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Social Safety, Environmental Sustainability and Realistic Computer Simulation Fire in Forest: the Biological Reserve of Piratuba Lake – Amapá

Segurança Social, Sustentabilidade Ambiental e Simulação Computacional Realista de Incêndio em Floresta: a Reserva Biológica do Lago Piratuba - Amapá

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ABSTRACT
Motivated by urgent necessity to support the studies of strategies, controlling and combat of big fires, mainly in a forested conservation area, we developed a computing tool to assist the task. Our main goal in this work was to elaborate a software, and to develop a first case study, that is the fire drill in the REBIO of Piratuba Lake – AP. Then, we applied the software in real images obtained from satellite and did fire drills in virtual forests demonstrating a high degree of realism or similarity with what is observed in loco. We performed fire propagation tests on these images with the insertion of a natural and artificial obstacles to the fire. The results are interesting from the phenomenons understanding standpoint that occur in a larger geometric scale, in a small platform with simulacrum of variables, as a way of anticipating such nature phenomenons.

Keywords: Social Safety, Environmental Sustainability, Forest Fire, Computer Simulation, Amazon.

RESUMO
Motivados pela necessidade de auxiliar os estudos no campo da sustentabilidade ambiental, segurança social, das estratégias, do controle e do combate aos incêndios, principalmente em reservas florestais, desenvolvemos uma ferramenta computacional para auxiliar nessa tarefa. O nosso principal objetivo nesse trabalho foi realizar um estudo de caso para fornecer elementos na elaboração de um *software*, de simulação de incêndios na REBIO do Lago Piratuba – Amapá Floresta Amazônica - Brasil. Em seguida aplicamos o *software* em imagens reais obtidas via satélite e simulamos incêndios em florestas virtuais demonstrando um alto grau de realismo ou semelhança com o que é observado em *in loco*. Realizamos testes de propagação de incêndios nessas imagens com a introdução de obstáculos naturais e artificiais para o fogo. Os resultados são interessantes sob o ponto de vista de entender fenômenos que acontecem em uma escala geométrica maior, em uma pequena plataforma com simulacro de variáveis, como forma de se antecipar aos tais fenômenos da natureza.

Palavras-Chave: Segurança Social, Sustentabilidade Ambiental, Incêndio Florestal, Simulação Computacional, Amazônia.

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1 GLOBAL ENVIRONMENTAL ISSUES

Every day, there are significant changes in the environment, requiring interventions from society and institutions, whether legal or scientific, to minimize environmental accidents, as well as the excessive human actions. Nevertheless, there is an increase in sensitivity and ecological awareness. The ecological activity has experienced a spectacular expansion over the last few years (AMIGO, 2020). The phenomenon is worldwide, but most impressive in Western countries, convinced of the threat of ecological catastrophes, persuaded of the dangers that weigh on the planet and worried about the world that is left for future generations (ALPHANDÉRY, *et al*, 1992).

It is believed that ecology and the several discussions about it - nature, environment, environmental degradation and environmental sustainability - are a worldwide phenomenon (TOZONI-REIS, 2004). There are many interpretations of its concept, but it is notorious and almost unanimous that ecological fear is a great world fear. The great ecological fear lays in fertile soil. It feeds on the incessant discovery of new ravages of progress. It is amplified with the still unknown threats that weigh upon us - invisible pollution around us, hidden technological risks - and expands in countless scenarios - catastrophes and prophecies of apocalypse from which we are warned that they do not just belong to the exclusivity of the fiction realm (ALPHANDÉRY, *et al*, 1992).

At this perspective, global environmental agencies, concerned with the advance of the level of environmental degradation and its immediate consequences to the inhabitants of the Earth, point towards a path: environmental sustainability. The United Nations Conference on Environment and Development held in Stockholm June 16, 1972, and reaffirmed in ECO 92, aims to establish partnerships among countries, emphasizing the participation of public and private sectors, as well as individuals, on the preservation of nature, recognizing it as "interdependent and integral to the Earth" (AGENDA 21). One of the tasks of environmental agencies is to develop the consciousness of individuals of interdependence towards the Earth. Through this action, it is aimed to make the inhabitants aware about their several disordered interferences on the planet, as well as their consequences. The search for bonding between people and the planet it is also the central concern of a component of ecological awareness (ALPHANDÉRY, *et al*, 1992).

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2 ENVIRONMENTAL ISSUES IN BRAZIL: THE AMAZON CASE

The harmful actions of man to the environment is the subject of several analyzes and dissemination in the press. In Brazil and in the world the most obvious problems can be exemplified in some lines reported in quotations such as:

A) Degradation Dimension:

> "Today, 33 percent of land is moderately to highly degraded due to the erosion, salinization, compaction, acidification and chemical pollution of soils", (FAO *and* ITPS, 2015).
> "Brazil is a global exception in terms of forest policy change, with a dramatic policy-driven reduction of deforestation in the Amazon Basin", (FAO *and* ITPS, 2015).

B) Environmental impacts and social pressures:

> The environmental impacts derived from the national production of soybeans, meats, iron, aluminum, etc. act in synergy with the social or population pressures of the current globalized market (...). The increase in the birth rate of the low-income population and the displacement of part of the rural population to the cities lead to the slum development of large urban areas. (KLABIN, 2006).

C) Prediction by modeling pessimistic scenarios:

> The modeling of several scenarios of greenhouse gas (GHG) emissions indicates an increase in the temperature of the Southeast and Center-West regions of the order of 0.4 to 1.1ºC in 2025, reaching 5º in 2080 (KLABIN, 2006).

D) Awareness of reports of harmful consequences:

> Deforestation alters water and energy cycles, inducing an increase in air temperature and a decrease in precipitation, which may reduce the amount of water vapor exported to other regions. Fragmentation of forest areas reduces the number of habitats available for biological species. Solid waste (garbage and sewage sludge) in Brazil has been increasing, and there are already serious problems in metropolitan areas for the construction of landfills as final destination. The solution to this problem is a challenge for the coming decades (KLABIN, 2006).

E) Surveillance and risk of extinction:

> The remaining 5% of the Atlantic Forest are under constant threat due the activities at its surrounds. Your destination will depend on heavily capacity of management of the environmental control agencies (KLABIN, 2006).

Brazil, with its continental dimensions, leads another environmental milestone, which is to own 40% of the entire tropical rainforest area of the world, representing the Brazilian population a great source of natural resources, mainly because it generates income for farmers, currently, multinationals that industrialize the natural products coming from the Amazon Forest. The Brazilian forestry sector

represents approximately 8% of Brazil's total annual wealth (BARRETO, *et al*, 2005). It is unquestionable that Brazil, especially the Amazon, is under heavy pressure on the exploitation of its natural resources. Proof of this finding can be seen in the above quotes. In 2002, approximately 47% of the Brazilian Amazon was under some kind of human pressure, including deforestation, as well as areas under pressure indicated by the incidence of heat sources (fires) in forests. His greatness awakens in humankind his inexhaustible value. This vision masks an unprecedented problem: FAO data (*Food and Agriculture Organization*) reveal that, from 2000 to 2005, Brazil accounted for 42% of global net forest loss - most of which occurred in the Brazilian Amazon (BARRETO, *et al*, 2005).

Some authors define human pressure under two perspectives: consolidated human pressure and incipient human pressure. Consolidated human pressure is the permanent and intensive occupation of man (settlements, deforestation and the creation of urban areas). When this happens environmental impacts are generally irreversible. Incipient human pressure is represented by a temporary human permanence, such as mining, exploration and burning of wood, among others. This latter modality of human pressure requires much attention. It is the masked danger. Man's action in this proportion may influence future forest conditions, including uncontrolled fires, especially in heat spots, and consequently the onset of fires. BARRETO (2005) describes that zones of influence of heat sources are defined as areas of human activity associated with the incidence of forest fires.

Incipient human pressure is not responsible for all environmental degradation in the Amazon, but it is warning for something transient, accounting for 28% of cases. But in spite of these pressures on the Amazon, it still retains the greatest diversity of fauna and flora in the world, that is, a complex natural, social and cultural heritage. It holds 30% of the world's biological diversity and presents an enormous genetic potential, active principles of inestimable economic and social interest, and supply of forest products with high market value (Plano Amazônia Sustentável, 2006).

Thinking about the preservation of these ecosystems, the Federal Government created the Areas of Conservation, commonly known as Conservation Units – UCs. These Areas have two main points: those of integral protection and those of sustainable use. The first one is destined to parks and biological reserves, among others. The second, as its name says, has the purpose of guaranteeing the region's sustainability, that is, allowing the exploitation of natural resources in a moderate way, guaranteeing the future generations the same right. Among the various sectors or natural resources protected are forests, extractive areas and rivers. The management is also divided, there are state and federal conservation units. Our case study was motivated by the interest in protecting the Integral Conservation Unit of the Federal Biological Reserve in Piratuba Lake – REBIO, located in the State of Amapá. This is part of the scope of the United Nations global public environmental policies, given the fact that most of these are world natural heritage sites.

Reasserting, DIAS (2004) in his master's thesis entitled "Participatory Management: an Ecodevelopment Alternative for Biological Reserve Piratuba Lake", discusses the need to preserve Conservation Units, arguing that protected areas are an important instrument of public policies for the preservation of its natural resources, however, biodiversity conservation is part of a long and wide-ranging reflection on the future of humanity, guaranteeing the rights of present and future generations to have access to it (RAMIREZ,2019).

2.1 AMAPÁ INSERTED IN THE AMAZON CONTEXT

The Amapá draws attention to its complex territorial, social, cultural and economic structure. A larger territory than the State of Paraíba, but with only 16 municipalities (PORTO, 2003). A society with a population estimated at 766,679 inhabitants (IBGE, 2015) and with a higher rate of crimes against people and convicted ones than the state of Paraíba, over than 2 million inhabitants (IBGE, 1999). Its cultural formation, somewhat interesting and diverse, is the result of several migratory waves in the decades of 60, 70, 80 and, mainly, of 90.

The Amapá is a consequence of the dismemberment of the State of Pará (QUEIROZ, 2001). Its institutional history began in 1943, with the creation of the Federal Territory, at then the Government of President Getúlio Vargas (SANTOS, 1998). The aim of this project was to occupy the border areas with low population density (PORTO, 2003). In 1988, with the establishment of the new Federal Constitution, the Amapá, becomes a state of the federation. In this way, it grows autonomy, as well as inherits the institutional problems of a state of a third world country. The Amapá is a relatively large state, although with only 16 municipalities, it has a great vegetal and mineral cover, becoming, then, a great attraction for the multinationals and the agribusiness sectors. The interest in exploration in northern Brazil was based on the unequal distribution of manganese reserves in the world space, making Amapá productivity, considering its geographical position close to the major consumer centers, most notably North America, of great political value and economic to the regional and national realities, thus initiating several researches to assess the potential of the field. Once verified its potentiality, the Brazilian Government sanctioned the Decree-Law n. 9,858, dated 09/13/1946, which described the deposit as a national reserve. The placing of *Indústria e Comércio de Minérios Ltda. - ICOMI*, marked the beginning of the industrial and extractive mineral production of the Amazon (PORTO, 2003).

In the 1990s, with the promise of the emergence of new jobs, because of the newly created state, it started a huge migratory wave, which generates even more problems of housing, sanitation and health. With the population swelling the environmental problems appear: diversions, fires, deforestation, extinction of species, emission of polluting gases etc. At this juncture, there are regulatory institutions: State Secretariat for the Environment - SEMA, Institute of Studies and Research of Amapá - IEPA and

a management of the Institute of Environment and Renewable Natural Resources - IBAMA. These institutions helped Amapá to organize its main environmental policies, but also helped to create environmental reserves, which is the subject of our analysis. This institutional project was reinforced by the Sustainable Development Program of Amapá, by the Governor João Alberto Capiberibe 1994-2002 management. The program has two general guidelines: greater aggregation of value to natural products of the State and effort so economic activity respects biodiversity, avoiding its predation (PORTO, 2003). Due to this governmental activity, Amapá is one of the best preserved states of the Amazon: it has 69,485.80 square kilometers of conservation areas, corresponding to 48.4% of the total area of the State. Add to this the demarcation of indigenous lands, 14,965.39 km², representing 10.4% of the State, totaling 58.8% of protected area (PORTO, 2003). Regarding the State of Amapá, the percentage of protected areas is significant, there are 16 UCs. Of this total, 12 UCs[1] were decreed by the Federal Public Power (DIAS, 2004).

One of the major environmental problems of Amapá, mainly in the Conservation Units, it is forest fires and fires. Burns and fires can lead to consequences of difficult reversal. Fire in the Amazon region is seen as a global problem, since its consequences are noted throughout the Earth and felt in various species of the world's fauna and flora, notably due to the emission of CO (carbon monoxide) and CO_2 (carbon dioxide), arising from burning and fires, which directly influence global warming. The author NEPSTAD (1999), in the article about *A floresta em chamas: origens, impactos e prevenção do fogo na Amazônia,* describes a panorama of great value to understand how serious and complex is the fire in the Amazon. Each year, fire in the Brazilian Amazon reaches an area ten times the size of Costa Rica. When farmers and farmers use fire on their land to convert forests into crops and pastures and/or to reclaim grasses invaded by weeds, they inadvertently burn forests, pastures and crops (NEPSTAD, 1999). It is believed that the fires in the Amazon Forest are not recent. It dates approximately 2,000 years ago with intervals of 400 to 700 years of fire intensity. Although, today, it occurs more frequently because of human action.

We can classify the types of fire in the forest in relation to the type of human action and its consequences in: intentional burnings for deforestation are associated with cut down and forest burning; low-level forest fires that are out of control and invade primary forests or previously harvested for

[1] The Piratuba Lake Biological Reserve is one of these. The Federal Conservation Unit of Piratuba Lake is considered one of the most important in the Northern Region. In addition to housing a large and diverse amount of fauna and flora, it serves as a cradle for the reproduction of migratory birds and chelonians. It arose from Federal Decree No. 84,914, dated July 16, 1980, but only in Federal Decree No. 89,932 of July 10, 1984, it definitely has its real limits, as well as its full protection, allowing only visits education, with the prior authorization of the IBAMA. Its location is in the extreme east of the state, within the municipalities of Amapá and Tartarugalzinho, totaling 357,000 ha. It borders the municipalities of Pracuúba and Cutias and is bordered to the north by the Macarri River. To the east it is bordered by the Atlantic Ocean, to the west with a community known as Chameleon and to the south by the Araguari River. Its geographic coordinates are: latitudes of 01˚10 'N and 01˚50' N and between longitudes 49˚34'O and 50˚34'O. (Database: IBAMA)

timber, and fires and fires in areas already deforested resulting from intentional or accidental fire in pastures, fields and farms (NEPSTAD, 1999). By making a brief analysis, we identify that the first form of fire in the Amazon is more ecologically harmful because, in addition to emitting pollutant gases, they destroy important ecosystems, which most of the times do not recover. And in Amapá it would not be any different. Fire coming from both burnings and fires is a major problem for nature and for society. Besides the smoke being harmful to people's health, it can cause closure of airports, destruction of plantations and rare species of fauna and flora.

Another problem that is related to the context of fire, not only of the Amazon, is the utility that the fire has in pastoral agriculture activity. The burning of some areas occurs as a way to prepare the soil for planting, for raising cattle and even to ward off pests. It is precisely in these activities that there is the danger of fire: the lack of control of the fires generates the crimes of fires. Why criminals? Many of these actions happens because some farmers, without authorization to explore protected areas, cause fires, and therefore burned. In other cases, they want to expand their holdings, commonly known as illegal occupation. Still, it can happen accidentally, when those who handle non-criminal burnings do not have the necessary instructions. Fire is so useful that it represents an inseparable component of the expansion of agricultural frontiers. Burning is used as a cheaper method to fertilize the soil of new agricultural areas. Fire converts deforested trees due deforestation into nutrient-rich ashes that are incorporated into the soil, as well as clearing the soil from the tangle of logs and cut down branches (NEPSTAD, 1999).

To Amazon, especially in Amapá, when this lack of control in the fires occurs, it is practically impossible to reverse the situation because of the immensity that is the Amazonian biota. Amapá suffers annually with the fires and the criminal fires, mainly in the periods of July to December, because it is the moment of greater drought in the north of the country.

3 TECHNOLOGY IN FIRE PREVENTION: THE CASE OF THE REBIO PIRATUBA LAKE

Undoubtedly, the environmental problems that plague nature are obvious. In the Amazon region, deforestation - whether due to forest fires or not, or due to anthropic action for pasture - is the environmental problem that causes the greatest impact. In the case of REBIO, in addition to others there is an interesting form fire, although to a lesser extent: the underground. The fact of being underground represents a difficulty that in most cases causes great damage. They are fires that propagate beneath the earth's surface, fed by dry organic matter, peat roots - thin, well compacted, slow-burning and continuous combustion, multiply more rapidly due to the presence of more oxygen in the combustion of the material,

this kind of fire spreads slowly (SILVA, 1998). However, it does not occupy significant importance, since they are difficult to occur, and when they occur can be quickly controlled by *aceiros*[2].

Then said, after understanding a little about the characteristics of the fires in this REBIO we began the process of computational modeling [3] of the area that suffers with the most varied types of fire.

We chose the cellular automaton model as the best way to represent our object of study or environmental system, which is a forest. In view of their characteristics, cellular automata models (AC) for the study of the spread of fire treat the forest as a matrix and fire as a disturbance or state of every element of the matrix that can contaminate its neighbors. Within these computational systems it is possible to study the effects of distances between points and time of fire arrival from one point to another. It is possible to add several variables to the model to make it richer or more realistic, such as: wind, humidity, fuel type or tree wood, among others (BERJAK, 2002; HEARNE, 2002).

Our objective with this work was to model and implement software to simulate fires and computations from individual tree characteristics such as: quantity of wood to be burned or time to burn each tree, temperature required to start combustion of that type the average temperature of the place where the tree is located. The algorithm based on cellular automata also takes into account the inherent variables of the forest environment, treated as a two-dimensional matrix of trees. In this way we will try to get closer to a natural system of this type, but with the minimum of complexity and variables to be controlled.

3.1 THE MODEL

The basic cell for the proposed model of forest burning is a simplified tree generalized as a fuel source surrounded by oxygen, present in the atmosphere. Of the generalized variables used, the most important is the tree temperature, which should be understood as the average temperature or the approximate temperature of the center of the tree, the trunk. The basic idea is that this temperature varies in time following approximately a Gaussian behavior with great characteristic width.

[2] This is a fire control technique widely used by fire brigades. It consists of opening cracks that prevent the contact of a burning area from another that is intact. In this study it was adapted as a variable in the fire-fighting simulacrum.
[3] Computational simulation modeling is one of the most effective tools for studying the relationships between fire, climate and vegetation (KEANE, 2004).

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3.2 STAGES OF THE MODEL EXECUTION

Figure 1: Image of the object in Borland's C ++ Builder 5.0 compiler, whose properties and methods allowed us to graph not only the terrain but also the trees in it.

Figure 2: Image of the object "Vegetation" representing the modeled forest, divided into four quadrants.

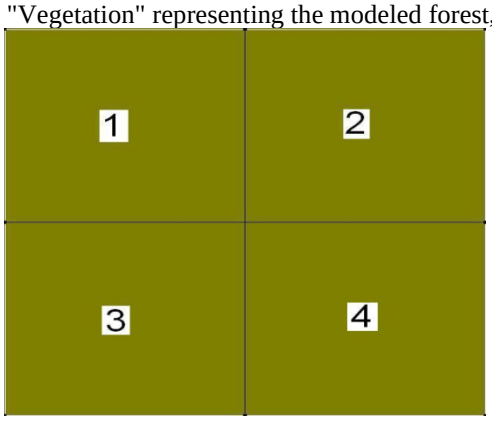


Figure 3: Part of the forest modeled with *aceiros* inserted by the user, to block the advance of the fire.

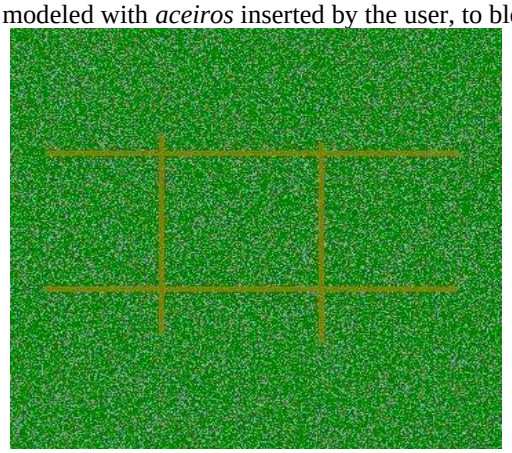
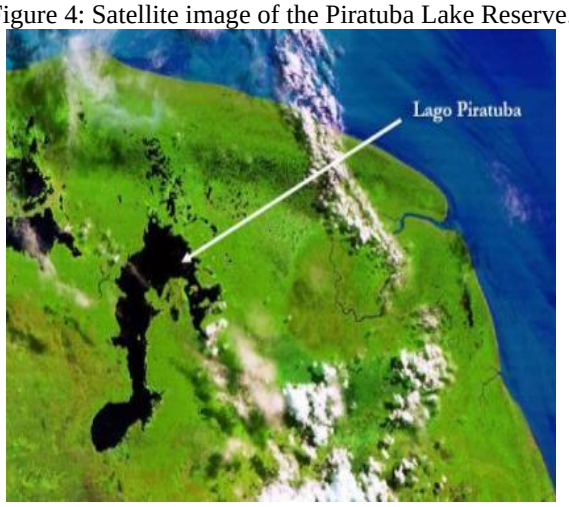
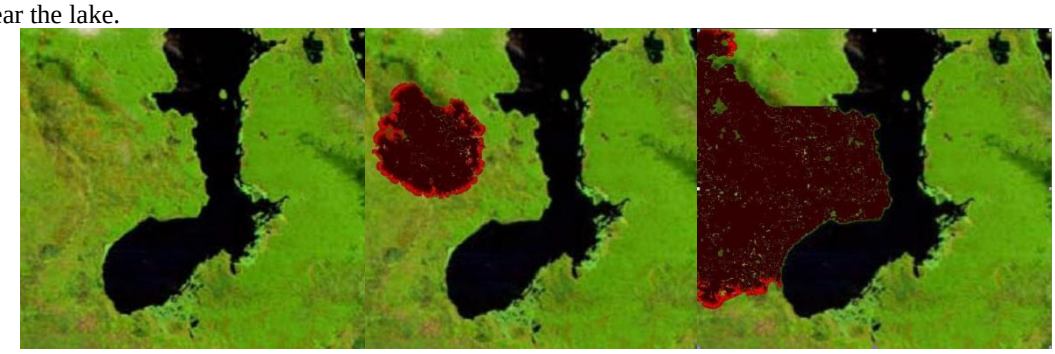


Figure 4: Satellite image of the Piratuba Lake Reserve.



4 APPLICATION AND RESULTS

Figure 5: Satellite image traveled by software. It is observed, essentially, trees of two types, cerrado[4] and equatorial, part of the Piratuba Lake and regions of relief without vegetation.
Figure 6: Simulation of a fire started in the cerrado region, without the presence of *aceiro*.
Figure 7: Simulation of a fire started in the cerrado region, with the presence of *aceiro* preventing the fire from progressing easily up near the lake.



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5 CONCLUSIONS

The main objective of this work was fulfilled with the development of a model and its implementation as a computer program to simulate fires in forests or areas of dense vegetation. A differential point of this proposal is a modeling from the individual characteristics of the smallest unit of autonomy: one or the other. Tests according to a Gaussian model for the temperature of a combustion burn and take in a minimum ignition standard to inflame the wood with self-sustaining fire. There are no charred trees. At that moment all the generated heat is concentrated without a circle of fire without internal areas of cooling. Soon after, the number of trees burned grows more than from burning trees

[4] The *Cerrado* is a vast tropical savanna ecoregion of Brazil. In the eastern region of the Brazilian state of Mato Grosso, gallery forests and *cerrado* can often be found in close proximity to one another, but these plant communities are characterized by a distinct transition in terms of species composition and other characteristics (LENZA *et al*, 2015)

and the area hit by the fire is quickly outdated by charred trees, when the radius of the area of charred trees from twice a width of the fire range .An important finding is that the average temperature values in the radial direction show a Gaussian-like behavior, although the only elements modeled as Gaussian are the historical individual temperatures of each tree in time and not a collective effect along the direction of fire propagation. A more predictable fact was the percentage of around 50% of trees with greater fire immunity to prevent it from spreading in the forest.

The initial motivation for this work had to do with fires in the Amazon forest, but we concluded that this program can be well used by planted forests or agricultural plantations, such as sugarcane. Several other types of parameters can be studied with this software, easily considering other types of trees, not just two as we did; place multiple fire points at different points; studies of propagation dynamics such as speed and acceleration of fire under different conditions of vegetation or obstacles. Finally, we can apply the capabilities of this software to real or satellite aerial images and do tests where they can be very useful for firefighting or fire control services and be able to add artificial obstacles such as *aceiros.*

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