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A methodological review for the selection and ecological restoration of riparian forests in agricultural sites

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Abstract
The traditional planting system still consists in intensive use of pesticides in Brazil. In the case of the municipality of Bueno Brandão, southern Minas Gerais, Brazil, there is a high concentration of potato crops. Some of the physical characteristics of the area are important for the subject since it´s plenty of springs and watercourses and very steep and rich in hills slopes that may offer risks to water quality by pesticide runoff. The cultivation sites are often located near slopes greater than 20 % in permanent preservation areas (APP/PPA) or near these. The most common APPs in the region refer to 30m wide areas along the river banks and 50m around the springs The Antas River is the main water source for Bueno Brandão and its contamination would be very detrimental to the health to both rural and urban population. Water contamination can occur due to sediment transport along the slopes toward rivers and springs that are found degraded riparian areas, causing water quality loss. One alternative that reduces the incidence of this problem would be the systematic application of Federal Law 12.651/2012 and banning any use of pesticides in plantations near the water bodies, preventing their degradation. As an additional measure the riparian forests should be recovered along rivers and around springs. Nowadays there are degraded forestal areas and open spaces. So even when crop fields are out of APPs if the scenario presents potentially steep slopes there is still risk of sediment transport towards rivers. This study presents a macro view and a micro view to guide the recovery of gaps in the riparian zone and make it more feasible. The Macro view is a methodology to select priority areas more apt to promote the protection of the waters that may be vulnerable to degradation, and therefore more qualified to ecological restoration. Aiming at the resolution of the macro view, different physical characteristics and agricultural uses were correlated and some values were assigned to the associated impacts of each occurrence. Seeking resolution of the micro issues a survey was conducted on techniques and methodologies within Brazilian and foreign literature aiming at ecological rehabilitation and the regain of ecological functions that had been altered. These methods and techniques may be used at the discretion of the executors responsible jointly or separately depending on the project budget and the peculiarities of the chosen area.

Keywords
Riparian forests, water degradation, land use, erosion vulnerability, slope declivity, ecological restoration.

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1. Introduction

In potato crops at Bueno Brandão, State of Minas Gerais, Brazil, there are many potential causes for water contamination of Rio das Antas. Some of them being uses on the watershed: (1) the intensive use of pesticides and agrochemicals (2) the frequency of planting (3) the presence of naked land located in Permanent Protection Areas (APPs/PPAs), (4) use of fertilizers are generally applied before and after the plantation.

Some natural characteristics have a great role in water contamination as well such as slopes which are higher than 20%, close or into PPA, and high abundance of waterbodies.

In places with a high declivity soil conservation methods must be applied, to avoid superficial runoff towards rivers and springs, specially in naked land or open fields where there are no natural vegetation protecting water streams.

One of the sustainable solutions for protecting these waterbodies from contamination is to recover them restoring vegetation and ecological functions along with plant cover alongside the rivers and springs.

In the Brazilian Forest Code that had been elaborated in 1965, and was renewed by the Law 12.651/2012 added to the CONAMA Resolution 303/ 2012, there are many kinds of areas that are considered as permanent preservation areas, denominated among Brazilian citizens as APPs and denominated in the paper as PPAs (PPAs). However, the considered ones, according to their occurrence in the study area, will be: a) in the river margin, measured from the highest level, in horizontal projection, with the minimum width of 30m, for the water course of less than 10m wide; b) around any kind of water spring, with the minimum buffer zone of 50m; c) in a declining area superior to 45°, at the line of highest declivity.

In all cases, according to Article 11 of the CONAMA Resolution 369/2006, the intervention or suppression of low environmental impact in the vegetation in PPAs must not compromise the environmental functions of these areas, specially: a) the stability of the margins of the waterbodies b) the drainage and the intermittent waterbodies; c) the maintenance of the biota; d) the regeneration and maintenance of native vegetation; and also e) water quality.

According to Vieira (1983), the slope is defined as the inclination of land surface related to the horizontal plan. The classes of slope are described as limitations to land use, which in the case of this study, regards crops and agriculture. The definitions of the six classes are detailed as it follows: Class A) soft slope or practically plan areas, inferior to 3%; Class B) low slope and slightly hilly, between 3% and 8%; Class C) moderate slope, between 8% and 20%; Class D) severe slope, between 20% and 25%; Class E) very severe slope, between 45% and 75%; Class F) cliffs, with slopes superior to 75%.

The use of geo technologies may contribute to gather the different features involved in the context in order to provide a priority map for ecological restoration. In a macro vision this methodology might be very useful to guide the researcher or the territorial manager in order to set priorities.

After this step a micro vision is required in order to have the restoration really taking place. For that purpose a series of strategies and techniques will be shortly discussed and can take place either separately or combined.

Material and methods
For the Multi-criteria and macro process of delineation of restoration priority areas the methodology was unfolded taking in account a specific territory that was chosen to be the city of Bueno Brandão, located in the south of Minas Gerais State, in the micro region of Alta Mantiqueira. The highest altitude is 1,719m and the lowest is 840m, with S 22º26'27" latitude

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and W 46º21'03" longitude, of W 45ºcentral meridian and fuse 23. The region has rivers with a low flowing volume, among which are the rivers called Antas, Cascavel and Cachoeirinha. The local topography is rich in mountains that cover about 70% of the area, thus forming multiple waterfalls. The municipal area is 355.23 sq-km, including the watershed of Rio das Antas, located before public water caption, with 50.22 sq-km between S 22º31'38" to S 22º24'15" latitudes, and W 46º22'13" to W 46º13'56" longitudes (Figure 1).

The material used in this study was: The Brazilian Chart – area between Munhoz and Ouro Fino, in the 1:50.000 scale (IBGE, 1972); The hydrographic chart of Bueno Brandão, in the scale of 1:75:000 (IGA, 2001); the LANDSAT TM5 image, orbit/point 219/76, bands 3,4 and 5, from September 9th, 2006; software SPRING v 4.3.3, modes IMPIMA and SCARTA (CÂMARA et. al, 1996); Software AUTOCAD, v. 2000; ETREX – GARMIN PS, v. 2.09.

The chart showing the altimetry of Bueno Brandão (IBGE, 1972) and the hydrographic chart (IGA, 2001), with the waterbodies of the study area, were digitalized using AUTOCAD software. On both sides of each drainage stream, the PPA buffer of 30m was drawn, added to the 50m radius buffer around each water spring. The satellite image was done by IMPIMA mode, and imported by a software called SPRING. All geographical corrections were made in the location by the use of 20 control points.

Figure 1. Location of the case study area: Bueno Brandão, MG, Brazil. Source: Boulomytis, 2008.

For the multi-criteria analysis, the factors considered for the identification of the priority riparian areas to be restored were: the location of the area, if it was inside the preservation areas it was prior; the erosion vulnerability according to slope classification; the land use at the present; and, the vegetation sustainability capacity.

The first thematic map produced provided the slope classification. It was done crossing the chart of Brazil, with altimetry representation, and the generation of a DEM (Digital Elevation Model) at SPRING software (Figure 2). The represented classes, from A to F, are those classified by Vieira (1983).

The following thematic map produced was the land use cover. Using SPRING software, the image was segmented by the use of the regional-growth algorithm. The tolerance of homogeneity adopted in this case was 10 tons of gray per region of 10 pixels. After the segmentation, the classification was done by the regional-growth Bhattacharyya classifier, with the limier of acceptance of 99% (Figure 3). The classes obtained were: crop area, riparian forest and meadow. The classification was supervised and based on a group of 30 samples collected in the area with a GPS (Global Positioning System). The original map of land use classification was overlaid with

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an APP (PPA) map, to make it easier to visually identify the proximity of the crop areas from the APPs (PPAs), represented around rivers and springs.

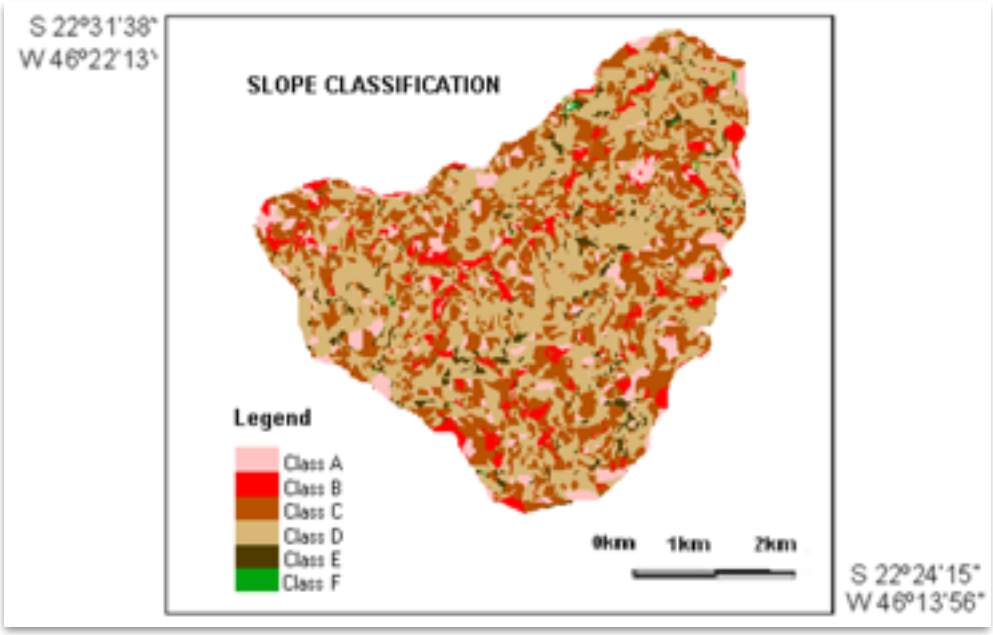

Figure 2. Thematic map of the slope classification of the Watershed of Rio das Antas.
Source: Boulomytis, 2008.

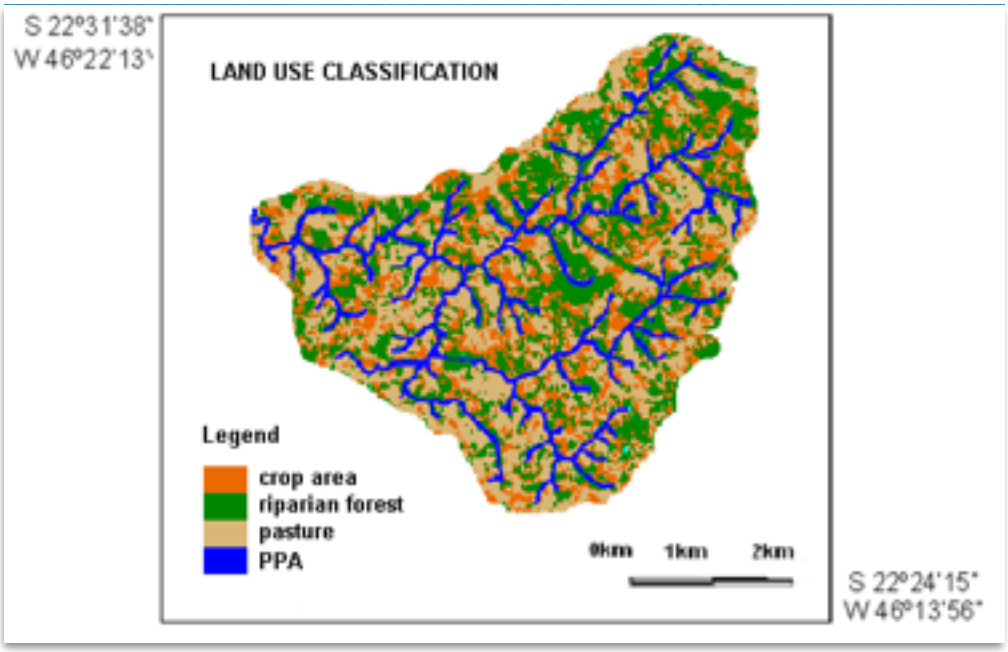

Figure 3. Thematic map of land use classification of the Watershed of Rio das Antas.
Source: Boulomytis, 2008.

Restoration priority was analyzed based on the following considerations:

- Crop area was the land use type that corresponded to the major risk of water degradation, because of the intensive use of agrochemicals and pesticides applied and the continuous removal of land and land protection for plantation purposes;
- Vegetation sustainability capacity was considered reasonable for all the areas in the

case study, based on the fact that this region was chosen because of the systematic potato plantations in it, which demands a lot of care from the producers;
- Erosion vulnerability was done according to slope classification – the higher the slope is, the more vulnerable soil becomes to erosion;
- Slope classes E and F associated to land uses defined as crop areas was considered high priority for restoration
- The location of the crop site in PPA (APP) was considered high priority due to the proximity of a waterbody;
- Slope class D associated to the land use defined as crop area was considered medium priority;
- Slope classes A to C associated to land use class defined as crop area was considered low priority;
- Remaining slope and land use classes combined among each other were considered no priority.

Considering all the previous data already produced by the software called SPRING, it was possible to use the LEGAL language to make the analysis aiming the definition of the restoration priority areas.

After priority areas were defined the following step is to define what to do in each one of them. Therefore a research on techniques took place aiming to make the restoration actions which are more feasible and less expensive economically involving Nucleation strategies among others.

This research was done mainly in book and papers published both in Portuguese and English languages and also legislation on this subject giving special attention to Brazilian juridical documents, once the study case is located in Brazil.

The results to the research on strategies and techniques available are presented as a micro vision and will be discussed as follows and all of them can take place either separately or combined according to executers needs and budget added to the peculiarities of each area.

2. Results and discussion

2.1. Establishment of criteria for the delineation of restoration-prone and priority areas

The purpose of this paper is to provide information and possible methodologies for soil conservation in watersheds, having as a model the Rio das Antas watershed. While collecting the sample points for calibrating the supervision, it was possible to observe many situations that represent a serious hazard for the water quality of the watershed of Rio das Antas, so there and in many other similar river basins these methods can be applied to avoid water quality loss.

Figure 4. Potato plantation in environmental fragile fragments of the Watershed of Rio das Antas.
Source: Picture taken by the author Vassiliki T. G. Boulomytis.

In some of the the crops that were along their river the riparian forest has been completely removed. Riparian area land cover removal happens all over Brazil and in most places around the world, thus populations longer for using these lands as financial supports for their living. As it is possible to observe in figure 4, the preparation for the potato plantation was done by the intervention in the PPA in a near waterbodies and promoting the removal of the riparian forest.

A GIS based on the multi-criteria approach was taken by the use of the thematic maps of slope and land use classifications, integrated by the LEGAL algorithm at the SPRING software. The obtained result was a thematic map that can be seen in Figure 5.

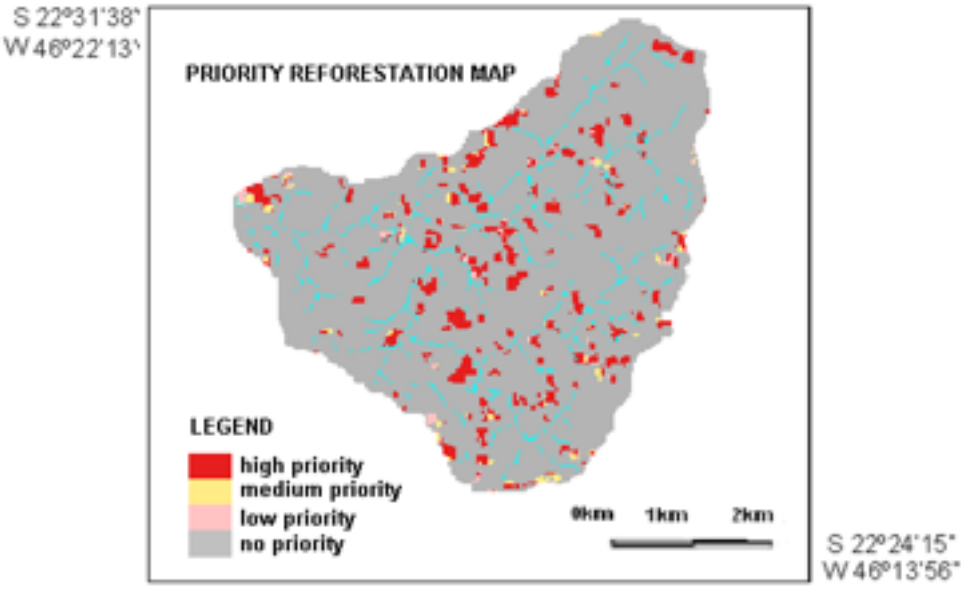

Figure 5. Priority Ecological Restoration map for Rio das Antas Watersheds and riparian forests.
Source: Adapted from Boulomytis and Fabro Neto, 2011.

The results were obtained per priority type. They can be observed in Table 1. It demonstrated that there is a high priority in the most fragile areas analyzed in the watershed of Rio das Antas.

Table 1. Priority Ecological Restoration map for Rio das Antas Watersheds and riparian forests.

Reforestation Priority	Area (sq-km)
High priority	3.58
Medium priority	0.37
Low priority	0.52
No priority	45.75

Source: Adapted from Boulomytis and Fabbro Neto, 2011.

For the reforestation of the high priority areas the watershed of Rio das Antas, if only seedlings were to be used, according to the research of Ferreira and Dias (2004), it is estimated the necessary amount of 518,050 seedlings for the high priority area (144,706 seedlings per sq-km). So as there are different methodologies for ecological restoration and reforestation some tactics explained in the sequence can be used.

After establishing the areas that are priority for receiving ecological restoration or rehabilitation it is important to choose between different methodologies of reestablishment of ecological features and relations. Some of these methods will be shortly explained and can actually use a little amount of seedlings and also raw material, turning this process less expensive.

2.2. Restoration Techniques to be applied in the indicated areas

Firstly it is very important to define which kind of recovery process will take place, either it can be an ecological restoration or an ecological rehabilitation, both according to Bradshaw (1996) and the Brazilian law regarding conservation areas (Law 9.985/2000) the concepts are different.

Restoration is used to describe a situation of recovery that can be compared to a former state or

even to an unimpaired or perfect condition. Therefore "to restore" means that the methodologies are being used to bring the area back to its original state or recreate it very similar to a healthy ecological state, considering both at once. Rehabilitation is more often defined as reestablishing an ecosystem to a previous condition which can sound quite alike restoration, but the differences lie in the perfection query of the restoration processes that are not present in rehabilitation ones. Anyways, most techniques can be applied to both cases in which the main goal is to remediate environmental damages made previously to avoid their externalities to spread and regain an ecosystem close to that one observed before the disturbance took place.

In any restoration or rehabilitation situation that may be chosen it is important to have the planners aware that there are many ecological natural processes that are taking place before the amends are done. This is true either for terrestrial ecosystems and aquatic ones, and one of the most important steps will be to study in detail some similar areas if possible in the same watershed to understand the ecosystem, collect some succession data, and define which species can be used in some methodologies that will be shown. It is also important to consider if there interferences of migration species and which, of soil contaminations, the effects of species interactions among other data.

The strategies that will be shown are to be used in areas in order to restore their ecological functions, thus they can be applied together or separately depending on the budget, the existence of a local arboretum or nursery garden that can offer native species seedlings to serve the patches. What means the professionals in charge of the project will have to evaluate the importance of using those methodologies and their location in the field due to their characteristics.

2.3. Isolation of the restoration area

This methodology is the plain area isolation. Usually it implicates on the use of fences to keep cows and greater mammals of trampling the area. It is important that this area is identified with a sign saying it is in restoration so that entrance is avoided and limits become respected. The appliance of this methodology is expensive, specially for large areas, so the need of it and the material involved if this tactics are used may be discussed and determined for each restoration-prone fragment.

2.4. Alien species control

The technique involving Alien species control and removal is important because exotic/alien and invasive species are those non native species that can be found in a determined environment invading the areas and often having harmful impact over native fauna and flora. These impacts are due mostly to competition among species what can lead to extinguishment, floristic alteration of the areas, and faunal changes.

The aim of this technique is to remove alien species and the means to do it depend on the species detected on a specific place and the techniques may be applied repeatedly in order to guaranty the total removal of the species. In restoration usually this is most done towards vegetal species. It is highly recommended that this strategy is applied in most cases.

2.5. Nucleation

One of the methodologies suggested as a strategy to ecologically recover areas is the nucleation; it involves usually planting small designed patches of seedlings as focal nuclei that may start off rehabilitation. After their implantation the patch have the potential to attract flora dispersers and are set to promote the growth of the recovered areas. This strategy usually is cheaper than those in which all the area is covered with seedlings and one of its main goals is to simulate a regular successful process that can end up having better ecological results than the first mentioned.

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Many results show that the diversity and ecological functions of recovered areas using nucleation are greater than either using seedlings in the whole area or only applying passive rehabilitation. The idea is to reestablish holistically the whole community evolving ecological relations amongst the beings that can potentially that area and those that actually do, as well as local physical soil, water, wind and atmosphere conditions.

The adoption of this methodology is based on some actions amongst which the formation of flora nuclei to serve as "biodiversity patches", "Soil transposition", implanting "artificial bird and bat poles" and "transposition of wood and raw material". Also another technique is based on "seed rain" and it´s deposition.

2.6. Biodiversity patches

Biodiversity patches described largely by Ademir Reis (REIS et al., 2003) are suggested to start the recovery areas in Nucleation. To plan it is highly recommended to have a deep study about flora and fauna in order to select the seedlings and their spatial arrangement in each focal nuclei. Reis et al., 2003 and Kageyama and Gandara, 2000 say that these patches may be helpful attracting fauna and facilitation pollinators, dispersers and can be used as nesting area or refuge.

Some of the species chosen should be capable of producing attractive fruits to fauna and may also be better off if heliophile since they might have to stand high insulation, at least in Brazil. The patches can be hexagonal and contain X species. In the case shown 7 species where planted in each "patch" and there were 6 different combined kinds of patches.

Each diversity patch has to be gathered with a table containing the scientific names of the seedlings selected, their popular name, the succession stages the plant in keen (pioneer, medium, climax), dispersion type and quantity of seedlings per patch.

The hexagon with a center was chosen so that each plant hole would be 2,0m away from the nearest plant, avoiding intense competition, and the figures showing the idea are presented in the sequence.

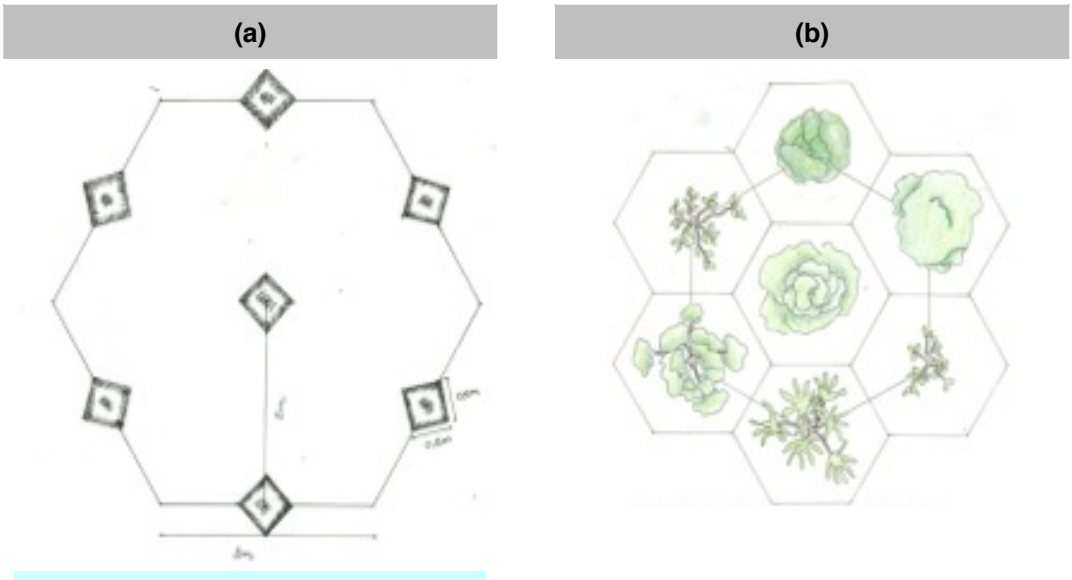

Figure 6. (a) Disposition of holes in a hexagon from for 7 seedlings; (b) Disposition of Plants in hexagon for 7 after implantation and growth of the seedlings.
Source: Elaborated by the author Marina Christofidis.

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2.7. Soil Transposition

This technique involves the transposition of small portions of soil that may be found in healthy ecological rich areas and led to restoration bound areas. The great importance of doing this is that soil can be full of propagules, seeds, and pioneer seedlings (REIS et al., 2003) and also microorganisms (bacteria, decomposers, verms, algae and fungi) that can help out fertilizing the soil of the restoration bound area giving energy and nutrients for its succession process.

Usually the layer of soil that will be "cut off" the donator area is between 10 to 15cm wide and the works of Reis et al. (2003) suggested advantages in this strategy. Other authors suggested a wider layer of soil is used, such as Rodrigues & Gandolfi (2000) that prefer 20cm.

The Idea of either this strategy and the following is to assure the area will have better seed support that an area with regular seedling restitution. All of the strategies to enhance seed rain and seed bank, such as soil transposition and bird and bat poles can be used to favor and make anthropogenic restoration processes closer to natural restoration processes

2.8. Bird and Bat Poles

Some groups of animals are fond of Artificial Poles, such as birds and bats. The idea is to use this habit to enhance restoration, especially because bats and birds are intense pollinators and seed dispersers.

There are some types of poles that can be used and all of them can be hand made with material found around the restoration area with low cost. According to Reis et al., 2003 these are very efficient manners of bringing seeds to the area because poles catalyzes initial succession increasing the amount of seeds and their diversity in around 150 times. In Ecological restoration literature there are 4 kinds of poles described, they will be shown as follows.

- Live Pole: Vegetal living poles with leafs that simulate usual habitats used for resting, mating, nesting and feeding (Figure 7a);
- Liana Poles: Those poles simulate many lianas intertwined and can be used as refuge and shelter by bats and birds that are not very keen of high luminosity (Figure 7b);
- Air cable pole: simulate electrical cables and are used often by birds to rest, observe, feed and can be strapped between any two poles to enhance seed dropping (Figure 8)
- Dry pole: Dead or dry wooden or bamboo structures that simulate branches and trees that are used for birds for observation and feeding (Figure 8).

Figure 7. (a) Live pole representation (b) Liana Pole representation – ideal for bats and birds.
Source: Elaborated by the author Marina Christofidis.

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Figure 8. Air cable and dry pole example with birds in an ecological restoration area.
Source: Elaborated by the author Marina Christofidis.

2.9. Transposition of wood and raw material

Figure 9. Transposition of wood and raw material forming piles.
Source: Elaborated by the author Marina Christofidis.

This strategy aims to offer fauna a refuge and nesting habitats around the restoration bound area. This can offer a variety of vertebrate and invertebrate reasons to "stay around" and play an important role on ecological matters. Many animals profit from this kind of piles, such as snakes, lizards, frogs and small mammals and also bees, larvae, worms, insects in general. Although the process can take quite a bit of work, time and resources it is one of the procedures that may be considered extremely important for the maintenance of the water quality of the watershed. In case there are available resources, the order of priority might be followed, guaranteeing the adequate sequence of necessary protection for the watershed.

3. Conclusions

By the use of a GIS based on the multi-criteria approach, it was possible to minimize cost and time in order to obtain the appropriate estimation for the priority sequence of areas that should have its riparian forest recovered.The use of nucleations associated to the macro areas chosen with the use of GIS can optimize and cut costs off ecological restoration processes.

It is important to notice that these are only a set of measures that could be used in order to avoid water degradation due to the intensive use of agrochemicals in the potato plantations. There are many other instruments and law enforcements that can be used for the same purpose, therefore it is necessary to establish the proper macro drainage management for the area, and promote territorial planning considering a whole series of procedures aiming the promotion of sustainable development for the watershed.

Ecological restoration requires financial investment that could be spared if the environment was not led to degradation, so the priority shall be avoiding greater environmental impacts.

Probably law enforcement measures added to Governmental and non-governmental programs, such as "The Water Producer Program" pursued by ANA (The National Water Agency of Brazil), may avoid water impact and improve its quality in the Brazilian watersheds. In this rural program, technical support and money compensation is given to the farmers who adopt water and soil preservation actions on their properties.

In case the negative impact has already taken place, in order to restore the environment without proposing high-cost measures, the techniques proposed in this paper, to select the appropriate

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areas and use nucleation strategies, might be handy and effective for the reestablishment of vegetal coverage and restoration of ecological functions.

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