

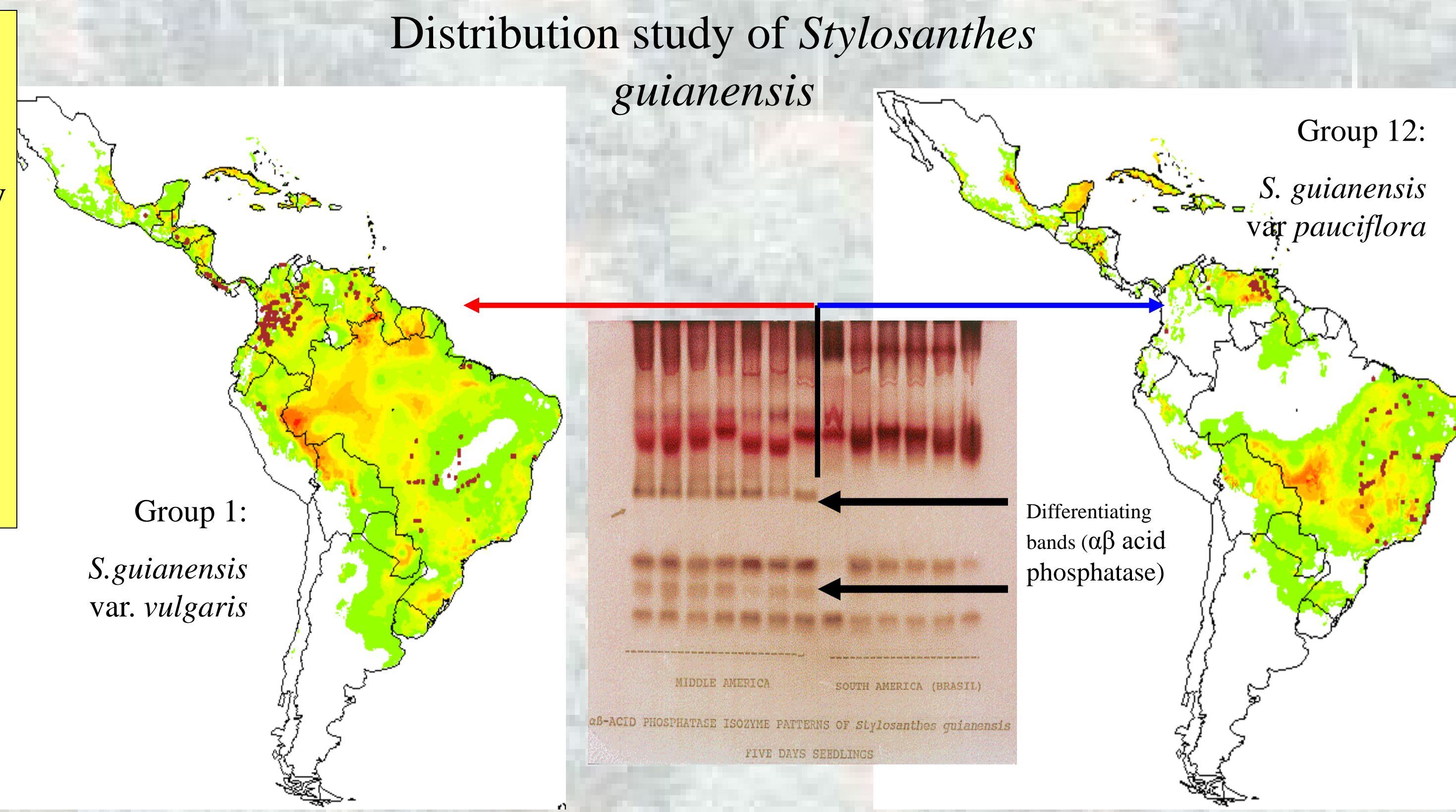
FloraMap

A Computer Tool for Predicting the Distribution of Plants and other Organisms in the Wild

P.G. Jones¹, S. Segura², L. Guarino³ & M. Peters⁴

1. Land Use Consultant, Centro Internacional de Agricultura Tropical (CIAT)
2. CIRAD-FLHOR/IPGRI, c/o CIAT
3. Scientist, International Plant Genetic Resources Institute (IPGRI)
4. Germplasm Specialist, CIAT

FloraMap maps the predicted distribution, or areas of possible adaptation, of natural organisms when little is known of the detailed physiology of the organism. The climate at the collection point of a set of individuals is assumed to be representative of the environmental range of the organisms. For plants, these are usually germplasm accessions or herbarium specimens.



Stylosanthes is the most widely used tropical legume genus for pasture and soil improvement (Edye 1987). The collection of germplasm of the genus has been a high priority over the last 25 years for a number of institutions throughout the world.

Stylosanthes guianensis is one of the most sought-after species in the genus. It has a wide natural distribution and can be found from Mexico to Argentina (Williams et al 1984).

This work formed part of a collaboration between CIAT, CSIRO in Australia, the University of Birmingham, and Kew Gardens in the UK. It was reported in Jones et al. (1997b).

We took an accession set of 438 individuals and using the FloraMap algorithms (this was before they were incorporated in the FloraMap software package), we fitted the projected distribution map. There was a considerable lack of fit of the probability surface. Many accessions fell in areas of very low probability, while large tracts of indicated high probability were void of accessions, even in areas that we knew had been collected.

We therefore made a cluster analysis of the climates in the accession set and grouped them into 12 classes. Groups 1 and 12 contained the majority of the collection and were clear, well-defined clusters. We then mapped the two probability surfaces, as shown on the left.

After we had finished this exercise we looked over the data set once more and found that an extensive isozyme study has been made for almost all of the accessions. What is more there was a clear link between the isozyme data and taxonomic variation in the species, which is differentiated into two botanical varieties, *S. guianensis* var. *vulgaris* and *S. guianensis* var. *pauciflora*. These differences also corresponded closely with our cluster analysis. Group 1 corresponded with accessions of var. *vulgaris*, while Group 12 corresponded with var. *pauciflora*. The latter is favored by warmer, drier climates.

With some specially introduced errors to extend the exercise, this data set now forms part of the extensive tutorial which constitutes chapter one of the FloraMap Users Manual.

The normal probability integral in multiple dimensions

$$p = 1 - e^{-r^2/2}$$

$$p = \text{erf} \frac{\sqrt{2}r}{2}$$

In even dimensions

$$p = \frac{1}{\sqrt{\pi}} \int_0^r \frac{e^{-t^2/2}}{t} dt$$

In odd dimensions

The method

The climate at the each collection point is extracted from a climate database, and used as a calibration set to calculate a climate probability model.

We standardise the climate data to a common time-scale
We use the 12 point Fourier transform to fit 6 frequencies to the climate data. The phase angle of the first frequency for the rainfall record is subtracted from each climate record. This produces a rigid rotation which sets the common time for rainfall, temperature and diurnal temperature range.

We calculate a model of the probability that a map pixel belongs to the calibration set
After a transformation to normalise the rainfall data, a Principal Components Analysis (PCA) produces a set of normalised orthogonal components. Any number of these can be selected to represent the probability distribution of the climate data from the calibration set. As these probability calculations are made with models embedded in a varying number of dimensions, we have derived the formulae for calculating the normal probability integral in spaces of varying dimensions.

We then map the probability surface from a set of interpolated climate grids
The eigenvalues of each pixel on the interpolated climate surface are used to calculate the probability that the climate at that pixel could belong to the probability distribution defined by the calibration set embedded in the space of dimension determined by the number of principal components chosen by the user.

The probability surfaces can be output to other GIS applications
The probability surfaces are ESRI® Shapefiles, with each pixel defined as a square polygon. These can be readily exported to other GIS applications where they can be overlaid with other information such as soils, natural vegetation, human intervention etc. This feature is also useful for producing individually crafted output maps. FloraMap does not pretend to be a complete GIS but is a tool for use with other systems.

The Map Window Tool

The map window is the central tool in FloraMap. It displays the maps and has controls for managing the map layers including probability surfaces and accession points used in the model. The political boundaries of Latin America, Africa and Asia can be displayed as back ground to the probability layers. Roads, rivers and cities can be overlaid as aids in geographically representing the study areas. Control of colours and characteristics of all layers is available through the Layer Control Window. There are facilities for saving and reloading complete maps, or individual map layers.

The Principal Components Window Tool

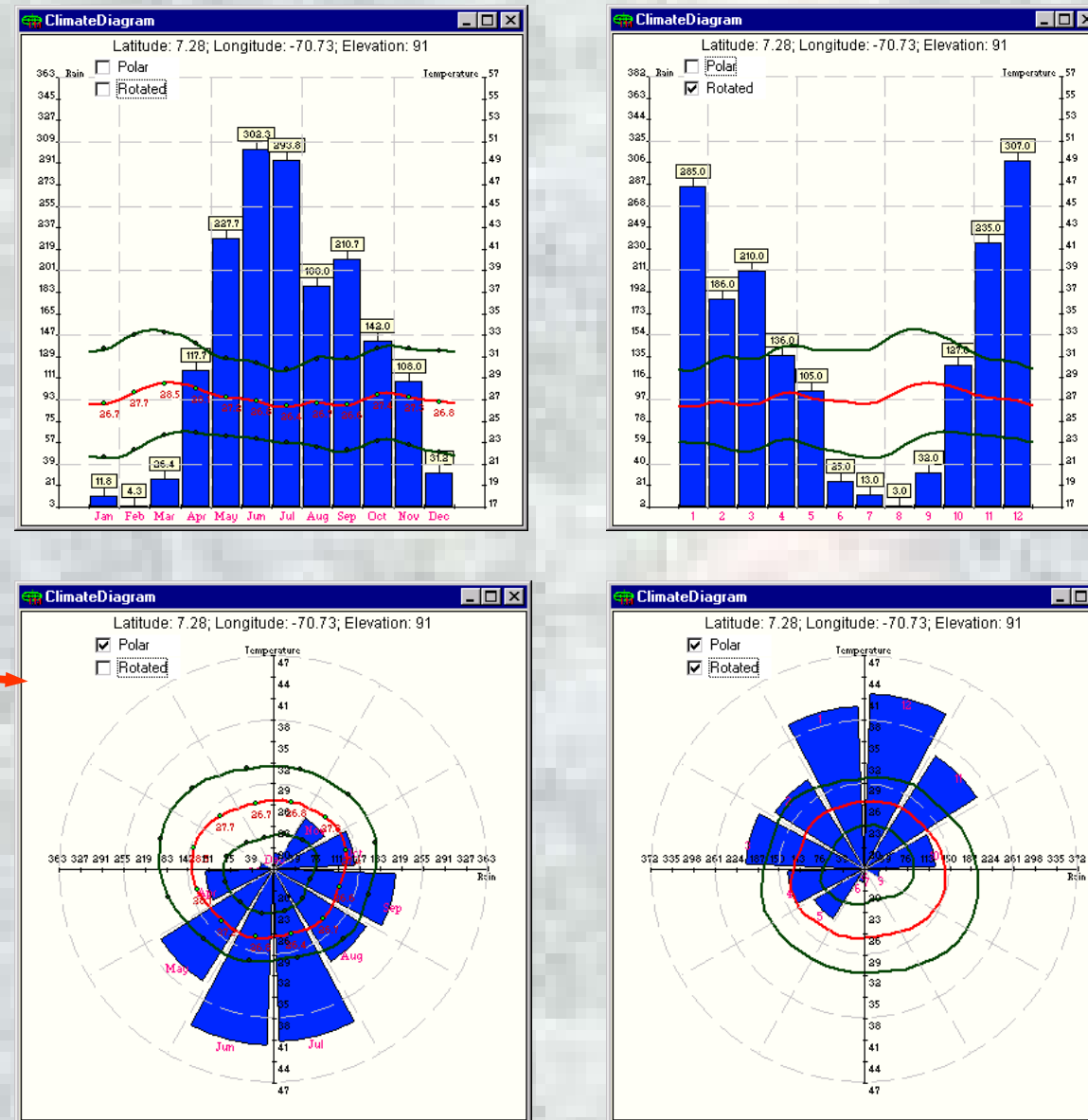
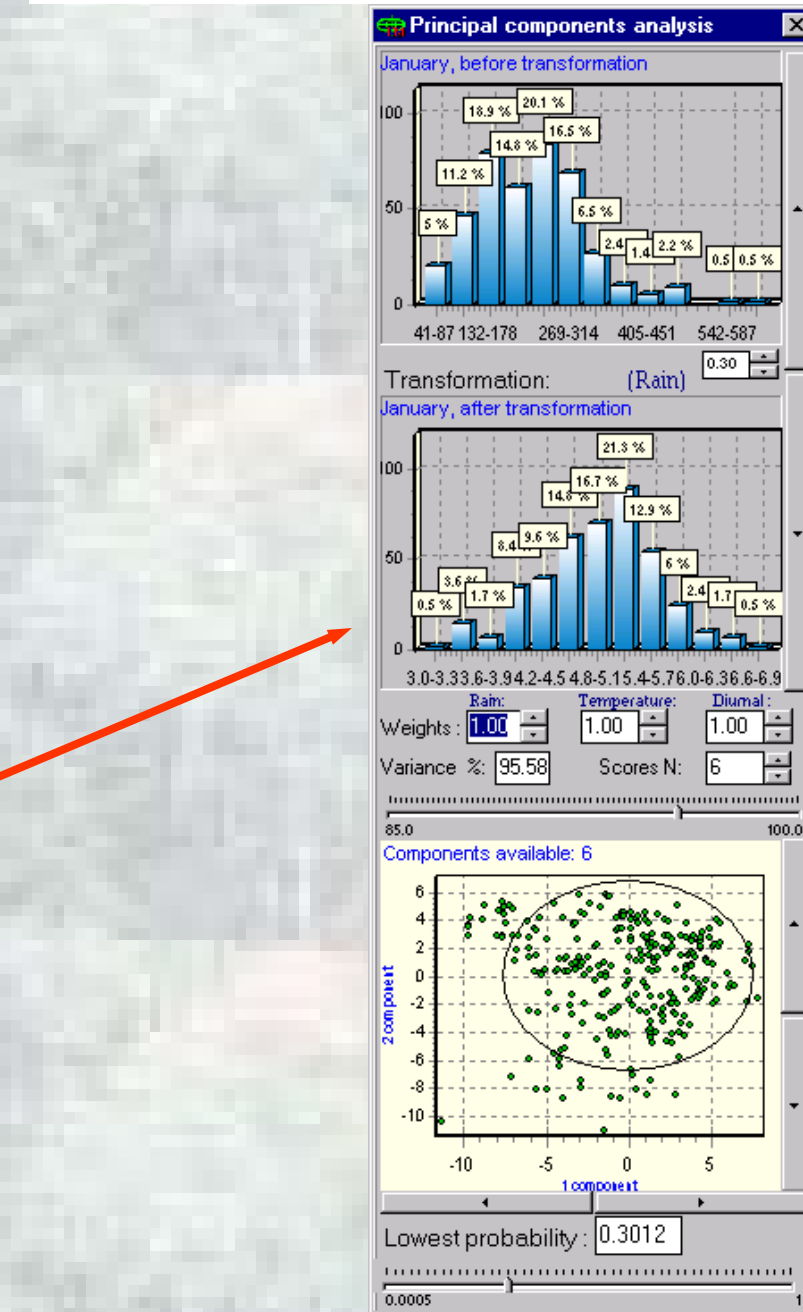
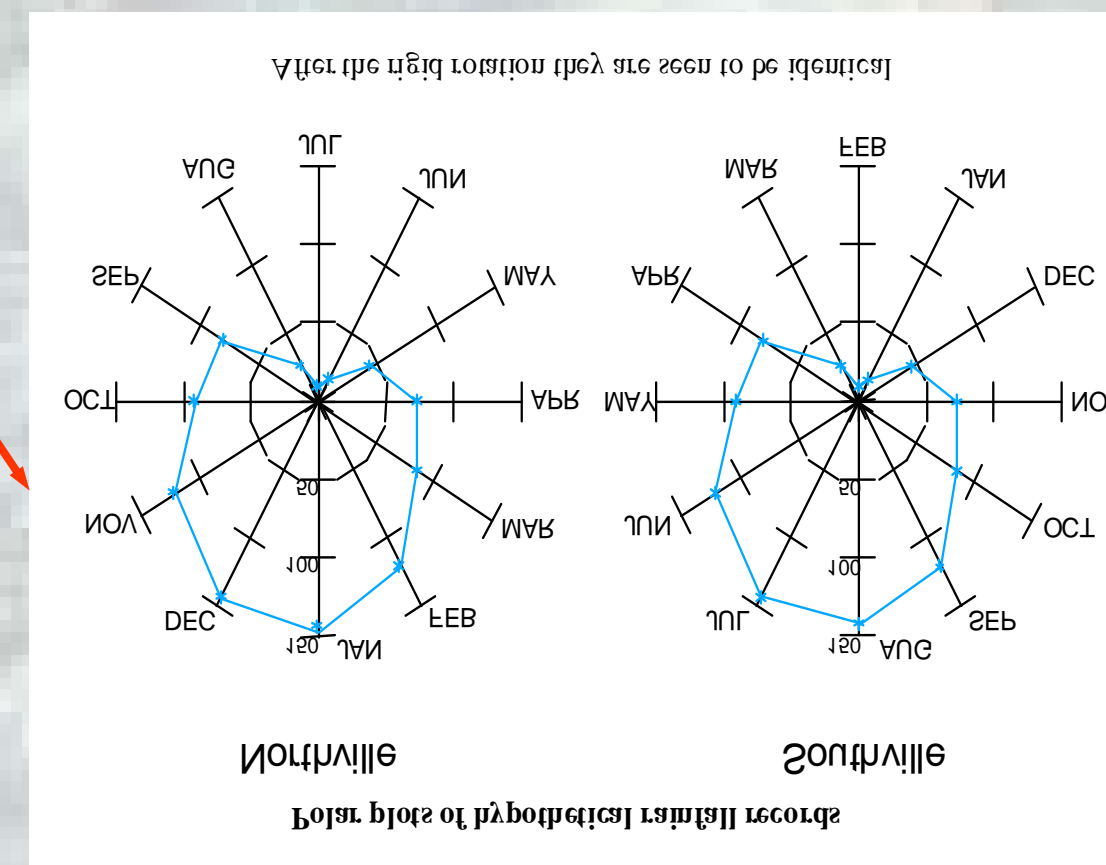
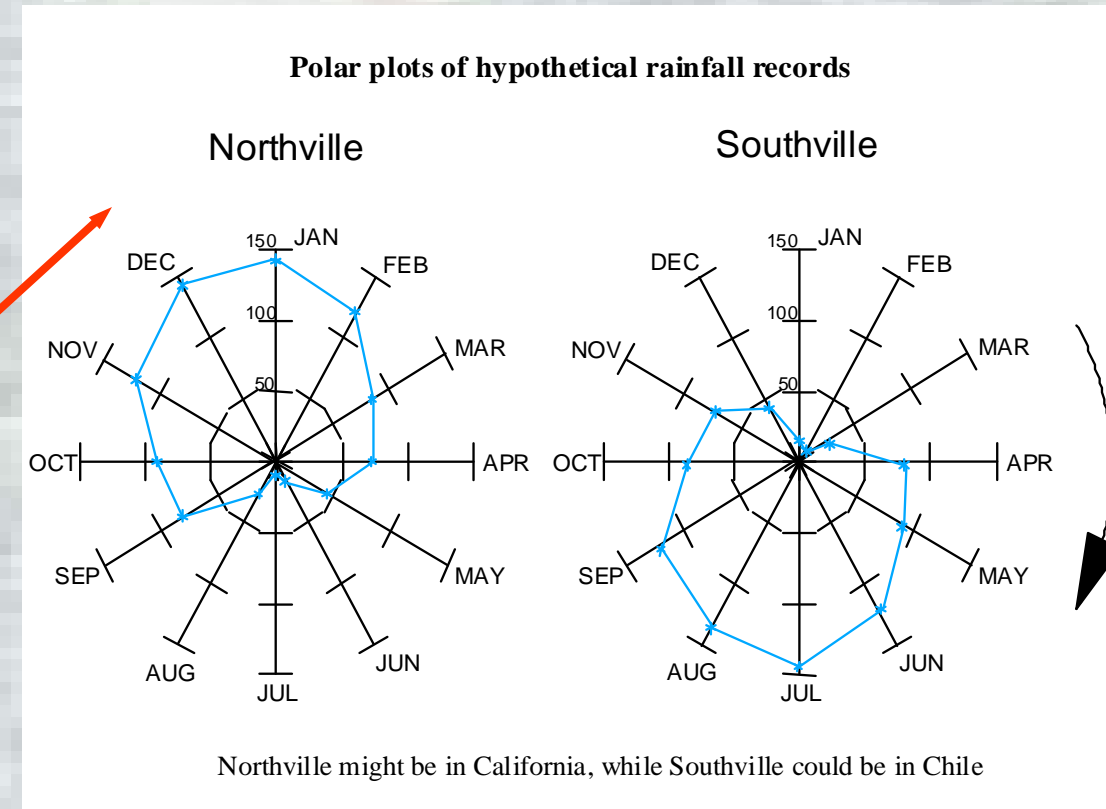
This window controls the principal components analysis. The scaling, weighting and transformation of the variates, choice of components and map probability limits are all at the control of the user, using handy sliders or by entering the values desired. A scatter diagram show the distribution of the accession points in any combinations of the principal component spaces. This is useful for identifying discontinuities in the distribution and for finding errors in the data. A powerful tool for selection of sub sets of the data works merely by drawing round the points in question. This also works from the Map Window.

The Cluster Analysis Tool

An accession set is often found to contain sub-populations that have distinct climatic ranges. The Cluster Analysis Tool gives the user access to seven powerful clustering techniques to investigate these possibilities. When clusters are found the user has only to point and select a cluster for reanalysis in the PCA or directly on the map.

The Climate Diagram Tool

The user can view the climate of a point from the map, an accession point from the scatter diagram or map and also the mean climate for groups of points from the scatter diagram or the map. The climate diagram can be displayed in Cartesian or polar co-ordinates and can show the data either by real date, or in rotated form. A



Mapping the distribution of five species of *Passiflora* in Andean countries

Sergio Segura¹, L. Guarino², L. López², M. Grum³ and G. Coppens d' Eeckenbrugge¹

¹CIRAD-FLHOR/IPGRI, c/o CIAT, AA. 6713, Cali, COLOMBIA
²IPGRI c/o CIAT AA. 6713, Cali, COLOMBIA
³IPGRI c/o ICRAF, PO Box 30677, Nairobi, KENYA

Introduction.
The Andean subgenus *Tacsonia* of the genus *Passiflora* is composed of more than 47 species (13 with edible fruits) (Escobar, 1988). *P. tripartita* var. *molissima* is cultivated and commercialized throughout the Andean region. Other widely distributed *Tacsonia* species including *P. mixta*, *P. cumbensis* and *P. paraitupulu* and *P. manicata* (subgenus *Manicata*) are of local commercial importance and have potential for breeding. However, knowledge about their environmental requirements is generally much less than for *P. molissima*, with few reports of their range and possible distribution, and until recently few germplasm accessions.

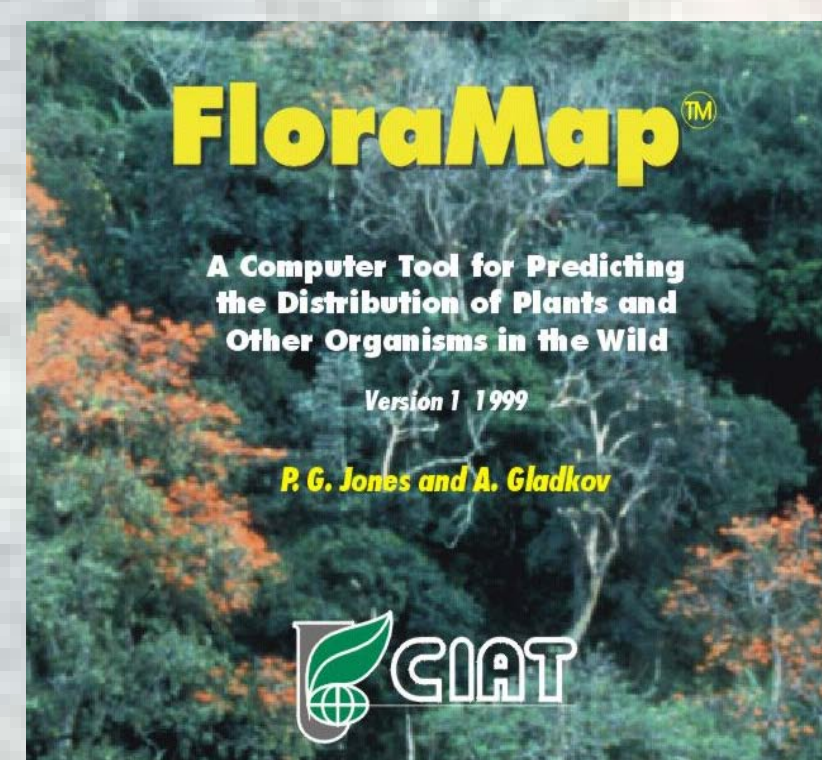
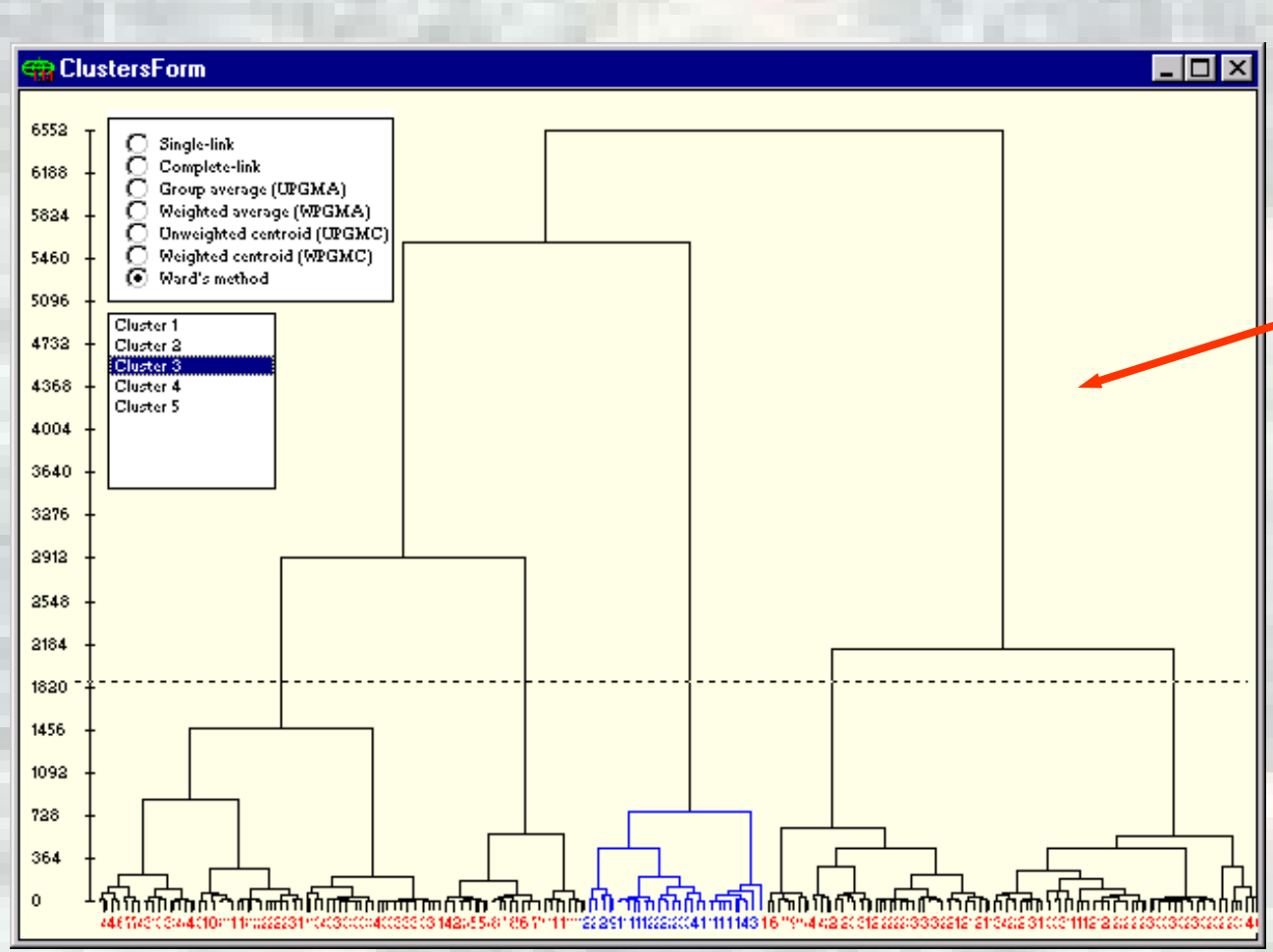
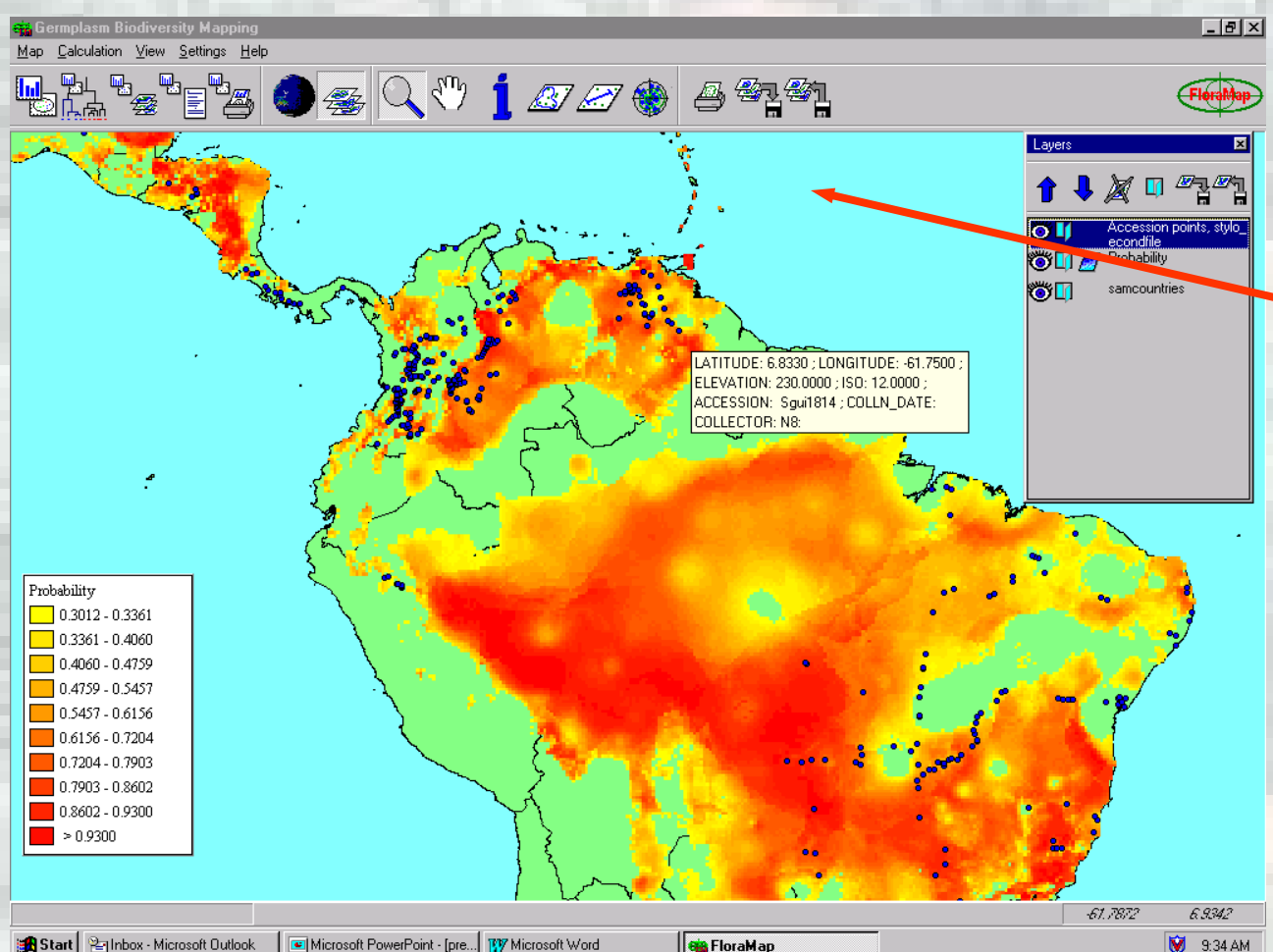
Results and Discussion
The distribution of the five most common species were mapped for Venezuela, Colombia, Ecuador, and Bolivia. Sites of collection are represented by points. Increasing color intensity shows an increasing probability of the pixel belonging to the multivariate frequency distribution represented by the pixels containing collecting points. Distinct patterns of climatic adaptation (as suggested from PCA) are represented by different colors.

P. tripartita var. *molissima*
Map presents the PCA results derived from the *P. tripartita* var. *molissima* data set. A probability density distribution based on the first five principal components (95% of variance) was used. Known areas of cultivation correspond closely with the areas of high probability identified by the analysis. The potential distribution map identified an area from Mérida, Venezuela to Cochabamba, Bolivia. Two clusters of climatic adaptation were recognized, possibly representing two ecotypes. The first cluster was warmer by 83 sites from Colombia, Ecuador and north Peru. A second cluster included sites from Peru and Bolivia mainly. Overlapping is present in southern Ecuador.

Isozymes studies on this species (Segura et al, 1998) report the presence of different zymotypes from Ecuador and Colombia based in the ACP system. Two electrophoretic bands were seen for this species, one in Colombian individuals and these could in Ecuadorian individuals only. One plant from Ecuador presented both bands suggesting that it is a heterozygote.

Objective
The goal of the present work was to identify areas climatically suitable for complementary germplasm collection. Variation in climatic adaptation could also be compared with genetic variation within the different species.

This example shows a selection from a study in which FloraMap was used to map the predicted range of five important tropical fruit species in the genus *Passiflora*. This was another case where the Cluster Tool proved useful in identifying differences in climatic adaptation which were also reflected in measured genetic differences.



FloraMap and its Users

The Users Group
FloraMap has a users group of over 80 individuals throughout the World. To join the group listserver, please send a message to: listserv@cgiar.org with the following text in the body of the message: **subscribe FloraMap-your email address**. The listserver is used to answer users questions, disseminate new information about FloraMap and as a platform for user-wide to exchange experiences and hints on its use.

The Web Site <http://www.floramap-ciar.org>
FloraMap has a Web site with information on the product, examples of its use and a growing list of Frequently Asked Questions with their answers. Your solution to difficulties with FloraMap could be merely a few mouse clicks away.

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Desmodium heterocarpum subsp. ovalifolium

Cross Continent Adaptability Mapping

This example is made with data from the CIAT Forage Germplasm Database. The genus *Desmodium* has shown promise as a pasture and cover legume in a number of situations. It is found throughout the tropics with species endemic in both Latin America and Asia.

Desmodium heterocarpum subsp. *ovalifolium* has been extensively collected in Malaysia, and also Vietnam, Thailand and Indonesia. The probability distribution for South East Asia, at the right, follows the accession points quite well. Some outlying points in the Thai and Sumatran highlands, and a few points on the low lying coast in Vietnam might indicate that there are sub-populations in the accession set, but for this exercise we have not applied the cluster analysis.

In Latin America it shows a large area of probable adaptability in the Brazilian, Peruvian and Colombian Amazon where it would possibly not be welcome as a pasture option for conservation reasons. However it would seem to be a useful possibility in the Colombian and Venezuelan Llanos and also in the wetter coastal areas of North East Brazil and in the wetter regions of Central America.

It's potential range in Africa appears to be quite limited. The highly significant area in southern Nigeria is interesting, as a few points in the Republic of Congo and Togo. Although most of these are Teste areas where the current utilisation for cattle pastures may be limited; however there may be other niches for the species, for example as ground cover in plantations.

Desmodium barbatum is widely represented through Latin America, as shown by the accessions points on the map to the left. In marked contrast to *D. heterocarpum* subsp. *ovalifolium* this species seems to be well adapted for many regions in Africa. Important areas through the moist savannas of West Africa, the Central African Republic right through to parts of northern Uganda, southern Sudan and even into the lowlands of southern Ethiopia.

In Asia, although the areas of potential adaptation are not extensive, it might find a place in Sumatra, Java and the Philippines.

These results quickly indicate an initial assessment of the possible adaptation of the legumes for trans-continental introduction. Initial trial material could be targeted precisely to areas where they might be expected to yield a good response for various, to be defined, uses.