Darwin Initiative
Overseas Territories Challenge Fund
Final Report

This report should be completed and submitted within a month of agreed end date of project

Darwin Ref Number	EIDCF009
Darwin Project Title	Mapping the Falklands: facilitating systematic conservation planning and implementation
Country (ies)	Falkland Islands and UK
Award Holding Organisation	Durrell Institute of Conservation and Ecology (DICE)
Partner Organisations	Partner 1: Falklands Conservation Partner 2: Environmental Planning Department, Falkland Island Government Partner 3: Department of Natural Resources, Falkland Island Government
Grant Value	£24,921.00
Start/end dates	Mid-May 2012 to end-March 2013
Author(s), date	Dr. Zoe Davies (DICE), Dr. Robert Smith (DICE), Mr. Mark Parnell (en:mapping), Dr. James Fenton (FC), Dr. Rebecca Upson (FC and Kew), Mr. Nick Rendall (FIG), Mr. Andrew Pollard (FIG) and Dr. Paul Brickle (SAERI) 30th April 2013

1. Challenge Fund Background

1.1. Conservation Context

The Falkland Islands are a UK Overseas Territory, lying in the South Atlantic approximately 600 km from the South American mainland (Figure 1). The archipelago consists of two main islands (East and West Falkland) and an additional ~750 smaller islands/islets, with a total land area of about 1,220,000 ha. Prior to 1764, the islands were uninhabited, but today there is a human population of around 3000 individuals. The majority of these people live in the capital, Stanley, with just 360 scattered across 70 further settlements, where the major land-use is livestock farming.

The primary economic activities on the Falklands are livestock farming, nature-based tourism and commercial fisheries, the latter being the single largest contributor to the economy. The farming system comprises low-intensity ranching of 500,000 sheep and about 6,000 cattle, with only 0.3% of the farmland under active improvement. Wildlife tourism is also well-established and continues to grow, with an estimated 45,000 visitors in 2010/11. However, the economy is currently diversifying as a result of the discovery of offshore oil reserves, and the human population is predicted to rise in the coming years as a direct consequence.

In the face of increasing pressure on the natural resources of the Falkland Islands, there has been a strategic move made by governmental agencies and non-governmental organisations to ensure their

Figure 1: Location of the Falkland Islands in relation to South America

appropriate management within a network of protected areas (PA). The Falkland Island Government (FIG) already has a suite of environmental legislation in place to help underpin this aim. FIG has been included in the ratification of 18 multilateral environmental agreements including the Convention on International Trade in Endangered Species (CITES), the Convention on Migratory Species (CMS), the Ramsar Convention on Wetlands and the World Heritage Convention; it is expected that the Convention on Biological Diversity (CBD) will also be ratified in the near future. Furthermore, a series of high-profile and complementary reports have been published (e.g. Falkland Islands Environmental Charter, Falkland Islands Biodiversity Strategy).

A terrestrial habitat classification has been developed for the islands to assist in the monitoring and conservation of biodiversity. Some distinctive habitats, such as coastal tussac grass and boxwood/fachine scrub, are believed to have undergone major declines in both extent and quality, and a number of processes are thought to be driving their loss and degradation (e.g. invasive species, livestock grazing, climate change, uncontrolled burns and greater disturbance by recreational visitors). Although some elements of Falkland biodiversity remain understudied (e.g. invertebrates, lower plants), the avifauna and higher plant communities are generally well known. The vascular flora consists of 348 species, with 171 native species and 13 endemic species. Twenty three species (13% of native taxa) are listed in the Falklands Red Plant List. Bird diversity on the islands consists of 37 resident, 22 breeding seabird and 8 annual non-breeding migrant species. The Falklands support globally significant populations of a number of species, such as the black-browed albatross, the striated caracara, the rockhopper and gentoo penguins, as well as two endemic species and 14 subspecies. Under IUCN classification, there are ten species of conservation concern on the islands. All but two bird species are protected under local legislation, and 11 species have action plans in place for their protection.

In terms of existing protected areas, there are 19 officially designated terrestrial National Nature Reserves (NNRs) and two Ramsar sites (Sea Lion Island and Bertha's Beach). The NNRs were established opportunistically and with little regard for the status of globally and nationally threatened species/habitats. Additionally, they do not adequately cover any of the locally designated 22 Important Bird Areas (IBAs) and 16 Important Plant Areas (IPAs). Ideally, a systematic conservation planning (SCP) exercise needs to be conducted to inform protected area decision-making and implementation. SCP is the 'gold-standard' approach for identifying areas needed to protect biodiversity, whilst accounting for the social and economic factors that influence stakeholder support for conservation. At the heart of SCP is a conservation assessment, which identifies priority areas for protection by: (i) compiling a list of, and mapping, important species, habitats and ecological processes, known collectively as 'conservation features'; (ii) setting representation targets for the minimum amount of each feature intended for protection; (iii) producing a cost surface map that reflects the risk of each area being affected by anthropogenic factors, financial value or opportunity costs, and; (iv) using computer software to identify priority areas that meet the representation targets, whilst minimising habitat fragmentation levels and socio-economic costs. However, a major stumbling block in the development of a systematic conservation plan for the islands is the lack of an accurate landcover/vegetation map.

1.2. Challenge Fund Project Objective and Aims

The objective of the project was to assess the feasibility of producing a landcover/vegetation map for the Falkland Islands, which would then underpin the development of a full Darwin Initiative project application in a future round. The specific aims of the Challenge Fund were to:

- Hold a stakeholder workshop (e.g. with the British Forces South Atlantic Islands, Falkland Island Government departments which are not already project partners) and establish project partner relationships
- Work with stakeholders to get full agreement on which vegetation types of conservation interest need to be mapped
- Collect all relevant Geographic Information System (GIS) data (e.g. aerial/satellite imagery) from stakeholders (developing data sharing/use agreements together where necessary) and international data repositories
- Undertake preliminary GIS analysis to begin mapping the different landcover/vegetation types across the islands, using training data (comprising existing information, such as Important Plant Area maps, or collected via field visits)
- Ground-truth sample sections of the newly generated GIS landcover maps, against a second sample of the training data. Where relevant, calibrate/refine landcover classification algorithms to improve mapping accuracy
- Discuss the potential for mapping socio-economic and conservation implementation data, to increase the effectiveness of current/future conservation land-use planning
- Develop a full Darwin Initiative proposal between the project partners which, if funded, would result in the generation of a complete landcover/vegetation map and the initiation of a systematic conservation planning project for the Falkland Islands

1.3 Ultimate Goals of a full Darwin Initiative Project

As outlined in the original Challenge Fund proposal, the goals we expected to be address via a full Darwin Initiative project were to:

- Generate a complete landcover/vegetation map for the Falkland Islands.
- Undertake a SCP assessment for the Falkland Islands, using the landcover/vegetation map and incorporating socio-economic and conservation implementation data
- Incorporate the findings from the conservation assessment into the Falkland Islands ‘Protected Area Strategy’, which will support the Falklands in meeting existing international conservation commitments
- Work with stakeholders to ensure the outputs of the conservation assessment are implemented effectively
- Train in-country conservation staff to use SCP software programmes (e.g. Marxan, CLUZ), so conservation planning in the islands can become an ongoing process, with assessments being carried out regularly when new/updated ecological, socio-economic and threat/risk information becomes available

2. Challenge Fund Activities

2.1. Summary of Project Development

The need for this project was initially identified by Falklands Conservation (FC), in collaboration with the FIG Environmental Planning Department and Department Natural Resources. FC is the leading NGO for the islands and has over 30 years of experience, monitoring and managing conservation activities in the territory. It has also played a central role in the development of the ‘Falkland Island Biodiversity Strategy’, and has established excellent working relationships with FIG and other environmental organisations with an interest in the islands. Due to a lack of proficiency in advanced GIS analysis and systematic conservation planning, the Challenge Fund proposal was developed in collaboration with Dr. Zoe Davies (DICE), Dr. Robert Smith (DICE) and Mr. Mark Parnell (en:mapping) in the UK. This team has a proven track record of producing high-quality spatial ecology and conservation outputs to inform protected area policy development and implementation. The roles of the Falkland Island and UK project partners were as follows:

Falklands (FC and FIG): facilitate stakeholder engagement through workshop/meetings; collect/generate in-country data; offer expert local knowledge; develop a full Darwin Initiative proposal.

UK (DICE and en:mapping): administer the project; contribute cutting-edge knowledge and expertise in landscape-scale conservation and systematic conservation planning (from inception through to mainstreaming); lead stakeholder workshop/meetings; review current spatial data/map availability; undertake GIS analysis; develop a full Darwin Initiative proposal.

2.2. Primary Activities

Four project activities are presented below, reflecting the aims set out in the Challenge Fund application and Section 1.2 of this report.

Activity A: Establish project partner relationships

The awarded funds allowed Dr. Zoe Davies and Dr. Robert Smith to travel to the Falkland Islands in July 2012 and January 2013 to meet the Falkland Island based project partners listed on the application. Meeting these individuals in person, rather than communicating remotely via email or skype, was invaluable. For example, in-depth discussions with Mr. Andrew Pollard from FIG Department of Agriculture highlighted the critical importance of us all striving towards full Darwin Initiative funding. He explained that overgrazing on the islands is extremely detrimental to native pasture, eventually causing erosion and soil loss. Creating an accurate landcover/vegetation map and undertaking a SCP exercise would facilitate finding the ‘win-wins’ for species/habitats and farmer, thus ensuring the protection of important biodiversity features in the long-term.

Furthermore, a new partnership was formed with Dr. Paul Brickle (Director of the South Atlantic Environmental Research Institute; SAERI). His valuable contribution and feedback related to our Challenge Fund project is acknowledged through authorship on this report, despite not being on the original proposal. The objective of SAERI, which was established in March 2012 and is located in the capital Stanley, is to become a world class academic institute producing high impact research, providing quality student education, and building capacity both within and between the UK South Atlantic Overseas Territories. As of summer 2013, a new GIS centre for the South Atlantic territories is to be hosted by SAERI, funded by the UK Joint Nature Conservation Committee (JNCC). Our future Darwin Plus proposal will aid the long-term development of the centre, by training staff to use state-of-the-art systematic conservation planning software programmes (e.g. Marxan, Zonation, CLUZ). This will enable conservation assessments to be carried out regularly, whenever new/updated ecological, socio-economic and threat/risk information becomes available, without the territories seeking external assistance.

More contacts were made in the UK, initiated by FC and the FIG Department of Agriculture, with people undertaking important and highly relevant conservation research in the Falklands. Particularly useful meetings were held with Dr. Colin Clubbe (Head of UKOTs and Conservation Training, Royal Botanic Gardens Kew) and Prof. Jim McAdam (Queen’s University Belfast), who are currently working on an EU Biodiversity and Ecosystem Services in Territories (BEST) project entitled: “TEFRA: Terrestrial Ecosystems of the Falklands – a Climate Change Risk Assessment”.

Activity A: Key achievements

- Continued to build relationships with members of FC and FIG
- Founded new partnerships with individuals at SAERI, RBG Kew and Queen’s University Belfast, that will be further consolidated through the Darwin Plus application intended for summer 2013
- Was given a list of spatial data available for the Falkland Islands by Prof. Jim McAdam:
  - Aerial photography: 1956 complete series in black and white, with coverage of the entire archipelago (from 12,500 feet); 1999 test series in black and white, as well as colour, but primarily for selected areas of East Falkand (from various altitudes)
  - Satellite imagery: Landsat TM 2002 with coverage of the entire archipelago; IKONOS 2009 of the Saladero area of East Falkland
  - Digital maps: base geological map, farm boundaries, annual and seasonal rainfall

- Liaised with Dr. Adrian Fox at the British Antarctic Survey (BAS) in regard to listing spatial data available for the Falkland Islands:
    - Aerial photography: as stated by Prof. Jim McAdam above
    - Satellite imagery: Landsat TM; SPOT at 2.5 to 10 m resolution (indicative cost £30,000 for the entire archipelago); GeoEye-1 at 0.5 to 2.0 m resolution (indicative cost £100,000 for the entire archipelago); Quickbird/Worldview at 0.5 to 2.7 m resolution (indicative cost £150,000 for the entire archipelago)

Activity B: Hold a stakeholder workshop and meetings

A large one-day stakeholder workshop was arranged for July 2012. The event was attended by 15 people, representing the following Falkland Island organisations: FC, FIG Environmental Planning Department, FIG Department Natural Resources, FIG Public Works Department, SAERI, Joint Nature Conservation Committee (JNCC), Beaver LandCare, Rural Business Association and British Forces South Atlantic Islands (Appendix 1.1). The purpose of the workshop was four-fold: (i) to find out what landcover/vegetation mapping had been undertaken in the islands to date; (ii) to determine what spatial data is available for use; (iii) to decide what key features or vegetation types need and/or can be mapped; and, (iv) to ascertain what socio-economic information would be important for informing land-use and systematic conservation planning. Dr. Zoe Davies and Dr. Robert Smith were delighted with the high degree of enthusiasm and buy-in shown by all stakeholder groups that were present.

Additional follow-up meetings were held with individuals after the workshop, to examine archive digital data. A session with Mr. Sam Cockwell (FIG Department of Mineral Resources) and Mr. Ross Chaloner (FIG Public Works Department) were particularly productive, reviewing the suitability of old aerial imagery of the Falklands.

Activity B: Key achievement summary

- Accomplished the four desired outcomes listed above (please refer to Appendix 1.2 for a synopsis of the discussions)
- Determined that existing aerial photography housed by FIG would not provide a suitable basis for the GIS analysis landcover/vegetation mapping exercise

Activity C: Undertake GIS analyses

After reviewing the aerial photography and satellite imagery available for the Falkland Islands (see above), analysis was undertaken in the UK using freely available medium resolution Landsat TM data, and high resolution GeoEye-1 commercial imagery. Habitat classification training and ground-truthing data was provided by botanist Dr. Rebecca Upson from FC (please refer to Appendix 2.1 for a technical report).

Activity C: Key achievement summary

- Applied for, and was awarded, a GeoEye Foundation Imagery Grant to obtain a ~75 km^2 sample of high resolution digital data for analysis
- Completed the preliminary analyses, identifying constraints and opportunities for generating a full landcover/vegetation map in the future (please refer to Appendix 2.1 for a technical report)

Activity D: Developed a full Darwin Initiative proposal

This objective is still ongoing; significant progress has been made and we are waiting for information pertaining to the next grant round to be released before preparing the finalised proposal. During the course of the Challenge Fund project, Defra launched a new funding scheme called “Darwin Plus: Overseas Territories Environment and Climate Fund”. It is our intention to submit an application to Darwin Plus in summer 2013, once the details of the call have been announced. Due to the recent establishment of SAERI and the GIS centre, it was decided that Dr. Paul Brickle would play a leading role in developing the work packages for the full project. Moreover, we are presently liaising with Ascension Island and St. Helena to assess the feasibility of extending the scope of the project to include landcover/vegetation mapping in these territories, in addition to the Falklands.

Activity D: Key achievement summary

- Produced a project concept document for circulation between potential project partners to stimulate discussion
- Started to cost up and decided on the broad logistical arrangements associated with the project (e.g. where project staff would be based, outlined the primary responsibilities of all individual involved, identified project tasks to be conducted, debated the key GIS capacity/knowledge gaps that need to be addressed in the three territories)

3. Outcome & Impact of Challenge Fund

The desire to have a landcover/vegetation map created for the Falkland Islands was clearly evident from the work conducted for the Challenge Fund. All the stakeholder groups unanimously agreed that the lack of such a resource severely hampers policy and practice related decision-making across the territory. We are now in a situation where we can submit a proposal for a full Darwin Plus project, to produce the map and undertake a comprehensive SCP exercise. This could not come at a more germane time because:

- The human population inhabiting the islands is set to expand in the near future, with industries such as oil exploration, tourism and intensive near-shore fisheries growing
- The Overseas Territories Environment Programme (OTEP) funded project entitled "Falkland Islands Protected Areas Strategy: Cooperative Management of Biological Diversity", will be coming to an end in 2014. It will have laid extensive groundwork that will underpin the delivery of a protected area strategy for the islands (e.g. having undertaken extensive consultations with private landowners regarding the mechanisms that could be used to maintain/enhance biodiversity, reviewed existing protected area legalisation) on which our full Darwin Plus proposal will build directly, maximising the on-the-ground impact of both projects. Dr. Zoe Davies and Dr. Robert Smith have been working closely with the OTEP Protected Area Project Officer, Mrs. Clare Cockwell, and will continue to do so (e.g. providing expertise in gap analyses)
- A more strategic and holistic approach to environmental protection has been initiated with the formation of SAERI, extending beyond just the Falkland Islands to encompass South Georgia, Tristan da Cunha, Ascension Island and St. Helena. As such, lessons learnt, resources produced and capacity built within the Falklands will now have a much wider geographic reach.
- The GIS centre to be hosted by SAERI will provide a central repository for spatial data. This will make environmental data storage and management more efficient. High resolution, baseline landcover/vegetation mapping would be an important resource for the centre. Similarly, establishing a framework for SCP, that could be updated in the future as required within the involvement of individuals/organisations external to the territories, would be invaluable.

There were aspects of the Challenge Fund project that were hard to realise. However, these did not affect the final outcomes of the work:

- Existing digital spatial data for the islands was hard to locate, particularly due to difficulties establishing a meaningful collaboration with the British Forces South Atlantic Islands. This was not due to a lack of interest in the work, but a result of frequent staffing issues (e.g. turnover, no dedicated personnel with environmental expertise). Efforts to build a relationship are ongoing
- The digital spatial data that was traced was not suitable for landcover/vegetation mapping because it was: (i) too old; (ii) not sufficient in coverage; and, (iii) lacked associated metadata.

4. Lessons

The process of undertaking the Challenge Fund has been a valuable experience, with important lessons being learnt that will be/have been taken into consideration when preparing the full Darwin Plus application. These can be grouped under the following three subheadings:

A. Project management/logistics

- Planning/booking trips to the Falkland Islands for UK staff needs to be well in advance of proposed dates to ensure flight availability, as well as minimising flight and in-country accommodation costs. This would be even more pertinent if Ascension Island and St. Helena are also integrated into the project
- Moving around the Falkland Islands takes time and careful planning, particularly due to the difficult terrain and issues surrounding accessibility. When we conduct our sustained ground-truthing campaign to assess pixel classification accuracy, we will need to explicitly account for this to ensure the efficiency of data collection is maximised; many of the landcover/vegetation types that are less represented in current datasets (e.g. conservation habitat monitoring) are likely to be extremely remote

B. Project legacy

- The community on the Falklands is relatively small and staff turnover within stakeholder organisations can be high (e.g. CEO of Falklands Conservation is a fixed-term position, personnel in the British Forces South Atlantic Islands change frequently), potentially having knock-on impacts for project progression and legacy. Long-term continuity will be improved now SAERI and the GIS centre have been established, under the leadership of Falkland Islander Dr. Paul Brickle
- Before SAERI and the GIS centre were formed, there was no central repository for georeferenced spatial data. As a consequence, the information was not standardised and/or used consistently, important metadata had been lost, and there was a lack of technical capacity. The timing of our full project would be highly complementary to this exciting new development for the South Atlantic overseas territories, as we could offer advanced systemic conservation planning training and assistance to the new GIS staff in SAERI, augmenting the suite of capabilities offered by the centre

C. Securing private landowner engagement with landcover/vegetation mapping and systematic conservation planning

- Although it appears that many landowners will welcome the development of a landcover/vegetation map that can be used to facilitate land-use planning, others may be highly sceptical. This is a key consideration given that there are only 84 farms across the islands. Concerns about the project are likely to include people’s attitudes/land (and thus the resources/conservation value it has) being too easily identifiable as a result of the systematic conservation planning exercise, and the false perception that their land may be designated for conservation purposes against their will and thereby restricting how they manage their properties
- Of the 84 farms and ~250 farmers, approximately half do not interact with any agency. This will make engaging with them harder. Furthermore, there are a number of absentee overseas landowners

5. Project Expenditure

Item	Budget for whole project*	Expenditure	Variance** as a %	Comments
Travel Costs			11.3%	Increased airfares for Dr. Zoe Davies and Dr. Bob Smith to travel to the Falkland Islands, when compared to quotes obtained when costing the grant
Subsistence Costs			-25.4%	Cheaper accommodation was kindly provided by project partners
Overhead Costs			Not applicable	
Operating Costs			0.0%	
Capital Costs			Not applicable	
Others: Consultancy			0%	
Others: Falkland Conservation staff costs			0%	
Staff costs specified by individual Dr. Zoe Davies Dr. Bob Smith			2.1%	
TOTAL				

* please indicate which document you refer to if other than your project application or annual grant offer letter
** please explain any variance of +/- >10%

6. Other comments not covered elsewhere

7. Darwin Challenge Fund Reporting Guidelines

All Darwin projects are required to report on the work they have undertaken with Darwin funds and this offers you the opportunity to report on your achievements and lessons learnt and on any other issues you would like to raise. You report should show how you have progressed against the activities outlined in your application, or clearly explain any changes and the reasons why these changes were necessary.

You are expected to prepare the report in conjunction with your partners and you are expected to submit a Final Report within 1 month of completion of the agreed dates for the award (max 6 pages excluding annexes).

We will acknowledge and read all reports submitted, but will only contact you about your report if there are specific concerns.

If you have any additional queries about reporting, please feel free to email or call on 0131 440 5181.

8. Checklist for Submission

	Check
Is the report less than 5MB? If so, please email to Darwin-Projects@ltsi.co.uk putting the project number in the Subject line.	Yes
Is your report more than 5MB? If so, please discuss with Darwin-Projects@ltsi.co.uk about the best way to deliver the report, putting the project number in the Subject line.	No
Have you included means of verification? You need not submit every project document, but the main outputs and a selection of the others would strengthen the report.	Yes
Do you have hard copies of material you want to submit with the report? If so, please make this clear in the covering email and ensure all material is marked with the project number.	No
Have you involved your partners in preparation of the report and named the main contributors	Yes
Have you completed the Project Expenditure table fully?	Yes
Do not include claim forms or other communications with this report.	

9. Appendices

Appendix 1.1. Photographs of the stakeholder workshop held in the Falkland Islands during July 2012

Appendix 1.2. Summary of the key material covered in the stakeholder workshop held in the Falkland Islands during July 2012

General points made by workshop participants

- The accuracy of the available base maps is considered to be very poor, with some islands either not included or positioned incorrectly. A vital aspect of any landcover mapping exercise would be to rectifying these omissions
- It would be essential to speak to individual private landowners and ask them to review the landcover/vegetation map. This would be invaluable in terms of both ground-truthing/verifying map classification accuracy, as well as securing their buy-in to the project
- One key factor will be to work with landowners and identify those where there are easy wins to be made. For example, focusing on government owned land parcels would be particularly straightforward, meaning that data could be assimilated rapidly
- There are around 250 farmers and 84 farms across the islands; about 50% do not interact with any agency. This will hinder successful engagement
- A critical element of any project that will underpin the successful implementation a protected area strategy, will be to excite landowners about what biodiversity they have on their doorstep. Negative false perceptions will have to be overcome through education (e.g. farmers tend to assume that conservation interest in their land will equate to them being told that they cannot shoot birds or undertake certain management activities such as rotavating). A good quality landcover/vegetation map could be an excellent tool to help achieve these two objectives

Discussion A. What spatially resolved data are available for mapping landcover and vegetation types?

1. Maps and digitised boundaries:
    - The Hydrographic Office has coastline charts
    - Base maps from the 1950s showing coastlines, infrastructure etc (known to be reasonably inaccurate)
    - Base maps from 2010 (1:50,000 resolution) but would need MoD approval for use
    - A previous landcover mapping exercise was undertaken by Sergio Radic (Universidad de Magallanes, Chile), Sergio Opazo (Universidad de Magallanes, Chile) and Jim McAdam (Queen's University Belfast) in Saladero, East Falkland, which is operated by the Department for Agriculture. The outcomes of the GIS analyses were mixed. The vegetation types were not well delineated, so the output was mostly used for calculating stock carrying capacity. Suggested that we contact Jim McAdam for further discussion

2. Satellite and aerial imagery:
    - 1956 aerial photography held by the FIG Department of Mineral Resources
    - 1990s aerial photography. Suggested the we meet with Mr. Sam Cockwell (FIG Department of Mineral Resources) and Mr. Ross Chaloner (FIG Public Works Department) to review this and the above resource
    - British Antarctic Survey has colour aerial photography from the late 1990s/early 2000s, but it occurs in strips and does not cover most of the Falklands
    - UK military has some aerial photographs, but they are not of particularly high resolution and the full coverage is unknown
    - US military has Controlled Image Base data

3. Ground-truthing and biodiversity feature point data
    - Beaver Island vegetation map could be used for ground-truthing (database contains spatial coordinates)
    - Shallow Marine Survey Group has georeferenced species distribution data
    - Falklands Conservation has mapped Middle Island, New Island and Charters Horse Paddock, all of which could be useful for ground-truthing.

Discussion B. What data should ideally be in a Falkland Islands conservation planning system?

1. Biodiversity data:
   - Vegetation types (as resolved a classification as possible, not just restricted to priority types for conservation – this is an important point if the map is going to be support all land-use planning)
   - Distribution maps of important species (e.g. of conservation concern)
   - Distribution maps of invasive species (e.g. gorse)
   - Important Plant Areas
   - Important Bird Areas
   - Carbon/peat distribution
   - Large burnt areas
   - Hydrology (e.g. permanent and temporary water bodies, recharge/discharge areas)
   - Reseeded areas

2. Physical data and infrastructure:
   - Contours
   - Geology (e.g. bedrock, soils, stone runs, bare rock outcrops)
   - Fence lines, property boundaries, roads, tourist tracks, off-road vehicle tracks, corrals, airstrips, military infrastructure, oil infrastructure
   - Shelter belts (e.g. turf dykes, trees)
   - Artificial drainage lines
   - Historical/cultural sites
   - Human population
   - Minefields
   - Tourist numbers
   - Human settlements

3. Threats, costs and opportunities:
   - Eroded areas (e.g. soil, sand, clay, gravel, stone, peat – ideally this need to be clearly distinguished from one another)
   - Old peat-cutting areas
   - Distribution maps of introduced species (e.g. gorse, rats)
   - Land costs (based on data from landowners about management costs)
   - Land tenure
   - Landowner perceptions of, and willingness to participate in, conservation initiatives. This may not be possible due to the concerns that farmer's attitudes/land (and thus the resources/conservation value it has) might being too easily identifiable in the outputs of the mapping and systematic conservation planning exercise, and the false belief that their land may be designated for conservation purposes against their will thereby restricting how they manage their properties

Discussion C. How could a Falkland Islands conservation planning system be used?

1. Broad strategies:
   - Informing the Protected Area Strategy (with a particular focus on biodiversity representation)
   - Informing the Biodiversity Strategy
   - Informing the Rural/Tourism Development Strategy
   - Informing the Department of Agriculture's Farm Improvement Programme (assessing scope for increasing conservation in unproductive lands and estimating sheep stocking density)
   - Improving buy-in from public and elected officials
   - Environment Impact Assessment planning (especially if planning regulations are strengthened in rural areas)
   - Oil development and spill contingency
   - Land valuation
   - Development plans (e.g. quarries, airstrips, settlements)

2. Project-based initiatives:

- Invasive species clearance and predictions of distributional expansion/shifts
- Potential for habitat restoration/vegetation planting
- Carbon-peat distribution mapping to underpin restoration efforts and develop carbon storage strategies
- Build on current EU project modelling plant distributions, and assessing the impact of livestock and climate change

Appendix 2.1. Summary technical report describing the GIS analyses undertaken and associated findings

Image classification

Surveying vegetation cover is important in initiating the protection and monitoring of the habitats of the islands, but the size of the Falklands, terrain, inaccessibility and extreme weather conditions mean that mapping landcover via traditional field survey methods is simply impractical and not cost-effective. In addition, some sites remain unsurveyed because of important breeding populations of species of conservation concern. As a consequence of these factors, although there are on-going localised habitat surveys across the Falklands in conservation priority areas, there has never been a thorough and systematic island-wide effort. The Falklands are predominantly covered in acid grasslands and dwarf shrub heath, with very little indigenous tree cover, although there are some patches of native scrub. The landscape is under pressure from agriculture, human disturbance and invasive species. A successful image classification model would need to offer the ability to differentiate, at the very least, between the broad habitat classifications (tussac, grassland, dwarf shrub heath, fern beds, montane, bog and flush, fen, marsh and swamp, open water, coastland, inland rock, scrub, woodland and other such as bare ground).

Landscape classification through remote sensing can work with a relatively small sample of underlying habitat information. It therefore requires substantially less survey effort than standard field survey techniques. Other benefits include the fact that remote sensing can be relatively inexpensive when compared with standard habitat survey techniques, the assessment can be conducted in a relatively short period of time, the output from the model is a geo-referenced layer of habitats (just as with field surveys, digitising over 12,000km^2 would be unfeasible). Additionally, the landscape classification and model steps are not a dead end; instead the process is highly repeatable and can be re-run when new satellite/ground-truthing data becomes available. This means that the landcover/vegetation map can be updated regularly and refined incrementally. One critical point that must be appreciated is that using remote sensing techniques to classify the landscape may give you total coverage of the area, but there will always be inaccuracies because the techniques rely on the spectral signals of the underlying habitat. It will also not provide the fine-scale and highly detailed botanical information which can be obtained in the field. However, it is hoped that any remote sensing output would act as a guide as to delineating habitats which may be floristically important and warrant further investigation.

We believe the inaccuracies associated with relying on remote sensing techniques are an acceptable trade-off for the ability to catalogue the habitats at a landscape scale and inform land-use planning at scale and resolutions pertinent to management/policy decision-making and implementation. Once a landscape classification model is complete, targeted field surveys can develop and improve the model if necessary, and will provide information on the accuracy of the landscape classification.

GIS analysis aims

- Identify data sources that could be used to map the Falklands
- Test to see whether image classification is possible with the data layers available
- Produce a draft landscape classification for a portion of the Falkland Islands
- Provide an assessment of the costs/benefits of using different datasets
- Assess the feasibility of producing a Falklands-wide habitat map through image classification and remote sensing techniques
- Identify future areas of research

Considerations when selecting data sources

As different remote sensors have different spatial, temporal, spectral and radiometric characteristics, the selection of an appropriate one is very important for mapping landcover/vegetation. The choice of images acquired by sensors is largely determined by three key considerations. Firstly, an individual/organisation must deliberate on the mapping objective and the level of accuracy that is expected. In general, images of low resolutions may be used for classifying between vegetation types that are visually distinctive or making coarse level distinctions, while investment should be made in high resolution imagery if fine-detailed classifications are required. Rough guidelines for defining spatial resolutions are as follows:

- Low or coarse resolution = pixels of 30.0 m or greater
- Medium resolution = pixels of between 2.0 and 30 m
- High resolution = pixels of between 0.5 and 2.0 m
- Very high resolution = pixels of less than 0.5 m

Secondly, remote sensing imagery may be very expensive. From a habitat mapping point of view, delineating vegetation at fine scales usually requires high resolution images and is therefore costly, whereas lower resolution images can be suitable for large-scale mapping (e.g. at 'national' scales). This is our justification for comparing a digital spatial data from a free (medium resolution) versus commercial source (high resolution; please note that the sample of commercial data was kindly provided via a data grant from GeoEye Foundation):

- GeoEye-1: high resolution (0.5 – 2.0 m) panchromatic and multispectral imagery obtained via the GeoEye 1 satellite; single scene area is 15.2 km; revisit frequency <3 days (depending on latitude); four bands; 16 bit radiometry; data from digital globe (www.digitalglobe.com).
- Landsat TM: medium to coarse spatial resolution with multispectral data (120 m for thermal infrared band and 30 m for multispectral bands) from the Landsat 4 and 5 satellite (1982 to present); each scene covers an area of 185 km; temporal resolution is 16 days, seven bands; 8 bit radiometry; obtained from NASA (http://glovis.usgs.gov/) (path 223 row 96).

Finally, temporal availability and quality can limit the usability of the data. Obtaining images that are not blighted by cloud or snow can sometimes be impossible.

Comparing the spatial resolution of GeoEye-1 and Landsat TM
As stated above, spatial resolution provides the discriminatory power of any image classification process; the higher the resolution of the data, the greater the likelihood of being able to differentiate and delineate habitats accurately. At 1:100,000, both maps are appropriate for visually assessing the general trend of the landscape but, when you zoom in, you can see that there is a high degree of averaging of the reflectance value of the Landsat data (Figure A2.1). As a result, areas of bare rock and stream are not visible.

Comparing the spectral resolution of GeoEye-1 and Landsat TM
The spectral resolution is the number of wavebands that can be recorded across the electromagnetic spectrum, including optical, thermal and microwave ranges (Table A2.1). Generally, the greater the number of bands recorded, the more ability there is to discriminate between pixels and, therefore, landcover/vegetation types. However, additional spectral information is not a linear multiplier of discriminatory power because the bands refer to specific spectral wavelengths which may not necessarily further enhance classification accuracy between similar habitat types.

The differing spectral bands can also be used to aid classification where supplementary visual interpretation is required (e.g. creating extra training data by expanding on known habitat patches, or through the visual categorisation of distinct landscape features such as bare rock or bare ground for the Falklands). Also, the bands can be combined to form composite layers which do not comprise of the standard red, green and blue bands. These are known as 'false colour' images, and can be used to accentuate differences in vegetation (Figure A2.2).

Comparing the radiometric resolution of GeoEye-1 and Landsat TM
The imagery sources under investigation have differing radiometric resolutions, equating to the degree of sensitivity to changes in the magnitude of energy sensed from a pixel. Many sensors have operated with 8 bits of precision (equivalent to 0-255), but new sensors are recording to 10, 12 and 14 bits (0-1023, 0-2047 and 0-4095 respectively). Increased radiometric resolution allows relatively small shifts in reflectance to be identified, thus providing improved discrimination between features within an image. This is an important consideration when different habitats occupy a relatively small radiometric range.

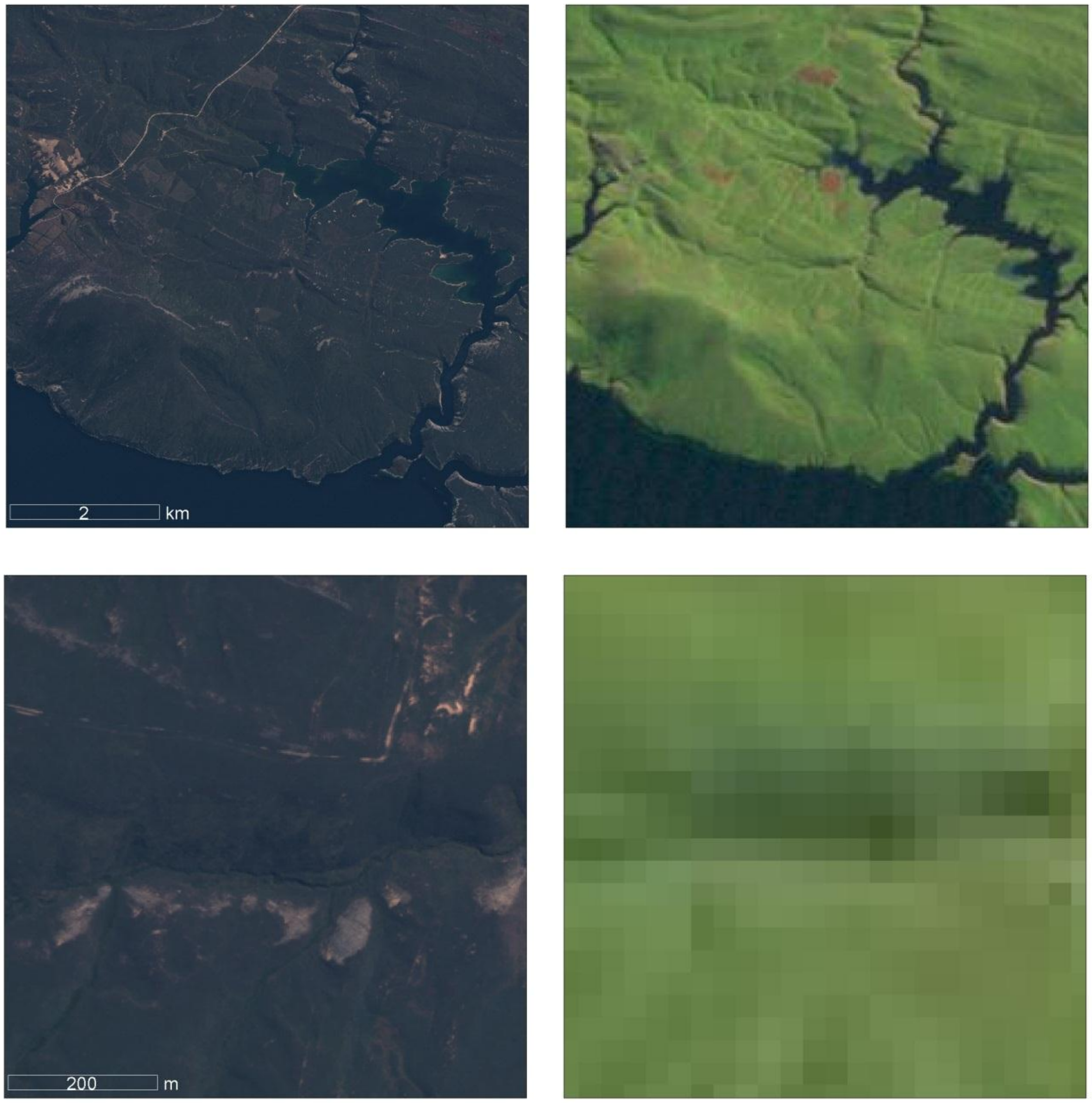

Figure A2.1: Data at 1:100,000 (two top panels) and 1:10,000 (two bottom panels), showing differences in pixel size and pixel values for images from GeoEye-1 (left) and Landsat TM (right)

Table A2.1: Comparison of the spectral bands available from GeoEye-1 and Landsat TM

GeoEye-1	Landsat TM	Spectral range (μm)	Use
Blue	Band 1	0.45 - 0.52	Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation
Green	Band 2	0.52 - 0.60	Emphasizes peak vegetation, which is useful for assessing plant vigour
Red	Band 3	0.63 - 0.69	Discriminates vegetation slopes
NIR1	Band 4	0.76 - 0.90	Emphasizes biomass content and shorelines
n/a	Band 5	1.55 - 1.75	Discriminates moisture content of soil and vegetation; penetrates thin clouds
n/a	Band 6	10.40 - 12.50	Thermal mapping and estimated soil moisture
n/a	Band 7	2.08 - 2.35	Hydrothermally altered rocks associated with mineral deposits

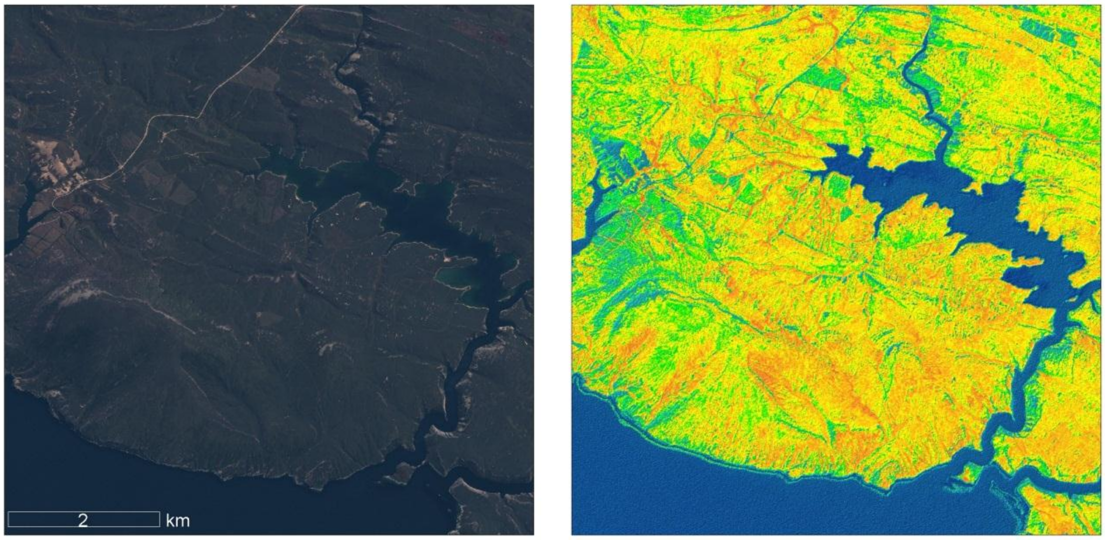

Figure A2.2: Comparison of GeoEye-1 red, green, blue bands (RGB; left) and normalised difference vegetation index (NDVI; right), which is derived from red and infrared bands

Comparing the temporal resolution of GeoEye-1 and Landsat TM

Temporal resolution can be an issue when trying to obtain meaningful imagery for analysis, as data should be captured at a time which allows for optimal discrimination between habitats. In locations such as the Falkland Islands, late spring is probably best as there is no snow on the ground and better differentiation between the habitats. Cloud cover is a problem as it obliterates the image and renders it useless. In some instances, it may be necessary to go back further in time than is ideal, in order to obtain the best spatial coverage of uninterrupted imagery (Figure A2.3).

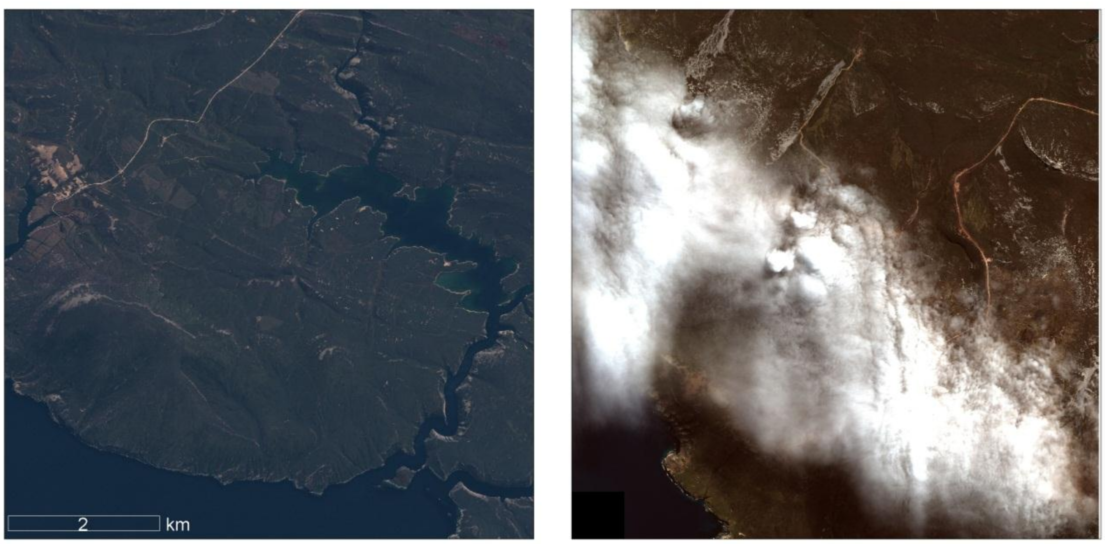

Figure A2.3: GeoEye-1 data illustrating the impact of cloud cover on image interpretation

Model Inputs

The imagery was made available as Geotiff files. Unfortunately, the datasets could not be matched in terms of the scale of their coverage (Figure A2.4) or the date of capture. The GeoEye-1 data was collected on 08/03/2012 and covered 75km^2. After assessing all Landsat TM imagery, the most appropriate data coverage was from 19/04/2006 and extended over 3,600km^2.

Figure A2.4: Coverage of satellite imagery used in the feasibility study, GeoEye-1 (left) and Landsat TM (right)

All data processing and manipulation was conducted in ESRI ArcGIS 10.0 running Spatial Analyst, with additional conversions in Idrisi Selva. As the Challenge Fund project was focussed on assessing the feasibility of producing a landcover/vegetation map for the islands, we chose not to lose time to layering/masking rasters and blending adjacent rasters to standardise pixel values, as you might if the map was being generated in full.

In addition to the raster dataset, we also had access to a large point database of geo-referenced habitat samples collected between 2007 and 2011 by FC, covering 4,310 sites across the Falkland Islands. This dataset formed the basis for the training dataset to be used in the supervised image classification, with a total of 63 and 2,547 sampling points falling within the area covered by GeoEye-1 and Landsat TM data respectively (Figure A2.5). As the number of sampling points was relatively low within the area covered by the GeoEye-1 imagery (Table A2.2), additional training data was collected via visual interrogation of habitats which were easy to interpret (e.g. bare rock, bare ground, heath and gully vegetation; Figure A2.6). This was done by examining the degree to which the spectral signatures overlapped (Figure A2.7).

Figure A2.5: Location of sampled vegetation plots, in relation to the GeoEye-1 and Landsat TM coverage areas

Table A2.2: Landcover/habitat sample data points (classified by Dr. Upson in the field, or Mr. Parnell remotely) occurring with the area covered by GeoEye-1 imagery and used for training

Habitat	Sampling points	Area (m^2)
Bare rock	26,205	104,820
Bare ground	1411	5,644
Bare peat/thin vegetation	40,985	163,940
Track	4943	19,772
Scrub	1063	4,252
Inland water	4877	19,508
Deep water	27,429	109,716
Coastal water	8636	34,544
Heath - A	3086	12,344
Heath - B	2207	8,828
Gully vegetation	18,225	72,900

Figure A2.6: Example of bare rock, bare ground, heath and gully vegetation (right to left) discernible from GeoEye-1

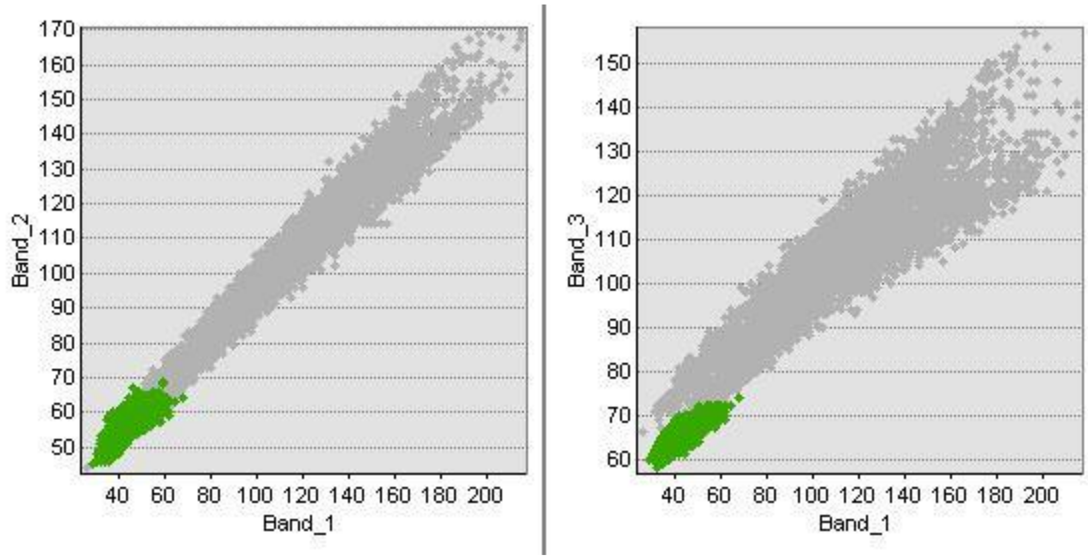

Figure A2.7: Signatures for bare ground compared to gully vegetation in bands 1 and 2 (blue and green) and bands 1 and 3 (blue and red): grey signatures indicate bare rock; green signatures represent gully vegetation

Classification

Habitat discrimination was achieved using a supervised Maximum Likelihood Classification (MLC) methodology. MLC considers both the variance and covariance of the signatures when assigning each pixel to one of the landcover/vegetation classes represented in the training data. It assumes that the distribution of a class sample is normal and then characterises a class by the mean vector and the covariance matrix. Given these two characteristics, the statistical probability is computed for each class to determine how to best assign the pixels (in this instance, we have weighted habitats equally).

It is worth noting that topological relief (slope and aspect) can play a significant role in the degree to which a pixel is illuminated and its subsequent reflectance value. Slopes which face the sun have higher reflectance values than those which do not, potentially leading to pixels of the same of landcover/habitat type in reality, being assigned to different classes. This is likely to have substantial influence in the Falkland Islands, which are hilly in places with the highest point being 705m above sea level. Software algorithms have been developed to counteract these issues, but they can only be applied if the underlying topographic information is available. Neither GeoEye-1 or Landsat TM provide this data, which would need to be secured as part of the full Darwin Plus project to maximise accuracy of the landcover/habitat map.

Discussion of findings

The results from the supervised MLC on the GeoEye-1 and Landsat TM data are presented graphically (Figures 2.8 to 2.17). It is not possible to explicitly quantify the actual overall classification accuracy of the two outputs because we had insufficient training data, but the qualitative trends are clearly evident when compared alongside the satellite imagery. The GeoEye-1 data offers a considerably greater degree of discrimination between landcover/habitat types, even despite the constrained amount of training data. This success can be directly attributed to the higher spatial resolution of the GeoEye-1 imagery and consequently, its better spectral signal (less interference from neighbouring pixels). This ‘blending’ effect is demonstrated in Figure 2.18, which shows a series of polygons measuring 30m x 30m (corresponding to the spatial resolution of the Landsat TM data); the polygons highlight how pixels falling squarely within a single landcover/vegetation class suffer from no blending and the pixel value throughout the polygon is constant. However, pixels that fall across habitat boundaries will receive a mixed spectral signal and may produce a signature that does not allow for classification.

Although Landsat TM data is a fantastic resource, having excellent worldwide coverage and an extensive digital archive stretching back over 30 years, it is not suitable for forming the basis of a landcover/vegetation mapping exercise for the Falkland Islands. Despite being relatively large in area, the islands require high resolution imagery to delineate habitats accurately using more resolved classifications (rather than merely broad categories such as urban, agricultural, rangeland, forest, water, wetlands). This is because the Falklands are predominantly covered in acid grasslands and dwarf shrub heath with very little indigenous tree cover and, therefore, are not composed of striking habitat blocks (with the exception of tussac grass). The distinctions between vegetations types are far more gradual and simply could be discerned with Landsat TM.

Even though the higher resolution GeoEye-1 data has more discriminatory power, we cannot state unequivocally that all habitats could be adequately classified via remote sensing. In order to do this, we would need to undertake an extensive randomised field-based ground-truthing assessment of model accuracy as part of a full Darwin Plus project. Presently, that habitat survey data collected for the islands is very skewed to particular types of conservation interest (Table A2.3).

Figure A2.8: The wider geographical location of the close up maps to follow in figures A2.9 to A2.17

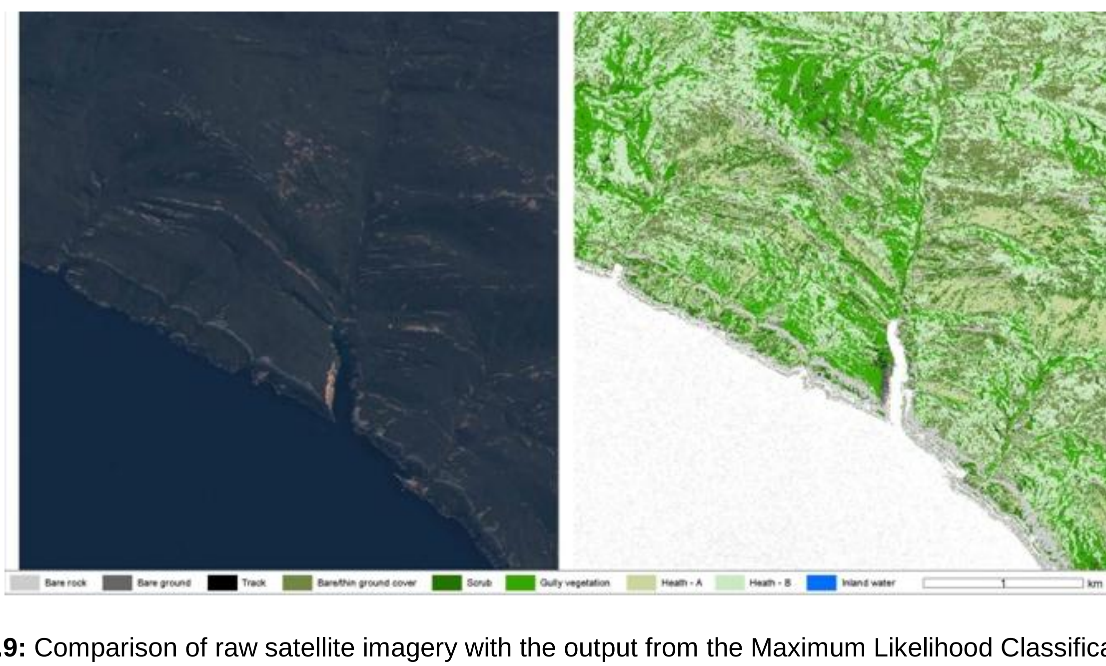

Figure A2.9: Comparison of raw satellite imagery with the output from the Maximum Likelihood Classification on the GeoEye-1 data – section A

Figure A2.10: Comparison of raw satellite imagery with the output from the Maximum Likelihood Classification on the GeoEye-1 data – section B

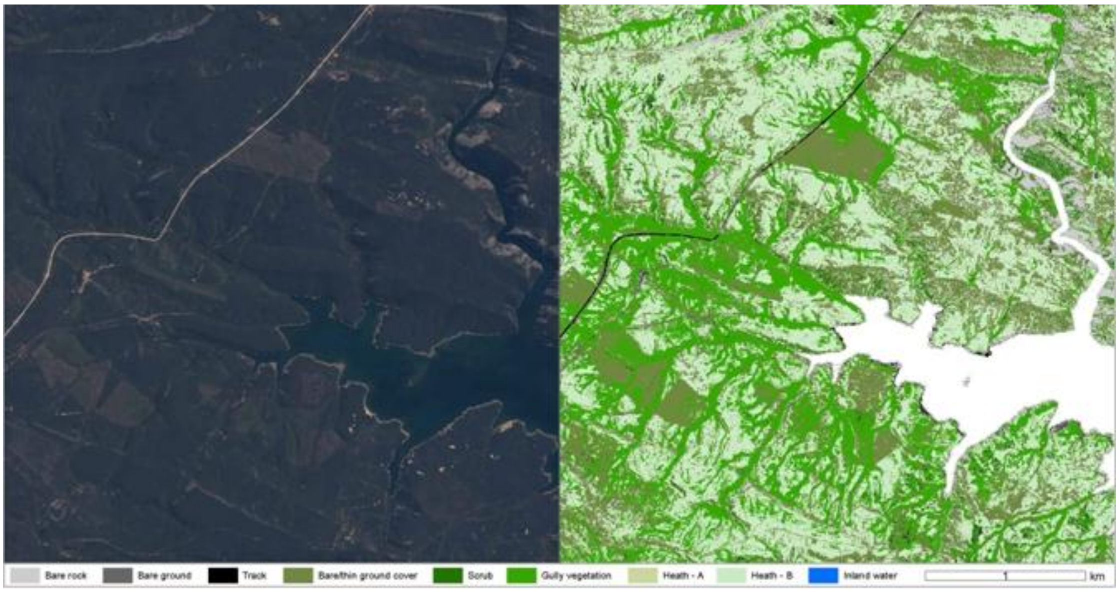

Figure A2.11: Comparison of raw satellite imagery with the output from the Maximum Likelihood Classification on the GeoEye-1 data – section C

Figure A2.12: Comparison of raw satellite imagery with the output from the Maximum Likelihood Classification on the GeoEye-1 data – section D

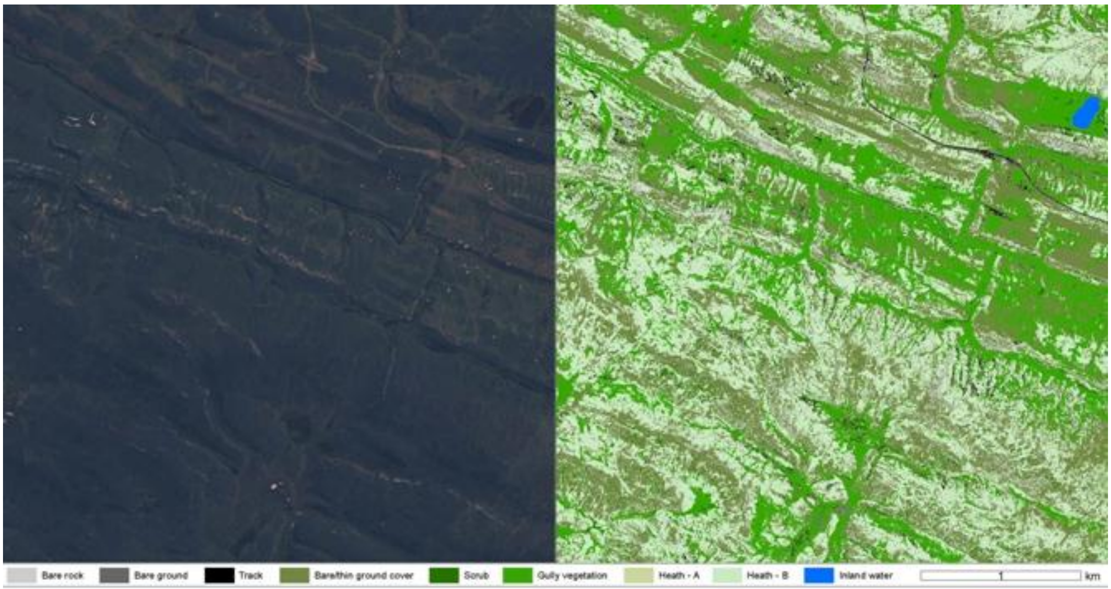

Figure A2.13: Comparison of raw satellite imagery with the output from the Maximum Likelihood Classification on the GeoEye-1 data – section E

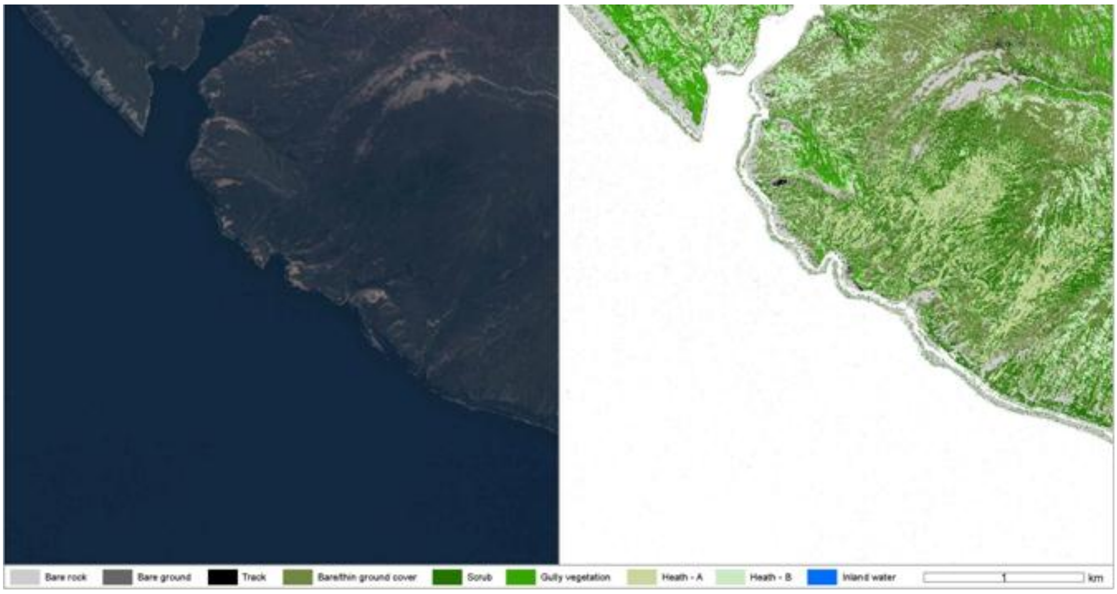

Figure A2.14: Comparison of raw satellite imagery with the output from the Maximum Likelihood Classification on the GeoEye-1 data – section F

Figure A2.15: Comparison of raw satellite imagery with the output from the Maximum Likelihood Classification on the GeoEye-1 data – section G

Figure A2.16: Comparison of raw satellite imagery with the output from the Maximum Likelihood Classification on the GeoEye-1 data – section H

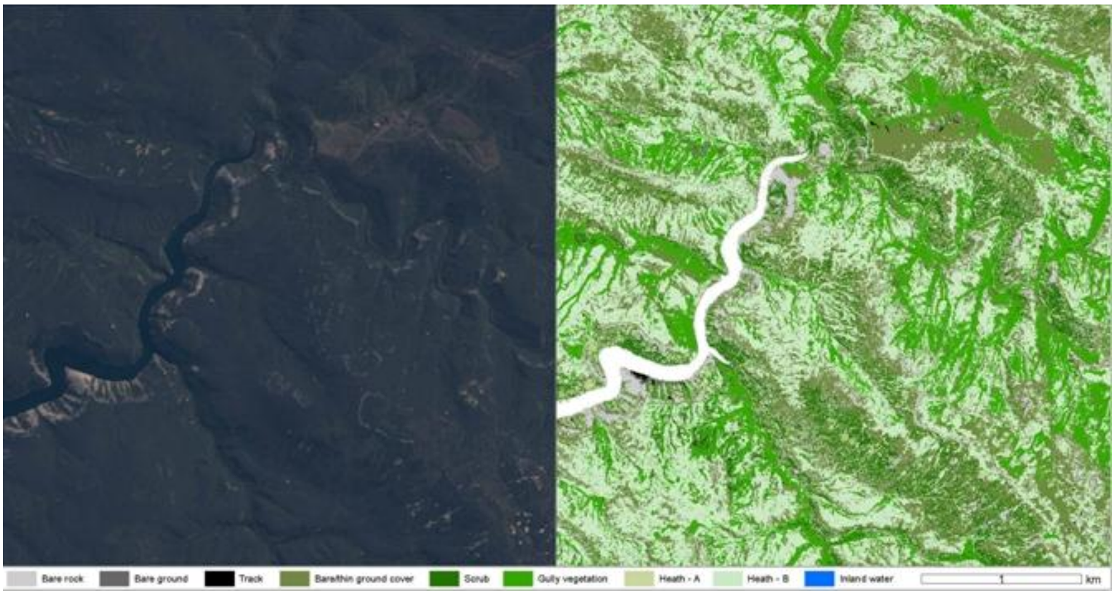

Figure A2.17: Comparison of raw satellite imagery with the output from the Maximum Likelihood Classification on the GeoEye-1 data – section I

Figure A2.18: GeoEye satellite imagery overlaid with polygons at the same spatial resolution as the Landsat data

Table A2.3: Inventory of the habitat survey data collected to date by Dr. Upson of FC, and its highly skewed representation across habitat types

Habitat types	Number of sampling locations
Acid grassland	291
Acid grassland (semi-improved)	4
Acid grassland - Coastal cushion heath	4
Acid grassland - Dwarf shrub heath	25
Acid grassland - Improved grassland	2
Acid grassland - Marshy grassland	4
Bare ground	337
Bare ground (gravel)	1
Bare ground - Coastal cushion heath	2
Bare ground - Dwarf shrub heath - *Festuca magellanica* grassland	2
Bare ground - Improved grassland	5
Bare ground - Maritime cliff	10
Bare ground - Tussac (scattered)	7
Bogs	24
Built up areas and gardens	6
Coastal (saline) grassland	171
Coastal (saline) grassland (semi-improved)	3
Coastal cushion heath	328
Coastal cushion heath (semi-improved)	1
Coastal cushion heath - Bare ground	3
Coastal cushion heath - Coastal (saline) grassland	2
Coastal cushion heath - Dwarf shrub heath	6
Coastal cushion heath - Improved grassland	5
Coastal cushion heath - Introduced vegetation	1
Coastal cushion heath - Tussac (scattered)	2
Coastal feldmark	14
Coastal slope	1
Coastland	1

Coastland (shingle)	1
Coastland (rock)	11
Coastland (rock/ boulders)	4
Coastland (rock/ boulders/ slope)	2
Dwarf shrub heath	937
Dwarf shrub heath (semi-improved)	1
Dwarf shrub heath - Acid grassland	19
Dwarf shrub heath - Bare ground	5
Dwarf shrub heath - Bare ground - Coastal cushion heath	1
Dwarf shrub heath - Coastal cushion heath	4
Dwarf shrub heath - Fern beds	1
Dwarf shrub heath - Improved grassland	15
Dwarf shrub heath - Improved grassland - Bare ground	3
Dwarf shrub heath - Tussac (scattered)	3
Fen	5
Fern beds	141
Fern beds - Dwarf shrub heath	1
Fern beds - Dwarf shrub heath - Improved grassland	1
Fern beds - Tussac (scattered)	1
Festuca magellanica grassland	50
Festuca magellanica grassland - Coastal (saline) grassland	3
Festuca magellanica grassland - Coastal cushion heath	2
Festuca magellanica grassland - Dwarf shrub heath	1
Festuca magellanica grassland - Improved grassland	1
Festuca magellanica grassland - Introduced vegetation	2
Flush	5
Flush vegetation	2
Garden	3
Improved grassland	434
Improved grassland - Bare ground	5
Improved grassland - Coastal (saline) grassland	1
Improved grassland - Coastal cushion heath	2
Improved grassland - Dwarf shrub heath	18
Improved grassland - Introduced vegetation	5
Improved grassland - Tussac (scattered)	5
Improved grassland - Tussac (scattered) - Fern beds	1
Inland rock	6
Inland rock (inland cliff)	14
Inland rock (other)	1
Inland rock (outcrop)	59
Inland rock (scree)	3
Inland rock (stone run)	67
Introduced vegetation	123
Introduced vegetation - Dwarf shrub heath	2
Introduced vegetation - Tussac (scattered)	5
Littoral sediment (saltmarsh)	1
Littoral sediment (shingle/ cobbles)	1
Marginal vegetation	6
Maritime (rock)	4

Maritime (strandline)	2
Maritime (cliff)	36
Maritime (cliff) - Coastal (saline) grassland	15
Maritime (shingle)	1
Maritime (slope)	12
Marshy grassland	135
Marshy grassland (*Acaena* herbfield)	1
Marshy grassland (semi-improved)	52
Marshy grassland - Dwarf shrub heath	1
Marshy grassland - Introduced vegetation	1
Montane	13
Neutral grassland	84
Neutral grassland - Bare ground	1
Running water (bank, seasonal stream)	5
Running water (bank, small stream)	5
Running water (bank, stream)	32
Running water (margin, seasonal stream)	1
Running water (margin, small stream)	7
Running water (margin, spring)	3
Running water (margin, stream)	7
Running water (seasonal stream)	9
Running water (small stream)	14
Running water (stream)	9
Sand dunes	50
Scrub (Fachine)	18
Scrub (dense, Fachine)	24
Scrub (continuous, Fachine)	9
Scrub (scattered, Fachine)	44
Scrub (semi-continuous, Fachine)	9
Scrub (dense, Gorse)	42
Scrub (Boxwood) - Dwarf shrub heath	1
Standing water (bank, large lake)	2
Standing water (ditch)	2
Standing water (large lake)	5
Standing water (margin, lake)	3
Standing water (margin, large lake)	8
Standing water (margin, pond)	7
Standing water (margin, seasonal pool)	3
Standing water (margin, small pond)	10
Standing water (pond)	3
Standing water (seasonal pool)	20
Standing water (small pond)	2
Standing water (stream)	1
Strandline vegetation	51
Strandline vegetation - Coastal (saline) grassland	1
Strandline vegetation - Coastal slope	2
Tussac	54
Tussac (dense)	50
Tussac (semi-continuous)	4

Tussac (scattered)	184
Tussac (scattered) - Fern beds - Dwarf shrub heath	1
Tussac (scattered) - Improved grassland - Fern beds	1
Tussac (scattered) - Introduced vegetation	1
Tussac - Coastal (saline) grassland	1
Unknown	1