



**Genetic Diversity in *Stylosanthes* Species:  
A GIS Mapping Approach<sup>1</sup>**

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**Abstract**

We describe a method of fitting a model of germplasm distribution to climate data and illustrate its use in mapping the continental distribution of five *Stylosanthes* species. The climate data used are the monthly totals of rainfall and the monthly mean temperatures and diurnal temperature ranges. The data are rotated in time to standardize dates and then used in a principal components analysis to develop a function giving the probability density of a climate being similar to those of a calibration set of germplasm accessions.

We present maps of the distributions of the calibration sets and probability densities and show how they can be used to guide further collection and to develop hypotheses of the genetic diversity within and between species.

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## Genetic Diversity in *Stylosanthes* Species: A GIS Mapping Approach

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### Introduction

Mapping the range of occurrence of a species depends strongly on mapping point sites where specimens have been collected. Unless a spatial saturation of collection points is available, there has always been a problem in extending this distribution to the full estimated environmental range of occurrence. This paper presents an objective method of analyzing climate data to facilitate this mapping. The method can be used to identify further potential collecting areas, areas for *in situ* conservation, and to suggest hypotheses on intraspecific diversity or similarity.

### Materials and Method

We selected five sets of accessions of *Stylosanthes* species from the germplasm banks of CIAT<sup>1</sup> and CSIRO<sup>2</sup>. We estimated the climate of the collection sites from the CIAT climate database (Jones, 1991), and used these collection site climates as a calibration set to estimate a statistical model of the multidimensional space occupied by the accession sample. Climates vary in two quite distinct ways; the form of the rainfall and temperature functions throughout the year, and the timing of the seasonal variation. An example of the latter is the inversion of seasons in the southern hemisphere. To remove this timing effect twelve monthly mean rainfall totals, monthly mean temperatures and diurnal temperature ranges were standardized to align the seasons.

To do this, we used a 12 point fourier transform to convert the data to frequencies and amplitudes (Jones, 1987). We subtracted the phase angle of the first frequency of the rainfall data from the other frequencies from the rest of the rainfall series and from each of the temperature and diurnal temperature range records. After retransforming the data to produce a rigid rotation of the original value, we then performed a principal components analysis on the calibration set. Taking the first four principal components, we used the latent vector values to map the climate characteristics throughout the continent. We calculated the probability that each 10 minute pixel in the climate files could have been drawn from the climate distribution defined by the calibration set. For details of this analysis see Jones et al. (1996).

We present the results of the exercise on *S. capitata* Vog., *S. guianensis* (Aubl.) Sw., *S. hamata* (L.) Taub., *S. scabra* Vog. and a new species, *Stylosanthes* sp. aff. *scabra* (Figures 1 to 5).

The tropical legume genus *Stylosanthes* has provided several species with

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potential for pasture and soil improvement, that have been comprehensively investigated and improved over the last 20 years (Cameron et al., 1993). As most species are native to the Americas, this is where their center of diversity is, as shown by both inter- and intra-specific variation (Burt, 1984). Many *Stylosanthes* are pioneer species that occur in ephemeral habitats. They are, for example, colonizers along roadsides in the Brazilian Cerrados and Amazon (Costa and Schultze-Kraft, 1993).

## **Results and Discussion**

### **Climate largely determines occurrence**

The distribution probability map produced for *S. capitata* (Figure 2) fits well with the collection sites of germplasm accessions. The natural occurrence of *S. capitata* is disjunct, in regions of Brazil and Venezuela (Williams et al., 1984), where *S. capitata* is not very frequent, according to Costa and Schultze-Kraft (1993). These authors consider that annual rainfall and the length of the dry season are the most determinant environmental variables for the natural distribution of *S. capitata* in Venezuela, while they described ample climatic variation for the Brazilian collection sites. Nevertheless, Brazilian germplasm accessions were mainly collected from semiarid, 'Caatinga' vegetation. This largely climatic determination of the natural occurrence of *S. capitata* probably led to the excellent fit of the map.

### **Other factors may be important locally**

*Stylosanthes guianensis sensu lato* is a pan American species, most widely found throughout the continent (Williams et al., 1984). Many of the potential areas for collection have been explored. Nevertheless, there would appear to be a broad area of potential exploration for *S. guianensis* through southern Peru and northern Bolivia, see figure 4. Williams et al. (1984) discussed the apparent absence of *S. guianensis* from the interior lowlands of South America. They suggested that this could be because *S. guianensis* is intolerant of periods of extended waterlogging, or its poor adaptation to the shady forest environment. This may support Ferrufino et al. (1991), who collected legumes in the humid tropics of Cochabamba and Santa Cruz, Bolivia, and found *S. guianensis* only in the more subhumid areas with rainfall of less than 2200 mm. However, *S. guianensis* has been collected in high rainfall areas (annual rainfall > 7000 mm) of the humid tropics, such as the Colombian Chocó department, where it was found relatively frequently at roadsides (B.L. Maass, unpublished data). As Williams et al. (1984) also considered that its apparent absence could be because of very little collection carried out in these regions, it may be worthwhile to consider other environmental characteristics, such as chemical and physical soil factors, for potential distribution of the species, in addition to plant exploration missions to areas, where the species has potential but has not yet been collected.

### **A validation of the method**

A serendipitous difficulty led us to an unplanned validation of the classification and mapping procedure. There are usually small errors of location in the files used

for the analysis. In the case of *S. hamata*, there were over 20 accessions collected in the small islands throughout the Caribbean, particularly some in the Bahamas. Slight errors in the passport data and minor systematic errors in the climate database made it difficult for us to align some accessions with the correct island. Since they then fell in the sea, we decided to eliminate them from the calibration set. We went ahead and fitted the model to the continental points.

Once mapped the unplanned validation became obvious. The islands onto which we had been trying to align the recalcitrant points lit up as highly probable climates for *S. hamata*, see figure 6. The actual natural distribution of *S. hamata* has been disputed for some time because the taxonomic status of diploid and tetraploid forms of the species occur in different geographical regions. Stace and Cameron (1987) describe the diploid *S. hamata* s. str. as an indigenous component of the flora of drier habitats of the Caribbean islands, Florida and the mainland of north-eastern South America, while the tetraploid form has only been found around the Gulf of Maracaibo and the surrounding Cordilleras of Colombia and Venezuela. A description of the biogeography of *S. hamata* is presently being developed (Edye and Maass, 1996). Our mapping would indicate that both forms appear to be found in similar climatic ranges.

#### Potential for further collection

The most striking indication of potential new collecting areas is the case of *Stylosanthes* sp. aff. *scabra*. There is now evidence that this species is distinct from *S. scabra*. It was first classified as a distinct plant type by Edye et al. (1974). Although Stace and Cameron (1987) suggested that these plants appear to be extreme segregants of the abundant natural variation occurring in *S. scabra*, in the morpho-agronomic classification carried out on a comprehensive collection, a number of accessions, previously labeled *S. scabra*, were determined as being distinct morphologically and agronomically, and belonging to this new plant type (Maass, 1989). Recently, much interest has been generated for this plant in Australia because of its frost tolerance and adaptation to heavy soils of central and southern Queensland (Jansen and Edye, n.d.); in Australia, two accessions are now in pre-release stage (L.A. Edye, 1995, personal communication).

New molecular studies (Liu and Musial, n.d.) have provided the genetic arguments for recognizing the material belonging to this plant type as a distinct species. However, in the germplasm collections of CIAT and CSIRO, there is only a small number of accessions available. Accession points are limited to an area in the states of Bahia and Minas Gerais in eastern Brazil. The climate probability density map (Figure 7) shows major potential collection areas in southern Brazil, eastern Paraguay and northern Argentina. As long as we do not appreciate the importance of other ecological factors for the occurrence of this species, new collection missions should focus on these areas identified to prove the validity of the generated map of distribution probability.

## Species consist of different populations

An example of the possible generation of hypotheses about the mapped species can be seen in the natural distribution of *S. scabra*. It has a wide, but disjunct distribution in tropical South America: it occurs naturally in Colombia, Venezuela, and Brazil (Williams et al., 1984). It has also been widely collected. However, if we look closely at the origin of the collection, we can see that considerable collecting has been done in Colombia, but that these collection points do not necessarily fall in high probability areas, see figure 8. However, we note that most of the points falling in high probability areas are in Central America or in Brazil. We can use this information to form a hypothesis. Are there in fact two or more populations of the species with different climatic requirements? By fitting a single multivariate normal distribution to the calibration set we may find spurious regions of high probability where no accessions exist, or we may find accession sites in areas of low probability; figure 9 shows schematically how this could occur.

A possible procedure to investigate this would be to cluster the calibration set climates to see if they fall into clearly separated population. Jones et al. (1996) attempt this for wild *Phaseolus vulgaris* L. Further work on the genetic characterization of samples of these populations should help to prove or disprove this hypothesis. In a morpho-agronomic classification of a large germplasm collection of *S. scabra*, different plant types were identified. Germplasm accessions from Colombia were not only morphologically different but had also lower tannin content and relatively higher forage quality, similar to the new species *Stylosanthes* sp. aff. *scabra* (Maass, 1989). A detailed analysis of the population structure of *S. scabra* may well confirm the hypothesis generated on the basis of climate data.

## Conclusions

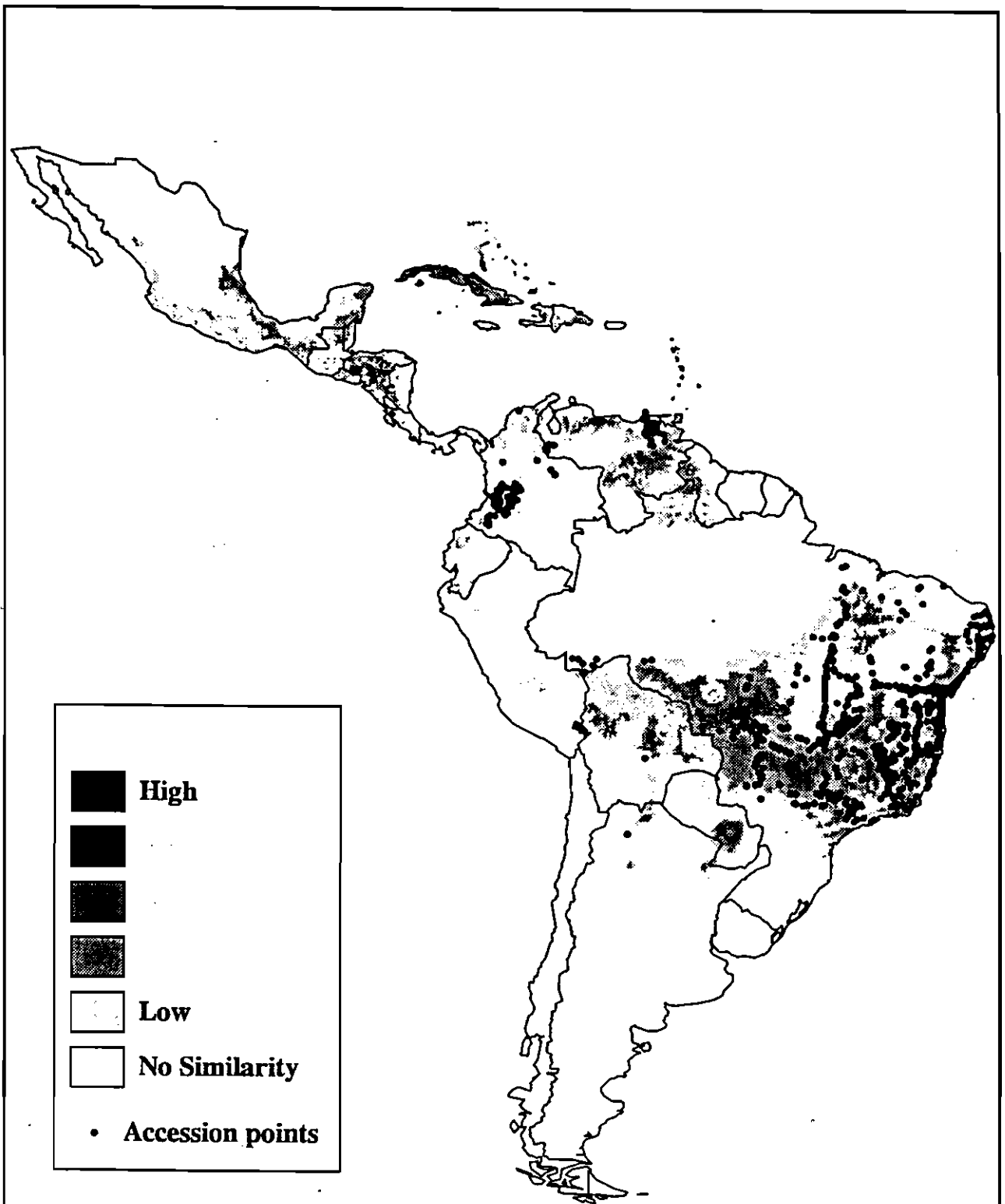
It would appear that we have a potentially powerful tool for explaining species distribution and forming hypotheses about genetic diversity both within and between species. There is, however, a need to include not only climate but also soils data into potential distribution maps.

This study only used site data from germplasm collection accessions. As germplasm collectors often set out to collect a limited range of promising germplasm, their preconceived idea of the environmental niche of the species may bias the distribution data. Unlikely environments may be undercollected. Herbarium collections, on the other hand will tend to give a less biased representation of the flora of a particular region and could be used to check the potential bias in the method.

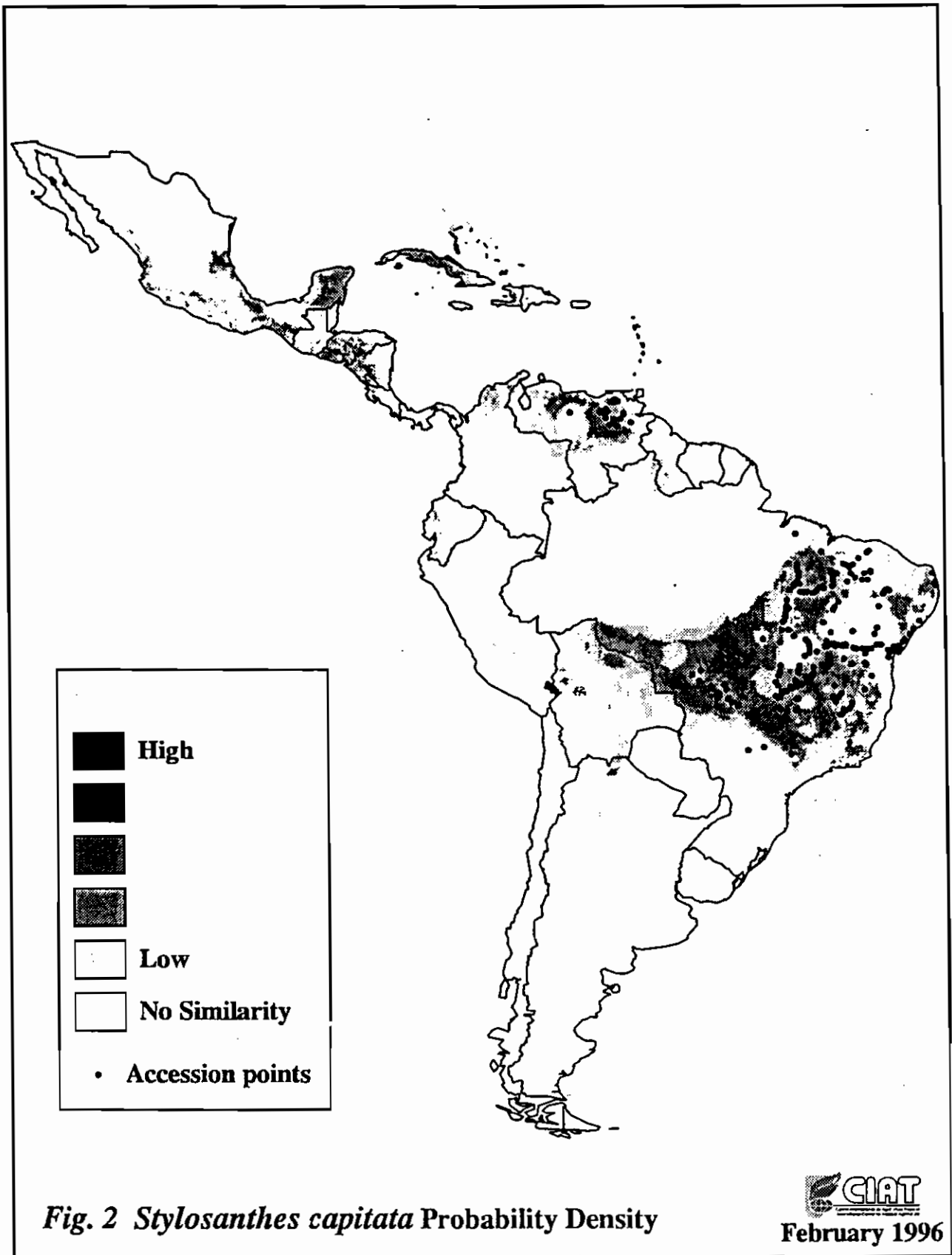
The resolution of the climate files at 10 minutes of arc (approx. 18 km) leaves a lot to be desired, particularly in broken, mountainous terrain. This will be solved in the near future when we construct new interpolated climate files with a precision of 30 second of arc (about 1 km). Although even then it may be difficult to "catch" the real distribution of a rather "ephemeral" species, that prefers open, disturbed environments and will be out-competed when vegetation is closed. The method should however show the envelope of climates favoring the species if other factors are taken into account. These could include; soil, vegetation type, anthropogenic influence by fire and grazing.

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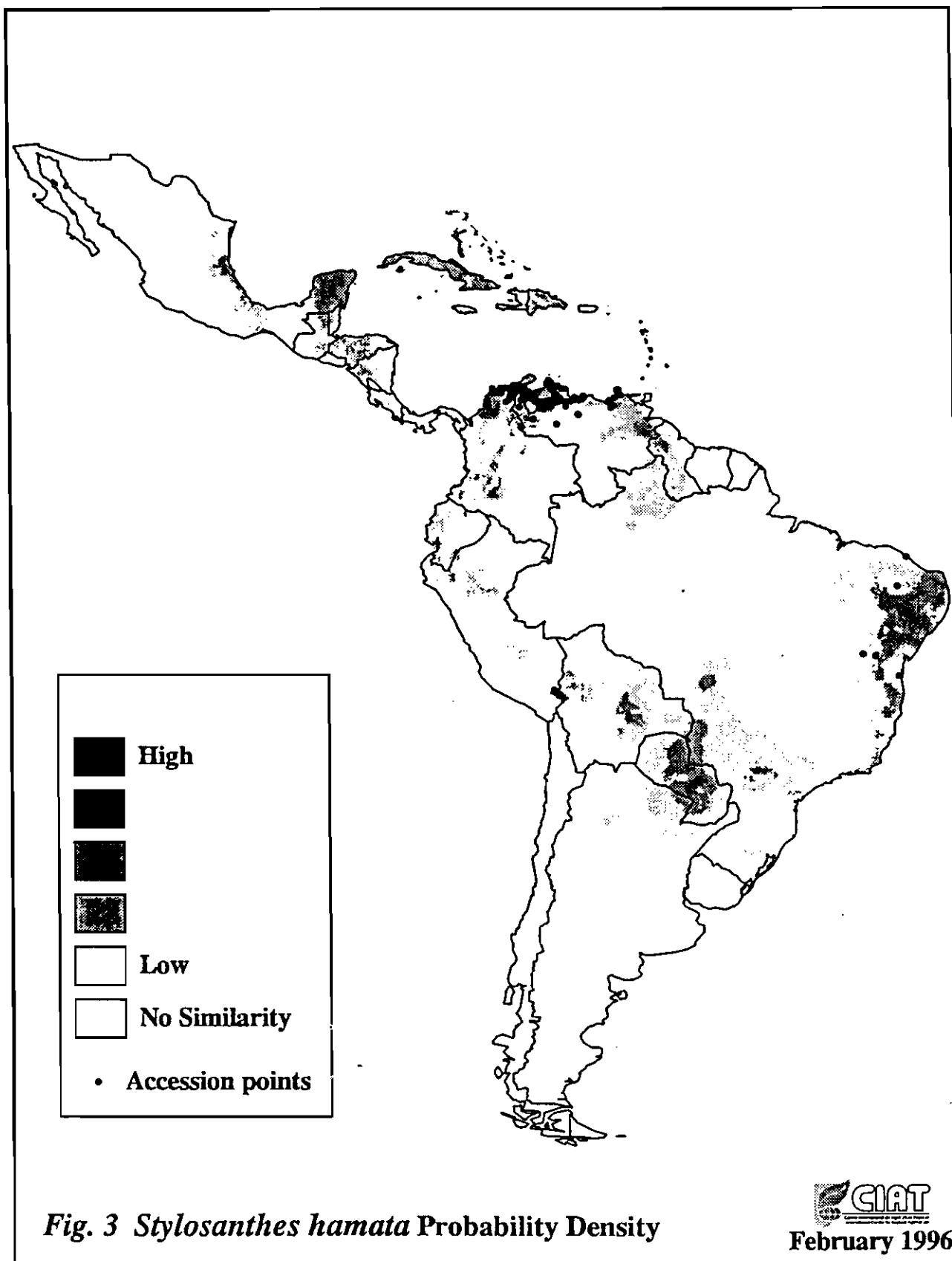
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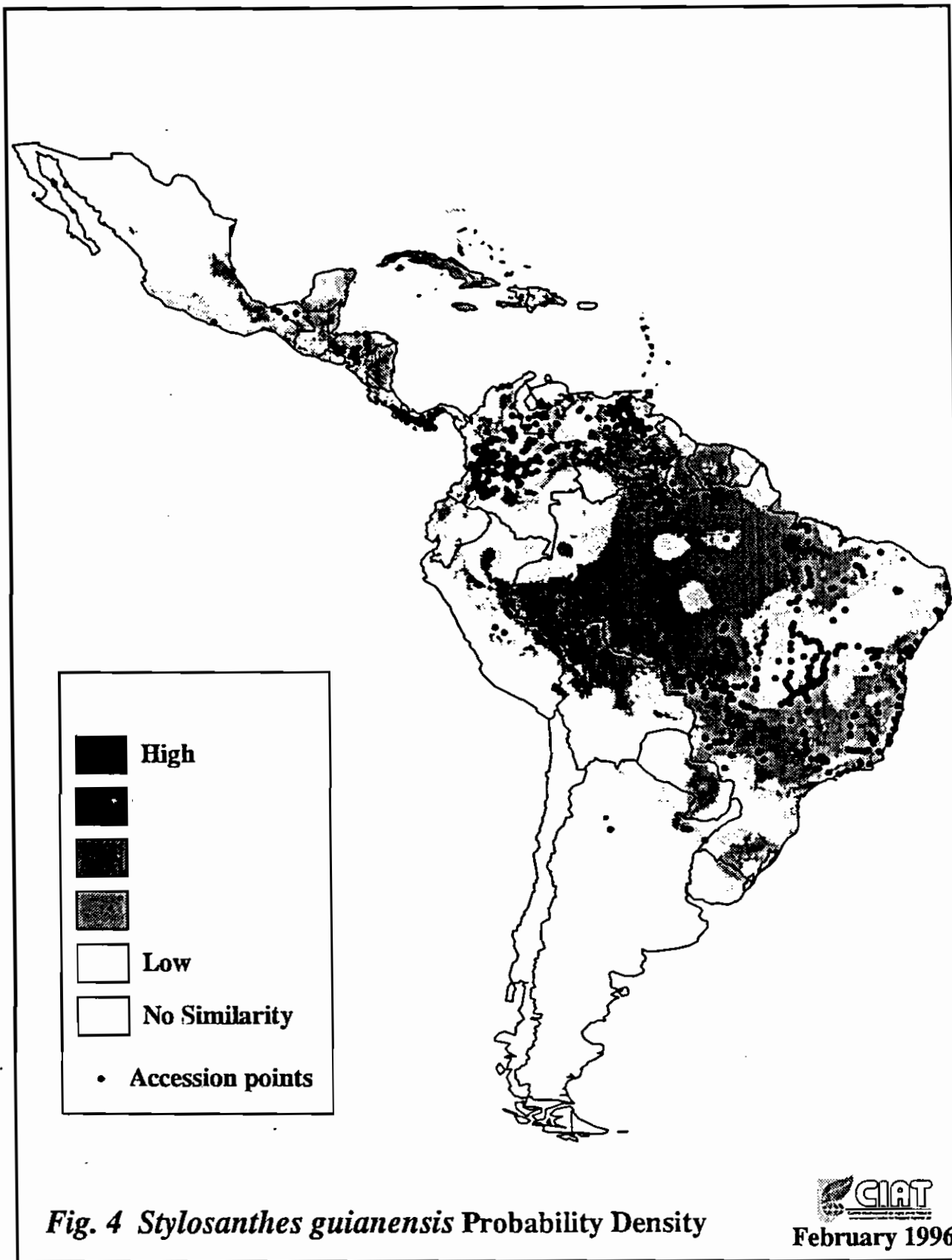
**Fig. 1** *Stylosanthes scabra* Probability Density

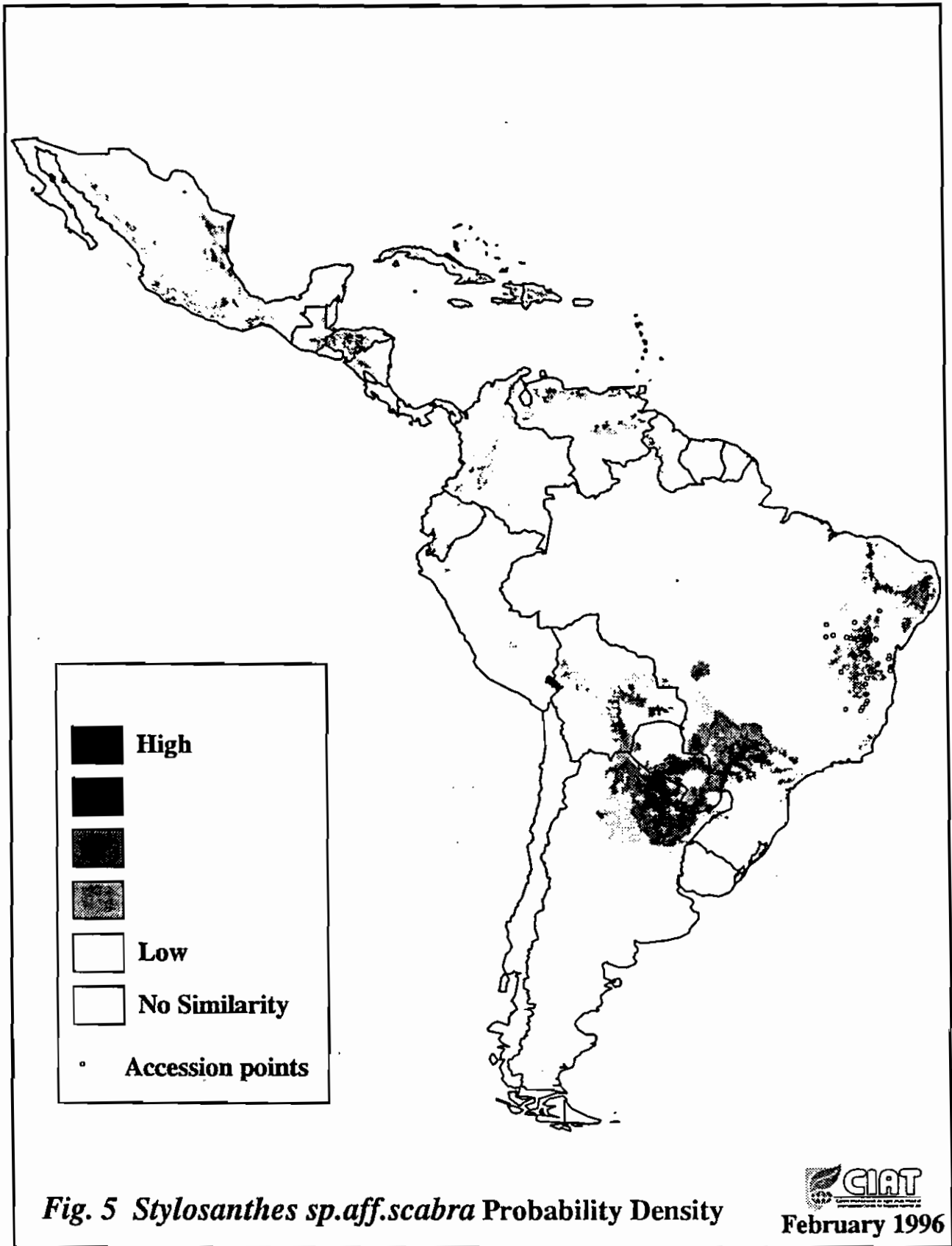






**Fig. 3** *Stylosanthes hamata* Probability Density





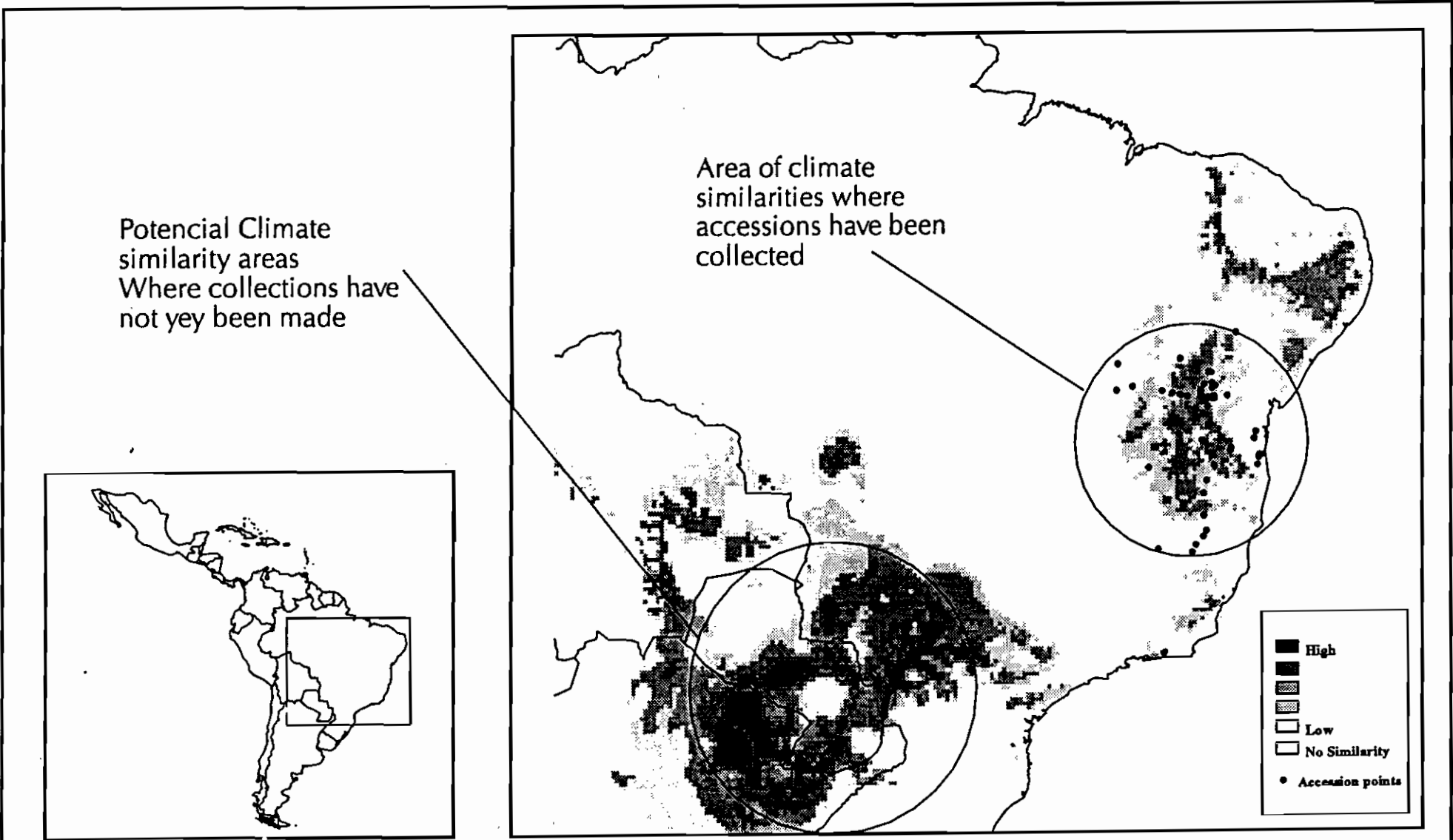
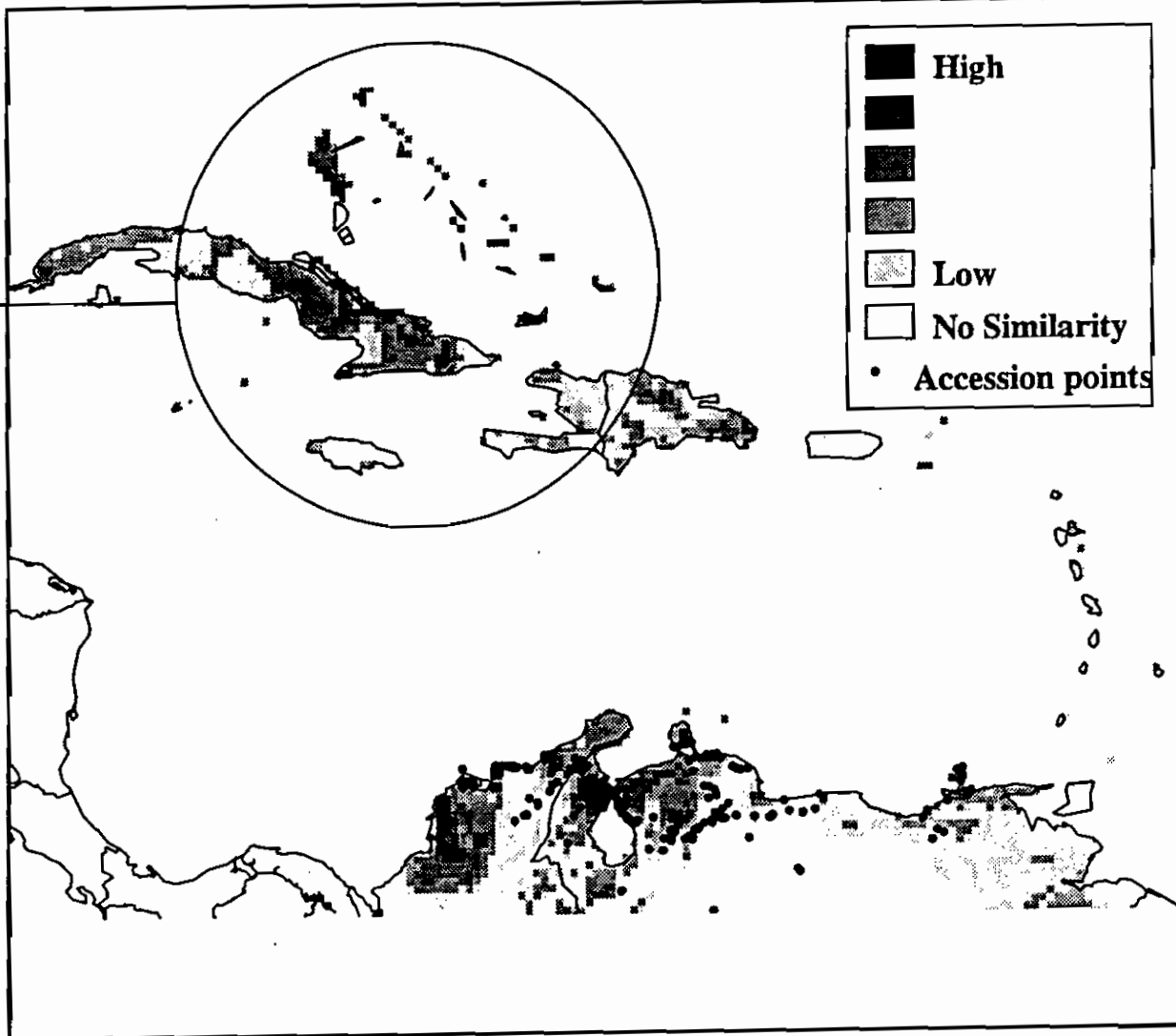


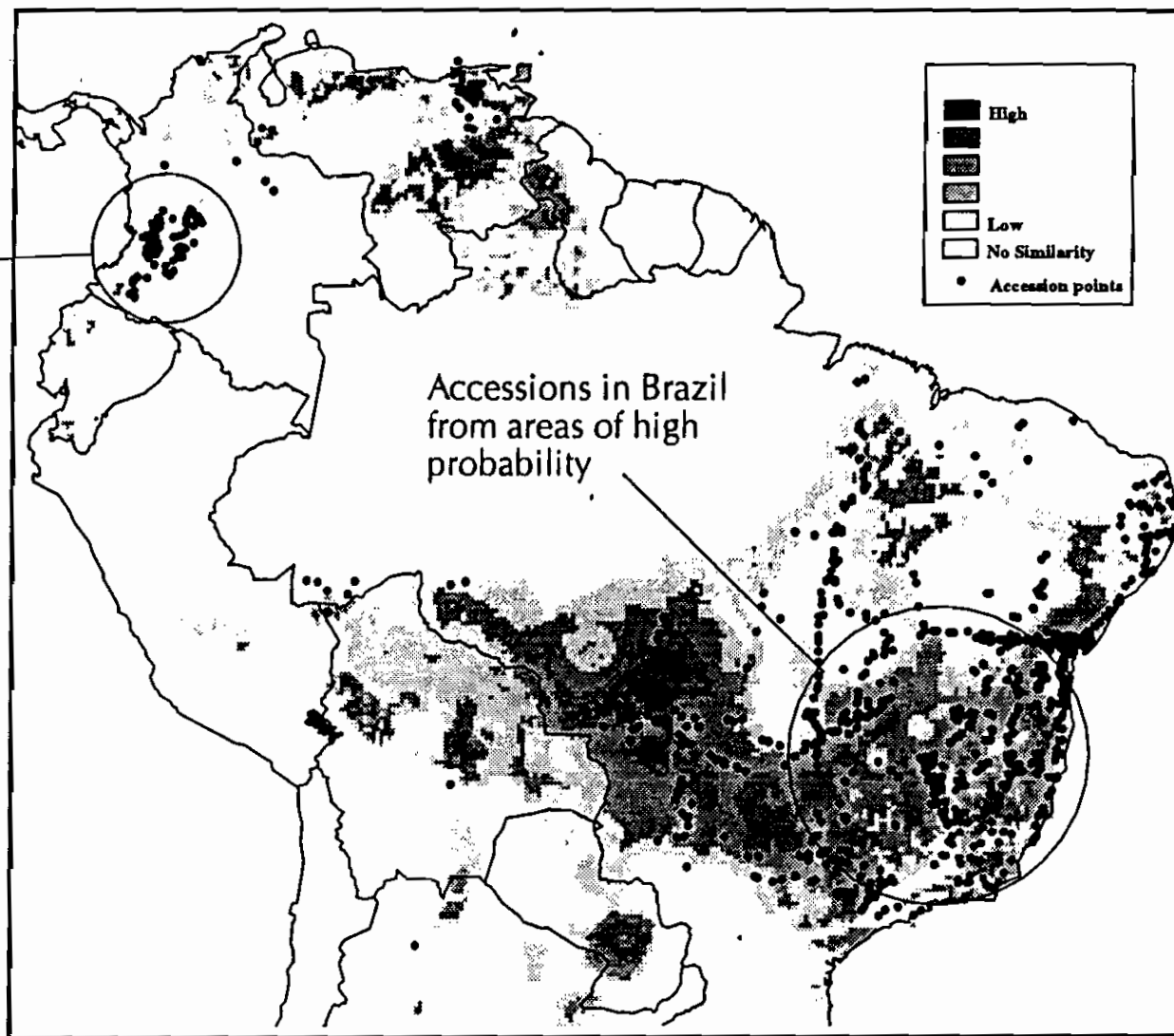
Fig. 6 *Stylosanthes sp.aff.scabra* Probability Density

High probabilities  
predicted on islands  
Where calibration  
points were eliminated



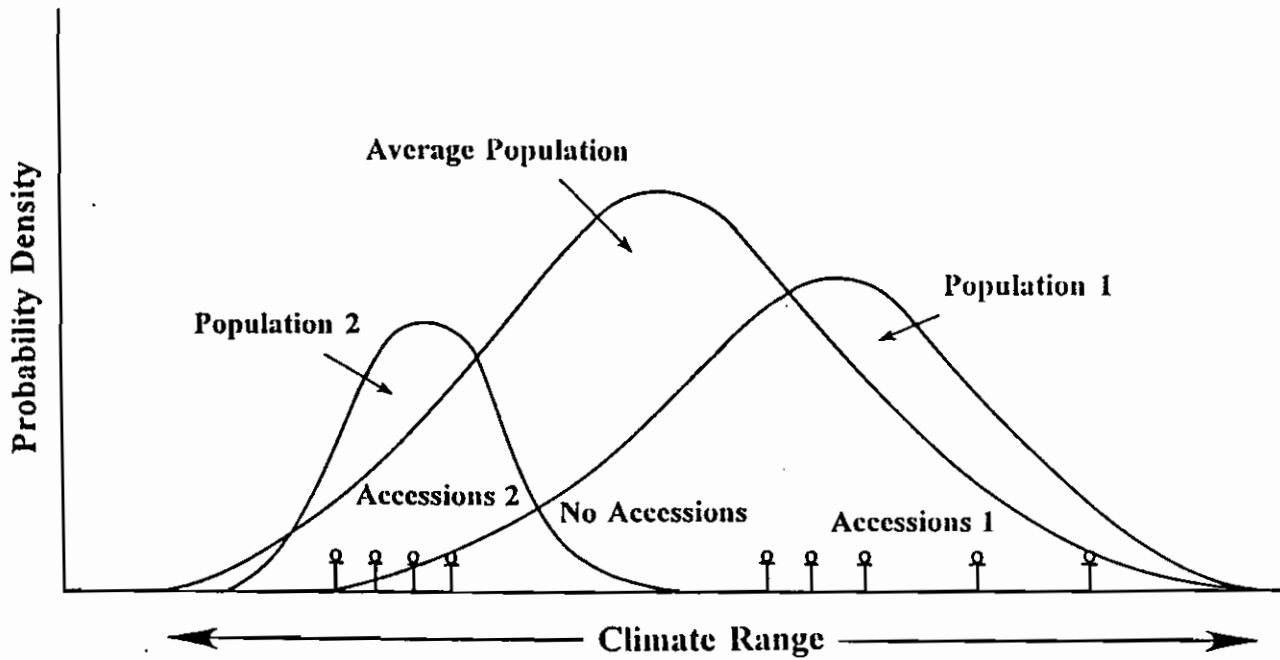
*Fig. 7 Stylosanthes hamata* Probability Density

Accessions in Colombia  
collected from areas  
of low probability



Accessions in Brazil  
from areas of high  
probability

**Fig. 8** *Stylosanthes scabra* Probability Density



**Fig 9. Why we can have high probability areas without accessions and accessions recorded from low probability areas**