2.4. SPACE MONITORING OF FIRES AND FIRE RISK

2.4.1 PRESENT CAPABILITY

Fire susceptibility:

Fire susceptibility can be derived from many sources. Among them are the daily images obtained in the afternoon by the AVHRR sensor, on-board the NOAA series meteorological satellites. They orbit the Earth at about 840 km and have a ground resolution of about 1 1km At least two of these satellites have been kept operational simultaneously in the last 25 years; this same configuration is anticipated in the future.

A quantity known as the "Normalized Difference Vegetation Index" (NDVI) is derived from the AVHRR images and 15-day composite mosaics are used to monitor the vegetation. Different methods exist for generating NDVI values, depending on how many AVHRR channels are used and how they are combined These values are useful mainly for regions with a marked dry season or phenology cycle, when strong vegetation stress develops. The fire susceptibility risk index is obtained by comparing NDVI values of stressed and normal vegetation. Australia, Brazil, Canada and the USA use such techniques as input in fire risk assessment.

NDVI values are prepared for the land areas of the planet by NOAA, and NASA also generates NDVI databases. The European Space Agency (ESA), in the Monitoring of the Tropical Vegetation group, Ispra, Italy (MTV, 1998) and many regional weather and remote sensing institutions in the world also generate NDVI values. AVHRR receiving stations today cost less than US$10 000, and the images are received at no cost from the satellites, making the use of this technology attractive. Application of NDVI to tropical regions would greatly improve the capability of identifying fire prone regions and vegetation.

In 1998 the National Space Development Agency of Japan, NASDA, launched the satellite for the Tropical Rainfall Measuring Mission (TRMM) (NASDA, 1998). The data from this satellite, combined with rain gauge networks, can be used to assess the precipitation density and from it, the fire susceptibility due to droughts. Although the rain data are available, there is still a need to develop a strategy for using these data for fire susceptibility determination.

Fire monitoring:

Four different types of satellites are currently used to detect fires, although none was designed or is fully fit for this purpose. Nevertheless, the information from these satellites is valuable in regions of the world where poor regional fire monitoring or control exists.

AVHRR images in the mid-infrared band (3.7μm) are particularly sensitive to the temperatures of fires in general and have been used successfully by many countries in different parts of the world (Setzer and Malingreau, 1996). Published field validation of AVHRR fire detection data in Africa, Amazonia (Brazil), Australia, Europe, and Southeast Asia corroborate the high effectiveness of this technique. Brazil, for instance, has had a near-real-time fire detection programme for 15 years, with acknowledged results. Examples of world fire emissions for periods of many months were made at the NASA Goddard Space Flight Center (SFC, 1998) and at the Joint Research Center (MTV 1998). At least four images per day anywhere in the world can be used, and although the image resolution is about 1.1 km, fire fronts over 30 m will be detected if no water clouds are in the satellite line of sight. Some sections of the images in the afternoon overpasses will present false signals, because of heated soil surfaces (rocks, sand) for some regions in specific seasons.

Application of the data to fire fighting and to monitoring hazards from biomass burning requires real-time processing of the AVHRR images. This can actually be done in the field, or in sites up to 2000 km away, where communication with field personnel is possible. As in the case of the Vegetation Index, reception of AVHRR images is relatively simple and low cost.

Fire detection with geostationary meteorological satellites 36 000 km away (such as GOES) is still in the experimental phase at the University of Wisconsin, USA, and at the National Institute of Space Missions in Brazil (UW, 1999; INPE, 1999; INPE-CPTEC, 1999); only one validation case was reported. The ground resolution of the mid-infrared channel at 4 µm that detects the fires is 4 km, and therefore only the largest fire fronts can be detected. However, the temporal resolution of 30 minutes makes this a unique and mandatory resource for fire monitoring. Geostationary images are received in real time by many weather centers and universities around the globe with stations that require individual decoders. Costs are in the US$ 150 000 range.

The European Space Agency (ESA) operates the Along Track infrared Scanning Radiometer (ATSR) on board the ERS-2 radar satellite (ESA Remote Sensing satellite), that has also been used to detect fires (ESA, 1999). The sensor is very similar to AVHRR, but its mid-infrared band has a lower saturation limit that prevents its use during daytime: another important limitation is that the same site is imaged only once every three days, a constraint in many fire events. Direct observations of satellite signals require investments of significant amounts of money and a good technical staff

Images of the US military Defense Meteorological Satellite Program (DMSP) satellites have also been used to monitor fires around the globe (DMSP, 1999). In this case only nocturnal images are applicable since the sensor is sensitive to light and not heat. Moon-lit nights preclude use of the images. Reception and processing of the data are restricted and will be done only upon special request through DMSP. Only one case of field validation for vegetation fires has been reported, and the confusion of fires with isolated and non-steady lights is still controversial.

Analysis systems that combine AVHRR satellite fire data with high resolution satellite (Landsat, SPOT, Radarsat) imagery, as well as meteorological and cartographic data, have also been implemented in geographical information systems for use in near real time (USGS, 1999b; Walker, 1996; MIDAS, 1997a; MIDAS, 1997b; CSA/NASA, 1997; CSA 1999a). A leading example in this case is the Brazilian "Proarco" effort for South Amazonia (IBAMA, 1999). Access to this system has facilitated logistical decisions, fire control strategies, and guidelines for policy makers.

Detection of emissions:

The AVHRR sensor was not designed to monitor aerosols. But techniques to measure the aerosol total column loading from AVHRR observations were developed and demonstrated for biomass burning in Brazil (Kaufman et al., 1990) From the AVHRR count of the number of fires and the aerosol loading in $\mu g/cm^2$, the authors estimated the total emission of smoke particles from a group of well identified fires and calculated the rate of emission of smoke particles per fire.

This procedure cannot be applied in every case. It requires the smoke to be transported by wind in a given direction from the fire (which requires wind speed of at least 3-5 m/s), over a dark surface such as water or vegetation. Note that the derived concentrations are of the entire vertical column, rather than ground level concentrations. However, in most cases of large smoke episodes a high pressure meteorological system develops with strong capping inversion and well mixed smoke under it. Therefore the ground concentration should be well correlated to the vertical column concentration. The ratio between the two will depend on the height of the inversion, and that may vary seasonally from one region to another. Regional studies of the ratio of the column concentration to the ground concentration are required to establish this ratio.

Although the applicability of the AVHRR method was demonstrated, there is presently no operational application of the method in any region. Note that the method should be applied manually in every case. To implement the method, the satellite data have to be received by a local receiving station and the necessary software should be in place to analyze and interpret the data. Together with meteorological information, the satellite data can be used to generate a statistic of the number of fires, derive the column aerosol concentration and, with the wind speed, infer the rate of emission of smoke from the fires. Since the AVHRR data for aerosol studies are available only once per day, the diurnal cycle of the fires and smoke should be studied using data from the Geostationary satellites (GOES or METEOSAT). Demonstration of the use GOES was performed at the University of Wisconsin (Prins et al., 1996, 1998). Information on METEOSAT is given by Cresswell (1996)

In some cases it may not be clear if the observed pollution comes from vegetation fires, or whether it is aerosol from urban pollution. To distinguish between them, a combination of AVHRR and Tropospheric Ozone Monitoring Satellite (TOMS) data can be used. TOMS is sensitive to the aerosol absorption of solar UV radiation scattered in the atmosphere. Since the scattering takes place in the whole atmospheric column, absorbing aerosol particles located higher in the atmosphere will have more scattered UV radiation to absorb, and their effect on the TOMS signal will be stronger. Thus, TOMS is not sensitive to aerosols from urban pollution, including sulphate particles, (in the lowest 1.5 km), and the value of the TOMS aerosol index depends on the assumed height of the aerosol. In contrast, AVHRR measures the light scattered by the aerosol particles and therefore measures both smoke and urban pollution But since sulphate particles do not absorb solar radiation, TOMS and AVHRR data permit smoke to be distinguished from urban pollution.

Neither AVHRR nor TOMS data can be used to estimate the aerosol size distribution, even though both are sensitive mainly to sub-micrometre aerosols.

TOMS data are designed to monitor tropospheric ozone, using a method similar to that described for monitoring aerosol. Here also an assumption on the vertical distribution of ozone has to be made. The accuracy of results depends heavily on this assumption.

2.4.2 CAPABILITY 1-2 YEARS FROM NOW

Fire susceptibility:

Many new remote sensing satellites and sensors are scheduled to be launched in the next two years by Brazil, Canada, China, Europe, India, and also within the frame of multi-national cooperation. Their data should increase the spatial, radiometric and temporal resolution of values indicating vegetation stress and fire risk. An improvement in the fire risk prediction is therefore expected, although along the same scientific rationale developed from the pioneering AVHRR work.

Because of these new satellites, the time needed to gather enough data on the vegetation cover over most of the planet may be reduced from 15 days to 10 days (without cloud cover or poor imaging conditions), and with a ground resolution of a few hundred meters. Institutions currently providing vegetation stress data derived from satellites are preparing the algorithms and processing of future data; from an user point of view only the capability to receive the new data via Internet should be upgraded.

The new satellites and sensors will also provide estimates of burnt areas, most needed information for evaluating the impact of fires in terrestrial and atmospheric environments. At present some efforts are being done in this direction by groups in Brazil (INPE) and in Europe (JRC, Ispra), also using AVHRR data. NASA (Goddard SFC) is pursuing the subject for future 250 m resolution data using the Moderate Resolution Imaging Spectro-radiometer (MODIS) facility on the TERRA (formerly EOS-AM1) satellite (SBRS, 1997; NASA, 1999a).

A significant change is also expected in the integration of remotely sensed data and data from ground monitoring; these include vegetation types, vegetation stress, meteorological and weather variables, topography, soil types, soil moisture, etc Powerful Geographical Information Systems (GIS) are being developed and should be available for fire risk assessment, management and control Skilled and trained technicians will be needed to operate and extract useful output from such sophisticated means.

Fire monitoring.

Two satellites with appropriate sensors for fire detection are to be launched in the next two years, adding new possibilities in this field

TERRA/EOS-AM1, scheduled for August 1999, with an expected life time of six years, will produce images very similar to those of AVHRR in terms of area coverage (about 2200 km swath) and ground resolution (about one kilometre) However, its 36 channels have a much higher saturation temperature limit in the thermal bands and will greatly improve current AVHRR capabilities (Kaufman et al., 1998) Radiation energy, which is related to the fire temperature and size, will be estimated, and confusion due to sun glint or exposed soils that occasionally impair parts of AVHRR images will be eliminated. One limitation, however, must be considered. AM1 overpasses will be around 10:30 (a.m. and p.m.), and therefore will miss most of the short duration fires of anthropogenic origin that are started early afternoon, at the peak of the daily temperature cycle.

The German Aerospace Center (DLR) is building a pilot satellite named BIRD, specifically designed for real-time fire detection. It is to be launched in 2000 and its expected lifetime is about 2 years. One wide-viewing camera in the satellite will identify fires, and a narrow-viewing camera will concentrate on specific fires. Access to the data will be free and will require special receivers and stations. Full details of the operational mode of this satellite are available from DLR (1999).

Detection of Emissions:

The detection of emissions will be similar to that presently available with AVHRR, but in addition it will be possible to use the MODIS and the Multi-angle Imaging Spectro-Radiometer (MISR) data (SBRS, 1997; JPL, 1999). The fire and aerosol detection will be enhanced in several ways:

(a) MODIS will not only measure the fires to a resolution of one kilometre, but will also indicate the value of the radiation energy emitted by the fire. The energy is a measure of the fire strength or the rate of consumption of biomass by the fire.

(b) MODIS and MISR are designed specifically to monitor aerosol. Their data will be used directly to derive the daily aerosol concentration with a resolution of 10-20 km. The fire and aerosol data will be generated and archived daily on a global basis within 48 hours of the data acquisition. It is possible that in the first year after launch only a fraction (20-40%) of the data will be available.

MODIS data from imaging over the ocean can be used to estimate the ratio of the concentration of the micrometre size mode to the sub-micrometre mode. The mass concentration in each of the modes will be routinely derived from the MODIS data and archived.

MODIS will have a direct broadcast capability. It is recommended that local receiving stations and NASA analysis software be acquired to produce local real-time data sets on fire occurrence and aerosol emissions.

As with AVHRR and TOMS, MODIS and TOMS can be used to distinguish between smoke and urban pollution.

EOS-AM1 will also include a Canadian instrument for the Measurement Of Pollution In The Troposphere (MOPITT), to measure the concentration of CO in three altitude ranges of the atmosphere, as well as the total column concentration of CH_4. The ranges are: 0 to 3 km, 3 to 6 km, and over 6 km. Similar to aerosol data, this information can be used to derive the rate of emission of CO and CH_4 from the fires. MOPITT will not have a direct broadcast capability. The data on CO and CH_4 will be accessible from the NASA archives within 48 hours after acquisition (CSA, 1999b).

2.4.3 LONGER-TERM PLANNED CAPABILITY

In late 2000 or early 2001 NASA plans to launch the second EOS satellite - EOS-PM1 for an afternoon orbit with observation at 1:30 pm local time. It will also have on board the MODIS instrument with the same capability as the instrument on AM1, thus providing an additional and timely observation of smoke and fires every day.

The German Aerospace Center (DLR) and the European Space Agency (ESA) are working on a second fire detection satellite, FOCUS (DLR, 1997), an improvement over BIRD. The DLR Innovative Infrared Sensor System FOCUS is to be flown as an early external payload of the International Space Station (ISS, NASA, 1999b) with:

- forward-looking imaging IR sensor with a direct link to a processor dedicated for near-real-time, on-board autonomous seeking, detection and selection of hot spots.

- high resolution IR-spectrometer / IR-imager sensor combination for remote sensing high-temperature event gas emissions. The data allow the burning efficiency and emission factors of vegetation fires to be estimated, as well as those of volcanic gas emissions. FOCUS was selected by ESA as one of five European "Groupings" to be flown as an external payload in the period 2003 - 2005 and is now running in Phase A

There are also plans for the launch of an advanced geostationary satellite with a fire detection capability down to one kilometre resolution, thus enabling accurate fire detection every 30 minutes throughout the day and night. This will be the ultimate remote sensing detector of fires, but technical limitations still need to be solved in this case.

In 2001 NASA also plans to launch the first polar orbiting satellite with a lidar system - the Geoscience Laser Altimeter System - GLAS (NASA, 1998). Lidar units include a laser and receiver/detection system that can profile the vertical distribution of the smoke and the height of the capping inversion Although MODIS and GLAS will not be in the same orbit, their combined data enable a better estimate of the ground concentration of the smoke aerosol.

2.4.4 IMPLEMENTATION RECOMMENDATIONS

Coordinating the fire activity

Satellite data are available for monitoring fires and smoke aerosol. Additional satellite sensors will be available within the next 1-2 years It is recommended that a centre of excellence in fire and smoke monitoring be established. The centre should be familiar with the technology and with the available software to analyze the satellite data It would be responsible for overseeing both the regional estimates of fire emissions and the regional validation of the smoke and emission analysis from satellite data. The centre can be structured similar to the FIREGLOBE monitoring centre (GFMC, 1999a). It should develop new strategies for fire and smoke detection, and it should advise the international bodies and agencies of its needs It would also integrate the ground-based, aircraft and satellite information. It would work with regional centres (described below), disseminating information and new technology to them, as well as coordinate the training of technicians to handle new fire emissions and software.

The development and establishment of a scale to grade the severity of on-going fire episodes is also an important step to be undertaken Such an indicator could combine satellite data about the number of active fires per unit area, the size of the areas burning and the energy released by the fires, with the extent of smoke palls and the concentration of pollutants in them. Current scientific and technical knowledge allows the definition of such indicators.

Also recommended is the development of a space fire-monitoring system, comprising fire-detection satellites and real-time portable receiving hardware to provide information on the location of active fires, smoke, and trace gases emitted from the fires. The measurements should represent the diurnal cycle. The information generated by this system should be provided to the affected countries and localities in near real-time, in a simple and inexpensive manner; if possible, directly from the satellite to local users.

Regional fire activity centres

On a regional level there is a need for fire activity centres. These centres will receive the regional satellite data using their own receiving stations, and integrate it with meteorological information and the ground and aircraft monitoring efforts. The centres will use the data to monitor the development of the fires and smoke and predict the spread of the smoke. The centres are needed since the biomass burning changes from region to region, and since direct reception of the satellite data is essential for real time operation. Since there are already WMO centres or representatives with satellite and meteorological capability, they are natural candidates for the location of the regional fire activity centres.

Data availability

The recommendation is to approach NASA and other appropriate agencies to continue placing relevant data on the Web. For example, the global coverage images of the TOMS aerosol index and the NDVI.

Data receiving stations from the MODIS instrument are not yet well developed. This issue requires attention in order to have affordable receiving stations

Software development

Software packages and instruction material for using the satellite data need to be developed, to allow warnings of smoke impacts and analysis of smoke concentrations.

It is recommended that a smoke assimilation model be developed that uses global circulation models, enhanced with local meteorological data and simple smoke mass-balance equations. The model should be initiated by the density of the fires, or the fire radiation energy, and fire emission factors. It should be updated on a regular basis using satellite data on the presence and spread of smoke

Validation

Reliability of fire emission estimates from remote sensing should be ensured by continuous validation, using both ground based *in situ* and remote measurements in areas where severe health problems are known to occur as a result of extensive and intense fire episodes. Such validation will enhance the usefulness of satellite data as input to the simulation model. Once developed, they will also help determine the environmental hazards for human health.

A ground-based network of air samplers (air pumps and filter holders) is necessary to measure the concentration of aerosols for sizes under 2.5 μm in diameter.

2.4 CLIMATE MONITORING AND MODELLING THE DISTRIBUTION OF FIRE EMISSIONS

The distributions and concentrations of fire emissions must be described by the calculation of atmospheric transports using models designed for this purpose.

The task of describing the spatial and temporal distributions of fire emissions is divided into determinations, which can be made:

- before the event;
- during the event; and
- after the event.

Defined goals are to be achieved in each of those three stages of the event.

2.5.1 BEFORE A MAJOR FIRE EVENT - IDENTIFICATION OF FIRE RISK

Before the occurrence of any major episodic fire, national or regional centres need to carry out preparatory studies that will serve both as early warning indicators and provide the framework for monitoring fire plumes when and if major fires occur. Such preparatory studies can be partitioned into spatial and temporal components.

Space

The historic distribution in space of major fire episodes needs to be determined for each region. An effort should be made to:

- identify past major fire events for the region.
- define a major fire event in terms of the magnitude of emissions (mass, concentration, extent)
- obtain as long a record as possible of these major events.

The spatial distribution of major fire events in the regions should be correlated with climatic controls in the region. Climatic information on the spatial distribution of rainfall, drought or fire indexes should be correlated with the historic record of major fires.

Time

The temporal distribution of major fire events in the region should be determined on inter-annual, annual and seasonal time scales. Particular attention should be paid to time intervals corresponding to known climate oscillations, such as the El Niño - Southern Oscillation (ENSO) events (NOAA, 1999).

Seasonal and annual predictions, or monitoring, of such important phenomena as the ENSO should be related to the observed historic occurrences of major fire events in the region.

On shorter time scales, including daily monitoring, full use must be made of existing fire-prediction systems. These systems usually include

- drought index
- number of dry days
- readings of relative humidity
- vegetation index
- air quality index

A number of these measurements are now available from satellite-borne sensors.

Large-scale transport models

A history of regional atmospheric conditions, typical of the major fire events identified above, should be compiled. Such prototypical atmospheric conditions should be used to calculate long-range trajectories (up to 10 days) from the points of occurrence of major fires

These long-range trajectories should be computed for a series of levels in the atmosphere (e g. 850, 700, 500, 200 hectoPascal) and used to establish.

- the most likely transport pathways
- centres of population at risk
- optimum locations for surface monitoring sites
- indicators of transport times
- indicators of the likelihood and location of re-circulation and increased concentrations
- indicators of the persistence of polluted conditions.

Large-scale transport calculations can be carried out using existing trajectory models at national, regional or WMO meteorological centres. Such models should be exchanged between centres to resolve any inconsistencies between them and to standardize procedures before any major future fire event occurs. Information can also be used in determining locations for ground based monitoring sites

2.5.2 DURING A MAJOR FIRE EVENT - PROVISION OF TRANSPORT MODELLING DATA TO EMERGENCY RESPONSE AGENCIES

Once a fire has reached a threshold that triggers a full-scale emergency response, a critical component of the emergency response will be to provide information on likely emissions impact areas downwind of vegetation fires and, if possible, information on pollution concentrations. Atmospheric Transport Modelling (ATM), based on assimilated observations and Numerical Weather Prediction (NWP) models, is the most useful approach for determining the local and regional impacts of vegetation fires. These predictions must be readily accessible to the emergency response agency.

This activity could be undertaken by national or regional meteorological services that have the capability. WMO has a network of Regional Specialized Meteorological Centres (RSMCs) that provide meteorological support during environmental emergencies associated with nuclear or radiological accidents (WMO-TD/No. 778). These centres have full atmospheric transport modelling capability (global and regional area modelling capability along with a fully integrated ATM). Each centre is responsible for providing advice in their region in the form of a basic set of products, which includes the prediction of trajectories for release at specified heights, atmospheric exposure and surface deposition.

Acquisition of Data for ATMs

The nominated meteorological agency will provide the meteorological information and NWP outputs for use in their ATMs, at time and space scales consistent with current modelling capabilities and emergency response requirements. For modelling the trajectory and relative concentrations the best possible current information on locations and areas of fires is required, along with the heights of emission release, if possible This information is currently available from satellite remote sensing. Detailed concentration modelling requires additional information on the emission rates of particles (or other pollutants), particle size distributions, and deposition rates that is not yet routinely available.

Trajectory and Dispersion Modelling Using ATM

The nominated meteorological agency will provide the best possible information to the emergency response agency on transport trajectories and pollution dispersion from the vegetation fire. Trajectories can be run forward in time to determine receptor areas, or backwards in time to determine pollutant source areas. Relative concentration modelling, requiring limited input data, will provide information on the spatial distribution of likely pollution impact.

The transport modelling that is undertaken should be consistent within forecasting errors, suggesting that transport forecasts should not extend beyond 3-4 days. Transport modelling should also be continuously updated during the episode, using assimilated observational data (as distinct from forecast data)

Validation of Model Output

During the fire emergency there should be continuous qualitative and quantitative validation of the model output. Verification of the general smoke patterns and trajectories predicted by

ATMs can be performed using satellite, aircraft and ground-based data. Transports based on assimilated observational data can be compared with the equivalent forecast transports. This is sufficient for relative (qualitative) modelling. However, for health applications, and when absolute concentration modelling is attempted, quantitative modelling will be needed. In this case, the determination of emission rates as a function of particle size, emission area and height, and measurements of airborne concentrations and surface depositions, will be needed

2.5.3 AFTER A MAJOR FIRE EVENT- REVIEW OF TRANSPORT MODELLING DATA AND ITS PROVISION TO EMERGENCY RESPONSE AGENCIES

After the fire episode is over, the overall performance of the models and their use should be evaluated:

- The model(s) performance should be validated against measurement and satellite data
- If several models were used, did they give similar results?
- Did the modelling results reach the intended audience?
- How was the information used?
- Was the audience satisfied with the information they received?
- What needs were not addressed?

2.5.4 RECOMMENDATIONS

- To identify in each region the responsible agency capable of carrying out the complete suite of tasks associated with climate monitoring and modelling of the distribution of fire emissions. These capabilities must include:
    - Utilization of historical fire and climate data, to produce spatial and temporal distributions of major fire events.
    - Production from the historic record of an assessment of fire prone areas and times for each region.
    - Development from the historic record of a description of: the most likely transport pathways and times; the population at risk of exposure on these pathways; optimum locations for surface monitoring sites; areas where re-circulation and concentration of fire emissions occur and where high concentration of fire emissions may persist.
    - Development of a verification database for long-range transport and dispersion models, including access to global model-generated databases.
    - Predictions of climate change, including knowledge of periodic changes, ENSO/climate variability, and seasonal-to-daily changes in variables such as the drought index, to anticipate fire potential locations and times
    - Installation of trajectory and dispersion modelling capabilities, using state-of-the-art models most applicable to the region.
- To upgrade and install emissions monitoring systems, including access to satellite-generated remote-sensing measurements.
- To carry out model verification studies including:
    - dry run studies
    - comparisons between dry runs and ground and satellite-based observations.
    - comparisons between, and standardization of, products developed by different agencies for the same case studies.
    - test runs of the complete emergency response system in each region, to determine that real-time products reach the user groups in a useable form and in timely fashion.
- To finalize capabilities for producing model-generated descriptions and predictions of the distribution of fire emissions, by providing clear documentation of the capabilities and products to all user agencies in the respective regions.
- To carry out post-event evaluation of both the climate monitoring and modelling capability, including comparisons with satellite and ground-based observations, as well as user satisfaction with the materials provided. The systems should be updated as required

2.6. EMERGENCY RESPONSE PROCEDURES

2.6.1 INTRODUCTION

A strong prevention programme is a prerequisite for effective fire emergency management. It requires regular monitoring of fire and other haze-causing sources, of air quality and visibility and of meteorological and weather conditions. It also requires the building of advanced prediction and early warning systems. The necessary management must be in place in terms of legislation, institutional arrangements, financial resources, and technical support. Such a set of strategies has to be supported by clear objectives and guided by consistent policies.

This review is largely based on various national haze action plans of ASEAN member-countries and the Report of the ADB-ASEAN Preparatory Meeting on National Haze Action Plans, held in Manila, Philippines, 8 - 9 June 1998. It covers policies and strategies for assessment and management, particularly those concerning emergency response mechanisms and possible legal issues. It also highlights the need, not only to address the causes and impacts of fire as external sources of haze and pollution, but also to take into account the local pollution, particularly those places impacted by the vegetation fires.

2.6.2. POLICY REVIEW

As summarized in the outline below, most countries, particularly in the Southeast Asian region, have introduced their respective policies as part of their national action plans to prevent and mitigate land and vegetation fires.

The most common policy objective of the region is "to prevent and control fire and haze," with minor variations in emphasis among seven of the eight ASEAN countries. But only four countries have introduced and enforced policies strictly prohibiting open burning: Malaysia, Myanmar, Philippines and Singapore. In Brunei Darussalam, the prohibition is enforced only during the dry period. Such a policy is highly recommended for the other countries in the region

Indonesia sets itself higher policy objectives by introducing the development aspects of its policy. A specific policy objective is to establish land conversion targets, set at sustainable levels Implicitly, areas are set aside that are invaluable in bio-diversity, and mitigation measures for those communities at risk from vegetation fires and haze are only marginal. Fire management is quite focused and narrows down to the need for effective fuel management through controlled burning. But it is silent on the timing of such a practice, especially with respect to practice in dry periods.

On the need to address other local sources of haze and pollution, five countries, namely, Brunei Darussalam (Br), Malaysia (My), Philippines (Ph), Singapore (Sg) and Thailand (Th), have established and enforced their respective emission standards for motor vehicles, industries and other domestic sectors Controlling local sources of pollution, particularly during the haze episodes, is equally critical to safeguard public health and safety and other environmental concerns.

On the assessment aspect of the Policy framework, six ASEAN countries, not including Indonesia (Id), have emphasized the need for ambient air monitoring and reporting. Monitoring and reporting are basic to assessment and management functions. In addition, Brunei Darussalam sets itself "to determine the source of haze", while the Philippines wants "to determine health hazards", as part of the assessment aspect of their respective policies.

On management, greater focus is needed to introduce and strengthen legal and institutional arrangements at both national and regional levels. Six ASEAN countries, not including Brunei Darussalam, have emphasized the capability and capacity for regional co-operation, particularly in the deployment of fire fighting resources. The need to provide the public and other relevant entities information on the episodes and responses is important. This has been specifically emphasized, at least by three countries: Brunei Darussalam, Singapore, and Thailand. Management specifics that are relevant to others have been introduced by certain countries:

- to establish incentives to use degraded land (Id).
- to substitute slash and burn methods with sustainable cultivation techniques (My).
- to promote the utilization of agricultural wastes (Th).
- to provide infrastructure for collection and disposal of solid wastes (Sg).
- "to minimize haze, pollution by fuel management" through controlled burning (Id).

<u>A Summary of National Policies Relating to Haze in the Southeast Asian Region</u>

POLICY OBJECTIVES

A. To prevent and control land and forest fires and resulting air pollution (Br, Id, Ma, My, Sg);
To prevent and monitor haze/transboundary air pollution (Ph);
To mitigate, minimize the environmental and health impact from the Indonesian forest fires (Th);
B. To safeguard public health and safety (Br);
C. To prohibit open burning (My, Ph, Sg);
D. To control emissions from mobile and stationary sources (Br, My, Ph, Sg, Th);
E. To introduce provisions of ambient air quality guidelines and standards (Ph);

DEVELOPMENT OF POLICY

A. To set land conversion targets at sustainable levels (Id);
B. To protect communities and valued ecosystems at risk from the effects of fire and haze (Id);

ASSESSMENT:

A. To obtain information on the state of air quality (Br);
To monitor air quality (Br, My, Ph, Sg, Th) and report on air quality (My, Ph, Th);
To determine source of haze (Br);
B. To monitor smoke and particle emissions from mobile and stationary sources (Ma);
C. To determine health hazards (Ph);
D. To promote vigilance measures (My);
To carry out surveillance to prevent and detect fires (Sg, Th);

MANAGEMENT:

A. To provide the public and authorities with information on air quality and the action taken (Br),
To promote public awareness, education, and feedback (Sg, Ph, Th);
B. To ensure adequate medical and health facilities (Br);
C. To provide considerable support to neighboring ASEAN countries (Th);
To promote cooperation among Asian countries (Ph);
D. To minimize haze pollution by fuel management (Id);
E. To strengthen interagency collaboration (My, Sg, Ph, Th);and to mobilize resources to strengthen the capacity of agencies responsible for the plan (My, Sg, Th).

2.6.3 EMERGENCY RESPONSE MECHANISMS

A review of the aspects and components of existing "emergency" response mechanisms, at both the national and sub-regional levels within the Southeast Asian region, provides a basis for formulating an overall response mechanisms for the region Essentially the required mechanisms (Figure 2.6.3-1), involve the following functions in decreasing order of priority:

- Early Fire (Hot Spot & Smoke) Detection
  - Satellite Monitoring
  - Aerial Surveillance
  - Ground Surveillance
  - Weather Forecasting
  - Surface-based Atmospheric Modelling

- Fire Fighting
  - Coordination at national level
  - Coordination and assistance at sub-regional level
  - Action at local level

- Communication Links
  - Internet
  - Intranet
  - Telephone/Telefax
  - Radio

- Enforcement

- Public education and awareness campaigns

- Air quality monitoring

- Studies of health and other socio-economic impacts

- Fire danger rating

- Land-use planning

The need for international and regional cooperation in exchanging satellite data, as well as those from air-borne and ground surveillance, is implicit in the plan. Such data will provide a basis for national and regional authorities to prevent and control forest fire incidents. This co-operation is to be conducted with technical assistance from all centres of excellence, particularly for weather forecasting and for modelling long-range transport of haze. Timely forest management is critical in ensuring the success of any emergency response plan.

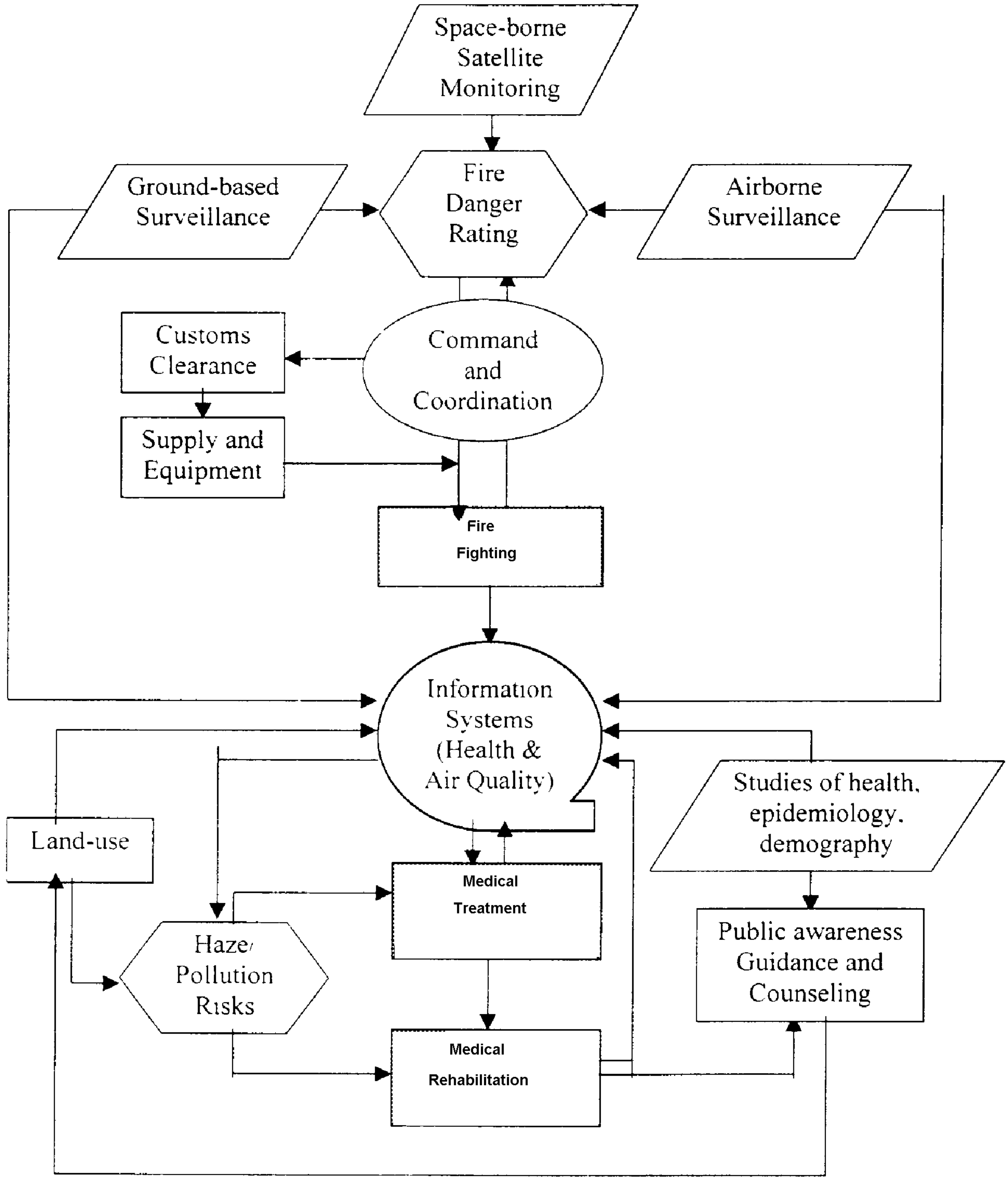

Figure 2.6.3-1 Schematic diagram of the essential emergency response mechanisms

2.6.4 OTHER POSSIBLE LEGAL ISSUES

It is generally anticipated that no legal issues at the regional level will arise from the execution of the emergency response plan. This relates particularly to the mobilization of vessels, aircraft, equipment, and personnel across national boundaries, as such activity has been pre-planned; a standard operating procedure (SOP) is put in place especially for customs and immigration clearance.

However, some legal issues are anticipated at national levels, as various authorities implement or activate their National Haze Action Plans (NHAPs) during an episode. As external sources of haze or pollution are beyond their control, national authorities have to reduce, control, and even prohibit certain internal polluting activities during the episode. Such an action will certainly have both financial and economic implications.

Most countries have general or specific laws and regulations both for controlling vegetation fires and air pollution and to protect public health and the environment from the impacts of these sources. As an example, the specific laws and regulations in Malaysia come under the Environmental Quality Act (1974, Amendments 1996) and include:

- Environmental Quality (Clean Air) Regulations 1978 – setting emissions standards for stationary and mobile sources;
- Environmental Quality (Amendment) Act 1998 (Act 1030) - introducing provisions prohibiting open burning;
- Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987.

There are many other laws and provisions in Malaysia that are applicable to the control and mitigation of land and forest fires, and air pollution. These include acceptable practices in forest management, land development, solid waste disposal, etc

To complement regulatory measures, it is good policy for those responsible for air pollution to exercise "self-regulation" in response to a worsening condition of the environment, without having to rely on directives from the authorities.

2.6.5 SUMMARY

Many, if not most, countries have already established to some extent policies, legislation and emergency response measures to control and combat vegetation fires and air pollution, and to minimize the impacts arising from these occurrences For this reason, the development a common set of Health Guidelines for the interest of all the countries involved is most timely. To ensure that the objectives of these Guidelines can be achieved, mechanisms for providing assistance to the respective countries are most important, and should include Guidelines into their existing policy, legislation and emergency response. Areas of inadequacy can thereby be identified and strengthened.

In terms of policies, the essential elements to be incorporated can be extracted by combining approaches developed by the individual countries. The elements identified are

- To prevent and control land and forest fires
- To safeguard public health and safety in such an occurrence
- To prohibit open burning
- To introduce and implement ambient air quality guidelines and standards
- To strengthen controls on emissions from mobile and stationary sources

The elements with respect to Policy on Development are:

- To set land use planning, based on sustainable development principles
- To protect communities and ecosystems at risk from fire and haze effects

The elements with respect to Policy on Assessment include:

- To monitor and report on air quality
- To develop an effective mechanism for monitoring land and forest fires
- To develop the capability to detect and predict forest fires and haze
- To monitor the health and environmental impacts of haze

The Management Policies focus on the following aspects:

- To provide the public and authorities with information on air quality and action to be taken
- To advise the public on action to be taken for health protection
- To ensure medical supplies and facilities to mitigate health impacts
- To provide support to countries in need and to promote cooperation among Asian countries
- To minimize haze pollution from fuel burning
- To strengthen capabilities of the relevant agencies
- To strengthen interagency cooperation and support

Most countries have in place some form of laws for the control of forest fire and air pollution and for protecting public health and the environment. The present needs lie in identifying areas of weakness and establishing the means to strengthen enforcement. A framework for the formulation of emergency response mechanisms can be derived from the cooperative experience among the three countries most affected during the 1997 haze episode, namely Indonesia, Malaysia and Singapore. The framework encompasses coordination activities, monitoring and detection of fires, fire fighting, communication channels, enforcement, monitoring of air quality and health impacts, public education and awareness campaigns, and land-use planning and fire-danger rating.

The success of any policy will rest on the timely exchange of data and experiences, possibly by electronic means or by teleconferencing, among various national, regional, and international authorities or centres of excellence, and on their close co-operation and continuing support.

2.6.6 RECOMMENDATIONS

- This section of the Guidelines should continue to be updated and expanded to interpret the experiences of regions other than Southeast Asia.
- To protect fire-hazard and haze-sensitive subgroups of the population, a health guideline should be developed, advance warning should be provided, and provisions made for translocation of such groups as a preventive health measure.
- Institutional arrangements at international and regional levels need to be developed and used, similar to those of the ASEAN Specialized Meteorological Centre, for advanced warning of meteorological conditions that lead to a haze-episode. Such early warning capability is invaluable to national authorities trying to enforce strict controls on both controlled and open burning of any form of biomass or waste.
- As a follow-up to such early warning an infrastructure for ambient air monitoring, similar to that of privatized monitoring networks in Malaysia, should be located downwind of areas prone to fire and in communities likely to be affected.
- For the communities affected by both vegetation fires and other sources of pollution, a series of guidelines needs to be developed to protect public health not only from the impacts of particles, but also from other health-affecting pollutants, in particular sulfur dioxide, ozone, and carbon monoxide.
- During a fire event, national authorities should consult competent international bodies, including WHO, WMO, and UNEP for advice. These international bodies should investigate the feasibility of establishing an ongoing panel of experts on haze, whose members are linked via electronic media for the rapid exchange of data.

2.7 HOW TO USE AND APPLY THESE GUIDELINES

The following sections list measures which should be undertaken before, during and after fire events.

2.7.1 PRE-EVENT ACTION

- International organizations, such as WHO and WMO, should make efforts to motivate national authorities so that they integrate these Guidelines in their emergency planning.

- At the national level, the responsible authorities (Ministry of Health, Ministry of Environment) should identify an Emergency Task Force, to include a Vegetation Fire component in their National Health Sector Plans, or to create a Plan for Vegetation Fire Emergencies

- Coordinate multidisciplinary meetings to elaborate the "Response Planning," including:
  - fire fighters (prevention and control)
  - health services (health centres and hospitals)
  - epidemiological surveillance unit
  - environmental surveillance networks
  - environmental monitoring and meteorological services

- These Response Plans must.

  - Identify general responsibilities, technical aptitudes, experiences and human resources of each sector

  - Divide the Plan into three blocks:
    - Pre-Event measures and Early Warning
    - During-Event measures Response and assessment of damages and needs
    - Post-Event Evaluation and update of the plan, including dissemination of lessons learned

- Define Information Sources·
  - Public health epidemiological surveillance
  - Air quality monitoring
  - Meteorological surveillance
  - Satellite data

- Evaluate availability and quality of information

- Evaluate needs for complementing information sources (frequency, additional monitoring, other techniques, new investigations, etc.)

- Evaluate needs of training and financial sources;

- Identify baseline levels for health and air quality

- Describe the responsibilities and actions of each agency in vegetation fire emergencies

- Define coordination and information flow between different agencies

- Define Risk Communication with:
  - Authorities
  - Mass media
  - Public

- Call upon other relevant entities to improve the response planning with their contributions

- Training teams, simulations and coordination exercises

- Replication of the plan at regional and local levels

- Budget and resources planning

2.7.2 DURING-EVENT ACTION

Response to, and assessment of, damages and needs:

- Evaluation of surveillance systems
- Compare information during the event with baseline information
- Mitigation
  - Public advice and awareness
  - Evaluate the capacity of the Public Health System to provide services, and reinforce its human resources, pharmaceutical and other needs

2.7.3 POST-EVENT ACTION

- Critical evaluation of measures taken during the event

- Evaluation of the impact of the fire event on public health and the environment

- Evaluation of the socio-economic impact

- Updating and improving the plan for vegetation fire emergencies

- Dissemination of lessons learned