Toolbox of Applied Metrics and Analysis of Regional Incentives

TAMARIN

Manual for Version 4.6
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A Planning Support System for Designing and Evaluating Conservation Strategies

Produced by Cooperation Among

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Credits

Many people and institutions contributed to the development and realization of **TAMARIN** and associated datasets. We regret any inadvertent omissions from the following list of contributors.

Concept and framework

The original **TAMARIN** concept is due to Kenneth Chomitz (World Bank). The framework was developed in collaboration with Gustavo Fonseca and Keith Alger of the Center for Applied Biodiversity Science (CABS) and Conservation International (CI); and David Stoms and Frank Davis of Institute for Computational Earth System Science (ICESS), and Donald Bren School of Environmental Science & Management University of California, Santa Barbara.

Software

The initial software design and implementation was undertaken by David Stoms (co-principal investigator) and Frank Davis (principal investigator). Contributing ICESS staff include Kathy Scheideman and John Sanchez (contract administration); Mike Colee (computing support); Peter Choi (review and testing).

Miroslav Honzák (CI) made substantial enhancements and improvements to the **TAMARIN** software in order to incorporate new ideas and concepts that emerged since the original development took place, and revised the users' manual.

Data and review

Crucial data components included: the land cover characterization undertaken by Elena Charlotte Landau (Universidade Federal de Minas Gerais); the vegetation classification by Andre Carvalho (Centro de Pesquisas do Cacau) and Wayt Thomas (The New York Botanical Garden); the land value survey data gathered by Instituto de Estudos Sócio-Ambientais do Sul da Bahia (IESB) under the supervision of Heloisa Orlando and interpolated by Timothy Thomas (World Bank); the RADAMBRASIL land characteristics maps provided by the Instituto Brasileiro de Geografia e Estatística (IBGE) and species ocurrence studies coordinated by Raquel Moura. This project benefited greatly from additional contributions of data, expertise, and local knowledge of the ecological and cultural environments of south Bahia provided by participants in a sister project funded by Programa Estadual para a Conservação da Biodiversidade (PROBIO) of the Ministério do Meio Ambiente administered by IESB and CABS. We are grateful also to participants in three workshops (two in Ilheus and one in Salvador) who provided in-depth feedback on **TAMARIN** during its development. Other contributing institutions include: Conservation International do Brasil (CI-Brasil), Departamento de Desenvolvimento Florestal do Estado da Bahia (DDF) and Núcleo de Estudos e Pesquisas Ambientais da Unicamp (NEPAM).

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Proprietary Rights and Disclaimer

TAMARIN is a customized **ArcView** project developed by researchers at the University of California, Santa Barbara, under a grant from the World Bank and completed in early 2002. Since then **TAMARIN** was further developed by researches at the World Bank and Conservation International in order to enhance its functionality and accuracy by implementing new concepts and new data. **TAMARIN** is being placed in the public domain as “Freeware” and therefore may be freely used and redistributed. It was developed specifically for the GIS data for southern Bahia, Brazil, and therefore, may not be suitable for other regions without modifications. **TAMARIN** is provided "AS IS", without warranty of any kind, either expressed or implied, including, but not limited to, the implied warranties of merchantability and fitness for a particular task.

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Although **TAMARIN** has been operated successfully on computer systems at the University of California, Santa Barbara, The World Bank, and Conservation International, no warranty is expressed or implied.

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ArcView is a registered trademark of Environmental Systems Research Institute, Inc. (ESRI). Users of **TAMARIN** need to be authorized users of **ArcView**.

Table of Contents

1. INTRODUCTION

TAMARIN, the Toolbox of Applied Metrics and Analysis of Regional Incentives, is a planning support system developed to assist in regional conservation planning. It is a customized **ArcView** project with scripts originally written specifically for the Central Atlantic Forest Corridor project in Bahia, Brazil. The tool was designed to test various strategies and assumptions about future land use against a set of descriptors of forest landscape configuration believed adequate to meet biodiversity conservation objectives. The toolbox is NOT intended as a stand-alone decision-making device or to usurp the role of policy makers. The initial development of the toolbox was conducted by researchers at the University of California, Santa Barbara, under a grant from the World Bank and completed in early 2002. Since then, **TAMARIN** has been further enhanced and developed by Conservation International and The World Bank, such that it is now easy to adapt the system for use in emerging corridors worldwide. This document is a manual to instruct users in the functioning and operation of **TAMARIN** to create and evaluate conservation strategies using example data from Bahia. If not specifically stated it should be assumed that the descriptions of methods and examples in this manual refer to the particular case study of the Central Atlantic Forest Corridor in Southern Bahia.

TAMARIN performs two sets of GIS-based procedures. Firstly, it assists planning teams to design scenarios, and secondly, it evaluates the economic and ecological consequences of these scenarios. Scenarios can be created by drawing on an electronic map or by defining rules for selection based on conservation and/or economic criteria. Scenarios can be constrained by a maximum budget limit. The framework can then calculate the ecological effects and costs of the scenario and create a series of GIS themes, tables, graphics, and reports that summarize the salient features for comparison with the current situation, projected future conditions, and other scenarios.

This manual is intended to be a complete user's guide to the toolbox, but assumes the reader is already familiar with **ArcView** and **Microsoft Windows**. To make the manual easier to follow, program names are always shown in **bold font** and pre-defined input and output file names are in ***bold Italics***. Menus and their options are listed in 'single quotes'. Pre-defined program variables and parameters are generally underlined.

Before describing the software and its use, here are definitions of key terms that are used throughout the manual:

- bioregion—a subdivision of the planning region or corridor that distinguishes distinct biological composition. In south Bahia, bioregions were delineated by vegetation formations (east to west) and assemblages of endemic flora and fauna (north to south). Section 3.4 describes this GIS theme in more detail. Representation goals (see below) are set for each bioregion.
- business-as-usual scenario—a future land use/cover pattern that is expected from current trends if no conservation intervention occurs. One such scenario for Bahia is provided with **TAMARIN** (Section 3.2), but the system allows users to substitute their own projections.
- caatinga—savana-like open canopy xerophytic deciduous vegetation growing in western part of Bahia.

- cabruca—a traditional system of growing cocoa under the shade of native overstory trees in Bahia, often with intervening patches of primary forest, and therefore considered important for the preservation of flagship primate species in the corridor (Alger and Caldas 1994).
- core forest—mature or restored forest (see below) that is beyond the influence of edge effects and thus provides habitat for forest interior-dwelling species.
- corridor—a planning region comprising a mosaic of land uses, including a network of parks, reserves and other areas of less intensive use whose management is integrated to ensure the survival of the largest possible spectrum of species unique to that region.
- depth-of-edge influence zone—the transition zone between the edge of agriculture, pasture, or urban land uses (see below) and core forest (see definition above) in which it is assumed that ecological processes such as fire regime and microclimate are altered. In **TAMARIN**, users can specify the distance of the depth-of-edge influence zone, although for Bahia we provided a default value of 300 m based on Gascon et al. (2000).
- easement opportunity cost—this represents an estimate of the opportunity costs to the landowner if their land were included in the conservation corridor. Because the owner maintains title to the land and some opportunities to use it, this value is less than the land value (see below). For Bahia, several estimates of easement value were made based on different assumptions of the opportunity costs for forest and tree-shaded cocoa land (Section 3.1).
- edge forest—forest adjacent to agriculture, pasture, or urban land uses and therefore subject to conditions hostile to forest regeneration, which leads to a decline in its value as forest habitat for interior-dwelling species (in contrast to core forest) (Gascon et al. 2000).
- Environmental Benefits Index (EBI)—we use this term that was coined for the USDA Conservation Reserve Program (described in Chomitz et al. 1999) as a measure of the ecological feasibility of restoring or protecting a planning unit. For Bahia, several versions of an environmental benefits index are provided in **TAMARIN** based on different assumptions of the value for secondary forest and cocoa land (Section 3.1).
- framework—we refer to **TAMARIN** as a framework because it structures the design and evaluation of alternative conservation strategies. We prefer this term to “model”, which implies an underlying ecological or social process.
- gap-crossing distance—the distance across non-forest habitat that a species is known or believed to be able to traverse to move between forest patches. Patches of forest separated by less than this distance are considered part of the same functional patch. In **TAMARIN**, we assume this distance to be 1km for secondary forest and other forested media (e.g., cabruca, other tree-shaded cocoa, caatinga) and 0.5 km for agriculture. In Bahia, the values were based on expert opinion about the ecology of the yellow-breasted capuchin, although users have the option to modify this variable.
- incentive offer— a potential payment to a landowner in exchange for a modification in land use that will achieve desired conservation objectives, prescribed by a formula or schedule. Landholders accept or reject the offer depending on whether it is greater or less than the opportunity costs associated with the change in land use. In **TAMARIN**, we assume that incentive offers are equal across the entire corridor, although the user can specify the amount in a given scenario.

- land value—the market value of the land and improvements. In Bahia it was imputed from a survey of ~250 farms in the corridor and represents the price of acquiring title to the land suitable for forest restoration i.e., all land cover categories except water, urban, cloud, and shadow (Section 3.1).
- matrix—the dominant land use or land cover of a region in which forest fragments are embedded. Some matrix types are more conducive to biodiversity conservation than others. For instance in Bahia, a matrix of tree-shaded cocoa is more valuable to the maintenance of forest primates than a matrix of pasture.
- planning unit—the spatial unit used to analyze patterns of biotic diversity and land values in order to identify priority areas. For this project, we have chosen square cells of 990 meters on a side as the planning units. These units are large enough to compensate for uncertainty in the spatial data and to keep the size of the analysis manageable, yet small enough to allow flexible selection of alternative scenarios that respond to spatial variation in costs, restoration suitability, and existing land uses.
- rastinga—arboreal or herbaceous open canopy vegetation growing on costal plains of Bahia.
- redundancy—designating multiple sites for each element of biodiversity as backups to guard against catastrophic environmental or population fluctuations (Shaffer and Stein 2000).
- representation—maintain the full range of biodiversity, including species, habitats, environmental types, and genetic variation by designating a network of sites that saves some of everything (Shaffer and Stein 2000).
- reserves—lands legally protected for biodiversity conservation.
- resilience—designating sites of adequate size so that natural processes can operate at their characteristic spatial and temporal scales and increase the likelihood of maintaining species (Shaffer and Stein 2000).
- restored forest—forest that regenerates spontaneously (if near existing mature forest or other forested media, e.g., cabruca) or through reforestation (if isolated from existing forest) if the current land use is abandoned, such as in response to an incentive payment to the landowner.
- scenario—an alternative strategic allocation of land uses guided by a set of assumptions and choice of planning units for conservation intervention.
- tree-shaded cocoa—*Theobroma cacao* L. trees that produce cocoa beans that are used to make chocolate growing in the shade of larger trees. In Bahia, cocoa trees are being shaded either by native trees (cabruca) or by exotic tree species (e.g., *Erythrina* spp.).
- viable habitat unit—a patch, or functionally connected set of patches (within the gap-crossing distance—see above), that is at least as large as the specified minimum size to maintain a population of one of the flagship species of the corridor e.g., the yellow-breasted capuchin in Bahia. A viable habitat unit can include both core and edge forest, although scenarios are evaluated in part by the proportion of edge forest. In **TAMARIN** for Bahia, we assumed that this minimum area is 10,000 ha, based on a population viability analysis, although users can modify the size for a scenario.

1.1 Background

Because environmental and socioeconomic conditions and conservation goals are location-specific, we have developed a general methodology and applied it to a specific, policy-relevant context linked to a World Bank-executed project: the construction of the Central Atlantic Forest Biodiversity Corridor in south Bahia. The Atlantic Forest is by far the most threatened major ecosystem in Brazil, with less than 8% of its original area remaining; Conservation International places it third on its list of the nineteen highest-priority habitats for conservation on the planet (based on the combination of threat and uniqueness). The northeastern section of this forest in south Bahia is now reduced to relatively small, mostly nonviable fragments. The operational problem is to deter further forest conversion and to induce abandonment of pasture and agriculture in the interstices between forest fragments. This will result in forest regrowth, reconnecting fragments into viable ecosystems. The impetus for the **TAMARIN** framework was a desire by the World Bank to examine the potential for novel economic incentives targeted at landholders, including purchase of conservation easements, sale of tradable development rights, and environmental services payments.

The challenge is to find cheap, enforceable approaches that result in desirable land use configurations. Pasture abandonment in different locations will have different ecological impacts, depending on proximity to existing fragments. Costs of abandonment, and of protecting forest, will also vary from place to place.

The underlying premises of the project in Bahia were:

1. That there is substantial variation in opportunity costs of land within areas of conservation interest

2. That economic instruments can, in principle, exploit this variation to achieve conservation goals at lower cost than is possible via command-and-control approaches

The strategies for restoration can be quite complex because conservation planning must balance multiple objectives and constraints, including cost efficiency. What seems obvious to achieve one objective (e.g., protecting habitat-friendly land use practices) may not satisfy social goals or may cost too much. The **TAMARIN** framework encourages planners to focus on specific measurable conservation objectives and then develop scenarios to evaluate rather than focusing initially on conservation actions.

Conservation science has identified three fundamental principles for conservation of biodiversity: representation, resilience, and redundancy (Shaffer and Stein 2000). It is critical to maintain the full range of biodiversity, including species, habitats, environmental types, and genetic variation by representing this range in a network of sites managed primarily to ensure their persistence. Besides affirming the intrinsic value of biodiversity, representation is a hedge against the loss of species that play a crucial but undiscovered role in ecosystem functioning or that could be a source of new biotechnological material. Even with samples of all biodiversity elements represented in multiple sites, each site must be resilient or resistant to impacts from adjoining landscapes. The most basic solution to this is to protect or restore sites of adequate size so that natural processes can operate at their characteristic spatial and temporal scales. If only a single large, resilient sample of each species or habitat is preserved, catastrophic environmental or population fluctuations could still extirpate it. Therefore, the redundancy principle prescribes managing multiple sites for each element of biodiversity. This replication of sites also reinforces the representation goal by requiring samples across environmental gradients with the corresponding variation in genotypic and ecotypic responses. With limited

resources, planners must choose between optimizing for resilience (size of each reserve) and redundancy (number of reserves). Pelletier (2000) found that if species survivability is low in the matrix, then single large reserves are optimal over many small reserves. In other words, the minimal strategy to protect the whole ensemble of biodiversity in a region is to manage a system of relatively large sites (not necessarily reserves) that represents several viable populations of all species.

Many studies have reported on the degradation of forest fragments in a zone around their perimeter (e.g., Gascon et al. 2000). Adjacent land use practices such as burning modify the disturbance regime, which in turn can change the structure, composition, and function of the forest edge for hundreds of meters. Not only does this alteration reduce the resilience of the fragment, it is a dynamic process of attrition that in a harsh landscape matrix will continue to penetrate inward and reduce the size of the core habitat. In fact, fragments as large as 1000 hectares could be entirely within this altered edge zone (Gascon et al. 2000) and thus be poor representatives of primary forest habitat.

Conservation science has been more equivocal on the subject of connectivity and distance between (or proximity of) protected sites (Shafer 2001). Designing a network of closely spaced sites may foster connectivity with interpopulation gene flow and recolonization opportunities. Having sites near each other, however, increases the risk of extinction from catastrophic events such as wildfire, disease, and extreme climate events. The ultimate form of habitat connectivity is to maintain corridors or linkages between habitat patches. These linkages contain the same habitat as the patches or at least habitat that is adequately suitable for a species to traverse. The corridor literature is similarly ambivalent about the pros and cons. Species differ in their behavioral response to corridors. Some species use them; some do not. The value of a corridor depends on its length and width, and thus a linkage of suitable habitat types is not automatically of benefit to a species. Long thin corridors by definition contain mostly edge habitat. For many species, this may increase their exposure to predators. At the biogeographic scale of the study area in Bahia, we have not found adequate supporting information to justify the specification of linkages between forest patches as a requirement of the desired landscape configuration.

If we assume there are two forest patches in a planning region, one larger and one smaller. There are at least five strategies, according to Possingham et al. (2001) regarding where to invest in a fixed amount of restoration, each of which increases representation equally in terms of hectares protected:

1. Make the existing large patch bigger (increases resilience);

2. Make the existing small patch bigger (increases resilience);

3. Link the two patches (increases connectivity with mixed effects on resilience, decreases redundancy);

4. Make one large patch (increases resilience, decreases redundancy);

5. Make many small, widely distributed patches across the region (increases redundancy).

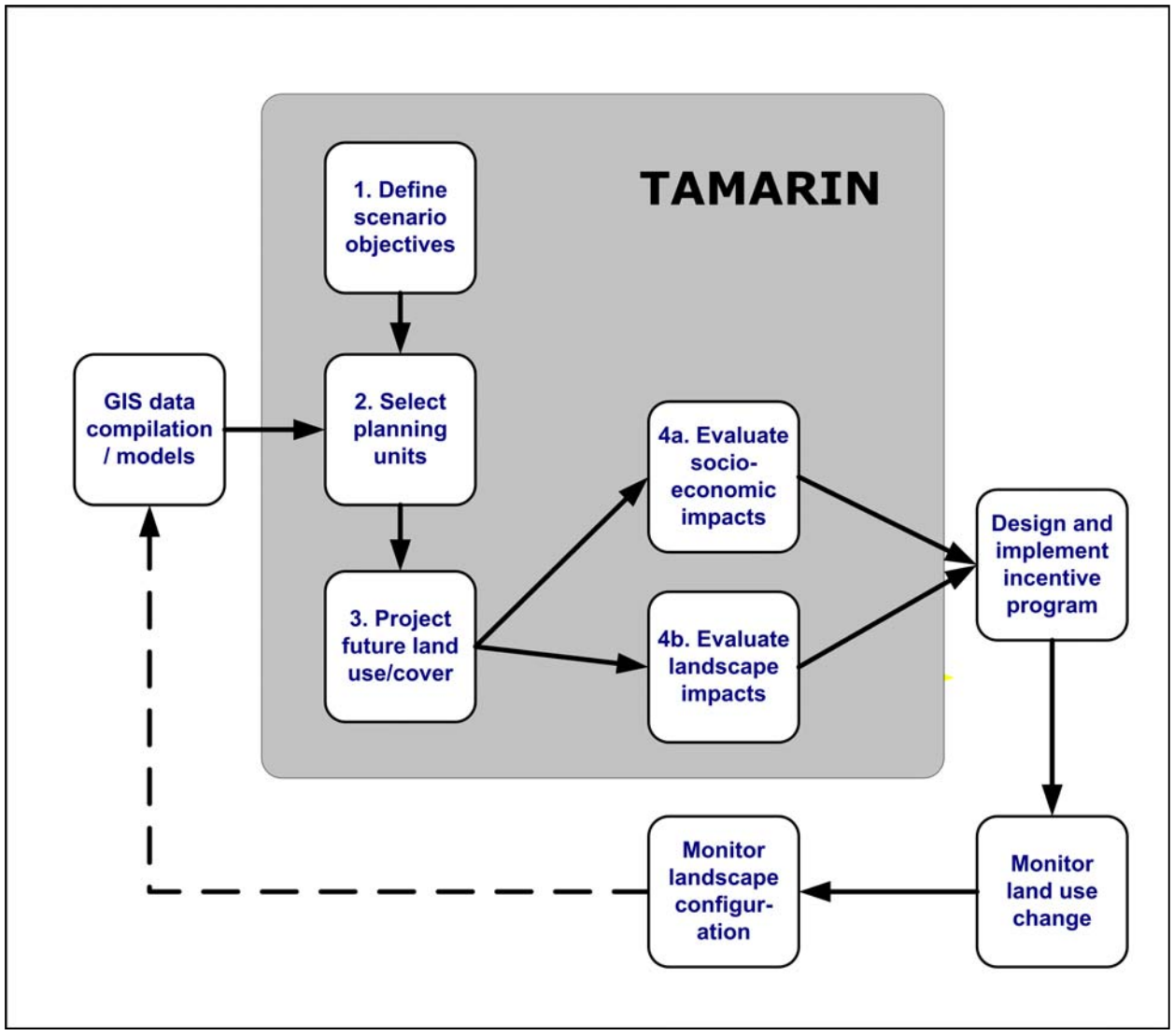
Each strategy helps achieve some conservation objectives, such as representation across environmental gradients, connectivity, or viability through larger contiguous habitats. Yet each strategy alone cannot satisfy all objectives simultaneously. The implications of the strategies on their relative effectiveness are not always obvious. The implications of various strategies on

other land uses, regional economics, etc. must also be considered. Thus planners must examine the trade-offs between strategies.

1.2 Basic Operations

TAMARIN is a planning support system to assist in designing a conservation corridor. The figure below illustrates both the major processing steps in **TAMARIN** and how the software fits into the overall planning process. Prior to running **TAMARIN**, it is assumed that the required GIS data have been compiled or modeled. Once scenarios have been designed and evaluated, a decision must be made and the program implemented, with appropriate monitoring to determine if the desired landscape is being achieved (Oñate et al. 2000).

Within **TAMARIN**, the software performs two basic kinds of operations. Steps 1 and 2 in the flowchart form the design phase of the process, and steps 3 and 4 are the evaluation phase. These steps will be discussed in greater detail in Section 5.



1.3 Selection Options

There are many techniques for designing a conservation scenario, and **TAMARIN** accommodates several of them as outlined in this section. More details about the mechanics of selecting planning units for a scenario are provided in Section 5.1.2, this section merely explains the range of choices.

1.3.1 Select Graphically

You can select planning units interactively using **ArcView**'s *selection tool*, either by clicking on planning units individually or clicking and dragging the cursor across a rectangular area. This works well when you have specific sites in mind for a scenario.

1.3.2 Select by Query

Alternatively, you may not know exactly where to restore forest but have a good understanding of the characteristics of the best locations. Then you can query the attributes of the planning unit coverage by Boolean logic. For instance, you can query for planning units with attribute values =, >=, <= a given land value or restoration suitability.

1.3.3 Select by Theme

You or someone else may have created a shapefile (either previously or using the **ArcView** graphic tool and converting the graphic into a shapefile) that portrays a scenario. By choosing the 'Select by Theme' option, you can pick this shapefile with the browser and have it select all planning units that occur within the boundary of the polygons.

Note: If the theme has been digitized externally from the toolbox, it should be in the same projection as the standard themes, as described in Section 3.

1.4 Outline of the Manual

The rest of the manual is organized as follows:

Section 2 describes the installation process, system requirements, and utility programs;

Section 3 describes the required and optional input GIS themes and their attributes;

Section 4 illustrates the customized menus and buttons created for this application;

Section 5 explains the step-by-step procedures for designing and evaluating conservation scenarios and their impacts;

Section 6 demonstrates the steps for a hypothetical scenario;

Section 7 outlines how **TAMARIN** could be modified either for updated GIS themes for Bahia or for adaptation for use in other corridor projects.

2. INSTALLATION AND SYSTEM REQUIREMENTS

TAMARIN requires the following hardware and software:

- **ArcView** 3.0+ with **Spatial Analyst** 1.0+ extension
- **Microsoft Windows 95/98/2000/NT/XT** operating system
- Some GIS operations on this large data set are very computationally intensive. We recommend your computer have minimum of 128 megabytes of RAM and a fast processor. A high-resolution display is useful for displaying the graphic and map data.
- The 'Landscape Configuration' menu generates several very large grids as temporary files. We recommend at least 1 gigabyte of available disk space in the partition where **TAMARIN** is installed to accommodate these grids. Once the script has executed the large temporary grids are automatically removed.

2.1 Installing and running TAMARIN as ArcView project

The copy of **TAMARIN** that you possess is in one of two formats, either an installation CD or a zip file (received via **ftp** on request). To install **TAMARIN** from an installation CD, insert the disk into your CD drive and wait for an installation dialog to appear. Follow the series of dialogs to finish the installation. If your auto launch is disabled, start the installation by double clicking on ***Install.msi***, located on the distribution disk. In the case that you received **TAMARIN** as a zip file, simply use **WinZip** or similar software to unzip the file.

Once you have performed those steps, to run the **TAMARIN** project, double click on ***tamarin.apr*** (**ArcView** project file located in **TAMARIN** directory) or open the project using **ArcView** by selecting 'File→Open Project…' and select ***tamarin.apr***.

Note: Avoid using directory names comprised of several words with spaces between them (e.g., "C:\My Documents" MAY NOT ALWAYS WORK CORRECTLY).

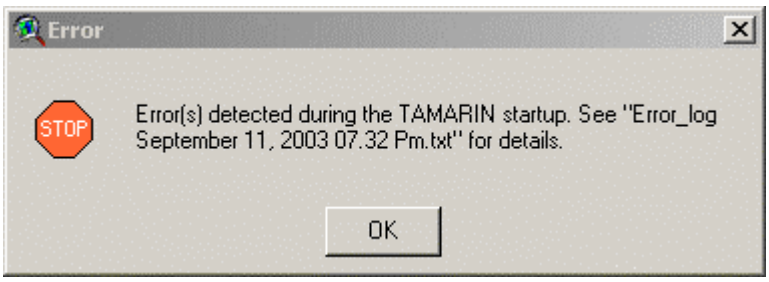
2.2 Running TAMARIN as ArcView extension

Use this option only when you intent to build a new **TAMARIN** project from scratch (e.g., when migrating **TAMARIN** framework to a different region). After installing **TAMARIN,** double click on ***tamext.bat*** located in the ***tamext*** directory. This batch file copies the ***tamarin.avx*** (**TAMARIN** extension file) to ***AVHOME**ext32*** directory; the **ArcView** program will start automatically. Proceed by loading the **TAMARIN** extension: click: 'File→Extensions…' and activate the **TAMARIN** extension by clicking the checkbox (all associated scripts will load into the **ArcView** project). Proceed with building your new **TAMARIN** project (see Appendix B for complete set of steps).

Note: If ***AVHOME*** is not set as ***C:/ESRI/AV_GIS30/ARCVIEW***, which is the standard location of the **ArcView** program, use the text editor to edit ***tamext.bat*** so that the correct location of your ***AVHOME*** will be reflected.

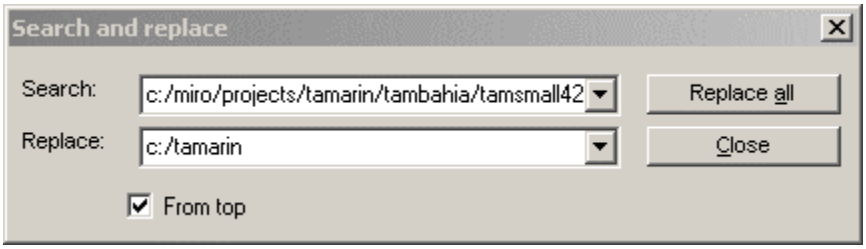
2.3 TAMARIN Project Error Reporting

Each time **TAMARIN** starts, an **AVENUE** start up script (Tam.Startup) runs a series of checks and report errors caused by the omission of required datasets or by the use of inappropriate names for them. If the error occurred, a popup window, similar to the one below, appears, and a log of all errors is written into a text file created in a current **TAMARIN** directory. This error log file lists all encountered errors and suggests actions for correcting them. The name of the error log file includes the date and time of creation.

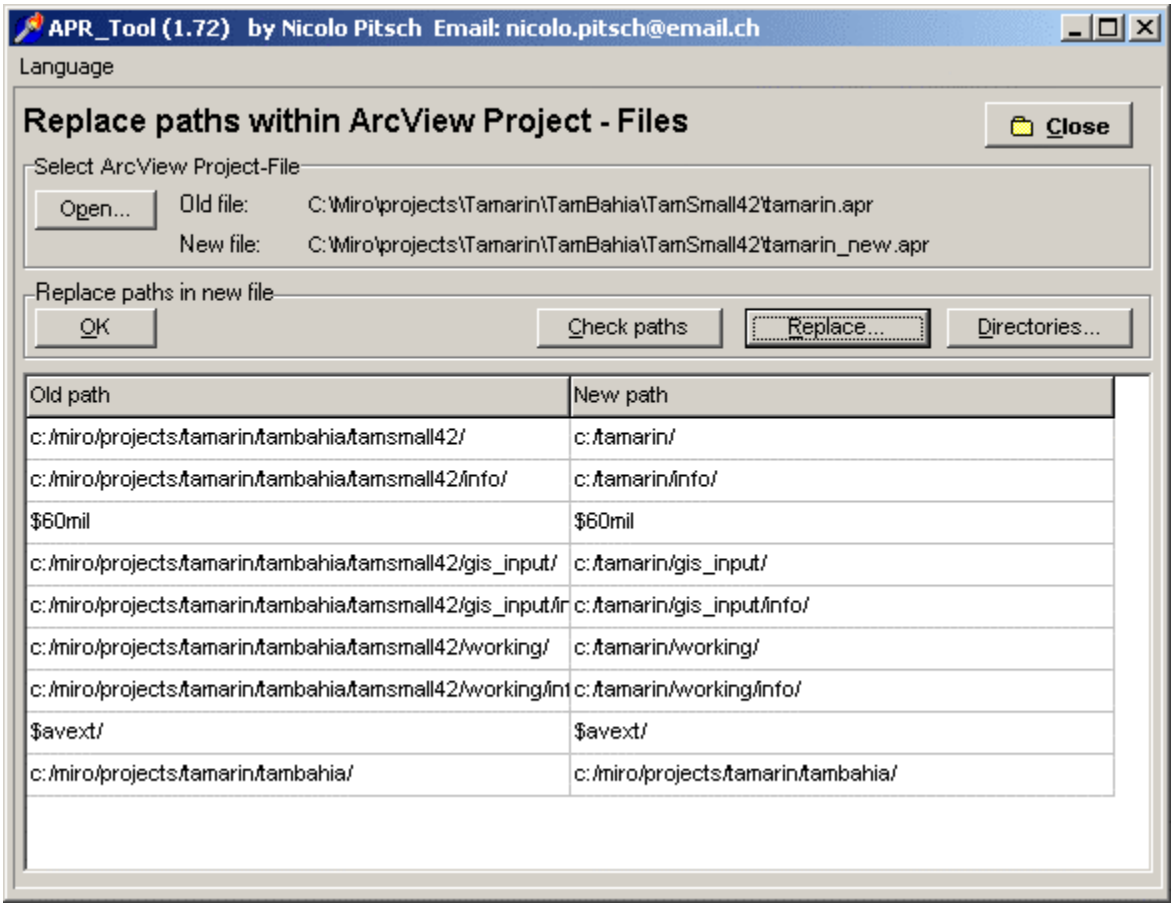


2.4 ArcView Project Pathnames Update Utility

Once you save your **TAMARIN** project, the pathnames of data files associated with the project will become hard-coded. As long as you keep working in the same directory into which you initially saved your project you will not need to update them. If you move the project to any other location you will need to update the pathnames. To do this, go to the **Exploring** window and double-click on the ***APR-Tool.exe*** icon or filename (this helpful program by Nicolo Pitsch can be obtained from http://gis.esri.com/arcscripts/scripts.cfm if it is not obtained with the **TAMARIN** package). Click the 'Open' button and select ***tamarin.apr*** as the input project name (Old file). The default name for 'New file' will be ***tamarin_new.apr***. Change this name if you wish. Click the 'Replace' button and enter the old pathname and the pathname that matches the directory structure where you copied the files.



Next, click the 'Check paths' button to make sure the folders actually exist. Then press the 'OK' button to make the global change in the project file.



After fixing pathnames, double-click on the ***tamarin_new.apr*** filename (or whatever you chose to call it) to run **TAMARIN**.

2.5 ArcView Views Resize Utility

The default window size for **TAMARIN** is set to your maximum screen resolution. The view windows (those with maps) are automatically scaled to fit in this window. If you choose to resize the application window, the view windows may become too large or too small. Click on the button with the three dots to automatically resize all the view windows to the appropriate size.

3. REQUIRED AND OPTIONAL INPUT THEMES

TAMARIN for Bahia was distributed with several GIS themes that are the basis for conservation scenario design and evaluation. Several additional themes were provided for geographic reference and visualization. This section briefly describes the required and optional themes. Users may substitute new versions of any theme. Guidance is provided in Section 7. These substitute themes must be in the same map projection and datum as the originals. For Bahia project, all themes have the following ARC/INFO projection properties:

```
PROJECTION UTM
UNITS METERS
ZONE 24
SPHEROID SOUTHAMERICAN1969
DATUM SAN_C
YSHIFT 10000000                    /* FOR THE SOUTHERN HEMISPHERE
PARAMETERS
```

3.1 Planning Units (PU) (Required)

This shapefile (e.g., cell990m.shp) is used for selection of priority conservation areas in a scenario.

At the regional scale of the Corridor project, it is neither appropriate nor feasible to use parcels as the basic spatial unit for selection. Maps of parcels often do not exist, and the information on costs, environmental benefits, etc. are too uncertain, both in value and geographic location, to be reliable at the parcel scale. In Bahia, **TAMARIN** uses a square grid of planning units that are 990 x 990 m. These are the spatial units that can be selected by various means (see Section 1.2) for either protection or restoration. However, users should be aware that the areas of planning units are not identical to one another even though they are all represented by equally sized squares. For example, in Bahia, most planning units are composed of 98.01 ha of land (990 x 990 m squares), however, some of the 990 x 990 m squares contain a smaller eligible area for selection. This is because portions of the grid cells that contain water, urban, and protected areas were excluded from consideration as a potential conservation area. As a result, the values reported in the Hectares attribute may range from only a few hectares to the entire area of a square (98.01 ha). This has certain consequences for the selection and sorting of planning units further described in Section 5.1.4.

Besides the Hectares attribute mentioned above the data fields include: Land_Value, which is the predicted or imputed land value for the planning unit (i.e., the cost to acquire the land in the unit); Easement_Value, which is the imputed value of the resource potential of the land without considering the land value (i.e., the minimum cost to acquire a conservation easement); and Environmental Benefits Index, which is a suitability score for restoration or conservation based on the current land cover of the unit. Chomitz et al. (2004) estimated Land_Value using a multivariate regression hedonic model with variables for soil properties, land cover, distance from roads etc. (for more details see Appendix D). Besides economic values and environmental benefits, the attribute table contains fields that can be useful in selection queries, such as the percentage of a unit with mature forest, the population density, and variables used in the hedonic models. One field contains our interpretation of whether a unit can be restored as forest by natural regeneration or not, based on an assumption that this process can only operate without human intervention (and cost) within 1 km of existing mature forest fragments.

Because there is little experience with conservation easements in Bahia, there were uncertainties about the magnitude of opportunity costs. Consequently, we provided four alternative assumptions about the opportunity costs that should be paid to landowners as environmental compensation (or easement value) as an incentive to participate in restoring the corridor. Users can select the alternative Easement_Value as the conservation intervention. Here are the four alternatives and their assumptions. In the explanations of the options, 'actual' value is the imputed Land_Value in a unit with its current mix of land cover types suitable for growing forest. Its 'value if all forest' is the land value predicted if the unit were all forest and could not be used for agriculture or timber. The easement value (or opportunity cost) is some proportion of the difference between the two. Each alternative uses different assumptions about this difference. The value is the sum of the easement cost for all lands within a planning unit that contain forest or could be restored as forest. That is, land use such as urban and cover types such as water or mangrove incur no cost, nor do they contribute to the forest conservation objectives and therefore they were excluded from the value imputed for south Bahia.

- Easement_Value1— We asserted that the easement value was equal to the difference between the "as is" land value, and half of the "all forest" land value. This assigns a relatively low opportunity cost to maintenance of mature forest. EV1 = 'actual' value – (value if all forest / 2).
- Easement_Value2—This assigns a zero opportunity cost to maintenance of mature forest, based on the assumption that current law forbids cutting mature forest (also assumed in #3 and #4). EV2 = 'actual' value - value if all forest.
- Easement_Value3—This assigns a zero opportunity cost to maintenance of mature forest or tree-shaded cocoa. EV3 = 'actual' value - value if (tree-shaded cocoa stays tree-shaded cocoa and everything else is forest).
- Easement_Value4—This assigns a zero opportunity cost to mature forest maintenance and a relatively low cost to tree-shaded cocoa maintenance. This is the default easement value for south Bahia, given the current legal, social, and economic situation. EV4 =.5* (EV2) + .5*(EV3).

A blank User_Defined_Easement field is also provided to allow planners the option of making different assumptions about the opportunity costs that must be compensated to motivate landowners to conserve forest. Planners can recalculate this field prior to designing and evaluating a scenario.

Because spontaneous forest restoration in Bahia is unlikely beyond approximately 1 km from existing forest, we attributed an additional cost of R$2000/ha for manually-intensive reestablishment (Viana et al. 1997) when the Restorable field contains a value of 'N'. Otherwise, there is no restoration cost.

There are also alternative assumptions about the Environmental Benefits Index variable. We have computed eight alternative values for this index, based on different assumptions or criteria about the value of tree-shaded cocoa and/or secondary forest in a unit. The eight alternative indices are described below. The extent of each cover type is also stored in the planning unit attribute table.

- EBI_Orig—this was the original environmental benefits index we calculated. It gave greatest weight to mature forest, only gave moderate weight to tree-shaded cocoa if mature forest was present, and relatively low weight to secondary forest if it was in a matrix with mature or tree-shaded cocoa, as follows:

  Define the function D(x) = 0 if x = 0
  = 1 if x > 0
  let P_mature = proportion of mature forest in a given planning unit
  let P_cabruca = proportion of tree-shaded cocoa in a given planning unit
  let P_secondary = proportion of secondary forest in a given planning unit
  generate:
  P_cabprim = P_mature + P_cabruca
  then
  EBI_Orig =
  5 * P_mature +
  5 * P_wetland +
  3 * P_cabruca * D(P_mature) +
  2 * P_secondary * D(P_cabprim)

- EBI_Cab— EBI_Orig gave no weight to planning units with tree-shaded cocoa without mature forest interspersed with it. From the methods for mapping land cover, this situation applied to most units with tree-shaded cocoa and so tree-shaded cocoa generally scored very low. This variation on EBI gives value to tree-shaded cocoa in any context, while mature and secondary forest are the same as in EBI as follows:

  Define the function D(x) = 0 if x = 0
  = 1 if x > 0
  let P_mature = proportion of mature forest in a given planning unit
  let P_cabruca = proportion of tree-shaded cocoa in a given planning unit
  let P_secondary = proportion of secondary forest in a given planning unit
  generate:
  P_cabprim = P_mature + P_cabruca
  then
  EBI_Cab =
  5 * P_mature +
  5 * P_wetland +
  3 * P_cabruca +
  2 * P_secondary * D(P_cabprim))

- EBI_Pref—A historically preferred variation that modified EBI_Cab slightly. It gives moderate weight to tree-shaded cocoa if mature or secondary forest is present and to secondary if either mature or tree-shaded cocoa is present; otherwise, tree-shaded cocoa and secondary receive a low weight as follows:

  Define the function D(x) = 0 if x = 0
  = 1 if x > 0
  let P_mature = proportion of mature forest in a given planning unit
  let P_cabruca = proportion of tree-shaded cocoa in a given planning unit

let P_secondary = proportion of secondary forest in a given planning unit
generate:
P_anyfor = P_mature + P_secondary
P_cabprim = P_mature + P_cabruca
then

EBI_Pref =
5 * P_mature +
5 * P_wetland +
3 * P_cabruca * D(P_anyfor) +
3 * P_secondary * D(P_cabprim)+
1 * P_cabruca * (1 - D(P_anyfor)) +
1 * P_secondary * (1 - D(P_cabprim))

- EBI_Pref_per_LV—this index was calculated according to the following formula:

  EBI_Pref_per_LV = 1000 * Nourbwat_ha * EBI_Pref / Land_value

  where Nourbwat_ha = total area in hectares of land cover categories suitable for supporting forest growth except urban, water, no data, and area which falls inside an existing protected area; Land_value = total monetary value of the above categories. Nourbwat_ha and Land_value are standard attributes listed in a planning unit theme (see Appendix E for details).

- EBI_5—A currently preferred variation of EBI_Cab. It gives a moderate weight to tree-shaded cocoa and secondary forest if mature forest is present. If mature forest is not present, tree-shaded cocoa and secondary forest in combination with each other or standalone receive a low weight as follows:

  Define the function D(x) = 0 if x = 0
  = 1 if x > 0
  let P_mature = proportion of mature forest in a given planning unit
  let P_cabruca = proportion of tree-shaded cocoa in a given planning unit
  let P_secondary = proportion of secondary forest in a given planning unit
  then

  EBI_5 =

  5 * P_mature +
  5 * P_wetland +
  3 * P_cabruca * D(P_mature) +
  3 * P_secondary * D(P_mature) +
  1 * P_cabruca * (1 - D(P_mature)) +
  1 * P_secondary * (1 - D(P_mature))

- EBI_5_per_LV—was calculated using the same formula as for EBI_Pref_per_LV calculation, except it uses the EBI_5 as numerator instead of EBI_Pref.

- EBI_Core—the previous EBI indices are based solely on the content of each planning unit. We also include an EBI that accounts for the context of the planning unit as well. It is designed to identify potential core areas for forest blocks. First the land cover theme was

reclassified into suitability values adapted from a table developed at one of the PROBIO workshops. This table rated each cover type for structural complexity, soil conservation, regeneration potential, and dispersal potential and then aggregated into an overall rating. Second, the 30 m pixels are summarized over a circular neighborhood 990 m in radius around each focal pixel using the FOCALMEAN function. Each pixel is assigned the mean suitability value of its neighborhood. Then the neighborhood values are summarized for each planning unit, again by calculating the mean and normalizing to a maximum value of 5.0.

- EBI_CORE_per_LV—was calculated using the same formula as for EBI_Pref_per_LV calculation, except it uses the EBI_Core as numerator instead of EBI_Pref.

A blank User_Defined_EBI field is also provided to allow planners to make different choices about the factors of environmental benefits they wish to emphasize. Planners can recalculate this field prior to designing and evaluating a scenario.

Note: We have created planning unit theme and its attributes as part of **TAMARIN**. Information contained within these attributes can be used in selecting planning units or in evaluating scenarios (see Appendix E for a summary of all attributes). You may wish to use a different spatial unit for designing and evaluating scenarios (e.g., census tracts, or regular units of a different spatial resolution). **TAMARIN** asks which theme to use for planning units during the 'Define a scenario' dialog. Simply select your theme instead of the default version we have provided. However, be aware that your theme must contain the identical set of attributes as the default theme to prevent errors (see Appendix B for a guide to create a new planning unit theme).

3.2 Business-As-Usual Scenario (Required)

TAMARIN compares conservation scenarios to the current situation and to the land use trend. This raster theme portrays a forecast of future land cover/use in the absence of conservation intervention. The modeling framework asks the user which theme to use as the business-as-usual forecast, and users can create their own (but it should be saved into the options folder).

In the absence of quantitative information on socioeconomic drivers of future land use change in Bahia, authors employed a simple deterministic model of change, based on the following assumption: the recently observed land use trends will continue over the next two decades if conservation interventions are not applied. In particular, primary forest will no longer be converted to other uses because it primarily occupies marginal lands and is legally protected when growing on steep slopes and within a certain distance from a river. However, it will continue to be degraded into secondary forest through firewood gathering and other resource extraction, hunting, and other human-related impacts. Secondary forest will be permanently converted to pasture or agriculture except in areas where it is near primary forest; in such situations, it will remain secondary forest. Cabruca and other tree-shaded cocoa will be partly replaced by other forms of agriculture including sun-grown cocoa, coffee, or crops or pasture except in areas where previously established on soils with the highest agricultural production capacity (prime farmland), on steep terrain (larger than 70% slope) or on floodplains. However, for convenience of processing tree-shaded cocoa was actually reclassified to secondary forest based on an assumption that it 'acts like' secondary forest when buffering edges and facilitating gap crossing. Pasture and agriculture will generally remain unchanged, as we assume no spontaneous abandonment and regeneration of farmland. Bare land is assumed to be a temporary state of agricultural land that is reclassified as agriculture/pasture for the future. Urban land uses and other habitat types (e.g., mangrove, wetlands, water bodies) cannot be

converted into forest and are assumed to remain in their present condition. Similarly, we did not anticipate changes for restinga and caatinga. The BAU layer was constructed to reflect this situation by reclassifying the current land cover layer of southern Bahia.

It is important to remember that the decisions about the future land cover under BAU scenario for southern Bahia was the authors' best guess based on personal observations of practices of local people in the area (for summary of all rules see Table below).

3.3 Restoration Interventions (Required)

This raster theme reclassified existing land cover/use (Section 3.6 below) into the highest level of habitat possible if the pixel is in a planning unit that is selected for conservation action. We assume that restoration or regeneration produces a class we call 'restored forest', which will be similar to secondary forest for the short term, but will eventually resemble primary forest. The reclassifications applied to the current land cover/use are given in the table below.

After the user selects planning units for conservation intervention, by any of the methods discussed in Section 1.2, the restoration theme is extracted for those units and then merged with the Business-as-Usual scenario (section 3.2) for unselected units to predict the future land cover/use pattern for the scenario.

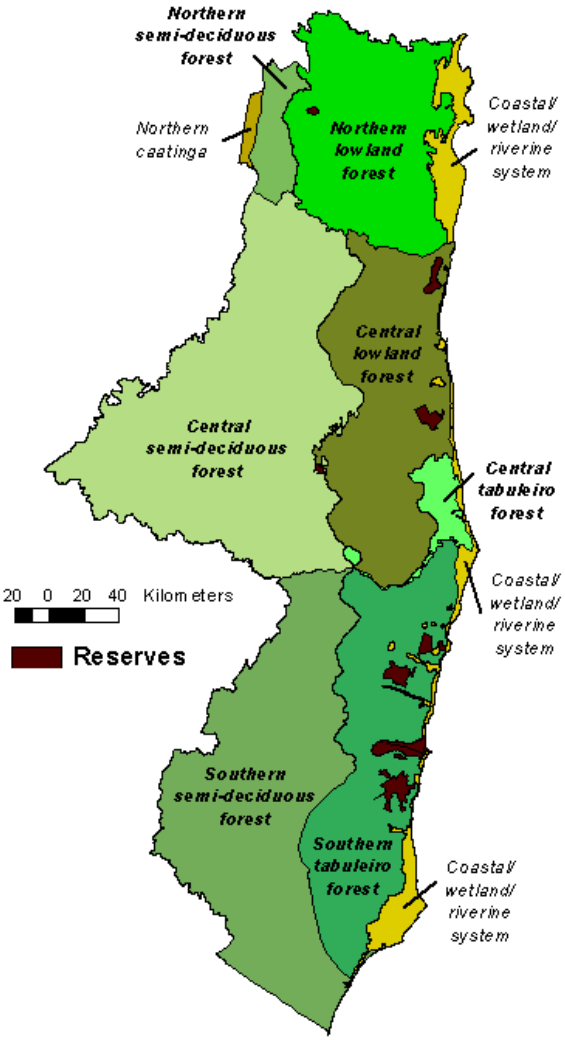
Table of assumptions about transitions in land use/cover form current to the future without or with protection/restoration

Land Cover Class	Business As Usual Scenario	Restoration Scenario
Mature Forest	Secondary Forest	Mature Forest
Secondary Forest	Secondary Forest (see in the text) if near Mature Forest; otherwise Pasture/Agriculture	Restored Forest*
Tree-shaded cocoa	Secondary Forest on fertile soils, in steep terrain or on flood plains; otherwise Pasture/Agriculture	Restored Forest*
Eucalyptus Plantation	No change	No change
Pasture/Agriculture	No change	Restored Forest*
Bare Soil	Pasture/Agriculture	Restored Forest*
Restinga	No change	No change
Caatinga	No change	No change
Mangrove	No change	No change
Wetlands	No change	No change
Water	No change	No change
Urban	No change	No change
No Data	No change	No change

* If pixel is within 1 km of mature forest, restoration is spontaneous; otherwise a reestablishment cost of R$2000 / ha is imposed.

3.4 Bioregions (Required)

The conservation objectives for the Corridor are to preserve or restore examples of forest in each bioregion. For Bahia this layer was derived from a vegetation map compiled by Wayt Thomas and Andre Carvalho for the Corridor project, based in part on their previous research (Thomas et al. 1998). There are two formats for this theme. The vector shapefile version is used for visualization. The grid version is used in summary analysis to compare a scenario with the bioregional conservation objectives. The bioregions capture the major patterns of biodiversity in the corridor. From coast to interior, the vegetation grades from lowland wet forest to semi-deciduous Forest. The north to south zonation recognizes the biogeographic barriers of the Rio de Contas and Rio Jequitinhonhia. Distinct endemic flora and fauna occur to the north and south of both of these major rivers.



3.5 Prime Farmland (Optional)

Allocation of the best farmland to conservation purposes conflicts with social goals such as self-sufficiency in food production. In the absence of a map specifically delineating prime farmland, we use a map derived from Radambrasil's Potential Use of the Land map (Brasil, Ministério das Minas e Energia 1981, 1987). This map classified soil and climate attributes into a set of seven classes (six of which occur in the Corridor project area) and then rated each class for its potential for agriculture and other land uses. Only one class, called Lavoter, is rated as highly suitable for agriculture in the Corridor. We extracted the polygons with this class and converted it to a grid as a coverage labeled 'AOSI'. It is used in the summary analysis.

3.6 Paved Road and Urban Areas Mask (Required)

TAMARIN treats paved roads and urban areas as barriers that fragment forest blocks. In Bahia this grid theme excludes lands within 200 m of all paved roads and urban areas when grouping pixels into forest blocks. It was derived from shapefile theme of roads and land cover classification (described below) using **ArcView** according to steps listed in Appendix C.

3.7 Current Land Cover/Use (Required)

The land cover/use layer functions not only as a reference layer that guides a **TAMARIN** user in selecting planning units, but also as a base layer for deriving the BAU layer described above. The construction of the layer was based on an interpretation of eight adjacent Landsat-5 Thematic Mapper images with a pixel size of 28.5 m (Landau et al. 2003a). Seven of these images covered almost the entire area of interest, and were acquired within a five month period between October 1996 and February 1997. The only exception was a single image used from August 1994 that covered the most northern area. Prior to the interpretation the six available optical bands of each image were georeferenced using reference points obtained from 1:100k scale topographic maps, spectrally equalized and preprocessed into seven derived products. These derived products were obtained from: principal components analysis, a calculation of normalized difference vegetation index (NDVI), analysis of texture variance of band 7 and applying a low pass filter to bands 5 and 7, and were subsequently used as inputs into the ISODATA unsupervised classification process. This algorithm produced eighty arbitrary classes for each image. These classes were then interpreted and assigned to new categories in accordance with a legend defined by the official Brazilian vegetation classification system (Veloso et al. 1991). The resulting land cover/use classes are listed in Table below. The classification results were mosaiced together to produce continuous cover of the area.

Table of land use/cover codes in the GIS layer and corresponding class names.

GIS Code	Class Name
3	Mature Forest (mature tropical forest and advance stage of regeneration “Capoeirão”)
4	Secondary Forest (initial stage of regeneration “Capoiera”)
5	Tree-shaded Cocoa (cabruca/cocoa shaded by exotic tree species, e.g., *Erythrina* spp.)
8	“Restinga” Arboreal (arboreal vegetation on coastal plains)
9	“Restinga” Herbaceous (herbaceous vegetation on costal plains)
10	“Caatinga” (savana with open xerophytic deciduous vegetation)
11	Eucalyptus Plantation (monoculture plantation of *Eucalyptus* spp.)
12	Pasture/Agriculture (including rubber plantations)
13	Bare soil
6	Mangrove
2	Wetlands (including “Brejos” and “Várzeas”)
1	Water
14	Urban
No Data	Non classified areas (No data, cloud, shadow)

3.8 Existing Reserves (Optional)

This vector shapefile depicts all known nature reserves in the Bahia corridor that was compiled by INCRA and supplemented from other sources for recently established reserves and major RPPNs (Landau and Resende, 2003a). Área de Protegida Ambiental (APA’s) or Environmentally Zoned Areas were not considered protected for biodiversity as they are managed primarily for tourism. It is assumed that reserves are and will continue to be protected. This theme is included as a visual aid for selecting additional sites to expand/buffer (increase resilience) or to complement the existing reserves (increase representation).

3.9 Roads (Optional)

Roads are important geographic features for orienting a user in the map display. They also have significant impacts on land use, land value, and habitat value. Therefore, there is a benefit of having a shapefile version of roads for visualization and a grid version that has been buffered by road type. The latter theme is used in calculating edge effects on forest habitat and separates tracts of forest into smaller fragments when determining the number of viable fragments. For Bahia Landau et al. (2003b) had digitized topographic maps (1:100k), and then updated them with newer information about paved roads.

3.10 Municipios (Optional)

These are the basic political units of the Corridor. They are provided here as base map features for orienting the planning team in creating and evaluating scenarios. For Bahia the theme table contains many attributes from the Census of Agriculture (IBGE, 1994), which can be displayed if desired through standard **ArcView** tools such as the Legend Editor.

3.11 Cities (Optional)

Cities are also useful landmarks for orienting a planning team. A subset of all populated places in Bahia with at least a population of 25,000 people was extracted and annotated with their names (Landau and Resende, 2003b).

3.12 Fresh Water (Optional)

Major rivers and lakes were extracted from the Digital Chart of the World (DCW) – an Environmental Systems Research Institute, Inc. (ESRI) product originally developed for the US Defense Mapping Agency (DMA) using DMA data. We used the DCW 1993 version digitized from 1:1,000,000 scale maps.

4. CUSTOMIZED GRAPHICAL USER INTERFACE

We customized **ArcView** to make **TAMARIN** more useful for corridor planning. Several menus were added in the ViewGUI (see Section 5) and a series of buttons were added to the ViewGUI button bar.

The hut button always resets the current working directory to the root directory of **TAMARIN**. This is useful if you have used the browser to navigate to other folders and are having trouble navigating back (or if **TAMARIN** is having trouble finding files).

The dollar sign ($) button can be used when selecting planning units to discover how much the selected units will cost. You can see what proportion of your budget is left or how much you have exceeded it. This only works with the original planning unit theme, not with the new shapefile created of the selected units following the budget constraint step.

The downward arrow (or horizontal lines that get narrower towards the bottom) is used to close all table windows. **TAMARIN** can create many summary tables. When you are done reviewing them, click this button and it will automatically close every open table window. The tables are not lost or deleted. They can be reopened from the 'Project' window in the 'Tables' section by double-clicking on the name or clicking once and clicking the 'Open' button.

The '3 dots' button resizes the View windows according to the size of the **TAMARIN** window. This can be useful when starting **TAMARIN** for the first time on a different computer with a different screen resolution or when you simply resize the application window.

The Paper Clip and Redo buttons are used to save and recover a set of selected planning units. This guards against accidentally unselecting units that you have chosen manually and that would be tedious and frustrating to select again (see Section 5.1.2).

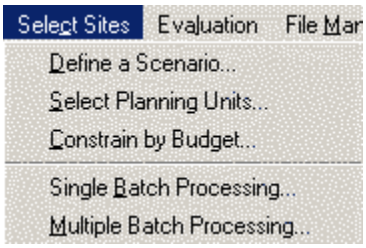
5. ANALYSIS PROCEDURES

TAMARIN contains two categories of analysis procedures. You use the first category to design your own scenario and the second to evaluate that scenario.

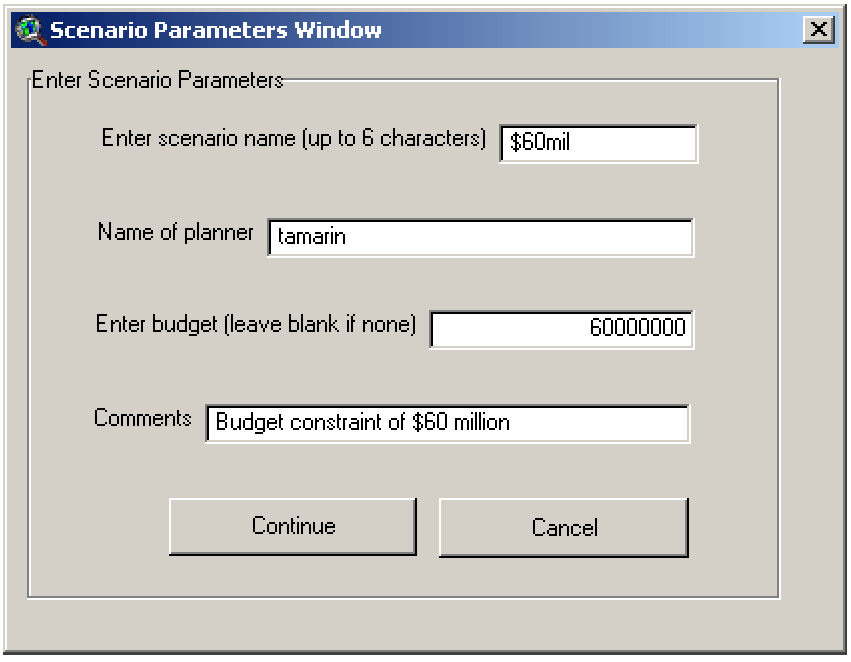
5.1 Procedures for Designing a Scenario

The procedures for selecting are divided into three sequential steps. First the planner defines the parameters of a scenario in a form or dialog box. Next the planner selects planning units for the scenario by one of the methods described in Section 1.2 above. The final step allows a budget constraint identified in the scenario definition to be applied to the selection. These three steps are described in detail next.

5.1.1 Define a Scenario



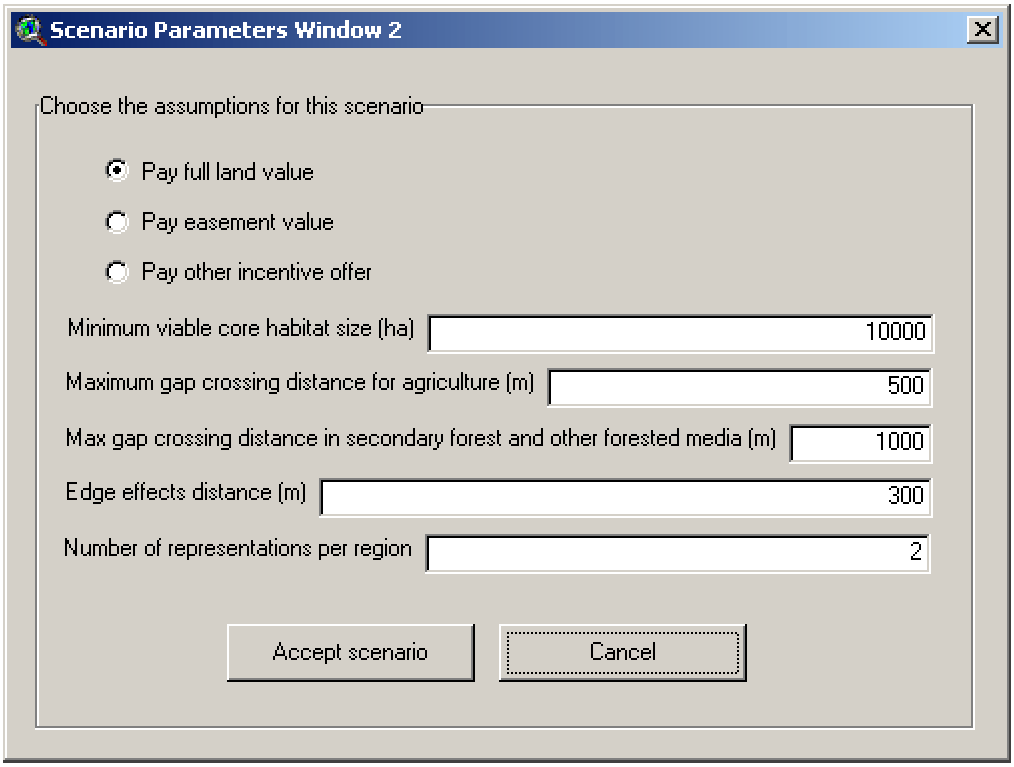
Each scenario will have different parameters. The first step is to define what those parameters will be for a particular scenario. From the 'Select sites' menu, choose the first option, labeled 'Define a scenario…'. This opens up a series of dialog boxes or forms with a combination of text lines for typing names or values, scrolling lists of files to select from, and radio buttons for selecting between mutually exclusive options. The results of this dialog are written to a text file to document the scenario.



Each scenario is given a unique name in the first text box. Type a name that helps identify the scenario but is no more than 6 characters long. Besides being written to the scenario text file, this name is used in naming many of the new themes, tables, and charts that are generated by the analysis procedures.

The second text box asks for the name of the person (or organization) who created the scenario. This is written to the scenario text file for documentation, along with the current date, which is determined automatically by the software.

The budget for this scenario can be set in the third text box. The default value is to have no budget constraint. If you enter a value, in arbitrary monetary units, this amount constrains the number of planning units for which a conservation intervention can be applied. Setting a budget lets you compare a single strategy with different budget levels or different strategies with the same budget. If a budget constraint is applied, it may reduce the number of planning units that you initially select (see Section 5.1.3 below for details). Click 'Continue' to proceed to the second dialog window.



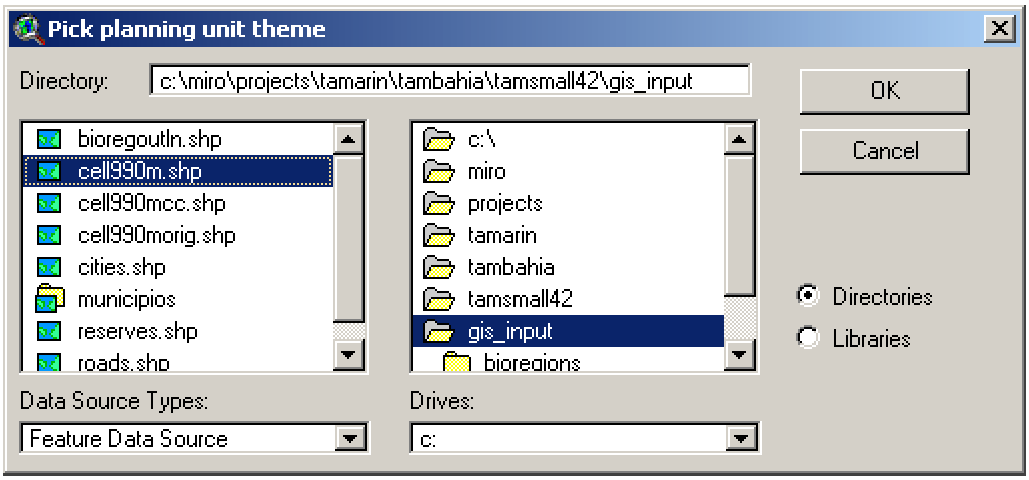
In this second dialog there are three radio buttons for choosing the conservation intervention to be used in this scenario. The first uses land acquisition. If the box is checked, the full purchase price of the planning unit will be assessed against the budget. If the second button is checked, the selected planning units will be conserved through some form of conservation easement. In that case, the cost of conservation action only includes payment of the opportunity cost to the owner. You will be asked later to select the alternative estimate of opportunity cost/easement value. The third radio button indicates a scenario where a fixed payment is offered for easements. Selecting this button triggers an input message window to specify the amount of the payment in monetary units per hectare.

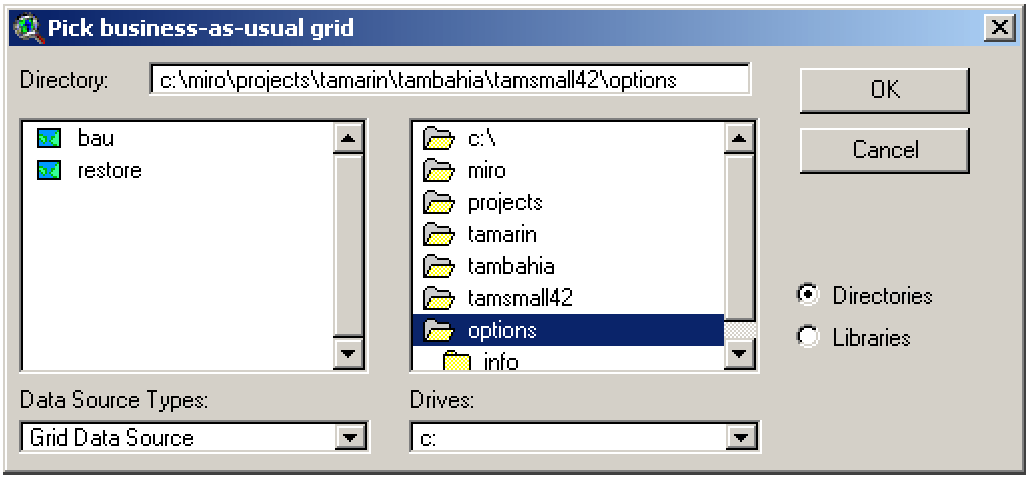
The first three text boxes control how forest habitat units are defined in the analysis procedures, including representation goals. The first box sets the minimum size (in hectares) of a block of mature and/or restored forest for it to be considered viable for maintaining native plant and animal diversity, assuming no immigration of individuals or propagules from outside the block. This is a difficult number to determine because it depends on the taxonomic group one is considering. Thus we have tentatively allowed this to be set as a variable in each scenario and

documented in the scenario text file. The default for Bahia is currently set at 10,000 hectares based on modeling by Adriano Paglia of the probability of extinction for the yellow-breasted capuchin. Note that Gascon et al. (2000) predict serious degradation from edge effects for forest blocks smaller than 5000 hectares, whereas Chiarello (2000) sets this threshold at 20,000 hectares. The second and third of these parameters specify the maximum distance (in meters) that species or propagules can travel across different land cover classes to reach nearby fragments. A cumulative result of the two maximum gap-crossing distances, set at the default of 500 m for agricultural land, eucalyptus, restinga and bare land and 1000 m for secondary forest, tree-shaded cocoa, caatinga and mangrove, defines the relative impedance for gap-crossing between the remaining forest fragments (urban area and water are considered to be impenetrable barriers). Fragments that are closer than the value of the relative impedance distance at a given place are treated as being part of the same functional block. It is the block that is compared to the minimum viable habitat size. The fourth text box asks you for the maximum distance (in meters) that you believe human-caused effects propagate from the edges of forest patches into their interior. The default value for Depth-of-edge-influence for Bahia is set at 300 m (Gascon et al. 2000) although this depends on the type of disturbance and its ecological impacts. This distance is used in calculating the amount of core versus edge forest in a scenario. The last text box sets the number of separate habitat units needed in each bioregion to achieve the desired conservation goals for the scenario. The default value is set at two habitat units per bioregion.

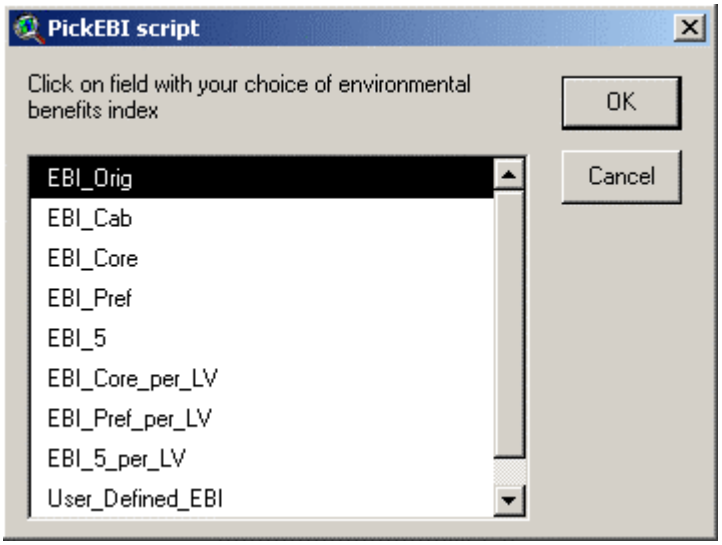
When you have finished defining the scenario, click on the 'Accept scenario' button at the bottom of the dialog window. You may also click on the 'Cancel' button to leave the dialog without saving your choices.

After clicking the 'Accept scenario' button, you will be asked to select three themes for the analysis. The first theme contains the set of planning units from which to select a scenario. Normally you should select cell990m.shp unless you are substituting your own planning unit theme. The second theme depicts your forecast for the future in the absence of conservation intervention (the business-as-usual scenario as described above). The third theme is your choice for the restoration grid, to be used for planning units that are selected for conservation action. **TAMARIN** will display a scrolling list of themes and ask you to select which theme to use for the three types of theme. Simply click on the theme name and click 'OK'. The default business-as-usual theme is called 'BAU' and restoration theme is called 'Restore'. You may substitute your own theme for one or both of these provided your theme meets all the format and data requirements of the default themes.

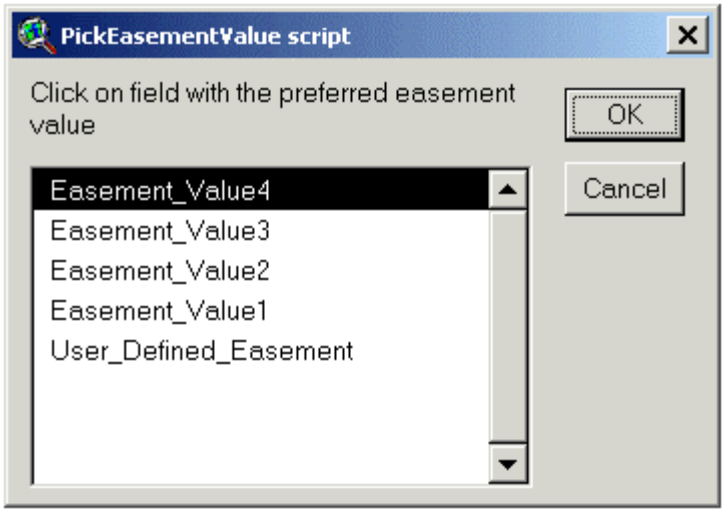




After prompting you for the themes to be used in the analysis, **TAMARIN** allows you to choose among other alternative assumptions. The first choice is to select the Environmental Benefits Index variable in the planning unit theme. For Bahia we have computed six alternative values for this index, based on different assumptions or criteria, plus one you can compute yourself. You will be shown a scrolling list and asked to select the name of the field you wish to use. The seven alternative indices are shown below and are described in section 3.1.

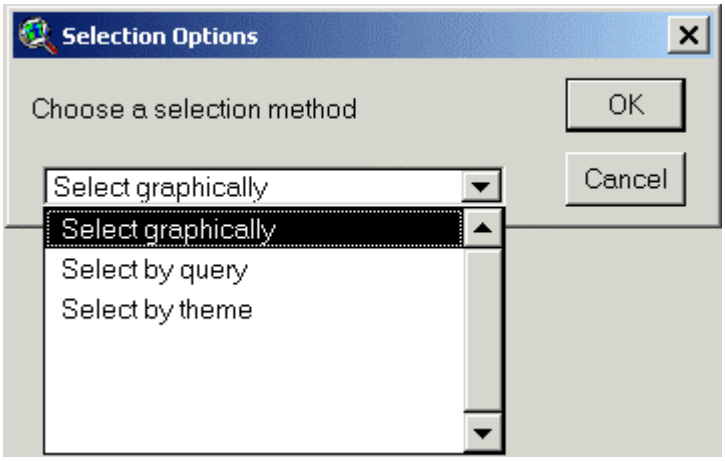


There are also several alternative assumptions about the opportunity costs that should be paid to landowners as environmental compensation (or easement) as an incentive to participate in restoring the corridor. If you selected Easements as the conservation intervention, you will next be asked which of four easement value assumptions you wish to apply in the scenario. The four alternatives are shown below and are explained in Section 3.1.



5.1.2 Select Planning Units

Section 1.2 described the three methods for selecting planning units for a conservation scenario. This section provides greater detail on how the selection is performed in **TAMARIN** for each method. The selection methods do not consider the budget constraint. The user may select as many planning units as desired. Applying the budget constraint that was identified in the Scenario Dialog in Section 5.1.1 occurs in the third step, described in Section 5.1.3. Therefore, the planning units selected in this step form only a starting or tentative set. In all selection options, the selected planning units are highlighted in yellow in the Analysis View window.



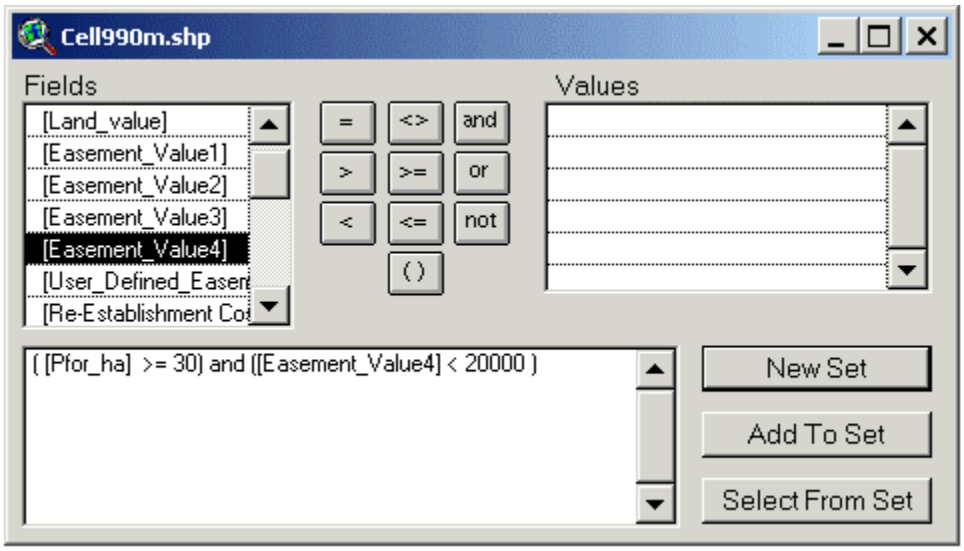
Graphical selection—In this selection method, the planner uses the **ArcView** *Select features* tool (see graphic of tool button below) to select planning units with the cursor based upon his or her judgment about priority locations for conservation. Select the 'Select graphically' option in the 'Selection options' menu. Clicking on a single planning unit in the Analysis View window will select that unit. Clicking and dragging the cursor with the left mouse button depressed will select all units within the rectangle drawn by the planner. To select additional units, hold down the Shift key while clicking or clicking/dragging with the cursor. Selected planning units will be highlighted (in yellow). To unselect planning units, hold down the Shift key while clicking on individual planning units. If you wish to start over, go to the Theme menu and select the 'Clear Selected Features' option. Alternatively, you can use the 'Clear Selected Features' tool on the

toolbar. Then you may begin selecting units again. Note that planning units will be selected if the rectangle intersects any part of the unit, not just those that are completely contained in the rectangle.

 The **ArcView** 'Select features' tool.

At any time, you can check on the current cost of the selected planning units by clicking on the '$' icon on the button bar (see Section 4). This computes the appropriate costs (for land or easement purchase or incentive offer as appropriate) of all selected units. This informs you of whether you have already exceeded your budget or can select additional units.

It is relatively easy to forget to use the Shift key to add planning units to the set you previously selected. This has the effect of unselecting those and only selecting the new units. To guard against this accidental loss of your work, **TAMARIN** provides a means of saving what you have selected in a file, and in case of accidental loss, of recovering what you had selected. The Paper Clip button saves your current selection (writes it to the savepu.dbf table). The Redo button to the right of the Paper Clip uses that table to select the units that you had saved (see Section 4).

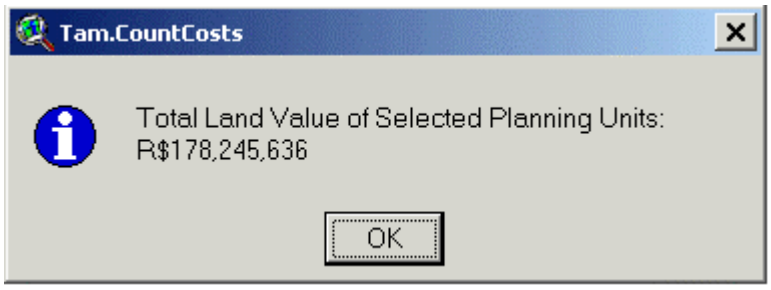


Select by Query—**ArcView** has built-in procedures for querying the attributes of the GIS database and selecting those planning units that match the Boolean search criteria. For instance, in a query of planning units with at least 30 ha of mature forest AND an easement value less than 20,000 reais per planning unit, those units that satisfy both conditions would be selected. Select the 'Select by query' option in the 'Selection Options' menu. This will open a dialog window in which you can specify the selection criteria. The list on the left side of the dialog box contains the set of attributes for the planning units. For our example above, you would double-click on the 'Pfor_ha' attribute, which would then appear in the query window in the bottom of the dialog box. Next, single click on the '>=' operator symbol in the middle of the dialog box. Then type the number '30' in the query window. To add the second criterion, single click the 'AND' symbol in the middle of the dialog box. Next, double-click on the 'Easement_Value4' attribute in the left window, followed by the '<' symbol. Type '20000' (no commas) in the query window and click on the 'New Set' button. Use the 'New Set' button if these are the first units you are selecting for this scenario. You could now add additional units with another query if you wish. For instance, you may wish to add units where tree-shaded cocoa is at least 30 ha and the same easement value limit. Select the text in the lower window and press the backspace key to delete it. Make another query, but this time, press the 'Add to Set' button. Now you can refine

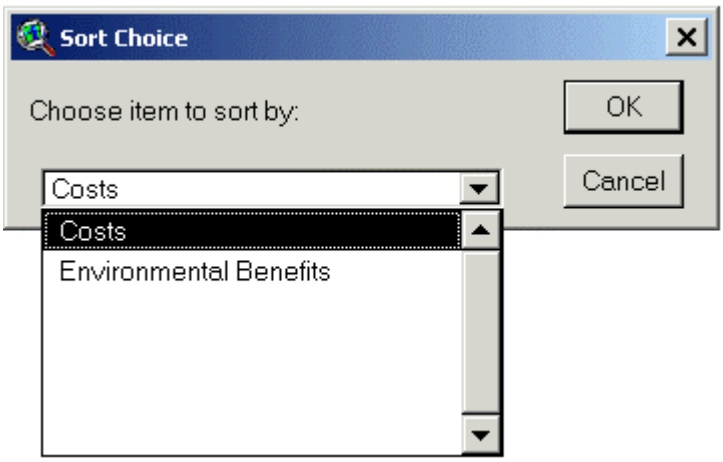
your selection by adding another criterion. For instance, you may only wish to select units from your previous selection that are not densely populated. Clear the query in the lower window again and put in your new query, e.g., [Population] < 15. 'Select From Set' will then only select a subset of planning units that satisfy the current query from the set that was previously selected. You can also use the graphical selection tool to further refine your choice by adding or removing individual planning units from the selected set. (DO NOT USE THE 'Selection Options' MENU AGAIN, HOWEVER, OR THE PREVIOUSLY SELECTED UNITS WILL BE UNSELECTED).

Select by Theme—If a stakeholder has already created an **ArcView** shapefile that represents a conservation scenario, you may use that shapefile to select planning units for evaluation. Select the 'Select by theme' option in the 'Selection Options' menu. You will be prompted to identify the shapefile in a browser dialog. Navigate to the shapefile's folder (the browser will begin in the current working directory), select it, and click the 'OK' button. This theme will be added to the Analysis View window and will be overlain on the planning unit theme. Planning units that are completely contained within the areas in the shapefile will be selected. (Currently no option is provided for other intersection options, e.g., 'Intersects' that selects if any part of the planning unit is within the shapefile area.) You can also use the graphical selection tool to add or remove individual planning units from the selected set. (DO NOT USE THE 'Selection Options' MENU AGAIN, HOWEVER, OR THE PREVIOUSLY SELECTED UNITS WILL BE UNSELECTED). This selection option would also be useful to refine a scenario that you have previously evaluated. Use the shapefile produced for the earlier scenario as the theme to select by, then modify the selection by further adding or selecting from the initial set.

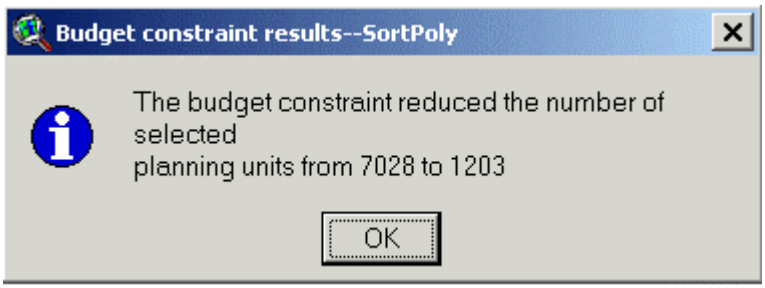
5.1.3 Constrain by Budget



To this point, the planner has selected planning units based on their attributes without regard to the total cost. It is possible that the total cost of the initial scenario exceeds the budget specified in the scenario definition step (Section 5.1.1). It is possible at this point to check the total cost, based on the selected payment method, by clicking on the $ tool, which displays the sum in a message box as shown here. Selecting the 'Constrain by Budget' menu, **TAMARIN** checks if a budget limit was set. If not, it gives you an opportunity to add one. If you did set a budget limit, the planning units are sorted either by costs (land value or easement value attribute as appropriate) in ascending order or by your preferred environmental benefits index in descending order and sums the appropriate costs (land value, easement value, or incentive offers) until the budget constraint is reached. Thus the procedure selects either the least expensive planning units or those with the greatest relative suitability for restoration or conservation for the given budget. The choice of which cost to use is based on your selection of whether to purchase land or easements or pay incentives in defining the scenario (Section 5.1.1). Planning units are then selected from your initial set until the budget is exhausted. After running this step, a new shapefile named after the scenario name will be created and added to the Analysis View. This shapefile will only contain the selected planning units that do not violate the budget constraint and is used in the evaluation procedures described in Section 5.2.



TAMARIN reports the reduction in the number of planning units as a result of imposing the budget constraint.



Note: When choosing to sort by Environmental Benefits, **TAMARIN** will automatically select the cheapest planning units with the highest EBI values. However, when sorting by Cost **TAMARIN** will select planning units with low total cost. Because the land value recorded in a given planning unit only totals the land values of categories suitable for supporting forest growth, planning units located on the boundary of the study area, containing water or no data, or planning units with urban areas even if the per hectare price is high could be in the selection. Choosing an EBI normalized by land value (e.g., EBI_5_per_LV) eliminates this problem.

5.1.4 Cautionary note on selection and sorting of planning units

The variation in area among planning units (as described in Section 3.1) has consequences when sorting planning units under a budget constraint, or when selecting units by query. Because the planning units are artificial constructions, it is probably most logical to sort them or select them according to per-hectare characteristics. In general, the EBI variants (including EBI adjusted by land value) are defined on a per-hectare basis or a proportional basis. This is also true for variables which describe the proportion of the planning unit under specific types of forest: 'propprimfo', 'propsecfor' and 'propcab'. However, the costs, easement values, and the other land cover variables are defined in absolute terms (for details on all variables see Appendix E).

Consider, then, selecting planning units by query. To preselect planning units with per hectare land values less than R$100, one would specify:

[Land_Value] < 100 * [Hectares]

If one used:

[Land_Value] < 9801

the results would include some small planning units, but possibly with high per-hectare land values – e.g., a 10 hectare planning unit with per-hectare value of R$900.

Similarly, consider sorting planning units under a budget constraint. If the user decides to sort by EBI, **TAMARIN** will sort by the per hectare EBI. The result of this procedure is that **TAMARIN** selects the highest ranking units with the highest EBI values per hectare (including EBI adjusted by land value), regardless of the sizes of the planning units. However, when sorting by cost using land value (or easement value), **TAMARIN** bases its analysis on the cost of the entire planning unit. This may lead to unexpected results. However, exclusion of "small" planning units may also be unsatisfactory. Some of the "small" planning units may be located on the border of protected areas and hence would be preferred sites for selection into a conservation set.

5.2 Evaluation Procedures

Once the scenario parameters have been defined and the set of planning units has been selected, the next group of procedures perform the evaluation of the scenario, including the forecast of future land cover/use (Section 5.2.1); a summary of the economic and environmental effects (Section 5.2.2); a series of landscape indices characterizing the resulting landscape configuration relative to the conservation objectives (Section 5.2.3); and preparing and printing a summary map the scenario (Section 5.2.4).

5.2.1 Forecast Future Land Use

This analysis step combines the data from two grids to create a future land use forecast for the scenario. The two grids are: 1) the restoration theme for selected planning units, and 2) the business-as-usual scenario for the remaining lands. **TAMARIN** merges those two grids to create a future land use forecast grid that is added to the Analysis View window.

Here is the processing logic used to create the theme of future land use:

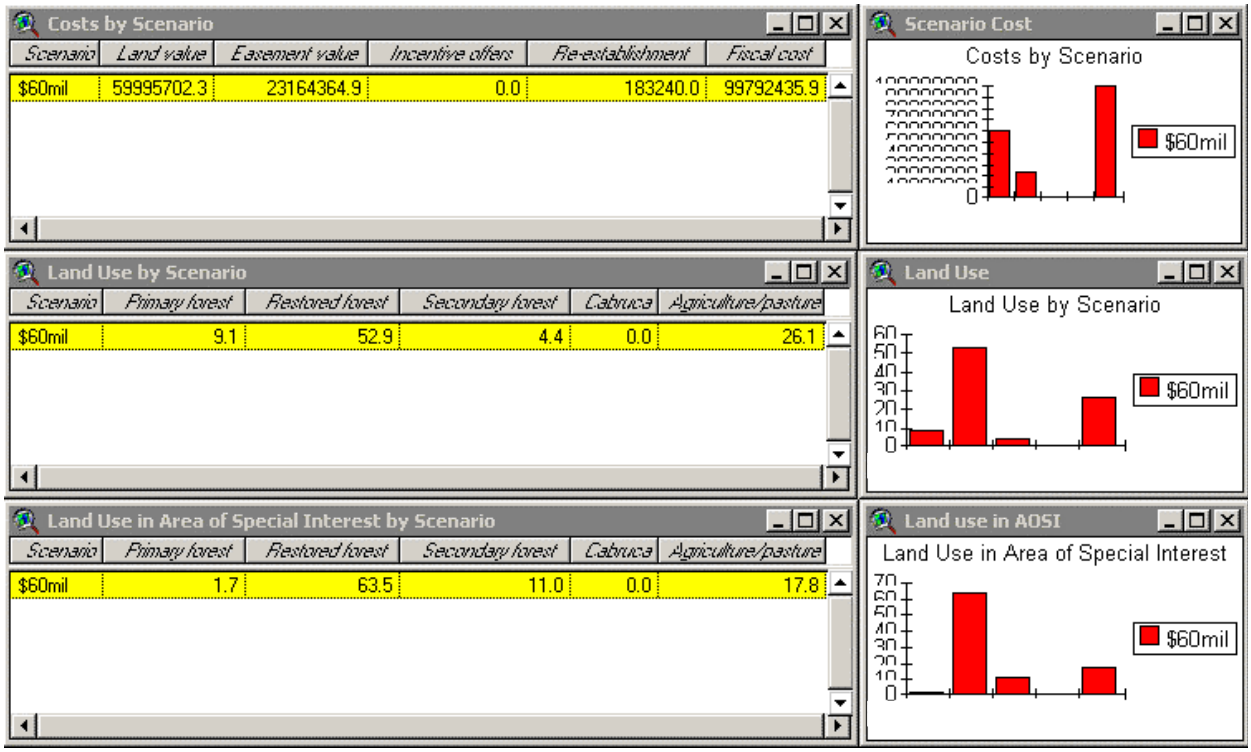
Was the planning unit selected?
If yes → Restore option as described in section 3.3 (or your own version)
If no → BAU as described in section 3.2 (or your own version)

This theme is given the name of the scenario that you entered in the opening dialog. The legend is very similar to the Land cover theme, except 1) the other forested media (e.g., tree-shaded cocoa in Bahia) and bare land classes are not used (they either become restored forest, secondary forest or agriculture/pasture land depending on the scenario), and 2) a restored forest class is added. Simply select the 'Forecast Future Land Use' option from the 'Evaluation' menu. This newly created grid is used in the remaining evaluation steps.

5.2.2 Summarize Scenario Solution

It is not enough to make a map of future land use, it is also necessary to derive some summary measures about it that can be compared to other scenarios, to the current land use, to the business-as-usual scenario, and to the conservation objectives. Simply select the 'Summarize Scenario Solution' option from the 'Evaluation' menu. **TAMARIN** computes the summaries and prints them to a series of tables and/or to a text file. In all the summary tables, the scenario being evaluated is highlighted in yellow and "promoted" to the top row of the table. The first table summarizes total scenario cost. Even though you specified whether to pay land or easement value or an incentive offer, the summary table lists totals for all three types plus the amount needed for forest reestablishment costs in units beyond the seed range from existing forest. The easement value total is based on your choice of assumption about easement values/opportunity costs in the 'Define a scenario' step. The second table lists the percent of land use/cover type in the scenario for the types that can change between scenarios. For Bahia the mangrove, wetlands, caatinga, restinga, water, urban, and eucalyptus types are not shown since they are assumed to remain constant in all scenarios. Therefore, the percentages of land use/cover types listed in the table will not sum to 100%. The third summary table gives a similar breakdown of land use/cover types inside the Area of Special Interest (AOSI) only when the AOSI grid is located the Working View. The scenario text file gives additional summary values such as the average/maximum/minimum of the Environmental Benefits Index (again based on your choice of index), minimum and maximum land and easement values, the number of units selected (and that do not exceed the budget), the net change in area and percent change in land use types from the current land cover, and the regional breakdown of cover types in percentages.

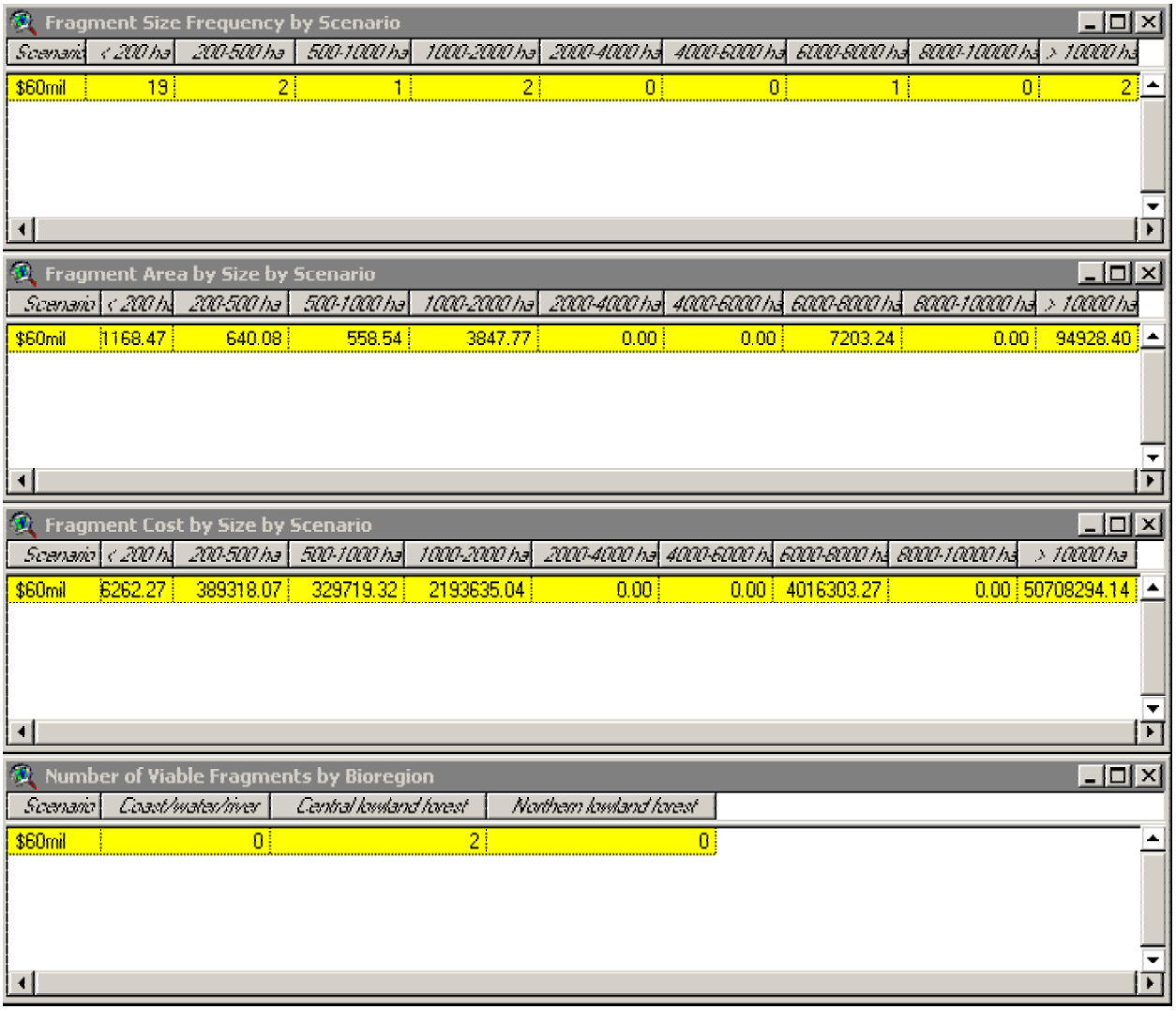
Summary tables with the scenario being evaluated highlighted in yellow



5.2.3 Landscape Configuration

The desired future landscape configuration is defined not just to achieve a target area of mature and restored forest in the Corridor but to do so in a number of relatively large, contiguous blocks of forest habitat with a large proportion in core or interior forest and a small amount of edge. The 'Landscape Configuration option on the 'Evaluation' menu computes a number of landscape indices, including the size of the largest forest fragment, the total area of mature and restored forest, the number of forest fragments, the frequency of size classes of fragments (0-200 ha, 200-500 ha, 500-1,000 ha, 1,000-2,000 ha, 2,000-4,000 ha, 4,000-6,000 ha, 6,000-8,000 ha, 8,000-10,000 ha, and > 10,000 ha), the number of fragments that are larger than the minimum habitat size specified in the opening dialog (Section 5.1.1), and the area and percentage of forest that is in core versus edge habitat. These results are written to a set of tables and/or to the scenario text file.

Example of summary tables in Landscape Configuration analysis



Fragment Size Frequency by Scenario

Scenario	< 200 ha	200-500 ha	500-1000 ha	1000-2000 ha	2000-4000 ha	4000-6000 ha	6000-8000 ha	8000-10000 ha	> 10000 ha
$60mil	19	2	1	2	0	0	1	0	2

Fragment Area by Size by Scenario

Scenario	< 200 ha	200-500 ha	500-1000 ha	1000-2000 ha	2000-4000 ha	4000-6000 ha	6000-8000 ha	8000-10000 ha	> 10000 ha
$60mil	1168.47	640.08	558.54	3847.77	0.00	0.00	7203.24	0.00	94928.40

Fragment Cost by Size by Scenario

Scenario	< 200 ha	200-500 ha	500-1000 ha	1000-2000 ha	2000-4000 ha	4000-6000 ha	6000-8000 ha	8000-10000 ha	> 10000 ha
$60mil	6262.27	389318.07	329719.32	2193635.04	0.00	0.00	4016303.27	0.00	50708294.14

Number of Viable Fragments by Bioregion

Scenario	Coast/water/river	Central lowland forest	Northern lowland forest
$60mil	0	2	0

The ‘Landscape Configuration’ option processes the following steps (see graphics below for an illustration):

1. Extract the forest pixels from the Future land use theme for the scenario (mature and restored forest only)

2. Expand from this set of pixels by half the gap-crossing distance (to determine which patches are functionally linked)

3. Mask out paved road/urban corridors as barriers to clustering pixels into habitat blocks

4. Use the RegionGroup command to aggregate pixels from #2 into clusters

5. Extract forest pixels in #3 by cluster, giving them unique numbers for each fragment and assess size-frequency (theme added to Analysis View, colored by the size of fragments)

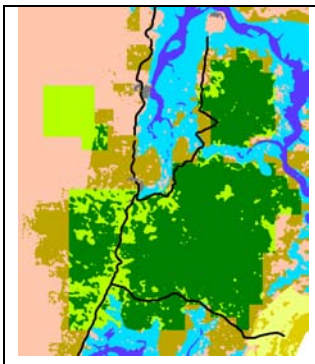
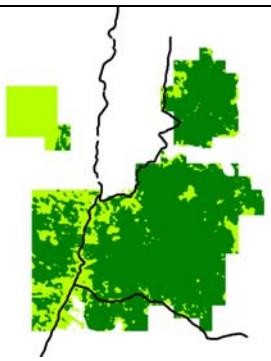
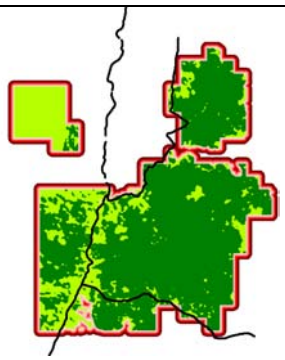
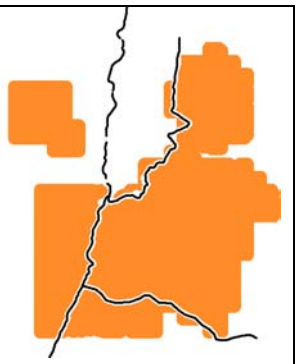
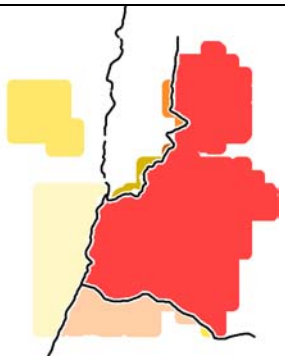
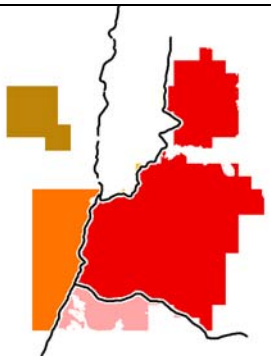
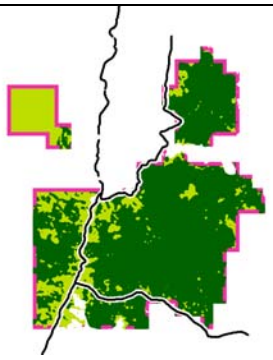
6. Expand agricultural and urban land use pixels by the edge distance into fragments to identify edge vs. core pixels. Forest adjacent to mangroves, wetlands, other native habitats, or secondary forest and eucalyptus plantations are not considered edge. That is, we are only concerned with anthropogenic edges here (theme added to Analysis View, colored by edge pixels (pink), mature forest (dark green), and restored forest (bright green)

7. Select fragments from step #5 that exceed the minimum viable habitat unit size (theme added to Analysis View, colored by unique ID number of the habitat unit), and determine largest fragment size

8. Summarize number of these fragments in each bioregion (not shown)

9. Summarize number of these fragments that have more than 1000 ha of mature forest (not shown)

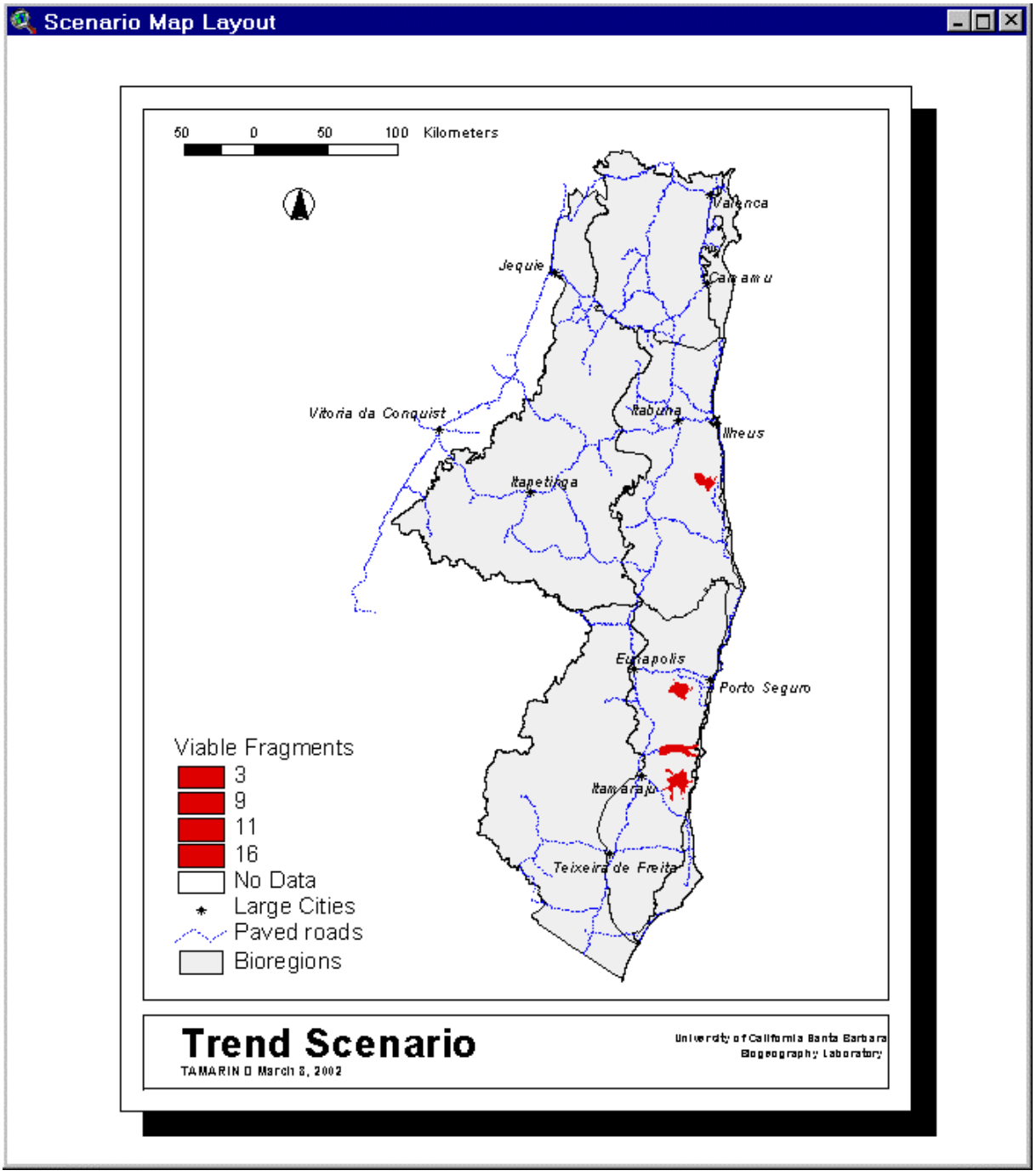
Example of processing steps in Landscape Configuration analysis

 Scenario future land use	 Step 1-Extract forest pixels	 Step 2-Pixels within gap-crossing distance (shades of red)	 Step 3-Mask out paved roads (black lines)
 Step 4- Regiongroup of clusters of contiguous pixels within gap-crossing distance	 Step 5- Extract forest fragments from clusters	 Step 6- Core (green) versus edge (pink) pixels adjacent to agriculture and urban pixels	 Step 7-Select viable habitat units (greater than 10,000 hectares in size)

5.2.4 Print Map of Fragments

This option compiles the maps from the evaluation of the scenario and organizes it into a printable page using **ArcView**'s built-in layout functions. The script assembles a layout document that contains an 8.5 x 11 inch map of the forest fragments larger than the minimum size. The report page is automatically formatted for you when you select the 'Print map of fragments' menu option. You can then use the 'File→Print' menu to send the page to a printer or print it to a file or the 'File→Export' menu to export the layout to a graphic format.

Example of a printout map



5.3 Scenario Outputs

TAMARIN creates several different types of outputs. One output is a text file containing the basic information about the scenario. It also generates a future land use grid with the name of the scenario, as described in Section 5.2.1.

5.3.1 Scenario Text File

The scenario text file contains a description of the scenario (e.g., name, date, business-as-usual and restore scenario names, budget constraint, minimum habitat unit size, etc.). This file is created when you select a scenario name in the opening dialog for defining the scenario. It is given the name <name>_scenario.txt where <name> is the name you assigned in the dialog. For example, a scenario textfile contains the following:

```
Scenario Name:         1+e8
Created by:            Tamarin
Date Created:          October 31, 2003
Comments:              Comment
Planning Units Theme:  Cell990m.shp

...Input Parameters from Scenario Dialog...SortPoly
Budget Constraint:                                  1e+008
Min Viable Habitat Size (ha):                       10000
Max Gap Crossing Distance in Agriculture (m):       500
Max Gap Crossing Distance in Sec. Forest (m):       1000
Edge Effects Distance (m):                          300
Number of Representations per Bioregion:            2
Future Forecast:                                    bau
Restoration Option:                                 restore
Conservation Intervention:                          Pay Land Value
Easement Option:                                    Easement Value4
Environmental Benefits Index:                       EBI Pref per LV

...Selection Method...chooseSiteSelector
   Selected by ([Bioreg_ID] <> 1)

...Budget constraint...SortPoly
Budget constraint by Environmental Benefits
The budget constraint reduced the number of selected
planning units from 73350 to 3675

...Statistics for Selected Planning Units...Summarize Solution Script...
Total Land Value:                    99987017.8
Mean Land Value:                     27207.4
Maximum Land Value:                  0.0
Total Reestablishment Costs:         0.0
Estimated Total Population Affected: 43,480
Total Fiscal Cost:                   155809579.5
Mean Fiscal Cost:                    42397.2
Mean EBI (EBI Pref per LV):          14.6
Maximum EBI:                         48.8
Minimum EBI:                         8.8

...Future Land Cover Totals...Summarize Solution Script...
Cover Type            Old Area (ha)  Future Area (ha)      % Change
Mature Forest         548604.36            278596.44      -49.22
Secondary Forest      1092747.60           670955.85      -38.60
Agriculture/Pasture   3836138.13           5828994.54     51.95
Restored Forest       0.00                 154712.97      N/A

...Representation of Land Cover by Bioregion...Summarize Solution Script...
Bioregion             Prim Forest (%)       Rest Forest (%)       Sec Forest (%) Agricult (%)
Coast/Wetland/Riverine               0.52          0.25          16.92          17.96
Central Lowland Forest               4.54          1.81          14.07          78.59
Northern Lowland Forest              7.53          4.06          8.29           75.47
Central Semi-deciduous Forest        1.05          1.06          6.06           91.61
Southern Tabuleiro Forest            7.95          3.44          10.92          67.25
Southern Semi-deciduous Forest       2.06          1.44          5.88           83.15
Northern Semi-deciduous Forest       0.76          1.67          9.00           73.94
Northern Caatinga                    0.00          0.00          0.00           42.57
```

```
Central Tabuleiro Forest             8.61          7.48          21.19          40.17
Total                                3.72          2.07          8.93           77.61

...Representation of Land Cover in Area of Special Interest...Summarize Solution Script...
Prim Forest (%)       Rest Forest (%)       Sec Forest (%) Agricult (%)
       0.95                  0.93          30.64          62.32

...Protected Areas...Summarize solution script...
Originally protected area was: 90617.85 hectares
Newly protected area will be: 440241.24 hectares

...Number of fragments by size by bioregion...Land Metrics Script...
               Bio1    Bio2    Bio3    Bio4    Bio5    Bio6    Bio9    Bio10   Bio11
< 200 ha       15      38      42      123     59      52      11      0       20
200-500 ha     0       8       13      28      11      19      4       0       2
500-1000 ha    0       6       5       11      5       10      1       0       3
1000-2000 ha   0       3       4       6       5       2       0       0       1
2000-4000 ha   0       0       4       1       1       1       0       0       1
4000-6000 ha   0       0       2       0       0       1       0       0       0
6000-8000 ha   0       0       0       0       0       0       0       0       0
8000-10000 ha  0       0       0       0       1       1       0       0       0
> 10000 ha     0       2       4       0       4       1       0       0       0

...Fragment statistics...Land Metrics Script...
The total area of core forest for all fragments will be: 285342 hectares

The percent of mature and restored core forest will be:     66.17%
The percent of edge forest mear agr., bare, urban will be:  33.83%

Mature core forest will be:          73.15%
Restored core forest will be:        26.85%

There are 12 viable fragments larger than 10000 hectares
The total area of forest in viable units: 241581 hectares
The largest forest fragment is: 31189 hectares
Number of viable fragments with at least 1000 ha of mature forest = 12

...Statistics for fragments in each size category...Land Metrics Script...
                     0-200   200-500 500-1k  1k-2k   2k-4k   4k-6k   6k-8k   8k-10k  >10k
Number of frag       345     84      43      24      8       2       1       2       12
Total area (ha)      38725   29186   31425   36371   19473   9746    6763    17926   241581
Prim forest (%)      17.95   29.79   33.22   43.89   34.68   47.60   60.46   58.25   58.26
Rest forest (%)      10.45   12.90   15.73   17.87   29.07   16.69   18.37   14.96   19.11
Edge forest (%)      71.61   57.31   51.05   38.24   36.25   35.71   21.16   26.79   22.63

...Cost statistics for fragments in each size category...Land Metrics Script...
       0-200   200-500 500-1k  1k-2k   2k-4k   4k-6k   6k-8k   8k-10k  >10k
Sum    12058725.32   8824211.38   9031663.33   9536494.40   5343486.64   2629100.47   1541036.83
3277179.14   49362504.49
Count  397   298   320   369   199   100   69   181   2462
Mean   30374.62   29611.45   28223.95   25844.16   26851.69   26291.00   22333.87   18105.96
20049.76
SD     4921.89   5828.97   6199.60   9532.06   3997.96   4303.10   4714.70   13250.15   12967.83
Range  40209.95   45588.78   30199.45   51931.59   18137.57   16967.82   17868.37   40423.02
68977.81
```

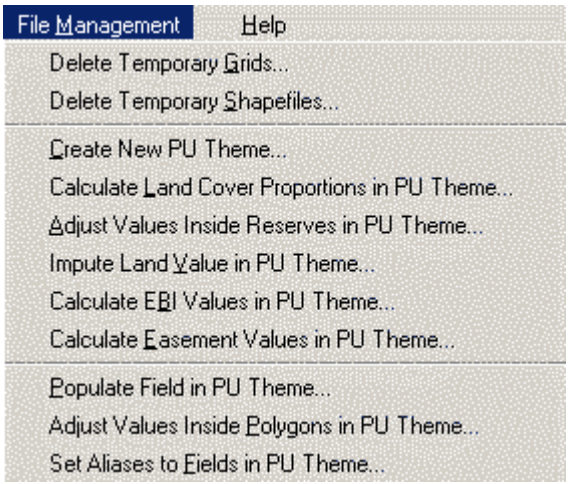
There are two options for viewing scenario text files under the ‘Evaluation’ menu. The ‘Show current scenario textfile’ opens a text window with the results for the scenario you named in the latest Scenario Dialog. If you would like to view text files from other scenarios for comparison, choose the ‘Show a scenario textfile’ option. This will prompt you for the name of a textfile from a list of all such files in the current working directory. Select a filename from the list and click the ‘OK’ button. A window will open on the screen. Click the ‘x’ box in the upper right corner to close the window.

5.3.2 Future Land Use Scenario Grid

For each scenario, a new **ARC/INFO** grid is created showing the land cover/use that is forecast based on the selected planning units, their specified conservation intervention, and the business-as-usual scenario for unselected units. This grid is given the name of the scenario and is saved permanently. Other themes may be created in the analysis procedures, but these are temporary files that are not automatically saved. If you look in the 'Theme → Properties…' menu, you will see these grids described as 'Temporary'. Once you exit from **TAMARIN**, these themes will be deleted from memory unless you explicitly save them. To save them permanently, make the theme active, go to the 'Theme' menu, and select 'Save data set…'. You will be asked for a filename for this theme. The themes properties will now identify this as a 'Permanent' theme.

These grids will be automatically saved if you save the project file (under 'File → Save…', or clicking the 'save' icon). In this case, however, the files are given their temporary names, such as GRID33, RCLSS4, and similar uninformative names. Therefore, it is recommended that you explicitly save them with meaningful names if you wish to keep them.

5.4 File Management



TAMARIN may create a large number of temporary grids and shapefiles. Two useful utility programs were provided under 'File Management' for a simple deletion of unnecessary themes from the **TAMARIN** folder. If you need assistance updating the planning unit theme with new data or creating a new one in order to migrate **TAMARIN** into a different region, use the wizard-type programs listed below; they will automate the task for you (see also Appendix B for step-by-step description of processing required for creation of a new planning unit theme).

5.4.1 Deleting Temporary Grids and Shapefiles

The first two options under this menu will help you to delete unwanted grids and shapefiles. They work in essentially the same way except that they only list the files of the appropriate type to be deleted. Click on one of the options. **TAMARIN** opens a dialog window that lists the themes (grids or shapefiles) in the root folder. You can navigate to a different folder if desired. To delete old themes, click on its name and then the 'Delete' button. The theme cannot be deleted if it is currently being used in **TAMARIN**, such as being displayed in a view or as a table. In such cases, click 'Cancel', delete the themes and tables from the **TAMARIN** project, save it again, and then try deleting the themes through the 'File management' menu.

5.4.2 Creating a New "Empty" Planning Unit Theme

The first of the eight utilities was designed to automate creation of a new planning unit theme. This utility creates a rectangular grid of planning unit cells with associated empty database fields as described in Appendix E. It has an ability to restrict **TAMARIN** analysis to a desired area of interest by allowing a user to utilize either a polygon or a grid theme for this delineation. After

starting the utility 'File Management→Create New PU Theme', a series of self-explaining dialogs will ask you to provide a name for the new planning unit theme, a size for the planning unit (in meters) and finally, a type and source name for the delineating theme. Once satisfied it will create an empty planning unit theme ready to be populated with data.

5.4.3 Calculation of Land Cover Area per Planning Unit

The second utility program calculates the number of hectares of each land cover class present within a planning unit and writes the resulting values into appropriate fields within a planning unit theme table e.g., Pfor_ha, Sfor_ha, Cab_ha (see Appendix E for a full list). It also calculates an area that contains every type of land cover with the exception of urban areas, water, no data (i.e., Nourbwat_ha). Similarly as for the previously described utilities, run the program from the 'File Management' menu and follow the series of input/output dialogs.

5.4.4 Adjusting Values Inside Protected Areas Polygons

The third utility program sets the Nourbwat_ha and Hectares attributes to zero for planning units located inside polygons delineating existing protected areas. It also adjusts values of the above listed variables to reflect different areas in 'slivers'—arbitrary polygons outside of protected areas created when polygons representing existing protected areas intersect with polygons of planning units. This step is necessary to reflect zero cost for area of existing protected areas. Similarly as for the previously described utilities, run the program from the 'File Management' menu and follow the series of input/output dialogs.

5.4.5 Imputing Land Values in Planning Unit Theme

This program was designated to impute land values using existing attributes of the PU theme and regression coefficients obtained from multivariable model of land values (Chomitz et al. 2004). The imputed values are written into attribute called Land_value within the planning unit theme. After starting the utility 'File Management→Impute Land Values in PU Theme…' a series of dialogues will guide you through the selection of a planning unit theme and the previously derived regression coefficients. If the spatial distribution of land values is available as a grid theme use the 'File Management→Populate Field in PU Theme…' utility instead (see Section 5.4.8 for details).

5.4.6 Calculation of Environment Benefit Index Values

Within a planning unit theme table, this utility calculates EBI values as they were defined in Section 3.1, i.e., EBI_Orig, EBI_Cab, EBI_Pref, EBI_5, EBI_Pref_per_LV, EBI_5_per_LV, and EBI_Core_per_LV. To be able to obtain the latter three indices, Land_value and EBI_Core attributes need to be calculated prior to running this program (see Appendix E for attributes description). Similarly as for the previously described utilities, run the program from the 'File Management' menu and follow the series of input/output dialogs.

5.4.7 Calculation of Easement Values

Within a planning unit theme table, this utility calculates four Easement Values as defined in Section 3.1 and stores the results in variables EaseVal1, EaseVal2, EaseVal3, EaseVal4 respectively. Knowledge of regression coefficients used for imputing land values is required prior to running this program. These coefficients were predefined within this utility according to the results of multivariate regression analysis for deriving land values (Appendix D). Similarly

as for the previously described utilities, run the program from the 'File Management' menu and follow the series of input/output dialogs.

5.4.8 Populating Planning Unit Theme

This utility program was designed to extract values from an arbitrary grid using a planning unit theme. The extracted values are subsequently written into a specified field within the planning unit theme. After starting the utility 'File Management→Populate Filed in PU Theme…' a series of dialogues will guide you through the selection of: a planning unit theme, a grid, a reference ID field and an output field. Use the utility program with caution. The program has the ability to overwrite existing values.

5.4.9 Adjusting Values Inside Arbitrary Polygons

Contrary to the previously described utility this program adds/subtracts an arbitrary land value (price per hectare) to or from the existing land values and adjusts all other associated variables (listed in the previous utility) inside arbitrary polygons defined by an input theme. This utility is particularly useful for updating a planning unit theme when the market value of land changes or if other previously hidden costs are associated with certain tracks of land with known boundaries. Similarly as for the previously described utilities, run the program from the 'File Management' menu and follow the series of input/output dialogs.

5.4.10 Restore Field Aliases in Planning Unit Theme

Occasionally after copying a planning unit to or from a different location the associated aliases, describing the individual fields using longer strings then 10 characters area, are lost. This utility restores the original aliases as described in Appendix E. Similarly as for the previously described utilities, run the program from the 'File Management' menu. Note: Errors will be generated if the aliases are not correctly set.

5.5 Running Batch Processing and Multiple Batch Processing

The time required for processing **TAMARIN** scenarios was found to be dependent on several factors. Namely it depended on the size of a data set, CPU speed, the number of planning units selected for the analysis, and, to a lesser degree, also on the amount of available RAM. The sorting of planning units, summary calculations and in particular landscape configuration calculations, took the longest time. In general while working with small subsets of data (circa 80 x 80 km in size) the processing time when using 1-2 GHz processors was not an issue and could be done interactively following processing steps as described previously in this section. However, conducting analysis on a regional scale for multiple scenarios using an interactive mode was found to be impractical. For this reason, single and multiple batch processing functions were added to **TAMARIN**.

5.5.1 Single Batch Processing

The Single Batch Processing function was designed to emulate the interactive processing steps as described previously in this section. Prior to processing, input parameters must be changed in the predefined text file located in the current **TAMARIN** directory. Using a text editor, open ***input parameters query.txt*** or ***input parameters theme.txt*** file and enter the desired parameters. Each line in a text file represents a single parameter entry made during the interactive session (Appendix F). The first file was predefined to select planning units using a

specific query, and the second one, using a specific theme. Run the program by 'Select Sites→Single Batch Processing…', select desired input parameters file and press the 'OK' button.

5.5.2 Multiple Batch Processing

Similarly as for the Single Batch Processing, change parameters in the predefined ***input parameters query multiple.txt*** file, located in the current **TAMARIN** directory, to desired values prior to execution of the program. Please note that the three initial parameters (line 1 to 3) differ from the Single Batch Processing parameters file and from the processing flow as described previously in this section (Appendix F). The parameters represent, respectively: 1) a starting budget, 2) an ending budget and 3) an incremental budget. It is advisable to choose these lines with caution; a simple error can lead to **TAMARIN** computing an undesirably large number of scenarios.

6. CREATING A SCENARIO—AN EXAMPLE

In this section, we illustrate the process for creating and evaluating a hypothetical scenario, following the steps described in Section 5. The example scenario is based on an economic incentive, where we assume a flat price offer is made rather than paying fair market easement value, and seeing which landowners are likely to accept it.

Let us assume some purchasing authority offers to pay environmental compensation for properties with specified characteristics or within specified zones. Let us further assume that the authority has a fixed budget. The authority publishes a formula that assigns an environmental benefit index (EBI) to each candidate unit. We cannot predict which landowners will choose to participate so let us simply say that any eligible units can be selected if the offered price is at least as high as the opportunity costs as estimated in the easement values. The authority ranks planning units by EBI and purchases from highest EBI to lowest until the budget is exhausted. How can this policy be demonstrated in **TAMARIN**?

Begin by defining the scenario and set the budget to R$30,000,000. In the second dialog box, select the 'Pay other incentive offer' radio button. We will accept the defaults for the desired landscape configuration. We select the 'EBI_Core' benefits index option and set the incentive payment offer at R$200 per ha. To identify eligible units, we use the 'Select by Query' menu option. We first query for units that are restorable without paying reestablishment costs ([Restorable] = "y") and 'Select from Set'. Existing reserves are already protected so we can exclude them from the candidate set by querying ([InReserve] = "n") and 'Select from Set'. We next select planning units outside the coastal bioregion where mature forest is not an issue. ([Bioregion_Name] <> "Coast/Wetland/River"). To identify potential sellers, we must limit the units to those whose opportunity costs are less than R$200 per ha, so we query for ([Easement_Value4] <= 19602) (i.e., R$200/ha * 98.01 ha/unit = R$19,602/unit) and 'Select from Set'. This leaves us with 19,275 units out of 77,010 total and a cost of R$364 million if we pay R$200/ha. In contrast, if the authority were only paying the estimated easement value (#4), the total cost would be R$233 million. This still far exceeds the budget so we further reduce the set of units by applying the 'Constrain by Budget' menu option. We elect to sort by the environmental benefits index (EBI_Core) in descending order and allocate funds until the budget is exhausted. This reduces the selected set to 1,539 units. The scenario summary indicates that these units could actually be purchased for only R$36 million and the easement value is only R$5 million. Thus there is a high cost of a flat incentive payment compared to other incentive mechanisms. This instrument, however, only achieves the conservation objectives in two of the seven bioregions, because the selection process chooses many relatively small, isolated fragments. Further refinement would be necessary to produce the desired clumping of fragments.

7. DATABASE REVISIONS OR SUBSTITUTIONS

The **TAMARIN** planning support system, based on **ArcView** and customized with AVENUE scripts, was originally designed specifically for corridor planning in south Bahia, Brazil, and to address specific research questions of interest to the research team. As a result, the GIS data and AVENUE coding are tightly coupled. It is highly likely that some of the themes will be updated during the remainder of the planning process. Therefore, there may be a need to replace or update themes or attribute data in **TAMARIN**. This section describes how to do so. Others may wish to adapt **TAMARIN** for other corridor projects in other regions of the world. **TAMARIN** will require some modifications. The second part of this section outlines some of the general changes in data and in the coding of AVENUE scripts themselves to be used in corridor applications in other parts of the world.

7.1 Updating Bahia Data

TAMARIN was developed with the GIS database that existed at the time. Some of the data layers were draft versions or needed some fine-tuning before final analysis. At least four types of revisions may be involved if revised themes are produced in the future: 1) substitution of a newer version of a theme (e.g., a land cover theme that fills in cover types where clouds obscured the ground in the initial version), 2) substitution of a new value for an attribute (e.g., revised model results for predicted land value), 3) replacement of derived GIS themes as a result of revision in the primary data layer (e.g., updating the business-as-usual scenario which was derived from the land cover theme), and 4) creating new themes as alternatives (e.g., creating your own business-as-usual scenario based on different assumptions about the future).

The safest method to replace a new version of a theme is to delete the Bahia themes in the **TAMARIN** view windows. Make a theme active by clicking on its legend in the table of contents. Delete by using the 'Edit→Delete' menu. Save the project file and then delete (or rename) the original theme from the folder by using the 'File Management' menu as described above or by using **ARC/INFO** commands. Also using the file management dialog, copy the new version to the folder and give it the same name as the original version. Then use the 'View→Add Theme' menu to add the new version to the appropriate view. While it is also possible to simply swap in the new version in the folder while **TAMARIN** is closed, so that the new version will be used the next time **TAMARIN** is run, this will be risky if the attribute table is slightly different.

In some cases, it may not be the whole theme that has been revised but only one or more attributes of a theme. The most likely example would be a revised prediction of land values or opportunity costs, as a result of more data points in the sample, additions to or changes in the independent variables, or improved regression modeling. The output may be a text or dBase format file with columns for the ID number of the planning unit and for the new values. Add the table to **TAMARIN** and proceed to Join the table to the Attributes table of the planning unit theme by the unit ID number. Use the 'Fields→Calculate' menu and calculate the attribute fields with the value in the new table. The original values in the fields can also be overwritten by the file utility program 'Populate Field in PU Theme' located under the 'File Management' menu described in Section 5.4.3 of this manual.

As noted in Section 3, some data layers are derived from the primary themes. Updating a primary theme also requires updating the derived themes. In the case of revisions to the Land cover theme, it will be necessary to reproduce the business-as-usual and restoration themes based on the lookup table shown in Section 3.3 or using an alternative model. The old themes must then be deleted from **TAMARIN**'s views and from the folder, just as the primary theme was

in the preceding paragraphs. The new themes must be added to the Working View. In the Legend Editor, Load the ***restore.avl*** lookup table to color the cover classes. Do not change the theme name in the Table of Contents of the view because **TAMARIN** expects to find it with that name.

You may wish to make different assumptions about future land use or restoration opportunities than those made in the original version. Simply generate a new theme, give it a meaningful name, and save it in the appropriate folder (in the case of business-as-usual and restoration themes, this should be in the Options folder). Make sure the theme has the same projection parameters as described in Section 3. When you run **TAMARIN** to create a new scenario, you can specify your new themes as part of the opening dialog for 'Define a scenario'. Likewise, you may substitute a different planning unit theme based on other kinds of spatial units, such as census tracts or squares of a different resolution. A set of utility programs provided under the 'File Management' menu and described in Section 5.4 were specifically designed to accomplish this task. A detailed list of steps necessary for creating a new planning unit is included in Appendix B.

7.2 Modifications for Other Corridor Projects

Conservation planning for the Central Atlantic Forest Corridor in southern Bahia was based primarily on meeting broad conservation objectives (i.e., representation, redundancy, and resilience) in the most economically efficient manner possible. The Corridor has been severely deforested, with only about 5% on the region remaining in primary forest, mostly in small fragments. The focus in this project was to decide on the best combination of protecting remaining fragments and restoring forest to expand, connect, or complement those fragments. **TAMARIN** may not be particularly useful in planning efforts where the conservation issues are significantly different than this. For instance, **TAMARIN** would not be useful where the objective was to represent many different habitat types to some specified level. In that case, a decision support system such as **Sites 1.0** (Andelman et al. 1999) might be more appropriate (see http://www.biogeog.ucsb.edu/projects/tnc/toolbox.html).

If **TAMARIN** is suitable for use in a given corridor study, the themes for the new corridor must correspond exactly to those for Bahia. The required GIS themes described in Section 3 are used in the analysis procedures in **TAMARIN**. In addition, they are generally referenced by their name in the view table of contents, so they must be given the same names in other applications. Furthermore, the attributes of the themes, particularly for the planning units theme, must exactly match those in the Bahia project, both in field name and its definition (e.g. width, type, decimal places). It is recommended that the themes be placed in the same folders as their counterparts in the Bahia project. To do this, first delete the Bahia themes in the **TAMARIN** view windows. Make a theme active by clicking on its legend in the Table of Contents. Delete by using the 'Edit→Delete' menu. Save the project file and then delete the Bahia themes from the folder by using the 'File Management' menu as described above or by using **ARC/INFO** commands. If you do not remove a theme from the project and save the project, the file manager will think the theme files are being used by an application and refuse to let you delete them. Insert your own themes in the same folder, either with the same file management dialog or with **ARC/INFO** commands.

The other issue in adapting **TAMARIN** to other areas is that some of the scripting is hard-coded. In particular, the Summary Statistics and the Landscape Configuration scripts use specific class values from the Land cover, Business-as-usual and Restoration themes. A user has two choices: 1) either to reclassify his/her themes so they match exactly the class values of the themes developed for Bahia (names of the classes may be different) or 2) modify the scripts to

match the different class values (recommended only for experienced **Avenue** developer). A "wizard-like" script that will have the above-described functionalities is under development. A step-by-step guide for creating and customizing Cell990m planning unit theme could be found in Appendix C.

Contact Miroslav Honzák at CI (mhonzak@conservation.org) or David Stoms at UCSB (stoms@bren.ucsb.edu) to discuss whether **TAMARIN** would be appropriate for your application and how to modify it. To obtain more information, the latest version of this manual and **TAMARIN** code visit http://www.tamarinmodel.org/ website.

REFERENCES

Andelman, S., I. Ball, F. Davis, and D. Stoms. 1999. Sites version 1.0. An Analytical Toolbox for Designing Ecoregional Conservation Portfolios. Manual prepared for The Nature Conservancy, December 1999. University of California, Santa Barbara, 55 pp.

Brasil, Ministério das Minas e Energia. Secretaria Geral. 1981. Projeto Radambrasil folha SD. 24 Salvador, geologia, geomorfologia, pedologia, vegetação e uso potencial da terra - Rio de Janeiro.

Brasil, Ministério das Minas e Energia. Secretaria Geral. 1987. Projeto Radambrasil. Folha SE. 24 Rio Doce, geologia, geomorfologia, pedologia, vegetação e uso potencial da terra - Rio de Janeiro.

Chiarello, A. G. 2000. Density and population size of mammals in remnants of Brazilian Atlantic forest. *Conservation Biology* 14: 1649-1657.

Chomitz, K. M., E. Brenes and L. Constantino. 1999. Financing environmental services: The Costa Rican experience and its implications. *Science of the Total Environment* 240: 157-169.

Chomitz, K. M., Alger, K., Thomas, T.S., Orlando, H., and Nova, P.V. 2004. Opportunity cost of conservation in a biodiversity hotspot: The case of southern Bahia. *Environment and Development Economics* (accepted).

Gascon, C., G. B. Williamson and G. A. B. da Fonseca. 2000. Ecology: Receding forest edges and vanishing reserves. *Science* 288: 1356-1358.

IBGE - Instituto Brasileiro de Geografia e Estatística. 1994. Malha Municipal do Sudeste da Bahia, Brasil.(mapa em formato digital adaptado por E. C. Landau), escala 1:1.000.000. *In*: Prado P.I., Landau E.C., Moura R.T., Pinto L.P.S., Fonseca G.A.B., Alger K. (*orgs*.) Corredor de Biodiversidade da Mata Atlântica do Sul da Bahia. Publicação em CD-ROM, Ilhéus, IESB/CI/CABS/UFMG/UNICAMP.

Landau, E. C.; Hirsch, A. & Musinsky, J. 2003a. Cobertura Vegetal e Uso do Solo do Sul da Bahia - Brasil, escala 1:100.000, data dos dados: 1996-97 (mapa em formato digital). *In*: Prado P.I., Landau E.C., Moura R.T., Pinto L.P.S., Fonseca G.A.B., Alger K. (*orgs*.) Corredor de Biodiversidade da Mata Atlântica do Sul da Bahia. Publicação em CD-ROM, Ilhéus, IESB/CI/CABS/UFMG/UNICAMP.

Landau, E. C.; Resende, N. A. T. & Miranda, F. S. 2003b. Rede Viária do Sul da Bahia, Brasil.(mapa em formato digital, modificado a partir de IBGE, 1967; SUDENE, 1976; 1977 e DERBA, 2000), escala 1:100.000. *In*: Prado P.I., Landau E.C., Moura R.T., Pinto L.P.S., Fonseca G.A.B., Alger K. (*orgs*.) Corredor de Biodiversidade da Mata Atlântica do Sul da Bahia. Publicação em CD-ROM, Ilhéus, IESB/CI/CABS/UFMG/UNICAMP.

Landau, E. C. & Resende, N. A. T. 2003a. Unidades de Conservação do Sudeste da Bahia, Brasil.(mapa em formato digital elaborado a partir de INCRA, ~1998; CRA, 1998 e dados inéditos), escala 1:250.000. *In*: Prado P.I., Landau E.C., Moura R.T., Pinto L.P.S.,

Fonseca G.A.B., Alger K. (*orgs*.) Corredor de Biodiversidade da Mata Atlântica do Sul da Bahia. Publicação em CD-ROM, Ilhéus, IESB/CI/CABS/UFMG/UNICAMP.

Landau, E. C. and Resende, N. A. T. 2003b. Centros Urbanos do Sul da Bahia, Brasil.(mapa em formato digital, adaptado a partir de IBGE, 19567 e SUDENE, 1976; 1977), escala 1:100.000. *In*: Prado P.I., Landau E.C., Moura R.T., Pinto L.P.S., Fonseca G.A.B., Alger K. (*orgs*.) Corredor de Biodiversidade da Mata Atlântica do Sul da Bahia. Publicação em CD-ROM, Ilhéus, IESB/CI/CABS/UFMG/UNICAMP.

Oñate, J. J., E. Anderson, B. Peco, and J. Primdahl. 2000. Agri-environmental schemes and the European agricultural landscapes: the role of indicators as valuing tools for evaluation. *Landscape Ecology* 15: 271-280.

Pelletier, J. D. 2000. Model assessments of the optimal design of nature reserves for maximizing species longevity. *Journal of Theoretical Biology* 202: 25-32.

Possingham, H. P., Andelman, S. J., Noon, B. R., Trombulak, S. and Pulliam, H. R. 2001. Making smart conservation decisions. Chapter X *in* Research priorities for conservation biology. Orians, G. and Soule, M., eds. Island Press, California. [http://www.ecology.uq.edu.au/links/ConDecisionPreprint.pdf].

Shafer, C. L. 2001. Inter-reserve distance. *Biological Conservation* 100: 215-227.

Shaffer, M. L. and B. A. Stein. 2000. Safeguarding our precious heritage. Pages 301-321 *in* Precious Heritage: The Status of Biodiversity in the United States. B. A. Stein, L. S. Kutner and J. S. Adams, eds. Oxford, Oxford University Press.

Stoms, D. M., F. W. Davis, R. L. Church, and R. A. Gerrard. 2002. Economic Instruments for Habitat Conservation. Final Report to the World Bank. University of California, Santa Barbara. [http://www.biogeog.ucsb.edu/projects/wb/wbrpt2002.pdf].

Thomas, W. W., A. M. V. De Carvalho, A. M. A. Amorim, J. Garrison and A. L. Arbelaez. 1998. Plant endemism in two forests in southern Bahia, Brazil. *Biodiversity and Conservation* 7: 311-322.

Veloso, H. P., Rangel-Filho, A.L.R. & LIMA, J.C.A. 1991. Classificação da vegetação brasileira adaptada a um sistema universal. IBGE, Rio de Janeiro.

Viana, V. M., A. A. J. Tabanez and J. L. F. Batista. 1997. Dynamics and restoration of forest fragments in the Brazilian Atlantic moist forest. Pages 351-365 *in* Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities. W. F. Laurance and R. O. Bierregaard Jr. Chicago, The University of Chicago Press.

APPENDIX A: TAMARIN SCRIPTS ACTIVATED DURING SCENARIO EVALUATION PROCEDURE

The following table lists the **AVENUE** scripts and dialogs (*in italics*) in **TAMARIN** that relate to the steps in the flowchart in Section 1.2.

1. **Define scenario objectives**
   - Tam.openScenarioDialog
   - *Tam.ScenarioParams*
   - Tam.openScenarioDialog2
   - *Tam.ScenarioParams2*
   - Tam.acceptScenarioParams
   - Tam.PickPUTheme
   - Tam.PickBAU
   - Tam.PickRestore
   - Tam.PickEasementValue
   - Tam.PickEBI

2. **Select planning units (and constrain by budget)**
   - Tam.chooseSiteSelector
   - Tam.CompPoly or Tam.SortPoly
   - Tam.qsort

3. **Project future land use/cover**
   - Tam.FutureScenario

4. **Evaluate socioeconomic and landscape impacts**
   - Tam.SummarizeSolution
   - Tam.PAsizeStats
   - Tam.LandMetrics
   - Tam.PatchSizeFreq
   - Tam.PatchSizeBioreg
   - Tam.PatchViableBioreg
   - Tam.PatchSizeStats
   - Tam.PatchSizeCost

5. **Printing a map layout**
   - Tam.MapLayout

APPENDIX B: STEPS TO BUILD NEW TAMARIN PROJECT USING TAMARIN EXTENSION AND FILE MANAGEMENT PROGRAMS

A set of file management "wizard-like" programs was developed to assist users in building a new **TAMARIN** project. Function and usage of these programs is described in Section 5.4. The following processing steps must be executed in the particular sequence as presented below.

1. Load **TAMARIN** extension (see Section 2.2), or alternatively, open ***tamarinnew.apr*** (**ArcView** project file located in **tamext** directory)

2. Add '(+)' the following themes to the ***Analysis View***

    a. ***Bioregions*** (required grid, see Section 3.4 for details)
    b. ***Landcover*** (required grid, see Section 3.7 for details)
    c. ***Existing Reserves*** (optional shapefile, see Section 3.8 for details)
    d. ***Roads*** (optional shapefile)
    e. ***Cities*** (optional shapefile)
    f. ***Bioregions Outline*** (optional shapefile)
    g. ***Provinces*** (optional shapefile)

3. Add '(+)' the following themes to the ***Working View***

    a. ***AOI*** area of interest layer (required grid)
    b. ***Paved Road Mask*** (required grid, see Section 3.6 and Appendix B for details)
    c. ***Existing Reserves*** (optional shapefile, see Section 3.8 for details)
    d. ***Landcover*** (required grid, see Section 3.7 for details)
    e. ***AOI*** area of interest layer (optional shapefile)
    f. ***Bioregion ID*** (optional grid)
    g. ***Population*** (optional grid)
    h. ***EBI core*** (optional grid)
    i. ***AOSI*** area of special interest layer (optional grid)

4. Activate ***Working View***, follow with 'File Management→Create New PU Theme…'

    a. Create a new planning unit (PU) shapefile in the ***GIS_Input*** directory (e.g., ***Cell990m.shp***)
    b. Enter size of a planning unit (recommended value is 990 m)
    c. Use ***AOI*** (a polygon shapefile or a grid) as an input theme

5. Activate ***Working View***, follow with 'File Management→Calculate Land Cover Proportions in PU Theme…'

    a. Select a PU theme (***Cell990m.shp***)
    b. Select land cover theme (***Landcover***)

6. Activate ***Working View***, follow with 'File Management→Adjust Values Inside Reserves in PU Theme…'

a. Select a PU theme (***Cell990m.shp***)
b. Select land cover theme (***Landcover***)
c. Select existing reserves theme (***Existing Reserves***)

7. Activate ***Working View***, follow with 'File Management→ Impute Land Value in PU Theme…'

    a. Select a PU theme (***Cell990m.shp***)
    b. Select land cover theme (***Landcover***)
    c. Enter regression coefficients obtained from multivariable regression model of land values

8. Activate ***Working View***, follow with 'File Management→Calculate EBI Values in PU Theme…'

    a. Select a PU theme (***Cell990m.shp***)

9. Activate ***Working View***, follow with 'File Management→Calculate Easement Values in PU Theme…'

    a. Select a PU theme (***Cell990m.shp***)
    b. Enter regression coefficients used for calculation of land values

10. Optional transfer of data to individual attributes in a PU theme: Activate ***Working View***, follow with 'File Management→Populate Field in PU Theme…'

    a. Select a PU theme (***Cell990m.shp***)
    b. Select grid theme from which source data should come from
    c. Select an attribute (field) in PU theme to be populated by the data
    d. Repeat for all other required/optional source data (e.g., Land Values, Population, EBI Core, Bioregion ID)

11. Optional adjustment of land values for extra conservation cost: Activate ***Working View***, follow with 'File Management→Adjust Values Inside Polygons in PU Theme…'

    a. Select a PU theme (***Cell990m.shp***)
    b. Select land cover theme (***Landcover***)
    c. Select conservation cost polygon theme (***Conservation Cost***)
    d. Enter regression coefficients used for calculation of land values

12. Add '(+)' the newly created PU theme (***Cell990m.shp***) to the ***Analysis View***

13. In the ***Analysis View*** set field aliases to ***Cell990m.shp*** theme using 'File Management→Set Aliases to Fields in PU Theme…'

APPENDIX C: PROCESSING STEPS USED TO OBTAIN PAVED ROAD MASK THEME

1. Activate ***Roads*** theme in ***Working View*** and open table 'Theme→Table…'; proceed with query 'Table→Query…' enter ([Tipo2000] = "11") OR ([Tipo2000] = "12") AND ([Tipo2000] = "13") and activate 'New Set' to select only paved (main) roads

2. 'Theme→Create Buffers...' Enter buffer of 200 m, only on selected records, dissolving barriers. Create new shapefile

3. 'Theme→Convert to Grid…' add '(+)' grid to the to the ***Working View***

4. 'Analysis→Map Calculator…', ([Rd200mbuff] = 200); 'Theme→Save Dataset…' and call it ***rd200mbuff***

5. Make ***Landcover*** the active theme. 'Theme→Table…' select [value] = 14 (urban). Then, go to 'Analysis→Find Distance…'

6. 'Analysis→Reclassify…' convert 0-200 to 1, and all other classes to No Data. 'Theme→Save Dataset…' and call it ***urb200mbuff***

7. 'Analysis→Map Calculator…' and enter the following formula ([rd200mbuff].IsNull + [urb200mbuff].IsNull)

8. 'Analysis→Reclassify…' to convert 0 and 1 to No Data, and 2 to 1. 'Theme→Save Dataset…' call it ***pvrd_mask***

9. Rename ***pvrd_mask*** theme using 'Theme→Properties…' to ***Paved Road Mask***

APPENDIX D: NATURAL LOGARITHMS OF LAND SALE PRICE PER HECTARE REGRESSED ON LAND CHARACTERISTICS†

Variable	Coefficient
sale date	-.00019472
	0.229
agroclimatic index 70-85	-.1280486
	0.342
agroclimatic index >115	-.43979397
	0.001
dummy,soil quality=0	3.4394615
	0.017
soil quality index squared	-.08062447
	0.033
soil quality index	1.1114396
	0.018
slope 5-15%	-.10736309
	0.483
slope 15-25%	-.15907475
	0.294
slope 25-40%	-.27883257
	0.070
slope 40-55%	-.34473497
	0.026
slope 55-70%	-.20097391
	0.194
slope >70%	-.43130017
	0.131
dummy,< 5km to coast	.90568368
	0.002
km to nearest road	-.01771909
	0.145
road distance*coastal dummy	-.2321012
	0.013
proportion of mature forest	-1.1784783
	0.000
proportion of secondary forest	-.39720246
	0.069
proportion of cabruca or other cocoa	.66136597
	0.026
proportion cocoa*climatic dummy	-.76290822
	0.018
Constant	5.9668794

Note: p-values underneath coefficients, n of observations = 231, r^2 (adjusted) = 0.274

† Extracted from Chomitz et al. (2004).

APPENDIX E: DESCRIPTION OF FIELDS OF THE PLANNING UNITS THEME (CELL990M.SHP)

Field Name	Alias	Units	Meaning	Process
Id	Plan_Unit-ID	None	Unique ID number of a planning unit	Automatically generated by script Tam.WizPUcreator
Hectares		Hectares	Area of a planning unit for which land value was calculated	Automatically generated by scripts Tam.WizLandcover and Tam.WizAdjReserves
Land_value		Monetary unit (USD)	Total purchase price of mature and restorable forest in a planning unit	Modeled from environmental and spatial variables, see Chomitz et al. (2004) for details
Easeval1	Easement_Value1	Monetary unit (USD)	Total opportunity cost of mature and restorable forest in a planning unit	See Section 3.1 for details
Easeval2	Easement_Value2	Monetary unit (USD)	Total opportunity cost of mature and restorable forest in a planning unit	"
EaseVal3	Easement_Value3	Monetary unit (USD)	Total opportunity cost of mature and restorable forest in a planning unit	"
Easeval4	Easement_Value4	Monetary unit (USD)	Total opportunity cost of mature and restorable forest in a planning unit	"
User_ev	User_Defined_Easement	Monetary unit (USD)	Left blank for user to create their own EV	"
Reestabcos	Re-establishmentCosts	Monetary unit (USD)	Total cost of restoration in a planning unit	If restorable field is 'Y' put 0 else if it is 'N', invoke cost as 2000 * Restore_ha
Inreserve		Y/N		'Y' if center of planning unit is in reserve (then set EV and LV to zero cost); else 'N'
Population		Number of people per square km	Density	Derived from census tract data
Municipio			Name of municipio (province) in a planning unit	Municipio name which intersects with a center of a planning unit
Bioreg_id	Bioregion_ID	N/A	Bioregion ID in a planning unit	Bioregion ID which intersects with a center of a planning unit

Bioregname	Bioregion_Name	N/A	Bioregion name in a planning unit	Bioregion name which intersects with a center of a planning unit
Ebi_orig		Index	Original Environmental Benefits Index	See Section 3.1 for details
Ebi_cab		Index	Modified Environmental Benefits Index that gives more weight to tree-shaded cocoa than EBI_orig	"
Ebi_pref		Index	Historically preferred Environmental Benefits Index	"
Ebi_pperlv	EBI_Pref_per_LV	Index	Ebi_pref adjusted by land value per hectare	“
Ebi_5		Index	Currently preferred Environmental Benefits Index	“
Ebi_5perlv	EBI_5_per_LV	Index	Ebi_5 adjusted by land value per hectare	“
Ebi_core		Index	Environmental Benefits Index derived using neighborhood habitat suitability	“
Ebi_cperlv	EBI_Core_per_LV	Index	Ebi_core adjusted by land value per hectare	“
User_ebi	User_Defined_EBI	Index	Blank EBI user can create their own EBI	“
Pfor_ha		Hectares	Area in a planning unit with mature forest	Automatically generated by scripts Tam.WizLandcover and Tam.WizAdjReserves
Sfor_ha		Hectares	Area in a planning unit with secondary forest	"
Cab_ha		Hectares	Area in a planning unit with tree-shaded cocoa plantation	"
Euc_ha		Hectares	Area in a planning unit with eucalyptus	"

Ag_ha		Hectares	Area in a planning unit with agriculture	"
Bare_ha		Hectares	Area in a planning unit with bare land	"
Urb_ha		Hectares	Area in planning unit with urban area	"
Water_ha		Hectares	Area in planning unit with water	"
Wetl_ha		Hectares	Area in planning unit with wetlands	"
Mang_ha		Hectares	Area in planning unit with mangrove	"
Rasta_ha		Hectares	Area in planning unit with arboreal rastinga	"
Rasth_ha		Hectares	Area in planning unit with herbaceous rastinga	"
Caat_ha		Hectares	Area in planning unit with caatinga	"
Nodata_ha		Hectares	Area in planning unit with no data	"
Nourbwa_ha	Nourbwat_ha	Hectares	Area of a planning unit except urban, water, no data and area inside existing protected areas	“
Restore_ha		Hectares	Area in a planning unit that can be restored	Sum of Sfor_ha, Cab_ha, Ag_ha, and Bare_ha
Restorable		Y/N	Proximity to mature forest	‘Y’ if within 1 km of mature forest, else ‘N’
Agclim		Index	Agroclimatic index derived from RADAMBRASIL maps	see Chomitz et al. (2004) for details
Declividad		Slope class	Slope class derived from RADAMBRASIL maps	“
Km2paved		Kilometers	Distance from paved roads used to estimate land and easement values	Mean of Euclidean distance from paved roads theme

Km2coast		Kilometers	Distance from coastline used to estimate land and easement values	Mean of Euclidean distance from coastline derived from corridor boundary
Cumcost		N/A	Temporary variable used during the scenario calculation	N/A
Cost_add		N/A	Temporary variable used during the scenario calculation	N/A
Dateint			Sale date	Put constant integer = 14725
Ag200		0/1	Dummy for Agro-climatic index	If Agclim is equal to 200 put 1
Ag200str		0/1	Dummy for Agro-climatic index	If Agclim is equal to 200* and 0 put 1
Dnopedo		0/1	Dummy for soil quality	If Pedology is equal to 0 put 1
Pedolog2		Index	Soil quality index squared	$(\text{Pedology})^2$
Pedology		Index	Soils quality index derived from RADAMBRASIL maps	see Chomitz et al. (2004) for details
Slope5		0/1	Dummy for slope 5-15%	If Declividad equal to “5-15” put 1
Slope15		0/1	Dummy for slope 15-25%	If Declividad equal to “15-25” put 1
Slope25		0/1	Dummy for slope 25-40%	If Declividad equal to “25-40” put 1
Slope40		0/1	Dummy for slope 40-55%	If Declividad equal to “40-55” put 1
Slope55		0/1	Dummy for slope 55-70%	If Declividad equal to “55-70” put 1
Slope70		0/1	Dummy for slope >70%	If Declividad equal to “>70” put 1
Dcoast5k		0/1	Dummy for distance from coast	If Km2coast equal or less then 5 put 1
Km2roads		Kilometers	Distance from all roads	Mean of Euclidean distance from all roads
Km2rdcst		Kilometers	Road distances in 5 km proximity to coast	Km2roads * Dcoast5k
Propfor12		Proportion	Proportion of a planning unit with mature forest	Pfor_ha / Nourbwat_ha

Propcapa		Proportion	Proportion of a planning unit with secondary forest	Sfor_ha / Nourbwat_ha
Prsomcoco		Proportion	Proportion of a planning unit with tree-shaded cocoa	Cab_ha / Nourbwat_ha
Prsomco_a		Proportion	Proportion of a planning unit with tree-shaded cocoa if agro-climatic index is low	If Ag200 and Ag200str is equal to 0 put Prsomcoco
Zcons		N/A	Constant adjusted for antilog of predicted ln values	5.9668794 + 0.126052, see Chomitz et al. (2004) for details

APPENDIX F: EXAMPLES OF PARAMETER BATCH PROCESSING TEXT FILES

Single batch processing using query to select planning units

```
$100m
Tamarin
100000000
Comment
10000
500
1000
300
2
Land
Cell990m.shp
bau
restore
EBI 5 per LV
Select by query
[Bioreg_ID] <> 1
Environmental Benefits
```

Single batch processing using polygon theme to select planning units

```
$100mt
Tamarin
100000000
Comment
10000
500
1000
300
2
Land
Cell990m.shp
bau
restore
EBI 5 per LV
Select by theme
reserves.shp
Environmental Benefits
```

Multiple batch processing using query to select planning units

```
20000000
200000000
20000000
Tamarin
Comment
10000
500
1000
300
2
Land
Cell990m.shp
bau
restore
EBI 5 per LV
Select by query
[Bioreg_ID] <> 1
Environmental Benefits
```