Field trip, Thursday 23rd Aug

Aims:

- To look at a transect of altitude, soils and cultivated to moorland landscape going over the hills from Deeside to the coastal lowlands. The land cover change is mixed farming in the river Dee valley to forestry, to moorland on the high ground with strategies for land improvement, then over a geological boundary to very intensive arable in the coastal lowlands.
- To then visit a small local distillery on route to Dundee.
- To go on to Balruddery for a look at the work of the Centre for Sustainable Cropping and the IBZ buffer site trials.
- Then to travel straight back to Aberdeen airport for those flying from there.

Approx timings

Stop	Arrive time	Depart time	Cumulative km	Travel time
Leave Aberdeen		08-30	0	
Stop 1, Cairn O'Mount	09-30	09-50	48	60 mins
Stop 2, Coffee at Clatterin' Brig'	10-00	10-30	50	10 mins
Stop 3, Fettercairn distillery	10-40	12-00	56	10 mins
Stop 4, Balruddery farm	13-15	15-15 latest	135	1h from fettercairn
Those going to Aberdeen airport	By 17-30		260	1h 43 min

The route:

Initially, we will travel westwards from Aberdeen along the Dee Valley, crossing the river near Maryculter. The surrounding land in the parish of Maryculter was once farmed and administered by the Knight Templars. We will then travel along the South Deeside road to the Bridge of Feugh. The soils along the route are mainly alluvial soils in the valley bottom, humus-iron podzols on the mounds and terraces of glaciofluvial deposits which flank the river, and beyond on the till derived from granite and granitic gneiss (the Countesswells Association).

The land use is in this area is predominantly arable agriculture with some established coniferous woodlands, particularly on the hill tops. Occasionally there are tree nurseries and aggregate quarries. There will be a short stop at the Bridge of Feugh (which is renowned for is salmon leap).

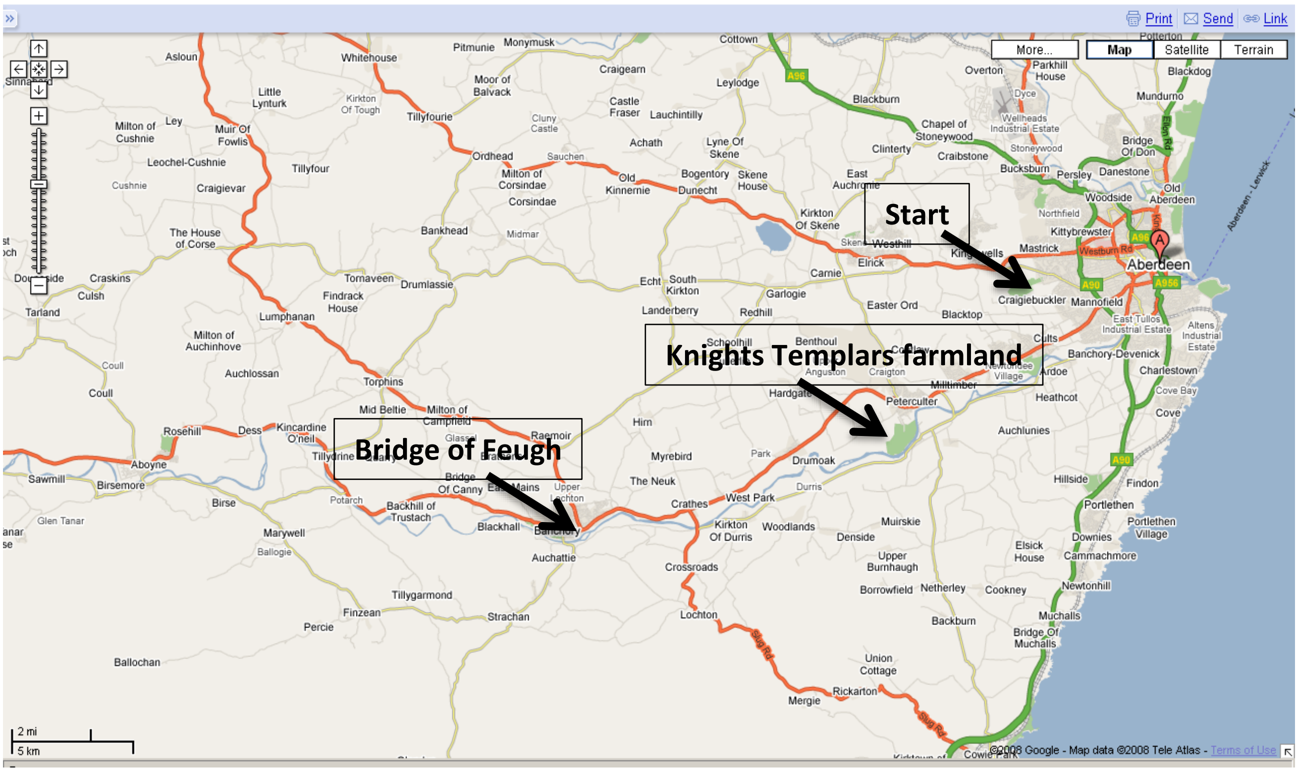
The route then follows the Water of Feugh south-westwards towards the village of Strachan (75 m O.D.). We then turn and head approximately south along the old drove road ultimately rising up and over the Cairn O' Mount (455 m O.D.). The mean annual rainfall at Strachan (Met Office 1941-70 Standard period) is 1000 mm rising to 1200 mm at Cairn O' Mount. Birse and Dry (1970) have described the climate as changing from fairly warm moist lowland and foothill to cold wet upland (accumulated temperatures of between 1100 and 1375 day degrees C and of between 550 and 825 day degrees C respectively). The presence of snow poles marking the roadside indicates the potential severity of the winter weather.

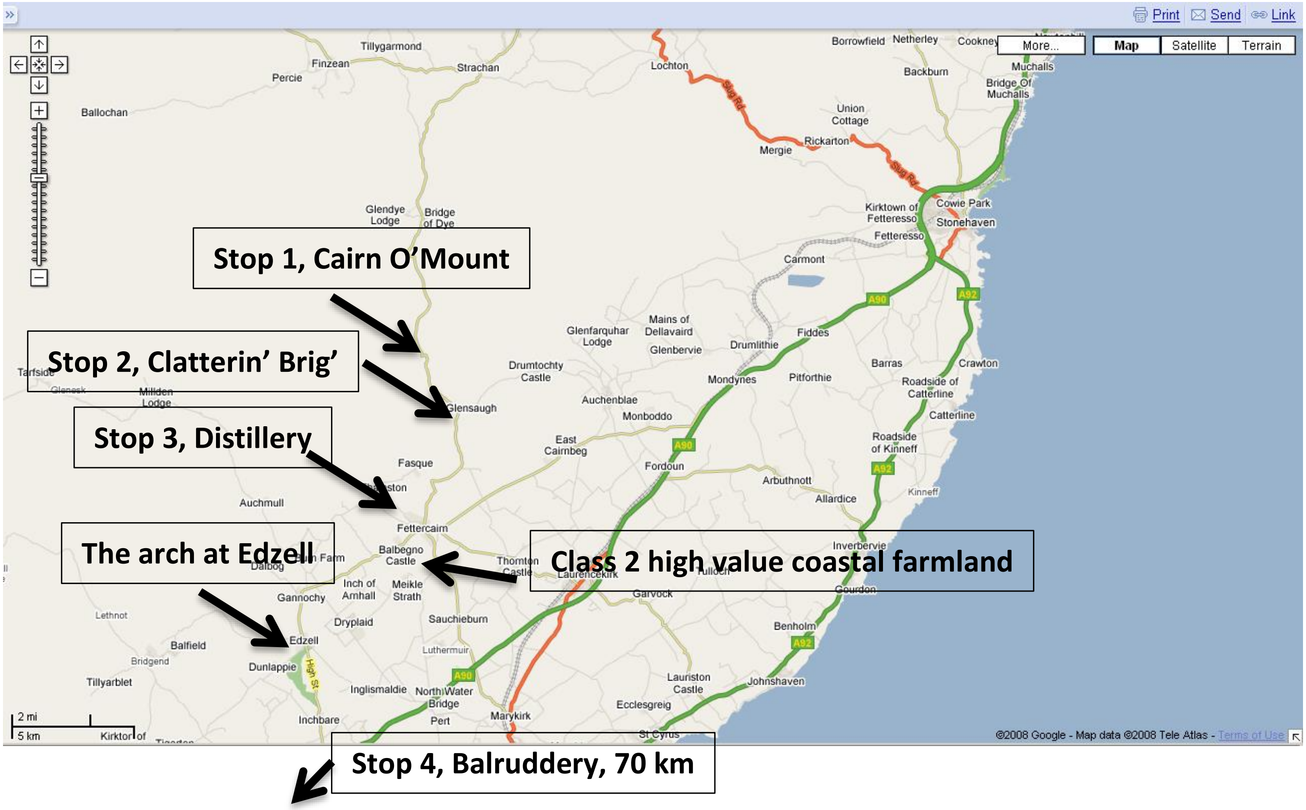
We then stop at the viewpoint at the top of the Cairn O'Mount to look over the JHI's farm at Glensaugh, a mixed upland – improved land sheep farm with some cereals ground. This sits across the Highland Boundary fault, an important geological division between the geology of the Highlands of Scotland and the younger rocks to the South. At the viewpoint the change to the intensive agriculture on the coastal plain is obvious. This is developed on readily-workable deep soils on old red sandstone.

We then stop briefly for coffee opposite the Institute's farm of Glensaugh where there are experiments into agroforestry and a long monitoring site for upland environmental change before going on to Fettercairn for a short tour of the distillery. Then we drive on toward the main coastal road (A90), which we join at Brechin. Just before joining the main road we pass through the arch of the small market village of Edzell. The arch built in 1887 commemorated the deaths of the 13th Earl of Dalhousie and his wife coincidently on the same day.

We then drive onto Dundee and round Dundee to Balruddery (see map and route directions).

The land use changes greatly into the lowlands and there are areas of specialised covered agriculture, mainly for soft fruits that the region around Dundee is famous for. We then drive on to the Balruddery site. This takes ~1 hour and involves through the outskirts of the city of Dundee. This is Scotland's 4th city, population ~150,000, once a centre for exploration (Shackleton's ship the Discovery is here complete in the city centre harbour) and for whaling and later for trading e.g. a textile called jute was milled here.





Feughside Bridge car park. We pass over an old stone bridge on the River Feugh: High DOC system and significant control on lower Dee chemistry and hydrology. Also a popular local visitor place to watch for jumping Salmon.

Soil and land cover transect

Strachan sits approximately on the edge of the Dalradian Schist and the rock changes to granite as we go south. The drifts in the river valley are again alluvial, with glaciofluvial deposits of granitic origins and, at higher elevations, glacial tills derived from the local granite. As the soil parent materials are similar from the valley bottom at Strachan to the top of the Cairn O' Mount in that acid granites or acid schists are the major component, then the changes in soil type which occur with the rise in elevation are largely due to the changes in climatic conditions and is therefore a good example of a soil toposequence. The land use also changes from a mixed arable agriculture in the valley to forest, sheep and grouse moor on the middle and upper slopes and finally deer forest near the summit. The glaciofluvial and morainic mounds which flank the river valleys have some of the oldest tree plantings in the area eg Scots Pine (*Pinus Sylvestris*) was planted around 1859.

Coming up the north side of the hill the soil profiles typically are developed on glaciofluvial sands and gravels derived from acid parent rocks (granites and schists) and would be classified in the Scottish Soil classification system as a humus iron podzol (Soil Survey of Scotland Staff, 1984) and as ortsteinic, albic, folic podzol (IUSS Working Group WRB, 2006).

As we come out of the forest initially onto the moor we pass a ruin on the right before a narrow bridge. This is the 'spittal' of Glen Dye. Spittal was a hospice or some kind of rest or shelter for travellers. This was a key drove road; droving was the movement of walking cattle across the hills from the Dee valley to the busy markets in the coastal market towns.

Also look at the patterns of burning in the heather. This is done to regenerate the shoots on younger regrowth of heather to feed game birds (grouse) that form the basis of sporting estate shooting revenue.

The soils at the top by stop 1 have deep enough organic horizons to classify as peats in the Scottish classification system.

Stop 1. Cairn O'Mount viewpoint

Discussion points:

- Land cover change and the Highland Boundary fault
- Scottish Land Capability for Agriculture Mapping and uses

Here we look north at the peatland but south to one of the most fertile agricultural areas of Scotland. The Institute's farm Glensaugh extends from the hill top ground on the east of the road to the valley and crosses the Highland boundary fault. This is the major boundary running at an angle from east to west coasts separates between the hard Precambrian and Cambrian metamorphic rocks to the North (e.g. the Dalradian supergroup of schists, phyllites and slates) and some granites and the later, softer sedimentary rocks to the South of the Devonian and Carboniferous (e.g. the old red sandstones on which the intensive agriculture is based).

Land Capability for Agriculture Mapping

The National scale land capability for agriculture map provides information on the types of crops that may be grown in different areas dependent on environmental and soil characteristics.

The land capability for agriculture assessment was carried out in 1981 using data collected between 1978 and 1981. The National scale land capability for agriculture map was then created in 1983 at a scale of 1:250 000. The map should be cited as: 'Soil Survey of Scotland Staff (1981). Land Capability for Agriculture maps of Scotland at a scale of 1:250 000. Macaulay Institute for Soil Research, Aberdeen'.

Access to the Scottish soils resources can be gained at: http://soils.environment.gov.scot/

Stop 2. The Clatterin' Brig' café

Discussion points:

- The James Hutton Institutes farm Glensaugh – hill ground improvements and the Environmental Change Network site.
- Coffee and tea!

Glensaugh Research Farm and ECN Terrestrial and Freshwater Site. From the coffee stop we can see the hill area of the Environmental Change Network site at Glensaugh (ECN - http://www.ecn.ac.uk/). The UK Environmental Change Network (ECN) is the UK's long-term, integrated environmental monitoring and research programme. ECN gathers information about the pressures on and responses to environmental change in physical, chemical and biological systems. It is supported by a consortium of fourteen sponsoring organisations and seven research organisations. ECN's objectives are:

To establish and maintain a selected network of sites within the UK from which to obtain comparable long-term datasets through the monitoring of a range of variables identified as being of major environmental importance.
-To provide for the integration and analysis of these data, so as to identify natural and man-induced environmental changes and improve understanding of the causes of change.
-To distinguish short-term fluctuations from long-term trends, and predict future changes.
-To provide, for research purposes, a range of representative sites with good instrumentation and reliable environmental information.

Data on nine driving and/or response variables are collected at this site in accordance with set protocols for the Terrestrial ECN sites. Additional data, also collected to strictly defined protocols, is collected as part of the Freshwater Environmental change Monitoring. It has collected biological records and fortnightly soil solution, stream water, atmospheric deposition chemistry and continuous discharge since 1993.

Role of the UK ECN

UK Environmental Change Network | The James Hutton Institute

The ECN is the UK's long-term environmental monitoring and research (LTER) programme.

ECN make regular measurements of plant and animal communities and their physical and chemical environment.

The long-term datasets are used to increase understanding of the effects of climate change, air pollution and other environmental pressures on UK ecosystems.

ECN terrestrial, river and lake sites

UK Environmental Change Network | The James Hutton Institute

ECN TERRESTIAL SITES

● - Each terrestial station is named on the map

ECN RIVER SITES

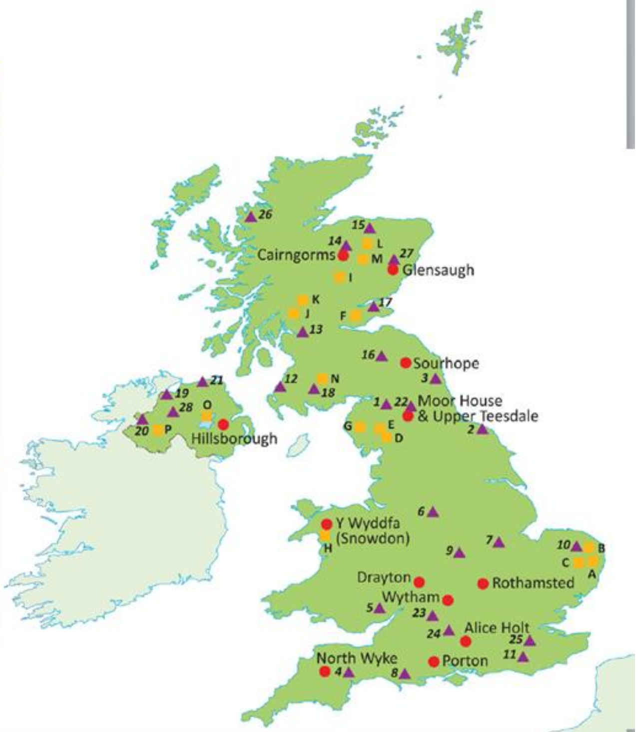
▲ - Each river station is indicated by the number listed below

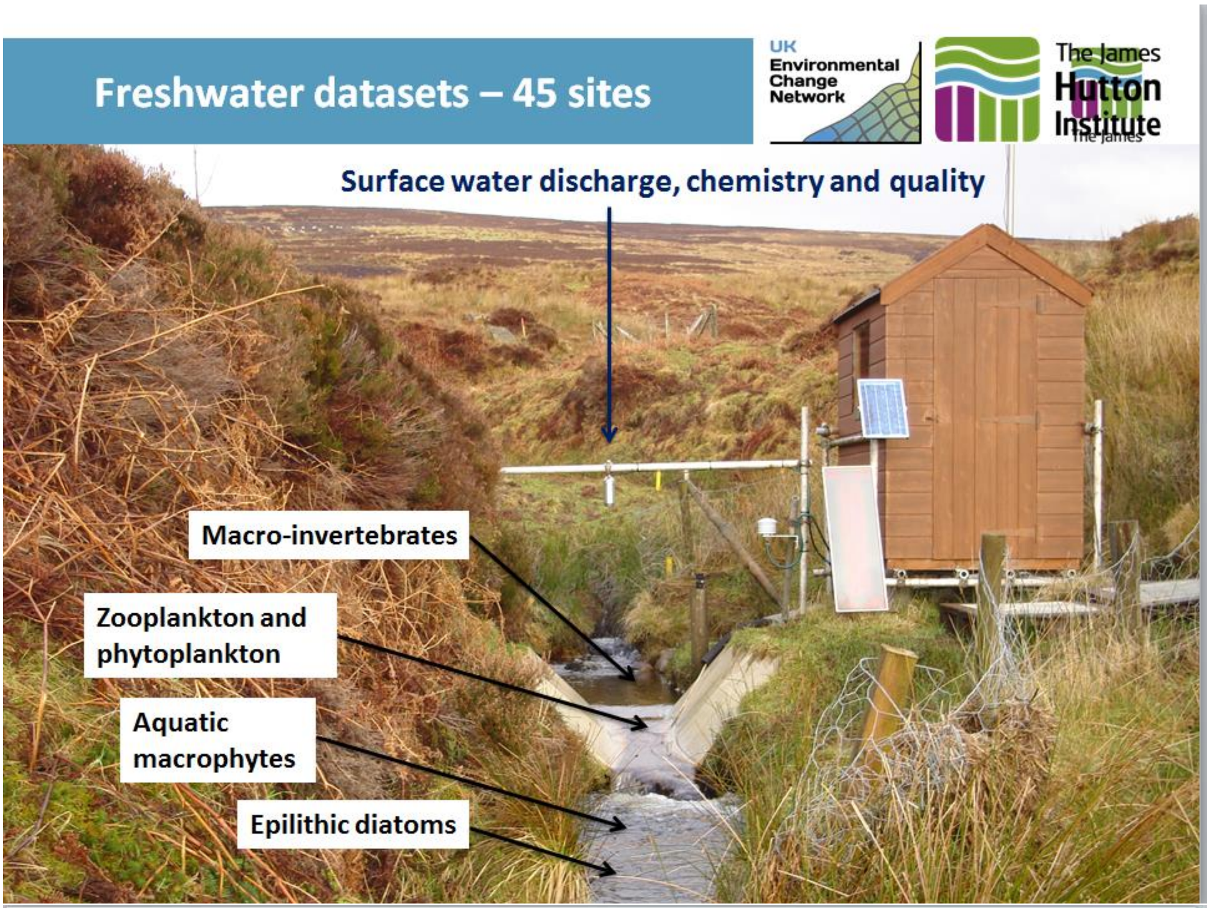
1	Eden (Cumbria)	15	Spey (Fochabers)
2	Esk	16	Tweed (Galafoot)
3	Coquet	17	Eden (Fife)
4	Exe	18	Cree
5	Wye	19	Faughan
6	Lathkill	20	Garvary
7	Cringle Brook	21	Bush
8	Frome	22	Trout Beck (Moor House)
9	Bradgate Brook	23	Coln
10	Bure	24	Lambourn
11	Old Lodge	25	Eden (Kent)
12	Stinchar	26	Ewe
13	Lower Clyde	27	Birnie Burn
14	Allt a'Mharcaidh	28	Owenkillew River

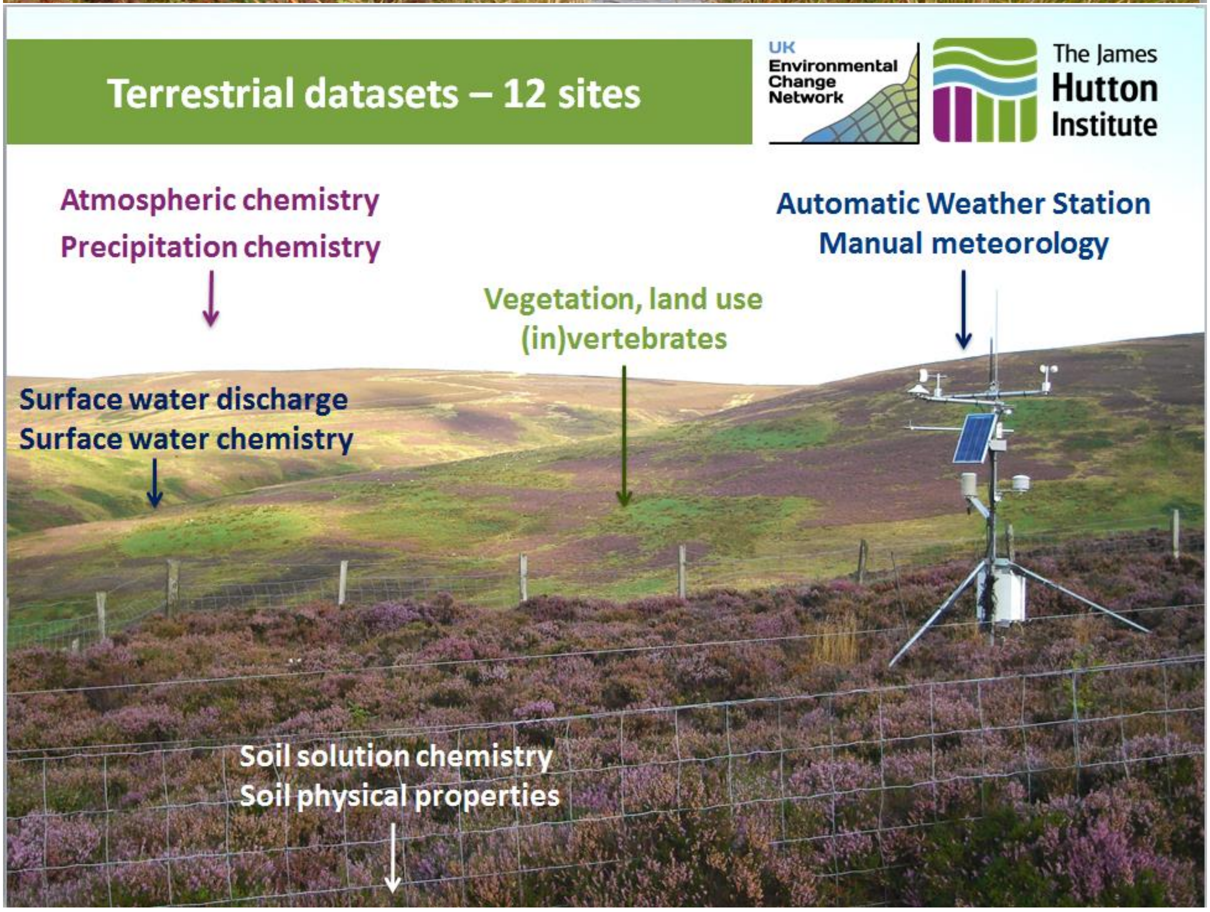
ECN LAKE SITES

■ - Each lake station is indicated by the letter listed below

A	Upton Broad	I	Lochnagar
B	Hickling Broad	J	Loch Lomond
C	Wroxham Broad	K	Loch Katrine
D	Windermere	L	Loch Davan
E	Eshwaite Tarn	M	Loch Kinord
F	Loch Leven	N	Loch Dee
G	Scoat Tarn	O	Lough Neagh
H	Llyn Llagi	P	Lough Erne



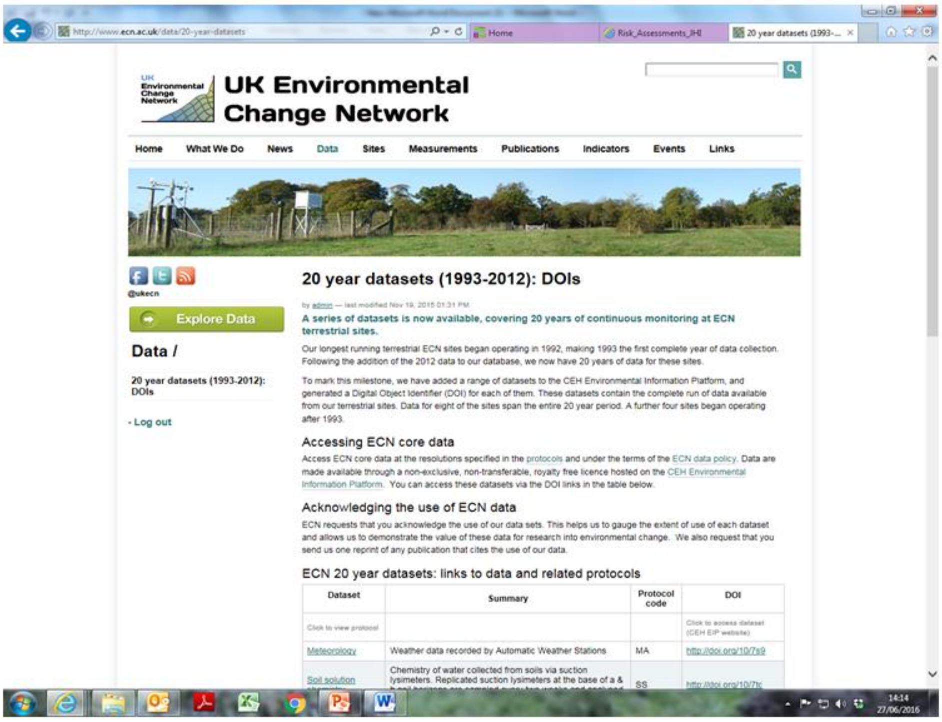

Freshwater datasets – 45 sites
UK Environmental Change Network
The James Hutton Institute
Surface water discharge, chemistry and quality
Macro-invertebrates
Zooplankton and phytoplankton
Aquatic macrophytes
Epilithic diatoms


Terrestrial datasets – 12 sites
UK Environmental Change Network
The James Hutton Institute
Atmospheric chemistry
Precipitation chemistry
Automatic Weather Station
Manual meteorology
Vegetation, land use
(in)vertebrates
Surface water discharge
Surface water chemistry
Soil solution chemistry
Soil physical properties

Terrestrial Datasets: DOI

UK Environmental Change Network

The James Hutton Institute



Glensaugh and Sourhope, UK ECN sites

Changes in management and ecosystem services over 20 years of ECN monitoring

Nikki Dodd, Helen Watson, Donald Barrie, David Hamilton

The Environmental Change Network

The presence of long-term monitoring at ECN sites aids assessment of changes in ecosystem services over the period 1993 to present.
Changes in ecosystem services at Glensaugh and Sourhope, two of the upland terrestrial UK ECN sites are summarised here.

UK ECN terrestrial sites map

The Scottish Government funds research at the James Hutton Institute on the multiple benefits of land management to society.

Acknowledgements:
Photographs : thanks to Carol Taylor and [illegible]

Glensaugh

Glensaugh Research Station of the James Hutton Institute is located to the south west of Aberdeen, on the edge of the Grampian hills and covers over 1100 hectares. The primary land use activity is commercial livestock farming which is supported by an extensive grazing resource.

Ecosystem services:

Decrease in	Driver
Sheep numbers (in line with industry trends) → reduction in feed purchases and decrease in grazing intensity	Changes in agricultural policies in the EU in the late 1980's-1990's
Use of bought in fertilisers over the last 10 years	Increased cost of fertilisers
Deer numbers after November 1994, fairly steady for the last 10 years. 40 deer currently used in an experiment	Attempts to control deer numbers in Scotland, whilst continuing study of deer for informed management

Increase in	Driver
Heather burning in the last 10 years	Change in farm manager
Forestry and agroforestry practices	Grants for multiple biodiversity and landscape benefits
Built landscape and facilities	Expanding areas of research
Alternative energy sources	Grants for renewable energy production
Visitor/educational provisions	Current farm manager

Sourhope

Sourhope farm lies to the south east of Kelso on the western slopes of the Cheviots and covers an area of around 1100 hectares. Between 1946 and 2007, research organisations held leases for the farm - prior to and after these dates, Sourhope was leased to hill farmers.

Ecosystem services:

Decrease in	Driver
Intensive farming productions	Changes in agricultural policies in the EU in the late 1980's-1990's
Use of fertilisers	
Research projects, research visits, experiments, built landscape and facilities after 2007	Sourhope Research Station closed and the lease for the farm was taken up by a hill farmer
Fine wool production (cashmere goats left farm in 2008)	

Increase in	Driver
Sheep stock numbers from 2007	Change in land manager in 2007 brought change in numbers and breeds of sheep
Research into Natural Flood Management (NFM) measures	James Hutton Institute Scottish Government-funded core work on flood mitigation measures

Main changes and drivers

Changes in ecosystem services at Glensaugh and Sourhope have been driven predominantly by government policy, grant-led initiatives and by change in land managers. Public engagement and breadth of research have increased at Glensaugh, whilst Sourhope farm has returned to being a privately-leased hill farm.

Research underpinned by ECN data at Glensaugh

Examples

Nikki Dodd[1,2], Benoit Demars[1], Sarah Dunn[1], Joe Oyesiku-Blakemore[1,3], Javier Perez-Barberia[1]
Glenn Iason[1], Steve Chapman[1]
[1]The James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8QH. [2]School of Geography, University of Leeds, LS2 9JT
[3]School of Biological Sciences, University of Aberdeen, AB24 2TZ
Email: Nikki.Dodd@hutton.ac.uk Website: www.hutton.ac.uk/ecn

UK Environmental Change Network
20 YEARS of data 1993-2013 ECN Terrestrial sites

The James Hutton Institute

University of Aberdeen

University of Leeds

Introduction

The existence of a long-term ECN dataset which covers meteorology, precipitation chemistry and water discharge and changes in vegetation, soils, vertebrates and invertebrates has led to numerous experimental projects being conducted at Glensaugh Research Station by research scientists and students alike. Here, examples are given which show some of the breadth of research underpinned with ECN data at Glensaugh.

Freshwater ecosystem functioning

- The Birnie and Cairn streams have been used in a paired design since 2007 for the manipulation of DOC (sugar cane additions) using a before and after controlled experiment.
- Carbon stable isotopes are used to trace the added DOC through the food web from the bacteria to the macro-invertebrates. Stream metabolism was also measured continuously in both streams for more than one year to quantify seasonal variability and effects of storm flows.
- Additional mesocosms (12 channels) were built in 2009 to study the effect of two stressors and their potential interaction on stream ecology.

Contact: Benoit.Demars@hutton.ac.uk

Forestry, soils and carbon

- Glensaugh is one site at which biodiversity responses of Caledonian pine forest to climate change is being studied through monitoring performance of Scots pine saplings under contrasting climatic regimes in relation to the population of origin.
  Contact: Glenn.Iason@hutton.ac.uk
- Study of carbon dynamics under forestry in agroforestry plots.
  Contact: Steve.Chapman@hutton.ac.uk
- Analysis of dissolved organic carbon (DOC) and nitrogen concentrations in soil water samples, and experimentally determining the portion of DOC that is biodegradable is underway to validate, improve and integrate terrestrial and hydrological Carbon and Nitrogen models.
  Contact: j.oyesiku-blakemore.09@aberdeen.ac.uk


Scots pine saplings ready for planting


PhD students taking soil cores in the field

Muir burn, grazing and biodiversity

- The effects of muir burn (moorland burning) of dry heath and blanket bog on the biodiversity of plants, arthropods and small mammals with and without grazing by sheep and deer are being studied through the establishment of a series of burnt plots.

Contact: Javier.Perez-Barberia@hutton.ac.uk

Modelling hillslope ecohydrological response

- Spatial variability of plants, soil properties and soil moisture were investigated during development of a spatial eco-hydrological model of moorland hillslopes.
- The model was later set up to resemble the ECN target sampling site and surroundings. Model findings suggest that hydrological behaviour is sensitive to the age of *Calluna vulgaris* at the time of burning and the position of burning on the slope.

Contact: N.H.Dodd09@leeds.ac.uk

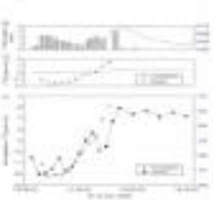

Spatial soil moisture measurements


Model prediction of *Calluna vulgaris* plant age distribution

Understanding flow pathways, mixing and transit times for water quality modelling

- Dunn et al. (2008) investigated how understanding gleaned from hydrochemical data could be used to help underpin the parameterisation of a hydrological and water quality model.
- Waters were sampled from a set of nested sub-catchments to examine how chemical and isotopic characteristics changed across a geomorphic gradient from a steep upland area of rough grazing through to a flat lowland agricultural area.
- As part of the nested system, the Glensaugh ECN site formed a core monitoring point providing baseline historic data for setting up the model and ongoing meteorological and hydrological data to underpin the experimental set-up.

Contact: Sarah.Dunn@hutton.ac.uk


Results of stream event monitoring at Glensaugh 11-13 Nov 2006 showing:
(a) precipitation volume;
(b) δ18O in precipitation and stream water and
(c) cumulative ... on different scales.

Acknowledgements:
Thanks to Javier Perez Barberia, Joe Oyesiku-Blakemore and David Sim for photographs, to Donald Barrie, Carol Taylor, Helen Watson and David Hamilton for support at the farm and to the staff named for contributing details of their projects.

References:
Dunn SM, Bacon JR, Soulsby C, Tetzlaff D, Stutter MI, Waldron S, Malcolm IA. 2008. Interpretation of homogeneity in δ18O signatures of stream water in a nested sub-catchment system in north-east Scotland. Hydrological Processes, 22: 4767-4782. DOI: 10.1002/hyp.7088

Conclusions

There is a wealth of data, facilities and support at Glensaugh Research Station for researchers to build on or explore the findings of ECN monitoring. There is potential for continued establishment of a range of types of experimental plots and laboratory experiments, supported by research staff and land manager site knowledge and on-site facilities such as laboratories, metabolism rooms, calorimeter chambers, meeting rooms, computing facilities and residential accommodation.

Glensaugh agroforestry experiments (1988-2001).

Agroforestry is a system of land management which combines livestock farming and forestry: trees are grown for timber on the same land as that used for animal production. The growing of trees on farms diversifies and sustains production leading to increased social, economic and environmental benefits for land users at all levels.

Silvopastoral agroforestry is a system in which trees are planted at wide spacing into grazed, permanent pastures. Silvopastoral agroforestry is also known as wood pasture.

Silvopastoral agroforestry has been shown in the UK to provide a number of benefits to farmers. With good management, trees can be grown to produce timber (or for firewood, craftwork, artwork) with no reduction, or only a small reduction, in agricultural production from the same piece of land. This compares with more conventional farm forestry in which land must be allocated separately to woodland, resulting in a loss of agricultural area and agricultural production. The total return from the land is, therefore, potentially greater from agroforestry, although the required level of management input is greater than in conventional systems.

Benefits

- Agroforestry provides both biodiversity and landscape benefits.
- Creates welfare benefits to grazing livestock through the provision of shelter and shade.
- Tree shelter can encourage better pasture growth.
- Generates new opportunities for wildlife.
- Recreates historical landscapes, similar in appearance to the traditional forests in which animals grazed.

Agroforestry research plots were planted at Glensaugh in 1988. Three tree species were selected and planted at different densities to compare their performance.

- Scots Pine (Pinus sylvestris) planted at a density of 400 trees per hectare.
- Hybrid Larch (Larix eurolepis) planted at a density of 100, 200 and 400 trees per hectare (lower densities have now been felled).
- Sycamore (Acer pseudoplatanus) planted at density of 100 and 400 trees per hectare.
- Control plots planted at conventional forestry densities of 2,500 trees per hectare.
- Commercial ewes, with lambs at foot in spring and early summer, are grazed in and around the trees between April and November.

Results: By the time the experiment ended in 2001, there was no measurable reduction in sheep output, although production of grass in closed canopy plots of larch and sycamore has subsequently declined. In addition, a new timber source had been created and a positive impact made on the landscape, and its biodiversity value.

Ongoing: Suckler cows were introduced to the Scots Pine plot in 2008 as part of an experimental grazing project to determine what benefits tree pasture will bring for the cattle and to identify any disadvantages to the trees.

More details: http://www.hutton.ac.uk/sites/default/files/files/glensaugh_infosheet.pdf

Welcome to Glensaugh's Self-Guided Trail and some top tips.

MANAGEMENT MATTERS!

Bring in some vision as well as value

- Your long and short-term aims need early consideration.
- Your management choices involve a balance between maintaining the grazing, and the timber value of the trees.

Benefit: You can get more grazing from an agroforestry system, compared with an open hill grazing system. Tree shelter can encourage better pasture growth, feeding, and animal welfare.

Benefit: Trees and woodlands can add greatly to the landscape quality of the countryside and its tourism value. The careful choice of species and planting pattern can add to this effect.

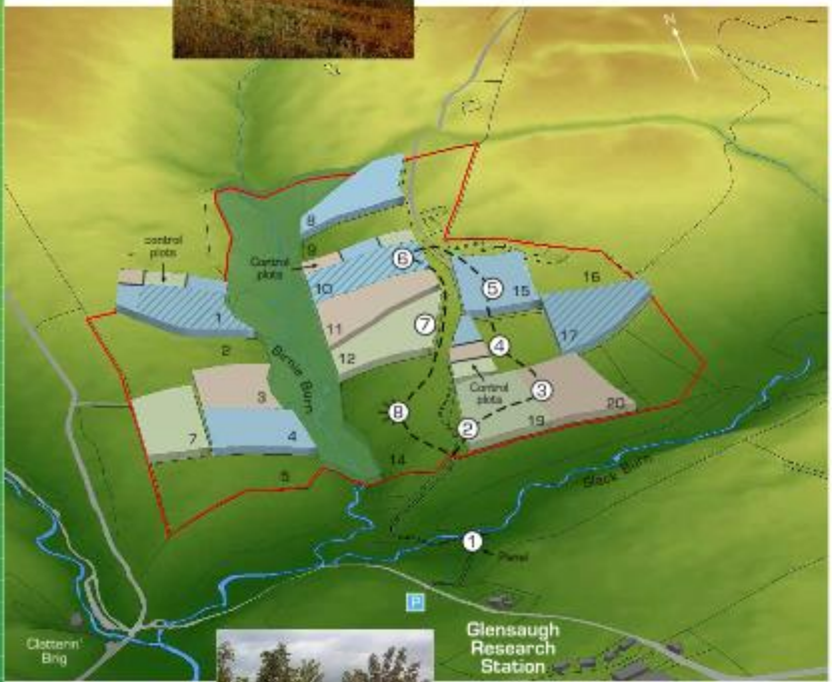
PLANNING & TREE SELECTION

Choosing which tree species will depend on your aims - economic, social, or environmental. Do your research carefully, and seek advice from local woodland management specialists.

- Whichever species you choose, obtain whips of local provenance, from a local tree nursery source. The saplings are better adapted to local conditions and will grow better. Replant (beat up) unsuccessful whips after 1 year.
- Planting parallel with the contours, and avoiding straight lines enhances the landscape value of tree planting. Otherwise, plant in a grid and thin selectively later, for a more natural look.

Benefit: Trees add biodiversity value to integrated systems - increasing the variety of species present, as well as the numbers of individual species. Especially, trees benefit less visible insects, bats, birds and lower plants.

Benefit: Both hardwoods and softwoods on a farm can bring socio-economic benefits from diversification, within rural areas. Every part of a tree can be used for a variety of purposes, e.g. craftwork, art/photography, firewood, or timber.



TREE PROTECTION

Use plastic tubes and/or netmesh protectors to give protection from browsing animals (hare, deer, rabbits, and livestock), and wind exposure. Be aware they are costly and labour intensive to maintain.

The original rigid plastic tubes caused damage to tree form of the Hybrid larch. After 6 years we replaced the tubes with netmesh, but the trees never recovered. Generally, protection can be removed after 10-12 years depending on species.

- Use netting tree protectors for all conifers, not rigid plastic tubes.
- Hybrid larch is less susceptible than Scots pine to de barking by lambs; Sycamore appear unattractive to sheep.

TREE PRUNING

Pruning reduces the tree canopy, allows transmission of light for pasture growth, and improves the timber value. At Glensaugh the knots are much larger than normal - pruning took place too late. Even so, although taking more time and effort, all pruning on Glensaugh was achieved with hand tools.

Once the canopy closes, the most likely plants to colonise after pruning are pernicious weeds e.g. nettles and thistles, and pruning can be hazardous requiring cherry pickers and/or chainsaws.

- Decide early on whether you want a timber resource, or to continue under-grazing
- Similar issues apply to pruning hardwoods or softwoods.

- Use the rule of thumb - when a branch gets to thumb thickness it's time for pruning.
- Generally aim to prune to a level 50% of the trees top height.
- Thin branches can be left to decompose and recycle nutrients to the soil, without being a hazard for people/livestock.

TREE THINNING

Selective thinning is an option, enhancing the amenity and landscape value of the plot, the grazing, and the remaining timber value. At Glensaugh, no thinning was considered during the early experimental phase.

- Use selective thinning strengthens tree stems - giving protection from wind and snow damage.

Stop 3. Fettercairn distillery

Situated under the Grampian foothills in the Howe of Mearns, Fettercairn town's name is loosely based on the phrase "the foot of the mountain". Fettercairn Distillery was founded in 1824 by Alexander Ramsay, owner of the Fasque estate, who converted a corn mill at Nethermill into a distillery. After losing his fortune, Alexander was forced to sell the estate to the Gladstone family in 1829. John Gladstone's son William Gladstone, went on to become Prime Minister and Chancellor of the Exchequer and was instrumental in passing various reforms on the taxation of whisky. In 1973 Whyte & Mackay acquired Fettercairn distillery and it has remained with the company since.

As we drive from Fettercairn to the A90: Class 2 farmland

Here we can see typical management and cropping.

<u>Scottish production in Eastern Scotland (taken from nfus.org.uk)</u>

Cereals: Cereal farms are concentrated in the east of the country where the best quality land tends to be found. In 2016, 462,000 hectares of cereals and oilseeds were grown in Scotland. 286,000 hectares of barley were grown and 110,000 hectares of wheat. There were 31,000 hectares of oats and 30,000 hectares of oilseed rape.

1.9 million tonnes of barley were produced and one million tonnes of wheat were produced in 2015. More than 12% of the UK cereal area was grown in Scotland. The UK is the third largest cereal producer in the EU after France and Germany.

The main cereal crop in Scotland is barley and 28% of the UK's barley area is in Scotland. 35% of it goes into malting. 55% goes for animal feed. There are two types of barley: winter barley is sown in the autumn and spring barley is sown in March or April. 80% of the Scottish crop is spring barley. Milling wheats grown in Scotland are mainly used for biscuit making. Wheat is also used in distilling and for animal feed.

Potatoes: Most of the seed potatoes for the UK potato industry are grown in Scotland. In 2016, just under 28,000 hectares of potatoes were grown in Scotland. Scottish potato output was over 1.03 million tonnes in 2015.

Oilseed Rape: Scotland's farmers produced over 148,000 tonnes of oilseed rape in 2015. Oilseed rape goes towards producing oil for cooking but also for producing biofuels.

Fruit and Vegetables: There are 21,000 hectares of vegetables and soft fruit grown in Scotland. Scottish producers produce more than 2900 tonnes of raspberries and 25,000 tonnes of strawberries; 231,000 tonnes of carrots; 64,000 tonnes of turnips; 34,000 tonnes of peas and 14,000 tonnes of Brussels. Soft fruit production tends to be concentrated in fertile areas, for example Tayside and Angus.

Stop 4: The Centre for Sustainable Cropping and the Balruddery IBZ

The postcode for the Balruddery farm is: DD2 5LL (ie that's what UK sat navs work from).

The Centre for Sustainable Cropping Platform is based at Balruddery Farm near Dundee, Scotland and is run by the James Hutton Institute. The farm platform comprises a 42 ha block of six fields, established in 2009 to integrate cross-disciplinary research on sustainability in arable ecosystems.

The platform provides a whole systems framework for designing and testing cropping systems to optimise yield and environmental health for long-term food security. We aim to enhance biodiversity for ecosystem services, and reduce the environmental footprint of crop production by minimising losses and increasing the efficiency of resource use.

It is the first of its scale in the UK and provides an open research facility to test and demonstrate the economic, ecological and environmental trade-offs in sustainable land management over many decades.

Access to all the resources of design, layout, publications and the data are available at: http://csc.hutton.ac.uk/

The Centre for Sustainable Cropping:

Results from the first crop rotation 2011-2016

Find out more at our website csc.hutton.ac.uk, on twitter @huttonCSC, or email csc@hutton.ac.uk

Aims & Background

Arable intensification has resulted in increases in yield, but only at heavy environmental cost: greenhouse gas emissions, water pollution, loss of biodiversity and degraded soil structure. This has raised concerns about the long-term impacts on farmland ecosystems and sustainability of food production. We are designing an integrated management system to balance inputs and yield against environmental health, biodiversity and ecosystem processes.

The site is located at Balruddery Farm, a 170 hectare arable farm, seven miles west of Dundee on the lower, south facing slopes of the Sidlaw Hills .

Latitude: 56.4831
Longitude: -3.1324
Elevation: 70-124 m above sea level
Average rainfall: 800 mm
Day degrees above 5.6 ° C: 1100-1375
Wind speed: 2.6 - 4.4 m/s
Soil type: sandy loam
Top soil depth: 25 - 38 cm
Top soil stone content: 5 - 12%

Find us at DD2 5JL

This long-term platform is funded by Scottish Government and is an open access resource for arable research.

Site Design

The platform comprises 6 fields over 42 hectares. Each field is divided into two: integrated management on one half is compared against standard commercial practice on the other. 3-5 varieties of the six crops are sown in each field half and key system indicators are monitored throughout each growing season.

Integrated Management System

1. Soil. Aim: improve soil structure by increasing organic matter content, to aid water retention/infiltration, enhance root growth, support soil processes such as litter decomposition and nutrient cycling, and reduce pollution from leaching, run-off and erosion.

In practice: non-inversion tillage for 1st rotation, now direct drilling; green waste compost amendments (35 t/ha for 1st rotation, now 10 t/ha); incorporation of crop residues, cover cropping (oil radish before potatoes), tied-ridging in potatoes.

2. Biodiversity. Aim: enhance abundance and diversity of farmland wildlife, particularly arable plants and associated invertebrate foodwebs, to improve ecosystem services such as pollination, natural enemy control of crop pests and carbon/nutrient cycling.

In practice: targeted weed control to allow an understorey of broadleaved weeds while controlling grass weeds; species rich wildflower margins for beneficial insects; threshold monitoring for pests and disease and IPM strategies to reduce negative impacts on non-target insects.

3. Yield. Aim: maintain crop yields at levels comparable with standard commercial practice but with less mineral fertiliser and other agrochemical inputs.

In practice: improve soil structure to reduce losses of nutrients and enhance root growth; use of legumes to fix atmospheric nitrogen (field beans and clover under-sown in spring barley; fertiliser rates calculated from Soil Nitrogen Supply.

Developments

The development of a more economically and environmentally sustainable cropping system is an iterative process, incorporating new practices as they become available.

Specific areas that we would like to develop over the coming rotations include:

- Renewable sources of plant nutrients
- Opportunities for more cover cropping and intercropping
- Better weed management for beneficial plants and their associated insects
- Integrated Pest and Disease Management options

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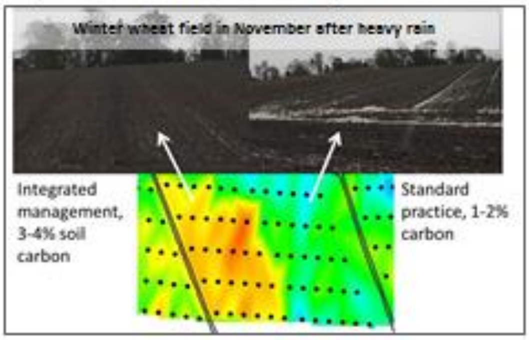
Soil Carbon

Soil structure is assessed by carbon content and the shear vane test for soil strength. No differences in shear strength were found between treatments, suggesting that more soil organic matter in the integrated management system may help ameliorate increases in soil strength due to reduced tillage. Soil carbon content was higher under integrated management (3-4%) after 4 years of organic amendments compared to 1-2% in standard management treatments.



Better drainage results in drier, warmer soil in early spring, and therefore more rapid crop development. Water retention in dry summers is also improved.

Visual Evaluation of Soil Structure (VESS)

Soil structure affects root penetration, water availability and soil aeration. VESS is a simple spade test that provides scores on soil structural quality and was developed by an international group of soils specialists.

Integrated management | Standard management

Sq1-2: mix of porous, rounded aggregates (2 - 7mm) which are easy to break/crumble

Sq2-3: most aggregates break with one hand, but lower porosity and some clods present

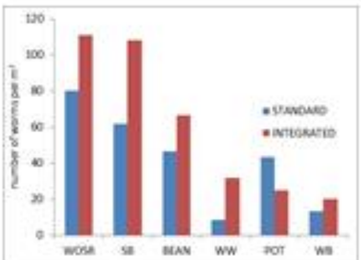
Integrated management resulted in soil with greater porosity and finer aggregates than standard practice.

A full description of the method can be found at http://www.sruc.ac.uk/vess

Earthworms

Earthworms play a key role in improving soil structure by burrowing and mixing soil. They aid decomposition and nutrient cycling, and redistribute nutrients in the soil profile. The beneficial effects of earthworm activity stimulate root growth and improve nutrient and water uptake efficiency by plants.

On average, across all fields, there were more worms in the integrated management treatments (85 per m² to a depth of 10 cm) than under standard management (60 per m²). There were also big differences between crops: potato and winter cereals had fewer worms than spring barley, winter oilseed or beans.



Litter decomposition

Soil biodiversity has an impact on carbon turnover and nitrogen dynamics, processes essential to help maintain yields in low input systems.

We use litter decomposition rate as an indicator of these processes. Decomposition is calculated from the loss in mass of tea bags, buried in after sowing and retrieved just before harvest. Rates are faster in the integrated system where soil organic matter and microbial activity is greater.

The method is described at http://www.teatime4science.org/ for anyone to try. Or have a look at http://www.farmersguild.org/soil-my-undies-challenge.html for a fun alternative using cotton underpants!

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Plant biodiversity

Intensive farming practices have a negative impact on farmland biodiversity. Many plant species have declined in abundance, taking with them a diverse array of insect herbivores, detritivores, pollinators and natural enemies that depend on them for food and shelter. Declining weed diversity is therefore likely to have serious consequences for ecosystem services including carbon and nutrient cycling, natural enemy control of pests and pollination.

At the CSC, we aim to enhance biodiversity by allowing an understorey of beneficial broad leaved weeds within fields whilst controlling grass weeds and minimising competition with the crop. Margins are also sown with a diverse mix of wildflower species to provide resources for pollinators and natural enemies.

Both broad leaved and grass weeds were more abundant in the integrated management system – weed dry weights just before harvest were 40 g/m² (grass) and 20 g/m² (broadleaved) compared to 16 g/m² and 9 g/m² in the standard treatment.

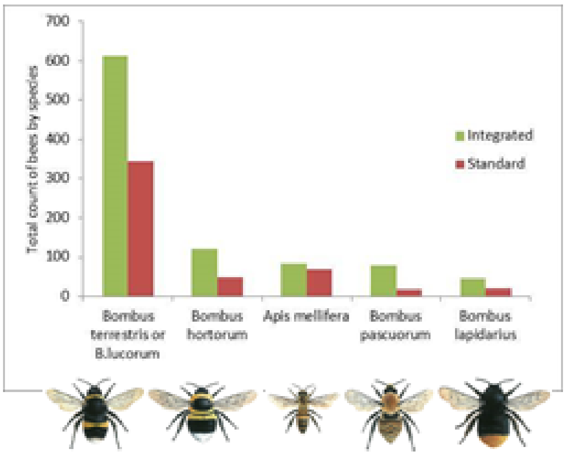
More emerged weeds produces a greater return of weed seeds to the seedbank. We measured weed seed abundance in the soil every year and found that integrated crop management had an overall positive effect on the numbers of broadleaved weed seeds, but there was no increase in densities of grass weeds over the course of the rotation.

Achieving a balance between managing weeds for biodiversity and minimising competition with the crop is a particular challenge in reduced tillage systems and there is much scope for more research and development in this area.

Insect biodiversity

Arable plants support a diversity of invertebrates that make up arable food webs and represent a wide range of different functions including herbivores, seed predators, decomposers, and natural enemies. The interactions between these invertebrates, plants and higher trophic groups such as birds and mammals, result in ecosystem services which are an important component of sustainable farming.

A key ecosystem function provided by insects is pollination, the annual economic value of which is estimated at $153 billion globally. Declining pollinator populations have the potential to seriously affect yields of insect-pollinated crops and populations of wild plant species.



At the CSC, we monitor pollinator activity using standard transect walks and pan traps. Caged and uncaged flowering bait plants are also used to measure pollination rates.

During the first crop rotation (2011-2016), more bees were recorded in the integrated management treatments and in the wildflower margins surrounding these half fields. More weeds in fields and a greater diversity of flowering plants in the field margins therefore boosted the activity of bee pollinators in these areas.

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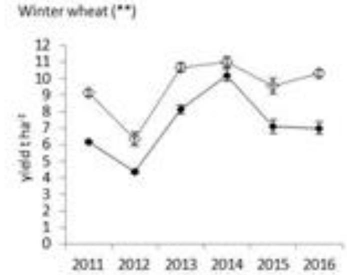
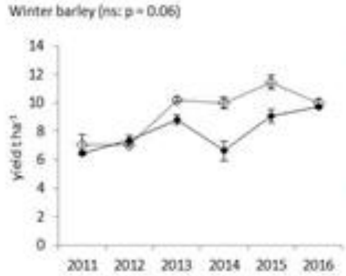
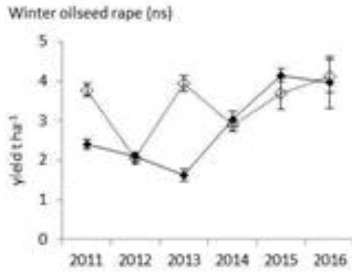
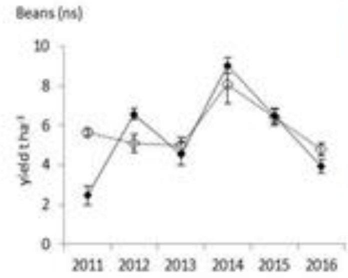
Crop yields

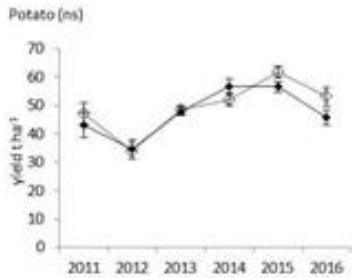
Yields were maintained at levels comparable to standard commercial practice for all crops except winter wheat where reduced inputs resulted in a 2 t/ha yield penalty. More work is required to close the gap for winter wheat, but other crops faired reasonably well under the integrated management system. Trends over time and for each crop variety are shown below. Solid lines = integrated management; dashed lines = standard practice.

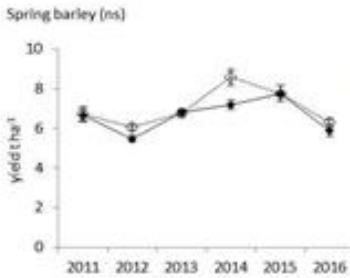












	yield average (t/ha)		
	Variety	Integrated	Standard
Winter barley	Retriever	8.7	9.8
	Sequel	8.3	9.4
	Mixture	8.1	9.0
	Saffron	7.6	9.6
	Cassata	7.0	8.9
Winter wheat	Viscount	6.8	10.4
	Istabraq	7.3	9.6
	Consort	7.0	9.5
	Beluga	8.1	9.3
	Alchemy	6.9	8.9
Winter oilseed	Catana	3.5	3.9
	Flash	3.0	3.5
	NK Grace	2.8	3.3
	Excalibur	2.7	3.1
	Lioness	2.7	3.4
	Cracker	2.2	3.0
Field beans	Maris Bead	6.6	6.2
	Boxer	6.2	5.5
	Fanfare	6.0	5.7
	Fuego	6.0	6.2
	Pyramid	5.3	6.0
	Babylon	5.1	5.4
	Ben	4.9	5.6
	Tattoo	3.7	5.3
Potatoes	Lady Balfour	54.3	53.7
	Maris Piper	48.3	49.6
	Vales Sovereign	47.8	51.5
	Cabaret	45.5	50.1
	Mayan Gold	37.7	39.7
Spring barley	Concerto	7.4	7.3
	Waggon	7.0	7.3
	Westminster	6.5	6.9
	Optic	6.3	6.7
	Mixture	6.3	7.0

Financial margins

Yield and sale price, input costs, fuel use and tractor time will be used as indicators to estimate the financial implications of converting to an integrated management system. Initial results suggest that, for the first 6 years, there were no overall significant differences in fuel use or tractor time between management systems, though this may become more apparent in future rotations now that we have moved to direct drilling. On average, yields were also no different between systems, apart from the winter wheat crops. These indicators will be converted to monetary values for each year of the rotation to estimate relative differences in financial margins and the overall costs and benefits of our integrated management system.

The Scottish IBZ buffers site

Hyp: Eco-engineered riparian margins can improve integrated, multiple benefits in intensively managed farmlands

Marc Stutter, Tim George, Jenni Stockan, Carol Taylor, Helen Watson.

With thanks to: Paul Neave, Linda Nell, Cathy Hawes

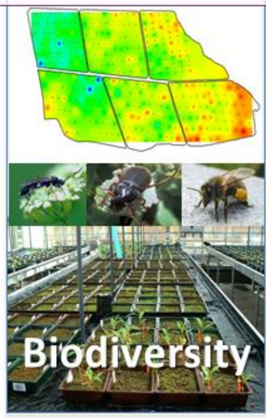
The James Hutton Institute

Location: Centre for Sustainable Cropping

The James Hutton Institute

Buffer site before installation: typical straightened stream in intensive arable farmland

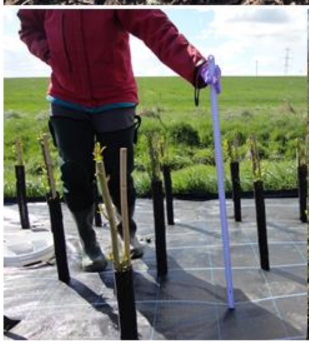
A whole-systems approach for optimising crop production, biodiversity and system health for long term food security.



IBZ installation 2015

The James Hutton Institute



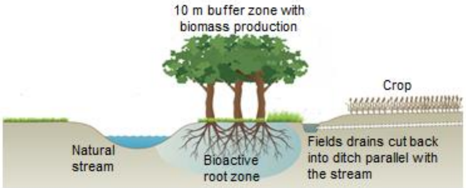
.....6 months after establishment

The James



Eco-engineering riparian buffers

Bringing the most benefits from precious space in farmed landscapes



Issues with conventional riparian margins:

- The perception is often of land taken out of production
- No incentive to do more than the minimum requirements
- Soil erosion crosses the buffer
- Dissolved nutrients often pass under buffers through drains
- Buffer soils become nutrient enriched with limited plant and animal biodiversity

A zoned buffer:

- Cropping continues on the field slope
- The erosion slope is interrupted by a ditch into which field drains are broken back from the stream
- The ditch increases the residence time of nutrient-rich waters
- Planted trees introduce a bioactive root zone, taking up nutrients into biomass, producing an energy crop, introducing habitat and stream shading
- The stream bank remains a protected ecological zone

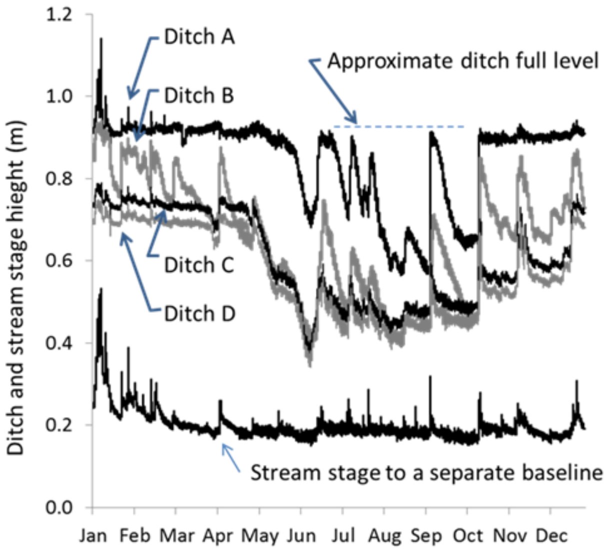
Site characteristics and data

The James

Year of establishment	2014
Coordinates	56°28'47.0"3°07'32.0"
Altitude a.s.l.	50 m
Upslope field size	4.5 ha bounded field area but with ~9.6 ha catchment
IBZ size	300 m^2
IBZ:field ratio	0.7%
Adjacent cropping	grain, potatos, beans
Annual averaged precipitation	705 mm
Average January temp.	3.2°C
Average July temp.	14.7°C
Climate data source	On-site met station
Main soil type	
Tree species	A. glutinosa (L.), Salix spec.
Hydrology data	Soil moisture, ditch water level (semi-continuous)
Soil data	2015 vs 2017: soil C, N, pH, microbial C, extr. NO3, NH4, SRP, DOC
Soil solution data	Monthly SRP, NO3, DOC, TDP, TDN suctions cups, then piezometers (triplicate field vs buffer, 10 cm and 40 cm)
Tree data	Standing above ground biomass in 2017, leaf, stem C, N, P contents and stocks
Biodiversity data	Invertebrates by pitfall and vortis suction traps seasonally (beetles, spiders by number; carabids to species). Vegetation by quadrat, vascular plants by species and % cover, species richness.

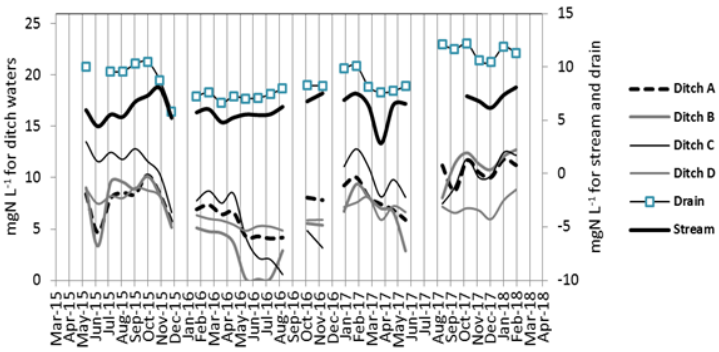
Ditch levels

- Ditch A commonly full, ditches B, C, D filling/emptying more rapidly
- Is there a natural flood benefit for temporary additional runoff water storage in the ditches



Ditch, soil drain and stream chemistry

	Nitrate range mgN/L
Ditch A (willow)	4.1-11.8
Ditch B (willow)	0.1-12.7
Ditch C (alder)	0.6-13.5
Ditch D (alder)	4.8-9.0
Soil drain	5.8-12.2
Stream	2.8-8.0



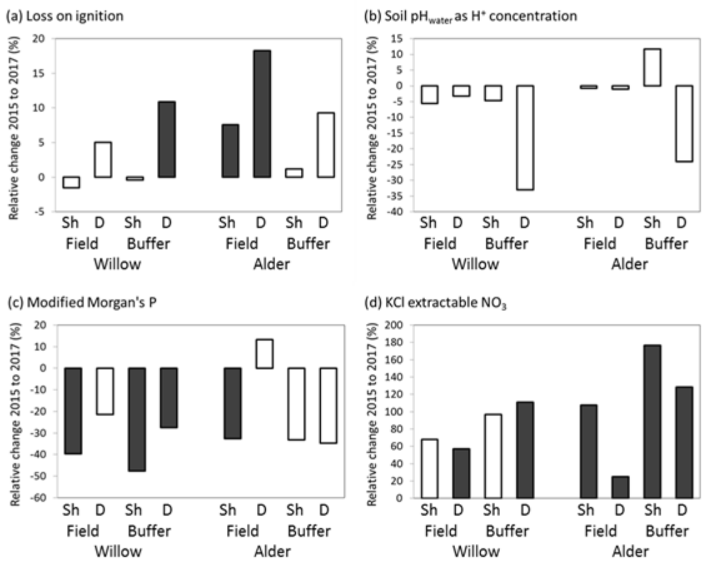
- In summer 2016 NO_3 concentrations in the ditches became greatly depleted relative to drain concentrations indicating that summer biological activity in ditches B and C provided assimilative or degradative removal of NO_3 from field runoff in the ditch system before the tree zone, but that this was not consistent spatially.

Soil solution chemistry: 2015-2017 suction cup samplers

All mg/L	Field mean values: Shallow		Field mean values: Deep		Buffer mean values: Shallow		Buffer mean values: Deep		ANOVA, p values: Field (F) vs buffer (B)	ANOVA, p values: Shallow (Sh) vs deep (D)	ANOVA, p values: Willow (W) vs alder (A)	Overall R^2adj
TDN	3.5	a	3.8	a	10.3	a	6.2	a	*	ns	ns	4
TDP	0.45	a	0.44	a	1.32	a	0.47	a	ns	ns	*	12
NO3-N	1.8	b	2.4	ab	5.5	a	5.2	ab	*** (B>F)	ns	*** (A>W)	30
SRP	0.37	a	0.37	a	1.23	a	0.40	a	ns	ns	*	13
DOC	10.8	a	11.0	a	9.5	a	8.9	a	ns	ns	ns	<1

- 'Field' (reference) locations turned into grass margin vegetation at upper buffer edge – need new reference for field conditions
- 'Buffer' sites within trees had higher NO_3 (esp alders) and topsoil SRP than above the ditch, but less DOC in the tree area than above the ditch
- Generally the site is dry and suction sampling ofetn failed to see water

Soil chemistry: 2015 vs 2017 change in time



- Increases variably in loss on ignition between 2015-2017.
- Modified Morgan's P (agronomic P index) showed decreases, some significant.
- Soil extractable NO_3 showed large significant increases

Black bars indicate statistically significant change in time; Sh = shallow soil (10 cm), D = deep (40 cm).

Tree biomass at 2017 (means and 95%ile range)

	Plot A, Willows	Plot B, Willows	Plot C, Alders	Plot D, Alders
No trees/plot	205	198	36	55
Total biomass DM (tonnes ha^{-1})	40 (32-48)	17 (7-28)	2 (1-3)	10 (6-13)
% attributed to leaf	13	18	18	12
Total biomass C (tonnes ha^{-1})	19 (18-19)	8 (7-9)	1 (1-1)	5 (4-5)
% attributed to leaf	13	18	18	12
Total biomass N (kg ha^{-1})	458 (339-579)	201 (137-266)	16 (12-21)	70 (59-81)
% attributed to leaf	26	32	63	52
Total biomass P (kg ha^{-1})	70 (61-78)	30 (25-37)	1 (1-2)	4 (4-5)
% attributed to leaf	17	27	74	61
Topsoil C stock (tonnes ha^{-1})[1]	70 (58-83)	67 (52-84)	65 (54-76)	65 (54-78)
Topsoil KCl extract NO_3 (kgN ha^{-1})	136 (108-166)	85 (48-125)	32 (19-48)	64 (36-97)
Topsoil Mmorg extract P (kgP ha^{-1})	43 (32-56)	29 (17-43)	16 (10-23)	23 (18-29)

- A strong and a weak growth plot of each alder and willow (shade, deer attack)
- Above ground biomass C, N, P for 2 years was near equivalent to that of 9 years poplar growth in U.S. (Fortier et al. 2015)
- Biomass N and P uptake far greater in willow than alder and alder much of it is in leaf ie recycled to soils.

Biodiversity

Taxonomic group for pitfall traps	Integrated buffer zone	Conventional riparian margin
Coleoptera	10.33	14.46
Araneae	12.67	14.83
Opiliones	7.92	1.21
Collembola	24.08	19.88

- Pitfall trapping showed carabid activity-density and species richness were significantly higher in controls (adjacent grass margins not utilising the IBZ design) compared to eco-engineered margins.
- Total invertebrates, as sampled by pitfall trapping, showed no differences between control and IBZ buffers, nor between alder and willow plots of the latter.
- Plant species richness and diversity similiarly show no difference between alder and willow plots.
- 28 months since establishment is considered a very short time over which to expect changes in habitat and biodiversity

Comments from farmers

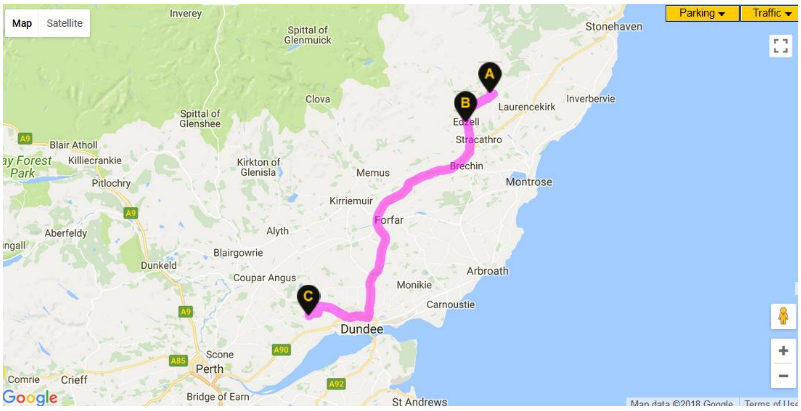
Why not invest the money in measures in the field? Can that have more multiple benefits?

Will harvesting the biomass be allowed under the CAP Ecological focus areas?

Don't the drains benefit from good flushing that will not occur if you break the drains into the ditch? Then the field may get wetter and with more saturation-excess erosion.

Is it realistic to harvest the biomass from these? Will it need a machine, can it be done by hand? Maybe for farms with a biomass boiler it might be worthwhile

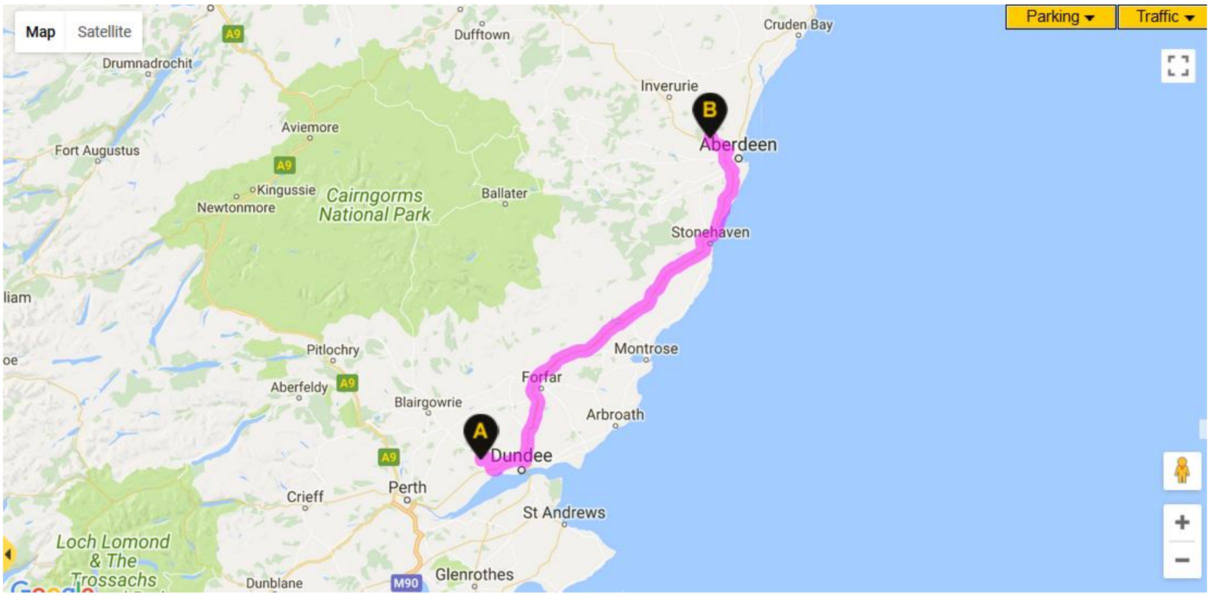
Directions: Fettercairn to Balruddery DISTANCES IN KM



Distance	Directions ☑ Include points of interests (eg services)	Total	
0.0	**Start:** 39 Distillery Rd, Fettercairn, Laurencekirk AB30 1YB, UK Head east on Distillery Rd towards Dowrie Pl	0.0	Show map
0.3	Continue onto School Rd	0.3	Show map
0.1	At the roundabout, take the 2nd exit onto Main St/B966 Continue to follow B966	0.5	Show map
8.1	Turn right onto Dunlappie Rd	8.6	Show map
0.2	Turn left onto The Dr	8.8	Show map
0.0	**Arrive:** The Shieling, The Dr, Edzell, Brechin DD9 7XX, UK	8.8	Show map
	Section time: 11 min 34 s, Total time: 11 min 34 s		
0.0	**Start:** The Shieling, The Dr, Edzell, Brechin DD9 7XX, UK Head north-west on The Dr towards Dunlappie Rd	8.8	Show map
0.0	Turn right onto Dunlappie Rd	8.8	Show map
0.2	Turn right onto High St/B966 Continue to follow B966	9.0	Show map
5.4	At the roundabout, take the 3rd exit and stay on B966 **Brechin B966** **Edinburgh (M90)** **Dundee A90**	14.5	Show map
0.5	At the roundabout, take the 2nd exit onto the A90 slip road to Dundee/Edinburgh/M90 **Edinburgh (M90)** **Dundee A90**	15.0	Show map

0.2	Merge onto A90	15.2	Show map
40.0	At the roundabout, take the 2nd exit and stay on A90 Go through 1 roundabout	55.2	Show map
1.6	Continue straight onto Kingsway/A90 **Edinburgh (M90)** **Perth A90**	56.8	Show map
2.3	At the roundabout, take the 2nd exit onto Kingsway W/A90	59.1	Show map
1.6	Take the A923 exit towards City Centre/Coupar Angus/Birkhill /Lochee **City Centre** **Coupar Angus A923** **Birkhill** **Lochee**	60.7	Show map
0.2	At the roundabout, take the 3rd exit onto Coupar Angus Rd/A923 Continue to follow A923 **Coupar Angus** **Blairgowrie A923** **Birkhill**	61.0	Show map
6.4	Turn left	67.4	Show map
1.3	Continue onto Benvie Rd	68.6	Show map
0.5	Turn right to stay on Benvie Rd	69.1	Show map
0.2	Turn right onto Berryhill Rd	69.3	Show map
2.0	**Arrive:** Balruddery Farm, Dundee DD2 5LL, UK	71.3	Show map
	Section time: 53 min 18 s, Total time: 1 h 4 min		

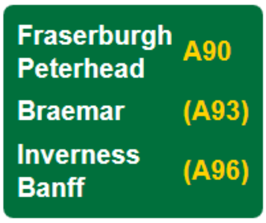
Directions Balruddery to Aberdeen airport (beware peak time traffic in Aberdeen ~5pm, but there's plenty of time allowed!). DISTANCES IN MILES I FORGOT TO CONVERT IT!



From Balruddery Farm, Dundee DD2 5LL, UK **to:** Airport Road, Aberdeen AB21, UK
Distance: 78.0 miles (show in km) | **Time:** 1 hr 41 min

Distance	Directions ☑ Include points of interests (eg services)	Total	
0.0	**Start:** Balruddery Farm, Dundee DD2 5LL, UK Head north towards Berryhill Rd	0.0	Show map
0.2	Continue onto Berryhill Rd	0.2	Show map
1.0	Turn right onto Benvie Rd	1.2	Show map
1.9	Turn left onto A90	3.1	Show map
1.0	At the roundabout, take the 2nd exit onto Kingsway W/A90	4.1	Show map
0.8	At the roundabout, take the 2nd exit and stay on Kingsway W/A90	4.9	Show map
2.5	At the roundabout, take the 2nd exit onto Kingsway/A90	7.4	Show map
1.4	Turn left onto Forfar Rd/A90 Continue to follow A90 Go through 1 roundabout **Aberdeen Forfar A90**	8.8	Show map
1.0	At the roundabout, take the 2nd exit and stay on A90	9.9	Show map
60.4	At the roundabout, take the 2nd exit onto Stonehaven Rd/A90 **Fraserburgh Peterhead A90** **Braemar (A93)** **Inverness Banff (A96)**	70.3	Show map

0.1	Ghillies Lair Aberdeen	70.3	Show map
0.2	At the roundabout, take the 2nd exit onto S Anderson Dr/A90	70.5	Show map



2.3	Toby Carvery Cocket Hat Aberdeen	72.8	Show map
0.7	At the roundabout, take the 2nd exit onto N Anderson Dr/A90	73.6	Show map
0.4	At the roundabout, take the 2nd exit and stay on N Anderson Dr/A90	73.9	Show map

0.7	At the roundabout, take the 1st exit onto Great Northern Rd/A96 Continue to follow A96	74.6	Show map

1.3	Slight left towards Inverurie Rd/A96	75.9	Show map
0.1	Slight left onto Inverurie Rd/A96 Continue to follow A96 Go through 1 roundabout	75.9	Show map
0.8	Keep right to stay on A96	76.8	Show map
0.2	Turn right onto Dyce Dr	77.0	Show map
0.8	Turn left onto Airport Rd Destination will be on the left	77.8	Show map
0.2	**Arrive:** Airport Road, Aberdeen AB21, UK	78.0	Show map