EUFAR
European Fleet For Airborne Reasearch

EUFAR Research Project

1.General Information

Project title :

Applicability of hyperspectral sensors to map the spread of invading plant species

Acronym :

ALIENS

Main scientific field/specific discipline :

Earth Sciences & Environment/FP6 - Ecosystems & Biodiversity

Scientific theme :

Airborne hyperspectral data to model the distribution of exotic invading plant species in Doñana National Park and surrounding areas

Participants undertaking research :

Name	Institution	Department	Position
BUSTAMANTE Javier (lead scientist)	Estación Biológica de Doñana, CSIC	Applied Biology	Tenure Scientist
CASTELLANOS VERDUGO Eloy Manuel	University of Huelva	Department of Environmental Biology and Public Health	Associated Professor
DÍAZ-DELGADO HERNÁNDEZ Ricardo	Estación Biológica de Doñana, CSIC	Dept. Applied Biology	Technical Responsable of Remote Sensing Lab
FERNÁNDEZ ZAMUDIO Rocio	University of Seville	Department of Vegetation Biology and Ecology	PhD Fellowship holder
FIGUEROA CLEMENTE Manuel Enrique	University of Seville	Department of Plant Biology and Ecology	Professor
GARCÍA MURILLO Pablo J.	Fac. of Pharmacy, University of Sevilla	Dept. of Vegetal Biology and Ecology	University Professor
LUQUE PALOMO Carlos Javier	University of Huelva	Department of Environmental Biology and Public Health	Asistant Professor
PACIOS ROBLES Fernando	Estación Biológica de Doñana, CSIC	Dept. Applied Biology	PhD Fellowship holder
URDIALES ALONSO Carlos	Doñana National Park, Ministry of Environment	Conservation Team	Technician Conservation Team

Lead scientist's background:

(Scientific background and experience, English level, etc)

Dr. Javier Bustamante PhD in environmental biology in 1990 at the University Autónoma of Madrid, with a doctoral

thesis in behavioural ecology of birds of prey. He has been researcher at the National Science Museum, CSIC, Spain, the Division Wildlife and Ecoloy, CSIRO, Australia, Berchtesgaden National Park, Germany, and Doñana Biological Station, CSIC, Spain, where he finally got a fixed position as Tenured Scientist in 1996. Since then his research interests have focused on predictive modeling of species distributions, and on the use of remote sensing data as predictors in species distribution models. He is currently the scientist in charge of the Remote Sensing and GIS Lab of Doñana Biological Station, lead scientist in a project on the use of Landsat images to reconstruct the flooding regime of the Doñana marshes, and researcher in a project on the use of VEGETATION images to model species distribution in Argentinean Patagonia. He has directed four doctoral thesis, he is currently director of three doctoral students, and has published more than 50 research papers. He is fluent in English.

Lead scientist consider himself as:

Inexperienced in the use of research aircraft: Yes

Requiring access to an aircraft he/she has not used before: Yes

Number of participants on campaign site:

7

Total number of participants:

9

Scientific problems being addressed by the experiments and brief summary of experiments:

Doñana National Park is a wetland of international importance. There are several exotic plant species like Azolla filiculoides and Spartina densiflora that have recently invaded the park or neigbouring areas. We think hyperspectral airborne sensors can be a very usefull tool to map the distribution and density of invaders and indicate where management actions should be carried. The marshes where this two exotic invaders spread are an extensive area over 20,000 ha . that is difficult to access when flooded. It is a very dynamic ecosystem with water level depending on a variable rainfall, and with a rich community of aquatic plants. We plan to fly airborne hyperspectral sensors covering the visible, near infrared and mid infrared at different altitudes in areas with different densities of the exotic species, simultaneous with field work to quantify the density these exotics and other aquatic plants.

Aircraft:

NERC - Do 228

Why this aircraft bests suits for this experiments? :

This aircraft can be fitted with two hyperspectral sensors operated by NERC: Eagle (400-970 nm) and Hawk (970-2450 nm) wich would give us a complete coverage of the spectrum in the visible, near infrared and short wave infrared

Alternative aircraft:

FUB - C 207

2.Description of the experiment

Scientific objectives/Proposed Work/Anticipated output:

The main objective is evaluate the use of hyperspectral sensors to map the distribution and density of individual species of plants in a flooded marsh environment. In this case we would focus on two exotic invaders Azolla filiculoides and Spartina densiflora, for which there is a need to locate areas colonized by the species to perform erradication measures within Doñana National Park.

Azolla filiculoides in an aquatic fern originary from North America that contains a symbiotic, heterocystous, blue-green alga, Anabaena azollae within cavities in its leaves. By the process of nitrogen-fixation the alga is capable of fulfilling the N requirements of the association. Azolla is highly productive having the ability to double its weight in 7 days and forms dense mats that float on the water surface. Some populations of this species were discovered in spring 2001 in the marshes of Doñana National Park, and since then the species has continued spreading. The plant can form dense mats more than 10 cm thick that block sunlight and kill submerged vegetation. These mats are clearly visible from an aircraft.

Spartina densiflora (dense-flowered cordgrass) is a perennial salt tolerant grass that grows erect in dense, cespitose (tufted) clumps. It is originary from South America and was introduced in spain in the XVI century. It is an exotic invader in the Odiel Marshes, close to Doñana, where Spartina denisflora invasion is extensive.Some populations have been located in the limits of Doñana National Park. Monitoring the spread of these populations before the invasion is more extensive is esential for the conservation of other native marsh plants with which it would compete.

We propose to fly two hyperspectral sensors one covering the VNIR spectrum (Eagle) and other covering SWIR spectrum (Hawk) in spring in areas of the Odiel and Doñana marshes, including areas with different densities of the two invading plant species. We would fly the sensor at different altitudes to identify the optimal spatial resolution to

map these two species, and identify them from other marsh vegetation. It would be desirable to plan the flight simultaneous with an adquisition of a satellite hyperspectral sensor (CRHIS-Proba or Hyperion-EO-1) to improve the project up-scaling. Simultaneous with the flight we would measure on the ground the reflected spectra of both species and other submerged, floating and emergent native marsh plants. Also we will locate with DGPS sampling plots with different densities of exotic invaders and measure plant coverage at the species level.
We expect to produce maps of the density of exotic invaders that will guide management actions to erradicate them. The hyperspectral data and the up-scaling would allow us to evaluate the optimal spatial resolution and the optimal spectral bands to map the species on an operational basis. In this way we could decide if airborne or satellite multispectral or hyperspectral remote sening techniches can be use to guide management acctions for the erradication of invaders.

Weather conditions:
(e.g. clouds, atmospheric stability, wind speed and direction, weather...)

Clear sky conditions

Time constraints:
(night time, under-pass(es) of satellites, weekends...)

Flights should take place in spring (mid march to the end of may) when the marsh is flooded and aquatic vegetation is growing. They will be precisely timed acording to flood level and vegetation growth. It is necessary that rainfall in previous autumn and winter is equal or above average to guarantee a flooded marsh and aquatic vegetation growth. It would be possible to fly in spring 2007 or 2008. We are simultaneously asking for adquisition of CHRIS-Proba data in which case it would be desirable an underpass with this satellite. An alternative would be an adquisition/underpass with EO-1 Hyperion.

Location and reason for that choice:

Flights will take place in Doñana and Odiel marshes (Andalusia, Southwestern Spain) where both species of exotic invaders have populations mixed with native vegetation. In Doñana National Park we would cover areas with different degrees of Azolla invasion and some small populations of Spartina densiflora. In Odiel Marshes Natural Park we could cover an area with different degrees of invasion of Spartina densiflora.

Number of flights and flight patterns :

We plan three flight paths of approx. 20 km legth at two different altitudes that would give pixel sizes of approx. 5 and 10 m (total of 6 flight paths). One would be located at the Odiel marshes and two at the Doñana marshes. We think the total area could be covered in one day and less that 10 flight hours.

1.- refinement and reduction of area of coverage;

In our proposal we indicated three flight lines, one in the Odiel marshes Natural Park (No. 1) and two in Doñana National park (No. 2 & 3 in the map attached). We provide a new map indicating the presence of Spartina densiflora and the gradual spread of Azolla filiculoides (2000-2004) The minimum flight requirements would be one flight line (No. 2) in Doñana National Park. This flight line would be enough for the study of Azolla filiculoides discrimination and would include some stands of Spartina densiflora. We cannot guarantee this would be enought for the study of the discrimination ability in this second invasive species, because there are just few, almost monospecific, stands of Spartina that would be included in line No. 2, and there is very little variability in plant density. For this reason we included fligth line No. 1 that covers an area with a lot of variation in Spartina density. Flight line No. 3 could be reduced if necessary, but is interesting from our point of view because we expect a lower density of Azolla mixed with a different comunity of aquatic plants

2.- Data acquisition at only one height to provide approx 3m resolution for both hyperpectral instruments;

Minimum flight altitude allowed by regulation over Doñana National Park is arround 1800 m, this would limit the maximum resolution for both instruments (you should contact INTA (EUFAR-Net partner Spain) for flight regulation details as they have flown the area several times). We can assume a single resolution although this would limit our possibilities for estimating an optimal resolution for regular monitoring the spread of both species.

Other constraints or requirements:

None

3.Parameters to be measured / Instrumentation:

Description of parameter/measurement required for the experiment :

Surface reflectance would be meassured in the VNIR (Eagle) and SWIR (Hawk) regions of the spectrum. GPS/INS data of the sensors would be necessary for precise geometric correction. We would simultaneously measure field reflectance of test areas (sand dunes, water) to allow for the correction of atmospheric effects and samples of plant species with a portable spectro-radiometer ASD FieldSpec Pro JR model A110080 (spectral range 350-2500 nm)

instruments to be provided by hosting Aircraft Operator:
(basic instrumentation described on EUFAR website only)

Aisa Eagle VNIR Hyperspectral sensor (400-970 nm)
Aisa Hawk SWIR Hyperspectral sensor (970-2500 nm)
GPS/INS unit for precise geometric correction of reflectance data

Own instruments to be added :
(have they already been flown? Do they have their own data acquisition system?)

None

Number of instrument operators needed onboard:
(in addition to those provided by the Aircraft Operator)

0

if applicable, plans for simaltaneous field work plans / ground equipment to be used:

The local research team will identify previously areas with different densities of exotic invaders to adjust the location of optimal flight paths. On the day of the flight we will record surface reflectance of test areas with a portable spectro-radiometer ASD FieldSpec Pro JR model A110080 (spectral range 350-2500 nm) plus reflectance of areas covered by exotic invaders and native plant species. Once the fligth has been successfull, part of the team will obtain spectra of fresh plant materail of different native plant species and exotic invaders in comparable conditions, while other members will meassure plant coverage to the species level in a 5x5 m grid within 30x30 m squares georeferenced with DGPS. We will select a minimum of 12 30x30m squares, 6 per exotic species, representing a minimum of 2 low, 2 mean an 2 high coverage of each Azolla and Spartina.

4.Data processing and analysis:

Methodology for handling the data and analysis of output:
(airborne data acquisition, ground-truthing / observations,data processing and interpretation)

.We would require radiometric data georeferenced with a mean error below 5 m. Surface reflectance of test areas will be use to correct sensor data for atmospheric effects. Initially we will analyze species field spectra to determine the spectral bands with higher discrimination potential. Then we will build models using as response variables the ground coverage of Azolla and Spartina and using as potential predictors the ground reflectance of the different spectral bands recorded by the airborne hyperspectral sensors. We will test Generalized Linear Models (GLM) and Generalized Additive Models (GAM) built with a forward stepwise selection of predictors. We will also test Classification and Regression Tree (CART) models using plant species presence. Part of the ground-truth data will be reserved for model validation. Models will be built at different spatial scales and compared in their predictive ability. Final models will be used to produce an abundance map for Azolla filiculoides and Spartina densiflora. These maps will be used to design new field sampling campaign to validate them.

3. Crucially, that the Investigators provide ground-based evidence that the invasive species can be distinguished from native species.

We have collected spectral signatures from most of the plant species present in Doñana marshland. We used the ASD FieldSpec Pro JR, a field spectroradiometer covering 350-2500 nm. For every plant species 10 individuals were in field measured, every individual being selected according to a gradient between low vegetative plants to very active ones in an homogeneous population retained as training area (GPS delimitation). For every individual, ten-second average of reflectance values was recorded considering the whole canopy. For every measure, a sample of soil and shadow around the plant was also acquired in order to characterize the background response. For emergent and floating plants we also recorded water signature.

Seeking to evaluate spectral separability among average spectral signatures, we have applied binary encoding (BE), spectral feature fitting (SFF) and spectral angle mapper (SAM) algorithms to score similarity among spectral behaviour of every plant species. The most distinct signal comes up with
Azolla filiculoides, which scores under 0.1, leading to think in an easy discrimination in hyperspectral images and most likely in the visible spectral region. The other exotic and invasive plant species, Spartina densiflora, grows in tightly closed stands and has a canopy structure that might be easily recognised in hyperspectral images. Similarity value for it reached 3.4, although the closest spectral signature shares almost the 50% of reflectance values (belongs to Juncus acutus, a similar spiny-stems plant in terms of canopy). Detailed results are provided in the attached excel

file.

These preliminary results point out the need for hyperspectral images for both study areas since discriminability is affordable from the similarity values. However, special attention should be put on the definite date of flights since the vegetative status of plants may be quite different mostly
in the case of Azolla. Azolla starts its vegetative cycle with a very "green" signature and develops quickly to a "red" and conspicuous signature.

Finally, during the sampling period we have observed the rapid spread of Spartina densiflora in Doñana National Park. Accurate mapping of this invader may allow to take relevant conservation decisions to avoid wide spread of such species.

What resources are available to support the project beyond flying/data acquisition:

(funding, cooperation with other projects, manpower for analysis of results and preparation of user report availability of laboratory facilities, etc)

Dr. Javier Bustamante, Ricardo Díaz-Delgado and Fernando Pacios are currently working on a project financed by Doñana National Park to study the historical flood dynamics of the Doñana marshes using remote sensing data. A new application has been made to the Spanish ministry of Science and Technology that would provide funding for field work for the period 2007-2009. Dr. Pablo García Murillo and Rocio Fernńadez Zamudio are botanist working on Azolla filiculoides distribution in Doñana National Park and have applied for a funding extension to Doñana National Park administration. Dr. Eloy M. Castellanos Verdugo, Carlos Luque and Enrique Figueroa have applied for funds to study the invasion potential of Spartina densiflora in Doñana National Park. The National Park Administration, represented by Carlos Urdiales is interested in the results of the project and will provide access to hidrological and meteorological stations data. The research group will have the funds and manpower for field campaigns and data analysis.

5.Planning:

Primary/Preferred dates:

Starting date:15-04-2007

Ending date:15-05-2007

Acceptable dates:

(season / time windows)

Spring 2008 (15 March to 15 May). This could be an alternative if 2007 is a drought year.

Agree to share aircraft time:

Yes

6.Other useful comments:

Training benefit of project (for ET evaluation):

(e.g. spred potential of airborne research to a wide scientific community, training of research students in experimental planning, methodology, data analysis and applications, etc)

We think this project would show the huge potential of hyperspectral sensors to ecologists and to resource managers for mapping plant distribution. If the project is successfull the National Park and /or the Regional ministry of environment could start thinking on using airborne or satellite sensors for operational monitoring of the spread of exotic invasive plant species, and as a tool to direct erradication efforts.

Scientific reviewers suggested by applicant:

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Other European Funding:

We think this project would show the huge potential of hyperspectral sensors to ecologists and to resource managers for mapping plant distribution. If the project is successfull the National Park and /or the Regional ministry of environment could start thinking on using airborne or satellite sensors for operational monitoring of the spread of exotic invasive plant species, and as a tool to direct erradication efforts.

Is the applicant aggreing to host a student during campaign and data analysis:
(in the frame of Education & Training "Join an existing campaign" activity)

Yes

Number of students:1
Number of days recommended for students:30

Where do you know EUFAR Transnational Access and Education&Training opportunities from?

EUFAR website