8 Acoustics for Fire Control in Forest

For several years, the number of forest fires all over the world has been increasing. Three main factors are responsible for this phenomenon: long-term drought, the effect of pollution which determines the decline and decay of trees, the formation of loose canopy and the lush growth of grasses which are very inflammable; and another factor is the increasing presence of tourists in forests. For more than 25 years, different remote sensing techniques have been used in forestry (Hildebrandt 1980; Suzuki et al. 2000; Courtier et al. 2001; Angelis et al. 2002).

The remote sensing techniques employ electromagnetic energy (wavelengths from ultraviolet to radio regions) and allow the measurement and analysis of the radiations reflected, transmitted, absorbed and scattered by the atmosphere, by the hydrosphere and by materials on the land surface, for the purpose of understanding and managing the Earth's resources and environment. The first step in the development of remote sensing for the management inventory of forest condition and mapping was oriented to the development of techniques for aerial photos with thermal imagery (e.g. infrared color photos). Radar imagery was also developed, especially for use under difficult meteorological conditions (zone very cloudy or hazy, night observations, etc.). The development of high-resolution imagery obtained with satellites has enormously contributed to the survey of tens of thousands of square kilometers on

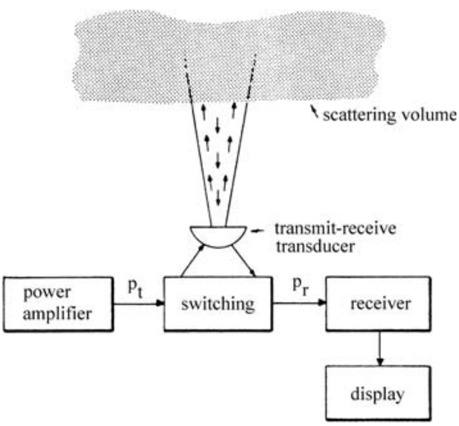

Fig. 8.1. Monostatic acoustic sounder (Beran 1975). Reprinted with permission from the Society of American Foresters, copyright 1975

one image. Regular inspection of the same area with recordings in different wavelengths provides information on the state of forest resources, evaluation of damages, monitoring post-fire forest activities, reforestation and the regeneration of natural forests.

To my knowledge, the first article on acoustic methods for forest fire control was published by the *Journal of Forestry* in 1975 (Beran 1975). The acoustic echo sounder operates as shown in Fig. 8.1, using a single antenna which first transmits a pulse and then switches into receiving mode to collect the

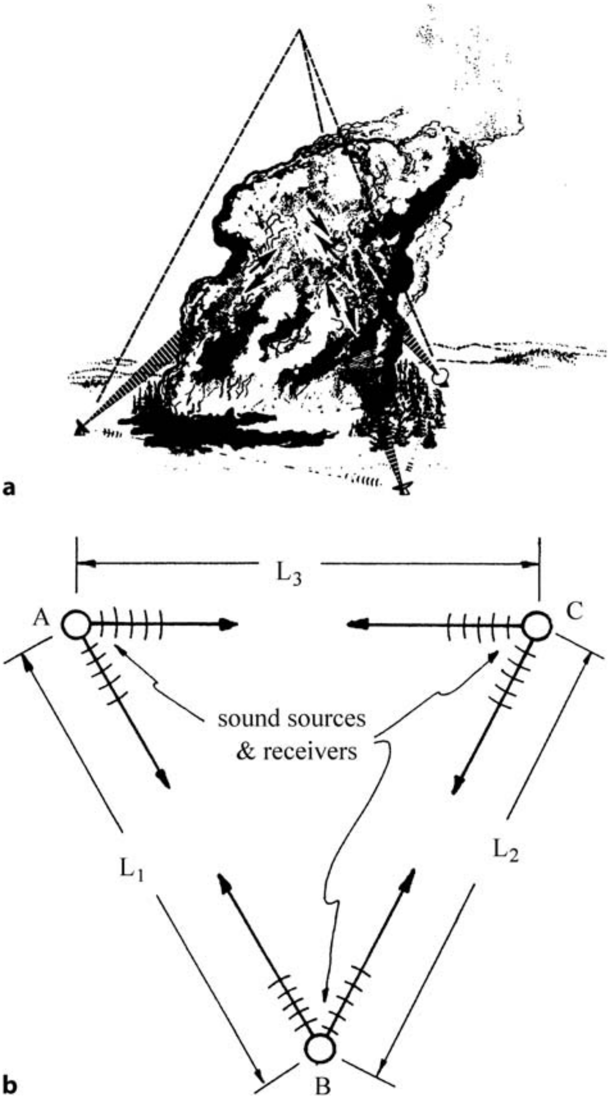

Fig. 8.2. Disposition of receivers for measuring the wind which drives the vortex (Beran 1975). **a** Tridimensional view. **b** Horizontal disposition of the sensors. Reprinted with permission from the Society of American Foresters, copyright 1975

backscattered sound. Variations in the intensity of the signal, directly related to atmospheric turbulence along the path of the original pulse, are recorded as a function of time and indicate the velocity of sound propagating in this field. If three sensors are used, sound scattered from fluctuations in wind turbulence can also be detected. The thermal structure of the boundary layer can be deduced from the monostatic system. The transition from a stable air zone with a horizontal stratification to unstable regions characterized by vertically oriented regions can be identified (Fig. 8.2).

High-quality images and data about the internal structure and external environment of fires and convection columns are necessary for forest fire control. The development of a smoke column in real time, by observing forest fire plume behavior with Doppler lidar (10.6 μm wavelength) and Doppler radar (3.2 cm wavelength), was reported by Banta et al. (1992). The Doppler effect (which is a shift in the acoustic frequency between source and receiver, caused by their relative motion) has been used to detect the kinematics of the convection column and to monitor the smoke plume. The Doppler lidar, which uses a light transmission pulse instead of a radio frequency wave for radar, allows estimation of the radial component of the wind speed. Simultaneous utilization of lidar and radar with two different wavelengths gives information about the size, shape and distribution of particles inside and near the convection column. At the same time, data about topography can be obtained. Tridimensional datasets on kinematics and smoke distribution in the vicinity of the fire helps understanding of the convection column dynamics and smoke plume development.

Satellite data collection and the development of synthetic aperture radars (which are very sensitive to forest biomass), together with the development of multi-frequency microwave sensors for fire and forest monitoring at a local and global scale, are important challenges for the monitoring of forest ecosystems in the near future.