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Sustainability Research at SCRI

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Summary

- *The long-term viability of farming in Scotland depends on the sustainable management of our agricultural habitats. Sustainable agriculture is the ability of farming to be productive indefinitely, without causing irreversible damage to the environment, and in a manner that provides economic and social sustainability for rural communities. Agricultural systems must be managed in a sustainable way if we are to meet our ever-increasing demands for food and fuel.*

- *To help meet these environmental, social and economic goals, research is needed to identify agricultural practices that enhance economic production, are cost-effective, and are beneficial to the environment.*

- *SCRI has a strong track record in research that is central to these issues of sustainability. New management practices and crop varieties are being developed to allow enhanced production, reduced inputs, increased efficiency and improved resilience of the arable ecosystem. These measures not only increase environmental sustainability, but also have a positive impact on economic sustainability by increasing market competitiveness.*

- *Future research at SCRI on the sustainability of agroecosystems will build on this existing expertise by bringing together research at different scales to develop cropping systems that enhance economic return whilst reducing pollution and stabilising system processes. Key topics include resource use efficiency, pest and disease control and ecosystem management.*

- *SCRI has a unique set of skills and resources, covering a wide range of scales from the genome to the landscape, that are essential for developing new techniques to improve agricultural sustainability in Scotland and further afield.*

Background

Sustainable agriculture is the ability of farming to be productive indefinitely, without causing irreversible damage to the wider environment. The sustainable management of our agricultural habitats is therefore vital to the long-term success of farming. Over the past 50 years, intensification of crop production often solely for economic gain, has led to the systematic erosion of arable biodiversity and the degradation of arable habitats. This has raised serious concerns about long term sustainability, particularly where intensive management has negative impacts on the processes that are essential to the functioning of these systems. These processes include water and nutrient cycling, regulation of pest and pathogen populations, detoxification of chemical deposits and many others. As these processes degrade, ever more inputs are required to compensate. There is therefore a need to balance immediate economic gain with long-term environmental, social and economic sustainability.

In the Scottish Government's "Forward Strategy for Scottish Agriculture" (2006), it is recognised that there is a need to review the priorities and direction of Scottish Agriculture. In this strategy, it is stated that "the priority for future agri-environmental policy in Scotland is to tackle the potential tensions between economic, social and environmental aspects of sustainable development, while finding more ways to benefit all three".

To meet these goals, research is needed to identify crop varieties and management practices that enhance economic production, are beneficial to the environment and are cost-effective. A range of opportunities for development are outlined in the Forward Strategy:

- Cereal production: introducing non-food crops into existing standard cereal rotations may provide new opportunities for good economic returns while meeting wider environmental objectives. New varieties and crops for pharmaceutical and other products and biomass crops for local fuel production, may benefit Scotland if they can be used to enhance sustainability.
- Set-aside land: uncropped areas may be used for a variety of other purposes, including conservation of biodiversity.
- Soft fruit: strategic research and development in fruit genetics, breeding and interactions with key pests and pathogens is required for the future sustainability of Scottish soft fruit production, including a reduced reliance on pesticide inputs.
- Potatoes: improved seed potato varieties are required for the economic sustainability of the Scottish potato industry

SCRI already makes significant contributions in all of these areas, and is well placed to develop new approaches that enhance the long-term sustainability of agricultural production systems.

SCRI.

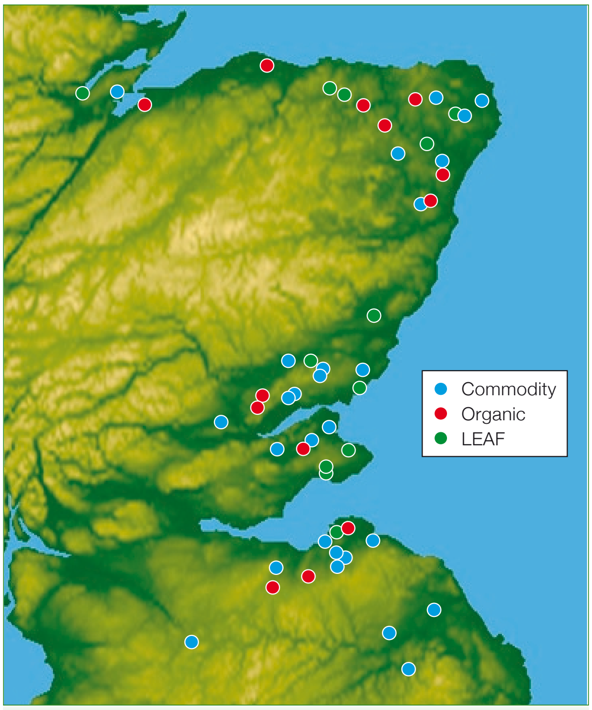
"The systematic destruction of the Earth's natural and nature-based resources has reached a point where the viability of economies is being challenged - and the bill we hand to our children may prove impossible to pay"

Achim Steiner, United Nations Environment Programme. The Scotsman 26 Oct 2007.

Sustainability Indicators

There is no universally accepted definition of sustainability and the focus tends to shift between economic, social and environmental aspects depending on the political context.

The Scottish Government defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"



Distribution of farms participating in SCRI's surveys of arable sustainability, resilience and biodiversity.

The sustainable management of agricultural systems is one that ensures a continuing and stable supply of healthy and reasonably priced food, that is produced without depleting non-renewable resources and in a way that maintains healthy ecosystem functioning and the wildlife and cultural value of agricultural land. To achieve this, we need to be able to monitor trends in sustainability and relate these trends to changing land use, crop types and management practices. Sustainability cannot be measured directly since it is made up of very different economic, ecological, social and environmental factors. We therefore need to identify indicators that can be used to assess the state of Scottish agricultural systems.

Indicators can be divided into two main categories:

Biophysical - soil resilience and resistance to physical and biological stresses, arable weed seedbank diversity and functional composition, invertebrate foodweb interaction strengths, soil microbial function, and fluctuations in pest and disease populations.

Socio-economic – spatial and temporal diversity of crop types, crop yield, crop quality, agrochemical inputs, farmer choices (organic, integrated or commodity management styles, management of land for purposes other than food production).

At SCRI, we are monitoring these indicators at farms throughout the arable east of Scotland to provide a baseline and to develop criteria for assessing future changes in agricultural sustainability.

Current sustainability research

SCRI has a strong track record in research that is central to issues of sustainability and a broad range of relevant skills and resources, from expertise in ecosystem research to molecular pathology and crop genomics. New crop varieties and management practices are being developed to allow increased efficiency, quality and nutritive value, reduced inputs and improved resilience of the arable ecosystem. Research on the interactions between plants and their pests and pathogens, for example, will lead to more effective control strategies, thereby reducing pesticide inputs to the system. Similarly, studies of the interactions between crop plants and arable weeds can be used to reduce herbicide inputs by identifying crop traits for improved weed competitiveness. Reducing inputs while maintaining or improving the quality and stability of crop yield can be achieved by the production of improved varieties that are tolerant to stress. These measures will not only increase environmental sustainability, but also have a positive impact on economic sustainability by reducing costs and increasing market competitiveness.

Highlighted below are three main areas of research at SCRI that relate to sustainability in arable ecosystems: resource use efficiency, pest and pathogen control and ecosystem management.

Resource use efficiency

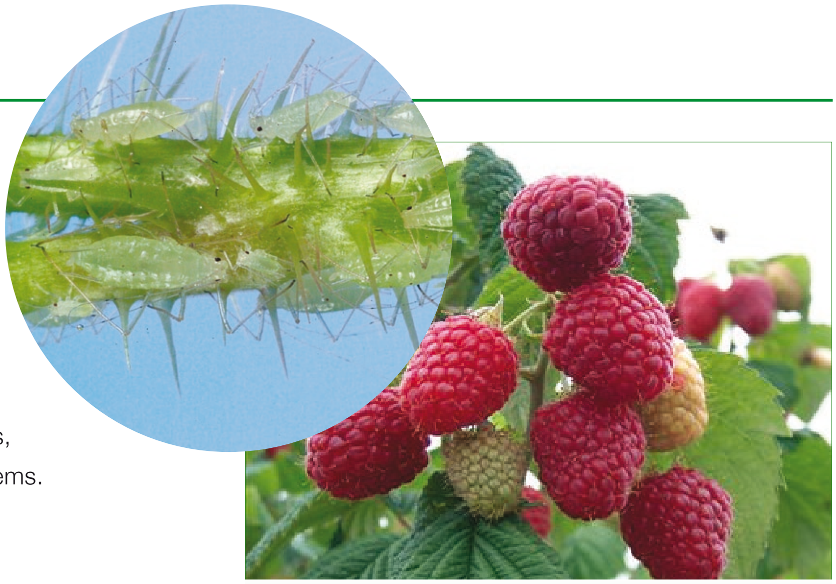
Using SCRI's advanced genomics skills, new barley, potato and soft fruit varieties are being developed for environmentally and economically sustainable production. Breeding for characteristics

The Genetic Reduction of Energy use and Emissions of Nitrogen (GREEN grain) project seeks to facilitate variety production, by understanding the genetic basis of nitrogen use efficiency and developing a DNA marker-based selection system that can be used in future breeding. The project aims to reduce nitrogen emissions and growing costs of wheat production whilst enhancing the quality of the grain.

such as increased yield and yield quality, while improving water and nutrient use efficiency and stress tolerance, results in reduced inputs and therefore improved environmental and economic sustainability. Management strategies are also being developed as alternatives to conventional herbicides and pesticides for control of weeds, pests and diseases under reduced input systems.

Pest and pathogen control

SCRI is contributing towards sustainable crop production by developing environmentally benign and cost effective ways to reduce the incidence of crop diseases. We are investigating ways to monitor, predict and avoid disease through integrated crop management strategies such as the use of diagnostics, changing habitat conditions and improved durable resistance of soft fruit, barley and potato varieties. By understanding how pest and pathogen populations change, and how they interact with their host plants and the wider environment, we can devise ways to reduce the reliance on chemicals to control diseases in accordance with EU legislation that aims to decrease pesticide use.



Changing aphid populations are starting to overcome existing resistance in raspberry cultivars, leading to an increase in viral infections within plantations. New sources of resistance within the *Rubus* genus are currently under investigation for their potential utility in future cultivars.

Susceptible and resistant potato varieties grown in PCN infested soil. As nematicides are withdrawn new sustainable control strategies, such as those being pursued at SCRI, are required

Ecosystem management

Crop traits, rotations and associated soil and weed management practices (including tillage and herbicide regimes) are being identified to achieve high yield whilst maintaining the biophysical resilience and ecological sustainability of arable systems. Current research aims to identify a balance of different functional types of organisms to enable the system to satisfy economic, aesthetic and environmental functions. Research is focusing on identifying indicators of resilience at the field scale for monitoring the potential ecological impacts of new management regimes and crop types.

Experimental plots at SCRI designed to test the impact of reduced tillage and the addition of compost and slurry on system resilience

Future sustainability research

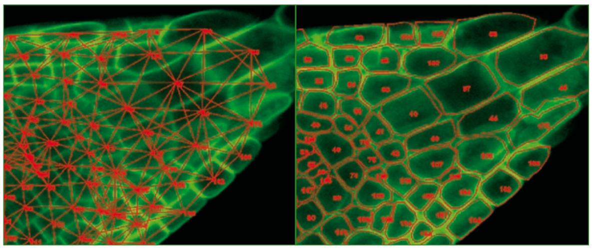
Although current research strategies are important for improving the sustainability of agro-ecosystems, the true effectiveness of each can only be properly assessed in the context of the farming system as a whole: a full life-cycle analysis of all sustainability options and an integrated, whole farm approach is required if we are to achieve the dual environmental and economic objectives set out in the Forward Strategy. This emphasis will be included in future sustainability research at SCRI. Our future research will build on existing expertise in resource use efficiency, pest and pathogen control and ecosystem management.

Plant traits for resource use efficiency

SCRI is looking at new ways to produce the major cereal and horticultural crops more efficiently, with less water and agrochemical inputs. This work will focus on enhancing yield and quality while reducing fertiliser requirements and will link expertise and resources in crop breeding, nutrient/carbon cycling and soil biodiversity research. New research opportunities include combining the effects of plant traits and soil microfaunal composition to optimise plant use of nitrogen and phosphorus and to minimise leaching. Opportunities also exist in the development of new crops, such as biomass and biofuel crops or high value nutraceutical and pharmaceutical crops, that enhance coexistence with non-crop organisms and improve economic return.

Phosphorus is a major limiting nutrient in low input systems. Identification of plant genotypes which use phosphorus efficiently, under a range of water availability conditions, is therefore essential to secure sustainable yields in the face of global environmental change, while also guarding against wasteful use of inorganic P resources and any subsequent environmental impacts.

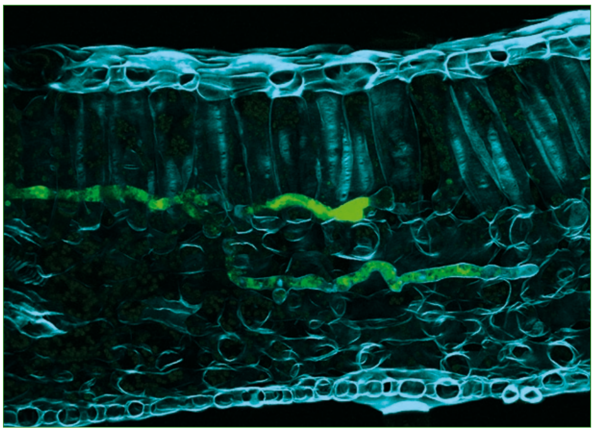
Potatoes are considered to be inefficient in their utilization of resources such as nutrients and water. Plants which have large root-soil interfaces (e.g. longer roots) are likely to be more efficient in capturing certain resources. As little is known about the genetics of the rooting habit of potato, studies are needed to measure the variation in rooting traits of a range of potato genotypes grown in the field. Characterising and quantifying the genotypic variation in rooting traits will potentially identify cultivars with a greater ability to acquire resources, thus reducing the need for fertiliser application and irrigation.



Another strand of research will develop computer modelling approaches to study the behaviour of plants as they react to their environment. Using image analysis methods for tracking cell expansion and division, it is possible to extract information from live microscopy and build models of plant cellular development. Here, the segmentation of live imaging data of the root apical meristem is used to understand cell development and how it relates to genetic processes. Such an approach will allow us to predict how crop plants will behave when faced with the need to locate and utilise patchy mineral and water resources.

Integrated control of pests and pathogens

Pathogens and pests are continually evolving to overcome resistant crops. Global change will add further uncertainty to the way we protect crops from diseases and pests. Powerful new techniques and methods are needed to continue past successes in crop protection. In response to these challenges, new research in molecular genetics, diagnostics and systems ecology is being put in place at SCRI to provide the scientific base for more integrated approaches to the management of pests and pathogens.



Hyphae of *Phytophthora infestans* (expressing green fluorescent protein) invading a potato leaf. Modern molecular and cellular techniques can inform on the mechanism of entry and systemic infection of plant pathogens.

Increasingly powerful genomics and diagnostic methods will allow us to understand the molecular and cellular basis of disease and thereby to breed and select crop varieties with enhanced resistance. Powerful molecular diagnostics will allow us to check for the presence of pathogens and track their movement and survival in plants, in the soil and over landscapes.

SCRI research to understand the molecular mechanisms of resistance and susceptibility to plant pathogens is producing new information (e,g. pathogen effector molecules) that can be used to screen wild potato species for novel resistance. New sources of resistance against a range of pathogens are being exploited to create the potato cultivars for future sustainable production.

The value of a systems approach to disease is increasingly recognised at SCRI. It is essential to know what happens to the pathogen or pest when it is not infecting its main host crop. Under what conditions does it live freely in the environment and which alternative hosts does it associate with? Within the main host itself, we need to know which combinations of plant architecture and chemical composition are least favourable to the disease organisms. Such knowledge will enable us to manage cropping sequences and weed communities that interfere with the life histories of pathogens and to put in place alternative crop protection strategies, for example involving attractant chemicals.

Resilience & ecosystem management

Research into ecosystem management will identify management practices that best encourage the combination of crop and weed traits, microbial communities and soil physical properties that are necessary to maintain the stability of system processes. These processes include nutrient decomposition, cycling, energy flow and plant and insect population regulation, and are essential for the overall sustainability of arable systems. At SCRI, we use functional groups of arable plants, invertebrates and micro-organisms to assess the sensitivity of these systems to change. Communities are divided into functional groups on the basis of a set of eco-physiological traits that relate to the flow of nutrients and energy through arable food webs. Changes in the strength of interactions between different parts of the foodweb will be used to investigate the effects of new management and crop types on system functioning. Future research opportunities include:

- Identifying phenotypic traits that increase crop tolerance of weed competition thereby allowing greater understorey weed biodiversity
- Designing rotations that include management practices and crop varieties that enhance pest population control over greater temporal scales
- Quantifying the relation between biodiversity and ecosystem functioning
- Identifying key functional groups from the vast range of above and below-ground biodiversity
- Evaluating the impact of land management on whole-system resilience and ecological sustainability.

Monitoring the impact of management intensity on key plant and insect functional groups in arable farms across the east of Scotland. This work is part of a programme to develop and test indicators of sustainability and arable system resilience.

The diversity and traditional management of Machair systems are important for environmental and economic sustainability, providing crofters with an alternative source of income from tourism. We are studying the interaction of biological and physical factors in traditional mixed farming systems.

Sustainability in Practice

The Scottish Government's Sustainable Development Strategy, "Choosing our Future" emphasises the need "for individuals, businesses, local authorities and communities to take action to change the way we use resources and minimize our environmental impact". SCRI is contributing to this effort in several ways:

Linking Environment And Farming (LEAF)

SCRI is a LEAF Innovation Centre which aims to promote agro-ecological research and to pioneer new approaches for sustainable land management and integrated farming. New techniques to enhance sustainable farm management are tested and validated at SCRI, and are demonstrated to farmers, policy makers and the public at regular open days.

The Living Field

The Living Field is a developing set of resources and activities that will bring together farmers, the public and the scientific community to increase understanding and appreciation of biodiversity and sustainability in arable systems. It has created a Living Field Community Garden, produced The Living Field CD, and established the Living Field Study Centre (http://livingfield.scri.ac.uk/). The Centre has strong

working links with a range of organisations including the Tayside Biodiversity Partnership, the Field Studies Council, Scottish Natural Heritage, Countryside Rangers, local records centres and the Farming and Wildlife Advisory Group.

WRAP

To highlight the environmental and commercial benefits of using composted green wastes in agriculture, replicated trials, sponsored by WRAP, of spring barley and potatoes have been established on our conventional farm and at an organic farm. The aim of these trials is to assess the potential benefits of using such composts on improving crop yield, reducing fertiliser inputs, improving moisture availability, and reducing weeds and plant diseases.

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