MACAULAY LAND USE RESEARCH INSTITUTE

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'Countryside Change - Policies, Practice and Prospects'

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Introduction

The theme of the paper is 'countryside change - policies, practice and prospects', it is used to explore and discuss a number of topics that are important in relation to land use and the research undertaken at the Macaulay. The main drivers of countryside change over the next two decades, and how policies and technological opportunities will influence the likely direction of change and the rationale for research at the Macaulay is discussed. The paper presents some of the important contributions that the Macaulay has made in providing objective information about the processes of change and the tools whereby change can be managed and forecast. The unique features of the institute research environment and how it relates to the university sector will be highlighted. Finally, the paper deals with the need to consider research as an investment in the future.

The Drivers of Countryside Change

Sustainability and Policy Development

Whatever we may think about its likely effectiveness, the concept of sustainability now lies at the heart of European, UK and Scottish policy development. It is the context within which the social, environmental and economic drivers of change are increasingly being considered and debated.

But, as I have said before from this podium, the concept of sustainability is not founded on absolutes and even over a period as short as 10-15 years, we will see change in how society interprets sustainability. Pearce (1996) has described a 'sustainability' spectrum. Within this spectrum the interpretation that seems to most fit current and probable future thinking in the medium term, at least as it is likely to apply to Scotland is that described by Pearce as being 'accommodating'. This suggests that natural resources will increasingly be conserved, protected and enhanced; economic instruments will be used to deliver goods that have been produced in an 'environmentally friendly' way; measures of economic growth will increasingly take account of natural resource use; the concept of

infinite substitution of capital is likely to be rejected; the ethical position both globally and locally is likely to be motivated increasingly towards 'caring for others' and satisfying intergenerational equity.

The rate of change within this sustainability spectrum, however, will almost certainly depend on the success of the macro-economy and its ability to deliver secure levels of income for the majority of the population. In a Scottish land use context this means that the extent to which agriculture and forestry remain viable and prosper and the extent to which the environment and our natural heritage is conserved, protected and managed will depend on the willingness of the public to accept that at least a part of their 'disposable' income is used to such ends.

The implications for landowners and land managers are that they will need to be willing and able to adjust to meet a changed, and probably constantly changing set of objectives in managing and using land for the foreseeable future. The need to adjust arises from several different directions. The first has to do with adjusting to the changing economic prospects for agriculture and forestry.

Agriculture

It is now generally accepted that changes in the policy structures that have surrounded agriculture for a long time are not the primary instruments that will determine future change in agriculture. Rather it is low growth in product demand and downward pressures on prices that will determine change. In Scotland we can see this continuing decline in the real value of outputs from both the livestock and crop sectors. Despite there being significant year to year variation, the mean decline in output from crops is estimated to have been £5.5m per annum in real terms since 1973. The decline in livestock output in real terms over the same period has been much more consistent at £26.4m per annum. Arresting this decline will not be easy and though it is reasonable to assume that both crop and livestock production will continue to be important industries in Scotland there is considerable uncertainty about their ultimate size in the longer term.

The conclusion for the longer term, irrespective of the policy changes that may arise from CAP reform, WTO negotiations and Agenda 2000, is that agriculture will be characterised by a low but highly selective growth in demand for its primary produce, downward pressure on prices, and higher resource productivity. The consequences for land use change in the longer term seem inevitable. There will be less land in conventional primary food production and there will be a change in the relative intensity that land is farmed, depending on farm size, farm type/farming system and land quality.

Currently, the agricultural industry is attempting to resolve its financial problems by becoming more efficient, developing and targeting niche markets and cutting costs. There are also increasing calls for greater co-operation in marketing, thereby creating market strength. It is also clear that the potential exit from farming is being at least delayed by an increased proportion of farm household income being derived from non-agricultural activity.

However, more generally, the evidence from a study carried out in Grampian of farmer typologies by Schucksmith (1999) suggests that large farms (100-<200 ESUs[1]) with land of good quality are increasingly likely to become intensive agri-businesses with the aim of achieving greater efficiency in production through optimising inputs and maximising the usable product to meet precise requirements. They are also likely to get bigger.

Medium-sized businesses (40-<100 ESUs) are on the one hand likely to pursue a conventional route of enlargement and continue as before within an ever tighter economic environment, their continuing viability depending on availability of capital and innovation. But some will inevitably fail and the land released will go towards the enlargement of similar sized successful businesses. On the other hand, many of these medium-sized businesses may become increasingly diversified reflecting a new attitude of entrepreneurship that is already developing among some farmers, seeking both to add value to primary produce and to exploit environmental goods on the farm.

Smaller businesses (8-<40 ESUs) are increasingly likely to operate on a part-time basis or be sold to hobby farmers who are not dependent upon their source of income from farming.

Forestry

Recent changes that have taken place in the area and proportion of different forest types in Scotland demonstrates that an increasing proportion of new planting is broadleaved woodland (currently 60% - the green on the histogram). These changes represent an ascendancy of the conservation and recreational benefits of forestry and a relative decline in the weight placed on traditional or commercial objectives of forestry policy and are largely confirmed in the draft Forestry Strategy for Scotland which is out for consultation.

[1] 1 European Size Unit (ESU) is approximately equivalent to £1000 of farm Standard Gross Margin (SGM). The total SGM for a farm is calculated by multiplying its crop areas and livestock numbers by the appropriate

However, even though the UK is self-sufficient for only about 20% of its wood products and it is predicted that there will be a shortfall in meeting the demand for softwood by 2050 it remains uncertain, under present market conditions and international cost-competitiveness, (e.g. costs of transporting timber) as to whether there is sufficient commercial incentive to invest in extensive new planting. For the near future, unless there are dramatic changes in timber prices or a significant fall in land prices or new markets for forest products are found, widespread conversion of agricultural land to forestry seems unlikely. However, other considerations will influence new planting in Scotland. These will emerge as part of the implementation of the Rural Development Regulation and Agenda 2000. The aim will be to bring about a further integration of forestry and agriculture, increase recreational access and encourage the regeneration of native species. There is also the prospect that a significant role for forestry linked to international carbon sequestration and carbon-trading strategies could be established. It is reasonable to assume, therefore that there will be a continued but modest increase in the area of forest in Scotland and that it will have a high natural heritage value.

The Technological Drivers of Change

The productivity of our agricultural and forestry industries will of course continue to be influenced, as in the past, by emerging technologies. As it has in human health care, biotechnology will impact on livestock and crop health and consequently on productivity. The potential benefits of biotechnology will only be realised, however, if research on these technologies is integrated with that on the biophysical and applied sciences – what I call the 'bread and butter' sciences - that create the appropriate systems context for their application. Advanced information technology and the design of decision support tools will increasingly provide the means of options analysis, exploration and knowledge transfer. Equally, the social sciences, dealing with economics, social behaviour and ethics will inform and influence both the producers' and public's acceptability of new production methods. It is in this context that the social and environmental drivers of change are important.

The Social and Environmental Drivers of Change

During the last three decades societies in Europe have become increasingly concerned about the quality of their rural environments and have developed changed perspectives on how they should be used particularly since each European household is contributing £1000 per annum in support of farmers. The influence of the tax-paying public on the use of the countryside and the delivery of market and non-market goods is likely to become even more specific than it is at present. The public will expect that in future greater attention is given to environmental protection, improved water quality and the

remediation of contaminated land. The EU Water Framework Directive will have an increasing impact on catchment management and will be the focus of greater regulation and control by the environment agencies.

Countryside agencies and non-government voluntary bodies focus increasingly on environmental enhancement and proactive environmental management. The Wildlife and Countryside Act 1981, the EU Habitats & Species Directive, the Natural Heritage (Scotland) Act, the National Parks Bill and the Land Reform Bill provide the statutory instruments whereby natural heritage management, the creation of national parks and the right of access will be introduced. This is because there is an explicit demand from the public for environmental goods and services associated with recreation, sport, tourism and a general enjoyment of the countryside. So finding ways whereby our land can be shared more equitably and responsibly is important for the future. It is not only important with respect to the wider social and cultural benefits that can be achieved but also because of the additional economic benefits that can be brought to our rural areas.

Access, however, and managing increasing numbers of people visiting our countryside is likely to become a primary concern for the successful management of the natural heritage over the next two decades. The future designation of land for conservation and protection purposes will need to take this into account while at the same time creating opportunities for access. This will not be a trivial task.

And it is worth reminding ourselves that, at present, many of the non-market benefits valued by the public are delivered indirectly through the support of agriculture, to the tune of around £3 billion per annum in the UK (£700-£750m in Scotland). Clearly, the implications of a possible reduction or redeployment of such funding in support of the rural economy requires some consideration.

CAP reform, through the Agenda 2000 proposals, has already begun to shift the balance of payments further away from commodity support and it is generally assumed that this is just the start of a process which will go much further in removing production related support. But for primary food producers the message is clear: it will be essential to strive for efficiency and the production of high value products using appropriate technology and marketing strategies to be able to compete effectively in world markets. Restructuring land holdings within this general context seems inevitable. The means of facilitating this restructuring needs to be considered in relation to current proposals, embodied within the Rural Development Regulation, towards integrating agriculture within the broader context of rural development. But increasing the proportion of structural funds, at the expense of

commodity support, should provide opportunities for the development of a range of farm and land based activities over many areas of Scotland.

In some areas with a high potential for efficient and demand led agriculture, strategic regional planning and resource allocation might be organised accordingly. In other areas the same argument may be appropriate for forestry. In yet other areas, which may be far the greater proportion of our land in Scotland, a more appropriate route may be to encourage an integration of agriculture and woodland/forestry with a region's recreation and tourist potential. Such an area by area approach would allow a closer examination of the balance that needs to be struck between achieving economic, social and environmental objectives on a local basis.

So in relation to this broad analysis what is the rationale for our research at the Macaulay?

The Rationale and Goals of our Research

As we enter the 21st century it is clear that land use is about achieving multiple objectives and managing change. It is not just about producing primary food products or timber. It is about producing many other outputs or non-market benefits as well; benefits for which the public is prepared to pay. Whether the public will be prepared to deploy the whole of the £3 billion that annually supports UK agriculture and the rural economy for such purposes is questionable and the consequences of not doing so cannot be readily foreseen. But change in the structure, ownership, and intensity of use of land holdings, as well as the nature and value of the countryside they represent seems inevitable.

For all these reasons it is vitally important that we continue to research the underlying processes of change at all levels of organisation, the soil; the soil:root interface; the plant; the behaviour of animals in relation to habitat and vegetation change; the impact of land use on water quality in rivers, estuaries and lochs; and the decision-making behaviour of people in relation to their economic, social and environmental goals. Our research is also about managing change: about modelling and forecasting land use change as well as designing decision support systems to manage change. It is also about monitoring change. These have been and are the fundamental goals of the Macaulay's programme of research.

'Creating sustainable solutions for land and people – the Macaulay contribution'

The Macaulay has a strategic remit for 'land use research', nationally and internationally. Within Scotland its programme of research is set within the SERAD Strategy for

Agricultural, Biological and Related Research (1999-2003), in particular within the end-use domains of Sustainable Agriculture, Environment and Natural Heritage and Rural Communities and Development. It takes account also of the remits of the other SERAD sponsored bodies, in particular its sister institutes and the Scottish Agricultural College. This sets the context for its research.

But because land use happens at the interface between human and biophysical systems our research at the Macaulay requires us to span the disciplines of soil and plant science, plant and animal ecology, hydrochemistry, hydrology, geography, agriculture, forestry and socio-economics. The resources that are concerned with land use are many and varied. They include the soil, the plants, crops and forests that it supports, the domestic and wild herbivores that utilise grassland and the natural and semi-natural vegetation of the hills and uplands and importantly the people that work and use these countryside resources for a variety of purposes. We focus our research on these topics.

Soil

Soil is a basic resource. Its use and function are crucial in any consideration of land management. When the Institute was set up in 1987 soil science research throughout much of the UK was generally regarded as being expendable in the interests of diverting funding towards molecular and cell biotechnology, particularly in plants. This was less the case in Scotland and not so at the Macaulay. Already at the Institute important research on the biology of soils had made significant advances in our understanding of organic matter turnover: it had also an unrivalled analytical capability. Equally, our understanding of the mineralogy and surface chemistry of soils had begun to provide us with the basis of a quantitative understanding of the absorptive and release characteristics of soils. This continues to be important in the research we do on the impact of anthropogenic pollution, and particularly the atmospheric deposition of oxides of sulphur and nitrogen and the estimation of critical loads for the acidification of soils and waters.

However, if we are to understand fully the function and resilience of soil in terms of its sustainable use there is a continuing need to discover much more about its biology. Any definition or statement that we make about soil quality or soil protection will only be made with confidence if we can get much closer to describing the function of the 90% of soil biota about which we know very little.

Recent advances in soil microbiology and ecology have been made possible by using signature lipid biomarkers and molecular biological methods. To date these methods have provided primarily taxonomic information indicating the relative presence and

absence of the major microbial groups in a soil. Changes in functional attributes are being assessed by community level physiological profiles. We are also using molecular probes that are specific for soil processes such as phosphatase activity, ammonia oxidation and denitrification. At the Macaulay we are currently developing these methods and utilising them to understand the impact of different land uses and pollutants on soil microbial diversity and function. This is a major step forward. Our research will lead to a much more precise understanding of the role of soil biota in enabling soils to act as absorbers of waste on the one hand, and in releasing nutrients for plant growth for production purposes and in natural and semi-natural ecosystems and forests on the other.

However, there is equally a need to advance our ability to integrate our understanding of soil biology, with soil inorganic and organic chemistry and the movement and fate of chemical species within the soil. Only by doing so will we be able to quantify more precisely the impact of a range of soil managements and potential remediation routes for decontaminating soils and preventing the entry of potential pollutants such as nitrogen and phosphorus into rivers and lochs. The recent development of the aptly named modelling framework ORCHESTRA by the Institute opens up the opportunity of combining the latest multi-component absorption models, with physical transport models to do just this. It provides the potential to undertake integrated quantitative analyses of a whole range of soil physical, chemical and biological processes. This will provide the Institute with unparalleled opportunities in the future. Soil quality will become more clearly defined and the attributes and function of different soils under different uses more precisely characterised. Ways to achieve sustainable use will become more clearly understood.

Soil/Plant Relationships

The development of ORCHESTRA and the advances in soil microbiology and ecology also provide some of the ways in which we will be able to link soil biology and chemistry to plant nutrient uptake and the influence of carbon released from roots on soil microflora in the rhizosphere. It has now become possible by using a combination of ^{13}C pulse labelling and soil microbial phospholipid and DNA analysis to assess which members of a microbial community are metabolically active and respond to a change in carbon flux arising from the release of carbon from plant roots. Such interactions between root exudates, root herbivores and the macro- and microflora is a hitherto under researched, but important aspect of nutrient cycling in soil. Future work will substantially extend our knowledge in this area and provide information that will enable the impact of urine and dung from the grazing animal and other perturbations such as the use of pesticides to be evaluated, not only on the effects of invertebrates but on the soil system as a whole.

Ultimately, the findings will assist in the formulation of more precise soil and land use management guidelines and decision making for a range of land use systems.

To achieve this our research needs to be done in relation to whole plants and crops. Again, because of the emphasis of research funding being directed towards cell and molecular biology and genetics, there is now a paucity of capability in whole plant physiology and biochemistry in the UK. At the Macaulay we have retained this capability and by doing so are in an almost unique position of being able to link research at the soil-plant interface with research on nutrient uptake, storage, remobilisation, development and growth. These are vital processes in natural and semi-natural ecosystems and no less important in the management of forests and orchards.

Nutrient Cycling

Our ability to measure the partition of nutrients in whole plants, using a range of stable isotopes, but especially ^{15}N, therefore, has been crucial. It has enabled, for example, a more rigorous analysis of how management affects the storage and remobilisation of nutrients by a range of tree species such as pine, birch and rowan. This is important in developing sustainable management strategies that in the case of semi-natural woodlands includes the avoidance of browsing damage from animals such as deer. This type of information is critical to a more precise understanding as to the extent that there is a need to control the density of free ranging herbivores in our semi-natural regenerating woodlands. It also contributes to improved management of more intensive tree systems in determining efficient pruning and fertiliser options.

By making similar measurements on a range of grass species, we are also making significant progress in quantifying the effect of how defoliation and excretal returns influence grass physiology both above and below ground; in particular the effect on carbon flux in the rhizosphere which in turn affects microbial activity and the availability of nitrogen and phosphorus to the plant. This detailed understanding of the mechanisms and processes determining nutrient cycling provides the information necessary to construct models of nutrient acquisition and allocation in order to interpret responses of whole plants to effects of competition. Such information will be valuable in underpinning our understanding of the spatial dynamics of natural and semi-natural vegetation.

Plant Ecology and Community Dynamics

Our focus on plant ecology and community dynamics is important for a number of reasons. The plant communities that exist in our sown and permanent grasslands and the natural and semi-natural vegetation of our hills and uplands serve a number of purposes.

On the one hand they are an important nutrient and their management affects the quality and availability of the nutrient resource. On the other hand, these same plant communities are important habitats for a wide range of wildlife and contain much of the natural heritage of our countryside. The pattern of these plant communities combined with land topography, river catchments and lochs, and the cropping patterns of lowland agriculture, provide the unique landscapes and distribution of wild mammals and birds, not only in Scotland but in many countries throughout the world. We too often forget that it is the change in the productivity, distribution and pattern of these plant communities that can have such a dramatic influence on domestic livestock and wildlife productivity and the overall biodiversity of our countryside.

It is why our research on the role of spatial pattern in plant communities in determining plant competitive relations, and how this pattern is created by herbivore grazing, soil heterogeneity and nutrient cycling is so important. The recent advances that we have made in understanding the processes of fragmentation, particularly in grass/heather mosaics, and predicting the requirements for succession in woodland generation, added to our research on the dynamics of heather moorland and heathland communities over many years, places the Institute in a unique position. Few other institutes so effectively integrate research in plant and animal ecology and are in a position to develop suites of models that integrate experimental information and have predictive capability.

Animal Ecology in Grazed Ecosystems

Our long term commitment to research in plant and animal ecology in grazed ecosystems and the important advances that we have made in recent years in translating the output of that research into practical guidelines for grazing management has given this Institute a unique place in the international arena of grassland and rangeland management research.

For example, the advances that we have made in measuring the intake and food choices of a range of herbivores while grazing in situ and our ability to measure the movement and distribution of free ranging herbivores using GPS technology places us at the leading edge in developing techniques and methodologies for undertaking research on the ecology and grazing behaviour of a range of mammalian herbivores. It has provided the basis by which we have been able to develop a quantitative understanding of the impact of social interactions, as well as the role of secondary plant compounds and the influence of nematodes on intake and grazing behaviour. Experimentation undertaken within an evolutionary and developing theoretical framework of foraging behaviour has been an important and unique feature of our research approach. Within this paradigm, empirical data and theory have been successfully combined in the design and development of a

range of decision support tools for the management of grazed natural and semi-natural vegetation by sheep, cattle, goats and wild herbivores, such as deer. For the future, investigating the role of trade-offs between behavioural goals in determining the intake and diet selection and the spatial distribution of populations of animals across landscapes is crucial to a better understanding of how to manage free ranging domestic and wild herbivores in the rangelands of Africa and Asia as well as in Scotland.

Integrated Land Use Systems

But a central role for the Institute is determined by a need to integrate all the underpinning science that we do into systems of land use that are relevant to end-user needs and to policy change. It is about exploring systems of multiple land use and being aware of their potential environmental, economic and social impacts. Our research has taken a lead in many of these crucial areas of interdisciplinary research. Our research to maintain and enhance productivity in traditional extensive sheep and cattle systems and diversified livestock systems such as for deer, cashmere goats and fine-wool sheep and agroforestry are continuing features of our programme set within a changing market and policy context particularly in relation to CAP reform and the introduction of Agenda 2000 and the measures adopted by Scotland in implementing the Rural Development Directive. We have been at the forefront in developing thinking about options for integrating agricultural, forestry, game, and natural heritage management. The Institute was the first to design computerised decision support tools for the management of natural and semi-natural vegetation in the UK for the setting of stock carrying capacities for sheep, deer and cattle to meet particular objectives. It has also been able to propose an approach based on land quality for the conversion of HLCA headage payments on cattle and sheep to area payments.

At the level of the farm/estate significant progress is also being made in developing decision support tools to assist in the planning, appraisal and evaluation of change with an ability to explore economic, social and environmental outcomes. The potential complexity of land use on farms nowadays requires an optimising system capable of finding satisfactory multi-objective solutions. One example, LADSS – a land allocation decision support system does just this. It integrates a Geographic Information System, a simulation system and a multi-objective optimising system based on the use of genetic algorithms. The latter enables the generating of a population of land allocations solutions describing the trade-off between, for example, economic and environmental risk. At the local level this is precisely the kind of information that will be required in the future to aid decisions in managing change within a rapidly changing market and policy context.

Integrated Catchment Management

The impact of potential changes in land use on river catchment management is being addressed within the context of the EU Water Framework Directive (WFD) and the strategy proposed for Scotland by SEPA. The selection of the river catchment as the fundamental spatial management unit and the incorporation of cost:benefit scenario analysis are strong themes throughout the WFD and are mirrored by the multidisciplinary approach to catchment research being undertaken within the Macaulay.

It was the approach used in assessing the impact of agriculture within the Ythan catchment and in evaluating the potential economic impact on agriculture of declaring the catchment a nitrate vulnerable zone. While nitrogen is regarded as important it is clear that the entry of phosphorus into water bodies will also be important in determining their trophic status. Our research on groundwater monitoring, the nature of phosphorus absorption, and the transport of solutes and particulates is fundamental to the determination of impacts of land use on water quality. Our collaborative catchment models integrate hydrochemical and hydrological processes both temporally and spatially and provide explicit information on the impact of land management and the consequences of changing levels of pollutants and atmospheric acidic ions. A major theme of our research in the future will be a collaborative evaluation of the extent of acidified freshwaters in Europe by 2010. These are important achievements and contributions to the maintenance and enhancement of the quality of our aquatic resources.

Land Use Change and Socio-economic Impacts

Exceptionally among the UK bioscience institutes the Macaulay's remit specifically requires us to address the economic impact of land use change. Since 1987 our economic research has made a unique and innovative contribution by focusing on rural policy analysis (particularly agri-environmental policies), and the valuation of non-market benefits by using and developing the application of contingent valuation methods. Rural modelling and policy analysis has also led to a better understanding of the linkages between rural and urban areas and the structure and performance of regional rural economies. We have also assessed forestry's contribution to the rural economy and are currently assessing forestry's role in tourism. Our evaluation of the woodland grant schemes and the environmental sensitive area schemes have influenced SERAD's measures to implement the Rural Development Directive. The integration of economic analysis into our biophysical research, for example in catchment management research and in assessing the non-market benefits of heritage management and sustainability has demonstrated unequivocally the benefits of an interdisciplinary approach to land use research. In order that we are able to explore the potential consequences of policy change

arising from CAP reform, Agenda 2000 and the Rural Development Directive, our economic research will develop improved models for understanding changes at the regional level, develop methods for analysing environmental sustainability and identify efficient policy instruments for delivering sustainability. Our aim is also to incorporate a greater sociological component into our research in collaboration with our colleagues at the University of Aberdeen.

Land Use Change – Monitoring, Modelling and Forecasting Change

It may seem remarkable but when the Institute was founded in 1987, there was no comprehensive audit of land use in Scotland. As a result of parliamentary questions about the nature and extent of land use change in Scotland at the time, to which only partial answers could be given, the Institute was commissioned by the Scottish Office, with SNH and the Forestry Commission to produce a land cover database based on the interpretation of air photography.

The land cover 1988 database represents a benchmark contribution to land use research in Scotland. It continues to be used by groups within the Scottish Executive (e.g. Ecological Advisors Unit), SNH and FC in discharging their responsibilities for environmental and woodland audits and assessment. Furthermore, the data have been used in unforeseen ways to develop woodland framework strategies, for example in the Cairngorms, and in the critical evaluation of strategies for disposal of sewage sludge, and developing renewable energy. To ensure that similar monitoring and evidence-based policy initiatives are possible in the future, it is essential that we have commitment to regularly updating the land cover database. It is inevitable that agricultural and environmental policies will bring about some change in the use of our natural resources. It is important to know whether these policies are effective. We cannot and should not develop policies in a vacuum. Whilst the Institute is taking a lead role in developing cost-effective technologies to update the land use database (e.g. exploiting new developments in digital photography), it is important that the Scottish Executive continues to promote and fund environmental audits of this type as part of their wider commitment to sustainable development. It is an investment worth making.

The need to be able to forecast change is also important though it is fraught with difficulty. Bearing in mind the complex inter-relationships between biophysical, social, economic and political issues and that change is often opportunistic, it is inevitable that predicting ultimate outcomes will be subject to great uncertainty. Put simply, where people are involved there has to be a healthy acceptance that the nature of change will be evolutionary and emergent. However, if it is the intention to manage some aspects of

change it is necessary to try to establish the likely direction of change if not its absolute extent.

A modelling approach currently being developed at the Macaulay provides a Framework for the Environmental Assessment of Regional Land Use Scenarios (FEARLUS). Based on complex theory it uses the SWARM agent based modelling environment developed at the Santa Fe Institute (Langton et al 1999). While accepting that the approach is speculative it could nevertheless represent a more explicit approach to decision making by combining our biophysical understanding with our goal-seeking behaviour often expressed currently through a mixture of concepts (like sustainable development), and imitation (doing what one's neighbour does).

As I indicated at the outset it is unlikely that we will be able to predict change with great certainty. Modelling can however, be used to contribute more explicitly to the explanation of potential evolutionary and emergent outcomes and provide an intelligent environment within which to explore the consequences of decisions and manage change. They will doubtless become increasingly important in the future.

There are, however, other tools that the Institute has developed to assess the physical impact of change, for example, on landscape. These tools are of immediate practical relevance to land use planning and in educating and informing people about the potential options and choices that can be made, for example, in the location of wind farms and forests. The harnessing of sophisticated geographic information systems with advanced information technology has allowed the Institute to take a lead in objective landscape analysis. We will continue to develop new knowledge and IT-based methods for monitoring and visualising land use and landscape change. Coupled with further research to integrate data on land use change from a range of sources such as agricultural and population census we will develop a greater capacity to model land use change and identify the major social drivers of change.

The Future

Within the economic and policy context of the drivers of change that I outlined earlier I reiterate that I believe that for the future it will be increasingly important to continue our research into the underlying processes of change at all levels of organisation so that we can monitor, model and forecast land use change as well as to continue to design and refine decision support systems to manage change. These remain our fundamental objectives.

The Institute Research Environment

These are also just the kind of mission-oriented, inter-disciplinary objectives that are best tackled within an institute research environment. Resources can be specifically deployed and programmes directed and managed to provide the relevant information and knowledge to address the issues that require to be resolved to provide solutions and reduce uncertainty about ultimate outcomes. While programmes of research in institutes may not provide for the same level of academic freedom as in universities and are more strategic and applied than basic, they have to be no less excellent. They also have the advantage of providing for a long-term experimental commitment and a stability that is difficult to achieve in universities that operate within a research-funding environment dominated by short-term research grants and contracts.

The unique features of institutes are their distinctive remits and their ability to focus their research on specific topics over a long time-scale, tackle issues in a holistic manner and network effectively. Institutes, as centres of excellence, represent research management environments within which innovative interdisciplinary research and technological innovation can flourish. But relevance is a dominant driver in determining what they do. This does not imply that their strategic research should not be speculative. Indeed, if some of it were not to be so it is unlikely that imaginative and visionary solutions would be forthcoming.

The Boards of Governors of institutes and the arrangements with their primary sponsors are also important. Institute Boards include academics and people who are knowledgeable and informed end-users as well as being entrepreneurial business managers. The Board members are in a position to monitor and influence the quality and relevance of institute research programmes and ensure the appropriate allocation of resources on a continuing basis. The sponsors on the other hand, have a direct contractual relationship with institutes and a requirement that the research undertaken meets their needs as well as the needs of others they represent (eg in the case of MLURI and SERAD, SNH and SEPA). The sponsor's use of the visiting group peer reviewing procedures every four years ensures the quality and relevance of its commissioned programme.

Institutes are also uniquely placed and constituted to develop close working relationships with their end use communities and commercialise their outputs through private companies. The Macaulay is well placed to bring about technology transfer to industry as well as to government departments and their agencies and does so successfully.

Institute /University Relations

The rationale for the institute/university structure in delivering a relevant and focused science strategy for Scotland is strong. Institutes are ideally suited to being conduits for delivering interdisciplinary solutions for specific policy purposes and technological demands. On the other hand, universities provide the basic research within disciplines that underpins and creates opportunities on which innovative strategic research and technology transfer can be developed. To secure economic growth in Scotland and an improved quality of life for its people, it will be important that the distinctive contributions institutes and universities can make, are integrated in such a way as to make the relationship between basic, strategic, applied and developmental research as seamless as possible. This requires institutes and university departments with common interests to work much more closely together to create high quality multidisciplinary teams of researchers and integrate their research planning accordingly.

This is why the recent creation of Research Units by the Aberdeen Research Consortium (a consortium of the universities and institutes in Aberdeen) is such an important development. The Macaulay's joint initiatives with Aberdeen University in Soil Health with the Departments of Plant and Soil Science, and Molecular and Cell Biology and in the Social Sciences with the Arkleton Centre are now both underway, funded respectively by Aberdeen University and the Macaulay Development Trust. It is the Trust's intention to fund these initiatives for a period of three years in anticipation that by then they will become self-sustaining. Other, similar developments are also likely to depend on Trust funding. That is why the Trust is currently realising some of its fixed assets in land. Increasing the investment portfolio of the Trust is crucial to the future development of new research initiatives as well as building facilities that will enhance the ability of the Institute to develop commercially.

Collaboration and Added Value

There are good reasons to continue to build on existing collaboration across the institutes and research organisations sponsored by SERAD. New initiatives, new scientific opportunities and policy requirements need to take account of the expertise and skill base in which SERAD and the institutes themselves have invested. Research proposals developed through the Committee of Heads of Agricultural and Biological Organisations in Scotland (CHABOS) on topics like biodiversity, provide for possibilities of networking across the institutes and universities in Scotland and the UK, as well as complementing and linking with research themes sponsored by the UK Research Councils (particularly BBSRC, NERC and ESRC). These developments need to continue and be encouraged.

While it is often argued that competition for funding militates against collaboration, the true test is whether potential collaborators and those who fund them are failing to recognise the potential added value that can arise from collaboration. The Macaulay has collaborated extensively within Scotland, the UK and Europe in recent years and some of our achievements would not otherwise have been possible. We acknowledge the contribution that our many collaborators have made to the success of our research.

Research as an Investment in the Future

There is no doubt that the major constraint on realising the full potential of Scotland's research base, including the Macaulay, will be funding. The talent exists and as part of the UK funding base our researchers in Scotland remain at the top of the world league in terms of the number of papers published for the amount of money spent on science (Research Fortnight Vol 6, No12). But there has been no significant real terms growth in research and development spending since 1994. Current levels of performance are unlikely to be sustainable unless an increased proportion of our gross domestic product is spent on research and development.

We too often forget that high quality research is an investment in the future. Our ability to remain economically competitive and deliver an enhanced quality of life for the people of Scotland will be determined only in part by the short term issues that dominate the life of a four yearly cycle of Scottish Parliamentary business. Agendas dominated by health services provision and education reflect the matters uppermost in the public's mind. They are the issues upon which politicians will be judged. They are indicative of a culture in society that is obsessed by short-term 'wants' as opposed to long-term aspirations. No one can deny that these 'wants' are important but a balance has to be struck. Research is predominantly about the future and societies, on the whole, focus on the present. So there is a dilemma as to how to influence society to think differently. The adoption of the concept of sustainability and the idea of intergenerational equity provide a clue. If we have a concern about the welfare and quality of life of our children and our children's children we cannot ignore the fact that they will require information and knowledge that we don't have. It is our responsibility to make the necessary investment now to make such information and knowledge available to them in the future. Nor can we ignore the fact that we are abysmally ignorant about many aspects of life that affect us now and will continue to affect us during our lifetime.

But of course the case for science and research as investments for the future can be undermined if issues like BSE, and GMOs fail to be handled objectively. In general the public's view of science is not well served by the way in which the media sensationalise

issues and attempt to 'sound bite' them to the point of absurdity. But neither have scientists excelled at explaining complex issues in ways that are meaningful to the public and in ways whereby the individual can come to an informed view. Scientists are also perceived to be too much influenced by vested interests. Their integrity and their objectivity are frequently called into question. There has been a failure to separate the imperatives of populist politics and commercialisation from the objectivity that science and the measurement of uncertainty can provide. If future investment in science and research is to have public support then things will have to be done differently. Creating a more positive relationship between scientists and the societies that they serve will depend on the vigilance of scientists in considering the ethical basis of what they do, and how they behave. It will also depend upon their integrity in being open about their activities and making freely available the information that they produce.

Nevertheless, none of this should detract from the incalculable benefits that have arisen from science and technology in recent decades. The advances, for example, in biotechnology and information technology, that have been made would simply have not been possible without the significant investments made in research since the Second World War. Yet, we are now in a period of unprecedented global technological and societal change. The demand for information grows day by day. It is no less so in the practical business of managing land. Investment in land use research will continue to be needed irrespective of the current economic state of the land using industries. The land will continue to be used and it will continue to be managed. Objectives will change, the environment will change and there will be different people living in and using the countryside with different ideas as to what they expect to gain from the experience. And who can predict with certainty the demands that may be made on our land resources in the future for primary food and timber production?

Continuing to fund high quality research enables us to face the certainty of change with a greater certainty of being able to manage change. A focus on contemporary issues to the exclusion of discovering possibilities for the future denies the progressive nature of humankind. We need to redress the balance; as a nation we need to increase our investment in research now.

We need to make the kind of commitment that T B Macaulay made to this Institute in 1935. He believed in a better future for those who lived off the land in Scotland but he also knew that their quality of life could be improved only if they knew more about the resources on which they depended. Acknowledging the enormous progress that has been made over the last 65 years, the fact is that the more we know, the more we realise how

little we know. Perhaps it is in the nature of things that we remain always at the threshold. But by making the endowment that he made here, in this Institute, Thomas Macaulay demonstrated foresight and faith in men and women's innovative capacity to make a difference. And it is that foresight and faith, and his vision to which we pay tribute today.

When I retire in October I will have more to say to my colleagues but on this occasion as I prepare to hand over to my successor may I take this opportunity to thank you all for your support and for coming to this 24th Macaulay Lecture. For the commitment that all of you who work here have given to this exciting and imaginative enterprise that was launched in 1987, I pay tribute. It has been a privilege and a pleasure to work with you. Much has been achieved and I am confident that much more will be achieved in the future. I wish you all and my successor Professor Gill every success in the coming years in:

'creating long term sustainable solutions for our land and people'.

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