields can exceed 1000kg in a lactation. In Sikkim, Katiyar & Sinta (1983) report that age at first calving is 4–4.5 years and average gestation period is 285 days. The National Research Council (1983), however, states that gestation length is 258 days.

Domestic Yak breed freely with Cattle, and the fertile offspring are known as Dzo. These are often preferred for ploughing.

From the UK's point of view, Yak are important for their fibre. Textile companies have traditionally imported Yak wool and hair for many decades. In their natural habitats, the cold season lasts as long as eight months of the year and during this period the wool grows densely among the course hair. The latter itself grows profusely, wrapping the animal in a thick layer of air and protecting it against frost-bite. Yak fibre yields for the Chinese province of Gansu are shown in Table 3.5.

It is extremely difficult to ascertain the quantity and value of Yak fibre imports. In the official statistics, Yak fibre is grouped with other speciality fibres. One importer reported that he had not imported either Yak wool or hair for many years and it would appear that this is due to two reasons. First, the producer countries, particularly China, are consuming more of their own output themselves, and secondly, weather conditions in recent years have killed many Yak, thus severely reducing fibre supply (Wool Record, 1985).

Table 3.5
Yak fibre yields (kg per animal per year)

	Male	Female
Hair (greasy)	3.62	1.18
Wool	0.4	0.75
Tail fibres	0.62	0.35

Source: Adapted from Zhang Rong-Chang (1985)

The Yak's hairy coat reduces its ability to sweat and thus it has difficulty eliminating surplus heat. In warm climates, respiration rate and body temperature increase and the animals become exhausted and susceptible to infection. It is reported that, at low altitudes in Nepal, Yaks die of a variety of diseases. Apparently not even Yak-Cattle hybrids can successfully live below 700 m in Nepal. The US National Resesarch Council (1983) consider that this is due to overheating, since during the first half of this century Yak lived successfully at low altitudes in Alaska and northern Canada.

Regents Park Zoo has successfully developed techniques for deep freezing Yak semen which should prove invaluable in any future breeding work.

FREE-RANGE CHICKENS

The demand for free-range eggs has grown spectacularly over the last five years and it is estimated that over this time free-range eggs have increased their share of the egg market from 1% to 5% (Morris, TR-personal communication). The rise of the free-range egg is due to the demand by consumers for eggs which they regard as healthier than those produced in batteries. Some of the popularity of free-range eggs may also be due to consumers consciously choosing not to buy products produced in conditions which they find unacceptable.

Whilst free-range egg production has expanded, there does not appear to have been a comparable expansion of production of free-range Chicken meat. This study considers the likely development of both free-range egg production and free-range Chicken meat production.

Free-range egg production

Free-range Hens require more feed than housed birds for the same quantity of eggs produced. In addition, egg production from Free-range Hens requires more labour and more skill than do conventional housed systems. Furthermore, housing costs for free-range Chickens are, somewhat paradoxically, higher per Hen than for battery systems. Nevertheless, the National Agricultural Centre (NAC) has found free-range egg production to be a lucrative activity (*Farmers Weekly*, 1985a). In a 52-week laying period, NAC calculated that gross margins on a flock of 304 Hens kept under free-range conditions were £8.19 per bird. This compared with a gross margin of only £2.31 per bird kept in battery cages in 1980. It has to be noted, however, that labour costs were excluded from this calculation.

In the NAC trial, the free-range Hens laid fewer and smaller eggs than caged birds, suffered higher mortality and ate more food, but the higher egg value more than compensated for their lower biological efficiency. NAC received 74p per dozen for free-range eggs compared to 48p per dozen for battery eggs.

It is unlikely that free-range egg production will continue to expand at the same rate as it has done over the past five years. The reason for this is that most of those consumers who are potential buyers of free-range eggs, will be able to purchase *barn eggs* less expensively than free-range eggs. Barn eggs have been defined by the Commission of the European Communities as those produced in deep litter systems, and such eggs carry a connotation of a healthy product, produced under humane conditions. Morris (personal communication) forecasts that, in the future, 50% of eggs sold will be battery eggs, one third will be barn eggs and the remainder (ie 16%) will be free-range eggs.

This forecast presupposes that the EC does not impose a ban on battery cages. The German and Dutch governments favour a ban, but so far the EC has failed to reach any agreement on this controversial issue, and this indecision is likely to persist. The British Government is able to act independently of Brussels in this matter, but is unlikely to do so (Morris, TR-personal communication). This means that the future structure of the egg industry will be decided by the prices that consumers are willing to pay for different types of eggs. In the short term, barn eggs will fetch a premium over battery eggs of some 5p per dozen, but the long term equilibrium premium (ie after contraction of production following oversupply) is likely to be only 2–3p per dozen.

The implications for agricultural land of this probable structure are two-fold: first, more land will be required to produce the additional feed and, second, more land will be required for rearing and housing chickens. Barn layers consume 10% more feed per egg than battery Hens and for Free-range Hens the equivalent increment is 20%. The laying fowl population of the UK is 36 million, and each bird consumes some 40 kg feed per year.

The future structure will therefore induce a 7% increase in the demand for feed, ie: demand will rise from 1.44 Mt to 1.54 Mt feed per annum. The feed comprises 75% European grown cereals (mainly from the UK) and 25% soya protein or maize gluten meal. Assuming no change in feed formulation, and an average cereal yield of 3t per ha, the land required to grow the cereal component of the feed will rise from 360 kha to 380 kha, an increase of 20 kha.

It is not altogether clear what egg producers mean by *free-range;* the Commission of the European Communities, however, has recently defined this type of production as, *inter alia,* having a maximum stocking density of one Hen per 10 square metres (Poultry World, 1985). If 16% of British hens are kept under free-range conditions, and at this specified density, 5 760 ha of land will be needed. Assuming that all free-range Hens currently in the country are kept at this specified density, 1-8 kha are used for their enclosures. Barn eggs are unlikely to require significant extra land. Another 24 kha (20 kha plus 4 kha) will therefore be required for the future pattern of UK egg production.

Free-range meat production

There exists a small market in the UK for free-range chicken meat and it is possible that such meat will supply 10% of the chicken meat market (Morris, TR-personal communication). Free-range birds raised for meat have a feed conversion ratio of about 2.3:1, which is higher than that for seven-week broiler production at 2:1. Hence, 15% more feed is required for the same weight of carcase meat.

If 10% of the market is supplied by free-range methods, feed requirements will increase by 1.5%. There are 400 million broilers in the UK, and feed consumption by the industry totals 2 Mt. The increase in feed is therefore 30 kt. Assuming that cereals comprise 75% of the ration and cereal yields are 3 t per ha, another 7.5 kha of land will be required for the additional feed required by the industry.

DUCKS

Egg Production

Very little information is available on Duck egg production in the UK. The foremost Duck breed is the Khaki Campbell which, when well fed and properly managed, can lay over 300 eggs per bird per year. Furthermore, their high egg laying rates continue for three to four years and laying Ducks therefore outlive laying Hens (MAFF, 1983).

Standard poultry layers' mash or pellets are suitable for laying Ducks which require about 180 g of pellets or mash and grain per day.

Housing is important for Ducks as 95% of eggs are laid during the night: if these are laid in the open then there is a high risk of loss by predation. For free-range systems it is usual to allow 0.5 ha for 100 Ducks.

It is possible that there is a large unsatisfied demand for fresh Duck eggs from the Chinese community in the UK.

Meat Production

It is difficult to ascertain the number of table Ducks consumed in the UK, but one estimate is one seventh of a Duck per head per year. The retail market for Duck meat is worth some £30 million a year (MacCarthy, 1984).

Ducks are produced by a small number of concerns located mainly in Norfolk, Lincolnshire and Wiltshire. Some 7.5 million birds are produced each year. A small number are imported from Denmark and Eire. UK producers, however, export oven-ready, frozen Duck to about 30 countries. There is even a demand in the Far East for Duck feet and tongues (MacCarthy, 1984). From each fattened bird, producers obtain 1 kg carcase and 1 kg feathers – the latter are a very valuable secondary product.

Ducks eggs can be kept under controlled conditions for up to seven days before being incubated under a broody bird or in an incubator. Eggs hatch in about 28 days. Ducklings reared for the table are fattened from about three weeks and are ready for slaughter at 7–8 weeks, when good table strains weigh 3 kg. Oven ready weight is a about 2.15 kg. The ducklings generally consume some 8.5 kg of feed per head, giving a feed conversion ratio of 2.82:1.

It is felt that a major expansion of duck production is unlikely. The reason for this is that ducks cannot at present compete with turkeys or poultry in terms of feed conversion efficiency. Producers are conducting research on nutrition and have already lowered the fat content of the carcase significantly.

GEESE

Geese used to be very popular in this country. Farmers kept them to guard buildings (Geese take exception to strangers and can honk and hiss very loudly), and flocks were frequently seen in the fields at harvest time, enjoying the stubble left in the fields.

For a number of years the breeding Goose population has declined. The market for oven-ready Geese is small compared with that for Chicken and Turkey and has been largely met from imports. This situation may have arisen from consumer resistance to what is traditionally considered as 'a large fat bird'. Recently a number of serious Goose breeders have arisen and are developing imported breeding stock.

The Goose is undoubtedly the least exploited of all poultry species which suggests scope for development.

In 1982, the UK produced some 200 000 Geese for meat – equivalent to 900 t (Prodfact, 1984). Practically all the output is sold for the Christmas market. Goose producers estimated that Christmas sales increased by

30% from 1982 to 1983; part of this increase is apparently due to the trend towards freezing Goose meat.

Goose eggs take about a month to hatch, and up to six eggs can be placed under a broody Hen, a method still favoured by many Goose breeders. Young birds from about three weeks old are put out to pasture (still the traditional way of rearing Geese). The Goose is a fast-growing bird, kept out in the open by day but brought into shelter at night. A diet of short-growing herbage is supplemented by special feeding stuffs.

Work in Canada indicates that, for the first three weeks, goslings grow best on a 20–22% crude protein feed in the form of 2.5–5.0 mm pellets. After this the crude protein level can be reduced to 17% and the pellet size increased to a minimum of 5 mm. On good grass the pellet feed can be restricted to 0.5–1.0 kg per Goose per week until 12 weeks of age. After this stage *ad lib* feeding is practised. For the smaller weight ranges, killed at nine to ten weeks of age, a higher proportion of compound feed may be necessary. Geese convert grass to meat inefficiently, compensating with a large throughput for their inability to digest fibre.

Breeders are specially concerned in the feeding of Geese to prevent over-development of fatty birds, no longer in public demand.

The production of Geese is geared to the autumn and pre-Christmas period because of their breeding habits. Goslings are hatched in the spring and producers have not yet found a way of producing a strain which will breed all the year round.

Geese are relatively free from most diseases, particularly when kept in small isolated groups.

The most likely disease problem is that caused by gizzard worm in young birds. This infection arises from continued use of the same pasture over several years. Regular dosing with recommended anthelmintic drugs, in soluble form, should control the problem.

The potential for expansion of the Goose industry would appear to be small, however, in relation to the Turkey and Chicken industries for which technology has been well developed and which go a long way to satisfying the public's demand for cheap and low fat meat.

GUINEA FOWL

Guinea Fowl comprise all seven to ten species of the family *Numididae*. One of these species, *Numida meleagris*, is widely domesticated for its meat and as a *watchdog* on farms.

UK consumption is estimated at 500–750 t per year (Cairns, -personal communication). Ten years ago, one UK producer was a monopoly supplier, but now the UK imports some 40% of its requirements from France and Belgium.

The technology of Guinea Fowl production is well developed. In the UK the birds are housed and, in winter, the houses are heated. Slaughter is generally at six weeks when the birds weigh about 1.5 kg. Broiler rations are used, and feed conversion ratios of 2.5–2.9:1 are obtained.

The principal constraints facing UK producers are therefore not technical; rather they derive from EC regulations and the competition faced from French and Belgian imports.

First, under the regulations, Guinea Fowl are classed as poultry, rather than as game. As such, they have to be eviscerated immediately after slaughter. Thus it is illegal to hang birds, a process that enhances the flavour of the meat. Cairns, (personal communication) reports that the potential demand for hung Guinea Fowl is substantial.

Secondly, continental imports are reported to be subsidised by the producers. As it is, continental producers have several advantages over UK producers: the French domestic market is much larger than the UK domestic market and feed costs are apparently lower on the continent. The strength of sterling relative to the French and Belgian francs in recent years has further benefited the continental producer.

In September 1985, wholesale prices for imported oven-ready birds were £1.70-1.80 per kg. In contrast, UK birds were wholesaling at £2.10 per kg. In the same month, retail prices were £2.50 per kg (Broome, EH & Co. Ltd -personal communciation).

If domestic production was to substitute for imports, the impact on land use, through increased demand for feed, would be negligible, at about 140 ha. This calculation assumes that imports are 260 t per year and that the average feed conversion ratio is 2.75:1. On the basis of these assumptions, 715 t of feed would be required. This feed is 60% wheat: thus, at an average yield of 3 t per ha, only 143 ha would be needed to produce the requisite quantity of feed wheat.

TURKEYS

Turkeys were first brought from the Americas by the Spanish Conquistadors and were introduced into the UK in the mid-16th century. From their first appearance until the mid-1950's they were exclusively eaten at Christmas time.

In the last ten years particularly, there have been major changes in the field of Turkey production. Not only has there been an increase in the total production of Turkey meat, from 86 kt in 1975 to 128 kt in 1983, but there have also been changes in the way the meat is marketed. There has been an important switch from Christmas Turkey production to the production of products requiring further processing and which are sold throughout the year to the *cut-up* market.

Presently, some 16.5 million whole Turkeys are consumed in the UK. 65% of these are still eaten at Christmas time, with the remainder eaten at Easter, May Day and Bank holidays. The cut-up market in 1983 consumed some 8.5 million birds. It is generally considered that this latter market holds great promise for the Turkey industry, since Turkeys are efficient meat producers and have high meat to bone ratios (Morris, TR-personal communication).

The incubation period for Turkey eggs is 28 days. Turkey chicks, known as poults, tend to be highly susceptible to disease. Houses are therefore fumigated between batches and the poults are given vaccine in the drinking water at three and sometimes also at five weeks of age.

Christmas Turkeys are traditionally heavy and some producers rear them to 24 weeks when they weigh 18 kg or more. Light oven-ready birds are reared in half the time, to a weight of 7–8 kg. It is for this mature, unfinished bird that demand is expanding.

Feed conversion ratios for light Turkeys are comparable to those currently achieved in broiler production – around 2.2:1. Turkey rations comprise 75% home grown cereals.

There appear to be no serious constraints on the expansion of light Turkey production and competition throughout Europe is keen.

EDIBLE FROG

The edible Frog *(Rana esculenta)* is found in Europe, Asia and North Africa. It is green or brown, with black spots and usually measures seven to eight cm in length.

The UK annual consumption of Frogs' legs amounts to some 100 t with a wholesale value of about £300 000. There appear to be no domestic producers (Shelton, JW-personal communication). In the past, France was an important supplier of Frogs' legs and some traders do still import French varieties. However, the main sources are now Bangladesh and India, where frogs are culled from the wild population.

Frogs' legs vary greatly in size. The most popular size class is 8–20 legs per kg. French restaurants in the UK prefer legs that are in the lower half of this size class. Much larger legs, however, are sold: the largest class being 2-4 legs per kg.

Two years ago, UK demand for frogs' legs declined after a television programme showed the manner in which frogs were treated after capture. Demand, however, has now apparently recovered. In the meantime, prices appear to have risen substantially. Wholesale prices in 1983 were £1.60–2.00 per kg whilst in September 1985 they were in the region of £3.00 per kg. Retail prices at Billingsgate in September 1985 were about £4.00 per kg. The reason for the price rise is generally felt to be an upsurge in demand for the USA.

It is not clear to what extent supplies may diminish due to overhunting in India and Bangladesh. If supplies from these countries are likely to fall, then there would be a case for investigating the economic feasibility of Frog production in the UK.

BEES

In 1984, the UK produced some 3.3 kt of honey (Young, T-personal communication). Generally, half the UK's output of honey is exported. However, the balance of trade on the honey account is in chronic deficit, since imports run at some 20 kt per year. In 1984, the UK was estimated to consume some 0.4 kg honey per head. In 1974–6 per capita consumption was 0.3 kg, thus demand is steadily rising. Honey is attractive to consumers as it is a natural food and contains no additives.

The UK imports its honey from Argentina, Australia, Canada, China, Greece, Mexico, New Zealand, Spain and the USA. There is no official registration of beekeepers in the UK, but MAFF has estimated that in 1984, there were about 47 000 keepers, with 238 000 colonies. Most keepers operate small concerns of less than 10 colonies, with only few keepers managing more than 100 colonies. At present UK honey production is expanding due to the increased area of oilseed rape.

It is difficult to ascertain costs of honey production, since input and output levels are highly dependent on weather conditions during the season. In September 1985, one honey merchant in Berkshire was offering producers about £1.50 per kg (Rowse Honey-personal communication). At such a price, producers make little profit. However, many producers sell directly to consumers and obtain prices of £2.65–3.00 per kg. In August 1985 supermarket prices were as shown in Table 3.6.

Table 3.6
Supermarket prices for honey in August 1985.

	Pence per kg
Blended	170
Mexican	183
Canadian	218
English	289
Greek	293

Source: Waitrose–personal communication.

Price differentials are mainly due to variations in colour and flavour. UK honey is usually light in colour and has a mild flavour and is thus able to command a high price.

The level of honey output depends on the availability of nectar. There are large areas in the UK devoid of nectar-producing flora. Some modern agricultural practices – such as cereal monoculture and removal of hedgegrows and trees – reduce nectar supplies. However, new crops such as oilseed rape and borage increase the supply of nectar.

It is possible that a greater proportion of the nectar that is already available could be collected if colonies were moved during the season in synchrony with flowering and nectar production.

There are a number of side benefits and by-products of honey production which are pertinent when considering the industry from a national perspective.

(i) Pollination of fruit trees, soft fruit, Field beans, Oilseed Rape and Borage. In the case of the last three crops, the introduction of Bees causes more uniform pollination and seed ripening which in turn results in reduced seed shedding.

(ii) Beeswax. This is used for furniture polish, candles, and by the cosmetic and pharmaceutical industries. There is evidence that sufferers from hay fever may benefit by eating wax cappings from honeycombs (Redfern, 1985).

(iii) Pollen. Collection of pollen from returning Bees is made possible by attaching a pollen trap at the hive entrance. Pollen is used by the pharmaceutical industry and is processed into tablets for sale as a health food.

(iv) Propolis. This is a resinous substance used by bees for sealing cracks in the hive. Bees collect propolis from resin-producing trees and shrubs. It has become a popular health food and is also used by the pharmaceutical industry.

(v) Venom and royal jelly are also collected and used for health foods and by the pharmaceutical industry.

EARTHWORMS

In the UK, Earthworms are produced and sold to anglers, to gardeners and to organic farmers. Earthworms have a protein content equivalent to fishmeal and there is, therefore, scope for their use as feed for domestic livestock and fish. The technology for intensive Worm production has already been developed by the bait industry. However, the effects of feeding worms to livestock are not well understood.

The major features of the Worm's biology which contribute to its potential as a waste converter are its high protein content (up to 72% of the dry weight of the body tissue), its palatability to many bird and mammalian species, its high productivity and the fact that the natural habitat of many Worms, particularly *Eisenia foetida* and *Lumbricus rubellus*, is manure, sewage beds and compost heaps.

An estimated 4 million anglers in the UK and 50 million in continental Europe provide the potential market for the bait industry and it seems that current production of Worms in Europe is scarcely adequate for the demand (Spedding *et al*, 1979). Fishing is one of the most popular pastimes in Britain and, with the possibility of leisure time increasing, it is probable that the market for Worms will increase. At the same time the problems of obnoxious odours associated with maggot farms is encouraging local Health Departments to close down many of these, thus further opening up the market to Earthworms (Denham, 1977).

Most commercial Worm farmers seem to use a substrate consisting mainly of animal faeces: Rabbit, Chicken, Horse or Cow manure. Vegetable waste and even shredded cardboard can be used in the Worm bed. Peat provides no nutrients. It is possible that Worm production may be slower in pure vegetable waste than in mixed animal/vegetable substrates, especially when tough, fibrous material (which does not decompose quickly) is used.

Fosgate & Babb (1972) analysed samples of *Lumbricus terrestris* and these were found to contain 22.9% of dry matter which comprised 58.2% protein, 3.3% fibre and 2.8% fat.

Earthworms require a moist, shady and warm environment (5–25°C) as well as a plentiful supply of organic matter. Harvesting is one of the major bottlenecks in any Worm production system. The worms are intimate with their culture medium and their extraction is difficult. Several methods are in use. For relatively small quantities of Worms and bedding, Worms are extracted by hand. Bedding containing Worms is made into a mound and exposed to sunlight or bright artificial light. The Worms migrate inwards and the outer layers are removed. The process is repeated until the Worms are concetrated in a small quantity of bedding. They can then be removed by hand or by means of a special harvesting tray through which the Worms riddle themselves.

The residue from Worms has value as a soil conditioner and growth medium. The residue from the biodegradation of Cow manure by *Lumbricus terrestris* is described as more porous and friable and weighing only half as much as normal potting soil mixture. Analysis has revealed a content of 3% N, 0.32% P and 0.4% K. Trials have found that plants grown in this medium require more water, but grow faster, have larger root systems and more blooms than those in conventional potting mixtures (Fosgate & Babb, 1972).

The Earthworm thus seems to possess considerable potential as a component of agricultural systems and further research aimed at putting Earthworm systems into operation would be of value.

SILKWORMS

In 1983, the UK imported some £45 million of silk (Department of Trade & Industry, 1984). This was in a variety of forms: raw silk, yarn, fabric and made-up garments.

The UK's only silk farm is in Dorset and this is operated as a tourist attraction rather than as a commercial enterprise. The farm used to be in Hertfordshire and was on the point of closure in 1977, before it was transferred in its entirety to Dorset (The Times, 1985). Its output – amounting to only a few thousand cocoons a year – is retained for particular requests for garments made from home-produced silk.

In the 12th century, the Italians introduced sericulture (the raising of Silkworms) to Europe and for centuries the industry thrived in Italy and France.

The principal Silkworm moth species in *Bombyx mori,* or the mulberry Silkworm. Various strains of Japanese, Chinese and European moth have been crossbred in Japan. The cocoons of the Silkworm yield filaments of 600 to 900 m in length. Eggs are kept in cold storage for 6–10 months and germination is started in an incubator at the appropriate season of the mulberry tree. After ten days in an incubator, one gram of eggs produces 1500 to 2 000 worms. After about 30 days, the worms develop two large silk-producing glands and from each gland begin to secrete filaments made of fibroin. The two fibroin filaments are connected together by silk glue, called sericin. The Worm builds its cocoon by adding layer after layer of fibroin and the cocoon is completed in 24 to 72 hours. The pupa is then killed by refrigeration, and the cocoons are reeled. Four to nine filaments are required to produce a 14 denier silk thread (14 grams per 9 000 m).

Silk production is unlikely ever to be commercially attractive in the UK for two reasons. First, sericulture is labour intensive: cocoon rearing, silk reeling and mulberry tree husbandry all require a high labour input. It is this high labour cost that has caused the industry to collapse in France and Italy. Secondly, the UK climate limits the production of mulberry leaves to July and August. Even to produce leaf in July, mulberry trees have to be grown indoors. By the end of August, strong winds have usually desiccated the leaves of trees grown outside (Goodden, P–personal communication).

Some 20 years ago there were about 50 silk mills in the UK, but now only six remain. The reason for this decline is the increased processing of silk performed in the producer countries. However, customers on the continent are reported to prefer goods that are produced in the UK, due to their high quality (Moss, T–personal communication).

In September 1985, silk processed in the UK retailed at about £22 per kg, the exact price depending on the denier. Prices for imported combed and carded silk ranged from US $16.23 per kg for tops and US $6–6.50 per kg for noils (London Export Corporation–personal communication).

Sericulture is highly developed in Japan, where Silkworm nutrition is based on an artificial diet obviating the need for mulberry leaves (Goodden, P–personal comunication).

SNAILS

Snails have a long history as human food and in some cultures are an important source of protein, their protein content being 16% of body weight (Orraca-Tetteh, 1963). On the continent the Roman Snail, *Helix pomatia,* is a specialist food item. The possibility also exists of using Snails as animal feed: in the past they have been fed to Pigs (Thompson, 1945) and they are also acceptable to both Ducks and Hens: when the crushed shell is included with the Snail meat, then such a ration is high in calcium for eggshell production (Van Weel, 1948). In this study, however, Snails are considered only from the perspective of purveyors of human food, since this market is more valuable than the animal feed market.

Table 3.1 shows that, in 1983, the UK imported some 21 t of Snails, valued at £89 000. The demand is apparently increasing as British tourists become more familiar with Snails after spending holidays in France (White, CD–personal communication).

The UK imports its Snails from France, although it is not certain how French these Snails are: increasingly Snails are either collected from the wild or farmed in Greece and Turkey, being sent to France for processing and thereby acquiring a valuable trade name.

In the UK, Snails are sold either frozen or tinned. Frozen Snails are in their shells, are oven-ready and retail at about £1.65 per dozen. Tinned Snails have been extracted from their shells and, in September 1985, a tin of two dozen retailed for £1.90 to £2.50 (County Delicacies–personal communication). It is the normal practice for housewives to insert Snails into shells before serving, and shells can thus be bought separately for about £1 per two dozen. The shells can be used repeatedly if handled with care.

There is only one source of British Snails – and these are collected from the wild, rather than farmed. Snail farming is a laborious and delicate operation for the following reasons. New-born Snails are about the size of a pinhead – neo-natal management is therefore difficult. Once they are mobile, Snails have to be contained within environmentally controlled enclosures and constantly watered to prevent dehydration. Snails consume some ten times their body weight of fresh vegetable matter daily; considerable labour is thus needed to handle the feed. Heating is required to prevent hibernation during the winter and waste disposal can be problematic. Pollard (1975) reports that Snails exhibit an adverse reaction to high population densities.

A review of the literature describing the various farming attempts and other aspects of the exploitation of *Helix pomatia* is provided by Welch and Pollard (1977). Adams (1977) and Spedding *et al* (1979) both considered commercial Snail farming and suggested lines for further research.

The one British producer sells about 50 000 snails per year and has been in operation for 10 years. He reports that the market for snails is expanding (Haslam, B–personal communication).

FISH

The annual Fish catch of the UK is about 1 Mt per year (Isaac, P–personal communication). UK Fish farms produce some 10 kt annually, thus Fish farming provides only a fraction of the total requirement of Fish. However, Fish farming is a new activity – commercial farms only started after the Second World War – and some forms of Fish farming are of considerable economic importance in some areas. Moreover, other forms are expanding rapidly; it is thus pertinent to include Fish farming in this study. Three different Fish markets are examined: viz. table Fish, ornamental Fish and Fish for restocking.

Table Fish

Lewis (1984) estimated that the farm gate value of Fish produced in the UK was £25 million. After the Second World War Fish consumption per capita exhibited a gradual decline. However, in recent years consumption has increased, probably due to the fact that the price of farmed Fish has remained stable in real terms. In the future, Fish consumption may well continue to expand as Fish is beginning to be regarded as a desirable component of a healthy diet.

In terms of share of total Fish output, the salmonids and cyprinids are the most important. Salmonids include Trout (both brown and rainbow) and Salmon. Cyprinids are Carp: those varieties that may be important as sources of food are Common Carp and Grass Carp.

Salmonids

Trout output totals some 8 kt per year, four times the output of Salmon. There are some 250–300 Trout farms in England and Wales with a further 150 in Scotland. The main requirement for Trout production is a constant supply of large quantities of cool and clean flowing water. A few units produce as much as 700 t of Fish per year, with the smallest units producing less than 10 t per year.

Commercial Trout farming, like intensive poultry production, first became widespread after the development of complete dry feeds. However, despite the spectacular rise of Trout farming over the last 20 years, the UK still imports about 1 kt of Trout per year. These imports come mainly from Denmark where Trout production technology and more particularly marketing techniques, are very sophisticated.

Two main types of Trout are produced: brown and rainbow, although recent breeding has developed hybrid strains. Brown Trout are used only for restocking of angling waters. Rainbow Trout supply both the restocking market and the market for table Fish.

Rainbow Trout are invariably fed a compounded and pelleted ration with a dry matter content of 90%. On such a diet, feed conversion ratios (ie dry weight of feed consumed to the weight of fresh fish produced) approach 1.75:1.

Fish are sold at about 280 g weight; in England and Wales 10–12 months are required to attain this weight, whilst in Scotland the lower water temperatures prolong the production cycle to 18 months. Feed is the main cost. Labour is a relatively minor cost, the largest producers employing only about 10 staff.

There are two constraints on expansion of Rainbow Trout farming. First, there is a shortage of suitable water supplies for medium – and large-scale units: Trout farms require a constant flow of water and most sources are already exploited. Secondly, some Water Authorities consider that the pollution of water supplies, caused by excreta and uneaten feed, is problematic and they are therefore reluctant to grant water abstraction rights. Pollution effect could be ameliorated by settling solids and by aeration, but such treatment is prohibitively expensive.

In terms of Fish tonnage, Salmon farming is less important than Trout farming, annual output of Salmon being 2–3 kt. The great majority of Salmon farms are in Scotland, where the Highlands and Islands Development Board has been actively encouraging Salmon farms. Salmon reproduce in freshwater streams and rivers, but when they have attained a weight of 20 g they migrate to the sea. Commercial Salmon farming is therefore generally located on the coast or on the shores of brackish locks. The Fish are reared in cages which float at the surface of the water, and to avoid water turbulence, sheltered sites are necessary.

Salmon are grown to a weight of 2–5 kg – these being produced for the table. Smaller Salmon are grown for restocking angling waters. Table Salmon are sold at the farm gate to the trade at £5 per kg. Whilst feed conversion ratios of 1:1 have been obtained in laboratory trials, under commercial conditions a ratio of 1.75:1 is probably the best that can be obtained.

The early problems of suitable feeds and control of diseases have now largely been solved. The industry is steadily expanding in the UK, particularly in Scotland; suitable water supplies appear to be available, in contrast to the situation with trout farming. It is possible that Salmon farming could expand, particularly in Wales, farms being located in sheltered sites along the coast. Alternatively, land-based systems may be viable: the Fish being reared in tanks, and water being pumped from wells close to the waterline before filtering through shingle.

Cyprinids

Commercial production of table Carp is still in its infancy in the UK: a mere 40–50 t is produced each year. Imports, however, are important at 700–800 t annually. The thermal optimum of Common Carp is 25–30°C and this explains why Carp farms are mainly located in lowland England and Wales.

Common Carp are herbivores and are reared in ponds, which are drained in the autumn or winter to harvest the fish. Naturally-occurring algae or vegetation detritus can be used as feed. Outut of both these feedstocks responds favourably to superphosphate and ammonium nitrate application. Alternatively, poultry manure is used as feed.

The MAFF-funded Carp Farming Study at Reading University found that, in the case of a fertile pond, an output of 400 kg Carp per ha of water can be achieved without applying either feed or fertiliser. When poultry manure is supplied, yields increase to 750 kg per ha (a yield comparable to those achieved in Belgium, Poland and Germany). Fertiliser applications, however, can boost yields to 900 kg per ha.

The industry is expanding steadily, although it is not clear at what rate. Land and water for ponds are not constraints on expansion, neither is the climate, since the growing season is May to September.

Feed conversion ratios are similar to those attained in Trout farming: for intensive Carp farming the best achieved so far is 1.4:1.

At Billingsgate, dead imported Carp sell for £2.20 per kg, ie twice the price of Trout. At this price UK producers should be able to farm Carp profitably.

Chinese and Indian communities prefer live Carp – the demand (currently unsatisfied) from the Chinese community alone in the UK has been estimated to be 100 t annually, and live Carp could be expected to fetch up to £4.40 per kg.

The market for Carp for restocking purposes is much smaller than for consumption, but prices are high at about £8 per kg.

The Grass Carp, *Ctenopharyngodon idella,* is a herbivorous Chinese variety. It is used to control water weeds in fisheries and drainage channels (their use is cheaper and safer than chemicals), for angling purposes and for food.

Domestic production is very small at about 1 t per year. Grass Carp production is a relatively novel activity since it is only in recent years that brood-stock (ie breeding stock) have been acquired. The immediate task of research is to improve reproductive performance under UK conditions, which necessitates the development of sex hormones.

UK demand for this variety of Carp as food originates from the Chinese community, whilst in the fens Grass Carp are used to control weeds.

Grass Carp are able to consume their own body weight of duck weed (90% water) each day; when on a diet of grass, daily consumption is about one third of body weight. When fed on a diet of fresh grass, feed conversion ratios of 10:1 are common; this is equivalent to a ratio of 2 units of grass dry matter to 1 unit of fresh fish.

Ornamental fish

Some 10% of all UK households keep ornamental Fish and the total retail value of this market (Fish, feed and associated equipment) is £45 million per year. 3 500 retail outlets supply the market.

Koi Carp, also known as Japanese Ornamental Carp, is a variety of *Cyprinus carpio* which includes the Common Carp, discussed above. Goldfish are a different species of the Carp family, but are considered together with Koi Carp as both are currently in demand as ornamental Fish.

Koi Carp have been farmed in the UK for only a few years. Production is very small, a mere handful of producers being involved.

The demand for Koi Carp and Goldfish is increasing, in contrast to that for tropical ornamental Fish which is, at best, static. Annual imports of Koi Carp and Goldfish to the UK total £1.25 M landed value, which translates into a retail value of £5 million. Many countries supply the UK market, in particular Israel, Italy, Japan and the USA. Imports are subject to 8% duty.

Any study of the ornamental Fish market reveals the anomalies of the 1937 Fish Diseases Act. This was formulated with the intention of preventing the importation of fish which may be vectors of disease. The

Act has been selectively applied since 1975, but is restricted to imports of farmed Fish only. Thus it is not applied to ornamental varieties of farmed Fish. Since all non-ornamental Fish have varieties which are ornamental, and diseases are transferable between the two, it is evident that the current mode of applying the 1937 Act does not necessarily prevent the importation of Fish diseases. If MAFF was to extend the ban to ornamental Fish, then this would greatly stimulate domestic production of Koi Carp and Goldfish.

Imports notwithstanding, however, Koi Carp production is a profitable business. Fry fetch wholesale prices of 5p each, while small fish, 4 cm in length and weighing 2.5 g, fetch 25p each at the farm gate and retail at £1 each in pet shops. 20 g specimens from Israel currently retail at £3 each, equivalent to £150 per kg.

Fish for restocking

Annual expenditure on equipment and fishing fees by UK anglers totals £400 million and is thus substantial. However, it has not been possible to elicit what proportion of this expenditure is devoted to Fish for restocking.

In the case of Rainbow Trout, the restocking market is more lucrative than the table market (Fish fetching a price premium of up to 70% when sold for restocking). However, the market suffers considerable fluctuation from one year to the next, depending on local and temporary factors such as disease incidence and fishing pressure.

Lewis (1984) estimated that 115 fish farms were involved in production of Trout for restocking. Production of Salmon for restocking is much less common; in England and Wales there are probably less than a dozen such Fish farms and a similar number are thought to exist in Scotland.

Fish farming and the use of land

Trout and Salmon farming together consume some 20 kt of feed per year. This is mainly imported soyabean and fish meal from deep sea fisheries. However, 15% of most Fish feeds consists of wheat: thus some 300 ha of land is required for this component of the ration. If fish farming were to double its output, the impact on land use would therefore be negligible. However, the industry would be a more significant land user if Fish feeds were formulated from home-grown grain legumes, such as Field Peas and Lupins.

Moreover, in terms of land consumed by the ponds themselves the industry is not an important land user. Some 60 t of Trout are produced per ha of water. Thus 130 ha of water are currently used for trout farming. If ponds comprise 50% of the land area of Fish farms, Trout production is currently using only 260 ha of land.

CRAYFISH

Of the four species of Crayfish currently existing in the UK, *Pacifastacus leniusculus* is the main species which is farmed. Crayfish are crustaceans and therefore thrive in calcareous water. Production is centred in the South of England where water temperatures are higher than elsewhere in the UK. Crayfish were first imported from Sweden in 1976 and current output is low, although it is expanding dramatically. In 1983, about 0.5 t Crayfish was produced. In 1984 this had risen to 3–4 t, whilst 1985 output will be in excess of 5 t. Some 40 producers are involved in this activity.

Crayfish are reared in lakes and ponds and are caught using baited traps. They are omnivorous; in their natural habitat a high proportion of their diet is aquatic plant matter.

They grow slowly and moult at intervals. At the time of moulting, they are prey to cannabilism. It appears that low stocking densities reduce cannabilism, and some producers provide tiles or drain pipes at the bottom of ponds in which the crayfish can take shelter whilst moulting.

World market prices are presently in the order of £10 per kg. In order to exploit the supermarket trade, UK producers will have to set up an efficient marketing system.

In the future it may be possible to export Crayfish to Sweden. Recently a Swedish firm constructed the first Crayfish ponds in the UK.

4 Forestry

INTRODUCTION

Annual consumption of wood and wood products in the UK totals about 38 Mm^3. Some 50% of this is in the form of pulp and paper, 35% is sawn wood, of which about one fifth is hardwood, while panel products account for the remaining 15%. Consumption is expected to double by the year 2025, with a greater increase in the demand for panel products, pulp and paper than for sawn wood.

To meet this demand the UK relies heavily on imports: current home production meets only 10% of requirements and the UK is the major importer of forest products in Europe and one of the largest in the world. Home production will double by the year 2000, but because of the increase in demand, the percentage contribution from indigenous production will rise only slightly.

Wood is a mixture of three natural polymers: cellulose, hemicellulose and lignin. Cellulose is a major raw material for paper and viscose products, but all the components are potentially capable of serving as feedstocks for chemical or biological conversion to other products, including plastics and ethanol. Of particular interest is the potential of wood to provide various solid, liquid or gaseous fuels *via* a range of processes; many of these are the result of current research, development and demonstration. Further development of industrial processes of this type could increase still further the demand for wood.

In addition to the larger-scale uses of wood, several smaller and more localised uses can be identified. For example, there continues to be a demand for certain speciality woods for furniture making and decorative cabinet work (Cherry and Walnut are two which can fetch high prices) and a few growers are finding a useful market in selling tree foliage to the florist trade, for wreaths and flower decorations. It also seems likely that the market for various smallwood products, such as woodchips and domestic firewood, will increase in the future.

Conservation, recreational and amenity interests may also place further demand on UK woodlands. The value of woodlands, particularly lowland broadleaved woods, in relation to landscape, wildlife conservation, historical, recreational and educational interests is increasingly being recognised, and there is growing pressure to maintain, improve and expand the nation's broadleaved resources.

The total forest area of the UK is about 2.5 Mha, currently increasing at a rate of 25 kha per year or 1%. Forestry occupies about 9% of the UK land area, similar to the Netherlands, but less than half the figure for Belgium, France, West Germany or Italy.

Also in contrast to countries such as France, much of the UK's current forest area was established in the present century and an appreciable proportion since 1950. Rapid industrialization during the 19th Century speeded up the process of deforestation which had been going on for many centuries, and, by the early 1900s, forestry had dwindled to cover only about 5% of the total UK land area. The first world war highlighted the strategic importance of a productive indigenous forest industry, and in 1919 the Forestry Commission was established to improve the productivity of the industry and increase the UK forest area, both public and private.

The UK forest resource is, therefore, in what is essentially a restoration phase, and the UK is currently laying down forest capital, in terms of infrastructure and trees. In France, by comparison, the forest resource is well established, covers more than a quarter of the nation's land area and has been continuously managed since mediaeval times. Financial returns greatly outweigh the cost of re-establishment. In addition, land management is more integrated, and community forests are frequent.

While such a steady state is unlikely to be attained in the UK, the perceived economics of forestry production will become increasingly attractive as the forest resource increases and matures. In view of the current and likely future demand for forestry products and services and levels of national self-sufficiency, and the long-term value of an increased and mature national forest resource, further expansion of forestry in the UK would seem to be clearly in the national interest.

Given that most UK land is farmland, that most farmland is technically suitable for growing trees and that many farmers are, or will be, seeking alternative enterprises—as is the central theme of this report—and that is may be in the interests of both the farming community and the nation for farmers to continue to manage rural land, it is clear that there is a strong case for this expansion of forestry to occur on farms.

The major constraints on the adoption of forestry on farms relate to tradition and financial arrangements.

Forestry on farms represents a merging of two enterprises and industries which, in the UK, have been traditionally separated. This is a particular characteristic of the UK rural scene, and is in distinct contrast to much of the rest of Europe where forestry has traditionally formed an integral part of farming and well-managed farm woodlands are a fairly common occurrence.

The reasons for this are essentially social and historical. The deforestration of the previous centuries was accompanied by the establishment of land ownership patterns and traditions by which landlords managed forests and owned timber, while tenants were exclusively farmers. In the years since 1919 the Forestry Commission has done much to improve the UK forestry industry and to increase the UK forest area, but it has had little effect on the divisions between agriculture and forestry, and the Agricultural Departments have placed, and largely continue to place, strong restrictions on the afforestation of land with any agricultural potential.

As a result, the roles of the farmer and forester are separated in the minds of many farmers, and an attitude of disinterest or even antagonism towards forestry is a common phenomenon (Peart *et al*, 1985). Well-managed farm woodland is rare in the UK and farmers have much less expertise in the techniques of forestry than their European counterparts. Forestry clearly calls for different knowledge, skills and equipment from those associated with crop or animal production, and the adoption of forestry on farms will be strongly influenced by the availability of information and advice on woodland rehabilitation, planting and management.

The initial costs of establishing a forestry enterprise can be high, particularly for new plantings, and, in contrast to agricultural enterprises, there can be a considerable time-lag before the occurrence of benefits. High capital requirements and costs and the related cash-flow problems are the major constraints on the implementation of forestry on farms in the UK.

The necessary long-term commitment of land and capital may also reduce the farmers' ability to respond to opportunities or pressures arising from social and economic perturbations or trends. In addition, the opportunity costs of forestry on much UK agricultural land may appear high, owing, at least in part, to the high levels of direct and indirect financial support to agriculture compared with forestry.

Three approaches to forestry on farms can be distinguished.

(i) Farm woodland management; the renovation and management of existing woodland on farms for a range of possible products and services.

(ii) Forestry plantations; new plantations of hardwood or softwood trees for conventional or novel products, including energy, or possibly for amenity.

(iii) Agroforestry systems; systems where trees grown for various products and/or functions are intimately integrated with agricultural crops and/or animals in some form of spatial arrangement and, possibly, temporal sequence.

These approaches are by no means discrete, but provide a suitable framework for considering the potential for forestry on farms. Managing existing farm woods could include new plantings by infilling and/or extension, and agroforestry could be viewed as simply a means of establishing forestry plantations without totally displacing agriculture.

FARM WOODLAND MANAGEMENT

Many farms in the UK have small areas of currently unexploited, and often neglected or derelict, woodland. Managing these represents an alternative to leaving them to degenerate further. Ploughing them up for agriculture may not be profitable, owing to the high cost of removing the trees, or the poor quality of the land, and is generally not possible anyway owing to legal restrictions. They may become increasingly profitable as markets for smallwood products, notably firewood and feedstocks for biofuel production, and woodland services, notably recreational facilities, develop.

Farm woodland management does not represent a large scale land-use alternative, but may generate some additional income as well as providing other, less easily quantified, benefits. Managing farm woodland may also provide an alternative use for otherwise slack farm resources, notably labour during the winter.

Extent and characteristics of farm woodland

Estimates of the area of woodland on farms in the UK vary and it seems clear that none of the figures currently available is particularly accurate; they do, however, provide some indication of the approximate magnitude of the resource.

According to MAFF (1983b) the total area of woodlands on agricultural holdings in the UK in 1982 was 285 kha. Of this 206 kha were in England and Wales on some 36 000 holdings and 66 kha were in Scotland on about 6 000 holdings (Britton *et al,* 1984). DART (1983) suggested that the area of small woods *mainly on farmland* in England and Wales was about 340 kha; on this basis (ie assuming MAFF values for Scotland and Northern Ireland are similarly under-estimated) the national area may be as much as 470 kha.

Peart *et al* (1985) estimated the area of *unproductive* woodland in GB *(virtually all broadleaved and in private ownership, and much of it in small blocks on farms)* at 170 kha, but this does not necessarily indicate the total area of woodland on farms.

Some indication of the potential of the resource is provided by assuming that the estimated 285 – 470 kha of woodland on UK farms can be managed to produce an average output of 4 t DM per ha of fuelwood. At 20 GJ per t DM, UK farm woodland represents a potential fuel resource of 22.8 – 37.6 PJ per year of gross energy in wood, equivalent to 0.27 – 0.45% of 1981 UK primary energy consumption.

Most of this woodland occurs in very small units. Britton *et al* (1984), concentrating on the estimated 162 kha of *lowland* woodlands on about 28 000 holdings in GB, estimated their average area to be about 6 ha, and calculated that 90% of the total area of woodland was on farms having 3 ha or more, but that 60% of the 28 000 holdings had woods of less than 3 ha. The small size of farm woods was emphasized by DART (1983) who, on the basis of detailed surveys of study areas in each of 9 counties, concluded that nearly all farm woods in England and Wales were of less than 10 ha and 66% were of less than 1 ha.

Farm woods exhibit considerable variation both in composition and condition. In general, however, most farm woodland in the lowlands is made up of broadleaved trees, much is derelict or neglected and much is on land unsuitable for agriculture (DART, 1983; Evans, 1984; Wagner, 1984). Many farm woods are the remnants of formerly managed broadleaved woodlands.

Factors determining the value of farm woodland

Despite the often poor condition, variable composition and small size of most farm woods in the UK, many have a high conservation value, in terms of landscape, wildlife, historical or recreational and educational potential (DART, 1983; Evans, 1984), and many may also have the potential to provide a number of financially valuable products and services. In nearly all cases, there is considerable scope for improvement.

Clearly some of the products and services provided by farm woods are only of value from a national viewpoint; the value of some to the farmer may be easily quantified while others may present difficulties in relation to charging and marketing.

Amenity and conservation

The conservation value of a wood does not usually provide the farmer or landowner with any direct financial benefits, but may prevent its removal or any major changes in its appearance, and hence, may represent an incentive for profitable management. In most cases the conservation value of a wood is enhanced by management and may suffer if the wood is allowed to degenerate further. A well-managed wood may increase the overall value of the farm. Woodlands can also provide opportunities for a number of recreational or educational activities, some of which may generate income; these include rambling, camping and caravaning, orienteering, nature trails and waymarked walks, wildlife study etc.

Broadleaved resources
Many broadleaved farm woodlands represent an important genetic resource, and the conservation of genetic material may be an important goal of management which needs to be recognized. As genetic conservation is in the national interest, but is unlikely to provide the farmer with direct or immediate financial benefits, incentives to encourage farms to manage woodlands toward this goal would need to be sought.

Game rearing
Of particular consequence in financial terms is the value of woodlands for game rearing and shooting. Woodlands provide protection from the wind, breeding cover for wild pheasants, holding cover to retain both wild and reared birds and boughs for roosting (Game Conservancy, 1981). While the main potential in most farm woods is for pheasant rearing, there is also scope for managing and using woodlands for shooting partridge, wildfowl, deer, hare, rabbit, woodcock and pigeon (DART, 1983).

Shelter
Woodlands may also be of value in providing shelter for livestock, pastures or crops, although such benefits are difficult to quantify in financial terms. Even in lowland areas, giving cattle access to woodlands may help to conserve body heat and reduce the stress arising from exposure to the weather (Britton *et al*, 1984). The shelter provided by woodlands along field boundaries may also improve crop production or pasture growth in some areas (Russell & Grace, 1979). The possible role of trees in providing shelter is considered in more detail in a later section.

Woodland products

Apart from game rearing, the financial value of farm woods relates, primarily, to their potential to provide various woodland products for a number of possible markets; these include sawlogs, pulpwood, turnery wood, fence posts, pea and bean poles, hedging stakes, rural crafts, wood chips (for use as bedding, packing, mulch, soil conditioner, animal feed or fuel), charcoal, domestic firewood and large-scale energy production (eg direct combustion to produce heat, gasification or electricity generation).

Fiscal incentives and planting grants

It should also be noted that some of the costs of managing farm woodland may be met by various grants and some additional income provided by taxation benefits. Possible sources of grants for woodland planting and/or management in the UK at present, depending on the type and location of the woodland and the proposed aims of management, include the Forestry Commission, the Countryside Commission, MAFF, the Nature Conservancy Council, some Local Authorities, the Tree Council and National Park Authorities. In addition, in some areas, labour for woodland management may be available through various Manpower Services Commission schemes.

Impetus for commercial forestry

The management of existing farm woodlands could be implemented within a cycle of woodland management encompassing both existing woods and new plantings and, hence, provide a starting point for larger-scale adoption of forestry on the farm and generate an interest amongst farmers in commercial woodland management (Peart *et al*, 1985).

Employment benefits

Farm woodland management may also provide scope for utilizing labour and equipment at times of the year when they might otherwise be unused. In addition, woodlands can generate downstream jobs and, thus, benefit local employment (Peart *et al*, 1985).

Effect of woodland condition and farm circumstances

Clearly the realizable value, both monetary and non-monetary, of a wood depends strongly on the quantity, quality and type of products and services it can provide and, hence, on the type and condition of the wood, and on the characteristics and economic circumstances of the farm. Estimated standing values of the woods in the survey by DART

(1983) exhibited considerable variation. Of the 461 woods surveyed, 68% were judged to have a positive net standing value in that commercial buyers could be found in the locality who would *pay for the privilege of clearfelling the wood and disposing of its produce to the various markets available.* The remaining 32% were judged to have no standing value in that it was unlikely that local commercial buyers could be found. However, these woods could still be exploited by the farmer or landowner for his own use or if he was able to market the products himself.

Scope for coppice production
An appreciable proportion of small woods on farms could, after rehabilitation, support coppice regrowth (DART, 1983). In addition, coppice production from existing trees could be supplemented by enrichment of the stand by planting new trees of suitable species and potentially valuable timber trees could be retained, pruned etc (Evans, 1984). Hence, after realization of at least some of the standing value of a wood and once the coppice cycle is established, regular revenues can be obtained from the sale of coppice products.

Markets
The availability of markets for woodland products, and associated collection and distribution systems, will also influence the realizable value of a farm wood. Markets for, and prices commanded by, products such as firewood and recreational facilities, such as game shooting, are likely to be stronger close to centres of population than in remote rural areas. Similarly, the costs associated with woodland management and marketing the products are likely to be higher where access to the wood is difficult, and where the market is at some distance from the product source.

Rising fuel costs, unavailability of gas and electricity grid supplies in some remote places, ideas of self-sufficiency, increased interest in the aesthetic appeal of wood-burning stoves and open fires, and even Dutch elm disease, have improved the market for, and value of, firewood in recent years (Evans, 1984) and, hence, for the potential products of farm woodland, particularly smallwood and poor quality timber.

Possible future developments which may further increase the market for farm woodlands products include:

(i) increased interest in and improved markets for wood chips and associated improvements in the availability and cost of wood chipping machinery. (As very small stems, branches and twigs can be chipped, this would enable harvesting of a high proportion of the total product of a wood.)

(ii) improvements in hardwood pulp processes such that a wider range of species, billet sizes and a higher bark percentage are acceptable (DART, 1983).

(iii) further rises in the prices of conventional fuels increasing the incentive to use wood as a domestic or industrial fuel, and as a feedstock for gas or electricity generation.

Assessing the value of farm woodlands

While it is relatively easy to ascertain the sources and determinants of the value of farm woods, it is less easy to gauge their value in quantitative terms. In particular, the wide variation in woodland type and condition and in farm and market circumstances, makes generalization difficult. In addition, the perceived costs and benefits of managing a farm wood depend strongly on the basis on which those costs and benefits are assessed.

Conventional assessments of the relative financial performance of forestry and agricultural enterprises involve the calculation of discounted costs and revenues and the generation and comparison of Net Present Values. However, this technique may be less appropriate for assessing the returns from managing existing farm woodlands than for assessing new plantings. The procedure disguises the problems of the choice of discount rate and the difficulties of comparing the values of forestry and agricultural enterprises. It is only concerned with the return to capital, assumes the only aim of woodland management is to maximize revenue and is *inherently pessimistic* towards forestry (Dartington Institute, 1985).

Instead, the Dartington Institute (1985) proposed the use of Gross Margins, and that these should be compared with the income of the poorest land on the farm. There are a number of reasons for this view: the farmer is concerned with maintaining a satisfactory level of (annual) income rather than maximizing income; the woodland is already there and there may be social or legal incentives to retain it; most farmwoods have the potential to be managed to generate revenues on a much shorter time scale than conventional plantation forestry enterprises; many of the costs associated with managing a farm wood (notably labour) are rightly included amongst the farm's fixed costs; and, as already suggested, farmers may wish to use otherwise slack labour during the winter.

On the basis of a number of case studies, the Dartington Institute

(1985) calculated the potential financial performance of several types of farm woodland. Estimated annual gross margins for Oak coppice producing firewood fell between £85 and £94 per ha; values for coppice with standards or high forest producing timber and firewood were of the order of £180 per ha. Calculation of the gross margins for rehabilitating poor woodlands was more difficult, but the Dartington Institute (1985) concluded that *a shrewd combination of cropping revenues and grants for replanting bare areas can significantly reduce the cost of rehabilitation.*

The validity of the Gross Margins approach seems to depend strongly on a wood having a sufficiently uneven age structure and adequate scope for coppicing, infilling and extension to provide an annual income; it is unclear how many farm woods would be able to fulfil such conditions and it seems likely that, in practice, some, perhaps considerable, uneveness of cash flow would have to be tolerated.

In a study to determine the potential for biofuel production on British farms at different levels of increase in energy costs, Jones (1984) constructed linear programming models of four typical farm types and investigated the effects of introducing various biofuel production enterprises on the overall farm plan. The farm types and biofuel enterprises are shown in Table 4.1.

The management of existing farm woodland was investigated on two (ie arable and upland) of the four farm types considered. On the arable farm and at current energy prices farm woodland management to produce firewood to fuel a domestic central heating system on the farm

Table 4.1
Farm types and biofuel enterprises

Farm type	Biofuel enterprises considered in the model
Arable	Straw-fired boiler, management of existing farm woodland, oilseed rape oil, catch fuel crops.
Pig	Anaerobic digestion of manure
Dairy	Anaerobic digestion of manure
Upland	Energy forestry, management of existing farm woodland, bracken harvesting.

Source: Adapted from Jones (1984).

appeared in the optimal solution. At doubled energy prices, when it became economic to bale straw to provide heat for grain drying as well as domestic heating, wood was still collected, but was sold off the farm to the domestic fuel market. On the upland farm, woodland management for firewood for domestic heating and/or sale appeared in the optimal solution at current and double energy prices.

Future prospects

While it seems clear that the lack of accurate data on the extent and characteristics, and the apparent poor condition of farm woodlands reflect the low level of interest in their management and exploitation in the past few decades, it is also clear that, in more recent years, interest in the possibilities for successful farm woodland management has grown appreciably. A considerable body of information on the rehabilitation and management of farm woodlands is becoming available. However, much of this is oriented towards wildlife and nature conservation, and a greater recognition of the commercial aspects of woodland management and the value of farm woods as a genetic resource is needed.

Detailed and extensive financial analyses of farm woodland management have yet to be carried out, but it seems clear that many farm woods can be managed profitably. Successful exploitation involves simultaneously managing the woods towards a number of objectives and, in many situations, management of the woodland is preferable, for a combination of social and economic reasons related to both the farmer and the nation, to doing nothing or ploughing up the wood for agriculture.

The future potential of farm woodlands depends strongly on the further development of a number of markets for, and increases in the value of, various woodland products and services and on the attitudes of, and information available to, farmers. It also seems clear, particularly at present, that recognition and accommodation of the conservation benefits and potential of farm woods will do much to enhance their overall perceived. value.

Future research an development should aim to:

(i) more accurately assess the nature, extent, location and potential productivity of the farm woodland resource;

(ii) locate and encourage a range of potential markets and develop any associated technologies;

(iii) develop management techniques for maximum productivity within other objectives;

(iv) consider ways in which information and advice, on both woodland management and the marketing of products and services, can best be made available to farmers.

Possible measures to encourage farm woodland management include: promotion schemes by organizations such as ADAS, the Scottish Agricultural Colleges, the Forestry Commission, the Countryside Commission, local planning authorities, the Farming and Wildlife Advisory Group and various farming and land-owning representative bodies; education and training (eg training courses at County Agricultural Colleges); and financial support *via* new and improved existing grant schemes (Peart *et al* 1985).

FORESTRY PLANTATIONS

Forestry for conventional products

Potential and constraints

The restoration of the UK forest resource referred to earlier has centred around a few species of exotic conifer, notably Sitka Spruce, and conventional forestry, which is geared to the production of saw-logs and pulpwood, is dominated by large-scale plantations of this species grown on 50–60 year rotations and clear felled. The land made available for such plantations has been, primarily, the poorest agricultural land and Sitka Spruce has proved a very successful species in these conditions.

As already stated, the market for conventional forestry products is strong. In addition, the clones of Sitka Spruce used at present are the result of intensive breeding and selection, and understanding of the productivity and management of Stika Spruce on poor land is considerable. Given that much of the current forest area was formerly farmland, there would seem to be clear technical potential for an expansion of conventional forestry based on Sitka Spruce on farmland of a similar type.

As land quality improves, a wider range of species can be grown, growth rates and yields increase, an earlier harvest of thinnings is possible and trees can be grown on longer rotations to provide high value timber. At the same time, as most of these species have been less widely exploited and been subject to much less breeding and selection than Sitka Spruce, the genetic quality of available planting material and knowledge of exact productivities and optimum management decreases.

In addition to the possibility of establishing forestry plantations on better land, other characteristics of forestry on farms may provide opportunities for, or necessitate a consideration of, alternative species and/or management systems. Farm forestry is likely to be relatively small in scale, but may offer scope for more intensive management.

There would seem to be considerable scope for improving the yields of many of the less-exploited species by breeding and selection, and by careful matching of genotype to environment. Such procedures may contribute significantly to improving the performance of forestry on a wide range of types of farmland, as well as opening up the possibility for using a number of different species.

In particular the adoption of forestry on farms, together with the potential for improving yields by breeding and selection, may enhance considerably the scope for the planting of broadleaved species.

In a recent consultative paper, the Forestry Commission (1984) emphasized the value of broadleaves in relation to conservation, wildlife, landscape, amenity and recreational interests and proposed policy measures to ensure that the current broadleaved resource was maintained at its current level. The Forestry Commission (1984) did not, however, consider that large-scale planting of broadleaved species in commercial forestry was justified on economic grounds.

However, Roche (1983) suggested that there was insufficient data to justify the assumption that broadleaved afforestation will at all times and in all circumstances be uneconomic in Britain, and attributed much of the apparent poor financial performance of broadleaves in the UK to the absence of suitable species and cultivars.

Roche (1983) proposed an applied tree breeding programme for broadleaved species, drawing attention to the example of Finland, which in the last ten years has succeeded in producing cultivars of Birch and other broadleaved species capable of dramatically higher than average productivities. The adoption of such a programme, in addition to other measures, would significantly improve broadleaf productivity and economics, and serve to prevent the decline in commercial broadleaf production and the genetic impoverishment of the national broadleaved stock.

In addition to the direct financial benefits to the farmer, forestry may provide a useful outlet for slack farm labour and under-used machinery, enhance the farm's environment, increase the farm's value, provide a growing capital asset for the farmer's heirs and a use for land unsuitable for anything else.

As already stated, an expansion of conventional forestry in general and on farms in particular would seem to be in the national interest and, in view of the relative levels of financial support to agriculture and forestry, may be profitable from a national viewpoint in many situations where it does not appear so from the farmer's.

There would, therefore, seem to be appreciable potential for the adoption of forestry for conventional products on farms in the UK. However, a number of factors are likely to constrain the realisation of this potential.

As already stated, there is a considerable time-lag before new plantings for conventional products can affect supply and, hence, between investment and return. In general, conifers provide thinnings after 20–40 years and fellings after 40–70 years; broadleaves can provide thinnings from 25 years onward, species such as Ash and Sycamore can be harvested after 60–90 years while species such as Oak and Beech require 120–150 years to mature.

Initial capital requirements and subsequent costs are high and, as most farms are concerned primarily with income rather than investment, the resulting cash-flow problems are likely to place a severe constraint on forestry on farms in many situations.

The relatively high financial support to agriculture, via grants, subsidies, price guarantees etc, may make estimates of the relative financial performance of forestry compared with current land uses appear unattractive on many farms. In addition, such estimates may be based on the expected yields of unimproved genotypes, and would also involve assumptions regarding such uncertainties as forestry costs and revenues and discount rates.

There are many economies of scale associated with forestry in relation both to production and marketing; this may make it difficult for the farmer, whose operations will in general be small, to compete successfully with the large plantation owners.

About 60% of UK farms are owner-occupied, but the remainder are farmed by tenants. Although there are now some provisions, at least in England and Wales, to enable tenants to claim compensation in respect of trees they have planted on termination of the tenancy, many tenants may still be reluctant to invest in forestry plantations on their farms. Afforestation on many farms will also be restricted by current planning regulations.

Finally, the absence of a farmer-forester tradition and the associated attitudes to, and lack of expertise in, forestry in the UK seem likely to constrain the adoption of conventional forestry on farms by farmers and information, advice and reliable services may not always be readily available.

In the light of some of these constraints, Peart *et al* (1985) concluded that, at present, forestry on farms is only likely to attract farmers where they wish to create a growing capital asset for their heirs; where they wish to enhance the farm's environment; on land which is unsuitable for anything else; and where forestry can provide an outlet for slack labour and under-used machinery.

Future prospects

More widespread adoption of forestry on farms in the future would seem to depend on the extent to which the constraints described above can be overcome. A number of possible technical opportunities and developments and organisational and financial measures, which would address the problems posed by these constraints, can be envisaged.

Farmers may be able to cash in on the small scale of their forestry operations by applying more intensive management to produce a high value product and, hence, compete more effectively with larger operators. On better land and on a small scale it would also be possible to establish species mixtures perhaps producing a range of products in succession (eg Christmas trees, tree foliage, firewood, poles, softwood timber, hardwood timber). This may alleviate some of the cash flow problems by providing some income in the short term.

Farmers may also be able to improve their competitivity, adding value to various wood products by on-farm processing and by marketing some of their products themselves. This applies particularly to smallwood products such as poles and firewood. The establishment of co-operatives of farmer-foresters would also facilitate marketing.

In addition to the use of mixtures, cash flow problems may be alleviated by improvements in the markets for, and marketing of, early thinnings and a development of markets for coppice products. Short rotation coppices in the lowlands could be managed on cutting cycles as short as 5 years.

Breeding and selection and greater understanding of the optimum management of a number of species may bring about significant increases in growth rates and yields, and appreciably improve the financial performance of forestry relative to agriculture, particularly on better land.

The opportunity costs of forestry would be reduced if a political decision to encourage the adoption of forestry on farms were made and Government financial support to agriculture were reduced. This may need to be accompanied by additional financial support, *via* grants, subsidies, fiscal incentives etc to forestry and by an appropriate easing of planning restrictions. Peart *et al* (1985) suggested a *Woodland Compensatory Allowance* comparable, in terms of its proposed socio-economic or environmental objectives, to the *Hill Livestock Compensatory Allowance,* to facilitate afforestation in the Less Favoured

Areas, and recent changes in the Hill Livestock Compensatory Allowance now make it possible for farmers to continue to receive the grant for 15 years after afforestation of land which was previously part of the forage area.

Partnership schemes between farmers and forestry companies or tenant farmers and landlords, and reverse mortgages are possible means by which farmers may be able to receive regular incomes for forestry enterprises, thus alleviating cash-flow problems.

In some situations, a farmer may benefit from simply selling part of the farm's land to a forestry company and using the proceeds to improve the rest of the farm; this seems to have proved successful in some cases (Mutch & Hutchinson, 1980).

Finally, a recognition of the scope for forestry on farms should stimulate the generation and flow of information regarding forest management and marketing *via* promotion schemes, advisory services, educational and training.

Future research should aim to develop improved genotypes of a number of species for a wide range of environments, provide recommendations for management, investigate markets and marketing and examine the various social, economic and practical factors likely to affect the adoption of forestry on farms.

The most immediate prospects for forestry on farms would seem to be on poorer land in the uplands, where forestry is more profitable from a national viewpoint than heavily subsidized livestock farming. Forestry may also have some social advantages; according to MacBrayne, C (personal communciation) forestry provides about seven times as many jobs locally as hill farming.

In the medium to long term, technical developments and changes in financial arrangements along the lines already described would considerably enhance the scope for forestry on better land in the uplands and the lowlands.

Wood energy plantations

Wood energy plantations have been examined at a number of research centres in the UK and the EC in recent years. Much of this work has centred on technical aspects and included: investigation of technologies for utilizing wood as, or for converting wood to, fuel; assessments of the productivity of various species and production systems; field trials; and the development of management systems and harvesting machinery (Bonicelli *et al*, 1984; Dimitri, 1985; Keville & Devenish, 1984; McLain, 1983; Mitchell, 1984; Neenan & Lyons, 1984; Pearce, 1984; Stott *et al*, 1983; Teissier du Cros, 1984).

The technical potential for growing trees for energy has been clearly established *via* these studies, and ongoing experiments and trials should provide refined estimates of yields and production costs, and recommendations for management.

Wood utilization and conversion technologies

Wood can be used to provide heat *via* direct combustion. The efficiency of conversion varies from 25–45% in conventional stoves, to 80% in modern boilers. Even higher efficiencies have been obtained experimentally (Kofoed Nielsen & Nielsen, 1983) The technology is well developed and a range of wood burners are available for domestic, farm and industrial applications. Large-scale direct combustion of wood could be used to generate electricity in wood-fired power stations (Rose, 1977; Neenan & Lyons, 1982).

Wood can also provide low-grade heat *via* aerobic decomposition. A system for providing hot water from the decomposition of wood chips has recently been developed and commercialized under the name of *Heat Heaps*. Essentially, a large stack of wood chips is built around a matrix of pipes through which water is pumped. The decomposing chips heat the water to about 60°C. The system provides hot water for 1.5 to 2 years, is pollution free and also yields a valuable compost (Farmers Weekly, 1984). The system has yet to be scrutinized economically, but appears promising in specific circumstances, particularly for glasshouse enterprises.

Three types of gasification process for wood have been developed using air, oxygen and hydrogen. These yield a low energy gas for combustion, synthesis gas (for conversion to methanol) and methane respectively. Air gasification can achieve 70–80% efficiency (Paine *et al*, 1983) for heat production, or 15–20% efficiency generating electricity (Leuchs, 1983). Methanol production may achieve 55% efficiency (Bridgewater, 1984). Small-scale air gasification units are available; methanol and methane production are less developed and very large-scale.

Pyrolysis of wood yields a mixture of char, liquid fuels and gases. The process is relatively simple and can be operated on a small scale, but the products are unreliable. The main potential of the process is probably in the production of charcoal as a luxury commodity (ie for domestic barbecues) and as a feedstock for specialist industry. Improvements in charcoal technology and development of indigenous production and markets could provide the basis for a new farm enterprise or rural industry. Currently the UK imports 20 kt of wood charcoal per year; this is valued at about £4 million. The bulk is from Spain and Portugal although 3 kt comes from Ski Lanka (HMSO, 1984).

Direct liquefaction, strong hydrolysis, yeast fermentation and bacterial fermentation are all technologies yielding liquid fuels. These are currently at an experimental stage or an early phase of development.

Species and productivities

Table 4.2 lists species suitable for use in wood energy plantations together with recorded or estimated annual productivities. These data should be treated with caution. The figures quoted are estimates from experiments, results of trials or averages from a number of sources and are not necessarily an accurate guide to the yields which may be obtained in the practical managed systems. The main distinction is between species suitable for coppicing and for single-stem production. In either case, as stem diameter is less important for energy production, rotations are significantly shorter than those of conventional forestry systems. In addition to the species listed, Black Alder, Pubescent Birch and Hybrid Larch are suitable species for single-stem energy plantations.

Table 4.2

Annual productivity of various energy forestry species in the UK

Crop	Yield t DM per ha	GJ per ha[2]	Source
Coppiced trees			
Eucalyptus[1]	20.0	400	c
Eucalyptus[3,4]	3.1	62	e
Eucalyptus[3,5]	8.3	166	e
Poplar[1]	20.0	400	c
Poplar[3,4]	10.3	206	e
Poplar[3,5]	15.2	304	e
Willow[1]	15.0	300	c
Willow[3,4]	8.3	166	e
Willow[3,5]	11.2	224	e
Willow[3]	11.8	236	d
Southern beech[1]	10.0	200	c
Alder[1]	6.0	120	c
Sycamore[1]	6.0	120	c
Sweet chestnut[1]	4.0	80	c
Hazel[1]	1.0	20	c

Single-stem trees			
Southern beech[1,6]	14.0	280	b
Douglas fir[1,6]	11.4	228	b
Douglas fir[1,7]	3.7	74	b
Douglas fir[1]	4.65–11.16	93–223	b
Corsican pine[1,6]	9.0	180	b
Corsican pine[1,7]	4.5	90	b
Corsican pine[1]	2.89–9.62	58–192	a
Sitka spruce[1,6]	8.9	178	b
Sitka spruce[1,7]	2.4	48	b
Sitka spruce[1]	2.21–8.83	44–177	a
W hemlock[1,6]	8.9	178	b
Ash[1,6]	8.3	166	b
Birch[1,6]	8.3	166	b
Japanese larch[1,6]	8.2	164	b
Japanese larch[1,7]	6.7	134	b
Japanese larch[1]	1.99–6.96	40–139	a
European larch[1,6]	6.5	130	b
European larch[1,7]	6.4	128	b
European larch[1]	2.18–6.54	44–131	a
Sycamore[1,6]	7.7	154	b
Grand fir[1,6]	7.5	150	b
Poplar[1,6]	7.3	146	b
Poplar[1]	1.66–5.82	33–116	a
W red cedar[1,6]	6.8	136	b
Lawson cypress[1,6]	6.8	136	b
Lodgepole pine[1,6]	5.8	116	b
Lodgepole pine[1,7]	4.7	94	b
Lodgepole pine[1]	1.92–6.73	38–135	a
Norway spruce[1,6]	5.4	108	b
Norway spruce[1]	2.40–8.80	48–176	a
Noble fir[1,6]	5.2	104	b
Scots pine[1,6]	4.9	98	b
Scots pine[1,7]	3.6	72	b
Scots pine[1]	1.99–6.96	38–139	a
Oak[1,6]	3.7	74	b
Oak[1]	2.76–5.51	55–110	a
Beech[1,6]	2.8	56	b
Beech[1]	2.76–6.89	55–138	a

[1] Estimate.
[2] Assuming 20 GJ per t DM.
[3] Yield in trial.
[4] 2 m^3 spacing.
[5] 1 m^3 spacing.
[6] Fertile lowland sites.
[7] Less fertile lowland sites and uplands.

Sources: (a) Callaghan *et al* (1978), (b) Mitchell (1978), (c) Pearce (1980), (d) Stott *et al* (1983), (e) Mitchell & Pearce (1984)

The economics of wood energy plantations
The economic potential of wood energy plantations on GB farms was investigated in a recent study (the *Land Availability Study*) (Price & Mitchell, 1985) involving a number of institutions, including the Centre for Agricultural Strategy, and coordinated by the Energy Technology Support Unit of the UK Department of Energy. Three types of wood energy plantation were considered.

(i) Short rotation coppice energy plantations using fast-growing hardwoods on rotations of up to five years (primarily in lowland areas).

(ii) Single stem energy plantations using hardwoods or softwoods managed intensively on rotations of 15 to 20 years (primarily in upland areas).

(iii) Modified conventional forestry, in which a proportion of the early thinnings and all the residues are used for energy and the rest for timber (primarily in upland areas, but to some extent in the lowlands).

The financial performance (in terms of Net Present Values) of these systems was compared with that of the current agricultural land use and with conventional forestry on 8 sample squares from each of the 32 land classes of the Institute of Terrestrial Ecology Land Classification System. Assuming that the land use which gave the best financial returns would be implemented, the areas of land available for the above energy forestry systems (and resulting fuel and timber outputs) were than calculated and the results raised to provide an estimate for GB as a whole. Net Present Values for the current agricultural enterprises were based on estimated Gross Margins, while those for the forestry systems were based on established forestry costs and revenues.

The procedure was carried out using a number of different values for a number of economic parameters. The results of an exploratory case appear in Table 4.3. These are based on the following assumptions: all costs and revenues in 1977 terms; a 5% discount rate; a 60 year

Table 4.3
Estimated area and production of GB land potentially available for wood energy plantations

Forestry system	Area (Mha)	Fuelwood (Mt DM)	Timber (Mt DM)
Modified conventional forestry	2.03	9.78	25.8
Short rotation coppice	0.23	2.98	–
Total	2.26	12.75	25.8

Source: Adapted from Price & Mitchell (1985) investment period; agricultural costs and revenues, and timber prices constant in real terms; cost of land purchase not included (ie afforestation done by owners); agricultural and forestry grants included; wood for energy valued at £20 per t DM (£36 per t DM in 1983 terms). Most of the land potentially available for wood energy plantations was poor pasture or rough grazing, currently used to graze sheep (mostly upland) and cattle (mostly beef).

Effects of social and institutional constraints. Various constraints, arising from "national needs, public pressures" and "legal impediments to land use change" (Price & Mitchell, 1985), on the availability of land for wood energy plantations were identified. The results of applying these to the 'exploratory' case appear in Table 4.4.

Table 4.4
Estimated area and production of GB land potentially available for wood energy plantations excluding land subject to social and institutional constraints

Forestry system	Area (Mha)	Fuelwood (Mt DM)	Timber (Mt DM)
Modified conventional forestry	0.73	3.32	8.84
Short rotation coppice	0.09	1.36	–
Total	0.82	4.76	8.84

Source: Adapted from Price & Mitchell (1985)

Effects of changes in financial parameters. The effects of increasing and decreasing the value of wood for energy, of a lower discount rate and of the removal of the Hill Livestock Compensation Allowance and forestry planting grants on the area and production of land potentially available for wood energy plantation were examined; results appear in Table 4.5. Only with wood valued at £25 per t DM did single-stem energy forestry appear in the solution (only 10 kha), and conventional forestry was not financially competitive with forestry for energy or the current land use under any of the assumptions tested.

In order to examine the effects of farming's fixed costs and of the practicalities of implementing forestry systems in the context of the overall farm business environment on the area of land available for wood energy plantations, Thompson (1984) constructed Linear Programming models of representative farms from four of the land classes of the Institute of Terrestrial Ecology Land Classification System. The models allocated the farm resources of land, labour, machinery and

Table 4.5

Area of GB land potentially available for wood energy plantations under variou: scenarios including and excluding land subject to social and institutiona constraints

Case	Area (Mha)	Fuelwood (Mt DM)	Timber (Mt DM)
Exploratory	2.26 (0.82)	12.75 (4.76)	25.80 (8.84)
Wood at £15 per t DM	1.70 (0.63)	8.42 (3.23)	21.25 (7.82)
Wood at £25 per t DM	3.82 (1.83)	30.09 (17.09)	28.05 (10.03)
Discount rate at 3%	5.82 (2.82)	29.90 (14.70)	65.60 (29.50)
No HLCA	2.45 (0.87)	13.43 (4.85)	27.71 (9.44)
No forestry grants	1.30 (0.58)	7.99 (3.40)	15.30 (6.72)
No HLCA or forestry grants	1.41 (0.59)	8.59 (3.40)	16.92 (6.80)

Source: Adapted from Price & Mitchell (1985).

working capital to the various possible activities in order to maximize Management and Investment Income over a 60 year period (assuming a 5% discount rate).

A number of runs of the models were used to examine the effects of various fixed or allowable areas of forestry, of whether or not the farmers had access to forestry contractors, of reducing forestry Net Present Values by 10% and of limiting the allowable increase in working capital to 150% of the base level. Some of the results appear in Table 4.6.

In general, the results indicated that the introduction of wood energy plantations could generate an increase in farm income over a 60 year period on both lowland and upland farms, although benefits were appreciably greater on the latter. The *advantages were enhanced by possible economies of scale with large plantations and by minimizing the use of forestry contractors through reallocation of farm labour, machinery and working capital* (Thompson, *et al* 1984). The lowland farm was most sensitive to changes in forestry values, while restricting the availability of contractors or capital had an inhibiting effect in all cases.

The Linear Programming study thus confirmed the general findings of the earlier Land Availability Study, but also indicated that farm management factors were an important determinant of the viability of wood energy plantations and that the areas of forestry recommended by the Land Availability Study were not necessarily the most beneficial from the farmer's viewpoint.

Table 4.6

The effect of introducing forestry enterprises on Management and Investment Income (MII) and working capital requirement on four representative GB farms

Farm	Proportion to forestry %	Change in MII %	Change in working capital %
Forestry area fixed at levels predicted by the 'Land Availability Study'			
A[1]	21	+1	−5
B[2]	52	+45	−10
C[3]	43	+325	0
D[4]	59	+66	+28
Free choice of compatible forestry			
A[1]	42	+7	−9
B[2]	81	+128	−38
C[3]	90	+1 025	+2
D[4]	86	+282	+42

[1] Specialist dairy farm with cereals from southern and central England (108ha, MII – £24 000 per year).
[2] Upland livestock rearing farm in Wales (65ha, MII – £3 000 per year).
[3] Mainly dairying farm on marginal land in the Yorkshire Dales (101ha, MII – £500 per year).
[4] Upland rearing farm in NE Scotland (460 ha, MII – £85 000 per year).

Source: Adapted from Mitchell *et al* (1983).

Future prospects

Studies so far on technical aspects of wood energy plantations have indicated their broad technical feasibility, provided some assessment of the kinds of yields that can be expected and some recommendations for management. Further experimentation to verify the estimated energy-forestry costs and yields used in some of the studies (notably the 'Land Availability Study') reported above is, however, needed.

Ongoing research and development at a number of centre in the UK include: small-scale trials of coppiced and single-stem energy plantations; large-scale trials; studies of weed control and ground preparation in coppiced woodland; coppice harvester development; and investigations of the environmental impact of energy forestry.

Work is also needed on the breeding of improved cultures for wood energy plantations, and to investigate and develop means of providing planting material of the most desirable genotypes in sufficient quantities for large-scale implementation.

The studies reported above indicated that wood energy plantations may be a profitable enterprise for farmers in many situations, and could be implemented over a significant area in GB. However, both the Land Availability Study and the Linear Programming study were based on a 60 year accounting period and took no account of the cash flow considerations likely to affect the decision to introduce wood energy plantations. Other factors likely to affect the adoption of wood energy plantations include: tax benefits; changes in discount rates, grants and subsidies; farmers attitudes and other practical, social and psychological effects; and availability of markets for wood energy products.

Some of these effects are being examined in a study currently being carried out by the Centre for Agricultural Strategy, but work is also needed on the availability and development of markets for wood energy products, and on the likely national costs and benefits of wood energy plantations. The main determinant of the viability of energy forestry is the current price of conventional fuels. While this does not provide a strong incentive to develop biofuel production systems at present, it is clear that research is needed now to ensure such systems can be implemented as and when they are needed.

AGROFORESTRY

Agroforestry is a term used to describe systems and practices where woody perennials are deliberately grown on the same land-management unit as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence, such that the agricultural and forestry components interact both ecologically and economically (Anon, 1983).

This definition encompasses a wide range of land-uses which vary in the relative proportions of agricultural and forestry components, the relative economic importance of the components and the nature and extent of ecological interactions. Agroforestry includes such practices as the use of trees to provide shelter for livestock or as windbreaks in orchards, the grazing of livestock in forestry plantations and the cultivation of arable crops in strips between rows of trees.

The main reason for considering agroforestry in the UK is the growing evidence from around the world, and particularly from recent experience in New Zealand, that agroforestry is more profitable in some situations than either forestry or agriculture alone. This may relate partly to product diversity, partly to a more efficient use of resources (ie light, water and nutrients) and possibly to other beneficial interactions between components.

Agroforestry may also be more desirable in relation to various conservation interests than agriculture and/or plantation forestry. Systems in which trees are intimately integrated with crops or pasture may be more visually pleasing, comparable to traditional parklands or hedgerow landscapes, and a diversity of species may provide a diversity of habitats for wildlife. Agroforestry systems may also provide opportunities to exploit a wide range of tree species and, perhaps, some rare breeds of domestic livestock. Finally, agroforestry systems may maintain or improve soil conditions and fertility – a feature which has been central to their perceived value in the tropics.

Combining forestry with agriculture rather than replacing agriculture with forestry may be more acceptable to the farmer. Interim income would be provided by the agricultural component, while retaining the agriculture enterprise and planting trees at the necessary lower densities may make it easier for farms to adjust to unforeseen change. The gradual land-use change which agroforestry would facilitate may be more psychologically and organisationally acceptable, and may also follow the development of new markets.

Forestry has been proposed herein as one possible alternative use for land currently producing surpluses. However, it may be more desirable and acceptable to reduce the output of currently overproduced commodities while, at the same time, retaining the production system; agroforestry represents a means of achieving this.

However, there are likely to be a number of disadvantages associated with agroforestry systems. Some of the interactions between components may be detrimental, and there may be some conflict between the management requirement of the agricultural and forestry components. For example, wide spacing is likely to promote much branching in some tree species and, hence, a loss of quality, while the high nitrogen fertilizer applications usually applied to pasture are likely to suppress apical dominance in the trees with a similar effect. Adoption of agroforestry may also result in a loss of scale economies and of the benefits of specialization.

Many of the perceived disadvantages of agroforestry systems are in fact uncertainties reflecting the very limited state of knowledge and understanding of the behaviour and management of such systems. They should provide an incentive for further investigation rather than dismissal.

Characteristics of agroforestry systems

Agroforestry is, essentially: a concept rather than a technology (Percival & Hawkes, 1985); a land-use approach which may incorporate a number of techniques, technologies and components; a generic type of land management system with many specific manifestations.

Common to all manifestations of the agroforestry approach is an association of woody perennial and crop and/or animal components; specific agroforestry systems are characterized by the number, types, functions, products, spatial and temporal arrangements and interactions of these components. Certain definable technologies or practices may result from particular component combinations (eg silvopastoralism), functions (eg shelterbelts, live fences, shade trees), products (eg apiculture with trees), spatial arrangements (eg alley cropping) and temporal arrangements (eg taungya), and certain agroforestry techniques or technologies, not related to specific components can also be defined (eg homegardens) (Carruthers, 1984).

Agroforestry systems can also be characterized in terms of primary land use. Where agroforestry represents an innovation it will be, primarily, the result of the introduction of an agricultural component into forestry (or, perhaps, tree crop) plantations, or the planting of trees on farmland, and the primary land use will be a particular type of forestry or agriculture. Such a distinction is less easily made where a traditional system that has developed over a long period of time is being considered.

Other characteristics of agroforestry systems are those which also describe farming systems in general and include natural and social environment, size and scale of operation, land tenure, labour, input and capital intensity and inputs and outputs (Carruthers, 1984).

Component types

Within the broad concept of agroforestry, different types of system will result from different combinations of components. A major distinction is usually made between combinations of trees and animals and trees and crops; the former can be described as *silvopastoral systems,* the latter as *agrosilviculture* and combinations of all three as *agrosilvopastoral systems,* although acceptance of such terms is far from universal (Labelle, 1983).

Forestry components of agroforestry systems can be broadly classified into *forestry species* (grown primarily for wood products) and *tree crops* (grown primarily for fruit or nuts), but the distinction is less clear where a tree provides both types of product. Depending on the other component, tree crops can also be regarded as agricultural components; hence, Apple trees sheltered by Poplars and sheep grazing in orchards can both be regarded as examples of agroforestry.

Possible animal components for silvopastoral systems in the UK and involving forestry species or, in some cases, tree crops include: beef and dairy cattle, sheep, pigs, free-range chickens, ducks, geese, deer and game birds. While most emphasis is currently being placed on the potential for grazing ruminants between forestry species (Adams, 1976; Doyle *et al,* 1986; The Furrow, 1985; MacBrayne, 1982), there may be some scope for silvopastoral systems based on tree crops, or involving poultry, game birds and deer (Harrington, 1984; Wagner, 1984).

Similarly, agrosilvicultural systems in the UK could involve combinations of forestry species or tree crops with arable crops (Miller, 1976) or horticultural crops or combinations of forestry species and tree crops (Sturrock, 1984a).

The choice of genotypes of components is an important aspect of the design of an agroforestry system and the particular nature of agroforestry may provide an opportunity or necessity to consider new species and genotypes within those species. For example, in silvopastoral systems different tree genotypes may react differently to wide spacing, pruning, browsing, debarking and nitrogen fertiliser, and pasture species vary in their shade tolerance. Similarly, animal species and breeds may perform differently on the herbage provided by a silvopastoral system, and the breed used in a conventional system may not necessarily be the most appropriate.

Products and functions

Both the forestry and agricultural components of an agroforestry system can provide one or a number of a wide range of products. Possible tree products include: sawlogs, pulpwood, speciality woods, veneers, turnery wood, domestic firewood, feedstocks for biofuel production or other industrial processes, wood chips (for various uses as listed earlier), fence posts, pea and bean poles, charcoal, fruits, nuts, animal feed (Robinson, 1985), bee forage and various chemicals.

While in the UK and other temperate regions the primary envisaged use of the tree component of agroforestry systems is to provide conventional forestry products, the scope of agroforestry may be broadened by considering novel products and the simultaneous production of a number of commodities (New, 1985).

Similarly, there may be scope for considering novel or existing, but currently small-scale, agricultural products. For example, while there is a growing market for free-range eggs in the UK, profitability is constrained by low productivity per unit land area; combining chickens with trees (perhaps simply by introducing chickens into existing forestry plantations) is unlikely to reduce the density of either on a given area of land, but should result in increased overall profitability. Such a system has yet to be examined in detail. There is currently a growing market for venison and although the rearing of deer in forests is a contentious issue, there may be scope for carefully managed agroforestry systems based on species other than Red deer.

The components of an agroforestry system may also serve one or a number of functions; these may be of some benefit to the other component, or represent a non-product output of the system as a whole. Possible functions of trees include:

(i) provision of barriers to livestock or boundary delimitation (live-fences, hedgerows);
(ii) protection of crops or animals from the environment (shelterbelts, shade trees, overwintering areas, windbreaks);
(iii) maintenance or improvement of soil conditions or fertility (soil conservation, erosion control, land reclamation, green manuring with trees, mulching with trees);
(iv) crop support (live stakes).

Of particular interest is the possible value of trees in providing shelter for crops and livestock. The use of shelter to improve the yields of crops is well-established in regions with windy climates (Marshall, 1974; Russell & Grace, 1979), but the mechanisms are unclear. Experiments on sugar beet and turnips by Marshall (1974) in East Lothian suggested that shelter may reduce plant water stress, at least during parts of the growing season, while Russell & Grace (1979), on the basis of experiments on grasses in southern Scotland, suggested that the effect of shelter on yield was due to mechanical stimulation of the plants and changes in the distribution of assimilates.

Cumming (1981) investigated the overwintering of cows with calves in young stands of Scots Pine and European Larch in Sutherland and concluded that *under certain conditions of soil drainage, the advantages to the farmer are reasonably interesting without causing undue damage to the plantation.* Holmes & Sykes (1984) suggested that shelter could be of value in reducing cold stress in lambs in New Zealand, but that shelter could also bring with it certain management problems, and that shelter was likely to be of less benefit to cattle than to sheep.

Chavasse (1984) examined world literature on the management of shelterbelts for wood production and concluded that timber could be produced from shelterbelts without detriment to their shelter value provided proper management is applied and the products efficiently marketed. Chavasse (1984) also drew attention to the shortage of serious information on the subject and the need for further research.

What seems clear is that there is appreciable evidence from around the world that shelter can benefit both arable and horticultural crops, grassland and livestock (Radcliff, 1984; Reid & Wilson, 1985; Sturrock, 1984a, 1984b), and that the use of trees for shelter can be integrated with productive uses, but further work is needed to identify the mechanisms and define the circumstances under which shelter is likely to be beneficial and to define potential productivities and management systems more exactly. Demonstration of the value of trees as shelter may enhance the potential and attractiveness of agroforestry in a number of situations.

An important function of agroforestry systems, and in particular the tree component, in some situations may be the maintenance or improvement of the environment. For example, Batini *et al* (1983) considered that the greatest potential for agroforestry in Australia was in developing systems for the control of stream salinity in catchment areas and soil salinity on farms.

Within an agroforestry system crops may also assist in maintaining or improving the soil, in some of the ways listed above, and provide some protection for young trees, while grazing animals in forestry plantations may assist in weed control, reduce fire risk and improve nitrogen cycling (Adams, 1975; Sharrow & Leininger, 1983).

Agroforestry systems may also improve landscapes and provide opportunities for recreation, conservation and education (New, 1985; Reid & Wilson, 1985). In addition, agroforestry systems may provide greater job opportunities than current agriculture or forestry, and the possibilities for complex and diversified systems with many components and products may enhance employment prospects stil further (New, 1985).

Spatial and temporal arrangements

Agroforestry systems will vary with respect to the relative spatial geometry, density and temporal arrangements of the agricultural and forestry components. Between the extremes of complete separation and intimate mixture there is a range of possibilities; trees can be grown in blocks, strips, rows, along boundaries or access routes, or randomly scattered at varying densities. Agroforestry techniques associated with particular spatial arrangements include: shelterbelts, hedgerows, live fences, alley cropping, strip cropping, row intercropping, multistorey cropping (Labele, 1983).

Possibilities for temporal arrangement of agricultural and forestry components include:

(i) static (components coincident for full duration of system operation);

(ii) discrete (components in discrete rotation);

(iii) partially overlapping (components in rotation, but subsequent established before removal of previous);

(iv) concurrent rotation (one component occupies land for full duration of system operation, the other for one or a number of separated periods).

The last category applies to systems where, for example, it is only possible to graze livestock during the early and late stages of a forest rotation, when the canopy is relatively open. Most systems for UK application are likely to be static or to fall into this category.

Interactions

While there is much empirical evidence of both beneficial and detrimental interactions between the agricultural and forestry components of an agroforestry system, scientific understanding is fairly limited. Uncertainty is therefore attached to the types and intensity of interactions which may occur within innovative agroforestry systems.

Adams (1975), discussing the potential for grazing sheep and cattle in forests in the UK, in addition to the beneficial interactions described above (weed control, improved nitrogen cycling, reduction of fire risk), drew attention to a number of possible detrimental interactions including damage to trees by grazing animals and chemical impoverishment and physical damage to soils by grazing.

On the basis of literature from various parts of the world Adams (1975) concluded that while some damage to trees is inevitable, damage can be minimized by careful timing and control of grazing. Damage also varies with animal species, sheep browse while cattle trample, and trees differ in their susceptibility to damage. Sitka Spruce, the main species of upland Britain, is unpalatable to stock. Adams (1975) also concluded that while grazing adversely affected the chemical status of forest soils, this was only a problem in unfertilized soils. However, damage to soil and roots by trampling, particularly in the wet conditions of upland Britain, may be a greater problem and would seem to exclude cattle from many upland forests in the UK.

In addition, the value of the fleeces of sheep grazed in Sitka Spruce plantations in Northern Ireland was reduced by some 40% owing to twigs caught in the fleece (MacBrayne, C–personal communication).

The major interaction between trees and crops or pasture in an agroforestry system is ecological competition. Percival & Hawkes (1985), reviewing New Zealand experience of silvopastoral systems based on *Pinus radiata* and sheep, concluded that pasture yields declined with increasing tree density and tree age/size, but that young trees may reduce the effects of other factors limiting pasture growth resulting in greater pasture yields under trees during the early stages. Gillingham *et al* (1976) reported that in trials on such systems in the central North Island of New Zealand, during the first three years after planting 20, 40 and 80% respectively of full grazing potential was achieved with adequate development of the tree crop, while inter-row cropping of hay or silage exhibited a production loss of about 8%.

Tentative projections of pasture yield and livestock numbers at later stages of New Zealand *Pinus radiata*–sheep systems suggested that, at 200 stems per ha, pasture yields and livestock numbers would be about 10% of open pasture after 16 years, while at 100 stems per ha the value would be about 30% after 20 years. However, reductions in pasture yield with increasing tree growth were related not only to direct competition, but also to smothering of pasture by pine needles and the effects of the debris from thinning and pruning (ie slash). Slash may also encourage some annual and perennial weeds. There is also some evidence that feed quality declines with increasing tree density and age (as a result, perhaps, of changes in pasture botanical composition, including a declining white clover content), and ingestion of pine needles (Percival & Hawke, 1985).

Competition may also affect tree growth, particularly during seedling establishment. New Zealand experience suggests that this effect is more severe on drier sites, but can be alleviated by using larger planting stock and by grass control using herbicides. In the New Zealand systems trees were most susceptible to browsing and debarking damage during the first 5–7 years. The amount of damage depended on the quantity of other feed offered, the stocking density and grazing system, and damage could be minimized by careful control of stocking density and by ensuring good tree establishment (Percival & Hawkes, 1985).

Practical experience

Agroforestry is and has been widely practised in the tropics and sub-tropics, and many traditional land-use approaches fall within the scope of agroforestry as defined earlier. These include shifting cultivation with a forest fallow; mixed plantation cropping; cattle grazing in plantation crops or between timber trees; taungya; homegardens; and the cultivation of trees on rangelands.

In temperate regions however, while the remnants of ancient systems may still be found and many areas have traditions of agroforestry-type systems, recent experience of agroforestry is fairly limited. Referring to Western Europe, Halle (1982) stated that, apart from *ancient and* *declining traces* in Scotland, the Isle of Man, the Netherlands, France (Brittany, Cevennes) and Northern Germany, the practice of agroforestry was almost negligible at present. This may be less true for Mediterranean regions and less-developed areas of Europe. For example, Kotar (1982) listed a number of systems and practices currently being exploited in Yugoslavia. These included silvopastoral systems (eg Spruce and Silver Birch with pasture in the uplands, lowland Oak forests and pigs, *Acacia* and pastures), agrosilviculture, Poplar or Spruce and corn), apiculture with trees and the use of trees to provide animal feed (ie fodder trees).

In parts of Italy, agricultural crops have been grown between rows of young Poplars for many years. In the Po valley, for example, forage crops (eg maize) are grown for three or four years until the trees are well developed. Observations of such practices have suggested that cropping may, in fact, improve tree growth (Reid & Wilson, 1985).

A similar practice has been carried out in the UK in some Poplar plantations for traditional products. Poplars planted at 8m spacings were underplanted with wheat, barley or oats for the first 6 or 7 years; after this period the trees were no longer sensitive to damage by cattle and the area was sown with mixed grasses and grazed for the remaining period (Miller, 1976).

Other agroforestry practices in the UK include the use of forestry species to provide shelter for fruit trees, grazing and overwintering livestock in forest plantations and orchards, and the use of hedgegrows, windbreaks and shelterbelts. However, these systems and techniques are largely informal, are not well documented and limited and restricted in practice.

In contrast to other temperate countries, New Zealand has gained considerable experience in agroforestry in recent years. This has centred on silvopastoral systems based on *Pinus radiata*, the Country's major exotic timber species, and cattle or sheep. The initial impetus came from changes in the silvicultural practices advocated (lower densities, early thinning to waste, intensive pruning) which enhanced the grazing potential of forests, and a series of severe droughts in the early seventies which resulted in large numbers of cattle being grazed in forests (Percival & Hawke, 1985).

Early interest in the scope for silvopastoral systems came from the forestry companies which now manage much of the current area of agroforest in New Zealand but, subsequently, the concept gained interest among farmers. Commercial applications, therefore, involve both the grazing of cattle in forests and the planting of trees of farmland.

At present silvopastoral systems occupy an estimated 30 kha of farmland and 70 kha of forest areas.

Claimed advantages of forest grazing to the forester include improved stand access, improvement of tree growth, reduction of fire risk, weed control, additional revenue and intermediate income, and maintenance of public relations. Forest grazing provides additional grazing and offers the farmer the opportunity to rest farm pastures during critical periods. There is also considerable scope to improve pastures in existing forests by fertilizing and the introduction of legumes (Knowles & Cutler, 1980). The planting of trees on farms provides the farmer with an opportunity to broaden the farming base and enhance long-term security (Arthur-Worsop, 1985), and to enhance rural employment (Knowles & Cutler, 1980).

Commercial applications of agroforestry in New Zealand vary considerably in tree density, ranging from 100 to 350 stems per ha; this variation is largely due to the absence of clear management guidelines, such as would be provided by long-term experiments. However, there are a number of examples of the establishment of successful systems (Percival & Hawke, 1985). Specific case studies of some of these, together with examples of similar ventures in Australia, are presented by Reid & Wilson (1985). While it is clear that agroforestry in New Zealand is still in its infancy, it is also clear that the practice has gained appreciable ground over a relatively short time, that results so far are promising and that a substantial volume of documented experience, well in excess of that of the UK and most other temperate countries, is accumulating.

Research and development

The adoption of agroforestry systems in New Zealand has been accompanied by research and development on both biological and economic aspects of the systems. Some of this has already been reported above in connection with interactions between components of agroforestry systems, but a number of other aspects have been considered. In relation to trees planted on farmland, experiments, trials and observations at a number of sites indicated a higher basal area growth of trees than on straight forest sites. This may be due to fertility build-up from farming over a number of years or to the nutrient turnover by livestock. Observations suggest that wild types of Yorkshire fog grass may be better adapted to agroforestry conditions than the grass species and varieties currently used and that long internode forms of *Pinus radiata* may be preferable to the current types, highlighting the general point that a new type of system calls for new genotypes (Percival & Hawkes, 1985). Increasing attention is also being paid to the legume *Lotus pedunculatus* as a possible means of improving forage in forests (Knowles & West, 1984).

Studies in New Zealand using a computer-based simulation model, entitled SILMOD, suggested that final crop stockings of 100 stems per ha are likely to be most profitable to the grower (Knowles & West, 1984). A cost-benefit analysis by Arthur-Worsop (1985) indicated that, from the national viewpoint, the financial performance of agroforestry was better than pastoral agriculture or forestry alone at a 10% discount rate and given standard site and management conditions. Stewart (1985) concluded that investment in agroforestry is profitable to the farmer, but that many farmers would have difficulty in financing the investment due to the long period between planting and income.

Research to support the development and implementation of agroforestry in New Zealand continues on the themes described above and on other aspects, and is an important determinant of the future of agroforestry in that country.

Worldwide, the growth of interest and research activity in recent years is appreciable. Existing systems are being scrutinized and trials and experiments are being set up. In addition to providing a detailed account of current research activities in Australia and New Zealand, Reid & Wilson (1985) drew attention to a range of activities in North, Central and South America and China, and pointed out that, in almost all tropical countries, there has been some research effort in agroforestry.

In contrast, research in Europe is sparse and what interest there is is directed towards the tropics (Reid & Wilson, 1985). In the UK, interest has been slow to grow. Some work on forest grazing (Adams, 1975), overwintering in forest plantations, (Cumming, 1981) and lowland silvopastoral systems (Doyle *et al*, 1986; The Furrow, 1985) has been done and, very recently, a number of theoretical and experimental projects have been initiated at a number of centres.

An experiment by Adams (1975), to investigate the effects of grazing sheep in a young (6 years) Sitka Spruce plantation in Co. Antrim, concluded that grazing significantly reduced tree growth (probably owing to damage to tree roots); the plantation provided useful amounts of forage until the canopy closed; and both tree growth and forage yield were increased by NPK fertilizer. Damage to trees might be reduced by changing the grazing regime, which involved high densities over short periods, to lower densities over long periods. The effects on fleece quality have already been referred to.

A trial, begun in 1979 at Queen's University, Belfast on a lowland site, involved the planting of Japanese Larch, Sitka Spruce, Norway Spruce and Southern Beech in 7 m spaced rows. This enables the mechanization of grassland or even crops between the rows (The Furrow, 1985).

A mathematical modelling study of intercropping trees with grassland in lowland Britain (Doyle *et al*, 1986) indicated that, at a discount rate of 5%, combining wood and sheepmeat production on the same area could be financially attractive. However, the model was based on many assumptions which have yet to be tested and its results need to be treated with extreme caution.

A number of centres in the UK have recently initiated, or propose to carry out, various studies related primarily to silvopastoral systems. These include: a study of the effect of wide tree spacing on the interception of radiation by, and growth of, Sitka Spruce and pasture; a silvopastoral trial based on Sitka Spruce and sheep on an upland site; various proposed silvopastoral trials on both upland and lowland sites; an assessment of the potential of agroforestry to produce food and fuel in the UK and EC; and various modelling studies.

Future prospects

As already indicated, agroforestry represents an alternative land-use with a number of apparent advantages, some of which address certain current problems facing UK agriculture. Agroforestry also offers a means of facilitating the adoption of forestry on farms and, hence, of expanding the nation's forest resource.

It is clear from the above that interest in agroforestry in the UK and worldwide is growing, and there is an increasing volume of knowledge, understanding and data accumulating. Of particular interest is the recent example and experience of New Zealand.

While the central theme of this report is the scope for alternative land-uses and enterprises on farms, it is also clear that the agroforestry approach is of some relevance and interest in other contexts. The overall prospects for adoption of agroforestry practices and land uses in the UK are summarized below.

Shelter

The uses of trees to provide shelter may be of benefit to farming in a number of contexts. For example, studies on the overwintering of cattle in upland forest plantations indicate potential on dry, well-drained, unploughed sites with Scots Pine or Larch, but not on wetter podzolized soils. Shelter may also benefit livestock and crops in many parts of the UK, but information on the benefits and management of shelter is limited; an up-to-date review of relevant literature applicable to the UK and further research and development is needed.

Forest grazing

The grazing of sheep for short periods of rotational grazing in direct-planted forests on free-draining soils would seem to be possible, although there is likely to be little herbage available. It is unclear whether the problems of damage to tree roots by sheep on wetter soils can be easily overcome, but further investigation of optimum stocking densities and grazing management may be merited. In the light of New Zealand experience, there may be scope for forest owners to re-establish forests, after clear felling, as agroforests.

Silvopastoral systems on the hills and uplands

Experience in New Zealand and elsewhere, and current levels of profitability of agriculture in the hills and uplands, suggest that the most immediate prospects for agroforestry in the UK lie in the establishment of trees, at wider spacings than conventional plantations, on upland grazing areas. Such systems would seem to have more scope on better uplands where species of greater value than Sitka Spruce, which would repay the necessary intensive pruning, can be grown, and less on the poorer hill areas where the value of Sitka Spruce, which may be even less at wider spacings, would not repay the labour inputs for pruning. However, it may be unwise to dimiss, totally, systems based on Sitka Spruce at this stage. Research and development is needed to determine optimum tree densities and arrangements, and to develop tree, pasture and grazing management systems suitable for UK conditions.

Trees on lowland pastures

New Zealand experience and the work of Doyle *et al* (1986), referred to above, suggest there is also scope for silvopastoral systems in lowland areas; research needs are similar to those for the uplands.

Novel silvopastoral systems

There is some value in considering systems based on animal species other than sheep and cattle. Of particular interest is the scope for integrating free-range egg production with plantation forestry, for silvopastoral systems involving deer and for integrating forestry with game rearing (although many of the conflicts of interest between forestry and the latter would need to be resolved).

Agrosilviculture

There are very little data available, at present, on the performance of integrated systems of trees and crops although a number of advantages can be envisaged. Some of the studies currently underway may supply some data, but more detailed examination is needed before any conclusions can be drawn.

Complex systems

While temperate climates would probably be unable to sustain complex, multi-storey systems comparable to the homegardens of the tropics, there may be scope for small-scale, highly integrated agroforestry systems involving a number of tree, crop and animal species and incorporating a number of technologies.

CONCLUSIONS

Incentives to expand the UK forest resource in general and to manage existing woodlands and to carry out new plantings on farms in particular include:

(i) *Demand for conventional wood products.* Current levels of national self-sufficiency in conventional wood products are low and appreciable increases in demand are anticipated; a higher level of national self-sufficiency and, heance, an expanded forestry resource may be considered desirable.

(ii) *Potential of wood as a feedstock for biofuel production and the chemical industry.* Demand for wood could increase further as wood-based fuel production and other industrial processes develop.

(iii) *Markets for smallwood products.* It seems likely that the market for various smallwood products, such as woodchips and domestic firewood, will expand in the future.

(iv) *Conservation and recreational interests.* The conservation value of woodland and the scope for a range of woodland-based recreational activities are being increasingly recognized.

(v) *Importance of broadleaved resources.* The need to conserve and expand national broadleaved resources is also being recognized.

(vi) *Land availability and suitability.* A high proportion of UK land is in agriculture and most UK farmland is technically suitable for growing trees.

The major constraints on the adoption of forestry on farms are:

(i) *Cash-flow.* High capital requirements and costs and the related cash-flow problems place a strong constraint on the implementation of forestry on farms in the UK.

(ii) *High opportunity costs.* Opportunity costs of forestry on much UK agricultural land are currently high owing, at least in part, to the high levels of direct and indirect financial support to agriculture.

(iii) *Tradition.* In contrast to much of the rest of Europe, the UK does not have a tradition of farm forestry. Many farmers appear disinterested or even antagonistic to forestry and many may lack the necessary knowledge, skills and expertise. In addition, as commercial forestry in the UK has been largely restricted to a few species on poorer land, detailed know-how related to other species and better land may not be available.

(iv) *Availability of suitable planting material.* Nursery stock of genotypes of a suitable type and quality for use in environments and management systems other than those associated with current conventional forestry systems may not be readily available in sufficient quantities.

(v) *Land tenure.* Although there are now some provisions to enable tenants to claim compensation, in respect of trees they have planted, on termination of the tenancy, tenants may still be reluctant to invest in forestry plantations on their farms.

(vi) *Markets.* Many of the forestry systems described herein depend on markets which have yet to be developed.

(vii) *Economies of scale.* The farmer implementing forestry on a small-scale may have some difficulty in competing with large-scale plantations in relation to both production and marketing.

A number of factors can be identified which may serve to reduce the effects of the above constraints and facilitate the adoption of forestry on farms in the future; these relate to information dissemination, technical improvements, the development of markets and financial arrangements. In addition, farms may be able to capitalize on the relatively small-scale nature of their forestry enterprises by applying more intensive management and by marketing some of the products themselves.

Information dissemination

A range of measures to promote forestry on farms and to educate and advise farmers on forest management and marketing can be envisaged. The implementation of nearly all the systems proposed herein would depend on adequate promotion, education, advice and information dissemination.

Technical improvements

The productivity of trees on better agricultural land may be higher than that anticipated on the basis of the yields of current UK forests, and the potential to improve yields by breeding and selection seems considerable. Cash flow problems may be less where trees are grown on shorter rotations (eg for energy) and particularly where coppice management is practised, and where trees are grown in agroforestry systems from which intermediate income is provided by the agricultural component. Research and development to examine the production, management and mechanisation of these systems should enhance their potential considerably. In general, research along the lines indicated in the preceding sections should contribute to the identification and realization of both the technical and economic potential of forestry on farms.

Markets and marketing.

A recognition of the scope for using wood for a range of uses, and other factors, such as increases in energy prices, greater demand for countryside-based recreation and the further development of various technologies, should lead to an expansion of markets for forest products and services, particularly for those provided by short-rotation forestry systems. The development of co-operatives could facilitate the marketing of forestry products by farmers.

Financial arrangements.

A consideration of the relative value of indigenous food, timber and fuel production, at a national level, and of the value of an expanded forest resource may lead to changes in the levels of financial support to forestry relative to agriculture and to the provision of financial incentives for afforestation on farms. There are some small indications that this may already be occurring. In addition, a number of schemes to provide farms with interim income have been suggested, including reverse mortgages and partnership schemes.

In the short term, given some development of markets and dissemination of advice and information, there would seem to be appreciable potential to rehabilitate and manage existing farm woodlands towards a number of products and services. There would also be scope to use trees to provide shelter for crops, pasture and livestock in a number of situations. The establishment of conventional forestry on farms is technically feasible, but implementation would depend on improved financial arrangements.

Medium-term possibilities include the grazing of livestock in some (probably a very limited number of) forests, planting trees on grazing lands in both the uplands and lowlands, and various types of energy forestry. The viability of energy forestry depends ultimately on the prices of conventional fuels.

In the long term there may be scope for novel silvopastoral systems, such as free-range chickens and trees, mixtures of trees and arable or horticultural crops and for more complex agroforestry systems with many components and products.

5 Other enterprises on farms

INTRODUCTION

Changes in modern farming practices and the policy and economic outlook for UK agriculture have led to some of the resources of farm businesses becoming unused or under-utilised. Some think this trend will continue. At the same time many farmers have been examining their systems to see whether any of these spare resources could become the basis of other profitable non-agricultural enterprises within their existing businesses.

In this chapter, some possible non-agricultural enterprises for farm businesses which already have, or could have, potential in the future, are classified, listed and briefly discussed. The disposal of farmland for non-agricultural use (eg gravel-extraction) and the use of redundant farm buildings (eg by craft industries), important subjects as they are, were not considered in the study of which this Report forms the background. The former was fully covered in *Land for agriculture* (CAS, 1976) and an interesting socio-economic review of the latter was provided for the Crafts Council by Bruce & Filmer (1983). Their non-inclusion is not a reflection on their being unimportant (for they can, and do, provide useful sources of capital and income), just that they were not considered in the terms of references as they are not integral to the farm business.

Perhaps the most common non-agricultural enterprises on farms are those that provide facilities, opportunities and accommodation for a wide range of leisure and recreational pursuits, both on a day-trip and tourist basis. Before classifying, listing and discussing these, it is helpful to set them in the national context. For example, in England in 1983, 110 million tourist trips were made taking up 435 million nights and in 1982, 539 million day trips were made (Southern Tourist Board, 1984). Phillips & Worth (1985) reporting on a Countryside Commission survey in 1984 showed that visiting rural areas in England and Wales is now the most popular all-year-round leisure activity. Some 7–8 million people visit the countryside at least once a week and a further 20 million go most months. Growth in such activity has increased, aided by the rise in car ownership. For example, between 1970 and 1980 indices provided by the Countryside Commission (1982) show an increase in Caravan Club membership of 180%; overnight stays at youth hostels increasing by 448%; and visits to National Trust properties increasing by 113%.

Thus it can be seen that tourism is on the increase, as are visits to the countryside, and it is reasonable to suppose that these trends will continue. Further information from the 1984 Countryside Commission survey (Phillips & Worth, 1985) helps to put countryside recreation activities in context, for interviewees were asked which of 20 activities they had undertaken in the last 4 weeks (including 2 non-countryside activities). Table 5.1 summarises their answers to this question. It can be seen that the most popular countryside activities were: drives, outings and picnics; long (over 2 miles) walks, rambles or hikes; visiting friends and relatives in the countryside; and informal sport. The main aspect of these figures is that they show how important the wider

Table 5.1
Recreation activities of participants in the Countryside Commission survey, England and Wales, 1984

Location of activity or visit	Type of activity or visit	Proportion of days spent (%)
Urban	park/urban space	20
	seaside resort	11
Un-managed, (wider) countryside	drives, outings, picnics	13
	long walks	12
	visiting friends, relatives	10
	informal sport	8
	sea coast	6
Managed countryside	organised sport	5
	pick-your-own	3
	historic buildings	3
	country parks	3
	watched sport	2
	others	4

Source: Phillips & Worth (1985).

un-managed countryside is, for it accounted for 3 times as many days spent in countryside as the managed sites – in stark contrast to the proportion of funds spent on management of such sites.

In the remainder of this chapter, the range of recreation and tourist enterprises which are, or could be, located on farms will be discussed as well as future possibilities and constraints.

SOME POSSIBLE FARM-BASED RECREATION AND TOURIST ENTERPRISES

It is not known for certain how many farm businesses encompass recreation and tourist enterprises in the UK, but a figure of 20 000 (roughly 10% of the total) is probably of the right order. In certain parts of the country, such as the National Parks and other popular holiday areas, this proportion is higher. Not only do such enterprises bring in important additional income to farm-families, they also help to provide income and employment for the wider rural community and thus underpin the infrastructure of these areas.

Table 5.2 provides a classification of some possible farm-based recreation and tourist enterprises and activities. It will be seen that the list is divided into three main categories: tourist accommodation; resource-based activities and day-visitor enterprises. These are discussed below, in general, in descending order of numbers of enterprises, amount of income brought in and ease of charging by the provider. Thus, for example, tourist accommodation tends to be the most ubiquitous, brings in the most income and is the easiest to charge for, compared with the two other categories.

Table 5.2

A classification of possible farm-based recreation and tourist enterprises

TOURIST ACCOMMODATION	RESOURCE-BASED ACTIVITY
In farmhouse	*Horse and pony based*
Bed and breakfast	Riding and trekking
Guesthouse	Eventing
Farm holiday	Polo and racing
Auto-holiday	Hunting
	Livery and grazing
Self-catering	Equestrian centres and clubs
Farm cottages	
Chalets	
Converted farm buildings	

TOURIST ACCOMMODATION

Second homes
- Redundant farm buildings
- Surplus farm cottages
- Long-let caravans

Camping sites
- Specialist
- General

Caravan sites
- Transit
- Touring
- Static

Specialised holidays
- Field studies
- Sketching
- Fishing
- Horse-based
- Diet-based etc

RESOURCE-BASED ACTIVITY

Water-based
- Fishing
- Swimming
- Boating
- Mooring

Shooting
- Rough shooting
- Organised shooting
- Water-fowl shooting
- Clay pigeon
- Rifle
- Pistol
- Archery

DAY-VISITOR ENTERPRISES

Informal recreation
- Car parks and picnic sites
- Country parks
- Rambling and wandering areas

Access to areas of natural interest
- Caves
- Hills
- Woodlands
- Downland
- Bird and wildlife watching
- Conserved sites
- Nature walking
- Botanical study

Dog-based
- Exercise
- Training
- Showing

Sporting
- Squash, tennis
- Golf course or driving range
- Village football and cricket
- Athletics, jogging, running

Catering
- Teas
- Kiosks

Farm produce sales
- Shop on farm or road side
- Pick-your-own

Public events
- In tents or in the open
- Farm-related eg shows, ploughing matches gymkhanas, hedge-laying, tractor pulling
- Non-agricultural eg motorcycle scrambles autocross, pop concerts, religious meetings, archery, model and full size aircraft, balloons etc.

Educational activities
- Farm open days
- Farm trails
- Demonstrations
- School visits
- Adopted farms

Source: Adapted from Boddington (1978).

Tourist accommodation

Work reported on by the University of Exeter (1983) is the most comprehensive source of information on the economic benefits to the farmer of farm tourism. Table 5.3 summarises their main findings. They are average figures which account for family labour but do not include tax. The striking thing shown by the Table is that average returns are low and that much effort is required to achieve them. For example, a farm bed and breakfast enterprise will have to deal with 243 adult guests a year to obtain a Management and Investment Income of only £275.

Ascoli (1985) provided Table 5.4 which details the costs of four common farm tourism enterprises as a proportion of receipts. The attraction of providing touring caravan facilities and bed and breakfast, with their low costs, is clear.

In farmhouse

Such enterprises include bed and breakfast, farm guesthouses, farm holidays and autoholidays. There is said to be scope for an increase in these activities but experience has shown that the length of the season is severely limited. Furthermore, many farmers, their wives and families do not appreciate the periodic invasion of their homes by strangers.

Table 5.3

Returns from farm tourism, 1982

Type of enterprise	Average farm income[1] (£ per annum)	Return per adult guest per night (£)
Bed and breakfast	275	1.13
Bed and breakfast with evening meal	639	2.26
		Return per unit or pitch per annum (£)
Self-catering conversion of existing unit	1 059	778
Static caravans	687	245
Small touring sites	346	23
Large touring sites	710	11
Tents only	376	12
Static caravans owned by caravaners	3 400	94

[1]Management and Investment Income from tourism.

Source: Reproduced from University of Exeter (1983).

Table 5.4

The costs of farm tourism enterprises as a proportion of receipts, 1985 (%)

	Bed and breakfast	Bed and breakfast plus evening meal	Self-catering	Touring caravans
Food	23	34	–	–
Casual hired labour	2.2	2.2	4.4	3
Repairs, renewals and maintenance	5.5	7.4	17.3	4
Fuel and electricity	2	2.3	8.2	1
Advertising, postage and insurance	4	4	8.3	2
Sundries	2.2	2.2	7.2	8
Total direct costs	39.9	52.1	45.4	18
Gross margin	60.1	47.9	54.6	82

Source: Adapted from Ascoli (1985).

There are now agencies in existence that add farmhouse accommodation to their advertising lists and arrange lets etc for a fee (eg Sussex and Surrey Farm Holiday Group, 1985).

Opportunity and siting close to the main tourist areas is very important and 100% occupancy for more than six weeks in the year is unusual. ADAS (1982a) provide a comprehensive guide to those considering the provision of farmhouse accommodation for visitors.

Self-catering

Such enterprises include farm cottages, chalets and converted farm buildings. Many of the remarks made above for 'in farmhouse' apply (see also ADAS 1982 a & b). The higher the quality of the accommodation provided, the easier it is to let and charge higher rents. Profitability, as the University of Exeter (1983) figures show, can be high, but unless conversion is done by the farmer, return on capital is poor.

There is sometimes a demand for long winter lets, but owners are often doubtful about taking on these because of the fear of creating a tenancy that cannot be broken without legal action etc. Holiday lets are usually for two weeks or less.

Second homes

Redundant farm buildings and surplus farm cottages can be leased or sold as second homes and long-let caravans can also be provided for such purposes. This can often be a good way of using resources, but is often an option not open to tenants whose agreements can prevent the renting of surplus cottages or development other than agricultural. Care over the creation of an unbreakable tenancy needs to be taken, and rents may be curtailed by the action of Rent Tribunals. However, cottages in moderate repair can be expensive to bring up to a satisfactory standard and may absorb farm capital that might have been made available for the improvement of the farm business.

Camping sites

The size and nature of these will depend very much on location. Farmers in holiday areas may find it worthwhile to set up well-equipped sites with toilets, showers, litter disposal, fixed roads, a shop/office, public telephone etc. However, as the British climate tends to limit occupancy to about eight weeks per year, to provide facilities for such a short period is often too expensive thus making it difficult to take full advantage of peak demand. Siting, signposting and advertising are extremely important. Preferably, there should already be an existing holiday attraction before provision of a new site is contemplated.

Specialised camp sites (eg those designed especially for Youth Clubs, Social Services' Departments, Scout Groups, Army Cadets, Woodcraft Folk, Boys Brigades, Special Schools etc) can obtain better occupancy rates although it is felt that the market for this kind of site is now becoming saturated (Korbey, DC-personal communication).

In summary, it seems that the provision of further sites for camping are likely only to spread trade and reduce the profitability/viability of existing sites for many are already under-used.

Caravan sites

There is an obvious need for transit caravan sites in between areas of large population and popular holiday places or ferry ports and this has proved a contentious recommendation of many current County Structure Plans. For peak periods, such as Spring Bank Holiday and during July and August, perhaps an extra 30% are required, but substantial occupancy is likely to average less then nine weeks a year.

Touring and holiday caravan sites are very popular and much of the demand is already met. Nevertheless, there is scope for more Caravan Club and other owned and operated sites providing, for popular areas, double the number of pitches. At present, Marriott, E (personal communication) estimates that there are some 70 000 caravan pitches in the UK, 40 000 of which are either owned or certified by the Caravan

Club. These pitches have to accommodate the estimated national total of 455 000 caravans.

Langford, D (personal communication) stated that many of the members of the National Federation of Site Operators (who provide static caravan sites) are occupiers of farmland, but local planning restrictions have meant that it is almost impossible to provide additional or expanded enterprises of this description. Nevertheless, there is the possibility of a change in the situation with new legislation directly covering caravans, mobile homes, tents etc now being discussed.

Specialised holidays

This form of holiday, encompassing activities such as field studies, sketching, fishing, riding and naturism is helping to develop the use of farm-based accommodation. It will probably develop according to local circumstances and the skills, enthusiasms and interests of the farmer.

Resource-based activities

Horse and pony-based activities

These include riding, trekking, eventing, polo, racing and hunting, all of which can take place, or be based, on farmland. The provision of livery, grazing and the operation of equestrian centres and clubs are further horse and pony activities that tend to take place on farms.

Such activities involving horses are now fairly widespread. The current horse and pony population is estimated to be up to half of million (see Chapter 3 above), but the figures from various sources vary considerably as there is no official provision for the collection of horse statistics. The geographical distribution is very uneven with over 40% of the population said to be in the London and South East Area and less than 26% north of the Midlands, including Scotland and Ireland. Table 5.5 provides an estimate of the registered national horse population, class by class for 1981/2.

There are about 4 600 licensed and unlicensed schools, clubs and riding centres in the UK, holding about half the leisure animals, the rest being privately owned. Further opportunity for increased use, by horses and ponies, of agricultural land and facilities lie in the provision of livery, grazing and feeding-stuffs. Some feel that there is a real need for a higher proportion of privately owned leisure horses to be kept in less 'messy' circumstances, particularly in the urban fringes. Farmers in such areas could also provide more facilities and also, perhaps, develop a series of private bridleways, possibly combined with other equestrian facilities for the use of horse and pony owners on a paying basis. This

Table 5.5
An estimate of the numbers of horses and ponies in the UK, 1981/82

Class		No	Sub-total
In Training	Flat	7 061	
	Jumpers	5 358	
	Hunter/Chaser	668	
	Point to Point	3 445	
	Harness	974	17 506
Competition	Eventers	4 300	
	Dressage	2 011	
	Show Jumpers	7 953	
	Show Jumpers' ponies	4 479	
	Long Distance	246	18 989
Driving	Driving Society	6 936	
	British Horse Society	1 016	7 952
Working/Activity	Hunting	39 000	
	Polo	1 850	
	Police	495	
	Army	560	
	Draught	300	
	Circus	100	42 305
Leisure	Registered riding schools	17 422	
	Riding Clubs	18 765	
	Private Owner (registered)	37 037	
	Private Owner (non-registered)	11 000	
	Pony club members (owned)	10 250	94 474
			181 226
Breeding and Wild Horses of 40 different breeds		104 752	104 752
Total			285 978[1]

[1] The author of this table agrees that his figure could be 12.5% in error, making a possible figure of about 320 000.

Source: Reproduced from Equestrian Management Consultants Ltd (1982).

could complement the rise in the number of bridleway 'circuits' developed by Local Authorities and supported, in some cases, by the Countryside Commission.

The leisure use of horses has increased with the amount of leisure time available and the wealth of the sectors of the population who favour horse-based activities. Indicative of this is the fact that current membership of the British Horse Society is 36 500 and has been increasing at the rate of 4–6% per annum over the past 5 years (Milner, ML-personal communication).

Hunting with horses and dogs involves up to 39 000 horses full and part-time and there are now 260 hunts. The effect of the abolition of hunting could well mean the halving of the number of horses now in this class and, at the conservative estimate of four full-time servants per hunt, the unemployment of well over 1 000 persons. The Standing Conference on Countryside Sports (1983) put out far higher figures.

Even the use of grazing land by a few leisure ponies can make a useful addition to a farmer's income. A fee for 'field use' implying only the provision of a limited amount of grazing – the owner supplementing the grass according to need and season – can bring in £240 per year for very little effort and a net profit figure per animal well exceeding that of one average dairy cow. Stables can also be let, at up to £15 per box per week on a casual basis for livery (Korbey, DC-personal communication).

Water-based recreation

Where farms have expanses of water, consideration can be given to setting up either fishing, swimming or recreational facilities. These are likely to be captial intensive and require special skills, though the enlargement of an existing enterprise might be possible. Safety can be a problem.

The British climate does not lend itself to water-based recreation, apart from fishing and boating, because the season is too short. Fishing itself is popular and increasing (Ashworth, FE-personal communication) and there is growing interest in fish farming (see Chapter 3 above). These activities though, are likely to be separate enterprises rather than as an alternative for standard agricultural production.

Shooting

The rural population is already well aware of the possibilities of recreational shooting in appropriate locations and circumstances whether in organised shoots, both dry and wet, or on a more casual rough shooting basis. There are also indications that the urban population is becoming more interested in such pastimes. Many tenancies restrict the occupier and so the further development of this activity would be by the landowner (who nowadays may well be the occupier). As with most other activities considered, additional advertising/publicity for this form of sport might well result in a small increase in activity, but it is specialised and those likely to be attracted are probably engaged in it already. It is a sport which can range from a major enterprise over thousands of hectares and highly organised and capitalised, to one man with the rights on one hectare.

Clay pigeon shooting, rifle and pistol shooting and archery are popular sports, particularly with the urban population. However, there is a shortage of ranges for these sports. They use very little land, but are often considered to be undesirable mainly due to noise; safety matters also need consideration. An income can be derived from a club operating on a farm, the source being rental of facilities, and from a shop or club house if provided. Since meetings are infrequent – up to, say, two per month – the facilities – toilets, roads and shop etc – ideally need to be shared with some other recreational enterprise, such as camping or caravans.

The population interested in clay pigeon, rifle and pistol shooting is growing: it is also keen and wealthy. Planning permission in the right areas (not too far from centres of population) is hard to obtain for this activity.

Day visitor enterprises

Informal recreation

This includes the provision of car parks, lavatories, picnic sites, country parks and rambling and wandering areas. However, the problem is that the individual land occupier who provides these is often unable to benefit financially. Any expansion, though certainly an alternative use of agricultural land, needs funding from a public or charitable body. There is the slight possibility of charging for access, but the use of such areas is spasmodic and dependent on the weather, and the public would not be willing to pay enough for the use of such areas to warrant the cost of collection, apart from certain special cases. The sale of franchises, eg ice-cream, souvenirs, confectionery etc from (usually) mobile stalls can be worthwhile in some cases. Maintenance of roadways and cleanliness are problems and the provision of toilet facilities is a nightmare to the owner; it can take most (if not all) of any profit. From the point of view of the public though, such areas need to be increased in area and number.

Access to areas of nature interest

Most of the remarks made in the previous paragraph apply, but any area of particular value needs overseeing and also protecting from deliberate and non-intentional vandalism. Such enterprises need to be administered by competent bodies. They are unlikely to use much agricultural land.

Visiting such areas is increasing and is encouraged by bodies such as the RSPB and the NCC. Apart from the provision of associated accommodation on the farm, it is unlikely to increase farm income or utilise any significant area of farmland unless areas are specifically set aside, probably under a Management Agreement with a Local Authority and/or other interest body (see, for example, Countryside Commission, 1984a). This activity can well fit in with the general concept of conservation.

While not strictly coming under the heading of an enterprise, conservation in general could be a very important alternative use for agricultural land in at least two ways (Countryside Commission, 1984b). One is the taking out of active production of whole areas (farms, fields, districts, regions), to devote to: parkland; reversion to forest by natural means or planting; or recreational areas. The other is by entering into paid, formal or informal, agreements to change or restrict agricultural operations so as to preserve or develop a certain type of countryside, usually one that is less productive or profitable. Farms where the profitability is already poor may go out of production or become merely subsistence or part-time holdings, acting as a family home and little else.

Dog-based enterprises

Dogs play a very important part in British family life and there are Canine Societies everywhere. They need areas of land for their Annual Shows etc. Some enterprising occupiers of land could add dog showing and training areas to their special attractions thus adding to their non-farming income and using facilities already installed for other purposes.

Sporting

The provision of sporting facilities, eg football, cricket, golf and running, can always be considered. Farmers with appropriate locations will find themselves approached by such organisations and they can always publicise the fact that they have (or are willing to develop) such facilities. Some villages do not have a football or cricket pitch. A really ambitious farmer might set up a golf course or golf driving range. Experience has shown that in most cases the initiative comes from outside clubs or bodies looking for facilities to practise their own particular bent.

Regular use of land for non-agricultural purposes can lead to rating or restrictions based on the 28 day per year non-agricultural use rule. The thinking behind a recent White Paper on easing planning restrictions (HMSO, 1985) is interesting in this respect.

Farm catering

This is an incidental enterprise dependent entirely on opportunity and siting. It is unlikely to take land out of production (apart perhaps from slight enlargement of the farmhouse garden and adaptation of outbuildings). Naturally, it will fit in with other farm-based non-agricultural activities. In holiday areas, coach drivers of 'mystery tours' or regular outings may bring in groups for cream teas etc.

Farm-produce sales

The success of a farm shop depends both on good siting and an enthusiastic owner/manager. In successful cases special products may be developed; eg unique yoghurts, vegetarian or organically grown products, as well as a full range of fruit, vegetables, meats, eggs, dairy lines etc.

A successful well-run and well-sited farm shop will develop fast and it can soon become a leading enterprise. It quickly becomes an outlet for purchased goods as customers tend to demand a wide range once they have stopped the car.

Naturally, the opportunity for farm shops is limited, and excessive competition between them can make them unprofitable, particularly in sparsely-visited locations. On the other hand, an area with several rural attractions can be an extra encouragement for visitors.

The shop can mean an alteration in the pattern of crops and stock on the farm. Capital required is not great and the enterprise accumulates its own. Planning permission and adherence to health regulations is important and sometimes leads to difficulty. The main requirement, after siting, is entrepreneurial enterprise in a retailing context. ADAS (1981) provide a helpful booklet on the topic which also deals with pick-your-own enterprises.

Pick-your-own sites are growing in number and are well-developed in many areas. Proximity to a population with cars is important and so is skill in laying out the area and controlling the customers so that waste is minimised. Many of the comments made regarding farm shops apply here, but PYO tends to be more seasonal. PYO is more an alteration to farm enterprises than an alternative, though it involves an entry into retailing rather than the usual wholesale method of disposing of produce.

Public events

There can be no standard pattern or recommendation for these. It all depends on siting, existing facilities and opportunity and there can only be a limited number of such events held in one location. Reference to Table 5.2 gives an indication of the range of events that take place on farms.

These events can bring in a substantial income where there is a well-sited field near a road with 5–20 hectares of grass, with hard access, water points and other services not too far away. Indoor type events may take place in marquees and a huge variety of outside events is possible (Korbey, DC–personal communication).

The only adaptations necessary to the fields are extra gateways, water points, sewage disposal pits and temporary fencing for car control. Most special facilities necessary for events can be provided in a portable form (eg toilets, rubbish skips and public address systems).

In general, farms can be, and are, used for many farming-related, but not strictly agricultural events, eg ploughing matches, hedgelaying, tractor pulling, crop and stock demonstrations, many laid on by local organisations and ADAS or commercial bodies. There can only be a limited number of these and the fees paid are often very low or non-existent. An individual can only try to get a bigger share of what is already being held as it is unlikely that numbers in total will increase; nor are they likely to decrease.

Agriculturalists often have side-lines which are capable of development, eg. collections or examples of rare breeds, museums of farm machinery and equipment, collections of exotic animals or insects etc. These, in themselves, are insufficient to be classified as major enterprises, but are the owner's hobby as well as being a possible source of incidental income. Major developments on these lines are capital-intensive and have to be large and well managed to be viable in themselves and are usually set up as the primary exercise using professional advice – they should be to a high standard. There will be a few smaller units which are successful and have become established by development from a farming base but there has to be an existing special opportunity such as a geographical feature, a person skilled in the details of the enterprise set up, a special holiday area or very favourable siting or local speciality, eg clotted cream or cider.

Educational activities

These cover farm open days, farm trails, demonstrations, school visits and adopted farms. The public catered for can be divided into three groups: school parties (including mature students and naturalists); general public; specialist agriculturalists. Articulate and personable farmers are crucial to the success of such ventures.

There is a growing demand for facilities for town children in particular, especially those from deprived areas, to visit working farms. Some education authorities meet this by arranging with convenient farms to take parties round at intervals, usually one or two classes including the teachers who may provide notes, questionnaires and tests. The farmer often takes the party round. Fees are very low and under £1 per head is common. Mature students and naturalists usually yield nothing unless they are camping or using other farm accommodation. In addition, schools and colleges are increasingly using the countryside as a practical educational resource. A few Local Authorities have their own farms and there are now 55 City Farms also which have a specific national organisation (Egginton-Metters, I-personal communication). The need for these farms is growing and there could be scope for them being located on the urban fringe within working farms. One of the more satisfactory ways to meet demand in non-inner city areas could be to pay existing suitable farm units to develop a rudimentary facility for this (eg lavatories, shelter, farm details, a few notice boards).

Ordinary family and commercial farms can be open to the public, but usually in connection with another attraction as well. In itself, this is unlikely to be a great source of income and could be counter-productive, eg disease, litter, vandalism, disturbance of work routines. If there are further attractions and care is taken with routing, availability of information, catering and car parking, there is an opportunity for existing attractions to be expanded in this way, eg added on to the farm museum, farmhouse catering, rare breeds, PYO, farm shop, camping and caravan areas etc. The idea of tractor or horse-drawn wagon rides round the units might be viable and already exists in a few places.

Numerous bodies, whether experimental, educational or commercial are involved in the provision of demonstration farms and areas. With the cut-back in availability of funding for R, D & D, it is unlikely that the total area used for this purpose will grow, but as physical demonstrations and actual field research is so necessary and commercial pressures increase, it is unlikely that it will decrease either. There could be a small income to some farmers willing to co-operate in field trials or demonstrations but very little land would be taken out of normal agricultural use for the purpose and the additional income accruing will probably be insignificant.

AN OVERVIEW: FUTURE POSSIBILITIES AND CONSTRAINTS

This chapter has shown that there is a large range of possible farm-based recreation and tourist enterprises. The provision of farm-based accommodation for tourists is the most ubiquitous of these at present. However, as Maude & van Rest (1985) have stressed, despite farm tourism being seen by Government as a panacea for the problems of remote rural regions, in reality, financial returns from it are relatively low. In addition, there are disadvantages to society as a whole from farm tourism as, for example, it is expensive for public bodies to promote and can also reduce the housing stock available for local people (in both physical and financial terms.)

Clearly, there will be future opportunities for farmers setting-up a wide range of leisure and recreational pursuits and providing farm-based accommodation. These will make an increasing contribution to farm incomes, perhaps provide extra employment in rural areas and help to attract tourists from abroad. However, although potentially important in this respect, these enterprises are not likely to take up large areas of agricultural land at the national level; proportional land use on some individual farms may be greater.

Whether an individual farmer can benefit from one or more of the above enterprises will depend on: the availability of spare resources; whether he or his family has any especial skills, enthusiasms and interests; and the level of demand and/or proximity to a market for the enterprises. Some potential demand for the new enterprises will be limited by the mobility of customers and there is probably some deferred demand due to lack of facilities.

Although there is scope for some of the enterprises throughout the UK, rare or unusual ones may prove to be of great importance to only a few farmers. Although at present perhaps only 25 000 farmers have one or more of the above 'other' enterprises, this figure could well double within 10 years.

If the above opportunities are to be seized, farmers (and their advisers) will have to show great flexibility and learn to adapt and change from their traditional approach to farming. Their basic concepts of land-use and management may well have to alter to embrace mixed systems involving all of their farm resources instead of thinking and planning in terms of 'pure' enterprises. Problems in, and constraints on, operating these new enterprises will be numerous.

Difficulties of charging
This applies particularly to informal countryside activities which traditionally have been provided free with the costs often being borne by the public sector. An additional problem that arises is that return on capital in agriculture is low. This has not mattered in the past with much new investment being financed from within the farm business. However, in the future, capital for investment in new enterprises may have to come from commercial lenders and hence provide commensurate returns. A realistic solution would be to channel some of the present agricultural support paid to farmers into financial support for farmers providing leisure, recreational and conservation facilities.

Lack of sources of advice
The new enterprises will require new information and advice being provided to farmers. Such advice will have to cover a wider spread of subjects than farmers traditionally have needed. At present, advice and information on such matters is not readily available and, even where it exists, the authorities and agencies who can provide it tend not to have the resources to make it available on an individual level. Ideally, those responsible for such advice will make it available in, for example, a single publication.

The quality of advertising and interpretive material
Individual farmers are not used to providing, designing (and paying for) such material as they have been brought up in a system where their produce tends to find a ready market. The 'products' of the new enterprises are less tangible than traditional farm products and will need careful marketing using often expensive advertising and interpretive material/media if the necessary levels of return, occupancy and visits are to be achieved. The formation of more marketing groups or agencies for the new enterprises could help to spread the cost, improve efficiency and put over the message that farmers do not just produce food and timber.

The existence of legal constraints
A wide range of legislation, including that pertaining to planning, health, safety and nuisance, can limit, halt or slow the development of new enterprises on farms. Some of this legislation is thought to be especially restrictive in, for example, National Parks and Areas of Outstanding Natural Beauty – areas where demand for the 'products' of the new enterprises will probably be at its highest. However, there seems to be no strong case for the removal of such legislation as it affects farmers and perhaps they (who are still remarkably unaffected by such legislation) will have to adjust their attitudes towards these matters.

Labour suitability

If the possible new enterprises are to make a profitable contribution to the whole farm business, labour (and this will usually be from the farm-family) will have to develop new skills and attitudes. Adaptability will be the key personal characteristic needed to cope with an influx of visitors into areas which used to be regarded as the private domain of the farm-family.

The plethora of agencies and authorities involved

The number of central and local Government agencies, Departments and Authorities with remits and responsibilities for other enterprises on farms is large. However, despite the sterling efforts of District Councils, Tourist Boards and the socio-economic advisers of ADAS, there is much confusion in the minds of farmers about who can provide assistance in this somewhat new area of operation. All too often, bureaucratic delays result, leading to the abandonment of well-meant and enterprising plans. Perhaps, the time is now ripe again to echo the suggestion of those who, in the late-1970's, called for a comprehensive rural land-use policy and an agency to put it into action (see, for example, Bowman *et al*, 1978; Wibberley, 1976).

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Glossary

Aerobic decomposition The biological breakdown of biomass in the presence of air; commonly used as a treatment for animal wastes.

Agroforestry A collective term for land-use systems where woody perennials are deliberately used on the same land management unit as agricultural crops and/or animals in some form of spatial arrangement and/or temporal sequence.

Agrosilviculture An agroforestry system involving a combination of forestry species or tree crops with arable or horticultural crops, or a combination of forestry species and tree crops.

Anaerobic digestion the biological breakdown of biomass in the absence of air to produce a methane-rich 'biogas'; used in waste treatment.

Broad-leaved tree; broadleaf Angiosperm species, usually deciduous, also called hardwoods.

Cellulose A long-chain carbohydrate which is a major constituent of the cell walls of plants. Hemicelluloses are similar related compounds which can also function as reserve food materials.

Coppice Wood production system which involves cutting young trees to exploit early growth. The cut-over stumps produce fresh shoots in the year following harvesting, and the cycle is repeated.

Dicotyledons One of the two major classes into which the flowering plants are divided. They have two seed leaves and other features which distinguish them from the smaller class of Monocotyledons (cereals, grasses, palms etc.)

Direct liquefaction The chemical conversion of solid biomass directly to liquids.

Discount rate Rate used for comparing investment projects, by reducing forecast revenue and cost flows back to the present, to give the net present value.

Discounted costs (revenue) Costs (revenue) adjusted to allow for diminishing monetary values over a period of time.

Fermentation Decomposition of organic substances by organisms, usually bacteria or yeasts.

Forestry species Woody perennial grown primarily for wood products.

Gasification The thermal processing of biomass to produce mainly gases.

Gross margin of an enterprise is its enterprise output minus variable costs.

Hardwoods Term used in timber trade for wood produced by broadleaved trees.

Hemicellulose See cellulose.

Hybrid seed Seed produced by crossing compatible plants of different genetic make-up, commonly two varieties of the same species. The intended female parent may have to be emasculated by mechanical, chemical or genetic means, to avoid self-pollination.

Inflorescence The group of flowers produced on a single floral axis.

Management and investment income Net farm income minus farmer and spouse labour cost plus paid management costs.

Monocotyledons See dicotyledons.

Monoecious Where separate male and female flowers are borne on the same plant.

Mulch Material applied to the soil surface to protect soil and plant roots from drying out and from the effects of heavy rain and frost.

Net present value The value of a project, used for comparative purposes, derived by discounting both the forecast costs scheme and the revenues stream back to the present, at a given discount rate.

Photoperiodism In plants it is their response to the length of light and dark periods. Many aspects of development can be influenced by photoperiod including initiation of flowering.

Pulpwood Timber used to make pulp for papermaking.

Pyrolysis Destructive distillation in the absence of air.

Sawlogs Timber considered suitable for producing sawnwood. In Great Britain: logs with a minimum top diameter of 17cm together with 50% of logs with top diameter of 15–17cm; in Northern Ireland: logs with a minimum top diameter of 14cm.

Silvopastoral system An agroforestry system which combines forestry species or tree crops with animals.

Smallwood Timber of a top diameter of less than that required for sawlogs; also includes twigs and branches.

Softwoods Term used in the timber trade for wood produced by conifers.

Tip (or meristem) culture A method of vegetative propagation using small amounts of actively dividing cell tissue. Commonly these are derived from the apical meristems, or 'growing points' of the plant.

Tissue culture An *in vitro* technique of growing and multiplying separated plant (or animal) tissues or cells. It may be used as a means of propagation, or for the production of biochemical materials.

Tree crop Woody perennial grown primarily for fruit or nuts.

Vernalisation Exposure of a plant or imbibed seed to low temperatures to stimulate flowering.

Appendix: list of persons consulted

ALTERNATIVE CROPS

Bailey, W	Royal Botanic Gardens, Kew, Richmond, Surrey.
Ballam, L W	Bush Boake Allen, Blackhorse Lane, London E.17.
Bell, E A	Royal Botanic Gardens, Kew, Richmond, Surrey.
Bisgrove, R	Department of Agriculture & Horticulture, University of Reading.
Bunting, E S	337 Hills Road, Cambridge.
Burdekin, D	Forestry Commission, Alice Holt Research Station, Surrey.
Cooper, G	Herb Society, 34 Boscobel Place, London SW1.
Cooper, J P	Department of Agriculture & Horticulture, University of Reading.
Cowley, E	Bush Boake Allen, Blackhorse Lane, London E17.
Ebden, Pauline	Food from Britain, 301-304 Market Towers, New Covent Garden Market, London.
Galwey, N W	Department of Applied Biology, University of Cambridge.
Gray, D	NVRS, Wellesbourne, Warwickshire.
Grills, R	Shirley Institute, Wilmslow Road, Manchester.
Groves, R	Compak Systems Ltd, Gainsborough, Lincolnshire.
Guest, D	Paper and Board Research Association, Leatherhead.
Gunn, J	Upper House Farm, Callow, Kirk Ireton, Derby.
Hancock, J	ADAS, Southgate Street, Bury St Edmonds, Suffolk.
Hardwick, R C	NVRS, Wellesbourne, Warwickshire.
Harrison, D R	ADAS, Great Westminster House, London.
Hubbard, K R	ADAS, Great Westminster House, London.
Hopkins, A S	Courtaulds plc, Foleshill Road, Coventry.
Kitchener, H	ADAS, Government Buildings, Cambridge.
Last, F T	Institute of Terrestrial Ecology, Bush Estate, Penicuik.
Lockhart, D A S	East of Scotland College of Agriculture, Bush Estate, Penicuik.
Larkcom, Joy	Montrose Farm, Hepworth, Diss.
Mercer, L A (Miss)	Shirley Institute, Wilmslow Road, Manchester.
Nicholson, D J	Farm Business Unit, Wye College, Wye, Ashford.
Perkins, S	ADAS, NVRS, Wellesbourne, Warwickshire.
Pickergill, Barbara	Department of Agricultural Botany, University of Reading.
Rankin, A	Lambeg Industrial Research Association, Lisburn, Co. Antrim.

Simmonds, N W	c/o School of Agriculture, University of Edinburgh.
Snaydon, R W	Department of Agricultural Botany, University of Reading.
Staniforth, A	Reading Agricutural Consultants, Wallingford, Oxon.
Stott, K G	Long Ashton Research Station, Bristol.
Suckling, R	ADAS, Government Buildings, Oxford.
Twyman, M	Department of Typography, University of Reading.
Weatherill, N T	ADAS, NVRS, Wellesbourne, Warwickshire.
Whitwell, J	Stockbridge House Experimental Station, Cawood, N Yorkshire.
Wickens, G	Royal Botanic Gardens, Kew, Richmond, Surrey.
Wilkinson, J M	Consultant, 13 Highwoods Drive, Marlow Bottom, Bucks.
Watkin-Williams, D	Department of Agricultural Botany, University of Reading.

ALTERNATIVE ANIMALS

Chinchilla

Wadsworth, C	Chinchilla Fur Breeders Association, Leeds.

Horses

Bush, B	Manager, Shire Horse Centre, Littlewick Green, Berkshire.
Gibson, T	Shire Horse Society, Peterborough.
Morton, G	Farmer, Yorkshire.

Goats

Mowlem, A	Animal and Grassland Research Institute, Reading, Berkshire.
Waitrose Supermarket	Reading, Berkshire.

Kangaroo and wallaby

Frappe, D	Kentats Group, London.

Lamoids

Dawes, V	Farmer, Henley-on-Thames, Oxfordshire.
Isaac, P	Farmer, Bildenston, Suffolk.
Kitchenside, C	Overseer of Mammals, Whipsnade Zoo, London.
Skinner, S	Farmer, Padworth, Berkshire.

Fur-producing mammals

Confederation of British Wool Textiles Ltd.	Bradford.

Rabbits

Gough, A	Wingham Wool Work, Rotherham.

Sheep

Mills, O	British Sheep Dairying Association, Alresford, Hampshire.
Ryder, M	Hill Farming Research Organisation, Penicuik, Scotland.

Free-range chickens

Morris, T R	Department of Agriculture and Horticulture, University of Reading.

Guinea Fowl

Broome, E H & Co Ltd	Smithfield Market, London.

Turkey

Morris, T R	Department of Agriculture and Horticulture, University of Reading.

Edible frog

Shelton, J W	J Bennetts Ltd, Billingsgate Market, London.

Bees

Rowse Honey	Henley-on-Thames, Oxfordshire.
Young, T	Horticulture Division, MAFF, London.

Silkworms

Goodden, P	Lullingstone Silk Farm, Sherborne, Dorset.
London Export Corporation	Brighouse, Yorkshire.
Moss, T	Whitchurch Silk Mill, Whitchurch, Hampshire.

Snails

County Delicacies	Reading, Berkshire.
Haslam, B	Mendip Snails, Somerset.
White, C D	Hales Snails, 25 Pages Walk, London, SE1.

Fish

Isaac, P	Farmer, Bildeston, Suffolk.
Domaniewski, J	Department of Agriculture and Horticulture, University of Reading.

FORESTRY

Alcock, M B	Department of Agriculture, University College of Wales, Bangor.
Cumming, D	Department of Forestry, University of Aberdeen.
Evans, J	Forestry Commission, Alice Holt Lodge, Surrey.
Grundy, D	Forestry Commission, Edinburgh.
Hall, J	Department of Forestry and Wood Science, University College of North Wales, Bangor.
Hatfield G	Forestry Commission, Edinburgh.
MacBrayne, C	Tilhill Forestry Ltd, Stirling.
Maxwell, T J	Hill Farming Research Organisation, Penicuik.
Mitchell, C P	Department of Forestry, University of Aberdeen.
Roche, L	Department of Forestry and Wood Science, University College of North Wales, Bangor.
Sibbald, A R	Hill Farming Research Organisation, Penicuik.
Tabbush, P M	Forestry Commision, Northern Research Station, Penicuik
Thomas, T	Department of Agriculture, University College of North Wales, Bangor.

OTHER ENTERPRISES

Ashworth, F E	Angler, Selborne, Hampshire.
Baker, E	Socio-economic adviser, ADAS, Winchester, Hampshire.
Eggington-Metters, I	National Federation of City Farmers, Bristol.
Elliot, H	Parliamentary Division, NFU, London.
Evans, J M	Socio-economic adviser, ADAS, Reading
Holbeache, B	Parliamentary Division, NFU, London.
Korbey, Mrs D C	Farmer and Country Pastures Site Operator, Brockenhurst, Hampshire.
Langford, D	National Federation of Site Operators, Chelmsford.
Lloyd, D	County Conservation Officer, Hampshire County Council, Winchester.
Marriott, E	Public Relations Officer, The Caravan Club, East Grinstead, Sussex.
Milner, Mrs M L	Membership Officer, British Horse Society
Parker, R	Land and Valuation Adviser, CLA, London.
Shanks, P	Secretary, New Forest Show Society, Brockenhurst, Hampshire.
Ward, L	Socio-economic adviser, ADAS, Lewes, Sussex.
Wakeham, A	Director, British Equestrian Trade Association.

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Papers

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2 Tranter, R B (Ed) (1978) *The future of upland Britain* Proceedings of a symposium organised by CAS in conjunction with the Department of Agriculture and Horticulture, 19–22 September 1977 OUT OF PRINT.
3 Harrison, A, Tranter, R B & Gibbs, R S (1977) *Landownership by public and semi-public institutions in the UK* £1.75.
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10 Jollans, J L (Ed) (1981) *Grassland in the British economy* Proceedings of a symposium organised by the Department of Agriculture and Horticulture, the Department of Agricultural Economics and Management, the Grassland Research Institute and the Centre for Agricultural Strategy, 15–17 September 1980 £10.00.

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12 Hallam, D (1983) *Livestock development planning: a quantitative framework* OUT OF PRINT.

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