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A solution for worn-out tires, gully erosions, forests and dengue fever in Brazil

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Abstract

Rehabilitation of large gully erosions was improved in Piracicaba (Brazil) by using worn-out tires. Two procedures were evaluated in different case studies, the "ditch technique" (DT) and the "fill-up technique" (FT). In both, worn-out tires were placed at the bottom of the gullies, covered (naturally or artificially) with soil and reforested. In the DT the tires were placed in small pyramidal barriers perpendicular to the gully along its bottom and in the FT they were used as filling material occupying the lower part of the whole gully. The benefits of the suggested methods are an adequate disposal of worn-out tires, restoration of forest resources and the control of the mosquito species *Aedes aegypti,* whose larvae develop extremely well in the clean water accumulated in open-air stored tires. This mosquito species is vector of the tropical epidemic disease dengue fever. The paper reports on two case studies substantiating the practicability of the methods. The multiple advantages and the need of none or little capital investments for the adoption of the technologies contribute for its acceptance by decision makers, politicians and society.

Keywords: worn-out tires, gully erosion, forest rehabilitation, dengue fever

Zusammenfassung

Eine Lösung zur Beseitigung von Altreifen, zur Restaurierung umweltbedingter Landschaftsschäden und zur Eindämmung des Dengue-Fiebers in Brasilien

Durch Verfüllen mit verbrauchten Autoreifen wurden in Piracicaba (Brasilien) regenwasserbedingte Erosionsgullys in Böden beseitigt. Geprüft wurden in Fallstudien zwei Techniken, wobei in jedem Falle verbrauchte Reifen auf den Grund der Erosionsgullys eingebracht wurden, mit Boden bedeckt und dann mit Gehölzen bepflanzt wurden. Die Vorteile der Methoden sind eine unschädliche und umweltfreundliche Beseitigung von Altreifen bei gleichzeitiger Restaurierung erosionsbedingter Landschaftsschäden. Von großer Bedeutung ist aber auch, dass durch das Vergraben der Reifen, im Gegensatz zu einer Lagerung unter freiem Himmel, die Verbreitung von *Aedes aegypti*, einer Mückenart, die das in den Tropen epidemisch auftretende Dengue Fieber überträgt, eingedämmt wird. Denn bei offener Lagerung bilden sich innerhalb der Reifen Frischwasserlachen, die eine bevorzugte Umgebung für die Entwicklung der Larven darstellen. Die vielfältigen Vorteile, bei gleichzeitig minimalen Kosten, sorgen für eine hohe politische und gesellschaftliche Akzeptanz dieser Endlösung für verbrauchte Reifen.

Schlüsselwörter: Autoreifen, Bodenerosion, Dengue Fieber, Forst

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1 Introduction

Worn-out truck and car tires disposal, the maintenance and improvement of forest resources, dengue fever epidemic prophylactic measurements and gully erosion control are everyday problems on the agenda of municipality governors in the State of São Paulo, Brazil. Probably, these are also matter of concerns in other densely populated tropical regions. This paper describes an approach to solve all four problems with one procedure. Following, a detailed description of these problems.

Forest resources and agriculture are competitive for land, so surveillance and protective measurements are needed to preserve the remaining forests or to improve its occurrence by reforestation. Forests, especially the riparian forests, are recognized as essential for the protection of the aquatic environments and can be managed for the enhancement of water quality through the control of non-point source pollution (Lowrance et al., 1997; Montgomery, 1997). Because of the worldwide recognition of pollution to freshwater as one of the most important threats to mankind (Gleick, 1998), forest resources are increasingly protected by policies and legislation (e.g. section 208 of the USA Federal Water Pollution Control Act, Brazilian Federal Law 4771/65), and that is the reason why forests are more and more included in the agenda of decision makers.

Dengue fever is a tropical virus disease and has as transmission vector the mosquito *Aedes aegypti*. This disease may breakout in epidemic levels and recently has emerged as a major health problem in tropical America (Dietz, et al., 1990). The most effective prophylactic and protective factors against dengue transmission is to avoid the contact with the mosquito and/or restrict its reproduction (Ko et al., 1992). *Aedes aegypti* larvae stage development is most improved in clean and quiet freshwater, naturally a small lake or a splash of rainwater. In urban areas, water in flowerpot supporting plates, open water-tanks, open-air stored bottles, cans and tires are an excellent environment for the mosquito larvae to develop. Public education, surveillance, monitoring and control of *Aedes aegypti* larvae is being a routine operation in most urban areas of Brazil for a long time.

Soil erosion is a major factor related to hazards e.g. flooding (Xiubin and Juren, 1998); mass movements in urban areas (Guerra and Favis-Mortlock, 1998); global food security (Daily et al., 1998); environmental degradation (Matson et al., 1997); and global biodiversity loss (Sala, et al. 2000). Even considering all these deleterious effects soil erosion is still exceeding desired levels in the opinion of scientists (Pimentel et al., 1995). One of the reasons for that may be the failure of scientists and politicians in convincing the society to invest in erosion control.

Worn-out tires disposal in Brazil is regulated by resolution 005/93, that is the Brazilian legislation which defines the final destination of solid residues. The allowed final destinations are recycling, combustion in facilities equipped with adequate filters or burring by covering the tires with soil. In Brazil, the production of tires for disposal is greater than the recycling capacity. Garbage burning facilities are also limited available, and used exclusively for hazardous materials such as hospital wastes or contaminated materials. Most of the urban garbage is sent to landfills, where tires are not allowed to be dumped. The reasons for restricting tires in landfills are that they do not compact or decompose readily, consuming excessive space. Also because of the hollow shape, tires trap air or other gases. The result is that they may float, damaging the landfill cover or showing-up at its surface. Burrying tires, by digging a hole and covering them with soil, is not a usual method because of the high costs, complex logistic and environmental impacts that result from the artificial removal of vegetation and soil. In practice, tires are usually open-air stored in piles for long periods at the production places in the stores that deal with new tires and car repair shops inside the urban area. There are no special services for collecting tires so, this inadequate storage will go on until someone gets interested in the material. When this happens, the tires are first sorted and part of it is vulcanized again. The other part is open-air burned to recover the steel, disposed inadequately in the environment, or piled-up again in deposits outside the urban areas. A minor part is correctly burned, usually in cement industries. Therefore, a significant part of the tires is not adequately disposed. This is contributing to air pollution (e.g. open air burning to gain the steel, accidental fire in the piles) or promoting the reproduction of mosquito larvae (e.g. long periods of inadequate open-air storage), threatening the local population with epidemic dengue fever.

This paper reports an applied research and development project developed in Piracicaba (Brazil) during 1998 and 1999 that allows the rehabilitation of areas affected by large gully erosion process. The suggested procedures make use of worn-out tires as construction material in a way they can not host the *Aedes aegypti* larvae and end up with a reforested site.

2 Material and Methods

The rehabilitation of the gully erosion affected areas was made using two techniques, each one described in a different case study carried out on a specific site. The two methods were named: “ditch technique” (DT) and “fill-up technique” (FT). Both were applied in operational conditions in Piracicaba’s rural areas (central coordinates of S 22º35” and W 47º45”), which is a 1,368 km^2 municipality with 328,312 inhabitants (Demographic Census 2000, Brazilian Institute of Geography and Statistics). On the whole, there is one car for each ~ 10 inhabitants in Brazil, but in the region of Piracicaba the rate is one car for each ~ 3 inhabitants. Tires are usually substituted after 50,000 km and considering 15,000 km y^{-1} as a mean driving distance only in Piracicaba we can estimate a disposal of ~ 130,000 worn-out tires each year. Soil erosion is a serious problem in most rural areas of Piracicaba due to intensive rainfalls in the summer, favorable topography and intensive land use due to sugarcane cropping. Gully erosion in the most sensitive areas was estimated to occur at the rate of 1.5 gullies per hectare (Montolar-Sparovek, et al., 1999).

2.1 The ditch technique (DT)

The principles of the DT are presented in Figure 1. Tire ditches were built along the bottom of the gully. The ditches had a pyramidal format and not exceeded 1.5 m in height to increase mechanical stability avoiding runoff damages. The ditches were anchored to the gully's side walls to prevent the water to laterally erode it and extend the erosion channel. The ditches acted as a physical barrier for water outflow, but kept some permeability. By reducing water velocity at the upper side of the ditches, runoff transport capacity was decreased and sediments were deposited. After silting, the topography of the bottom of the gully was changed to a smoother slope. This slope was sufficiently smooth to reduce runoff velocity to none-erosive speed. With that, the gully development was reduced, allowing vegetation to grow inside the channel, stabilizing the gully. The revegetation process may be natural or be improved by reforestation, but in both cases, a natural forest should be restored on the site. The purposes of the forest are to reduce the erosion risk to prevent the area from another gully process to occur, restrict the access once natural forests are legally protected and are not allowed to be removed, and restore the regional forest resources for the benefit of wildlife and environment.

The case study for the DT was implemented in 1998 on a gully formed in 1984 due to a malfunction of the drainage system of a dirt by-road used for sugarcane transportation in a private farmland. The gully was measured with topographical equipment and the mean dimensions were: length ~ 300 m, width ~ 12 m and depth ~ 2.5 m resulting in ~ 9,000 m^3 volume of removed soil. The tire ditches were built in number of four, beginning at the upper part (~ 50 m from the highest position of the gully) and spaced regularly down to the smoother floodplain where the gully process ended. About 5,000 tires were used for building the ditches, resulting in ~ 0.5 tires per cubic meter of gully volume. The pyramid ditches were built by piling-up the tires manually. It took two days for three men to transport and construct the ditches. The mechanical equipment used to help construction were one 6 m^3 dumper-truck and a small backhoe loader (77 hp) used to transport the tires close to the gully and dump them down to the construction places.

2.2 The fill-up technique (FT)

The FT consisted of filling-up totally the bottom of the gully with tires, in this case, substituting conventional filling materials such as soil, stones, and construction encumbrance. More tires per erosion volume were used than for the DT. After the desired volume was filled with tires the remaining void space was filled with soil material, leveled and vegetated by reforestation. Natural silting should not be considered in this case, because of the excessive long time it would take. The tires should not be open-air exposed for long periods to avoid the possibility of *Aedes aegypti* larvae development and to reduce the risk of accidental fire. For these reasons it was indispensable covering the tires right after their deposition inside the gully in this case.

The case study for the FT was implemented in 1999 on a gully formed around 1995 due to a malfunction of the drainage system of a main road. The gully was approximately measured in the field using measuring tape and the mean dimensions were: length ~ 600 m, width ~ 25 m and depth ~ 5 m resulting in ~ 75,000 m^3 volume of removed soil. About 200,000 tires or ~ 2.5 tires per cubic meter of gully volume were used to fill-up the gully in ~ 2.5 m, half

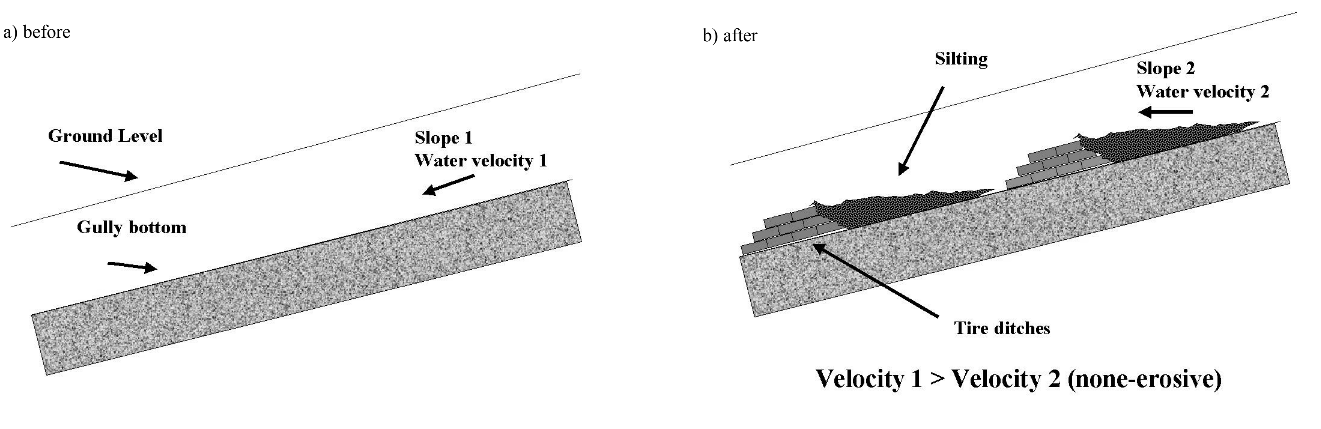

Fig. 1
Ditch technique for erosion control using worn-out tires as construction material: a) gully before tire ditch construction and b) gully after ditch construction

of its original depth. It took 12 days for a team of 10 men to transport and place the tires inside the gully, with additional help of six 6 m^3 dumper-trucks, one small backhoe loader (77 hp) and one medium wheel loader (160 hp). The tires were transported to the side of the gully by the trucks, and dumped-in using the backhoe or the wheel loaders. Final leveling and placement of the tires inside the gully were made manually. After reaching the desired filling level of half the initial gully volume, the gully was leveled to the end using soil material, scraped from its borders or from close to the gully. The final leveling used local standard procedures for gully rehabilitation. Vegetation was initially made with fast growing grass, to rapidly stabilize the structure of the filling soil material, and further enriched with native forest trees.

3 Results and Discussion

A visual perception of the two case study sites is shown in Figure 2.

The two suggested techniques showed to be in accordance to the Brazilian environmental legislation, economically attractive and socially acceptable. The economical advantages are related to the multiple benefits they offer, which are adequate disposal of worn-out tires reducing the dengue fever problem without polluting the environment. At the same time, two other problems get solved, which are the rehabilitation of gully erosions and the restoration of forest resources. If these problems are treated isolated, the costs will sum-up; treating them together, the costs are reduced. The cost of leveling the gully is not increased by the disposal of tires, and reforestation costs are not increased because it is being done on a leveled area. Possibly, there may be even a reduction in costs for leveling the gullies in the case of the DT because material is deposited naturally. In the case of the FT, less external soil material is needed to fill-up the gully, so one may expect lower off-site environmental impacts due to soil removal and transport.

The tire consumption is greater in the fill-up technique when compared to the ditch technique. The DT may be preferred when the main objective is gully erosion control and worn-out tires are not much available. The FT is more adequate if tires are present in excess and the main objective is disposal. In the DT the tires are first covered with sediments, which occurred after the second rainfall after

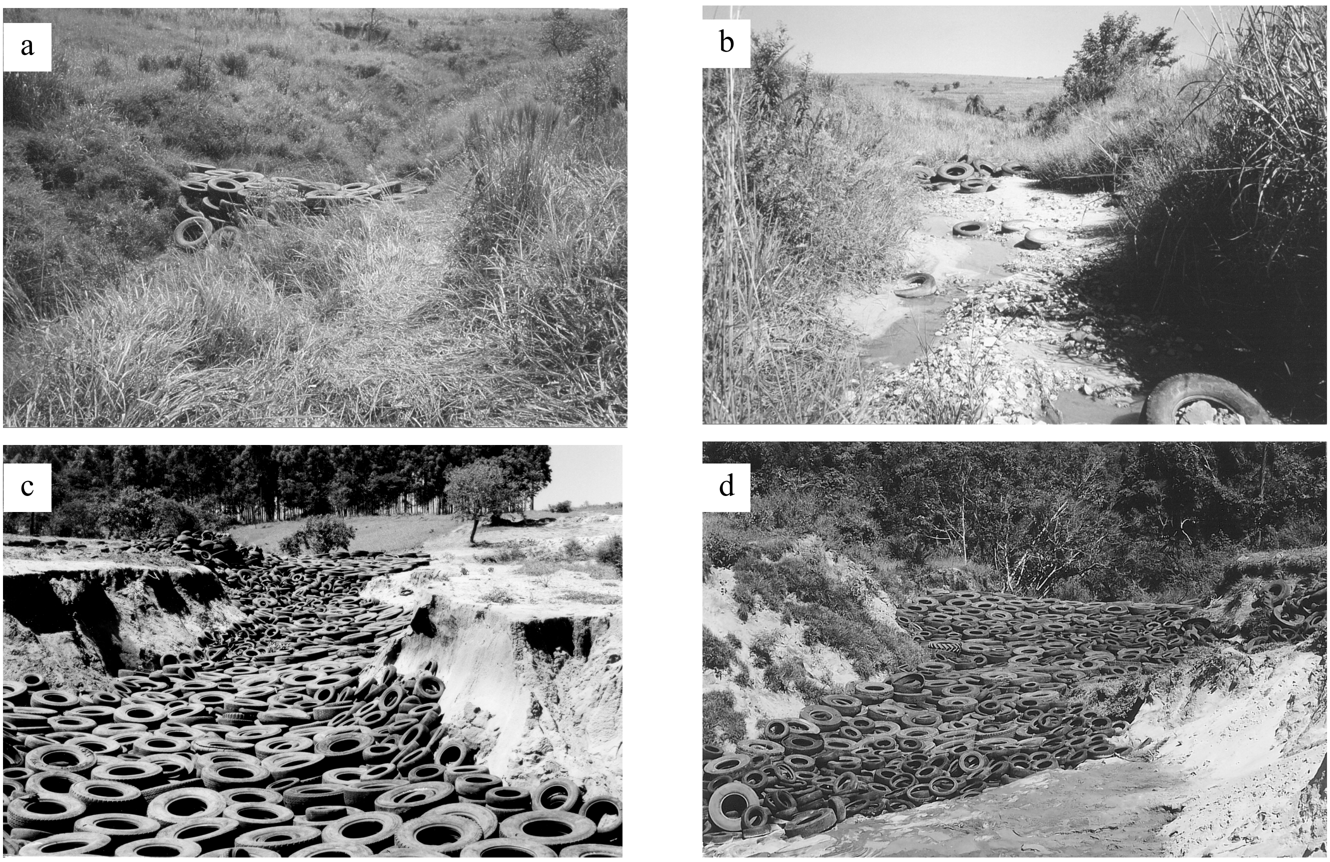

Fig. 2
Picture of the two case study sites where a) ditch technique (DT) site before silting; b) same ditch after silting; c) fill-up technique (FT) view from the middle of the gully looking up after 50 % of initial volume reached the desired filling level and d) FT technique view from the middle of the gully looking down

construction. In the FT, the tires are covered artificially, as part of the gully rehabilitation procedure. Thus, in both cases, there is no time for the development of mosquito larvae.

The multiple benefits and the absence of high investments (the mechanical equipment used is ordinary- trucks, loaders -, and is usually available in most municipally services), make this solution attractive for politicians and society. The proposed method is much cheaper, as for example, the construction of a burning facility. It should be remembered that high initial costs usually delay the implementation and are an additional factor to create resistance from decision makers or society that may indicate other priorities for the investments.

4 Conclusions

The two techniques described in the case studies showed to be practically executable, economically attractive, in accordance to local environmental legislation and capable to contribute to the solution of tire disposal, gully erosion control, restoration of forest resources and control of dengue fever vector.

The multiple advantages and the need of none or little capital investments for the adoption of these technologies probably contribute for its acceptance by decision makers, politicians and society.

No potential environmental impacts were identified during the case studies.

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