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The ForestWatchers: A Citizen Cyberscience Project for Deforestation Monitoring in the Tropics

EDUARDO F. P. LUZ, Centro Nacional de Monitoramento e Alertas de Desastres Naturais (Cemaden), São José dos Campos, Brazil

FELIPE R. S. CORREA, Instituto Nacional de Pesquisas Espaciais (INPE), São José dos Campos, Brazil

DANIEL L. GONZÁLEZ, Crowdcrafting.org, Spain

FRANÇOIS GREY, Citizen Cyberscience Centre (CCC), Geneva, Switzerland

FERNANDO M. RAMOS*, Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil

ABSTRACT

Millions of hectares of humid tropical forest are lost each year. Here we introduce the ForestWatchers project, a citizen cyberscience initiative that proposes to involve citizens around the globe in monitoring deforestation. ForestWatchers combines volunteered thinking with participatory sensing. In the project's volunteered thinking segment, volunteers with their own smartphones, tablets and notebooks, are asked to use a Web interface to review satellite images of forested regions, and confirm whether automatic assignments of forested and deforested regions are correct. In the participatory sensing segment, citizens are invited to contribute numerous types of data on the status of forested areas, such as pictures, videos or sound records. As the first forest-monitoring program to directly involve lay citizens in tropical forest monitoring, the ForestWatchers project aims at providing volunteer-assisted deforestation assessment for countries, regions or communities that do not have the necessary infrastructure or manpower to do so otherwise.

* Corresponding author: fernando.ramos@inpe.br

1. RELEVANCE AND GOALS

Tropical forests provide invaluable climatic, ecological and social services. They sustain numerous indigenous cultures and provide habitat for most of the world's known terrestrial plant and animal species. Tropical forests have a significant influence on the Earth's climate, both as carbon sinks and as a source of atmospheric carbon dioxide. In spite of their relevance, these ecosystems are under increasing threat worldwide. During the last few decades, several million hectares of humid tropical forest have been lost each year (MEA, 2003). Gross carbon emissions due to deforestation across tropical regions contributed to 6–17% of global anthropogenic CO2 emissions to the atmosphere (Harris et al., 2012; Baccini et al., 2012).

Despite these trends, information about the world's forest remains limited and unevenly distributed. Few developing countries undertake forest inventories as part of regular monitoring schemes (MEA, 2003). However, this situation is beginning to change. On one hand, with freely available data coming from different satellites and instruments, efficient algorithms for image classification, and increased connectivity and computing power, deforestation monitoring is no longer a technical challenge (Hansen, 2008). On the other, international policy initiatives, such as the United Nations Framework Convention of Climate Change Reducing Emissions from Deforestation and forest Degradation (REDD) program, are pushing more and more countries to invest in their own national forest monitoring schemes. In the last 5 years, for example, countries like India, Thailand, and Indonesia have begun using satellite data to monitor their forests. In 2013, the first global map with detailed information on forest change was launched, covering the period from 2000 to 2012 on a yearly basis and at a spatial resolution of 30 meters, with data freely available for registered users (Hansen et al., 2013).

Brazil has the longest and most successful tropical forest-monitoring program in the world (Kintisch 2007; Brown and Zarin, 2013). Since 1988, the well-known PRODES (Brazilian Amazonian Forest Monitoring by Satellite) program has been carrying detailed annual deforestation surveys in the Brazilian Amazon. PRODES uses a semi-automated procedure to perform the digital processing of TM/Landsat images. More recently, the DETER (Real Time Deforestation Detection System) program has been providing weekly alerts of deforested areas of 25 hectares or more, using MODIS (Moderate-Resolution Imaging Spectroradiometer) imagery from NASA's TERRA and ACQUA satellites. Overall, this monitoring framework, together with a free and open data policy (all software and results are available on the Web), enabled greater transparency and effectiveness in Brazil's conservation efforts, and helped the country to greatly reduce its annual forest loss in the Amazon (INPE, 2013; Hansen et al., 2013). However, both projects involve visual inspection of satellite images by specialists, which make difficult their replication in less developed countries.

Despite the proliferation of new monitoring technologies and remote sensing systems, deforestation levels remain too high. From 2000 to 2012, approximately 74 million hectares of tropical rainforests were lost or heavily degraded (Hansen et al., 2013). The causes of deforestation in the tropics are many and complex. They probably include, in addition to well-known factors such as population growth, poor governance, and increased consumption of primary products, the lack of efficacy of current conservation policies. In other words, the task of protecting for future generations an adequate share of the world's remaining tropical forests may be outside the reach of traditional conservation strategies alone, whose usual "top-down" approach, without much involvement from local stakeholders, does not encourage citizens and communities to be engaged in forest preservation efforts.

Today, regardless of the growing public awareness of the plight of tropical forests, it is difficult for concerned citizens to help preserve them. Here, we describe the ForestWatchers project, a citizen cyberscience initiative that proposes to involve citizens around the globe in monitoring deforestation. They will be able to do this from the comfort of their own homes, using a Web interface to review satellite images of forested regions, and confirm whether automatic assignments of forested and deforested regions are correct; or on the ground, uploading deforestation-related data such as pictures taken with their smartphones. The project goal is to evaluate in a rigorous scientific fashion the benefits and limitations of public participation via the Web in this sort of exercise, by comparing results obtained from many volunteers, for example by statistical averaging or merit-based systems, with results from deforestation mapping by experts.

The observation that aggregated responses of a group of individuals are as good as and, in some cases, better than the answers given by a single individual in the group is often called "The Wisdom of Crowds" (Surowiecky, 2005). In citizen science projects, error and frauds are handled by the system's intrinsic redundancy (Ipeirotis et al., 2010), since many volunteers perform the same task. One of the first frameworks that implemented these ideas is BOSSA, an open-source software project for distributed thinking that deal with the variance of volunteer skill (Anderson et al., 2014). Based on this finding, several projects used crowdsourcing for producing or processing geographical information; for details, see Antoniou et al. (2010), Goodchild (2007) and Soares (2011). However, to our knowledge, ForestWatchers is the first to use volunteers to perform deforestation monitoring-related tasks. Based on the open source crowdsourcing platform PyBossa (PyBossa, 2014), ForestWatchers is being designed to be easily scalable and replicated.

Multilateral frameworks such as the REDD+ Partnership, the Forest Carbon Partnership Facility (FCPF) of the World Bank and various bilateral agreements underpin many investments to reduce emissions from deforestation, forest degradation and associated land use change. ForestWatchers will be able to support national governments in determining the effectiveness of their conservation actions, a widely accepted pre-requisite for countries to participate in international agreements and incentive mechanisms related to forest carbon stocks preservation. At the local level, the project's potential beneficiaries include national forest management agencies, protected area managers, scientists and other stakeholders with interests in forest and biodiversity protection. In this case, ForestWatchers' main goal is to help local users adapting their conservation strategies in order that their frequently scarce resources are deployed where action is most urgently needed. To this end, ForestWatchers will provide a simple and intuitive graphical Web interface for reporting on deforestation hotspots, query-able for time-periods and administrative regions (countries, provinces, protected areas, etc). Full access to deforestation maps and databases for transparency and inter-operability with other forest monitoring systems is also being considered. Finally, a series of workshops and events in geographically representative countries will provide scientific training, build indigenous capacity and improve public awareness.

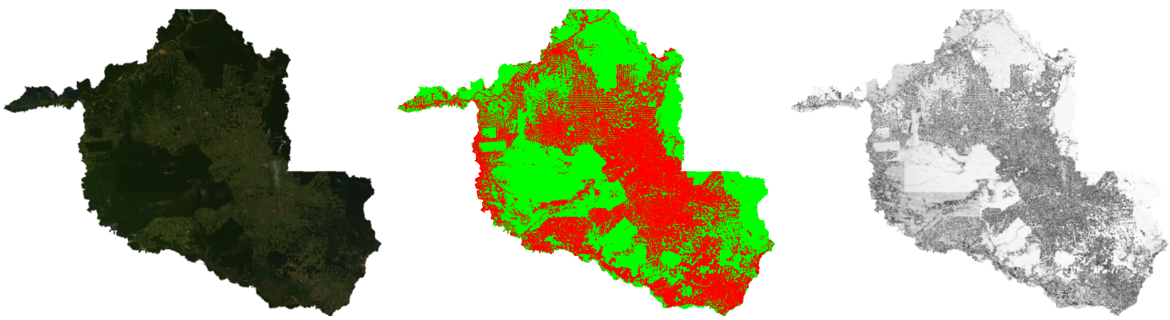
There is ample empirical evidence from other citizen science initiatives that a project like the ForestWatchers can attract a considerable number of volunteers. In general, their motivation is to learn more about science and get a chance to participate in a scientifically or socially relevant initiative. In Galaxy Zoo, one of the most successful citizen science projects, volunteers help to visually classify galaxies according to certain pre-defined patterns. In a matter of months, more than 100 million tasks were completed by a pool of hundreds of thousands of registered participants of the Galaxy Zoo project (Raddick et al., 2010; Lintott et al., 2008). Closer to our context, a small-scale experiment with one of the first ForestWatchers' components (BestTile, the cloud removal tool) attracted more than 500 volunteers from all five continents (Arcanjo et al., 2014).

2. FORESTWATCHERS GENERAL FRAMEWORK

Citizen cyberscience is a term used for a range of online projects in which individual volunteers or networks of volunteers, many of whom may have no specific scientific training, perform or manage research-related tasks such as observation, measurement or computation. It offers a low-cost way to both strengthen the scientific infrastructure and engage members of the public in science. According to Haklay (2013), there are three subcategories of citizen cyberscience: volunteered computing, volunteered thinking, and participatory sensing.

ForestWatchers combines volunteered thinking with participatory sensing. In volunteered thinking, citizens are asked to contribute with their cognitive capabilities. Participatory sensing involves the use of volunteers' hardware to sense the environment. Some mobile phones, for example, have up to nine sensors integrated into them, including different transceivers (mobile network, WiFi, Bluetooth), FM and GPS receivers, camera, accelerometer, digital compass and microphone. It is estimated that mobile phone users send and receive 1.3 exabytes of data and each household consumes 375 megabytes of data (Hsu, 2014).

In the project's volunteered thinking segment, volunteers with their own smartphones, tablets and notebooks, are asked to use a Web interface to review satellite images of forested regions, and confirm whether automatic assignments of forested and deforested regions are correct. The volunteered thinking module uses free MODIS imagery from NASA's TERRA and ACQUA satellites. This instrument has a viewing swath width of approximately 2,330 km, a revisit time of roughly 1.5 days, and a spatial resolution of 250 meters (Figure 1a). MODIS pixels are automatically classified into one of two classes, "Forest" (green) and "Non-forest" (red), generating a deforestation map like the one shown in Figure 1b. The latter class includes clear-cut deforested areas (pastures, savannas, crops, abandoned lands, etc.) and water bodies and rivers, urban areas and remaining cloud areas. The classification algorithm is based on a Simple Fuzzy Multilayer Perceptron (SF-MLP) artificial neural network (Looney and Dascalu, 2007), with backpropagation learning. MLPs are used in a wide range of applications, including pattern recognition and classification (Haykin, 1998). Essentially, a MLP network is a feedforward multilayer mechanism that uses a supervised learning model based on the adjustment of its internal weights according to the error between the actual and desired outputs of the network. In a SF-MLP, outputs are within the range [0, 1], and represent the degree of membership of the input pattern to each output class. Outputs also provide a simple and effective metric of classification confidence, in the sense that an (almost) evenly distributed output across the classes F and N denotes that the network has a low degree of confidence in its classification result. ForestWatchers uses this confidence metric to drastically reduce the volunteers' workload, sending for inspection only those pixels whose classification confidence level is below a given threshold (darker pixels in Figure 1c).



(a) (b) (c)

Figure 1. ***(a) MODIS image of Rondônia State, Brazil (mid 2011); (b) corresponding classification map with forested areas in green; (c) classification confidence map.***

The learning process involves the minimization of the mean square error between calculated and desired outputs, for a given input. The training data includes PRODES deforestation maps and corresponding MODIS images. Volunteers perform their tasks by means of the interactive interface shown in Figure 2. This interface, which contains a quick tutorial and all necessary information and tools for volunteers to easily perform their task, was developed using HTML/HTML5, JavaScript, Bootstrap and OpenLayers technology. It is functional on five platforms (Android, iOS, Windows, Windows Phone, Linux, Mac OS X) and two browsers (Chrome and Firefox). In a typical task, volunteers confirm or correct the class assigned by the SF-MLP to an area of 3 by 3 pixels (approximately, 56 hectares). The interface allows volunteers to zoom in or zoom out, and to adjust the brightness and contrast levels of the satellite image. Each task is simultaneously presented to several of volunteers. The class voted by the largest number of volunteers is chosen (ties confirm the automatic assignment). More sophisticated strategies for handling malicious behavior and outliers, and ranking and rewarding volunteers, are under development. Inspected images are aggregated as up-to-date deforestation maps, freely available on the project's Web page. If necessary, warning messages may be sent to the pertinent authorities and local appropriate stakeholders.

***Figure 2.* ForestWatchers' volunteered thinking user interactive interface.**

In the project's participatory sensing segment, citizens are invited to contribute with all sorts of data on the status of forested areas, such as pictures, videos, sound records, tracking data and measurement time series (temperature at a given location, for example). Targeted areas might be an indigenous reserve in the Amazon, a national forest in Borneo or a park in Queensland. Whenever a volunteer upload a picture or a video, an automatic procedure extracts the relevant pieces of information (device ID, date and time, latitude, longitude, height, etc.), and places it on its location on the global map, alongside with, satellite images, deforestation maps and other data (Figure 3). This procedure allows citizens to complement and eventually validate deforestation maps produced with ForestWatchers' volunteered thinking segment.

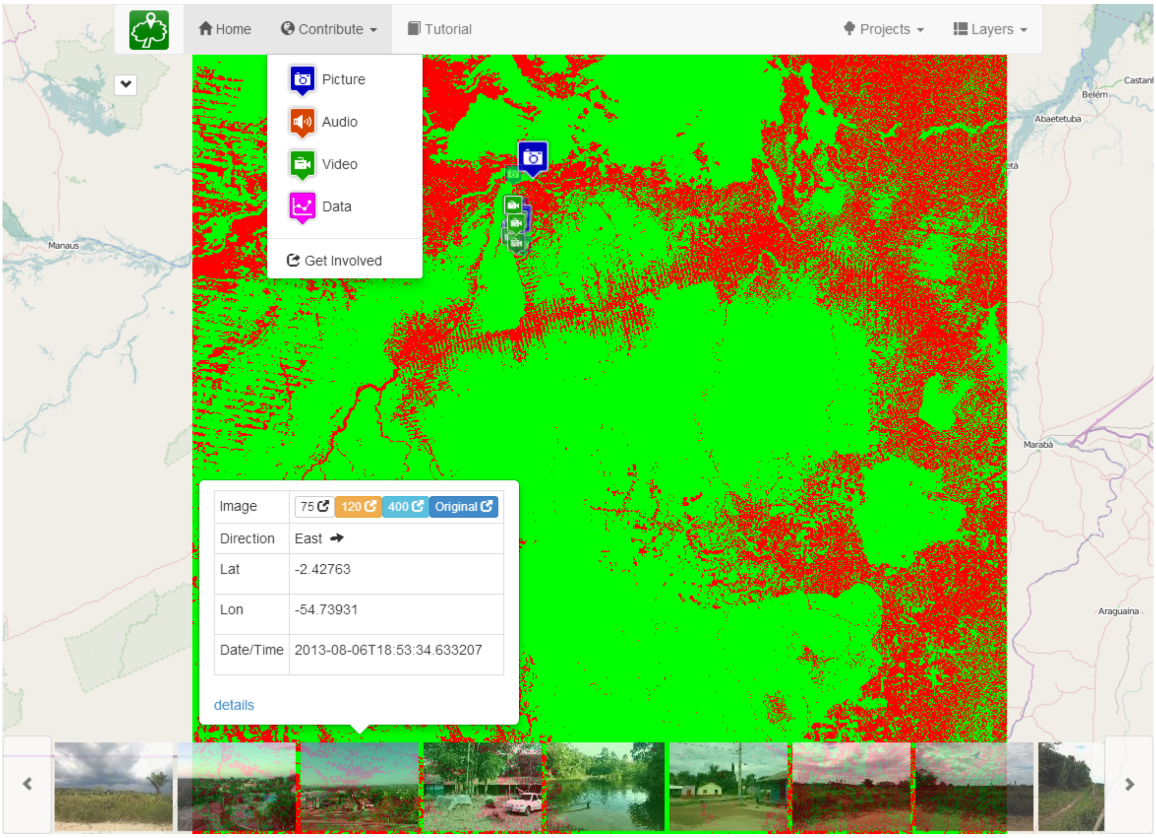


Figure 3. ***ForestWatchers' participatory sensing Web interface with deforestation map for Rondônia State, Brazil.***

ForestWatchers underlying crowdsourcing computational framework is based on the open source platform PyBossa (PyBossa, 2014). PyBossa development was inspired by BOSSA (Westphal, 2007), a crowdsourcing engine derived from BOINC, the Berkeley Open Infrastructure for Network Computing (Anderson, 2004). PyBossa is implemented with a RESTful API, which permits to easily distribute, collect, maintain and retrieve data, coming from a large pool of volunteers in different formats. PyBossa automatically generates several relevant statistics concerning tasks implementation and citizen participation.

3. FUTURE WORK AND CONCLUSION

ForestWatchers is based on the spirit of the 1992 Rio Declaration on Environment and Development, which preconizes in its Principle 10 that "environmental issues are best handled with participation of all concerned citizens". As opposed to initiatives like the Global Forest Watch (GFW, 2014), which require large scale computing resources, ForestWatchers proposes a “bottom-up” approach, with data and tools freely available on the Web. As the first forest-monitoring program to directly involve lay citizens, when fully operational the ForestWatchers project aims at providing volunteer-assisted deforestation assessment for countries, regions or communities that do not have the necessary infrastructure or manpower. Currently, both its segments – volunteered thinking and participatory sensing – have been concluded and tested with a small number of volunteers. The next steps include integrating the two segments in a single platform and performing a large scale of the integrated system, in selected forested areas in South America, Central Africa and South East Asia.

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