AMAZONIA BIODIVERSITY ESTIMATION
USING
REMOTE SENSING
AND
INDIGENOUS TAXONOMY

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ABSTRACT

Measuring and monitoring biological diversity is a priority for safeguarding life on Earth.
Measuring species richness is the most popular method to assess biodiversity. It is however laborious and expensive. To obviate this problem many studies of biodiversity use higher taxon richness (using genera and families) as a less data demanding surrogate for species richness, or select some taxa as "indicator groups" to act as surrogates for the whole of biological diversity. Also, according to the "ecosystem approach", as stipulated by the Convention on Biodiversity (CBD), an accurate biodiversity assessment would require other measures, such as ecosystem richness and data about the structure, processes and interactions of ecosystems.
This calls for the application, encouraged by the CBD, of the knowledge and know-how of indigenous and local communities in the assessment of biodiversity. For this purpose appropriate sampling methodologies will be developed yet still employing the standard biodiversity measures like the alfa, beta , gamma, Shannon and Simpson measures . This would lower the costs of biodiversity surveys and benefit the indigenous and local communities.
The technique of remote sensing, using spectral data from reflected sun radiation and back-scattered radar data, can also provide surrogate measures for biodiversity, such as diversity of terrain, habitat and vegetation. Thus spectral data (LANDSAT TM, ENVISAT MERIS) can provide chemical-physical information, while backscattered radar data (ERS SAR, JERS SAR, ENVISAT ASAR) can provide morphological information. The two types of remotely sensed data can be processed synergistically to provide significant information (such as vegetation indices and habitat patches) of use in the generation of map layers.

This project aims to set-up and test a methodology for the assessment of the biological diversity of Amazonia, by applying the knowledge and know-how of the local communities of the region and integrating the outcome with information obtained by remote sensing and Geographic Information System (GIS) technology, appropriate to the requirements of the indigenous and local communities.
It also intends to provide ground truthing for the remote sensing of Amazonia and contribute to the baseline data sets of pristine or near pristine biotopes against which "trouble spots" can be monitored
At the same time this project is an exercise in sustainable development: it aims to create new jobs, raise the living conditions of the local communities encouraging them to remain in the forest.
This project will contribute to environmental education and in particular to the view that protection and sustainable utilization of biodiversity has economic returns. Moreover it will also help towards the establishment of Leap-frog Technology (Computers, GIS, GPS, Internet) in the Amazonia region.
Finally, it intends to help towards capacity building for bioprospecting, believing that bioprospecting will be the natural evolution of "Extractive Reserves".

INTRODUCTION

The impending biosphere catastrophe

In a recent issue of Nature dedicated to biodiversity the following estimates were given:

- 5% to 20% of the species have already been lost
- tropical forest is lost at a rate of 0.5% to 2% a year
- 50% to 70% of species are found in tropical forests
- loss of 50% to 80% of the species of an ecosystems causes the collapse of most biogeochemical ecosystem processes [1][2].

According to Norman Myers, co-winner in 1995 of the UNEP Environment Prize, in the short term this will consist in the homogenization of biotas. a proliferation of opportunist species, an outburst of speciation among particular taxa , and a pest and weed ecology; and in the long term depletion of "evolutionary powerhouse' in the tropics, a decline of biodisparity, the elimination of mega vertebrates, an end to speciation among large vertebrates, and multiple constraints on origination, innovation and adaptive radiation.
The ethical implications are overwhelming: Norman Myers affirmed that as the recovery period could extend at least five million years, we are now in fact imposing a decision on behalf of 500 trillion people. This decision must rank as the most far reaching decision on behalf of such number of people ever made during the entire course of human history.
Only 10% of the existing species are known and classified We know even less about their distribution and still less about their interactions. Indeed, " like children playing with fire, we do not fully understand, and therefore cannot predict, the ultimate consequences of tampering with global biodiversity" [3].

The Convention on Biodiversity

The 157 countries that signed the Convention on Biological Diversity in June 1992 are

> "Conscious of the importance of biological diversity for evolution and for maintaining life sustaining systems of the biosphere;
> Concerned that biological diversity is being significantly reduced by certain human activities.
> Aware of the general lack of information and knowledge regarding biological diversity and of the urgent need to develop scientific, technical and institutional capacities to provide the basic understanding upon which to plan and implement appropriate measures."

The Ministers of Environment at the First Global Ministerial Environment Forum, held in Malmö, Sweden on May 2000 were

> "Deeply concerned that, despite the many successful and continuing efforts of the international community , the environment and the natural resource base that supports life on Earth continue to deteriorate at an alarming rate, conscious that the root causes of global environmental degradation are embedded in social and economic problems such as pervasive poverty, unsustainable production and consumption patterns, inequity in distribution of wealth, and the debt burden, and also conscious that success in combating environmental degradation is dependent on the full participation of all actors in society, an aware and educated population, respect for ethical and spiritual values and cultural diversity, and protection of indigenous knowledge"

Indigenous People and Local Communities

In the preamble of Convention on Biodiversity are recognized

> " the close and traditional dependence of many indigenous and local communities embodying traditional lifestyles on biological resources, and the desirability of sharing equitably benefits arising from the use of traditional knowledge, innovations and practices relevant to the conservation of biological diversity and the sustainable use of its components"

The Article 8(j) of the Convention on Biodiversity says that each contracting party shall

> " respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices ".

In the last two years the governments of the world who signed the Convention on Biodiversity have recognized that the lack of trained taxonomists or what has been termed the "Taxonomic Impediment" is hampering the seriopu attempts to deal with the biodiversity crisis. To address the Taxonomic Impediment a Global Taxonomy Initiative (GTI) has been launched in 1996. The following indications given by the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) could help to alleviate the Taxonomic Impediment.

> "Traditional and indigenous knowledge perspectives should be included on current taxonomic systems. Specialist knowledge holders, such as herbalists, within communities, should play a role, as should everyday users, with a range of monitoring techniques employed suitable for their skills and interests. While monitoring systems may often be lead by agencies, such as park, forestry and agricultural agencies, they should work collaboratively with communities, and new monitoring systems lead by local communities must be accelerated if we are to succeed in our objectives.
> Monitoring systems, especially involving local communities, should be based on integrating local taxonomic systems with western scientific understanding, nomenclature and units of measurement. Local taxonomic systems need to be translated into western scientific taxonomy to gain access to wider bodies of knowledge about species. The GTI should encourage day-to-day monitoring by local communities with support from agencies and specialist scientists, such as expert ornithologists or botanists. All groups involved in monitoring should have access to scientific systems of identification and information, which need to be orientated to their practical requirements " [4]

BIODIVERSITY ASSESSMENT

Definition of Biodiversity

Biodiversity is the variety of living organisms considered at all levels of organisation, from genetics through species, to higher taxonomic levels, and including the variety of habitats and ecosystems, as well as the processes occurring therein Biodiversity is not the same as the number of different kinds of species in a place : Biodiversity is in fact more complex than species richness, although species richness is certainly one component of biodiversity.
There are in fact four levels of biodiversity: genetic diversity, species richness, ecosystem diversity and landscape diversity and biodiversity also depends upon and encompasses processes, as well as entities. These processes include, but are not limited to, biogeochemical cycles; biotic and abiotic disturbances; predator-prey, mutualistic, or parasitic relationships; migrations; competitive effects, and so forth. Thus, biodiversity includes all the entities of the living world at various levels of biological organisation, plus the various things that those entities do [5].

Assessment of Biodiversity

The "ecosystem approach" which is the primary framework for the implementation of the Convention on Biodiversity requires that in the assessment of biodiversity all the components of biodiversity to be considered [6].
The ecosystem approach is described as a strategy for management of land, water and living resources that promotes conservation and sustainable use in an equitable way). It is based on the application of appropriate scientific methodologies focused on levels of biological organization which encompass the essential processes, functions and interactions among organisms and their environment, and among ecosystems. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems.
The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.
The assessment of biodiversity should include identification and monitoring of ecosystems and habitats as well as identification, monitoring and assessment of species.

In order to accelerate environmental research without having to wait for results from traditional taxonomy, which is perceived to be slow to deliver because it is based on monographic treatments, new methodologies have been developed for assessing biodiversity. These include inventories, surveys, rapid biodiversity assessment, monitoring, and the use of indicator species.
Rapid-assessment methods and sampling for indicator species are designed to monitor selected biotopes of critical value **.**
Base-line studies of pristine or near pristine biotopes are required against which “trouble spots” are monitored. Medium-levels identification skills are necessary. Collaboration between staff with parataxonomic skills is necessary.[7].

Further, monitoring changes in biological diversity at the species level essentially entails monitoring changes in the distribution and abundance of species. For many species this is likely to need detailed monitoring and population modeling over decades [8].

Identification, monitoring and assessment of species

The major problem with species is that there is a very large number of them, a high proportion of which, particularly invertebrates, are as yet undescribed. Moreover, the identification of described species often requires a high level of expertise. Identifying all species in even a limited area is thus a very onerous task and generally impracticable.
However several studies have shown that higher taxon richness (using genera or families) is a useful surrogate for species richness, and ultimately a more remote surrogate than species for gene or character richness [9][10][11][12].
Another common solution to the impossibility of performing complete counts of organisms is to select certain taxa as "indicator group" to act as surrogates for the whole biological diversity. The use of indicator species, that is species whose status provides information on the overall condition of the ecosystem and of other species in the ecosystem, is encouraged by the SBSTTA [8].

Identifying and monitoring ecosystems and habitats

The classification of the natural environment is far more problematic than the classification of organisms: In fact the natural environment is a highly variable continuum and can not be divided into a series of discrete, discontinuous units.
Planned use of Geographic Information Systems (GIS) , one of the most productive avenues for the development of biodiversity assessment. may obviate the need to develop the complex habitat and ecosystem classifications.
This is because representations of different, measurable attributes of the environment can be stored in separate layers within a GIS. Examples of such attributes are: soil characteristics; altitude; rainfall; percent canopy cover; mean height of dominant vegetation; and distributions of individual species. The baseline maps used may be generated from satellite data, aerial survey, and existing maps, or created by field survey and expert advice. Different combinations of these disaggregated data sets can be chosen to generate maps according to need, without having to choose a predetermined classification system.. Such systems also lend themselves to extrapolation in that, for example, species distributions can be predicted in unsurveyed areas on the basis of congruence in environmental characteristics with areas known to contain the species [8]

Ecosystem structure variables are most promising indicators of biodiversity because they can offer a lot of information on the state of ecosystems over large areas for relatively low effort. Many aspects of quality can be captured by identifying key-ecosystem structure variables which can indicate if the ecosystem is functioning correctly or not. For example, a crude measure of quality might be the total number of well-specified habitat types observed within a sample area(s) relative to the postulated baseline number. Depending on the area and the available capacity they might be both short term and long measures. Remote sensing techniques will play a major role in this category [13].
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Existing Methodologies

The SBSTTA has listed and summarised several existing methodologies for the assessment of Biodiversity. These generally use remotely sensed data, GIS systems as well as pre-existing cartographic maps and inventories.
These generally use indicator groups (for example the GAP Analysis Program (US Geological Survey) employs vertebrates, while Rapid Ecological Assessment (The Nature Conservancy) utilises birds, mammals, butterflies and vascular plants).
Of particular interest is the utilisation of gradient-directed sampling by National Conservation Review (Shri Lanka Forest Department) Transects are selected deliberately to transverse the steepest environmental gradients present in the area, while taking into account access routes. This technique is considered appropriate for rapidly assessing species diversity in natural forests, while minimising costs, since gradient transects capture more biological information than randomly placed transects of similar length. Also interesting is the creation by Rapid Biodiversity Assessment (MacQuarie University) of locally functional schemes for classification and identification to be used as an alternative to formal and correct species identification by expert taxonomist [8]

REGION

Xixuau-Xiparina Nature Reserve and Lower Rio Jauperi Basin (61 West - 0 South , 62 West -2 South).
The Associacao Amazonia, largely composed of Indigenous people from the Jauaperi region, has been working in the Xixuau-Xiparina rivers, in the area of the Rio Jauaperi, South Roraima, since 1991. It occupies an area covering 172.000 hectares which includes the basins of these two important rivers so as to reserve them from the sources to the mouths. The unexplored, pristine rainforest harbours a rich wildlife including several threatened mammal species.

The area is situated between the Rio Branco and the Rio Jauaperi and has never been altered by large scale projects or an increase in the human population preserving its ecosystems intact. This fact, as well as its placement between hydrographical basins of different geological ages, makes it of great biological relevance. Important species abundant in the area include: Giant otter (*Pteronura brasiliensis*), manatees (*Trichecus inunguis*), dolphins (*Inia geoffrensis* and *Sotalia fluvius*), black caymen (*Melanosuchus niger*), pirarucu (*Arapaima gigas*), harpy eagle (*Harpya harpija*), jaguar (*Panthera onca*), spider monkey (*Ateles paniscus*), giant anteater (*Myrmecophaga tridactyla*).

The reserve has been the site of a number of research projects with institutions like the National Amazon Research Institute (INPA), the University of Amazonas and the FNS (National Health Foundation) of Brazil, the Universita' la Sapienza of Rome (Italy), the University of Birmingham (UK), the Institute for the Quality of Life (Denmark) and the Colorado Springs High School (USA), Embrapa Roraima, the University of Siena (Italy) and the University of Salerno (Italy). The reserve has also been the site of many wildlife documentaries (BBC, Survival Anglia, RAI , PBS, Italian state TV, Danish state TV)

In June 1996 the Associação Amazônia instigated the formation of the first permanent working group between Italy and Amazônia, hosted by The Istituto Italo-Latino Americano in Rome. The aim of this group is to elaborate projects of sustainable development and scientific research at a multidisciplinary level, in the area. The Associação Amazônia is also member of the IUCN European Working Group on Amazônia, in Brussels.

Access to the reserve is exclusively by boat. From the city of Manaus where the Association has its headquarters, the journey is of approx, 500 km along the Rio Negro and then the Rio Jauaperí. This journey takes between 30 and 40hours depending on the season and water level. During the high water season, from March to September, the reserve presents huge tracts of Igapó' and during the low water season the aquatic life becomes highly concentrated and rock formations and sandy beaches emerge from the river. This creates a natural barrier to the area which is one of the factors that has ensured the richness of biodiversity.

The permanent presence of the Amazonia Association in the area along the first 130 kms of the river Jauaperí which marks the border between the Brazilian States of Amazonas and Roraima. , from where it enters the Rio Negro to the last inhabited area before the Indian Reserve of the Waimiri-Atroari tribe led to the creation of the Jauaperí Project with the following aims:

- the preservation, conservation and sustainable use of the extraordinary biological diversity present.
- To increase the level of self-sufficiency of the communities of the Rio Jauaperí.
- To study health and education problems and implement the necessary services.
- To investigate and implement techniques of sustainable exploitation of the forest resources.
- To work towards the realisation of scientific research projects, through agreements with universities, institutes and suitable organisations, to create new models based on local reality.
- To create an inventory of the natural resources of the area, like soil, vegetation, climate, social and biological diversity, the genetic bank.

The region is divided between the states of Amazonas and Roraima, belonging to the municipalities of Novo Ayrao (AM) and Rorainopolis (RR). The total population is of 570 people in 5 communities and some isolated settlements. Around 70% of the inhabitants are less than 15 years old.

The region is in excellent conditions from an anthropogenic point of view. . The total lack of services and assistance contrasts with an excellent natural production and the family groups tend to remain in the area. Therefore most of the inhabitants are long term residents and know the area very well.

GEOGRAPHIC INFORMATION SISTEM (GIS)

We are using GRASS a free software GIS application running under LINUX and originally developed by USACERL the U.S. Army Construction Engineering Research Laboratory. GRASS intended users are regional land planners, ecologists, geographers. It is ideal for managing parks and forests and generally large areas. Is not suited to modeling of traffic, electrical, water and sewage infrastructure or for precise positioning of urban structures.
GRASS is distributed under GNU licence (Free Software Foundation) It is maintained and developed by programmers world wide and has a large number of users. Complete source code is provided allowing modifications of the programs to fulfill special needs .
We hope to involve the GRASS programming community in the design of a local community friendly interface to the GIS and the Grass users community in helping preparing the maps and processing the data.
GRASS has the standard capabilities of GIS (vector, raster, principal component analysis, clustering, rectification, registration,pixel algebra, etc)

The GIS will have the following components: On-site workstation, off-site workstations, web server and web client.
The on-site work station will have, full GRASS, off-site pre-reprocessed GIS data and local community friendly interface to GIS. The web client component of the GIS , implemented in Java should be on-line before 2001. It will allow zoom and xy panning in real time by predicting and fetching ahead of time tiles of the image. The client side can aloso perform as java applets mapcalc , text printing, raster overlay etc.
The GIS will be an invaluable tool for the scientists coming to do research in the Xixuaú. The data collected, precisely localised in time and space and inserted in the GIS, will be made available to the global scientific community**.**

Below is given the current implementation of the GIS

Region: 0° North - 2° South 61° West 62 West (110 Km * 220 Km)

Cartography Maps (scanned and rectified)

- IBGE Amazonia Legal 1:3.000.000
- IBGE Roraima 1:1000.0000
- IBGE Manaus 1:1000.0000
- IBGE BARCELOS 1:250.000
- IBGE MOURA 1:250.000
- IBGE ALALAU 1:250.000
- IBGE CURARAU 1:250.000
- IBGE RADAR MOSAIC 1.250.000
- LEVANTAMENTO PLANIMETRICO Xixuaú 1:50.000

Digital Maps

- Digital Chart of the World DCW 1:1.000.000
- GTO030 – Elevation Map (1Km resolution)
- HYDRO1K

Elevation Maps
The Elevation map was obtained by digitizing from the IBGE 1:250.0000 topographic maps elevations and contours and then running the GRASS program r.surf.contour.
Another elevation map was otained from GTO030 with the GRASS program r.surf.tps
Successively we will obtain a better DEM with the help of SAR Interferometry [26].
Elevation maps are needed to perform terrain corrections of both SAR and multi-spectral satellite imagery and to produce 3-D maps .

REMOTELY SENSED DATA

Reflected Sun Radiation Spectral Data

We have acquired from Tropical Forests Information Center (TRFIC) several LANDSAT 5 images covering the area in object at diverse époques including high and low water seasons. The data was already geo-referenced and radiometrically calibrated

The data (bands 1-2-3-4-5-7) was transformed into GRASS raster data and opportunely rectified, registered. and patched.

Using the freely available program 6s from NASA/GFSC [27] atmospheric correction was performed to remove Rayleigh radiance and aerosol radiance using the ' dark object technique" .

The data was successively terrain corrected using the available DEM data and the GRASS program g.mapcalc.

The resulting data was used to produce Vegetation Indices and Landcover Clusters

Vegetation Indices

Normalized Difference Vegetation Index	NDVI = (TM4 -TM3 / (TM4+TM3)
Transformed Normalized Difference Vegetation Index	TNDVI = (NDVI+0.5)/2

Based on the tasseled cup transformation and using a set of empirically derived coefficients [14] the following indices were obtained

Soil Brightness = 0.3037*TM1 + 0.2793*TM2 + 0.4743*TM3 + 0.5585*TM4 + 0.5082*TM5 + 0.1863*TM7
Vegetation Greenness = - 0.2848*TM1 - 0.2435*TM2 - 0.5436*TM3 + 0.7243*TM4 + 0.0840*TM5 - 0.1800*TM7
Vegetation Wetness = 0.1509*TM1 + 0.1973*TM2 + 0.3279*TM3 + 0.3406*TM4 - 0.7112*TM5 - 0.4572*TM7

Other indices obtained were:
Soil wetness TM5-TM2
Water reflectance TM2-TM4

Spectral Mixture Analysis

Spectral Mixture Analysis (SMA) was developed in 1986 By Adams, Smith and Johnson fo r the Viking Mission [28].

Markus Neteler has given a very clear presentation of SMA [29].

SMA assumes that the reflectance of each pixel is a linear combination of contributing sub-pixels components.

Examples of these ground components are green vegetation, dead vegetation, soil, water, rock, etc. If the spectral signature of these components, i.e. endmembers are known the component fraction can be found by inversion and so for each pixel can be obtained the percentage of vegetation, soil, water, etc which constitute the area referred to by the pixel. The spectral signatures of the end components can be obtained from field measures or from libraries of spectra. Alternatively they can be obtained from the image itself via Principal Component Analysis and Parallel Coordinates Representation.

If the components which account for the most variance is N then the number of endmembers is N+1,

The spectral data mean corrected are projected into a N-dimensional space determined by the first N eigenvectors. to produce a N+1 vertices Polyhedron This space is called feature space or mixed space. The vertices of the polyhedron are the endmembers

The freely available graphical analysis program XOBI provides the user with the means to explore the feature space in search of the spectra that are acceptable as the spectral signatures of ground components. XOBY offers different contemporaneous real-time views: :spectra, PCA. Tassele Cap Transformation, Spectral Ratios, etc.

Clustering

The larger component areas of the landscape were singled out using the classification of the vegetation cover in the IBGE topographic maps of the area in scale 1:250000 as landcover signatures and the GRASS programs i.class. i.cluster, i.maxlik
Successively the areas thus obtained from supervised clustering were further subdivided with the help of unsupervised clustering performed using the GRASS programs i.cluster and i.maxlik. to obtain a layer of sub-patches.
Next the endemembers of these patches will be found with PCA and PCR and the patches will be analysed with SMA Clustering applied to the resulting data will thus provide a third level patches.
This hierarchy of patches should reflect the hierarchy of the landscape ecosystems. The preliminary results appear encouraging

Fragstats

The patches and sub-patches thereby obtained where measured using various Fragstats metrics.
Fragstat (Spatial Pattern analysis program for quantifying Landscape Structure) was developed and released to the public domain by Kevin McGarigal and Barbara J.Marks of the Forest Science Department , Oregon State University.
The classes of metrics used include area metrics, patch density, patch size, edge metrics, shape metrics, nearest-neighbor metrics diversity metrics the latter including Shannon and Simpson indices.

Landsat 7

We will presently be acquiring Landsat 7 data whose high resolution panchromatic band could be used for sharpening the lower resolution data.

Envisat Meris

MERIS data appears very promising and although it will have lower spatial resolution than Landsat it will have a highers pectral resolution especially in very promising zones of the spectrum. The thirteen bands provided will be radio calibrated and Rayleigh corrected but will necessitate eerosol correction. Of particular interest will be the Meris Global Vegetation Index furnished as a Level 2 product. Also very interesting will be the utilisation in tandem with ASAR and the consequent synergy which should arise. The application of SMA to the Meris data should also provide valuable new insights

Back-scattered radar microwave data

SAR images are obtained from back-scattering microwave radar illumination. As a rule of thumb the rougher the reflecting surface the stronger the back scattered radiation. Also wet surfaces are brighter. because of dielectric properties.
SAR images that are acquired at different times or different vintage points can provide additional information with the help of a class of techniques referred to as SAR Interferometry Interferometric correlation , that is a measure of the variance of the interferometric phase estimate of the backscattered data obtained from two passages can provide thematic information complementary to the back-scattered intensity data.
ENVISAT ASAR has the capability to acquire data at different polarisations. In the AP mode a pair of images at different polarisations can be acquired at once. Using an algorithm based on Cloude and Pottier 's Coherent Target Decomposition [15] [16] , it is possible to extract information related to the scattering particle shape and mean orientation. We are using a implementation of Coherent Target Decomposition coded by A. A. Nielsen [17]
In the last couple of years many models have been developed in the field of SAR polarimetric interferometry which promises to separate roughness from moisture [18], to provide information on 3-D vegetation structure and biomass [19][20]. We have starting the implementation of these algorithms on GRASS and expect to be ready when ASAR data will be available.
It is increasingly recognised that the inversion of SAR data to obtain geophisical parameters should involve an initial step of segmenting the image into different terrain classes, followed by inversion using the algorithm appropriate for the particular class. We intend to do the initial segmentation using unsupervised clustering of the spectral data and bayesian methods.
JERS-1 SAR data is also interesting as it employs L-band a longer wave-length and thus is capable of penetrating the canopy more than ERS SAR and ASAR the shorter wave-length C-band.

INDIGENOUS AND LOCAL COMMUNITY TAXONOMY, KNWLEDGE AND KNOW-HOW

Rationale for utilising Indigenous and Locale Conmunities , knweledge and know-how

- the Convention on Biodiversity requires the application of the knowledge of local communities
- higher taxon richness and species indicators are useful surrogates for biodiversity
- scientiific taxonomy covers more species than indigenous taxonomy, but it all the same covers only ten per cent of existing species
- according to the 'ecosystem approach" biodiversity assessment require also identification and assessment of ecosystem and habitats

Maynard Smith has suggested that ecological systems can be approached in one of two ways, either by a detailed mathematical description of specific systems, or by a general and abstract description that aims to capture the essential properties of the system [21]. Local communities posses a deep and extensive knowledge of the structure and processes of the landscape ecosystems that certainly allows at least the second approach of ecosystem description.

Some Biodiversity Assessment methodologies, make use of para-taxonomist (e.g. INBio, Costa Rica) and the SBSSTA encourages their training and employment. Their contribute to solve the so called taxonomic impediment is invaluable. At the same time we consider very important (and fundamental to the present project) the views expressed in the report o f the 2nd meeting of the SBSTTA :

> **"The question itself has to be rephrased. The challenge is not to find the ways to integrate, in modern management practices, knowledge, innovations and practices of indigenous and local communities. Rather, it is to define, in collaboration with indigenous and local communities, which modern tools may be of help to them, and how these tools might be used, to strengthen and develop their own strategy for conservation and sustainable use of biological diversity, fully respecting their intellectual and cultural integrity and their own vision of development."** [4].

Existing common names lists names lists

Most databases and species list provide together with the scientific name also the common name (see for example Species2000 [22]), INPA has published several monographs containing the common names of Amazonia plant species [23]. The Universidade Federal do Paraná as published a list of common names of insects [24] and the Universidade Federal do Acre as published a list of common names of plants [25].

Structuring of local communities taxonomy

The species and higher taxon known to the Amazonia local communities and used to estimate biodiversity will be categorized according to their economic function (food, pests, etc) , ecological function (keystone species, etc), the interaction with other species , habitat class, territory size, etc.. They will also be localized on the food web and in the tree of life (philogeny). This data, appropriately coded, will also be introduced in the GIS raster maps so that when a particular taxa is present in a given location a lot of other information can be inferred

DATA COLLECTION METHODOLOGY

A preliminary survey will be made, accompanied by the local inhabitants visiting all the places considered of interest by the local community (Brazil nuts tree, rubber trees, medicinal pants , hunting and fishing locations as well breeding grounds and "source habitats" that is areas where local reproductive success is greater than local mortality as well as other places of ecological interest. Also a set of environmental gradient direct transients will be selected using remotely sensed data and the indications of the local communities. All these sites will be precisely localized with the help of GPS.

Verbal explanations and visual and audio-visual evidence will be recorded with the help of a video camera time synchronized with GPS. The GPS could also be conveniently connected to a portable computer containing the GIS (and in the future also connected via Radio TCP/IP to Internet)

From the transcription of the precisely localised in time and space verbal real time recorded reporting by the members of the local community will be extracted the significant key word which , appropriately numerically coded, can be inserted as categories into raster maps of the GIS and thus become amenable to the standard GIS processing using then standard GIS tools.

When the GPS and video-camera are not available or inconvenient reporting will be made by registering into preprinted form time, location , and bio-data .

Appropriate sampling methods are being developed based on techniques already in use by the local communities (hunting, fishing, fruit and medicinal plants collecting etc.) and so that it will be possible to perform the standard measures of biodiversity such as the alpha, beta, gamma , Shannon and Simpson measures.

TESTING AND CALIBRATION

Contemporaneously with the assessment of biodiversity with the help of local communities knowledge and know-how other bio-diversity surveys will be made which will use more traditional methodologies and whose results will be used to test and calibrate the methodology under study. In particular will be used to calibrate the the cefficients used to determine the alpha . and other measures of biodiversity so that comparable data is produced .

Several inventories of the species present in the Xixuau-Xiparina Reserve have already been made to-date [30] [31]

Later this year the Zoological Museum-University of Copenhagen with the collaboration of the Museo Nacional, Universidade Federal do Rio de Janeiro and INPA in Manaus will perform a full scale mammal diversity survey in the Xixuaú-Xiparina. The overall objectives of the project are to carry out a full-scale mammal diversity survey in the Xixuaú Nature Reserve and develop the technical capacity of Associação Amazônia, to effectively monitor the biodiversity of the area. The project will begin in November 2000 and is expected to be terminated by the end of 2001.

Methods used will include TrailMaster camera traps, small mammal trapping (box traps, snap traps, pitfall traps), diurnal census, nocturnal spotlight census, identification of tracks and skulls, and interviews with locals. Information on habitat use as well as seasonal variation in abundance and distribution of various species in the reserve will be gathered.

Local reserve staff will participate in the field work and be trained in various basic wildlife survey and monitoring techniques. Training will include species identification skills, using field guides to mammals and birds provided by the project. An introductory course will be held at the Reserve headquarters.

The post-field assessment will include data analysis, report writing, publication of results in acknowledged journals, and preparation of a field key to the identification of the mammals of the region, in Portuguese, as well as a manual with recommendations for future surveys that could be carried out by Associação Amazônia itself to monitor the wildlife of the Nature Reserve [32].

A botanical survey is in preparation by the University of Perugia (Italy).

A study of the giant otter and the study of the possibility of using the giant otter as a biodiversity indicator is in preparation by the University of Roma (Italy) [33].

Associates of Nordisk Herpetologisk Forening and Exotiske Insekter will inventory certain forms of invertebrates, amphibians, and reptiles., employing methods of capture which do not harm the animals and , after registration, releasing them in the locations where they were captured .

All these studies and surveys will be done in close collaboration with the University of Amazonas, the University of Roraima , INPA and EMBRAPA and other Brazilians scientific institutions.

FUNDING

Thie project described in this paper will be an on-going project and while problems of monitoring and assessment have technical solutions, there is also the challenging but fundamental requirement to address the sustainability of the project in terms of funding support, in order to make use of these techniques for prolonged time [9].
Donations and subsidies will be actively looked for and welcomed. At the same time we shall look for some degree of self-sufficiency with income from amateur science tourism.
The Rio 92 Declaration on Sustainable Development and the Convention on Biodiversity support ecotourism and UNEP , the Conference of the Parties to the Convention on Biodiversity , the Government of Brazil and the state governments of Amazonas and Roraima are actively promoting ecotourism [8]
The Earthwatch Institute has for many years provided financial and volunteer support for scientific field research and conservation projects. The projects require the presence of motivated volunteer field assistants and is the funds paid by these volunteers that constitute the research grant.

SUSTAINABLE DEVELOPMENT, EXTRACTIVE RESERVES AND BIOPROSPECTING

The extractive reserve concept, pioneered by Chico Mendes and Mary Helena Allegretti was a new and very creative idea for protecting the Amazon forest and at the same time resolving a serious social problem. Of the mass unemployment among the Rubber Tappers of Amazonia after the collapse of Brazil rubber production

In this context, Mary Allegretti and the National Council of Rubber Tappers proposed a new category of ecologically protected area, the Extractive Reserves.

The extractive reserves were a brilliant idea in the context of the other conservation units, since they explicitly made the peoples of the forest the guardians of the extremely valuable ecological patrimony of the areas they inhabit, with the support of non-governmental organizations and the Environmental Ministry [34].

Chico Mendes. idea that improving the well-being of local populations should go with environmental protection has become unanimous. And principles that Chico defended as alternatives for the Amazon – adequately valuing the forest and of the knowledge of its peoples – are inscribed in international agreements such as the Convention on Biological Diversity. [35]

Bio-prospecting is supported by the Rio Declaration on Sustainable Development and by the Convention on Biodiversity. Bioprospecting also has a prominent place in the series of new priorities being pursued by the federal Secretariat for Amazonia as alternatives to economic activities resulting in deforestation and degradation .
We believe that bioprospecting, making full use of the great knowledge and know-how of the Local Communities of Amazonia is the natural evolution of Extractive Reserves. [36]

Mary Allegretti, Brazil's secretary of the Amazon region has said : "We want to turn biopiracy into bioprospecting. We want to be partners, not victims. We want recognition that the raw biomaterials and the knowledge of how to use them from our indigenous communities is worth as much as the research money spent on developing new products abroad" [37].

Much knowledge, know-how and technology utilised in the present project could be utilised also for bio-prospecting and we hope that this project will be a contribution towards Capacity Building for Bio-prospecting

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