SCOTTISH EXECUTIVE

SEERAD

Programme of Agricultural, Biological and Related Research

2002-2003

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INTRODUCTION

This is the 2002-03 edition of the Scottish Executive Environment and Rural Affairs Department (SEERAD) Programme of Agricultural, Biological and Related Research, which details the research programme commissioned and sponsored by the Department's Agricultural & Biological Research Group (ABRG).

The Group commissions a broad range of research from organisations within Scotland and elsewhere in the UK. The research programme reflects ABRG's aim:

> *"To support a high quality science base in agricultural, biological and related sciences, and to fund research of strategic relevance to, and in support of, policy areas of the Scottish Executive and the related end-user communities in Scotland and beyond."*

The research described here is predominantly (85%) carried out within the core (grant-in-aid) programmes of the five Scottish Agricultural and Biological Research Institutes (SABRIs): the Scottish Crop Research Institute (SCRI), the Hannah Research Institute (HRI), the Moredun Research Institute (MRI), the Rowett Research Institute (RRI), and the Macaulay Land Use Research Institute (MLURI); and at the Scottish Agricultural College (SAC) and the Royal Botanic Garden Edinburgh (RBGE). The remainder of the programme (15%) is commissioned by contract from these and other research organisations across the UK using the Department's Flexible Fund.

The programme covers a range of agricultural and related biological, environmental, food-related and socio-economic research. The bulk of the programme provides medium to long-term strategic research in these areas, but there is also a growing component of applied research building upon it. The annual direct cost of the research programme as a whole is about £43.5 million. Projects accounting for approximately £39.6 million of this are listed and the aggregate cost of the RBGE projects is in the order of £2.3 million. The final £1.6 million is non-commissioned research (NCR), a percentage of grant-in-aid that SABRI Directors and the Principal at SAC can use for research outside their commissioned programmes.

In 1999 ABRG published its *Strategy for Agricultural, Biological and Related Research 1999-2003.* This document is available on request or can be viewed on our web-site at www.scotland.gov.uk/abrg. The Strategy sets out five key objectives, summarised as follows:

1. To maintain a strategic research capability as part of the UK science base, building on strengths and responding to new opportunities.
2. To widen the range of end-uses of the Department's research programme and to ensure its continued relevance.
3. To enhance the quality of the research programme through an improved focus on co-ordination, collaboration and competition.
4. To foster knowledge and technology transfer.
5. To improve information dissemination from, and public awareness of, the Department's research programme and its outputs.

To assist in objective one, developing the strategic research capability, the research programme was revised in 1999 into five main "Themes". These Themes are described in this document, and are as follows:

- Theme 1: Soil and Environmental Sciences
- Theme 2: Plant Science
- Theme 3: Animal Physiology & Product Quality
- Theme 4: Animal Disease, Behaviour and Welfare
- Theme 5: Systems and Socio-Economics

Under the second key objective, ABRG is committed to broadening the range of end-users of its research programme. The Strategy identified five end-use categories for the research programme:

- Sustainable Agriculture (SA)
- Environment and Natural Heritage (ENH)
- Nutrition and Human Health (NHH)
- Food and Bioindustries (FB)
- Rural Communities and Development (RCD)

The relevance of the SEERAD research programme to these categories is highlighted in the introductory text that accompanies each Theme in this document. The main focus of the research programme has traditionally been on sustainable agriculture. However, a significant proportion of the programme now addresses issues relevant to the environment and natural heritage, nutrition and human health, and food and bioindustries. The rural communities and development end use category focuses specifically on economic development in rural areas and on the social and economic sustainability of rural communities, although the vast majority of the full research programme is in fact relevant to the rural sector. In future years we anticipate that as the involvement of, and utility to, end users is increased, the profile of the programme will shift with sustainable agriculture remaining the largest end use category, but with an increasing proportion being relevant to the other four categories.

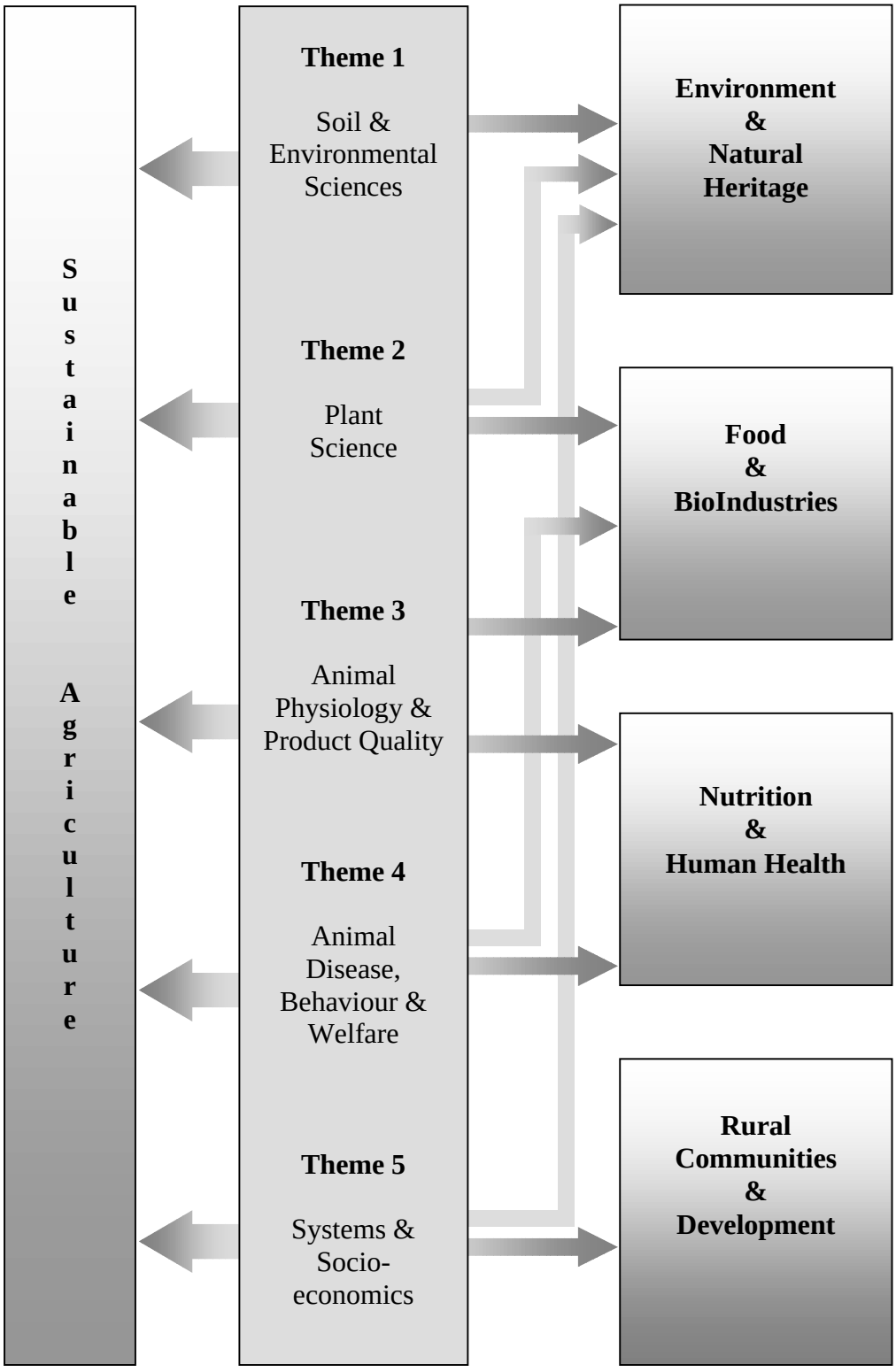
ABRG is also committed to enhancing the quality and effectiveness of the research programme (the third key objective). Last year, ABRG launched a Flexible Fund Collaborative Competition to encourage Sponsored Bodies to work on joint projects with other research organisations where this enables more to be achieved than working separately. Approximately £3.4 million was awarded for collaborative projects, which are included in this document.

Since the publication of the 1999-2003 Strategy there has also been considerable activity within ABRG, the SABRIs, SAC and RBGE to further implement key objectives four and five. These key objectives are to improve knowledge transfer and technology transfer from the science base to end-users, and to improve dissemination of project outputs and public awareness of the research programme. Progress in implementation of the Research Strategy against each of the five objectives has been reported in the Group's annual strategy implementation reports, which can be found on the ABRG website.

This document lists all projects underway in 2002-03 as at 1st August 2002. The projects are listed within the framework of the five scientific themes. Only commission number, title, end

date and estimated recurrent cost for 2002-03 are provided for economy of space, but further information on any project, or area of the programme, can be provided by the ABRG-Research Management Unit: please telephone 0131-244-5230 or fax 0131-244-6566 for further assistance.

The following diagram shows the relationship between the five scientific themes and the end-use categories in the research programme:



SUMMARY OF ESTIMATED COSTS FOR THE 2002-03 RESEARCH PROGRAMME (in £k)

THEME 1 – SOIL & ENVIRONMENTAL SCIENCES	**4,615**
1.1 Soil Sustainability	**3,001**
1.2 Water Quality & Catchment Management	**1,277**
1.3 Long-Term Environmental Change	**337**
THEME 2 – PLANT SCIENCE	**9,057**
2.1 Systematics & Genetics	**3,269**
2.2 Plant Physiology	**2,304**
2.3 Novel Plant Products	**593**
2.4 Plant Pathology	**2,891**
THEME 3 – ANIMAL PHYSIOLOGY & PRODUCT QUALITY	**11,173**
3.1 Nutrition	**3,440**
3.2 Tissue Growth & Development	**3,890**
3.3 Reproduction	**2,105**
3.4 Animal Product Quality	**1,738**
THEME 4 – ANIMAL DISEASE, BEHAVIOUR & WELFARE	**5,966**
4.1 Epidemiology of Animal Diseases	**77**
4.2 Pathology & Pathogens	**2,365**
4.3 Immunology & Host-Pathogen Interactions	**1,259**
4.4 Control of Animal Disease	**1,573**
4.5 The Physiological Basis of Behaviour	**439**
4.6 Welfare in Farming Systems	**253**
THEME 5 – SYSTEMS & SOCIO-ECONOMICS	**8,728**
5.1 Ecology	**2,966**
5.2 Biodiversity & Conservation	**645**
5.3 Land Use	**3,261**
5.4 Mathematical Support	**841**
5.5 Socio-Economic Studies: Rural Economy	**1,015**
TOTAL COMMISSIONED RESEARCH	**39,539**
NON-COMMISSIONED RESEARCH	**1,600**
UNCOMMITTED SPEND	**40**
ROYAL BOTANIC GARDEN EDINBURGH	**2,300**
TOTAL 2002-03 SPEND	**43,479**

KEY TO PROJECT LISTING

The listing comprises all "live" projects commissioned by the Department at August 2002. Each project entered in the list shows the commission number, title, month and year of completion, and estimated annual cost (ERc). [Please note that costs for some projects are not currently available.]

The key to information contained in the listing is as follows:

Commission number: comprises a three-letter organisation code, a three-digit number, and the year in which the project was commissioned. Where the research effort is shared among several contractors, each is given the same three-figure ("800" series) number within the SEERAD commission number.

Organisation codes:

ACT	membership subscription to ACTIN
ADA	ADAS
BGS	British Geographical Survey
BSS	Biomathematics and Statistics Scotland
CEH	Centre for Ecology and Hydrology, NERC
CJC	CJC Consulting Limited
CPA	Crop Protection Association
CRU	Central Research Unit, Scottish Executive
CSL	Central Science Laboratory
FEL	Fellowship
GAI	Gordon and Innes
HID	Hugh Inwood
HRI	Hannah Research Institute, SABRI
IAC	Institute of Arable Crops Research, BBSRC
ITE	Institute of Terrestrial Ecology, NERC
JEY	Just Ecology Limited
LUC	Land Use Consultants Limited
MLU	Macaulay Land Use Research Institute, SABRI
MRI	Moredun Research Institute, SABRI
MRS	Mylnefield Research Services
NHC	National Herb Centre
NIB	National Institute of Agricultural Botany
QBB	Biological and Biotechnology Sciences Research Council
QBP	British Potato Council
QDH	Contribution to Health Department, Scottish Executive
QEN	English Nature
QNE	Natural Environmental Research Council
QSR	SNIFFER
RBG	Royal Botanic Garden Edinburgh
RPB	RSPB
ROS	The Roslin Institute, BBSRC
RRI	Rowett Research Institute, SABRI
RVC	Royal Veterinary College, University of London
SAC	Scottish Agricultural College

SAN	Sanger Centre
SCH	Scottish Centre for Infection and Environmental Health
SCR	Scottish Crop Research Institute, SABRI
SDR	Strathclyde Institute for Drug Research
SNH	Scottish Natural Heritage
SRI	Silsoe Research Institute, BBSRC
UAB	University of Aberdeen
UCR	University of Cranfield
UEH	University of Edinburgh
UGW	University of Glasgow
UHE	University of Hertfordshire
ULE	University of Leicester
ULS	University of Leeds
UNM	University of Nottingham
URD	University of Reading
USA	University of St Andrews
UYK	University of York
VLA	Veterinary Laboratory Agency
WWT	Wildfowl and Wetlands Trust

Appendix 1 gives names and addresses and a contact point for each SABRI, SAC and RBGE. Appendix 2 provides a full listing of projects and costs, including the new collaborative projects.

Core: unless otherwise identified all projects listed are funded through grant-in-aid core funding of the Department's main sponsored bodies. A project-based commissioning system operates on a rolling three-year basis. Projects are proposed by the sponsored bodies in line with both their own Corporate Plans and SEERAD's Research Strategy objectives.

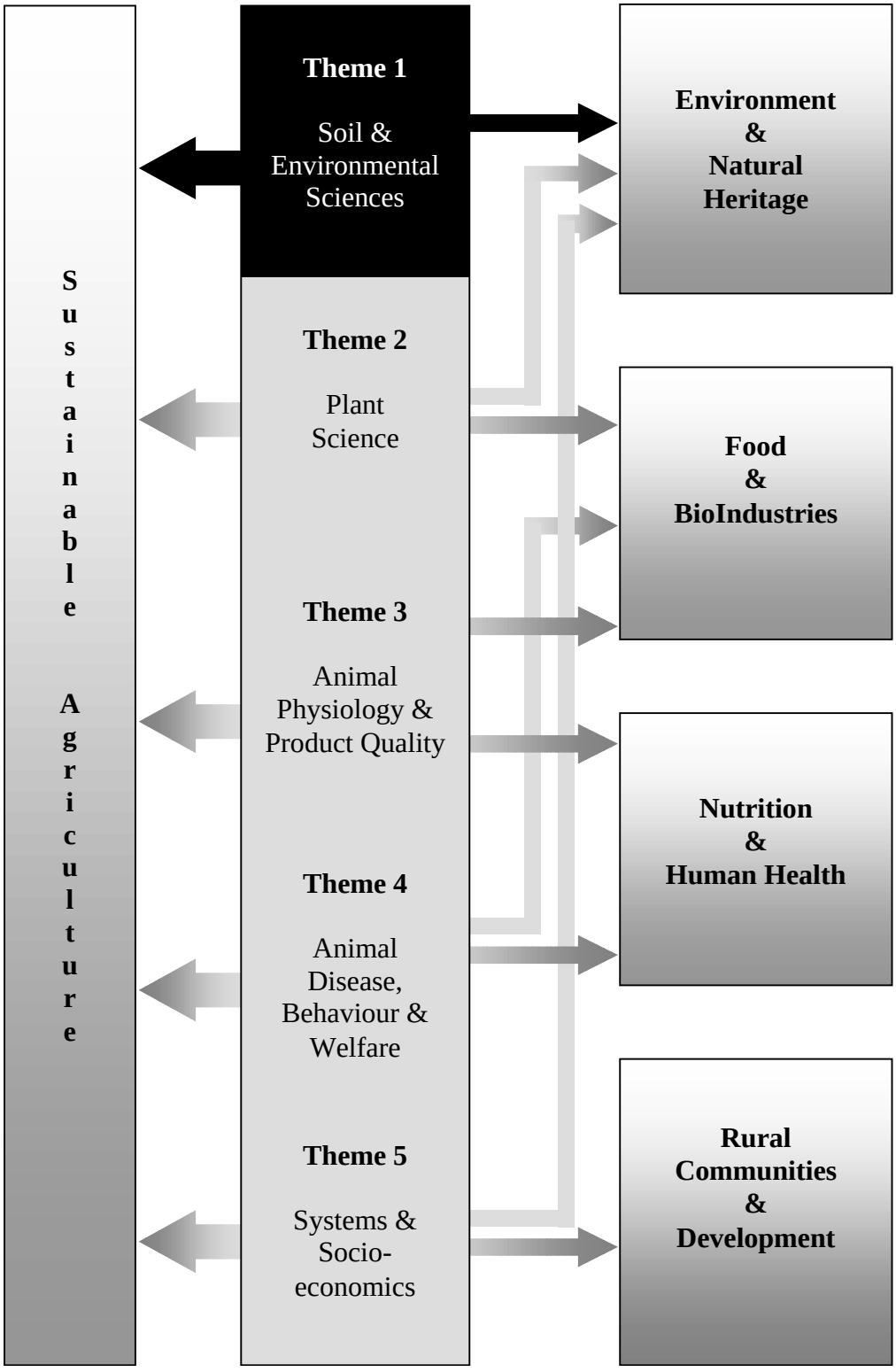
Non-Commissioned Research: sponsored bodies are permitted to use up to 5% of their grant-in-aid allocation for research activity outside the commissioning framework. This Non Commissioned Research is used mainly for short term speculative work, both basic and applied. It can also be used for funding visitors to the Institute or visits by Institute staff. Such projects are not listed in this document.

Flexible Fund: if project titles are identified by (FF) they are funded from the SEERAD's Flexible Fund. The Flexible Fund is used to commission individual projects on a contractual basis and is available to both sponsored bodies and other Institutes. The fund is used to initiate research in response to specific Scottish Executive Policy requirements, to promote collaboration among the sponsored bodies and with other research organisations, and to fund research in conjunction with other research sponsors.

Fellowships: project codes beginning FEL indicate Fellowship awards given to individual researchers out of the Flexible Fund.

LINK: project titles identified by (FF-LINK) are funded from the Flexible Fund through a UK Government-wide scheme bringing together companies and research-based organisations. Each project requires the collaboration of at least one company and at least one research organisation. Government Departments and Research Councils provide up to half of the total project cost.

THEME 1: SOIL AND ENVIRONMENTAL SCIENCES



SUMMARY OF COSTS:

	Estimated Recurrent Cost (£ k) 02/03
1.1 Soil Sustainability	**3001**
1.1.1 Soil Physics	629
1.1.2 Soil Microbiology	1101
1.1.3 Soil Nutrient Cycling	967
1.1.4 Soil Protection	304
1.2 Water Quality & Catchment Management	**1277**
1.3 Long-Term Environmental Change	**337**
TOTAL	**4615**

THEME 1: SOIL AND ENVIRONMENTAL SCIENCE

Theme 1 of the SEERAD-funded research programme provides a strategic research programme that underpins the sustainable management of soils and the protection of water quality. The research activities described here provide knowledge that directly supports and complements the programme of research in the Themes that follow, especially in relation to plant growth and development and systems research.

Soil is produced when weathered rock material is modified over time by the addition of organic matter, by biological activity, and through the action of temperature and moisture. Soil and water with air provide the medium in which most vascular plants grow: they are the basis from which terrestrial ecosystems derive and globally support the majority of the world's food production. The Royal Commission on Environmental Pollution report (1996) *The Sustainable Use of Soil* recognised that soils are not an infinite commodity, describing them as a vital resource "… which we believe has been taken too much for granted".

Basic studies of soil physics and soil microbiology provide the foundation for studies of soil nutrient cycling and soil protection, and this is reflected in the structure of Theme 1. These activities are improving our understanding of how soils can be managed to provide for economically viable agriculture, whilst limiting any negative environmental impacts. Information from the research of soils is available to inform studies of water quality, the importance of which is emphasised by the EU Water Framework Directive. The overall purpose of this Directive is to prevent further deterioration, to protect and enhance the status of aquatic ecosystems, and to contribute to the provision of sufficient supply of good quality surface water and groundwater, as needed for sustainable, balanced and equitable water use. In the context of sustainable land management, the emphasis of pollution impacts has shifted from point sources of pollution to diffuse sources, and from field scale to catchment scale studies. All these changes are reflected in the evolution of our programme of water quality research.

Of the five key end use communities identified in the ABRG *Strategy for Agricultural, Biological and Related Research 1999-2003* (sustainable agriculture, environment and natural heritage, nutrition and human health, food and bioindustries and rural communities and development), Theme 1 is most relevant to the first two categories. Sustainable agriculture requires balancing the exploitation of natural resources, maintaining an economically viable industry and minimising the environmental impact of that industry. Theme 1 provides the underpinning knowledge that will enable the primary resources of soil and water to be managed in a sustainable manner. Soil nutrient resources can be conserved through the understanding of soil physics, soil microbiology and the processes of nutrient supply. Water quality is protected through a more integrated, catchment scale approach to water resource provision that recognises the variety of roles that water must fulfil. This theme of the research programme will provide a component of the knowledge required to allow Scottish agriculture to operate within the Common Agriculture Policy and to adapt to the final Agenda 2000 CAP reforms.

In general terms the programme of soil and water research is relevant to the environment and natural heritage end-use community because it is concerned with the management of soils and water, which are two of the fundamental components of all terrestrial ecosystems. The diversification of this portfolio of research has also increased its utility; issues such as environmental contamination by zoonotic pathogens, maintenance of biodiversity, and

bioremediation of damaged environments can all be taken forward by this programme. This research will help policy advisors to model or consider the potential effects of proposals on the environment, including those emanating from the European Commission.

1.1 Soil Sustainability

1.1.1 Soil Physics

Knowledge of soil physical properties is the most basic requirement to improving our understanding of how soils function, enabling us to be in a position to manage them in a sustainable manner. A significant physical feature of soils is its apparent randomness, or heterogeneity. Building on research commissioned by SOAEFD in 1991, research is continuing that uses the theory of non-linear dynamics and fractal geometry to describe soil heterogeneity and the consequences for soil processes.

BSS/030/01	Application of stochastic geometry to understanding transport of micro-organisms in soil. (FF) (03/04)	3
MLU/697/00	Chemical fluxes in soils - processes and properties. (03/05)	224
QBB/008/00	BBSRC BIRE Initiative. (FF) (01/04)	100
SCR/525/99	Interactions between the structure of soil habitats and biological processes. (03/03)	248
SCR/901/02	Soil stability and resilience: The interplay between biological and physical recovery from stress. (FF) (07/05)	54

1.1.2 Soil Microbiology

Micro-organisms that inhabit soil play a vital role in making available nutrients that may be used by plants or lost from the soil system. Combining our understanding of soil physical properties with research on the composition and activity of soil microbial communities is important for developing soil management strategies that require less artificial nutrient input. SEERAD commissioned a 9-year programme (MICRONET) that is central to our research in this area. The MICRONET programme initially developed and applied molecular and community scale techniques to quantify the diversity of microbial populations. This work has shown significant differences in microbial populations from soils under different land uses. The research is being further developed within the programme to investigate the relationship between plants and microbial communities, and will contribute to the development of strategies for sustainable land use.

MLU/808/94 SCR/808/94 UAB/808/94	Development and application of molecular biological and physiological techniques in studies of the interactions between microbes, nutrient cycling and vegetation among a range of agriculturally important pastures, to enable scaling from microcosm to field. (FF) (03/04)	72 98 72

MLU/702/00	Rhizosphere processes of grazed ecosystems: carbon fluxes and microbial community structure and function. (03/03)	347
MLU/904/02	The application of microbial soil quality indicators to organic matter rich soils in the context of environmental change and carbon turnover. (03/06)	246
SAC/265/00	Microbial biotransformation of agricultural effluents in constructed wetlands. (03/03)	187
UYK/808/01	Micronet phase 3 - the mycorrhizal component. (FF) (06/04)	79

1.1.3 Soil Nutrient Cycling

The soil physical environment and the activity of soil microbial communities contribute to the cycling of nutrients within soils, their availability to plants and their potential for loss from the soil through leaching or gaseous emissions. The research programme on soil nutrient cycling focuses on transformations and movement of nutrients within soil to promote fertility and restrict nutrient losses.

MLU/703/00	Organic matter inputs to soil and their effects on the soil solution chemistry of nitrogen, phosphorus and carbon. (03/03)	108
MLU/905/02	The physiology of carbon assimilation, partitioning and transfer by trees to soils in regenerating semi-natural woodlands. (03/06)	0
MLU/913/02	Molecular methods to link carbon fluxes and microbial communities in upland soils. (03/05)	60
SAC/312/01	Preserving fertility and soil quality in organic production with emphasis on the conversion from ley to arable. (03/05)	107
SAC/329/02	Root mediated nutrient transfer in crop mixtures. (03/05)	88
SCR/542/00	Consequences of soil biological diversity for the functioning and health of agricultural soils in relation to C cycling dynamics and resilience. (03/04)	298
SCR/544/00	Consequences of soil biological for the functioning and health of agricultural soils in relation to N cycling processes. (03/04)	189

SCR/588/02	Consequences of soil biological diversity for the functioning and health of agricultural soils in relation to N cycling processes: II. carbon and nitrogen fluxes among major plant and soil pools, using natural abundance stable isotopes. (03/04)	117

1.1.4 Soil Protection

The Royal Commission on Environmental Pollution report *The Sustainable Use of Soil* (1996) stated that "…soils should be accorded the same priority in environmental protection as air or water". This programme of research aims to build on the understanding gained from previous programmes of wastes and pollutants research to provide a framework for the protection of soils. Research includes assessment of the impacts of sewage sludge, organic micro-pollutants and heavy metals on soil fertility.

MLU/328/93	Effects of sewage sludge applications to agricultural soils on soil microbial activity and the implications for agricultural productivity and long term soil fertility. (03/03)	84
MLU/699/00	Process-based indicators of soil quality and their application in support of a Scottish soil protection strategy. (03/04)	158
SAC/330/02	Effects of sewage sludge applications to agricultural soils on soil microbial activity and implications for agricultural productivity and long term soil fertility (Phase III). (03/06)	62
UCR/001/00	UK Soil database for modelling soil carbon fluxes and land use for the national carbon dioxide inventory (SP0511). (FF) (03/03)	-

1.2 Water Quality & Catchment Management

Quality and quantity of water are both important attributes of this common resource. The need for research on water quality has been emphasised by the EU Directive "Establishing a Framework for Community Action in the Field of Water Policy". Member States will be obliged to analyse the characteristics of each River Basin District (catchment), including geological, hydrological and demographic characteristics. This Directive has shifted the emphasis of SEERAD-funded research activities in the area from field to catchment. Most of the projects address issues relating to water quality rather than provision, since this is more appropriate in a Scottish context. Recent Government and public concerns over *Escherichia coli* have led us to commission projects that specifically address the issue of how long *E. coli* from agricultural soils can survive, and whether they can contaminate private water supplies.

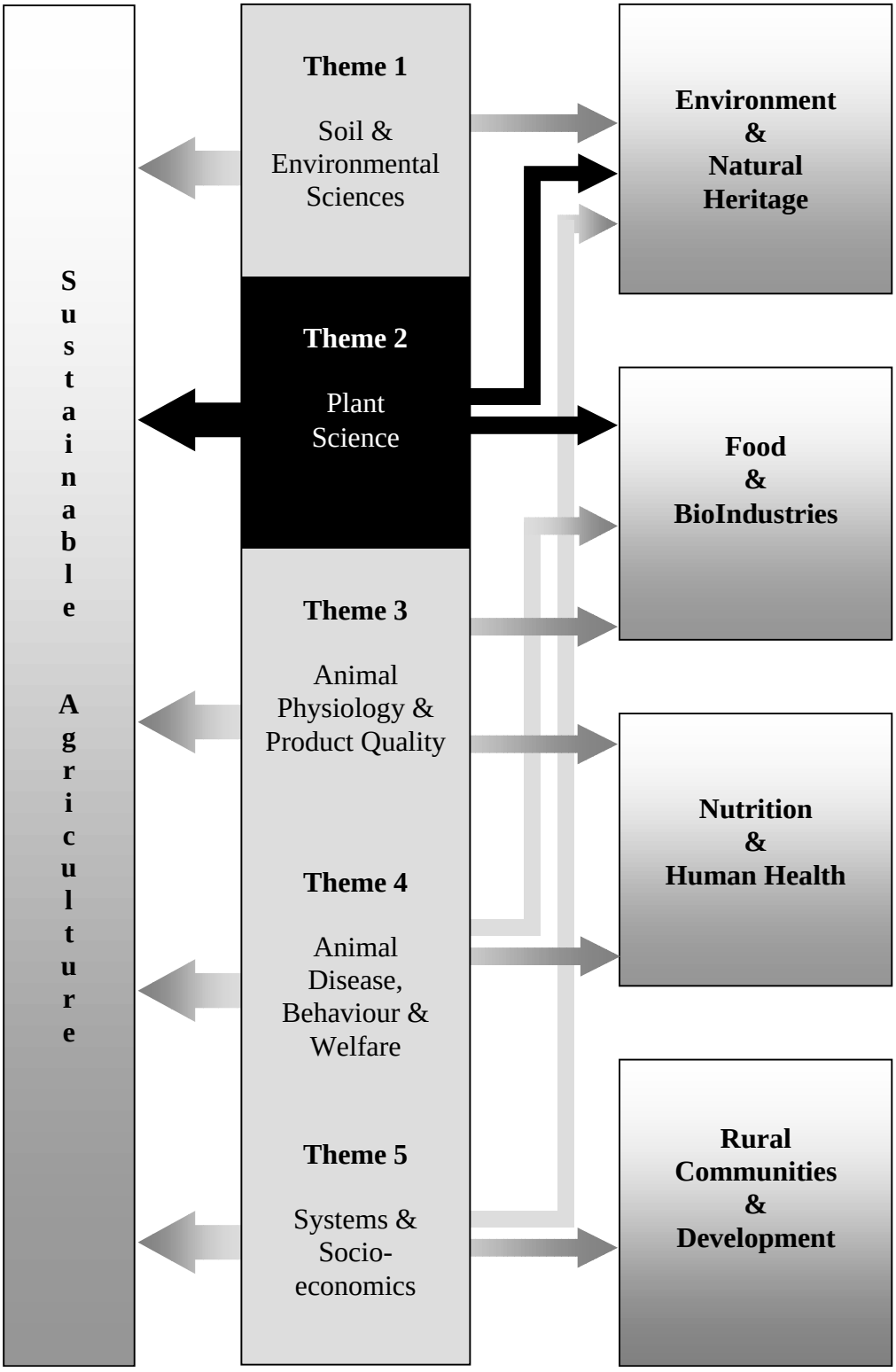
MLU/823/97 SCR/823/97 UAB/823/97	Significance of physical heterogeneity for scaling of solute chemistry in soils from fine scale to subcatchment. (FF) (12/02)	26 80 18

1.3 Long-term Environmental Change

SEERAD is a sponsor of the UK Environmental Change Network (ECN), which aims to study the effects of environmental change on aquatic and terrestrial ecosystems through long-term monitoring. The Department sponsors the terrestrial ECN sites at Sourhope and Glensaugh.

JEY/001/01	Review of UK and Scottish surveillance and monitoring schemes for the detection of climate induced changes in biodiversity. (FF) (10/02)	38
MLU/493/96	Environmental Change Network: use of long-term monitoring sites and historical re-sampling strategies in the detection of environmental changes. (03/05)	193
MLU/623/98	Environmental Change Network: measure long-term changes in climate, soils, vegetation and wildlife populations at two upland agricultural sites in Scotland. (03/03)	101
QEN/001/01	Monarch 2. (FF) (07/03)	5

THEME 2: PLANT SCIENCE



SUMMARY OF COSTS:

	Estimated Recurrent Cost (£ k) 02/03
2.1 Systematics and Genetics	**3269**
2.1.1 Angiosperm Systematics	-
2.1.2 Non-Angiosperm Systematics	-
2.1.3 Evaluation & Exploitation of Genetic Resources	1267
2.1.4 Plant Genomics	1658
2.1.5 Bioinformatics	344
2.2 Plant Physiology	**2304**
2.2.1 Plant Molecular Physiology	1177
2.2.2 Whole Plant Physiology	1127
2.3 Novel Plant Products	**593**
2.4 Plant Pathology	**2891**
2.4.1 Fungi & Bacteria	1345
2.4.2 Viruses	1135
2.4.3 Nematodes	411
TOTAL	**9057**

THEME 2: PLANT SCIENCE

All human activities on this planet depend on the ability of plants to capture the sun's energy and turn it into food, biomass and oxygen, the substrates for human and animal life. In addition, plants are the dominating features of the natural landscape, providing an environment which is valued by the public. In order to produce food and biomass from our crops most efficiently and at the same time to conserve the natural diversity of plant life, it is necessary to understand how plants function and how they interact with other organisms, including other plants.

Theme 2 describes a programme of basic and strategic plant science, which is internationally relevant. This includes work on the mandate crops (potatoes, spring barley and soft fruit), which are of particular importance to Scotland, and in addition, a programme of classical systematics research, which is undertaken on specimens collected mainly on overseas expeditions. The plant science research in Theme 2 complements and informs other parts of the SEERAD research programme, most notably the root microbiology work listed in Theme 1 (Soil, Water and Environment), and the farming systems and floristics/ecosystem studies in Theme 5 (Systems and Socio-Economics).

Plant science research in Theme 2 aims ultimately to understand processes which limit sustainable crop production in Scotland. Much of the research described is multidisciplinary, gaining added value through the combination of different skills. For example, genetic and pathological approaches are combined to identify new sources of resistance from the germplasm collections, which can be subsequently utilised for breeding improved varieties. In many cases, SEERAD-funded research is also vertically integrated, linking theoretical studies whose outputs will be of long-term value with strategic science, which in turn can be of direct relevance to Scottish farmers and growers. In some cases this integration is achieved through joint funding, for example, with the levy bodies. Conventional genetical approaches are also now being enhanced by the application of new genomics and functional genomics technologies, which use high-throughput analyses to provide detailed information on global gene expression and function. This aspect now includes the genomic sequencing of a key bacterial pathogen of potatoes, *Erwinia carotovora,* to obtain the complete DNA blueprint.

Theme 2 also includes botanical systematics research, undertaken by the Royal Botanic Garden, Edinburgh (RBGE), which aims to document and interpret global plant and fungal diversity. Much of this work is undertaken on specimens obtained from overseas, and focuses in particular on plant and fungal species found in the Far East (China and Bhutan), the Arabian Peninsula and parts of South America (Brazil and Peru). SEERAD sponsors the RBGE under The National Heritage (Scotland) Act 1985.

This theme is organised in four sections, which range from the study of the genetic material itself (2.1) through studies looking at the function of plants (2.2) and natural plant products (2.3) to the investigation of pests and pathogens and their interaction with plants (2.4).

The plant science research programme is relevant to several key end-use sectors. Research on the control of pests and diseases will ultimately deliver improved, sustainable methods of pest and disease control, and is highly relevant to both sustainable agriculture and environmental end-users. Much of this research underpins the needs of seed potato growers and the policy requirements arising from the operation of the Scottish Seed Potato Classification and Certification Schemes. For example, the plant pathology research focuses in particular on

pests and pathogens affecting potato production (*Phytophthora*, *Spongospora*, *Erwinia* and potato cyst nematode (PCN)). Research on germplasm collections, which helps to preserve and utilise biodiversity, is relevant to environmental interests. Research into genetics and breeding is relevant to sustainable agriculture and environment end-users. In addition, some of the newer molecular, genomic and biotechnological approaches are relevant to both bioindustry and to sustainable agriculture. The Plant Science domain also contributes to nutrition and human health interests and to the food end use, with research on antioxidants, free radicals and functional foods.

2.1 Systematics and Genetics

The SEERAD-funded Systematics and Genetics programme is one of underpinning research aimed at understanding genetic relationships and evolutionary processes in plants and fungi. The development and exploitation of the botanical germplasm collections is central to much of the research activity covered in this theme. On the botanical side, some of the systematics research at the Royal Botanic Garden Edinburgh forms part of Britain's obligation to develop and fulfil international policy requirements (e.g. the Convention on Biological Diversity: Rio, 1992). On the crop side, genetics research focuses on characterising and utilising crop-based germplasm collections for the mandate crops, potato, spring barley and soft fruit (*Ribes* and *Rubus*). In this case, a key research aim is to understand the heritability of key genes and traits of agronomic importance. A second aim is to identify molecular markers which are increasingly being used in crop breeding programmes.

2.1.1 Angiosperm Systematics

SEERAD-funded systematics research focuses on a number of temperate and tropical plant genera, including primitive legumes, rhododendrons and orchids. Classical methods for species differentiation and identification which rely on the identification of morphological characters are being expanded by newer methods of molecular taxonomy which examine differences in DNA sequence. These are enabling technologies that help researchers to understand how species have evolved from one another (the process of speciation) and how key biological processes such as floral development have evolved. The knowledge generated by this research will help explain species diversity and will inform conservation policies thus leading to the development of appropriate strategies for the sustainable management of genetic resources in Scotland and overseas. One fairly new area of activity which is partly covered here and partly in Theme 5, is the investigation of the evolution of species-rich tropical forest biodiversity. This research looks at the effects of population size on the maintenance of genetic variability, and should lead to sustainable agroforestry systems in South America, which utilise native vegetation. The research listed here under Theme 2.1.1 is closely related to other parts of the SEERAD-funded programme of research, most notably the floristics and the conservation work listed in Theme 5.

RBG/005/99 Systematics of the Podocarpaceae. - (03/03)

RBG/023/99 Speciation and reproductive biology in model terrestrial orchid genera. - (03/03)

RBG/028/99 Systematics and phylogenetics of old world Zingiberaceae. - (03/04)

RBG/030/99 Morphological and molecular systematics of the Umbelliferae. -
(03/04)

RBG/031/99 Morphological and molecular systematics of primitive papilionoid legumes. -
(03/03)

RBG/032/99 Systematics of the Rosaceae (Spiraea group) and of *Ribes* (Saxifragaceae). -
(03/04)

RBG/036/99 Monographic research in tropical Ericaceae and Musaceae. -
(05/03)

RBG/037/99 Molecular and morphological phylogenetics of the Orchidinae and Neottideae (Orchidaceae). -
(03/03)

RBG/046/02 Phylogeny, systematics and biogeography of Geraniaceae. -
(03/04)

RBG/050/02 Robert Wight and the botanical drawings of Rungia. -
(07/04)

RBG/053/02 Prometheus 2: capturing and relating character concept definitions in plant taxonomy. -
(10/03)

RBG/056/02 Investigations into the genetic diversity and speciation of *Streptocarpus*. -
(12/04)

2.1.2 Non-Angiosperm Systematics

Systematics research is also undertaken on lower and non-flowering plants such as algae, lichens and bryophytes. The research aims to use taxonomic and systematic approaches to understand the biodiversity of these organisms, many of which have become widely used as bioindicators of various environmental features such as atmospheric pollution, water quality and climate change. Diatoms form one important focus of this programme, and research aims to identify species and, perhaps more importantly, to development a fundamental understanding of the actual process of speciation in diatoms. Recent developments have included the application of image analysis for automatic diatom identification (ADIAC).

RBG/019/99 Species concepts and speciation in algae. -
(03/04)

RBG/021/99 "Total evidence" phylogeny of algae. -
(03/03)

RBG/039/99 Taxonomic and floristic studies of lichens and lichenicolous fungi. -
(03/04)

2.1.3 Evolution & Exploitation of Genetic Resources

A second major thrust of the SEERAD-funded genetics research, is the characterisation and utilisation of the germplasm collections for the mandate crops (potatoes, spring barley and soft fruit). The largest of these collections is the expanded Commonwealth Potato Collection (CPC) which includes Professor Hawkes' Birmingham Potato Collection (BPC). This combined collection, which is maintained as a potato spindle tuber viroid (PSTV)-free seed collection, contains just under 1500 accessions, representing 83 species, including many wild, diploid species of potato collected in South America, which should provide many useful traits for deployment by potato breeders. Research described here links very closely to research under plant pathology in Theme 2.3. Examples of useful traits currently being studied are novel sources of host resistance to the white form of potato cyst nematode (PCN) *Globodera pallida* and to bacterial and fungal pathogens that infect potatoes. Agricultural practices often involve the use of chemical inputs to control pests and diseases and these practices are not always sustainable. If new resistance genes can be identified and used in breeding programmes then there will be less need for chemical inputs and input costs for crop production will decrease. Other genes being targeted are those controlling product quality such as improved colour, flavour and texture. These features are now being demanded by retailers, processors and consumers. The soft fruit germplasm collections include 300 *Rubus* (raspberry) and 500 *Ribes* (blackcurrant) accessions, and these accessions are again stored as high health, pathogen-tested stocks. Recently modern molecular-based techniques have been introduced into the research programme to complement older approaches to genetic characterisation. Again understanding the genetic variation contained in this unique germplasm collection and determining how this genetic variation is linked to fruit quality is a key aim of the soft fruit research programme. Some of this work on potato and soft fruit genetics links to complementary research listed under Theme 2.2.2, where biochemical characterisations of the same material is being undertaken. This section also includes research on more applied aspects such as the use of cereal mixtures. In this approach a number of cereal varieties are mixed before sowing in contrast to sowing monocultures of just one cereal variety. This technique aims to broaden the genetic base within a crop therefore making it more resilient to attack from the environment and pests and pathogens. The biological mechanisms underlying this behaviour is not yet understood and are being studied in this research. Finally this section contains collaborative research between the Scottish Crop Research Institute (SCRI) and the Royal Botanic Garden Edinburgh (RBGE), to evaluate the potential of modern molecular marker technology as a research tool for conservation biology.

RBG/833/00 SCR/833/00	Microsatellites as population genetic markers. (FF) (01/04)	56 57
SAC/268/00	Exploitation of genetic diversity within cereal crop production. (03/04)	139
SCR/540/00	Genetics of cultivated potato. (03/05)	278
SCR/541/00	Genetic approaches to the evaluation and utilisation of soft fruit germplasm. (03/05)	213

SCR/563/01	Conservation and utilisation of the Commonwealth Potato Collection. (03/04)	276
SCR/566/01	Produce and maintain pathogen-tested stocks of *Rubus*, *Ribes* and *Fragaria* germplasm and index for infection material imported into SCRI. (03/04)	30
SCR/577/01	Molecular plant diversity and germplasm resources. (03/04)	104
SCR/585/02	Genetics of cultivated diploid potatoes. (03/05)	114

2.1.4 Plant Genomics

Genomics and functional genomics has become a significant component of the plant genetics programme. Research activity is most advanced in the diploid species barley, where a comprehensive molecular marker map of the barley genome has already been prepared and is currently being added to with Expressed Sequence Tag (EST) information. SEERAD is participating in the BBSRC Investigating Gene Function (IGF) Initiative by co-funding work to develop a UK cereal transcriptome resource which involves a collaboration between the Scottish Crop Research Institute (SCRI), the John Innes Centre (JIC) and IACR-Long Ashton. Within this consortium, SCRI's role is to develop a barley transcriptome resources and a barley mutant library. Also included in this Theme are new studies where genomics approaches are being applied to understand the genetic control of barley root growth and how root structure influences the local soil environment. Genomics research on the tetraploid potato species is technically more difficult to undertake and the current programme focuses on one specific linkage group (linkage group V) which is known to contain many desirable quantitative trait loci (QTL). A pathogenomics programme has been commissioned and focuses on two pathogens infecting potato the fungus *Phytophthora infestans* and a bacterium, *Erwinia carotovora* and is covered under theme 2.4.1.

SCR/516/97	Genetic mapping and molecular cloning of novel sources of resistance to *Globodera pallida*. (FF) (10/03)	125
SCR/526/99	Integrative mapping of the long arm of barley chromosome 5H. (03/03)	163
SCR/528/99	Use of an accelerated marker assisted selection scheme to introgress novel variation for economically important traits into cultivated barley. (03/03)	146
SCR/552/00	Barley 'deletion' mutation grid. (03/03)	93
SCR/555/00	Cereal transcriptome resources. (FF) (07/04)	90
SCR/560/01	Molecular bases of resistance and susceptibility in potato and barley. (03/04)	276

SCR/562/01	Genetics of seedling root traits in barley. (03/04)	107
SCR/564/01	A gene map of the interval between GP21 and GP179 on potato linkage group V. (03/04)	109
SCR/565/01	Identification and characterisation of bacterial artificial chromosome (BAC) clones from rich regions for the barley genome. (03/04)	98
SCR/578/01	Parallel gene expression technologies supporting the discovery of plant and pathogen genes important to agriculture and biotechnology. (03/04)	94
SCR/573/01	Functional analyses of novel genes from potato and barley. (03/04)	100
SCR/581/02	Cell and tissue engineering in barley and potato. (03/05)	257

2.1.5 Bioinformatics

The genomics research programme is underpinned by a programme of bioinformatics, which stores, annotates and analyses the data coming from the genomics research. This data can be in the form of molecular marker locations, chromosomal locations of QTL (for example resistance genes), or gene (or EST) DNA sequences. A new introduction is the development of computational biology expertise where bioinformatics and other computer-based techniques are being used for knowledge-based "dry science", or *in silico* approaches to biological research. Bioinformatics skills are also being used to capture information from systematics research in the Prometheus project.

RBG/045/01	Prometheus II: capturing and relating character concept definitions in plant taxonomy. (01/04)	-
RBG/052/02	Visual indexing for taxonomic information systems. (04/04)	-
SCR/527/99	Development of a graphical database for the visualisation of genotypic and phenotypic data in barley. (03/03)	196
SCR/572/01	Computational biology. (03/04)	100
SCR/589/02	Novel methodologies and tools for the analysis of germplasm collections. (FF) (09/05)	48

2.2 Plant Physiology

Research in this category falls into two main areas, either research at the sub-cellular and molecular levels (Theme 2.2.1), or research undertaken at the level of the whole plant (Theme 2.2.2).

2.2.1 Plant Molecular Physiology

Improving our understanding of the basic biology of key developmental stages in the mandate crop plants should help identify factors that limit sustainable production. One biological process being studied is the investigation of malting quality in barley. Fruit ripening and the understanding of biochemical controls of vitamin C (ascorbic acid) synthesis are also a strength in this part of the programme and there is related work under Theme 2.2.2 on the biodiversity of antioxidant status in soft fruit germplasm. The Department has commissioned research into a key area of gene expression namely, the processes of "transcription" which is the production of the message, mRNA, from the gene and the subsequent processing of this message, "mRNA splicing". Cell biology research includes work on transport of large molecules between plant cells and may be relevant to biotech end users. Information generated by this research will improve general scientific understanding, since it describes processes that are common to all plants, and could also have potential biotechnological application.

RBG/049/02	Evolutionary developmental genetics of plant biodiversity. (10/03)	-
SCR/537/00	Biochemical approaches to define novel targets for genetic improvement of malting barley. (03/03)	241
SCR/551/00	Post-transcriptional control of gene expression. (03/03)	287
SCR/557/01	Targeted long-distance transport of macromolecules in plants. (03/04)	187
SCR/576/01	Sequence diversity and horizontal genomics (targeted gene discovery). (03/04)	0
SCR/579/01	Development of robust, broad based QTL maps to improve barley breeding. (FF) (11/04)	55
SCR/584/02	Approaches to regulate the L-ascorbic acid content of commercially important plants. (03/05)	180
SCR/586/02	Cell-to-cell trafficking of macromolecules in plants. (03/04)	227

2.2.2 Whole Plant Physiology

A strength of the SEERAD-funded plant physiology programme lies in the depth of knowledge and expertise available to investigate root growth (turnover and mortality). This work has been expanded by the application of new techniques, such as using stable isotopes (^{15}N). Two new projects examine links between root structure, architecture and senescence. Ultimately this research will inform policies for better use of land, for example, by forestry or for coppicing, as well as grassland for grazing. Some of the biochemical work on potato tuber quality and soft fruit antioxidant status are linked with complementary projects listed under 2.1.3, where the genetic characterisation of the same material is being undertaken. Research on a key antioxidant, vitamin C, is listed under Theme 2.2.1. Other aspects of plant-derived food quality are also being studied with the aim of enhancing the nutritional quality of potato and barley. Recently these biochemical approaches have been expanded to include metabolomics research, where high-throughput biochemical screening is being used to understand key developmental processes in plants. At the whole plant level, research is looking at nitrogen acquisition by roots and nitrogen remobilisation within trees, for example, prior to spring bud break. Also included in this section is research on barley crop physiology, which is funded jointly with the Home-Grown Cereals Authority (HGCA) where the growth of the crop is being linked with agronomic practice.

ADA/002/01	Winter barley reference cropping to provide an improved understanding of growth and yield formation and produce a growth guide for growers. (FF) (03/05)	109
MLU/700/00	Nutrient uptake and re-mobilisation in relation to survival, growth and development of young trees in regenerating semi-natural woodlands. (03/03)	152
MRS/003/02	Development of the physiological and agronomic tools for increasing the L-ascorbic acid yield from blackcurrant bushes. (FF-LINK) (06/07)	56
SAC/255/00	Investigating the relationship between root architecture and root life-span. (03/03)	83
SAC/296/01	Characterising root senescence in wheat and clover and investigating its relationship to C supply deposition. (03/04)	86
SCR/536/00	Development and application of chemical strategies to facilitate genetic and molecular marker studies of factors affecting quality traits in potatoes. (03/03)	267
SCR/547/00	Biodiversity in the antioxidant status and composition of *Rubus* and other soft fruit germplasm. (03/03)	162
SCR/570/00	Mechanical properties of primary plant cell walls by micro-stretching *in vivo*. (FF) (01/04)	11

SCR/574/01	Development and application of metabolic profiling technologies to enhance the understanding and developmental processes in plants. (03/04)	116
SCR/575/01	Enhancing food quality and nutritional value through multidisciplinary approaches which exploit genetic molecular diversity. (03/04)	85

2.3 Novel Plant Products

The main thrust of the novel plant products programme lies in the "OVERCOAT" plant virus expression system, which should allow cheap, rapid and safe production of high-value pharmaceutical proteins (vaccines and enzymes) in plants. This research builds on the platform of basic virus research previously funded by the Department. The main project was funded through the CHABOS initiative (Committee of Heads of Agricultural and Biological Organisations of Scotland) and will explore delivery routes for plant virus expressed peptides and proteins. Other SEERAD-funded research focuses on high value essential oils, including those from rosemary and bog myrtle with roles as valuable antioxidants. A collaborative project has been funded involving the Scottish Crop Research Institute (SCRI), the Royal Botanic Garden Edinburgh (RBGE) and the Strathclyde Drug Research Institute (SDRI) which aims to screen bryophyte and *Solanum* collections for the presence of novel bioactive compounds.

HRI/824/97 MRI/824/97 SCR/824/97	Efficacy studies on a plant virus-based expression system and on alternative delivery routes for peptides and proteins with pharmaceutical, therapeutic and related uses for improving animal health, nutrition and welfare. (FF) (03/03)	97 46 103
SCR/834/01 SDR/834/01 RBG/834/01	Assessment of plant germplasm for bioactive molecules. (FF) (10/04)	58 59 56
ACT/001/99	Support for ACTIN - associate membership. (FF) (10/02)	3
NHC/001/99	Potential for extracting antioxidants from rosemary for the food and pharmaceutical industry. (FF-LINK) (12/02)	41
QBB/010/02	Development of *Myrica gale* as a source of natural products in toiletries and household care products (sweetgale). (FF-LINK) (03/05)	37
SAC/311/01	Developing bioactive crop components with antioxidant and antimicrobial properties. (03/04)	93

2.4 Plant Pathology

Crop losses due to pests and diseases represent one of the greatest problems faced in arable and horticultural production. SEERAD-funded pathology research aims to improve the sustainability of Scottish agriculture. The research is focused on strategies that will ultimately deliver improved, sustainable and benign methods of pest and disease control. If crop pests and diseases are not controlled then there is a loss of quality and/or yield of the harvestable product.

2.4.1 Fungi & Bacteria

SEERAD-funded research on fungi and bacteria is targeted on understanding the interactions that occur between the pathogen and host before and during an infection. The genetic mechanisms controlling a pathogen's host range and virulence (for example, the range of cultivars it can infect and the severity of the diseases they cause), and the physiological mechanisms underlying pathogenicity are often poorly understood, yet are central to studies on host resistance and to the breeding of new plant cultivars with increased and durable forms of resistance. SEERAD-funded research on fungal pathogens focuses on the species of *Phytophthora*, which cause a diverse range of plant diseases, including late blight on potatoes, raspberry root rot and red core of strawberries, and on *Spongospora subterranea*, which causes powdery scab on potatoes. Some of this research is funded jointly with the British Potato Council, thus ensuring that the outputs will be of use to the potato growers. A further project, which studies a range of fungal diseases on potato tubers and which aims to improve seed health during storage, has been commissioned through the SAPPIO-LINK programme. The main bacterial pathogen studied is *Erwinia carotovora*, which causes blackleg and stem rot of potatoes. Latent blackleg infection of seed tubers is a common disease in the UK, and infection can damage the reputation of Scottish seed stocks destined for export. Research on *Phytophthora* and *Erwinia* form the key foci for the Department's plant pathogenomics research. A SEERAD Senior Research Fellowship (FEL) has been funded to look at *Phytophthora* genomics. In addition, the Department has commissioned research jointly with BBSRC which compares pathogenicity in *Phytophthora infestans* with that in another oomycete, *Peronospora parasitica*, which causes downy mildew. This research involves a collaboration between scientists at SCRI and the Horticulture Research International. The research links into other European and overseas groups. A collaborative research programme has been funded between the Scottish Crop Research Institute (SCRI) and the Moredun Research Institute (MRI) to develop a platform in bacterial genomics. Within this programme the genomes of two bacterial pathogens *Erwinia carotovora* and *Chlamydophila abortus* will be sequenced. This section also includes work on mycorrhizal fungi, which form beneficial, symbiotic associations with plants.

FEL/001/01	Functional genomics of pathogenicity, host-specificity and avirulence in plant-*Phytotophora infestans* interactions. (FF) (12/06)	76
MRS/002/99	Epidemiology, autecology and control of *Spongospora subterranea*, cause of potato powdery scab. (FF) (11/02)	36
QBP/001/01	Application of recent developments in *Erwinia* diagnostics for a better understanding of the biology of seed stock contamination and blackleg control. (FF) (10/04)	-

RBG/035/99	Taxonomic revision of European Rust fungi (Uredinales). (03/04)	-
SAC/259/00	Influence of tuber maturity and wounding on infection of potato tubers by *Fusarium coeruleum*. (09/02)	27
SAC/266/00	A comparison of plant molecular responses to arbuscular mycorrhizal fungi and pathogenic organisms. (03/03)	79
SAC/267/00	Identification and study of functional genes expressed during pre-symbiotic and symbiotic growth of arbuscular mycorrhizal fungi. (03/04)	108
SAC/272/00	Towards an understanding of pathogenesis in brassica/pathogen interactions. (03/03)	127
SAC/286/01	Epidemiology studies of *Ramularia collo cygni*, to improve our understanding and assess the importance of a new disease of barley. (03/03)	39
SAC/320/01	Control of potato storage diseases by laser treatment. (FF-LINK) (09/04)	50
SAC/336/02	Biotic and abiotic control of potato pathogens and disorders: soil-borne *Rhizoctonia solani*. (03/05)	115
SCR/546/00	The development and use of molecular markers to study the epidemiology of late blight (*Phytophthora infestans*) of potato in Scotland. (03/03)	217
SCR/549/00	Characterisation of molecular interactions between soft rot erwinias and potato. (03/03)	240
SCR/556/00	Comparisons of the molecular bases of pathogenicity in the model oomycetes *Pe. parasitica* and *P. infestans* through a genomics approach. (FF) (01/04)	60
SCR/569/00	*Phytophthora* diseases of soft fruit: determining their prevalence and the source of new outbreaks in Scotland. (FF) (07/03)	26

SCR/582/01	Cloning of the avirulence genes from the oomycetes plant *Peronospora parasitica* and *Phytophthora infestans*. (FF) (02/05)	67
SCR/835/01	Genomic sequencing and proteomic analyses of the potato pathogen *Erwinia carotovora* subsp. *atroseptica* (Eca) and the animal pathogen *Chlamydophila abortus* (Ca). (FF) (10/03)	78

2.4.2 Viruses

SEERAD-funded research into plant viruses contributes significantly to the UK science base in this area, and is also of international significance. Plant viruses are obligate parasites and few can survive outside living tissue. The associations between viruses and their hosts are complex. While some viruses are passively spread, most depend on vectors for their transmission between plants, particularly insects, mites, nematodes and fungi. Research therefore needs to take account of the structure and physiology of viruses, their vectors and their host plants, and the interactions between all three. SEERAD-funded research concentrates on viruses which infect potatoes and soft fruit. Detailed examination can sometimes provide insights into features of the nucleotide sequences, which are responsible for the observed biological properties of a virus, for example, its replication (amplification), and movement within a plant. Both local (cell-to-cell) and long-distance (leaf-to-leaf) movement of major potato viruses are being studied.

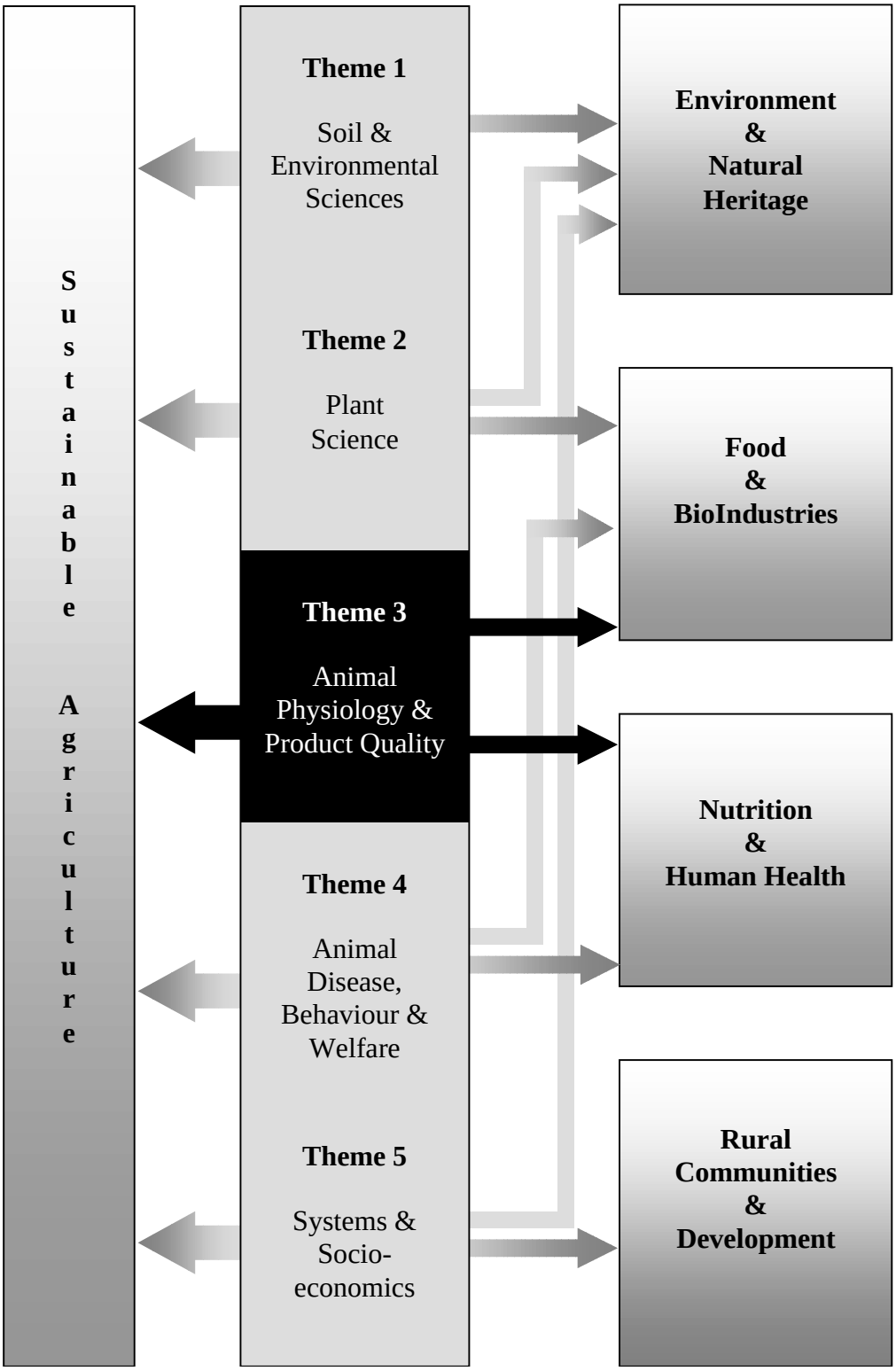
SCR/522/98	Development of *Rubus* genotypes with transgenic resistance to raspberry bushy dwarf virus. (FF) (09/03)	89
SCR/545/00	Detection, diversity and epidemiology of important viruses and their vectors in berry fruit crops, and strategies for their effective control. (03/04)	161
SCR/554/00	Protein-protein interactions and the role of virus proteins in disease processes. (03/03)	175
SCR/558/01	Resistance to potato viruses: exploitation of host gene resistance and transgenic resistance to study resistance mechanisms and to develop resistant germplasm. (03/04)	224
SCR/559/01	Molecular biology of potato leafroll virus: aphid transmission and the establishment of infection in host plants. (03/04)	240
SCR/580/02	Suppression of gene silencing by virus proteins. (03/05)	246

2.4.3 Nematodes

The potato cyst nematodes (PCN) *Globodera rostochiensis* and *Globodera pallida* are major pests of potatoes in Britain. *G. rostochiensis* used to be the dominant species, and, in the past, long rotations limited the build up of cyst populations in ware land. However, the introduction of potato cultivars carrying the H1 gene for resistance to *G. rostochiensis,* combined with the heavy use of nematicides, enabled rotations to be shortened. This practice led to a widespread increase in *G. pallida* populations, against which the potato H1 resistance gene is ineffective. A fuller understanding of the diversity, biology and genetics of cyst forming nematodes, including an understanding of the molecular basis of virulence are needed if breeders are to develop resistant cultivars. Two projects describe novel approaches to develop transgenic resistance in potato to PCN. In addition, ecological research has been commissioned on a new threat to horticulture and agriculture, the New Zealand flatworm.

IAC/004/00	Integrated management strategies for potato cyst nematodes. (FF-LINK) (12/04)	42
SCR/561/01	Molecular bases of pathogenicity in potato cyst nematodes, *Xiphinema index* and *Phytophthora infestans*. (03/04)	150
SCR/583/02	Variation in pathogenicity in *Globodera* spp. in relation to host resistance. (03/05)	219
ULS/002/97	The feeding tube of *Globodera pallida*. (FF) (09/02)	-

THEME 3: ANIMAL PHYSIOLOGY AND PRODUCT QUALITY



SUMMARY OF COSTS:

	Estimated Recurrent Cost (£ k) 02/03
3.1 Nutrition	**3440**
3.1.1 Cell/Nutrient Interactions	1922
3.1.2 Appetite Control	1229
3.1.3 Feed Intake – Theory and Modelling Studies	289
3.2 Tissue Growth and Development	**3890**
3.2.1 Digestive Tract Biology	1570
3.2.2 Mammary Gland	709
3.2.3 Structural Tissue	570
3.2.4 Regulation of Control and Development	1041
3.3 Reproduction	**2105**
3.3.1 Fertility	659
3.3.2 Foetal Growth and Development	1446
3.4 Animal Product Quality	**1738**
3.4.1 Functional Quality of Milk, Meat and Fibre	1738
TOTAL	**11173**

THEME 3: ANIMAL PHYSIOLOGY AND PRODUCT QUALITY

Livestock products, particularly meat and milk, remain an important output from Scottish agriculture. Consumer demand for high quality products that do not compromise the welfare of animals is increasing. Research described within this Theme covers both the fundamental studies needed to understand the growth, development and functioning of productive tissues, as well as quality attributes of the raw materials and foods derived from them. Since much of the Scotland's agricultural land cannot support commercial crops other than grass, animals are integral to economic production systems. Investigating ways of adding value to animal products is essential to improving the viability of the agricultural sector in Scotland.

Work within this Theme is very relevant to aspects of human biology, in particular the interaction between nutrition, diet and health. Studies on essential micronutrients, especially trace elements, essential fatty acids, vitamins, and phytochemicals and the mechanisms through which they protect against coronary heart disease and cancer are included within the programme. The studies on foetal development are relevant both to humans and to agricultural animals. Work on the mechanisms underlying the development of obesity and major diseases for which this is a risk factor is of particular relevance for Scottish health.

The research in this Theme spans a wide range of approaches from work at the molecular level through studies on cells, tissues and organs to the whole animal. Three major areas are emphasised: nutrition, tissue growth and development and reproduction. Work also includes research on animal product quality, mainly on milk and meat. The scope of these studies ranges from the understanding of the processes taking place within the animal, such as tissue growth or milk secretion, through the effects of different constituents on processing quality, to the design of new products with enhanced quality attributes. Most of this research has grown from programmes originally set up to increase efficient production of animal-derived foods and materials; however the objectives and applications of the high quality, innovative science carried out using animal systems are now much more diverse.

Research within this Theme relates to all end user categories as defined within the ABRG document *Strategy for Agricultural, Biological and Related Research 1999-2003*. Links with sustainable agriculture, nutrition and human health, and food and bioindustries are particularly important foci for the research on animal systems. The relevance of the work to environment and natural heritage and to rural communities and development centres on the importance of animals and animal products to the economic and social systems which support the rural communities in Scotland.

This Theme forms a significant part of the SEERAD-funded research programme, and as such relates to a number of other areas of the programme. There are obvious links with work on grazing ecology and farming systems in Theme 5, and with the studies of animal disease and gut pathogens in Theme 4.

Much of the large animal science carried out in the UK today is funded within the SEERAD programme; other sponsors traditionally fund work largely in other areas of animal science that are underrepresented in the SEERAD programme (e.g. genetics, which is mainly funded by BBSRC and DEFRA). Where there are subjects within the programme that are also included in the programmes of other funders (e.g. nutrition, diet and health), special care is taken to avoid unnecessary overlap or duplication, and to encourage co-ordination of the research undertaken.

3.1 Nutrition

3.1.1 Cell/Nutrient Interactions

There is increasing interest in the interaction between nutrition, diet and health in the human population. The report *Scotland's Health, A Challenge for Us All* (1992) highlighted a number of concerns about the Scottish diet and its link to health problems. Understanding all aspects of the links between diet and health can only make improvements to the situation. While there are many aspects to this, the SEERAD-funded research programme has an emphasis on the mechanisms by which dietary derived micronutrients affect susceptibility to heart disease and cancer. Work in this Theme encompasses studies on trace elements, antioxidant vitamins and polyunsaturated fatty acids. All can be shown to have beneficial effects when included in the diet but their mechanisms of action and interactions are not yet well understood. Studies here are aimed at improving that understanding with regard to cellular processes such as gene expression, DNA damage and immune function. Studies on the uptake and metabolism of these micronutrients are also important to understanding mechanisms of action. Once the activity of such nutrients at the cellular level is properly understood provision of dietary advice to humans for maximum health benefit will be possible, both at the population and individual level.

RRI/832/98 UGW/832/98 SCR/832/98	Identification and assessment of nutritional relevance of antioxidant compounds from soft fruit species. (FF) (03/03)	42 31 2
RRI/583/97	Phenylpropanoid-derived compounds of dietary origin and human health: links between chemical properties and biological effects. (06/03)	187
RRI/673/99	The functional role of selenium in mammals: redox control of gene expression and thyroid hormone and iodine metabolism. (03/03)	126
RRI/692/00	Cellular mechanisms by which dietary essential fatty acids and conjugated linoleic acids modulate blood-vascular and immune functions. (03/03)	128
RRI/696/00	Effects of polyphenolic phytochemicals on cellular redox status and functionality. (03/03)	295
RRI/714/01	The role of dietary phytochemicals in influencing molecular events associated with cancer. (03/04)	109
RRI/717/01	Protection by zinc and metallothionein against pathogenic mechanisms in atherogenesis. (03/04)	138
RRI/718/01	The influence of dietary components on DNA damage and stability. (03/04)	112

RRI/721/01	Nutrient demands of the immune responses to inflammatory challenges. (03/04)	227
RRI/738/01	Dietary constituents and the modulation of inflammatory processes associated with coronary heart disease. (09/04)	160
RRI/745/02	Metabolism and mechanisms of action of dietary fatty acids associated with coronary heart disease. (03/05)	99
RRI/749/02	Identification of genes involved in the processes associated with coronary heart disease: effects of diet. (03/05)	133
RRI/752/02	Maintaining the balance of oxidative DNA damage: DNA repair and its regulation. (03/05)	133

3.1.2 Appetite Control

Studies on the control of food intake within the central nervous system have progressed rapidly since the demonstration of the synthesis of leptin by adipose tissue and its effects on the hypothalamus region of the brain. The studies in this theme involve work on the regulation of appetite, energy balance and body weight. Some of the work uses animal models to investigate the central control of body weight and search for new genes involved in controlling appetite and energy balance. Studies in human volunteers are also being used to investigate the genetic basis for obesity and effective interventions. This work is important in the study of obesity and body weight maintenance. Obesity is an increasing problem in western societies and has considerable health consequences for man. In agricultural species, excessive fatness has not only negative effects on the animal's health and reproductive capacity, but can considerably lower the value of the end product.

RRI/634/98	The molecular basis of body weight control. (03/03)	256
RRI/705/00	A rodent model for diet induced obesity - the role of the sympathetics. (03/03)	103
RRI/711/01	Regulation of leptin expression by circulating - MSH. (03/04)	120
RRI/713/01	Leptin receptors in obesity. (03/04)	116
RRI/722/01	Characterisation of the factors involved in the development of obesity. (03/04)	67
RRI/723/01	Evaluating alternative candidate models of body mass regulation. (03/06)	100

RRI/733/01	Hypothalamic regulation of mammalian body weight: seasonally-appropriate body weight in the Siberian hamster. (03/04)	167
RRI/737/01	Identification of genetic traits linked to obesity using an analysis of candidate gene polymorphisms. (09/04)	139
RRI/746/02	The effect of protein supplementation, subsequent to weight loss, on lean body mass, appetite and the maintenance of weight loss. (03/05)	161

3.1.3 Feed Intake – Theory and Modelling Studies

The process by which any animal chooses and consumes food results from the synthesis of a number of sensory and physiological inputs. Understanding how these processes interact is a major challenge to nutritionists. Because of the complexity of the systems involved, a modelling approach can often provide insights into aspects of the process within different animals faced with diverse situations. The projects listed here involves theoretical and modelling studies using grazing ruminant animals. However the fundamental principles investigated are relevant to all animals, including man.

MLU/839/01	Developing an evolutionary fitness function for energy intake. (FF)	36
RRI/839/01	(12/04)	97
SAC/839/01		54
UEH/839/01		6
SAC/248/00	Testing quantitative frameworks to predict food intake across environmental conditions, genotypes and animal states. (03/03)	96

3.2 Tissue Growth and Development

3.2.1 Digestive Tract Biology

The digestive tract is the major site of digestion and absorption of food constituents and also plays an important role in the immune competence of animals. This Theme includes work on the interactions between diet, gut micro-organisms and the host immune system in health and in diseases of the large intestine in man. Ruminants have a particularly interesting digestive tract and work on the micro-organisms found in the rumen, which allows the efficient digestion of grazed herbage, is included here. The objective of these ruminant studies and those on growth of the gut is to improve the efficiency of the ruminant animal in converting grazed and fed material to meat and milk. Like the skin, the gut also forms an effective barrier to invasion of the body by pathogenic micro-organisms. This aspect of digestive tract biology is dealt with in the subsequent Theme, since the focus of that work is primarily on pathogens.

RRI/640/98	Influence of ciliate protozoa on microbial protein metabolism in the rumen. (03/03)	140

RRI/694/00	Micro-organisms and biochemical pathways involved in ammonia formation in the rumen: identification and manipulation. (03/03)	51
RRI/720/01	Analysis of microbial genes involved in gut survival and host interaction in gut commensal bacteria. (03/04)	131
RRI/724/01	Micro-organisms, enzymes and genes responsible for the production of conjugated linoleic acid in the rumen. (03/04)	157
RRI/726/01	Intestinal immune responses to bacterial antigens. (03/04)	167
RRI/739/01	Genomes of commensal and symbiotic gut bacteria. (09/04)	111
RRI/743/01	Transfer of newly-identified antibiotic resistance genes between bacteria in different gut and non-gut environments. (FF) (12/04)	61
RRI/744/01	Molecular analysis of lumenal and mucosal biofilm communities in the human large intestine. (FF) (09/05)	74
RRI/747/02	Understanding the effects of diet upon microbial activities relevant to health in the human large intestine. (03/05)	226
RRI/750/02	Microbial diversity and colon specific genes in inflammatory bowel disease. (03/05)	190
RRI/751/02	Bacterial and nutrient effects on toll-like receptors. (03/05)	179
RRI/756/02	The effect of gut environmental conditions on the survival of human pathogenic bacteria in the GI tract of farm animals. (12/02)	83

3.2.2 Mammary Gland

The primary function of the mammary gland is to provide nourishment for the young. This is essential to the successful production of viable offspring in mammalian species. Milk from the dairy animal is also an important output of Scottish agriculture, both in its natural form and increasingly as processed products such as ice cream or cheese. Much of the work in this theme is aimed at understanding the physiology and cell biology of mammary tissue. The mammary gland is also a good model system for the study of important aspects of cell biology, including apoptosis and cell morphogenesis, which are also relevant to aspects of human breast cancer.

HRI/127/00	Fundamental biology underpinning extended lactation. (03/03)	215
HRI/185/00	Control and manipulation of mammary gland involution. (03/04)	273
HRI/004/01	Regulation of tone in ruminant and rat mammary arteries. (03/04)	124
HRI/102/01	Function and expression of rat mammary gland amino acid transporters under different physiological conditions. (03/04)	97

3.2.3 Structural Tissue

Work within this Theme is aimed at understanding the basic biology of muscle tissue, with particular reference to growth and development phases. The work on muscle is closely aligned with studies on the quality attributes of meat and how these relate to muscle development. This work is described more fully in Theme 3.4.2. Work listed here also involves investigation of the abnormal metabolism of structural proteins characteristic of a number of debilitating conditions, including heart disease, and other diseases of ageing associated with fibrosis. This research aims to understand the processes that lead to the altered metabolism, and to identify targets for therapeutic intervention to alleviate the debilitating conditions.

RRI/672/99	Molecular and functional regulation of muscle growth. (03/03)	314
RRI/716/01	Identification of the mechanisms of collagen cross-linking in mammalian tissues and their manipulation as a means of controlling fibrosis. (03/04)	256

3.2.4 Regulation of Growth and Development

The integration of physiological processes in animals occurs by a variety of mechanisms operating primarily through endocrine systems. Effects may be elicited at organ, tissue and cellular levels, and involve a high level of co-ordination between the systems to ensure stability. Studies in this Theme include work on fundamental regulatory mechanisms operating at the physiological level relating to growth and development in animals. This work is relevant both to farmed animal species and to human growth and development in healthy and diseased states.

HRI/101/99	Regulation of hepatic lipid metabolism. (03/03)	232
HRI/126/00	Intercellular signalling in tissue morphogenesis and function. (03/04)	217
HRI/157/00	Control and manipulation of lipogenic gene expression. (03/03)	447

RRI/727/01	Effects of nutrition on spatial distribution of gene expression during early development. (03/06)	125
RRI/757/02	The role of orexigenic and anorexigenic pathways in nutritional regulation of the reproductive neuroendocrine axis. (FF) (09/05)	20

3.3 Reproduction

3.3.1 Fertility

Ovulation, the release of the ovum from the ovary, is the primary event in the reproductive cycle that leads to a viable offspring. The physiological controls on this process are not well understood and there are increasing fertility problems due to faulty ovulation cycles in a number of agriculturally important species. Interactions with the nutritional status of the animal are increasingly being recognised as important to fertility, and in particular to embryo quality. Work in this theme is aimed at understanding the mechanisms for control of ovulation and the quality of ova released.

RRI/704/00	Peripheral nutritional feedback and hypothalamic mechanisms regulating appetite and the reproductive neuroendocrine axis in sheep. (03/03)	129
SAC/246/00	Lipid and antioxidant effects on developmental competence of avian and mammalian embryos. (03/04)	238
SAC/299/01	Genetic covariation of fertility and energy balance traits in dairy cows. (03/06)	128
SAC/300/01	Peri-ovulatory effects on the developmental competence of ruminant ova. (03/04)	97
UNM/002/01	Nutritional improvement of fertility in dairy cows. (FF) (12/05)	67

3.3.2 Foetal Growth and Development

The development of a viable and healthy foetus in mammalian species requires the involvement of both the mother and developing offspring. Studies included in this Theme are concerned with effects and functions within the uterus, including placental control of foetal development. The nutrition of the mother has an important influence on embryo growth and these effects are thought to be central to the programming of foetal development. This programming is believed to have effects not only on growth within the mother, but may have long term effects on post-natal development stretching into adulthood. This effect, the so-called ‘Barker’ hypothesis, is the subject of considerable research in humans but is also important in agricultural livestock. In humans prenatal and early life influences are believed to have a major impact on adult susceptibility to cardiovascular disease, diabetes, hypertension and obesity. Work in this Theme aims to understand the mechanisms by which these early influences have their effect.

RRI/838/01 SAC/838/01	Biochemical and molecular determinants of differential porcine foetal growth. (FF) (12/04)	64 40
HRI/103/02	Cellular and molecular mechanisms involved in the induction of insulin resistance by neonatal and adult dietary patterns. (03/04)	135
RRI/695/00	Early events leading to the in-utero programming of adult metabolism. (03/05)	175
RRI/715/01	Maternal nutrition and placental growth and development: the underlying mechanisms and impact of reduced placental nutrient supply on foetal growth and postnatal wellbeing in ovine paradigms. (03/05)	416
RRI/725/01	Peri-conceptual programming of vascular development and adult disease. (03/05)	143
RRI/748/02	The effect of micronutrient deficiency on foetal and post-natal growth and development in humans and animals. (03/05)	233
SAC/244/00	Nitrogen metabolism on embryo and foetal development in ruminants. (03/03)	120
SAC/245/00	Cytokines as novel intercellular signals during development. (03/03)	120

3.4 Animal Product Quality

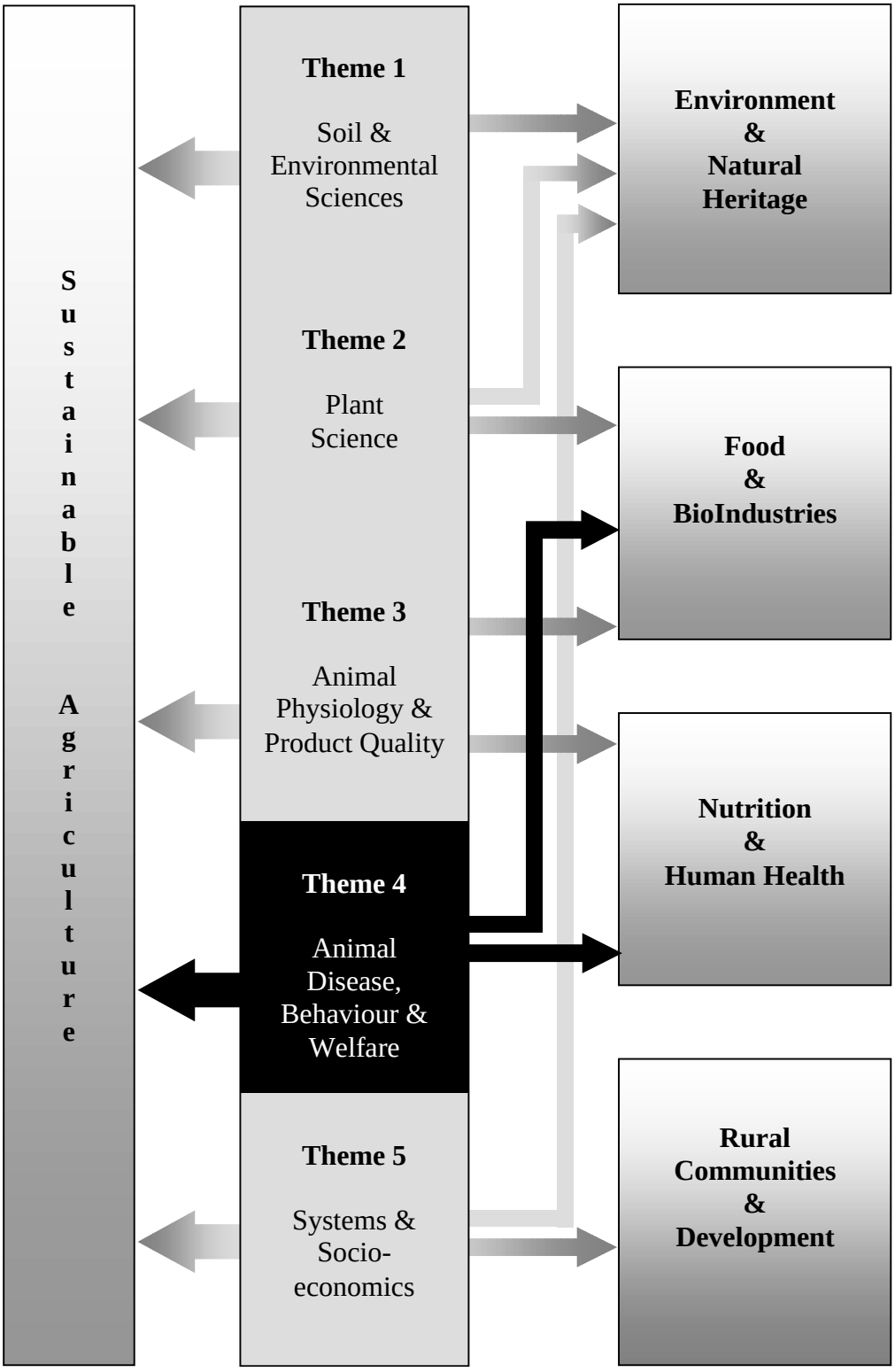
3.4.1 Functional Quality of Milk, Meat and Fibre

The major products from livestock agriculture in Scotland are meat, milk and fibre. The prevailing social and economic pressures are for quality products rather than volume. Work within this Theme is aimed at understanding quality with respect to both processing and sensory aspects. Research on meat links to studies in Theme 3.2.3 on muscle biology and currently has an emphasis on eating quality of red meat, processing quality in poultry meat and salmon product quality. These are areas of growing interest and importance within Scotland's food sector. In order to focus and develop expertise in these areas, in April 2002 SAC and HRI combined their facilities and expertise on food science and technology within a new centre – CHARIS Initiative. One part of this Initiative is a division of HRI, CHARIS Food Research, and the other is a commercial company jointly owned by the Scottish Agricultural College (SAC) and the Hannah Research Institute (HRI) – CHARIS Innovative Food Services Ltd. CHARIS's research is focused on producing innovative products and processes for the Scottish food industry, much of which builds on HRI's research on the chemistry of food constituents and sensory expertise. Work on fibres is aimed at improvements in the quality and yield of fine fibres from sheep and goats (cashmere), a potential area for diversification within the rural sector as sheep and goats are well suited to Scottish climatic and environmental conditions.

HRI/258/00	Reduction of risk associated with contamination of raw milk by *Mycobacterium avium* ssp. *paratuberculosis*. (FF-LINK) (10/02)	9
HRI/259/01	Developing science and technology platforms for the food & drink industries: Understanding the behaviour of protein-stabilised emulsions. (03/03)	191
HRI/260/01	Establishment of a basis for a participative Scottish Food Research Programme. (03/03)	37
HRI/261/01	Developing science and technology platforms for the food and drink industries: Control of network formation and subsequent transformation of particle gels. (03/03)	217
HRI/262/01	Developing science and technology platforms for the food and drink industries : Microbial metabolism and food biofermentation. (03/04)	186
HRI/265/01	Developing science and technology platforms for the food & drink industries: Exploration of the functionality of novel proteins derived from fish by-products. (03/04)	38
HRI/187/02	Structure and function of some rheomorphic phosphoproteins. (03/06)	250
HRI/266/02	Developing science and technology platforms for the food and drink industries: Biotechnology and the biogenesis of flavour in fermented food and cheese. (03/04)	232
MLU/715/00	Production of high quality fibre from sheep and goats. (03/04)	241
QBB/009/01	Eating, food and health effects of CLA- Implications for dairy production. (FF-LINK) (06/04)	-
ROS/003/02	Identification of dairy-associated QTL using the Roslin bovine resource herd (ROBOGEN). (FF) (03/06)	-
SAC/251/00	Poultry meat quality - a whole system approach. (03/03)	239

USA/001/02	Muscle microstructure and growth rate and its relation to product quality and processing characteristics in salmon. (FF-LINK) (06/05)	98

THEME 4: ANIMAL DISEASE, BEHAVIOUR AND WELFARE



SUMMARY OF COSTS:

	Estimated Recurrent Cost (£ k) 02/03
4.1 Epidemiology of Animal Diseases	**77**
4.2 Pathology and Pathogens	**2365**
4.3 Immunology and Host-pathogen Interactions	**1259**
4.4 Control of Animal Disease	**1573**
4.5 The Physiological Basis of Behaviour	**439**
4.6 Welfare in Farming Systems	**253**
TOTAL	**5966**

THEME 4: ANIMAL DISEASE, BEHAVIOUR AND WELFARE

Research on animal health and welfare forms part of a cohesive programme of research on animal science (see also Themes 3 and 5). Theme 4 contains research on major endemic diseases of livestock, strategic research on large animal behaviour, and applied research on specific welfare problems of farmed animals. Livestock diseases constitute a huge source of economic loss to the farming and related industries every year. In addition, the swing away from intensive agricultural practices, and the implementation of policies in such areas as veterinary medicines and growth promoters, public health and the environment, pull the strategic aims of the programme towards more sustainable and efficient livestock rearing.

Excellence in herd health and animal welfare is dependent upon underpinning discipline-based research on the diseases of animals. This is approached in studies that will extend knowledge of the pathogenic or metabolic aetiologies of animal diseases, and develop understanding of the innate and acquired immune mechanisms of animals that permit them to avoid and survive infections. This knowledge will ultimately enable the development of sustainable strategies for disease control.

As described in the ABRG document *Strategy for Agricultural, Biological and Related Research 1999-2003*, the targeting of diseases for study will be increasingly linked to disease surveillance. Research aimed at extending current knowledge of the epidemiology, transmission and pathology of animal diseases is anchored in this context within themes dealing with epidemiology of animal diseases and pathology and pathogens. Underpinning epidemiology studies, projects within Theme 4.2 (Pathology and Pathogens) aim to describe and understand at cellular and molecular levels, the significant pathogens of animals (bacteria, viruses and parasites). Since some of the pathogens of animals are also zoonotic in humans, many of the projects have direct bearing on human health.

Dissection of the complex mechanisms of interactions of pathogens with their animal hosts is tackled at the molecular, cellular and whole animal levels within Theme 4.3 (Immunology and Host-Pathogen Interactions). A number of studies are aimed at extending understanding of the ruminant immune system, *per se*. In addition, a collection of projects within Theme 4.4 (Control of Animal Diseases), ranging from fundamental biology through to highly targeted strategic science, have the specific aim of devising control mechanisms for disease of animals which impact on the Scottish rural economy. As with much of the work listed in Theme 4, knowledge of the fundamental mechanisms under study informs the wider field of comparative medicine.

Theme 4.5 (Physiological Basis of Behaviour) contains studies aimed at establishing the underlying physiology associated with phenotypic expression of animal health and well-being. Fundamental behavioural science is linked to physiology and nutrition research in a multi-disciplinary approach to the identification of behavioural parameters of animal health while commonly recognised welfare problems are tackled in the more applied multi-disciplinary context of Theme 4.6 (Welfare in Farming Systems). Research on the behaviour of grazing animals is also contained within Theme 5.1.2 (Grazing Ecology).

The strategic relevance of the programme of research described here in Theme 4 can be defined within the "end use categories" identified in the ABRG *Strategy for Agricultural, Biological and Related Research 1999-2003.* Much of the emphasis within the programme lies in the development of sustainable strategies for disease control, therefore the programme

is highly relevant to the development of sustainable agriculture. Research in this area builds on the opportunity afforded by the technique's revolution in both genomics and proteomics. The development of reagents and tools for research, vaccines and veterinary therapeutics is of particular relevance to the biotechnology industries. The increase in the fundamental understanding of zoonotic infections and of the biological systems that inform comparative medicine, ensures the relevance of the programme to human health. The pursuit of alternatives to traditional chemotherapeutics provides strategic relevance for parts of the programme within the end use category of environment and natural heritage.

4.1 Epidemiology of Animal Diseases

A major step in determining control strategies for animal diseases is to examine the epidemiology of disease. Within this developing SEERAD-funded programme, multi-disciplinary projects combine a variety of skills in order to tackle endemic diseases such as paratuberculosis, which have significant impact on the Scottish rural economy.

BSS/028/99	The application of statistics, bioinformatics and mathematical modelling techniques to improve the understanding of the epidemiology of *E. coli* O157 infection in cattle and its transmission to humans. (FF) (09/04)	27
SAC/316/01	Role of rabbits and the environment in the epidemiology of paratuberculosis of farmed ruminants. (FF) (03/04)	50

4.2 Pathology and Pathogens

SEERAD continues to support a skills base in animal pathology which is responsive to current and emerging diseases of veterinary significance. Molecular and immunological characterisation of major animal pathogens is an area of SEERAD investment in the Scottish science base which continues to extend knowledge, understanding, and ultimately provide control measures for a range of bacterial and viral pathogens. The emphasis on pathogens of small ruminants is appropriate within the Scottish agricultural framework. Organisms under study such as *Mannheimia* (*Pasteurella*), and ovine herpes and parapox viruses, are of significance to livestock animals while others, such as *Chlamydia*, are also of importance to human health either by virtue of their zoonotic properties or of having comparative properties with human pathogens or pathologies. This theme includes SEERAD's contribution to a joint initiative with BBSRC on the "Biology of Food-borne Pathogens" as part of the UK-wide research effort in this area. Several projects in this theme contribute to the development of techniques suitable in a wide range of areas, including work on microarrays and proteomics.

MRI/835/01 SAN/835/01	Genomic sequencing and proteomic analyses of the potato pathogen *Erwinia carotovora* subsp. *atroseptica* (Eca) and the animal pathogen *Chlamydophila abortus* (Ca). (FF) (10/03)	41 111
HRI/128/01	The acute phase protein response in an experimental model of *Staphylococcus aureus* mastitis in dairy cows. (FF) (12/03)	35

MRI/052/99	Pathogenesis and control of infectious abortion in ruminants. (03/03)	201
MRI/058/00	Comparative expression profiling in the three defined forms of ovine paratuberculosis. (FF) (11/03)	10
MRI/059/01	Immune regulation during pregnancy and control of *Chlamydophila abortus*. (03/06)	149
MRI/060/01	Immune interference by Orf virus. (03/06)	285
MRI/064/01	Molecular analysis of *Mannheimia haemolytica*. (03/04)	125
MRI/065/01	Controlling ovine chlamydial abortion. (03/05)	179
MRI/068/01	Molecular approaches to investigate the pathogenesis of, and prophylaxis for, *Mycobacterium avium* subspecies *paratuberculosis.* (03/04)	255
MRI/070/01	Immuno-modulation by the Gammaherpesviruses of Malignant Catarrhal Fever. (03/06)	267
MRI/071/01	Identification and analysis of difference between IS901+ *Mycobacterium avium* and *Mycobacterium avium* subspecies *paratuberculosis*. (FF) (07/04)	91
MRI/072/01	Development of bacterial proteomics. (03/04)	234
MRI/075/02	Towards the understanding of malignant catarrhal fever at the molecular level. (FF) (03/05)	50
MRI/076/02	Comparative studies of parapoxviruses that infect animals and man. (03/07)	207
QBB/006/99	BBSRC - BOFP Initiative. (FF) (03/03)	125

4.3 Immunology and Host-Pathogen Interactions

This Theme contains research projects on ruminant immunology and characterisation of the complex interactions between the ruminant host and invading viral, bacterial and parasitic pathogens. SEERAD remains committed to this important area of research, and the programme includes a range of immunological studies from molecular, to cellular, to specific tissues and biological microenvironments, through to the whole animal. The pathogens under study include species of agricultural relevance such as gastrointestinal parasites (nematodes and *Neospora*), microbial pathogens such as *Mannheimia* (*Pasteurella*) and *Chlamydia*. Novel studies on the immune response to sheep scab mites aim to exploit underpinning expertise in sheep immunology and immune responses to other types of parasites. Work in this area is closely linked to studies in Theme 4.2 (Pathology and Pathogens) and Theme 4.4 (Control of Animal Diseases) as part of a cohesive programme of disease-related research aimed at the development of control measures.

MRI/056/00	Immune reactions to endo and ecto parasites of sheep. (03/03)	288
MRI/061/01	Genetic variation of endotoxin within Gram-negative bacteria of the Pasteurellaceae family and its effects on innate immunity and the pathogenesis of infectious disease in ruminant lung. (03/04)	169
MRI/062/01	Protective immunity against *Neospora caninum*. (03/06)	219
MRI/067/01	*Teladorsagia circumcincta*: the host-parasite interface and immunity. (03/04)	140
MRI/069/01	Pathogenesis and diagnosis of Pasteurellosis. (03/04)	233
MRI/073/01	Comparative bacterial proteomics. (09/06)	187
VLA/001/00	Biochemical and physiological studies to identify potential targets for the control of *Psoroptes*. (FF) (06/03)	23

4.4 Control of Animal Disease

Projects in this Theme are aimed at control of major endemic diseases of large animals. The benefits to sustainable agricultural practice and the environment associated with reduction in the use of chemotherapeutics, and increasing problems with anthelminthic resistance are among the driving factors for research to develop prophylactic control measures for infectious diseases and non-infectious disorders of large animals. Many of these studies are based on vaccines or genetic selection. The programme includes a number of prophylactic and genetic approaches aimed at the control of nematode parasites. This reflects the impact of these diseases on livestock farming and the considerable skills base that SEERAD supports in this field.

MRI/840/01 SAC/840/01	Diagnosis and control of *Caseous lymphadentis* in sheep. (FF) (12/04)	70 23
CSL/005/00	Potential targets for biologically based novel methods of control of the sheep scab mite by study of its basic biology and endocrinology. (FF) (03/03)	23
MRI/054/00	DNA vaccination as a tool for understanding the pathogenesis of infectious bacterial disease and for controlling bacterial infections of ruminants. (FF) (06/04)	127
MRI/055/00	Towards control of gastrointestinal nematode parasites of ruminants through vaccines based on parasite gut membrane proteins. (03/03)	351
MRI/057/00	The nutritional basis of the peri-parturient relaxation of immunity to gastrointestinal parasites. (FF) (11/03)	44
MRI/063/01	Alternative approaches to the control of nematodoses. (03/04)	339
MRI/066/01	Strategies to control sheep pulmonary adenomatosis. (03/05)	191
MRI/074/01	Sheep scab: Host parasite interactions early in infection. (FF) (11/04)	47
MRI/077/02	Towards optimising dosage and minimising drug resistance for veterinary anti-infective chemotherapeutics. (03/05)	111
SAC/254/00	Antimicrobial resistance modelling. (03/03)	160
SAC/302/01	The nutritional basis of immunity to pathogens: development of a theoretical framework. (03/04)	64
VLA/002/00	Biochemical and immunological studies in sheep infected with the mite, *Psoroptes ovis*. (FF) (06/03)	23

4.5 The Physiological Basis of Behaviour

Behaviour is an essential component of the phenotypic expression of health and wellbeing in animals and can reflect very specific dysfunctions in the metabolic processes of animals. The welfare of farmed animals is of major importance to SEERAD, and research aimed at understanding the metabolic effects which underlie certain modes of behaviour will assist the

assessment of animal welfare in a non-anthropomorphic manner. Early indicators of disease and/or recovery may also be characterised by behaviour-based studies, and observations from this programme link to the other animal health sub-themes in a holistic approach to improving and maintaining animal health and welfare. SEERAD is committed to supporting this unique approach to animal welfare.

SAC/277/00	Characterising anxiety and depression in the pig. (03/03)	108
SAC/293/01	The role of early life factors in the development of pecking behaviour in domestic fowl. (03/03)	63
SAC/333/02	Genetics of behavioural traits associated with neonatal survival in the sheep. (03/04)	73
SAC/334/02	The development of aggressiveness in pigs: consistency and the effect of litter composition. (03/05)	110
SAC/335/02	Diet selection trade-offs and learning about food in pigs. (03/05)	85

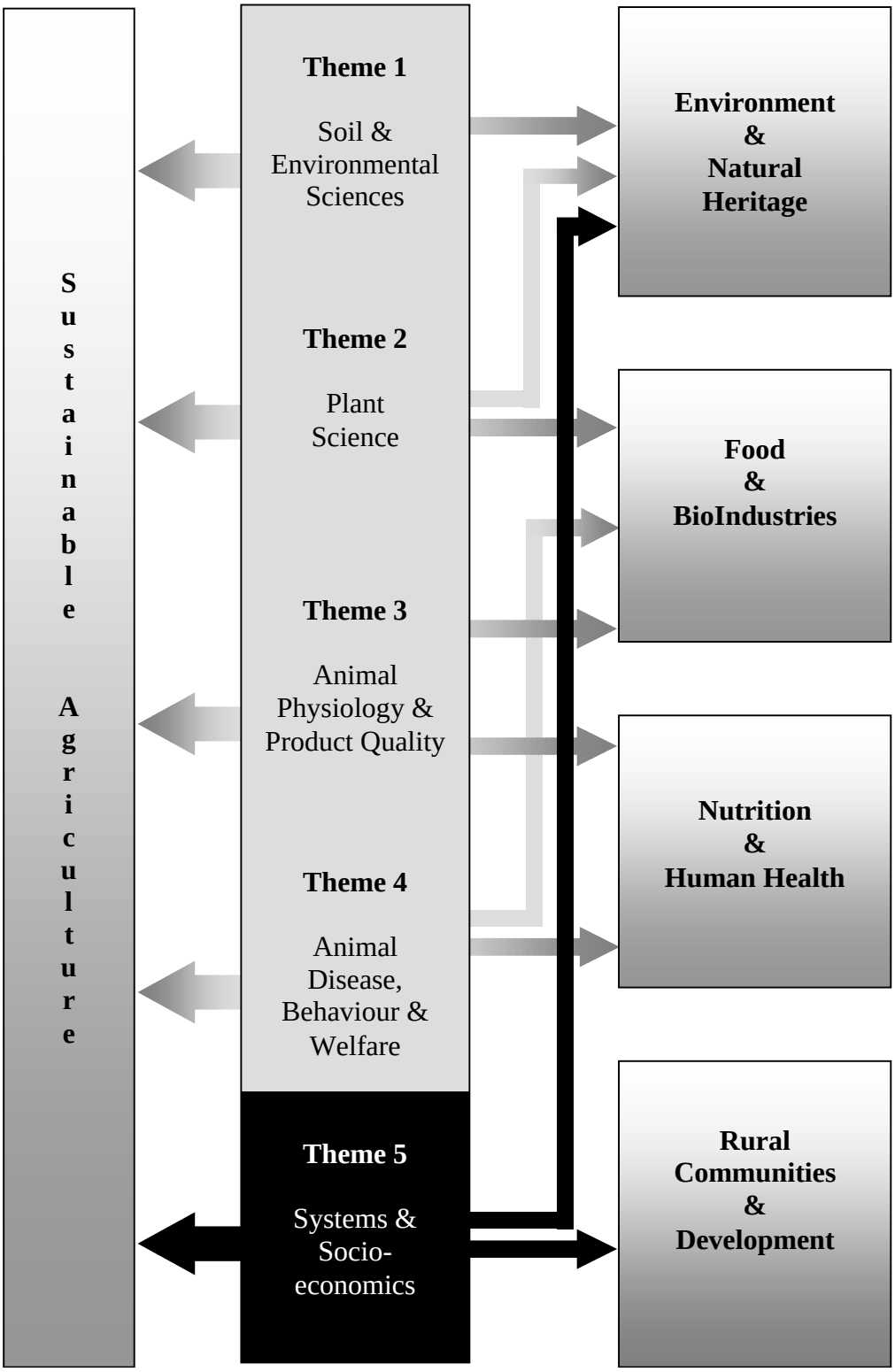
4.6 Welfare in Farming Systems

Strategic and applied studies contained within this theme have the objective of utilising fundamental scientific knowledge which will improve and enhance animal welfare within the complex context of the farming environment. These studies have a firm emphasis on improving sustainable agriculture in a very practical sense, and on resolving animal health issues, such as lameness in dairy cattle and psychological stress in pigs, which have been impacting on the welfare of these farmed animals in recent years. The programme relies on a strong policy emphasis and on consultation with industry to ensure that the subjects for study are appropriate and of high utility.

RRI/687/99	Studies of cervical function for improved artificial insemination and embryo transfer in sheep. (FF) (09/02)	22
SAC/202/98	Technology transfer in animal welfare research: identification of the best means of passing information on animal welfare to different types of farmer in the pig and sheep industries. (FF) (07/02)	18
SAC/215/99	Evaluating risk factors influencing lameness and the welfare of the dairy cow. (03/03)	7
SAC/297/01	Qualitative assessment of behaviour as a method for the integration of welfare measurements. (03/04)	49

SAC/314/01	Modelling risk factors for dairy cow lameness. (FF) (03/03)	4
SAC/331/02	Investigation of genetic and management strategies influencing lameness in dairy cattle. (03/05)	115
SRI/002/00	IPPC compliance in the UK poultry industry. (FF-LINK) (09/03)	12
URD/001/00	Animal welfare in organic farming. (FF) (01/03)	26

THEME 5: SYSTEMS AND SOCIO-ECONOMICS



SUMMARY OF COSTS:

	Estimated Recurrent Cost (£ k) 02/03
5.1 Ecology	**2966**
5.1.1 Plant Ecology	1682
5.1.2 Grazing Ecology	1284
5.2 Biodiversity & Conservation	**645**
5.3 Land Use	**3261**
5.3.1 Farming Systems	2296
5.3.2 Modelling, Data Collection & Interpretation	965
5.4 Mathematical Support	**841**
5.5 Socio-Economic Studies: Rural Economy	**1015**
TOTAL	**8728**

THEME 5: SYSTEMS AND SOCIO-ECONOMICS

Theme 5 provides a strategic research programme that integrates the activities of the previous four Themes. It includes research activities at large geographical scales, and builds the human sciences, sociology and economics, into the research programme. Theme 5 is of particular relevance to those forming policy in the areas of land-use, conservation, and the rural economy, as it combines biological research at a meaningful scale with an appreciation of socio-economic impacts.

The ecological research activities of the programme are focussed on the extensive Scottish uplands, with knowledge from the soil research in Theme 1 and plant science in Theme 2 integrated into Theme 5.1.1 (plant ecology) projects. The programme of grazing ecology (Theme 5.1.2) takes the animal nutrition, animal physiology and animal behaviour research in Themes 3 and 4 and combines it with the plant ecology to form a critical mass of projects that address issues of particular importance to Scotland. These include the impact and management of red deer and sheep. It is anticipated that following Agenda 2000 this sub-theme will provide vital information to manage and protect the Scottish uplands.

The upland ecology work is extended by research on biodiversity and conservation (Theme 5.2), where the ecology of natural and unmanaged ecosystems in Scotland is studied. The Royal Botanic Garden Edinburgh (RBGE) contributes significantly to the Department's biodiversity and conservation activities and its scientists undertake a significant amount of botanical research overseas. This research combines descriptive accounts of species found in key geographical regions with an interpretation of the economic and biological significance of these species and often results in the development of conservation strategies where the end users are sometimes in Scotland but are frequently located overseas.

Scotland has a unique and varied pattern of land use and management and this is reflected in the research contained in Theme 5.3 (land use). The programme of farming systems research (Theme 5.3.1) builds on the Department's unique ability to fund research across disciplines and scales. Farm systems research utilises the underpinning science to develop farm management systems that are economically viable and environmentally sustainable. The Department supports a strong programme of research into land use, including the development of new methods for the collection, modelling and interpretation of land use information (Theme 5.3.2). This information continues to prove valuable to all those involved in planning and managing the Scottish environment.

Following the review of SEERAD strategy in 1998/99, it was decided that there should be an increased emphasis within the programme of research on the socio-economic aspects of the research portfolio. This programme of research (Theme 5.5) also includes policy evaluations, economic evaluations, policy modelling and scenario testing.

5.1 Ecology

The ecological aspects of the programme are based on a broad area of plant ecological research. This work focuses on upland plant communities that characterise the natural and semi-natural areas of much of Scotland. In addition, there is work on fertile, lowland swards, such as those found in the important dairy areas of Scotland. The plant ecology research feeds into grazing ecology research. This research addresses problems of specific interest within Scotland concerning upland sheep management and over-grazing by deer. It includes

studies of herbivore diet and diet selection, the development of herbivory models and management tools, and research on extensive management systems.

5.1.1 Plant Ecology

The programme of plant ecological research provides the framework for studies on plant systems of Scottish interest, particularly extensive upland systems, which can be developed. These provide the knowledge of resource provision and heterogeneity that can provide information for the programme of grazing ecology. An expanding area of activity covered in this Theme is aimed at understanding the linkage between arable land management and biodiversity. Modelling is a key component of this research and examines links between the phenotypic trait space in several ecosystems (barley, brassica and wild raspberry) at a range of scales of patch (10m) and field (1000m). Research covered here seeks to identify what characteristics are required for a sustainable arable system and to identify genotypes which meet these criteria. The research thus links with the plant genetics work covered in Theme 2 and should inform future breeding programmes.

MLU/701/00	Adaptation of upland grasses to herbivory and excretal returns, and consequences for plant competition. (03/04)	378
MLU/706/00	Investigate the spatio-temporal interactions between herbivore populations, plant communities and soil resources. (03/04)	39
MLU/767/01	Plant species and plant community responses to grazing in grassland systems. (03/05)	374
MLU/768/01	Prediction of the impact of environmental and anthropogenic drivers of change in structurally and functionally diverse vegetation. (03/04)	225
SCR/538/00	Optimising production and biodiversity of arable plants and invertebrates at patch and landscape scales. (03/04)	188
SCR/539/00	Self organisation of plant and canopy architecture in barley and feral brassicas: trade-off's between production and defence. (03/03)	219
SCR/571/01	Ecological management and biotechnology. (03/04)	100
SCR/587/02	Optimising production and biodiversity of arable plants and invertebrates at patch and landscape scales: II, Invertebrates. (03/04)	159

5.1.2 Grazing Ecology

SEERAD-funded research on grazing ecology provides the theoretical and practical information that allows land managers to develop informed management strategies for deer, sheep and cattle. Activities in this programme range from studies of deer ranging behaviour using GPS systems, studies of diet selection and preference, to the development of decision support tools.

FEL/002/01	Ecology of disease: spatial hierarchy and agricultural systems biosecurity. (FF) (01/07)	79
MLU/704/00	Inter-relationships between nutrition, behaviour and diet diversity. (03/04)	461
MLU/705/00	Investigate the role of behavioural processes in determining the relationship between the spatial distribution of animal populations and their resources. (03/04)	243
MLU/769/01	The behavioural determinants of the redistribution of nutrients in grazed ecosystems. (03/05)	71
MLU/771/01	The development of a methodology for predicting the impacts of grazing and trampling by large herbivores using field-based and remote sensing approaches. (03/04)	103
MLU/772/01	Development of a decision support tool (WoodDeer) to aid the management of deer in woodlands and in the uplands of Scotland. (03/04)	66
MLU/791/01	Modelling the consequences of nutritional variation between individual herbivores for population dynamics. (03/04)	53
MLU/906/02	Sexual segregation in wild ungulates: understanding the mechanisms involved, the implications for habitat use and the consequences for the management of red deer. (03/05)	74
MLU/907/02	Ecological traits of insects and their responses to changes in vegetation structure caused by grazing herbivores. (03/05)	22
SAC/270/00	Plant structural complexity and spatial heterogeneity and their impact on the agricultural and biodiversity value of acid grassland systems. (03/05)	112

5.2 Biodiversity & Conservation

The SEERAD-funded programme of research on biodiversity and conservation now comprises work on both Scottish and overseas habitats and species following the inclusion of the research programme from the Royal Botanic Garden Edinburgh (RBGE). Floristics research is undertaken at a geographical level to understand species distribution within defined regions. Key regions for these studies are in the Far East (China, Bhutan and Pakistan), the Arabian Peninsula and South America (Chile and Brazil). In many cases this SEERAD-funded research forms part of a larger international effort. For example, botanists world-wide are collaborating to produce *The Flora of China* that will describe more than 30,000 species of vascular plants, accounting for 14% of the world's flora. The work is often aimed at assisting countries rich in biodiversity to develop strategies to conserve their biological diversity and to implement the Biodiversity Convention. This can include work on the assessment of conservation status or the development of a framework for the sustainable development of these resources. Research is also undertaken closer to home for example, to understand the distribution of lower plants in Scotland. This programme builds on the background of ecological research shown in Theme 5.1 and develops our understanding of the unique natural heritage of Scotland, allowing us to better manage this fragile resource. Two new collaborative projects focusing on different aspects of biodiversity have been commissioned, one examining the effect of grazing management on upland bird diversity, whilst the second project looks at the biodiversity of willow scrub in a range of habitats.

BSS/837/01 MLU/837/01 RBG/837/01 SAC/837/01 SCR/837/01	Biodiversity: taxonomy, genetics and ecology of sub-arctic willow scrub. (FF) (12/04)	3 31 59 28 58
CEH/836/01 MLU/836/01 RPB/836/01 SAC/836/01	Effects of grazing management on upland bird population: disentangling habitat structure and arthropod food supply at appropriate spatial scales (GRUB). (FF) (12/04)	54 94 1 50
CEH/001/00	Biodiversity in roadside verges. (FF) (01/04)	74
CPA/001/02	Sustainable arable farming for an improved environment (SAFFIE). (FF-LINK) (12/06)	50
ITE/004/99	Impact of white-tailed eagles on sheep farming on Mull. (FF) (09/02)	26
MLU/789/01	Processes and biodiversity at different ecological levels in woodland ecosystems (PROBECO). (03/04)	23 7
MLU/790/01	Scaling up from rhizosphere to ecosystem. (03/04)	42

RBG/010/99	Flora of China. (03/04)	-
RBG/013/99	Plant speciation and conservation biology on oceanic islands. (03/04)	-
RBG/024/99	Conifer conservation programme. (03/03)	- -
RBG/025/99	Conservation genetics of scarce Scottish and European plants. (03/04)	-
RBG/034/99	Floristics, conservation and management of the Cerrado biome of Brazil. (03/04)	-
RBG/042/01	Tree diversity and agroforestry development in the Peruvian Amazon. (09/03)	-
RBG/043/01	Morphological and molecular systematics of the S.E. Asian Sterculiaceae. (03/03)	-
RBG/044/01	Taxonomic revisions in Sapotaceae. (03/06)	-
RBG/047/02	Locating long term glacial refugia in Europe: autopolyploid complexes in *Asplenium* as a model system. (12/02)	-
RBG/048/02	Systematics and floristics of the *Pedicularis* L. (Scrophulariaceae). (03/05)	-
RBG/051/02	Evolutionary genetics of Caledonian *Araucaria.* (01/05)	-
RBG/054/02	Preservation, rehabilitation and utilisation of Vietnamese montane forests. (05/04)	-
RBG/055/02	An integrated conservation programme for threatened, endemic forest species in Chile. (03/05)	-
SNH/002/01	Mink eradication to protect priority birds in the Western Isles. (FF) (06/06)	30
SNH/003/01	Marine biodiversity and climate change. (FF) (03/05)	15

5.3 Land Use

5.3.1 Farming Systems

There is a diversity of farming activities taking place within Scotland reflecting the variety of soil and climatic conditions, as well as market, economic and social influences. Research within this theme covers a number of important systems all relevant in Scotland. A number of the studies relate to organic farming systems where nutrient budgeting and nutrient flows are an important element of the work. The organics research forms part of a wider programme on the development of environmentally-friendly farming practices. For example, the 3-D farming project, which is funded through the LINK programme, aims to manage field margins in order to increase the abundance, diversity and impact of beneficial insects. Other research is concerned with building effective decision support tools for increasing the efficiency, in both economic and environmental terms, of agricultural enterprises. The studies also cover important animal health and welfare issues within animal based systems. Also listed here is the Department's funding towards the Farm Scale Evaluation trials, where the possible impact of GM crops on natural biodiversity is being examined. The Department is also funding research looking at the management of herbicide-tolerant GM crops and data from related work looking at landscape gene flow is also relevant to GM crops. Social aspects of farming and other land uses are described in sub-theme 5.5.

IAC/003/00	3-D farming: making biodiversity work for the farmer. (FF-LINK) (03/04)	51
MLU/587/97	Effect of change in grazing pressure of sheep on erosion and vegetation cover on Trotternish, Skye. (FF) (03/04)	39
MLU/716/00	Matching animal genotype to extensive production systems: implications for nutrition, welfare and product quality. (03/03)	198
MLU/766/01	Concentrations of endocrine disrupting compounds (EDC) in Scottish soils and herbage, and their bioaccumulation in sheep. (03/04)	77
NIB/001/99	Botanical and rotational implications of genetically modified herbicide tolerance (Bright). (FF-LINK) (03/03)	35
QDE/001/99	Farm scale evaluations of the impact of the management of GM herbicide tolerant oil-seed rape and maize on farmland wildlife. (FF) (09/03)	200
ROS/002/99	QTL identification and utilisation in sheep sire referencing scheme. (FF-LINK) (09/03)	41
SAC/114/96	Development of methods to predict growth, efficiency and carcass composition of different sheep genotypes in different production systems. (09/03)	203

SAC/123/96	Sustainable breeding strategies for hill sheep. (FF) (03/03)	169
SAC/132/97	Development of an environmentally acceptable programme for an arable rotation based on autumn-sown crops and using the COIRE approach (En-COIRE). (08/03	170
SAC/191/98	Development of an extensive, high output system of sheep production for cool wet environments. (03/03)	45
SAC/242/99	Developing effective suckler cow replacement strategies. (FF-LINK) (09/03)	55
SAC/257/00	Resource use in organic farming. (03/05)	276
SAC/260/00	Environmental consequences relating to the introduction of transgenic rapeseed into agricultural ecosystems. (03/03)	162
SAC/269/00	Resource use in grassland-based dairy systems. (03/04)	130
SAC/289/01	Hill farming and environmental objectives. (03/03)	28
SAC/295/01	Factors affecting the availability and profitability of farmland bird food resources. (03/04)	107
SAC/326/02	Benchmarking multi-functionality within Scottish farming. (03/04)	37
SAC/328/02	Modelling weed population dynamics and control in organic agriculture. (03/05)	49
SAC/332/02	Decision support tools to enhance farm animal health, wellbeing and biosecurity. (03/05)	118
SCR/568/00	Significance and mechanisms of landscape-scale gene flow. (FF) (07/03)	88
UAB/008/99	Effects of staff training and development on indices of animal welfare, health, performance and profitability of dairy farms. (FF) (07/02)	6

WWT/001/01	Effects of foot and mouth disease on farming practice on the Solway in 2001, and the consequences for the Svalbard barnacle goose population in winter 2001- 02 and subsequently. (FF) (08/03)	12

5.3.2 Modelling, Data Collection & Interpretation

Much research activity, particularly within the study of land use, produces large data sets of information. This needs to be carefully and accurately analysed in order to yield maximum benefit and understanding. Studies within this Theme include a number of different types of project which are aimed at developing effective methodologies or systems for complex data analysis. These range from assessing satellite imagery for detecting land use change, to statistical methods for generating realistic weather patterns for predictive modelling of plant growth.

BSS/033/02	Spatial and temporal models. (03/05)	85
MLU/608/98	Framework for evaluation and assessment of regional land use scenarios (FEARLUS). (03/03)	124
MLU/709/00	Case studies of land use change in Scotland. (12/03)	45
MLU/710/00	Empirical modelling of land use change: a Bayesian statistical approach. (03/03)	115
MLU/718/00	Development of decision support tools for strategic farm-scale multiple-objective land use planning. (03/05)	215
MLU/793/01	Development of an operational methodology to extract physiological and morphological characteristics from semi-natural vegetation canopies using radar data. (03/04)	66
MLU/910/02	Effective monitoring of landscape changes. (03/05)	93
MLU/911/02	Visualisation tools for participation in the management of landscape change. 03/05	84
MLU/912/02	Assessing the potential use of land cover of Scotland data for mapping land quality in the context of a revised LFASS. (FF) (06/02)	84
SAC/315/01	Crop fertiliser requirements in relation to nitrate vulnerable zones in Scotland. (FF) (09/02)	9

UHE/001/01	Adaptation of EMA to Scottish agriculture. (FF) (03/03)	45

5.4 Mathematical Support

Much of the research within the SEERAD programme requires considerable support from statistical and biomathematical analyses in order to draw clear understanding and sound conclusions. A number of studies listed here are funded to develop a strong basis of statistical expertise for application throughout the programme but also to address new and exciting questions in the field of biomathematics *per se*. Mathematical and computational methodologies are progressing markedly and the application of these to biological problems is important and essential for rapid progress and understanding.

BSS/029/00	Research, consultancy and training in biomathematics and statistics in support of SERAD-sponsored R&D. (03/03)	508
BSS/031/01	Methods and software for statistical genomics and bioinformatics: development, benchmarking and training. (03/05)	107
BSS/032/01	Mathematical and statistical techniques for models of complex interacting systems. (03/05)	98
QBB/005/99	BBSRC - MAFS Initiatives. (FF) (09/03)	58
SAC/319/01	Increasing technology transfer efficiency by modelling variation in biological systems. (03/04)	70

5.5 Socio-Economic Studies: Rural Economy

Scotland has a particularly fragile rural landscape consisting largely of Less Favoured Areas. Much of this is also very desirable in scenic terms. The economy of the rural areas in Scotland is consequently also fragile and must maintain the delicate balance between economic and environmental sustainability. Studies within this Theme address both sides of this equation: effective management of the natural heritage and the impact of social and policy influences on this, and the improvement of the economic output of the rural industries. A variety of studies addressing a number of aspects of each of these areas are included here. Many of the projects include modelling, economic and socio-economic analyses.

CRU/002/02	Evaluation of national planning guideline (NPPG) 15. (FF) (02/03)	10
FEL/003/02	To assess and exchange the role of scientific data, expert opinion and local knowledge in supporting end users involved in policy formation, evaluation and implementation related to the environment and natural heritage in Scotland. (FF) (06/07)	41

HID/001/02	Special advisor to the nature and strength of public preferences to the output of agricultural systems project. (FF) (09/03)	-
LUC/001/01	New directions for land management schemes in Scotland's National Parks. (FF) (09/02)	3
MLU/788/01	Development of socio-economic methods to synthesise stakeholder priorities - using implementation of the Water Framework Directive as a case study. (03/04)	178
MLU/908/02	Developing socio-economic tools for environmental management: sustainability and drivers of change. (03/05)	162
MLU/909/02	Economic analysis of factors influencing rural development. (03/05)	149
QDH/001/02	Berry Scotland – scientific co-ordinator. (FF) (06/04)	14
SAC/217/99	Implications of supply chain developments, including efficient consumer response and category management, for the Scottish agri-food industry. (09/02)	10
SAC/262/00	Maintaining a competitive position in the Scottish organic fresh food market. (09/02)	13
SAC/283/01	Animals and welfare in Scottish rural recreation and tourism attractions. (03/03)	27
SAC/288/01	Participatory investigation into public involvement in the environmental planning process: a case study approach. (03/03)	30
SAC/290/01	Formulation of a domestic impact model for rural tourism. (03/03)	22
SAC/294/01	Transition in Scottish agriculture: its ability to compete, adapt and survive. (03/03)	30
SAC/298/01	Investigation into the relationships between community cohesion and the uptake of rural development opportunities. (03/04)	31

SAC/303/01	The economic value of animal welfare: choice modelling for preference based attribute selection. (03/03)	36
SAC/317/01	Occurrence, management and perception of risk associated with Paratuberculosis in cattle. (06/04)	55
SAC/318/01	The social construction and economic value of food borne risk perceptions: the case of genetically modified food ingredients. (06/04)	61
SAC/324/02	Business networks and supply chains in rural and peripheral Scotland. (03/04)	48
SAC/325/02	Exploring the market niche for sustainable nature-based tourism in Scotland. (03/04)	36
SAC/327/02	Changing recreational use of the countryside: estimating activities, consumption modes and environmental impacts. (03/04)	31
SAC/338/02	Farm business and environmental audit proposals. (FF) (01/03)	22
UAB/011/01	Demand for Agricultural Capital/ Diversification schemes. (FF) (11/02)	6

APPENDIX ONE
CONTACT POINTS FOR SEERAD-SPONSORED BODIES

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APPENDIX TWO
SUMMARY OF ALL PROJECTS AND COSTS

The following list shows the commission numbers, Theme codes, 2002-03 costs (ERc 02-03) and estimated lifetime costs (EtRc) for each project listed in the Themes chapters. Collaborative projects ('800' numbers) appear individually in the main list below, and are also grouped together in a supplementary list at the end. Numbers 834-840 specifically arose in response to the Flexible Fund Collaborative Competition.

Commission Number	Theme Code	ERc 02-03 (£k)	EtRc Lifetime (£k)
ACT/001/99	2.3	3	9
ADA/002/01	2.2.2	109	342
BGS/001/01	1.2	3	103
BSS/028/99	4.1	27	123
BSS/029/00	5.4	508	1,500
BSS/030/01	1.1.1	3	11
BSS/031/01	5.4	107	341
BSS/032/01	5.4	98	237
BSS/033/02	5.3.2	85	-
BSS/837/01	5.2	3	7
CEH/001/00	5.2	74	183
CEH/836/01	5.2	54	164
CJC/002/01	1.2	23	79
CPA/001/02	5.2	50	250
CRU/002/02	5.5	10	10
CSL/005/00	4.4	23	70
FEL/001/01	2.1.4	76	401
FEL/002/01	5.1.2	79	423
FEL/003/02	5.5	41	305
HID/001/02	5.5	-	-
HRI/004/01	3.2.2	124	-
HRI/101/99	3.2.4	231	918
HRI/102/01	3.2.2	97	-
HRI/103/02	3.3.2	135	270
HRI/126/00	3.2.4	217	-
HRI/127/00	3.2.2	215	857
HRI/128/01	4.2	35	55
HRI/157/00	3.2.4	447	1,383
HRI/185/00	3.2.2	273	-
HRI/187/02	3.4.1	250	-
HRI/258/00	3.4.1	9	30
HRI/259/01	3.4.1	191	392
HRI/260/01	3.4.1	37	95
HRI/261/01	3.4.1	217	367
HRI/262/01	3.4.1	186	412
HRI/265/01	3.4.1	38	62
HRI/266/02	3.4.1	232	533
HRI/824/97	2.3	97	464
IAC/003/00	5.3	51	206
IAC/004/00	2.4.3	42	167
ITE/004/99	5.2	26	83
JEY/001/01	1.3	38	48
LUC/001/01	5.5	3	31
MLU/328/93	1.1.4	84	720
MLU/493/96	1.3	193	1,294
MLU/587/97	5.3.1	39	248
MLU/608/98	5.3.2	124	506
MLU/623/98	1.3	101	421
MLU/670/99	1.2	97	309
MLU/697/00	1.1.1	224	930
MLU/699/00	1.1.4	158	715
MLU/700/00	2.2.2	152	566
MLU/701/00	5.1.1	378	1,132
MLU/702/00	1.1.2	347	755
MLU/703/00	1.1.3	108	504
MLU/704/00	5.1.2	461	1,332
MLU/705/00	5.1.2	243	896
MLU/706/00	5.1.1	39	193
MLU/709/00	5.3.2	45	73
MLU/710/00	5.3.2	115	302
MLU/711/00	1.2	246	1,446
MLU/712/00	1.2	120	693
MLU/713/00	1.2	178	545
MLU/715/00	3.4.1	241	1,005
MLU/716/00	5.3.1	198	717
MLU/718/00	5.3.2	215	1,154
MLU/765/01	1.2	71	136
MLU/766/01	5.3.1	77	231
MLU/767/01	5.1.1	374	1,592
MLU/768/01	5.1.1	225	557
MLU/769/01	5.1.2	71	163

Commission Number	Theme Code	ERc 02-03 (£k)	EtRc Lifetime (£k)	Commission Number	Theme Code	ERc 02-03 (£k)	EtRc Lifetime (£k)
MLU/771/01	5.1.2	103	363	MRI/076/02	4.2	207	-
MLU/772/01	5.1.2	66	141	MRI/077/02	4.4	111	-
MLU/788/01	5.5	182	435	MRI/824/97	2.3	46	416
MLU/789/01	5.2	237	584	MRI/835/01	4.2	41	86
MLU/790/01	5.2	42	104	MRI/840/01	4.4	70	213
MLU/791/01	5.1.2	53	136	MRS/002/99	2.4.1	36	170
MLU/792/01	1.2	51	127	MRS/003/02	2.2.2	56	375
MLU/793/01	5.3.2	66	309	NHC/001/99	2.3	41	152
MLU/808/94	1.1.2	72	563	NIB/001/99	5.3.1	35	155
MLU/823/97	1.2	26	179	QBB/005/99	5.4	58	230
MLU/836/01	5.2	94	229	QBB/006/99	4.2	125	500
MLU/837/01	5.2	31	96	QBB/008/00	1.1	100	300
MLU/839/01	3.1.3	36	114	QBB/009/01	3.4.1		-
MLU/902/01	1.2	76	80	QBB/010/02	2.3	37	110
MLU/904/02	1.1.2	246	862	QBP/001/01	2.4.1		179
MLU/905/03	1.1.3	0	-	QDE/001/99	5.2	200	610
MLU/906/02	5.1.2	74	200	QDH/001/02	5.5	14	39
MLU/907/02	5.1.2	22	75	QEN/001/01	1.3	5	10
MLU/908/02	5.5	162	557	QNE/004/98	1.2	80	400
MLU/909/02	5.5	149	378	RBG/005/99	2.1.1	-	-
MLU/910/02	5.3.2	93	176	RBG/010/99	5.2	-	-
MLU/911/02	5.3.2	84	192	RBG/013/99	5.2	-	-
MLU913/02	1.1.3	60	-	RBG/019/99	2.1.2	-	-
MRI/052/99	4.2	201	631	RBG/021/99	2.1.2	-	-
MRI/054/00	4.4	128	355	RBG/023/99	2.1.1	-	-
MRI/055/00	4.4	351	1,055	RBG/024/99	5.2	-	-
MRI/056/00	4.3	288	762	RBG/025/99	5.2	-	-
MRI/057/00	4.4	45	134	RBG/028/99	2.1.1	-	-
MRI/058/00	4.2	10	75	RBG/030/99	2.1.1	-	-
MRI/059/01	4.2	149	-	RBG/031/99	2.1.1	-	-
MRI/060/01	4.2	285	-	RBG/032/99	2.1.1	-	-
MRI/061/01	4.3	169	-	RBG/034/99	5.2	-	-
MRI/062/01	4.3	219	-	RBG/035/99	2.4.1	-	-
MRI/063/01	4.4	339	-	RBG/036/99	2.1.1	-	-
MRI/064/01	4.2	125	-	RBG/037/99	2.1.1	-	-
MRI/065/01	4.2	179	-	RBG/039/99	2.1.2	-	-
MRI/066/01	4.4	191	-	RBG/042/01	5.2	-	-
MRI/067/01	4.3	140	-	RBG/043/01	5.2	-	-
MRI/068/01	4.2	255	-	RBG/044/01	5.2	-	-
MRI/069/01	4.3	233	-	RBG/045/01	2.1.5	-	-
MRI/070/01	4.2	267	-	RBG/833/00	2.1.3	56	174
MRI/071/01	4.2	91	240	RBG/834/01	2.3	56	172
MRI/072/01	4.2	234	579	RBG/837/01	5.2	59	181
MRI/073/01	4.3	187	465	ROS/002/99	5.3.1	41	154
MRI/074/01	4.4	47	143	ROS/003/02	3.4.1	-	-
MRI/075/02	4.2	50	153	RPB/836/01	5.2	1	29

Commission Number	Theme Code	ERc 02-03 (£k)	EtRc Lifetime (£k)	Commission Number	Theme Code	ERc 02-03 (£k)	EtRc Lifetime (£k)
RRI/583/97	3.1.1	186	552	SAC/114/96	5.3.1	203	1,169
RRI/634/98	3.1.2	256	932	SAC/123/96	5.3.1		747
RRI/640/98	3.2.1	140	649	SAC/132/97	5.3.1	170	1,069
RRI/672/99	3.2.3	314	1,007	SAC/191/98	5.3.1	45	244
RRI/673/99	3.1.1	126	527	SAC/202/98	4.6	18	305
RRI/687/99	4.6	22	126	SAC/215/99	4.6	7	267
RRI/692/00	3.1.1	128	424	SAC/217/99	5.5	10	95
RRI/694/00	3.2.1	51	222	SAC/242/99	5.3.1	55	275
RRI/695/00	3.3.2	175	894	SAC/244/00	3.3.2	120	371
RRI/696/00	3.1.1	295	767	SAC/245/00	3.3.2	120	364
RRI/704/00	3.3.1	129	444	SAC/246/00	3.3.1	238	956
RRI/705/00	3.1.2	103	300	SAC/248/00	3.1.3	96	287
RRI/711/01	3.1.2	120	360	SAC/251/00	3.4.1	239	786
RRI/713/01	3.1.2	116	356	SAC/254/00	4.4	160	397
RRI/714/01	3.1.1	109	287	SAC/255/00	2.2.2	83	226
RRI/715/01	3.3.2	416	1,680	SAC/257/00	5.3.1	276	1,334
RRI/716/01	3.2.3	256	866	SAC/259/00	2.4.1	27	80
RRI/717/01	3.1.1	138	464	SAC/260/00	5.3.1	162	502
RRI/718/01	3.1.1	112	313	SAC/262/00	5.5	13	62
RRI/720/01	3.2.1	131	365	SAC/263/00	1.2	115	350
RRI/721/01	3.1.1	228	979	SAC/265/00	1.1.2	187	559
RRI/722/01	3.1.2	67	199	SAC/266/00	2.4.1	79	316
RRI/723/01	3.1.2	100	521	SAC/267/00	2.4	108	431
RRI/724/01	3.2.1	157	467	SAC/268/00	2.1.3	139	559
RRI/725/01	3.3.2	143	610	SAC/269/00	5.3.1	136	415
RRI/726/01	3.2.1	167	458	SAC/270/00	5.1.2	112	728
RRI/727/01	3.2.4	125	651	SAC/272/00	2.4.1	127	398
RRI/733/01	3.1.2	167	513	SAC/277/00	4.5	108	327
RRI/737/01	3.1.2	140	358	SAC/279/01	1.2	68	96
RRI/738/01	3.1.1	1160	406	SAC/283/01	5.5	27	79
RRI/739/01	3.2.1	111	288	SAC/286/01	2.4.1	39	117
RRI/743/01	3.2.1	61	190	SAC/288/01	5.5	30	61
RRI/744/01	3.2.1	74	259	SAC/289/01	5.3	28	85
RRI/745/02	3.1.1	99	311	SAC/290/01	5.5	22	64
RRI/746/02	3.1.2	161	508	SAC/293/01	4.5	63	126
RRI/747/02	3.2.1	226	888	SAC/294/01	5.5	30	60
RRI/748/02	3.3.2	233	734	SAC/295/01	5.3	107	321
RRI/749/02	3.1.1	133	420	SAC/296/01	2.2.2	86	259
RRI/750/02	3.2.1	190	599	SAC/297/01	4.6	49	186
RRI/751/02	3.2.1	179	564	SAC/298/01	5.5	31	94
RRI/752/02	3.1.1	134	421	SAC/299/01	3.3.1	128	640
RRI/756/02	3.2.1	83	83	SAC/300/01	3.3.1	97	292
RRI/757/02	3.2.4	20	100	SAC/302/01	4.4	55	186
RRI/832/98	3.1.1	42	160	SAC/303/01	5.5	36	73
RRI/838/01	3.3.2	64	204	SAC/311/01	2.3	93	378
RRI/839/01	3.1.3	97	316	SAC/312/01	1.1.3	107	347

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SAC/314/01	4.6	4	46
SAC/315/01	5.3.2	9	25
SAC/316/01	4.1	50	120
SAC/317/01	5.5	55	141
SAC/318/01	5.5	61	142
SAC/319/01	5.4	70	179
SAC/320/01	2.4.1	50	128
SAC/321/01	1.2	15	45
SAC/323/01	1.2	10	19
SAC/324/02	5.5	48	92
SAC/325/02	5.5	36	71
SAC/326/02	5.3.1	37	75
SAC/327/02	5.5	31	60
SAC/328/02	5.3.1	49	147
SAC/329/02	1.1.3	88	272
SAC/330/02	1.1.4	64	286
SAC/331/02	4.6	115	350
SAC/332/02	5.3.1	118	275
SAC/333/02	4.5	73	143
SAC/334/02	4.5	110	343
SAC/335/02	4.5	85	267
SAC/336/02	2.4.1	115	354
SAC/338/02	5.5	22	22
SAC/836/01	5.2	50	151
SAC/837/01	5.2	28	89
SAC/838/01	3.3.2	40	121
SAC/839/01	3.1.3	54	169
SAC/840/01	4.4	23	92
SAN/835/01	4.2	111	296
SCR/516/97	2.1.4	125	615
SCR/522/98	2.4.2	89	382
SCR/525/99	1.1.1	248	918
SCR/526/99	2.1.4	163	691
SCR/527/99	2.1.5	196	634
SCR/528/99	2.1.4	146	679
SCR/536/00	2.2.2	267	631
SCR/537/00	2.2.1	241	709
SCR/538/00	5.1.1	188	933
SCR/539/00	5.1.1	219	631
SCR/540/00	2.1.3	278	1,502
SCR/541/00	2.1.3	213	1,150
SCR/542/00	1.1.3	298	1,101
SCR/544/00	1.1.3	188	913
SCR/545/00	2.4.2	161	631
SCR/546/00	2.4.1	217	466
SCR/547/00	2.2.2	162	532
SCR/549/00	2.4.1	240	699
SCR/551/00	2.2.1	287	831
SCR/552/00	2.1.4	93	266
SCR/554/00	2.4.2	175	503
SCR/555/00	2.1.4	90	672
SCR/556/00	2.4.1	60	526
SCR/557/01	2.2.1	187	715
SCR/558/01	2.4.2	224	764
SCR/559/01	2.4.2	240	788
SCR/560/01	2.1.4	276	849
SCR/561/01	2.4.3	150	508
SCR/562/01	2.1.4	107	335
SCR/563/01	2.1.3	276	841
SCR/564/01	2.1.4	109	350
SCR/565/01	2.1.4	98	308
SCR/566/01	2.1.3	30	89
SCR/568/00	5.3.1	88	175
SCR/569/00	2.4.1	26	90
SCR/570/00	2.2.2	11	28
SCR/571/01	5.1.1	100	249
SCR/572/01	2.1.5	100	254
SCR/573/01	2.1.4	100	257
SCR/574/01	2.2.2	116	287
SCR/575/01	2.2.2	85	191
SCR/576/01	2.2.1	0	102
SCR/577/01	2.1.3	104	279
SCR/578/01	2.1.4	94	240
SCR/579/01	2.2.1	55	175
SCR/580/02	2.4.2	246	738
SCR/581/02	2.1.4	257	771
SCR/582/01	2.4.1	67	189
SCR/583/02	2.4.3	219	657
SCR/584/02	2.2.1	180	541
SCR/585/02	2.1.3	114	342
SCR/586/02	2.2.1	227	682
SCR/587/02	5.1.1	159	477
SCR/588/02	1.1.3	117	233
SCR/589/02	2.1.5	48	171
SCR/808/94	1.1.2	98	629
SCR/823/97	1.2	80	667
SCR/824/97	2.3	103	496
SCR/833/00	2.1.3	57	175
SCR/834/01	2.3	58	174
SCR/835/01	2.4.1	78	133
SCR/837/01	5.2	58	148

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SCR/901/02	1.1.1	54	195
SCR/902/02	2.4.1	34	177
SDR/834/01	2.3	59	166
SNH/002/01	5.2	30	170
SNH/003/01	5.2	15	60
SRI/002/00	4.6	12	35
UAB/008/99	5.3.1	6	105
UAB/011/01	5.5	6	25
UAB/808/94	1.1.2	72	518
UAB/823/97	1.2	18	193
UCR/001/00	1.1.4	-	-
UEH/839/01	3.1.3	6	19
UGW/832/98	3.1.1	31	155
UHE/001/01	5.3.2	45	68
ULS/002/97	2.4.3	-	237
UNM/002/01	3.3.1	67	191
URD/001/00	4.6	26	64
USA/001/02	3.4.1	98	182
UYK/808/01	1.1.2	79	197
VLA/001/00	4.3	23	70
VLA/002/00	4.4	23	70
WWT/001/01	5.3.1	12	59
MLU/808/94 SCR/808/94 UAB/808/94 UYK/808/94	1.1.2	321	1,907
MLU/823/97 SCR/823/97 UAB/823/97	1.2	124	1,039
HRI/824/97 MRI/824/97 SCR/824/97	2.3	246	1,376
RRI/832/98 UGW/832/98	3.1.1	73	315
RBG/833/00 SCR/833/00	2.1.3	113	349
RBG/834/01 SCR/834/01 SDR/834/01	2.3	173	512
MRI/835/01 SAN/835/01 SCR/835/01	4.2	230	515
CEH/836/01 MLU/836/01 RPB/836/01 SAC/836/01	5.2	199	573
BSS/837/01 MLU/837/01 RBG/837/01 SAC/837/01 SCR/837/01	5.2	179	521
RRI/838/01 SAC/838/01	3.3.2	104	325
MLU/839/01 RRI/839/01 SAC/839/01 UEH/839/01	3.1.2	193	618
MRI/840/01 SAC/840/01	4.4	93	305