The Roots of Power

Forest Fire Detectors Can Be Powered by Electricity Produced by Trees

by Chris Holt

Every year millions of square kilometres of the world's forests are destroyed by fire resulting in huge economic costs, tremendous damage to the environment, destruction of property, loss of timber, and loss of life. Anywhere in the world where there is vegetation subjected to extended hot, dry periods there are frequent fires. This is approximately one third of the land surface of the Earth with Australia, Southeast Asia, South Africa, the United States and Canada all badly affected. In the USA alone there are typically 100,000 forest fires each year destroying around 20,000 square kilometres of forest.

The environmental damage does not stop at the destruction of trees. Forest fires destroy organic nutrients and result in an increase in water runoff so creating the condition for flash flooding. Wind erosion of the burnt forest can strip away the ash and then strip away the exposed soil. In the rainforests fires can threaten the valuable collection of diverse species.

In recent years global warming has increased the frequency and intensity of forest fires as the vulnerable regions become warmer and drier. And the forest fires themselves contribute to the warming. It has been estimated that the forest fires in Indonesia in 1997 released 2.5 billion tons of carbon dioxide into the atmosphere.

Forest fires can be more easily controlled if they are detected at an early stage whereas once a fire is well established it may take weeks or even months to extinguish. So early detection is very important. There are methods in use for detecting the start of forest fires but none of these is entirely satisfactory. The US Forest Service uses remote automated weather stations to detect and predict the course of forest fires. But these are expensive and because they are sparsely distributed fires can burn for some time before they are detected. Sensors which measure temperature and humidity could also be used but manually recharging or replacing batteries in remote locations makes this impractical. Solar powered sensors avoid some of these problems but these have to be located in forest clearings to collect sunlight and can become overgrown with shrubbery. So the underlying problem is how to generate electricity to run detection systems in locations hundreds of miles away from an electricity grid.

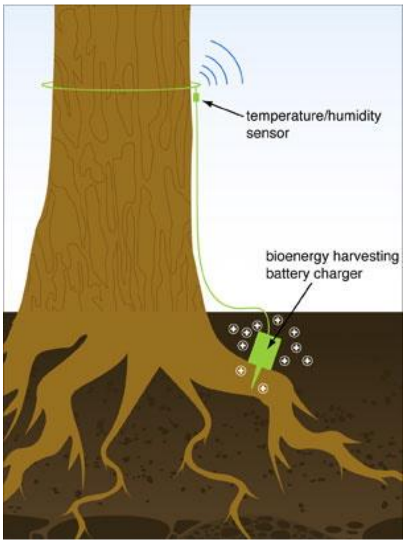
Now a system has been developed that gets round the problem: detectors have been devised which are powered by electricity generated from the metabolic energy of the trees themselves. It has long been known that there is a voltage difference between trees and the adjacent soil. Until recently the origin of the voltage was not known nor was it clear that such a voltage could be put to practical use. Recently Christopher Love and others at MIT have been investigating this phenomenon.

Love examined the voltage difference between a potted *Ficus benjamina* tree and its soil and obtained voltages of 50-200 mV. The tree and apparatus were placed in a Faraday cage to eliminate spurious voltages generated by radio waves, lightning and power line noise. One possible explanation for the voltage difference was the use in earlier studies of different metals for the two electrodes, tree and soil. This would result in a galvanic voltage so that the tree-soil system worked as a battery, like the "lemon battery" where dissimilar-metal electrodes are inserted into a lemon and generate a voltage. However this explanation was easily discounted when significant voltages were detected when identical platinum electrodes were inserted into the tree and the soil.

In the past people have proposed that the voltage is due to a streaming potential, that is, the voltage developed when an electrolyte flows through a channel which has charged walls. It was supposed that the observed voltage was due to the flow of the sap through the xylem of the tree. However when Love and his co-workers stopped the sap flow by inserting razor blades above and below the electrode position the voltage persisted. And a voltage was still observed between the severed branches of the tree and the soil.

The MIT group concluded that the voltage difference is due to the difference in pH between the tree and the soil. This is effectively a concentration cell where the voltage depends only on the relative concentrations. The pH of the soil was manipulated and it was seen that the voltage increased with the pH difference plant-soil. When solutions with varying pH were substituted for the soil, it was seen that the relationship between pH difference and voltage was identical to that obtained with soil. There was no significant change in the voltage difference with time of day, illumination, sap flow, changing height or orientation of electrode placement around the tree which is consistent with a mechanism depending only on pH.

This suggests that trees could be used to generate small electric currents which, over time, would charge up a battery to be used for low power, pulsed, distribution systems remote from the electricity grid. The batteries could run forest fire detectors allowing a much denser distribution of sensors than can presently be achieved.



The MIT workers set up a small company, Voltree, to exploit the idea. They ran a field trial in May 2009 in collaboration with the US Forest Service. Five sensors were set up in a forest in Idaho and trees generating 50 to 300 nanowatts were used to trickle-charge batteries to run low-power circuits. Enough power was generated over time to give a battery output of 1.1 volts and the batteries were used to power sensors which used only one nanowatt in sleep mode. The sensors measured air humidity and temperature and could send data four times a day or immediately if there was a fire. The sensors had embedded wireless transmitters which sent data signals from one sensor to another until they reached a central monitoring station which was up to a quarter of a mile away. These stations provided a satellite microwave uplink connection for the collected information. They claim this system could run for 20+ years without maintenance. The trial was completed successfully and the US Forest Service is now planning a much larger trial of five network systems for evaluation in various forests in the USA.

There is a interesting lesson here for those bodies which fund research. This project started out as curiosity-driven experiments but has now developed into a system which may have the potential to significantly reduce the damage done across the globe by forest fires. Governments are keen to push scientists towards what they see as business-friendly research. But the fruits of research are often unpredictable and attempts by governments and funding bodies to influence the direction of research will probably be counter-productive. It’s usually unclear where research will lead, or as Albert Einstein said “If we knew what we were doing, it would not be called research, would it!”

Dr Chris Holt is a retired member of The Institute of Physics

<u>Further reading:</u>

Love CJ, Zhang S, Mershin A (2008) Source of Sustained Voltage Difference between the Xylem of a Potted *Ficus benjamina* Tree and Its Soil, PLoS ONE 3(8):e2963. Doi:10.1371/journal.pone.0002963

Bioenergy Harvester: http://voltreepower.com/bioHarvester.html