South Sumatra Forest Fire Management Project

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# Developing Fire Threat Analysis for South Sumatra - Part II

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PREFACE

The South Sumatra Forest Fire Management Project (SSFFMP) is a technical co-operation project jointly funded, in terms of the financing memorandum IDN/RELEX/1999/0103, by the European Commission and by the Government of the Republic of Indonesia through the Ministry of Forestry (MoF).

This report has been completed in accordance with the project Overall Work Plan (OWP) and

in part fulfilment of Activity 4.1.2.4, Develop Fire Threat Analysis (FTA) map for district and province level,

to achieve Result 4 "Government and non-government organizations supported to establish systems to monitor the impact of improved fire management on the environment and people (gender-issues, livelihood, income, etc.), and the results of the work placed in the public domain.",

to realise the five-year project purpose, which is "Aid and facilitate the establishment of a coordinated system of fire management at province, district, sub district and village level throughout South Sumatra province in which all involved stakeholders, including the private sector, work together to reduce the negative impact of fire on the natural and social environment".

This report has been prepared with financial assistance from the Commission of the European Communities. The opinions, views and recommendations expressed are those of the author and in no way reflect the official opinion of the Commission.

The report has been prepared by:

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The report is acknowledged and approved for circulation by the Project Co-Directors when duly signed below.

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# EXECUTIVE SUMMARY


According to the overall work plan of SSFFMP, in Activity 4.1 an early warning system shall be established, consisting of Fire Danger Rating (FDR) and **Fire Threat Analysis** (FTA), in Indonesian ***Sistem Analisis Ancaman Kebakaran*** (SAAK). Both components shall be integrated into the Fire Information System (FIS). The main objectives of the consultancy were to define the scope of FTA and specify FTA functionality, assess the existing data available for FTA and develop an FTA prototype application for priority districts. Validation and evaluation phase of FTA by SSFFMP and stakeholders should be initiated.

FTA is a GIS-based approach that tries to map the overall threat by fire in an area; i.e. the risk of fire occurrence as well as the potential fire impacts. Threat Analysis applications generally consists of four components:

- **Risk of Ignition** (*Resiko Penyulutan Api*, PPA): is a fire causative agent, such as lightning or people
- **Potential Fire Spread/ Fire Behaviour** (*Potensi Perilaku Api*, PPA): is the potential of a fire to spread and the ease of ignition, resulting wildfire behaviour and its subsequent difficulty to control.
- **Suppression Capacities** (*Kapasitas Pemadaman Kebakaran*, KPK): the organizational ability to respond and suppress damaging wildfires based on personnel, equipment and operations procedures.
- **Values at Risk** (*Aset Yang Terancam*, AYT): are the values that are at stake; i.e. environmental, ecological, aesthetic values and monetary investment.

Following a general risk management approach these components can be grouped into **Probability**: how likely is it for a fire to start and spread; and C**onsequences**; i.e. the expected fire impact.

FTA output maps are designed to provide information on both probability and likely consequences of a fire starting at a certain location. In this way, threat can easily be assessed and decisions taken accordingly. FTA thus serves as an input to several other activities such as fire suppression planning, land-use planning, and the definition of fire detection and suppression objectives. FTA can thus provide valuable information related to all stages of the fire management cycle: Prevention, Preparedness, Suppression and Restoration.

During the 2006 consultancy, the product was developed further from a prototype stage. The new components on Fire Suppression Capacities and Values at Risk were added to the already existing Risk of Ignition and Potential Fire Behaviour components, which were improved and further developed to cover the whole province of South Sumatra.

**The Risk of Ignition** map indicates probability of a fire to start under different fire danger scenarios. The map legend of the risk of ignition map shows the estimated probabilities indicating if fire occurrence is rare, moderately frequent, very frequent or extremely frequent. This shall enable planners in different agencies to

quickly identify problematic areas.

Probabilities were estimated based on analysis of historical fire occurrence data from MODIS hotspot information in relation to different land use practices. Input data reflects the fire causes that were identified during the conceptual phase of FTA, which are related to land cover and use, accessibility, land use conflicts and fire history.

The **fuels map** is part of the **Potential Fire Behaviour analysis**. It shows the main fuel types that occur in South Sumatra. To map **Potential Fire Behaviour**, these fuel types have been assigned to categories according to their associated fire hazard. The fire hazard defines the ease of ignition, potential rate of spread and difficulty to extinguish of the fuel. It depends on vegetation type and condition, which is influenced by weather conditions, often expressed in fire danger rating systems (FDRS). Since currently no GIS data set on fire danger rating is routinely produced, potential fire behaviour maps are based on scenarios which correspond to low, high and extreme fire danger. When FDRS maps and vegetation condition data (through NDVI) become available in the future, these may be added to the estimation of potential fire behaviour.

A new experimental product "**Fire Danger Map**" has been derived from the Risk of Ignition and the Potential Fire Behaviour component. It consists of an overlay the two maps to support rapid identification of areas that combine both high probability of ignition and potentially sever fire behaviour.

The newly developed Values at Risk component comprise three maps:

- Economic assets (forest assets, forest plantations, oil palm and rubber estates, smallholder agriculture, etc.). Economic values can be assigned according to annual per hectare revenues that can be lost through fire. A land suitability modifier was included to account for the lower productivity of peat soils.
- Conservation assets: Conservation assets were ranked according to legal status and assumed biodiversity.
- Carbon storage: carbon storage for peat lands was calculated based on peat depth and area and an assumed bulk density and carbon content.

The new Fire Fighting Capacities map focuses on accessibility, since access was identified as the main factor limiting fire fighting capacities in Indonesia and South Sumatra. Two maps are produced:

- Accessibility map: A map showing the ease of access for different land cover types (e.g. easy access on roads and in settlements vs. difficult access in shrub swamp and secondary forest areas)
- Time to access: based on the locations of fire crews (village crews, POSKOS, Manggala Agni) time to access was simulated using cost-distance mapping algorithms. Thus areas that lie within the range were a rapid initial attack is feasible could be identified.

A computer program has been written that automatically performs the fire threat analysis as described in the main report. The program is named SAAK and is available as an extension for ArcView GIS. It can flexibly use input data that are provided by different agencies and for various analysis extents.

The SAAK extension needs several input data sets, namely land cover, roads, fire locations from previous fire season(s), land/forest status and soils in order to calculate the risk of ignition and fuel component. For the fire fighting capacities component, additionally, locations of ´different kinds of fire crews are needed.

In the scenario corresponding to a high (*Tinggi*) overall risk depicted, over 40 % of the territory of the three priority districts are in high or extreme risk areas. The district with the highest risk is OKI due to the large area proportion of degraded peat swamp areas that are used for *sonor* cultivation and other fire-related activities in prolonged dry seasons.

Most prominent fuel types are agriculture with 33 % and shrub land with 25 %. “Agriculture” in fact is an unspecified group of fuels which includes (mainly smallholder) plantations as well as shifting cultivation, fallow land and recent small clearings. MUBA has the highest share in this category. OKI has the highest share of shrub land on peat soil, which is a very hazardous fuel due to rapid propagation and difficulty to extinguish. 20 % of the district’s area is occupied by this fuel type.

MUBA, on the other hand, has the highest share of (disturbed) forested land, partly on peat (1,066 $km^2$), partly on mineral soil (2,257 $km^2$). Many of these areas are also hazardous due to the heavy degree of disturbance through illegal logging, previous fires and over-exploitation.

Fuel management should therefore be an important priority in land management and land use planning because in many areas of South Sumatra, hazardous fuels are widespread. These results from GIS data analysis based on land cover and soil maps have been confirmed through two field trips to the districts of MUBA and OKI.

A use case was developed as a demonstrator of the integration of FTA in the fire alert system to support suppression planning. Strategies for managing fires in different locations with different threat properties were discussed with stakeholders in the framework of a simulation exercise. Results of this exercise showed that participants were able to develop a basic fire management strategy based on the information provided by the threat maps. Further simulation exercises could greatly help to socialize FTA concepts and evaluate the information potential of the maps and thus further develop Fire Threat Analysis to improve fire management in South Sumatra.

A first round of evaluation after the development of the FTA prototype in 2005 gave important information regarding the improvement of FTA modules developed so far as well as dissemination and institutionalisation of FTA that has been used during implementation of the current version of FTA. It is recommended to allow for a second round of evaluation accompanying the next steps in institutional implementation of FTA to further improve the software and methods. A final development step should then conclude FTA development. This step could then be accompanied by socialization at national level. Recommendations on how various components of FTA could still be substantially improved through the inclusion of new or improved data are given in the main report.

Fire Threat Analysis will not become functional if it is not accompanied by adequate measures of capacity building. During the 2006 mission, various potential activities geared at enhancing the institutional capacities for FTA have been discussed. Three fields of activity that could be substantially supported by FTA were identified:

1. Fire suppression planning: produce smart fire alerts through linking hotspot location with FTA information
2. Fire Management Planning: plan fire centres, equipment acquisition and awareness campaigns
3. Land Use planning: support fire sensitive land use planning.

It is recommended to immediately start with activity one, and draw up and implement a concept on how FTA information can support smart fire alerts.

# RINGKASAN (INDONESIAN SUMMARY)

Berdasarkan rencana kerja SSFFMP, pada aktivitas 4.1 yaitu mengembangkan sebuah sistem peringatan dini yang terdiri dari **Peringkat Bahaya Kebakaran** dan **Sistem Analisis Ancaman Kebakaran** (SAAK). Dua komponen tersebut akan diintegrasikan dalam Sistem Informasi Kebakaran. Tujuan utama dari kegiatan ini adalah untuk menentukan ruang lingkup dan fungsi SAAK serta memilah data dan informasi yang telah ada untuk pengembangan SAAK untuk kabupaten prioritas. SSFFMP dan para pihak terkait akan menginisiasi tahap validasi dan evaluasi.

SAAK merupakan pendekatan berbasis GIS yang mencoba memetakan segala ancaman kebakaran di suatu kawasan, seperti resiko kemunculan kebakaran serta potensi dampak kebakaran. Penerapan analisis ancaman kebakaran secara umum meliputi empat komponen yaitu :

- *Resiko Penyulutan Api* : hal yang jadi penyebab kebakaran seperti petir atau manusia.
- *Potensi Perilaku Api*: kemampuan menyebarnya api dengan mudah yang menyebabkan kebakaran yang lebih besar dan sulit dikendalikan.
- *Kapasitas Pemadaman Kebakaran* : Kemampuan untuk merespon dan melakukan pemadaman kebakaran sesuai dengan kemampuan personil, peralatan dan prosedur operasional.
- Aset yang Terancam : aset yang dipertahankan dan dilindungi seperti lingkungan, ekologi, keindahan, dan investasi ekonomi.

Berdasarkan pendekatan penanganan resiko, secara umum empat komponen tersebut dikelompokkan ke dalam **Probabilitas** yaitu : bagaimana proses terjadinya penyulutan dan penyebaran api dan **Akibat** : misalnya dampak kebakaran.

Peta output SAAK disusun untuk memberikan informasi mengenai kemungkinan dan dampak terjadinya kebakaran pada lokasi tertentu. Dengan cara ini maka ancaman dapat dengan mudah diketahui sehingga dapat diambil keputusan yang sesuai. Karenanya SAAK bermanfaat sebagai masukan dalam melakukan perencanaan penanggulangan kebakaran, perencanaan penggunaan lahan, mendeteksi kebakaran, dan bertujuan untuk mengatasi kebakaran. Sistem analisis ancaman kebakaran juga dapat memberikan informasi yang berharga yang berhubungan dengan seluruh proses penanggulangan kebakaran : Pencegahan, Kesiagaan,Pemadaman, dan Pemulihan.

Selama kegiatan konsultansi 2006, produk ini telah dikembangkan lebih jauh dari versi propotip sebelumnya. Komponen baru dari Kapasitas Pemadaman Kebakaran dan Aset yang Dilindungi telah ditambahkan bersama dengan komponen yang sebelumnya telah dikembangan yaitu Resiko Penyulutan Api dan Potensi Perilaku Api yang telah diperbaiki dan dikembangkan sehingga meliputi seluruh kawasan di Sumatera Selatan.

**Peta Resiko Penyulutan Api** mengindikasikan kemungkinan terjadinya kebakaran dengan beberapa skenario tingkat bahaya yang berbeda. Peta Resiko Penyulutan Api dapat memperlihatkan perkiraan kemungkinan frekuensi terjadinya peristiwa kebakaran dengan frekuensi **jarang, cukup sering, sering** dan **sangat sering** terjadi. Hal ini memungkinkan bagi perencana penanggulangan yang ada pada instansi yang berbeda dapat dengan cepat mengidentifikasi kawasan.

Probabilitas kebakaran diestimasi berdasarkan analisis sejarah kebakaran yang terjadi di wilayah tersebut melalui data dari informasi titik panas MODIS yang dikaitkan dengan berbagai tipe penggunaan lahan. Masukan data tersebut mencerminkan penyebab kebakaran yang teridentifikasi selama tahap pengembangan konsep, yaitu yang berhubungan dengan tutupan lahan dan penggunaan lahan, aksesibilitas, konflik penggunaan lahan dan sejarah kebakaran.

**Peta bahan bakar** adalah bagian dari analisis **Potensi Perilaku Api**. Peta ini menginformasikan tipe bahan bakar utama yang terdapat di Sumatera Selatan. Untuk memetakan Potensi Perilaku Api, tipe bahan bakar telah dikelompokkan dalam kategori berdasarkan tingkat bahaya kebakaran yang terkait. Bahaya kebakaran adalah mudah tidaknya terjadinya penyulutan api, potensi kecepatan penyebaran api dan tingkat kesulitan pemadaman. Hal ini tergantung pada tipe dan kondisi vegetasi yang dipengaruhi oleh kondisi cuaca, yang sering dipresentasikan dalam sistem peringkat bahaya kebakaran. Mengingat saat ini tidak ada data GIS mengenai peringkat bahaya kebakaran yang diproduksi secara rutin, peta Potensi Perilaku Api didasarkan pada tingkat bahaya kebakaran yang rendah, tinggi dan sangat berbahaya. Ketika peta FDRS dan data kondisi vegetasi (melalui NDVI) tersedia maka ini dapat melengkapi dugaan Potensi Perilaku Api.

Suatu produk percobaan " Peta Bahaya Kebakaran" telah dihasilkan melalui komponen Resiko Penyulutan Api dan Potensi Perilaku Api. Peta tersebut merupakan hasil penggabungan dari dua peta untuk mendukung indentifikasi kawasan dengan cepat yang merupakan kombinasi dari Resiko Penyulutan Api dan Potensi Perilaku Api.

Peta Aset yang Terancam terbaru terdiri dari tiga peta :

- Aset ekonomi ( aset hutan, hutan tanaman, perkebunan sawit dan karet, lahan pertanian, dll). Manfaat ekonomi dapat dikelompokkan berdasarkan pendapatan per tahun yang hilang akibat kebakaran. Modifikasi informasi kesesuaian lahan ditambahkan untuk memperhatikan tingkat peroduktivitas lahan gambut.
- Aset konservasi: aset konservasi yang ada pada kawasan tersebut berdasarkan status kawasan dan kandungan keragaman hayati yang diperkirakan.
- Kandungan karbon: Kandungan karbon di kawasan gambut telah diperhitungkan berdasarkan kedalaman gambut dan luas kawasan gambut serta kerapatan jenis gambut dan kandungan karbon.

Peta Kapasitas Pemadaman Kebakaran baru difokuskan untuk aksesibilitas, mengingat aksesibilitas diidentifikasi sebagai faktor utama keterbatasan dalam upaya pemadaman kebakaran di Indonesia dan Sumatera Selatan, maka dibuat lah dua jenis peta yaitu :

- Peta aksesibilitas : Sebuah peta yang menunjukkan kemudahan akses untuk kawasan yang memiliki tipe tutupan lahan yang berbeda ( seperti : mudahan melalui jalan dan perkampungan dibandingkan dengan melewati semak belukar di rawa dan kawasan hutan sekunder).

- Waktu tempuh : berdasarkan pada lokasi petugas pemadaman kebakaran ( kru desa, posko, manggala agni) waktu tempuh telah di simulasikan menggunakan pemetaan jarak dengan algoritma. Termasuk kawasan yang berada dalam kawasan ancaman dapat diidentifikasi dengan mudah.

Sebuah program komputer telah dipersiapkan untuk menjalankan proses analisis secara otomatis seperti yang dijelaskan dalam laporan utama. Program tersebut bernama SAAK dan dapat di kembangkan untuk Arc View GIS. Ini dapat digunakan secara fleksible untuk memasukkan serta melengkapi data dari berbagai instansi dan untuk berbagai analisis tertentu.

Perluasan dari SAAK memerlukan input data berupa tutupan lahan, jalan, lokasi kebakaran dari lokasi kebakaran sebelumnya, status kawasan hutan, tanah, untuk mengkalkulasikan Resiko Penyulutan Api dan komponen bahan bakar. Untuk komponen kapasitas pemadaman kebakaran, dibutuhkan lokasi regu-regu pemadam kebakaran.

Pada skenario kebakaran "Tinggi", menunjukkan lebih dari 40 persen dari wilayah 3 kabupaten prioritas berada di kondisi resiko kebakaran tinggi atau ekstrim. Kabupaten dengan resiko paling tinggi adalah OKI terdapat pada kawasan gambut yang terdegradasi akibat sistem penanaman dengan sonor dan aktivitas pembakaran lainnya selama musim kemarau.

Tipe bahan bakar yang paling utama berasal dari lahan pertanian 33% dan berupa semak, 25%. "pertanian" ternyata merupakan kelompok bahan bakar dalam kelompok yang tidak terspesifikasi yang termasuk (pemilik lahan skala kecil) perkebunan dan perladangan berpindah, lahan kosong dan areal yang sebelumnya telah dibersihkan. MUBA memiliki tingkat paling tinggi untuk kategori ini. OKI memiliki kategori paling tinggi untuk kategori tipe bahan bakar berupa semak di tanah gambut yang merupakan bahan bakar paling berbahaya dan sangat cepat merambat serta sulit dipadamkan. 20% kawasan di kabupaten memiliki tipe bahan bakar ini.

MUBA, juga memiliki kawasan hutan (terganggu) yang paling luas, sebagian merupakan tanah gambut (1,066 $km^2$) sebagian tanah mineral (2,257 $km^2$). Sebagian besar kawasan ini juga berbahaya dan memiliki tingkat kerusakan yang tinggi meliputi, penebangan liar, kebakaran hutan, eksploitasi berlebihan.

Oleh karena itu pengelolaan bahan bakar menjadi prioritas penting dalam perencanaan pengelolaan lahan dan penggunaan lahan karena banyak kawasan di Sumatera Selatan memiliki sebaran bahan bakar yang berbahaya. Informasi ini berasal dari analisis data GIS yang berdasarkan pada penutupan lahan dan peta tanah berdasarkan dua kunjungan lapangan ke kabupaten MUBA dan OKI.

Sebuah ujicoba dikembangkan sebagai percobaan pengintegrasian SAAK did alam sistem peringatan bahaya kebakaran untuk mendukung perencanaan pemadaman. Strategi untuk pengelolaan api pada lokasi yang berbeda dengan komponen ancaman yang berbeda telah didiskusikan dengan para pihak dalam sebuah kerangka kerja dari percobaan simulasi. Hasil dari percobaan menunjukkan bahwa peserta dapat mengembangkan dasar strategi pengelolaan kebakaran berdasarkan informasi yang disajikan melalui peta. Percobaan simulasi selanjutnya akan sangat membantu dalam mensosialisasikan konsep Sistem

Analisis Ancaman Kebakaran (SAAK) dan evaluasi informasi potensi dari peta-peta tersebut dan selanjutnya mengembangkan SAAK untuk di terapkan dalam pengelolaan kebakaran di Sumatera Selatan.

Tahap pertama evaluasi setelah pengembangan SAAK di tahun 2005 telah memberikan informasi penting berkenaan dengan pengembangan modul SAAK yang sejauh ini telah dikembangkan secara luas dan tersebar di berbagai institusi. Kondisi ini menunjukkan agar dilakukan evaluasi tahap dua mengiringi evaluasi selanjutnya dalam penerapan SAAK pada institusi untuk kemudian mengembangkan perangkat lunak serta metode pendukung. Pada tahap akhir merupakan penyimpulan dari penerapan SAAK. Tahap ini diiringi juga dengan sosialisasi di tingkat nasional. Rekomendasi mengenai variasi komponen dari SAAK masih merupakan hal yang akan terus di kembangkan hingga diperoleh data yang baru sebagai laporan utama.

Analisis ancaman kebakaran tidak akan berfungsi jika tidak diiringi dengan tingkat pengembangan kapasitas. Selama tahun 2006, berbagai aktivitas untuk meningkatkan kapasitas instiusi untuk SAAK juga telah didiskusikan. Tiga bagian aktivitas yang mampu didukung oleh SAAK secara substansial adalah :

1. Perencanaan pemadaman kebakaran : menghasilkan peringatan kebakaran melalui hubungan lokasi titik panas dengan informasi SAAK.
2. Perencanaan Pengelolaan kebakaran : pusat pengendalian kebakaran, akuisisi peralatan dan kampanye penyadaran.
3. Rencana penggunaan lahan : mendukung perencanaan penggunaan lahan pada kawasan yang rawan kebakaran.

Hal ini sangat disarankan dimulai dengan aktivitas pertama, kemudian implementasi konsep bagaimana informasi SAAK mampu mendukung peringatan kebakaran yang baik.

# ABBREVIATIONS AND ACRONYMS

| Abbreviation | Indonesian | English |
|---|---|---|
| **AYT** | Aset Yang Terancam | Values to be Protected (Values at Risk) |
| **Bapedalda** | Badan Pengendalian Dampak Lingkunan | Environmental Control Agency on the Provincial Level |
| **BAPPEDA** | Badan Perencanan Pembangunan Daerah | Regional Development Planning Board |
| **BKSDA** | Balai Konservasi Sumber Daya Alam | Agency for Natural Resource Conservation |
| **BMG** | Badan Meteorologi dan Geofiskia | Agency for Meteorology and Geophysics |
| **BPN** | Badan Pertahanan Nasional | National Land Agency |
| **DIS** | Kabupaten | District |
| **Dishut** | Dinas Kehutanan | Forestry Department |
| **Dislinkup Pertanian** | Dinas-dinas pada lingkup pertanian | Similar to Agriculture Departement |
| **Distamben & LH** | Dinas Pertambangan & Lingungkan Hidup | Mining and Environment Department |
| **EU** | Uni Eropa | European Union |
| **FDRS** | | Fire Danger Rating System |
| **FIS** | Sistem Informasi Kebakaran | Fire Information System |
| **FMP** | | Fire Management Program/Plan |
| **FTA** | | Fire Threat Analysis |
| **GIS** | | Geographic Information System |
| **GTZ** | | German Technical Co-operation/ Gesellschaft für Technische Zusammenarbeit |
| **INTAG** | Badan Inventarisasi dan Tata Guna Hutan | Directorate of Forest Inventory and Land-use Planning |
| **KPK** | Kapasitas Pemadaman Kebakaran | Fire Suppression Capacity |
| **LAPAN** | Lembaga Antariksa dan Penerbangan Nasional | Indonesian Space and Aviation Agency |
| **MODIS** | | Moderate Resolution Spectrometer |
| **MoF** | Departemen Kehutanan | Ministry of Forestry |
| **MUBA** | Musi Banyuasin | (District in South Sumatra) |
| **NOAA** | | National Ocean and Atmospheric Administration |
| **OKI** | Okan Komering Ilir | (District in South Sumatra) |
| **PFB** | | Potential Fire Behaviour |
| **PPA** | Potensi Perilaku Api | Potential Fire Behaviour |
| **RoI** | | Risk of Ignition |
| **RPA** | Resiko Penyulutan Api | Risk of Ignition |
| **SAAK** | Sisten Analisa Ancaman Kebakaran | Fire Threat Analysis |
| **SOP** | | Standard Operating Procedures |
| **SSFFMP** | | South Sumatra Forest Fire Management project |
| **UPTD** | Unit Pelaskana Teknis Daerah | Technical Implementation Unit |
| **UTM** | | Universal Transversal Mercator Projection |

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# 1 Introduction

According to the overall work plan of SSFFMP, in Activity 4.1 an early warning system shall be established, consisting of Fire Danger Rating (FDR) and **Fire Threat Analysis** (FTA), in Indonesian ***Sistem Analisis Ancaman Kebakaran*** (SAAK). Both components shall be integrated into the Fire Information System (FIS).

During the 2006 mission, the work on FTA application was continued with the main objective of further developing the application beyond prototype stage with the inclusion of the components “Values at Risk” and “Fire Fighting Capacities”. The main objectives of this consultancy were to:

4. Improve the FTA application and make it to applicable for South Sumatra Province.
5. Develop and produce Value at Risk and Fire Fighting Capacity maps for South Sumatra Province.
6. Determine the relevance of the maps/information for the stakeholders.
7. Develop step by step manual for FTA application.

The main part of this report is aimed at introducing method and objective of fire threat analysis to the reader. It shall explain how the fire threat analysis prototype developed during the consultancy works.

The report is structured into four sections:

- The first section introduces the concept of fire threat analysis and its intended application
- The second section reviews the method of fire threat analysis applied and explains how the components developed for South Sumatra are derived. It also gives examples on how landscapes with different (high) fire threats look on the ground.
- The third section gives an overview on the results of fire threat analysis for the three priority districts in South Sumatra and reports on socialisation activities
- The last chapter summarizes the main findings and recommendations that were developed during this consultancy and briefly outlines the next intended steps.

The appendices contain a user guide to the fire threat analysis software and a short description of the method used for risk of ignition estimation.

## 1.1 The main benefits of Fire Threat Analysis

Planners in land management and disaster agencies have to identify areas threatened by fire and explore fire and land management options or plan capacities for suppression or preventive actions. They have to base their decisions on a large amount of spatial (and partly non-spatial) information.

With Fire Threat Analysis helps planners to questions like the following:

- What are the areas under fire threat in my subdistrict?
- What are the management options, e.g.:
  - Smart Alert – What is to be done with this fire/hotspot?
  - Prioritize Actions – which fire shall be attacked first of several burning in an area?
  - Preparedness for Suppression – should a new POSKO be established in subdistrict X or subdistrict Y?
  - Spatial planning – what are the likely consequences if a road is built through this forest area?
  - Prevention Activity Planning – where shall we target our extension workers for fire prevention?

## 1.2 What is Fire Threat Analysis?

FTA is a GIS-based approach that tries to map the overall threat by fire in an area; i.e. the risk of fire occurrence as well as the potential fire impacts. Apart of being part of the early warning system, FTA can serve as an input to several other project activities such as land-use planning, fire suppression planning and the definition of fire detection and suppression objectives.

Most Fire Threat Analysis applications consist of four components:

- **Risk of Ignition** (*Resiko Penyulutan Api*, PPA): is a fire causative agent, such as lightning or people
- **Potential Fire Spread/ Fire Behaviour** (*Potensi Perilaku Api*, PPA): is the potential of a fire to spread and the ease of ignition, resulting wildfire behaviour and its subsequent difficulty to control.
- **Suppression Capacities** (*Kapasitas Pemadaman Kebakaran*, KPK): the organizational ability to respond and suppress damaging wildfires based on personnel, equipment and operations procedures.
- **Values at Risk** (*Aset Yang Terancam*, AYT): are the values that are at stake; i.e. environmental, ecological, aesthetic values and monetary investment.

From a general risk management approach it is convenient to group these components further to express two basic concepts (see figure 1):

- **Probability**: how likely is it for a fire to start and spread, and
- **Consequences**: the expected fire impact.

FTA is therefore organized according to this grouping. FTA output maps are designed to provide information on both probability and likely consequences of a fire starting at a certain location. In this way, threat can easily be assessed and decisions taken accordingly (Table 1).

**Figure 1: Components of FTA**

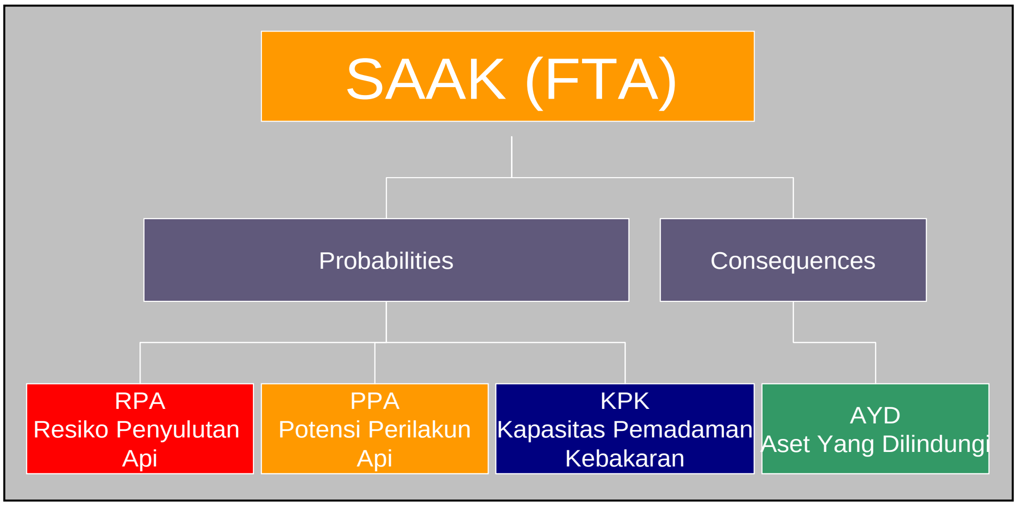



**Table 1: Risk Assessment Matrix**

| | Consequences | | | | |
|---|---|---|---|---|---|
| **Probab-ility** | **Insignificant** | **Minor** | **Moderate** | **Major** | **Catastrophic** |
| **Almost Certain** | **M** | **H** | **H** | **E** | **E** |
| **Likely** | **M** | **M** | **H** | **H** | **E** |
| **Possible** | **L** | **M** | **M** | **H** | **E** |
| **Unlikely** | **L** | **M** | **M** | **H** | **H** |
| **Rare** | **L** | **L** | **M** | **H** | **H** |

## 1.3 How can Fire Threat Analysis be used?

Fire Threat Analysis as a component of a fire information system can provide information related to all stages of the fire management cycle: Prevention, Preparedness, Suppression and Restoration. Different needs could be identified during the design phase of FTA which are shortly presented below.

**Institutional Preparedness:**

For achieving an adequate preparedness by relevant institutions the Fire Threat Analysis as part of an early warning system shall satisfy the following needs:

- Maps produce input to refined readiness level definition
- Maps assist in targeting prevention activities at province level
- Maps inform medium and higher level officials with clear, summarized information to support strategic decisions.

**Fire Prevention**

For purposes of implementing prevention campaigns the following main needs could be identified:

- Production of simple maps for the village level identifying areas with high probability of fires to spread uncontrolled
- Produce similar maps with values/ areas to be protected
- Maps shall serve as input to land use planning process.

**Fire Operations**

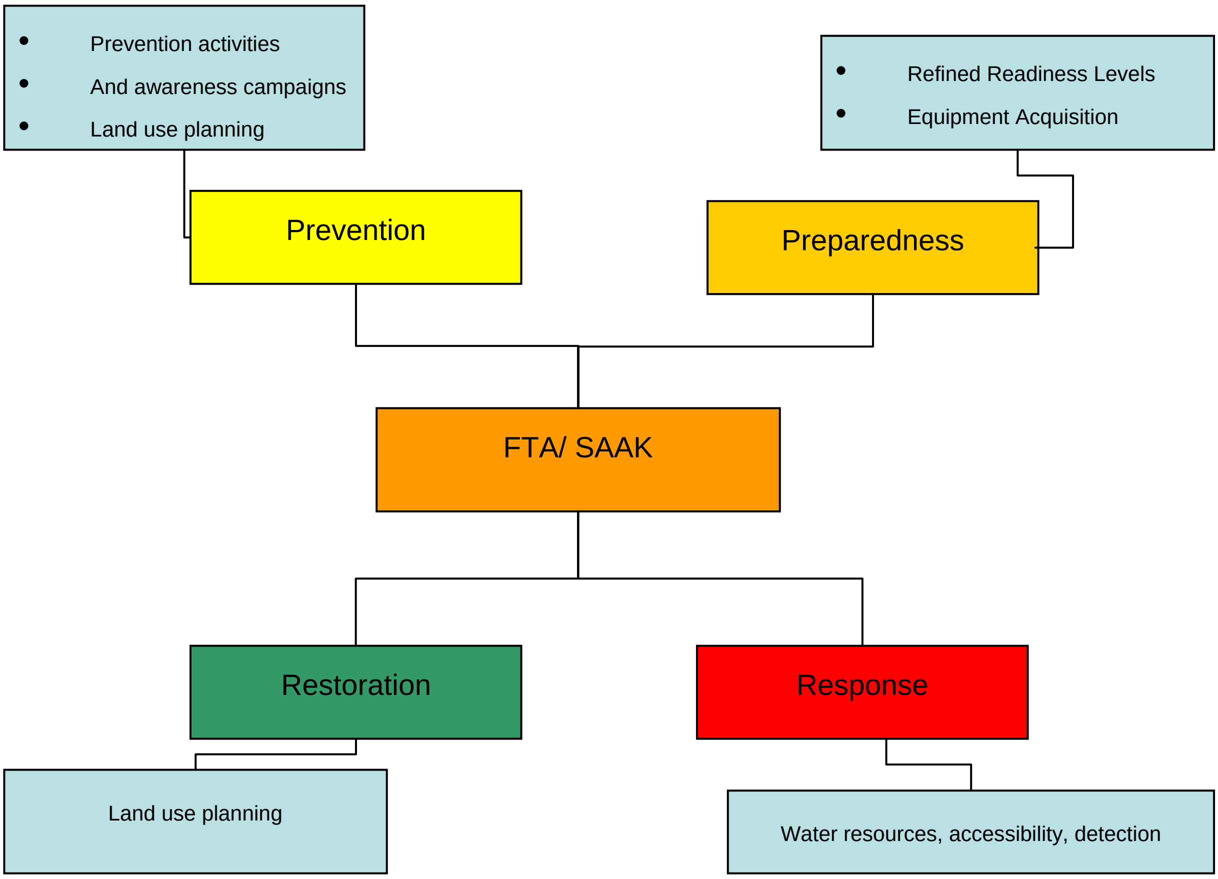
Concern of fire operations is fire preparedness at operational level, including facilitation of training and suppression equipment.

Following needs were identified for fire operations:

- Information on location of fire suppression related installations.
- Information on trained villages, equipment information.
- Information on fuel types and potential fire behaviour, wind direction and strength.

For operational purposes, a unified reference system for fire reporting and coordination is needed on fire maps. This reference system is based on grids in grid in spacing of 100, 20, and 1 km for different scales and should establish a nationwide reference code, so that at all institutional levels involved in the command chain, location information is delivered unequivocally. FTA maps relevant for operational procedures are therefore equipped with a grid in accordance with the world wide Military Grid Reference System based on the UTM projection.

**Figure 2: Application of Fire Threat Analysis within the fire management cycle**



# 2 The Fire Threat Analysis Method

## 2.1 Components of Fire Threat Analysis

Due to the cross-cutting nature of FTA and the different fields of application outlined above, FTA is not only a software mechanism that produces maps in the colour ranges from green to red to indicate increasing fire threat. It is also a way of looking at the fire threat in an area and provides the tools for assessing this threat by looking at it from different angles. It shall help in asking and answering the basic questions fire managers and land managers involved in fire management should ask:

- What is the fire risk on my area?
- What is the hazard? How big can a fire get?
- What are the values that should be protected?
- What are the capacities to prevent or fight a fire? Are they adequate?

Thus, Fire Threat Analysis is an exercise based on “what if” questions, it is “scenario based”. The application produces output maps based on different scenarios that relate to different fire danger ratings for the province or districts. There are scenarios for “medium”, “high” and “extreme” Fire Danger Rating, thus relating to readiness levels.

The application produces for each scenario the following map outputs:

**Risk of Ignition**

Map of probability of fire occurrence under different scenarios. This map expresses the probabilities based on analysis of historical fire occurrence data from MODIS hotspot information. The map legend expresses probability values.

Input data reflects the fire causes that were identified during the conceptual phase of FTA based on the following input data:

- Land cover,
- Potential land use conflicts (land with unclear status),
- Information on previous fires and,
- Accessibility.

A summarized breakdown of potential human induced fire causes in South Sumatra and how they can be expressed with the spatial data available is given in table 2. How the maps are derived in detail is described in chapter 2.2.

Apart from the overall probability map, information on input data is preserved as an output in order to retain the information on potential fire causes that is reflected in the input data.

**Potential Fire Behaviour**

Map of fuel types and (scenario-based) climate information to estimate the difficulty of a fire to be suppressed once started at a certain location.

Base data of this map are therefore:

- Land cover reflecting different vegetation types, and
- A soil modifier indicating peat/non peat land.

Output scenarios reflect different anticipated fire behaviour types under different meteorological conditions.

**Fire Suppression Capacity**

Accessibility has been identified as one of the main issues to be mapped in a fire suppression capacity map. The main map depicts crew locations and approximate travel times for crews to reach any location within the study area defined by the user.

A second maps indicates the relative difficulties that different land covers pose for travelling – from easy (roads) to very difficult (shrub, secondary forest).

The map data should be combined with other important information related to fire suppression such as location of water sources, fire towers etc.

**Values at Risk**

The Values at Risk component is not aggregated to a single map with a legend indicating “high” vs. “low” values to be protected, because this does not adequately reflect the complexity of the issue. It rather relates to fire management objectives, which are given by the legally defined tasks of the land management agencies involved. The Values at Risk component is therefore represented by three maps:

- economic values
- conservation values
- peat carbon storage

However, clear guidelines on fire suppression objectives are not always available, and of course they will be different for the various stakeholders, e.g. forest plantations will have different priorities then the conservation agency BKSDA, etc.

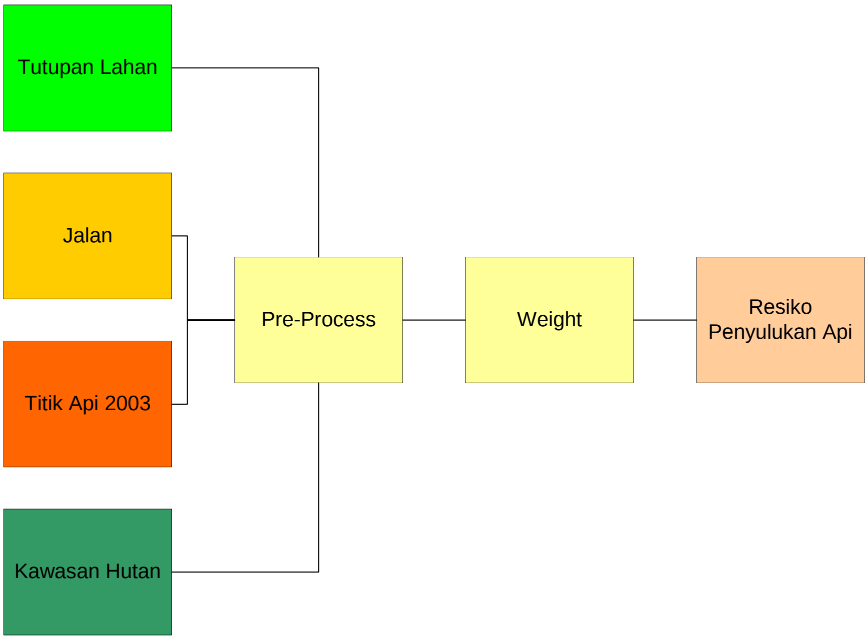
## 2.2 How FTA maps are produced and used

### 2.2.1 Risk of Ignition Map

The Risk of Ignition map indicates probability of a fire to start. It does not indicate potential fire severity, which is done by the map of potential fire behaviour. For an appropriate planning process it may be important to use both maps to assess probabilities of the fire to start and potential consequences of the fire.

The map legend of the risk of ignition map shows the estimated probabilities from 0 to 100 % grouped into five classes. A value of 0 % indicates that there is no practical possibility of a fire to start in an area, while a value of 100 % indicates that it is practically sure that this area will burn in the upcoming fire season. In reality values will be somewhere at the lower end between those extremes. We have to be aware that these probability estimates are very rough and shall basically only indicate if fire occurrence is rare, moderately frequent, very frequent or extremely frequent. This shall enable planners in different agencies to quickly identify problematic areas.

**Figure 3: Calculation Workflow for Risk of Ignition map in FTA software**




Factors determining Risk of Ignition have been derived from literature and field experience. The main fire causes, frequency of fire occurrence and associated land use are outlined in table 2. The remarks column of this table hints at how these fire causes can be represented in maps with the input data available. This has been done in a second step which included an assessment of how different fire causes can be put on a map with available GIS data. The third step then involved weighting according to an analysis of fire occurrence based on hotspot frequencies.

**Table 2: Summary information on fire causes in South Sumatra and their association with different**

**land cover types**

| **Fire Cause** | **Frequency** | **Associated Land use** | **Remarks** |
|---|---|---|---|
| **Smallholder Agriculture and Plantation Management** | | | |
| Wet Rice field preparation | Every two to three years in tidal areas | Wet Rice | |
| Dry Rice field preparation | Annual | Dry Rice | Land Cover in BPKH maps (lc): Mixed Agriculture |
| Sonor Rice clearing and field preparation | During prolonged drought, in smaller areas annually | Swamp areas | Lc: Shrub swamp, swamp |
| Clearing and preparation for slash and burn agriculture and establishment of new plantations | Annually after new land is cleared for plantation, then depends on rotation cycle (10 yrs.?) | Slash and burn areas | Lc: Mixed Agriculture |
| Smallholder plantation management | Annually until canopy closes (3-5 yrs.), then depends on rotation cycle (~30 yrs.) | Plantation (Rubber, Oil Palm, Fruits) | Lc: Mixed Agriculture |
| Conversion/Clearing | One year, encroaching neighbouring areas | Conversion | Lc: Bare soil;<br>Often associated with previous Ignitions and Roads; often<br>Land with conflicting land use |
| Hunting | +/-Annual | Swamp areas | Lc: Grasslands, shrub swamp, swamp, secondary swamp forest,<br>Often on land with conflicting land use |
| Grazing | +/-Annual | | Lc: Grasslands |
| Fishing | +/-Annual | Swamp areas, rivers | Lc: shrub swamp, swamp, secondary swamp forest |
| Gelam collection | +/-Annual | Swamp areas | Lc: secondary swamp forest,<br>Often on land with conflicting land use |
| **Largeholder activities** | | | |
| Largeholder Plantation management | Depends on rotation cycle (30 yrs.?) | Plantation | Lc: Forest plantation, plantation |
| Largeholder Clearing | One year in designated area | Conversion | Forest or unproductive land that is to be cleared. |
| **Arson and conflicts** | | | |

| Fire Cause | Frequency | Associated Land use | Remarks |
|---|---|---|---|
| Arson because of Land use conflict | Irregular | Mainly Plantation | Often on land with conflicting land use |
| Arson for other reasons | Irregular | various | Settlements |
| **Carelessness** | | | |
| Escape fire | Annual, more likely during prolonged dry season | Agriculture, plantations, settlements | Lc: mixed agriculture, others |
| Escape Fires | During prolonged drought | swamp areas with sonor rice cultivation | Lc: swamp, shrub swamp, often on land with conflicting land use |
| Carelessness in legal logging | More likely during long droughts | Designated areas for logging, HTI | Lc: Secondary or primary (swamp) forest, forest plantation; close to roads or rivers in these areas; close to previous ignitions. |
| Carelessness in (Illegal) logging | More likely during long droughts | Encroached forest areas | Lc: Secondary or primary (swamp) forest, forest plantation; close to roads or rivers in these areas; close to previous ignitions. |
| Carelessness | Irregular | various | Accessible areas |

*(Source: compiled after Anderson et al. 2000, Chokkalingam et al. 2005, Dennis et al. 2005, Applegate et al. 2001, other personal information from field trips and interviews)*

Based on this analysis, two main maps can be produced that show the major driving factors for fire occurrence:

- An extended land cover information map: this map displays the land cover, together with road buffers around roads in forest areas and areas of previous fires in forest areas. It thus gives information on where encroachment and land clearing activities can potentially take place.
- A map of potential conflicts in production forest: it shows production forest areas that have a non forest land cover (shrub, agriculture, bare soil, etc.) This map gives a hint at where areas with insecure or conflicting land tenureship are located.

Together with the fire occurrence probability map, these maps form the Risk of Ignition component of FTA.

Table 3 shows fire occurrence probabilities for different land cover classes and factor combinations. Every factor or factor combination were assigned different weights. These weights, together with the chosen scenario (medium, high/extreme) determine the probability estimate for each area. A weight above 1 is highly predictive for fire (much more than average number of fires are to be expected in these areas), a weight above 0.5 is moderately predictive, a weight around zero means that this area will experience about the average number of fires, and weights below zero indicate that there are less fires to be expected in these areas than in the average of all areas. Weights were derived from analysis of hotspot frequency in areas with different fire dynamics as outlined in table 2. Figure 4 shows the weights derived from hotspot analysis for different land cover classes. Red bars were derived from data for the years 2002 and 2004 (with severe fire seasons), yellow bars were derived from 2003 and 2005 (moderate fire seasons). The error bars indicate the higher and the lower of the two values.

The risk of ignition analysis takes all the input maps and analyses them according to the classes as outlined in table 2. In accordance with the chosen scenario it then displays the estimate for the ignition probability for each area. Details on the calculation can be found in Appendix 2.

For a detailed overview of fire causes, please refer to the non-exhaustive literature list at the end of this report.

**Figure 4: Weights for calculation of Risk of Ignition derived from hotspot analysis for different land cover classes**

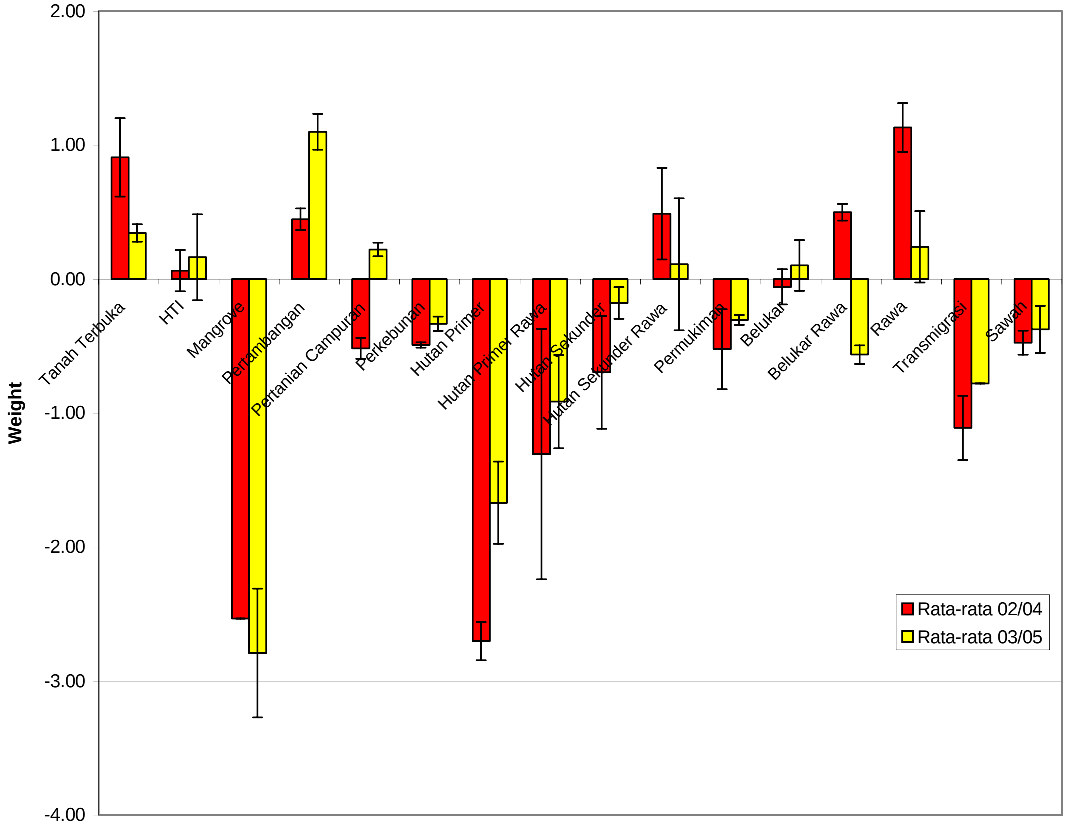


**Table 3: Weights for calculation of the risk of ignition (grouped after land cover classes, in Indonesian)**

| | Probabilitas | | | | | | |
|---|---|---|---|---|---|---|---|
| | Penutupan Lahan | | Adanya Jalan | Areal Penyulutan sebelumnya | | Di areal Hutan Produksi | |
| | Skenario | | Skenario | Skenario | | Skenario | |
| Penutupan Lahan | Tinggi-Ekstrim | Rendah | Tinggi-Ekstrim | Tinggi-Ekstrim | Rendah | Tinggi-Ekstrim | Rendah |
| Tanah Terbuka | | | | | | | |
| HTI | | | | | | | |
| Mangrove | | | | | | | |
| Pertambangan | | | | | | | |
| Pertanian Campuran | | | | | | | |
| Perkebunan | | | | | | | |
| Hutan Primer | | | | | | | |
| Hutan Primer Rawa | | | | | | | |
| Hutan Sekunder | | | | | | | |
| Hutan Sekunder Rawa | | | | | | | |
| Permukiman | | | | | | | |
| Belukar | | | | | | | |
| Belukar Rawa | | | | | | | |
| Rawa | | | | | | | |
| Transmigrasi | | | | | | | |
| Sawah | | | | | | | |
| | Permumkinan | RPA | | | | | |
| | 0-2 % | Sangat Rendah | | | | | |
| | 2-4 % | Rendah | | | | | |
| | 4-6 % | Sedang | | | | | |
| | 6-10 % | Tinggi | | | | | |
| | 10-100 % | Ekstrim | | | | | |

### 2.2.2 Fuels Map and Potential Fire Behaviour Map

The fuels map is part of the potential fire behaviour analysis. The legend for depicting the fuels is based on work by Bambang Hero Saharjo et al. and Caren Dymond et al. (2004). Bambang Hero arranges fuels in five main groups: **Open land** (*Tanah terbuka*), **slash and burn** areas (*Tebas Tebang*), disturbed forest (*hutan terganggu*), pristine forest (*Hutan Alam*). Not all sub classes can be identified with the help of a land cover map and a soil map, and some of the classifications in this system should be revised and classified in a new version of the fuel map. Table 3 depicts the land cover (with soil modifier for peat lands) and the associated fuel types and their fire problems as represented in the FTA maps. For a more detailed description of the associated fire behaviour please refer to the training material on fuel mapping and the literature list at the end of this report.

To map potential fire behaviour, these groups have been assigned to categories according to their associated fire hazard. The fire hazard defines the ease of ignition, potential rate of spread and difficulty to extinguish of the fuel. Fire hazard depends on the fuel load, condition and arrangement. Fuel condition is of course very much related to dominating weather conditions, which is often described through fire weather indices such as in the Fire Danger Rating System (FDRS).

Since currently no GIS data set on FDRS is routinely produced, potential fire behaviour maps are based on scenarios which correspond to low, high and extreme fire danger. When FDRS maps and vegetation condition data (through NDVI) become available in the future, these may be added to the estimation of potential fire behaviour.

In table 3, fuel types with their English and Indonesian names are listed. These fuel types are associated with typical fire problems and are assigned potential fire behaviour ratings expressed with the following symbols:

- "-" : low fire hazard: fuel is difficult to ignite, fires spread slowly and are easily controllable
- "o": mixed fire behaviour: fuels show a a range of different characteristics, which depend very much on current local conditions.
- "+": fuels tend to ignite more easily, but fires are still not difficult to control
- "++": fuels tend to ignite quickly, fires spread faster, and/or are more difficult to control.
- "+++": fuels ignite very rapidly, fire spreads quickly and/or is very difficult to control, often only extinguished by heavy rainfall. This fire behaviour occurs in prolonged dry seasons in swamp areas, if the water table is low, and more often in those areas where the water table is regulated, for instance in forest plantations on peat soils.

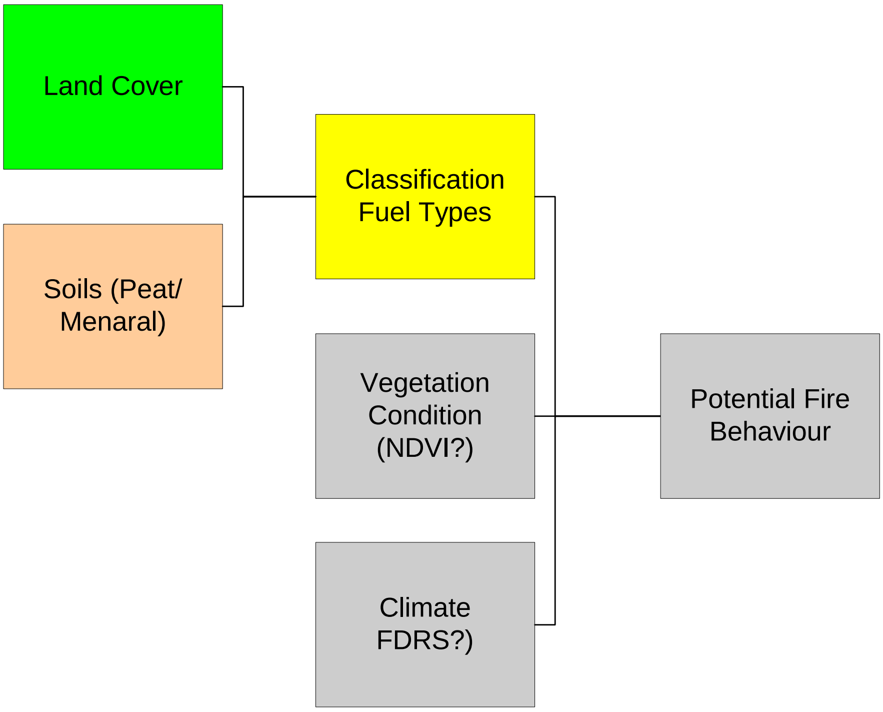
**Table 4: Land cover, fuel types, associated fire problems and fire behaviour as represented in the fuel maps of FTA**

*(for explanations see text)*

| **Land cover/soil modifier** | **Fuel Type (Indonesian name)** | **Associated fire problems** | **Associated Fire Behaviour** | | |
|---|---|---|---|---|---|
| | | | ***Fire Danger Rating*** | | |
| | | | ***Low*** | ***Medium*** | ***Extreme*** |
| *Open land* | *Areal Terbuka* | | | | |
| Shrublands | Semak Belukar | High rates of spread (if soil is dry) | + | ++ | +++ |
| Shrublands on peat | Semak Belukar – gambut | Peat fires – high emissions, difficulty to extinguish | - | + | +++ |
| Grassland | Serasah dan ranting | High rates of spread | + | +++ | +++ |
| Grassland on peat | Serasah dan ranting- gambut | Peat fires | - | + | +++ |
| Swamp grassland | Rawa | High rates of spread (if soil is dry) | - | + | +++ |
| Swamp grassland on peat | Rawa -gambut | High rates of spread, peat fires (if soil is dry) | - | + | +++ |
| *Agriculture and plantations* | *Pertanian, Perkebunan, Hutan Tanaman Industri* | | | | |
| Mixed Agriculture and Transmigration areas | Perladangan/Pertanian | Escape fires, emissions | o | + | ++ |
| Mixed Agriculture and Transmigration areas on peat land | Perladangan/Pertanian - gambut | Escape fires, emissions, peat fires | o | + | +++ |
| Forest or Estate Crop Plantation | HTI/Perkebunan | Emissions and tree mortality | - | o | ++ |
| Forest or Estate Crop Plantation on peat | HTI/Perkebunan - gambut | Emissions and tree mortality | - | +++ | +++ |
| Wet Rice Field | Perladangan/Pertanian | Emissions | - | o | ++ |
| *Pristine Forest* | *Hutan Alam* | | | | |
| Primary Forest on peat | Hutan Primer - gambut | Emissions and tree mortality, peat fires | - | - | + |

| Land cover/soil modifier | Fuel Type (Indonesian name) | Associated fire problems | Associated Fire Behaviour | | |
|---|---|---|---|---|---|
| | | | *Fire Danger Rating* | | |
| | | | ***Low*** | ***Medium*** | ***Extreme*** |
| Primary Forest | Hutan Primer | Emissions and tree mortality | - | - | + |
| Mangrove | Mangrove | Fires very rare | - | - | o |
| *Disturbed Forest* | *Hutann Terggangu* | | | | |
| Secondary Swamp Forest | Hutan terganggu - gambut | Emissions and tree mortality, peat fires | + | ++ | +++ |
| Secondary Forest | Hutan terganggu | Emissions and tree mortality, higher rate of spread than primary forest | + | ++ | +++ |
| Mining | Tidak Bahan Bakar | Damage to infrastructure, emissions | o | o | o |

**Figure 5: Calculation workflow for fuels map in FTA extension.**[1]




### 2.2.3 Experimental Fire Danger Map

As an experimental product, a Fire Danger Map can be produced from the Risk of Ignition and the Potential Fire behaviour component. The Fire Danger Map consists of an overlay of the two input maps. It is therefore possible to rapidly identify areas that have both a high probability of ignition and a high potential for severe fire behaviour. The map legend is based on the risk assessment matrix displayed in table 1. It is depicted in Annex 2.

### 2.2.4 Suppression capacity maps

The main factors driving suppression capacities are defined through the equipment at the disposal of fire crews (suppression and communications equipment), the availability of trained people, accessibility of the fire sites, and availability of water sources for extinction.

In South Sumatra, where vast areas are difficult to access, the most important factor is accessibility. Therefore, we have to answer the question how fast can the crews reach a fire?

Here, it is not enough to just calculate linear distances from crew locations, but to take into consideration that crews can travel fast on roads, but very slow e.g. in

[1] Due to lack of data on vegetation condition and fire weather, only fuel map is calculated up to now.

forest or shrub areas. This approach is called cost-distance mapping. Map output is a map of relative cost units, which relate to travel time. Our map legend relates this cost distance to travel times to give an approximate indication on how long a crew would take to reach a fire site.

Another map shows the accessibility rating of different land cover types, which were used as an input to calculate the travel times.

Thus, the suppression capacity component produces two maps:

- **Accessibility map**
- **Travel time map** (from crew locations).

One has to take into account however, that different crew types are equipped differently, and thus it may take them more or less time to reach a certain spot. Our legend with travel times assumes that crews can travel at a speed of 10 km/h (walking speed, as for village crews) on roads, and successively slower on other, less accessible, ground covers. If crews are equipped with cars or motorbikes, the travel times on roads will obviously be shorter.

Suppression capacities from estate crop and forest plantations have not been taken into account for the first release of these maps because of the scarcity and low quality of the data available at the time of the consultancy. However, these datasets can be used as input data into the FTA application.

One has also be aware that important factors determining suppression capacities have not been taken into account such as crew readiness and communication between crews and the time from initial detection to crew mobilization. Also, it has to be taken into account that village crews usually do not travel across village boundaries as well as that there are still deficiencies in command structures, e.g. between Manggala Agni brigades and village brigades. Also, private companies will be reluctant to attack fires outside their concession boundaries – and even inside their boundaries if no values are threatened or the fires are even used by the company for land clearing purposes.

Another limitation to village crews is that they will not travel to extinguish a fire that is not seen as threatening to villager's values or if they are not ordered to do so by the village head.

### 2.2.5 Values at risk maps

Values that are at risk can be grouped into economic, social, ecological and political values. A broader grouping would group values into tangible values (those that can be easily priced, e.g. lost timber), and non-tangible values (loss in biodiversity, loss in scenic beauty, social losses etc.). Not all values can readily be put on a map, either for a lack of data or because the concept is difficult to map, e.g. political implications due to fires through illegal logging in national parks or international pressure on Indonesia due to smoke haze problems in Singapore and Malaysia. In our analysis we therefore focus on those issues that can be more easily mapped, which are:

**Economic values** expressed as per ha economic values of stock at different sites. These values are derived from land-cover maps, land status maps and soil information to account for the lower productivity of peat soils. Classes evaluated are:

- Estate crop plantation (without differentiation between stand age and crop type).
- Industrial forest plantation
- Primary and secondary forest
- Agriculture (mixed agriculture and wet rice fields).

Protection areas are not included in this analysis due to the limitations imposed to economic activities due to the protection status. Settlement and mining areas are also not taken into account due to the difficulty of assigning economic values in these areas.

Grasslands and shrublands are considered as low productivity areas due to the limited (or often unknown) revenues that are generated from economic activities there such as fishing (Lebak Lebung), Gelam collection, hunting or sonor rice cultivation. Also, it has to be taken into consideration that many of these activities are directly related to fire use (such as sonor rice cultivation or fire uses as a means o clear access o fishing areas) and revenues generated by these activities can therefore not be considered to be threatened by fires.

The information content of the economic maps is presently still limited, because values of stocks or revenues under threat by fire still need to be researched. These values can then be set by the software administrator of the FTA application.

Another limitation is that the land cover maps can not differentiate between e.g. rubber and oil palm, or between different age classes in plantations. Also, we have to take into account that agriculture, fire is generally used as a tool and the economic threat posed by fire is limited to escape fires.

Often in contradiction with economic values are the **conservation values** at risk by fire. FTA produces two map outputs on conservation values:

- **Biodiversity & protected areas**, and
- **Carbon storage & potential pollutant release**

Biodiversity & protected areas are based on conservation status and land cover and a ranked in the following order:

1. National parks and game

reserves

2. Protection forest
3. Other forested land
4. Mixed agricultural land (which is often a mosaic of recently cleared areas, plantations and secondary forest)
5. Other land covers (estate crop and forest plantations, shrub, swamplands etc.)

This ranking does not imply that e.g. forest plantations do not have a certain conservation value in addition to their economical values; however it is clear that the other land cover types do have a higher conservation value in terms of species richness.

Carbon storage is presently only estimated from peat depth for peat soils only; i.e. above ground biomass is not taken into account. That leaves out a large carbon reservoir in the above ground biomass in forested areas, however, due to the scarcity of ground data no reliable estimates were at hand. This could and should be included into a future version of the program.

From experience and prior research it is clear that the air pollution potential is highest in peat areas, therefore this map does highlight the hotspots for air pollution risk.

#### 2.2.6 Overview of available products

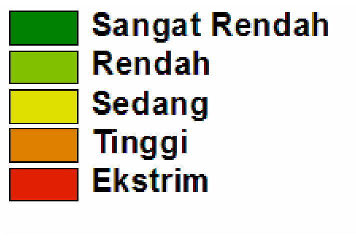
Thus, FTA produces a number of output maps that can be grouped under the four components of fire threat analysis (see figure 5). Thus a total of ten maps is produced by the FTA application. This may seem quite a lot, however we have to take into account that not all maps need to be used for all purposes. For analysis, values from these maps can be grouped into matrixes to analyse fire threat in an area. In order to further aid decision makers, a reporting tool could be developed so that threat can be readily assessed for an area and results put down in a report for decision makers.

#### 2.2.7 Examples for different fire threat types

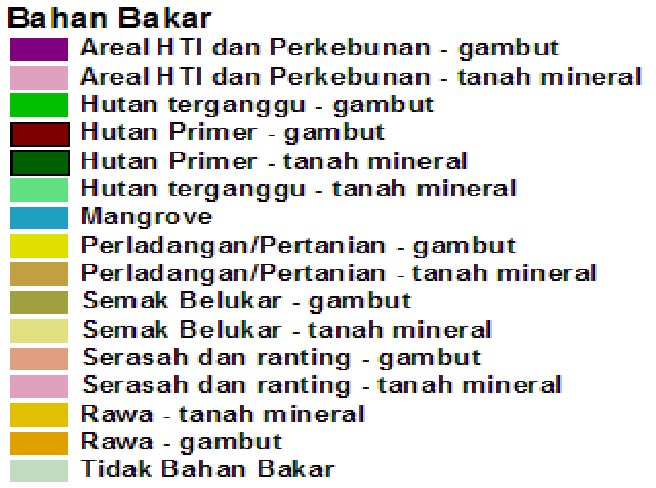
In the following section, I would like to illustrate how landscapes with different fire threat may look on the ground. These examples were taken from field trips made during the 2005 short time assignment to the districts of Musi Banyuasin (MUBA) and Okan Komering Ilir (OKI). Further examples may be developed for demonstration and training purposes in order to give users a “feel” for the FTA map output.

Figure 3 depicts the legends for the map subsets shown in the examples.

**Figure 6: Map legends for selected fire threat analysis maps (in Indonesian, for explanantion see text)**

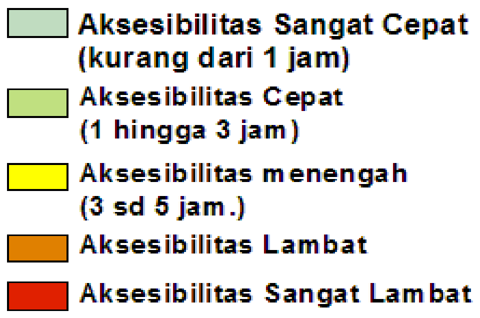



Risk of Ignition

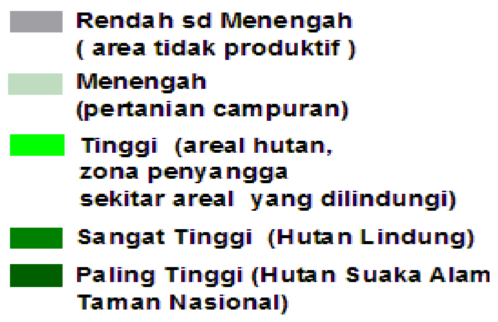



Fuel Types

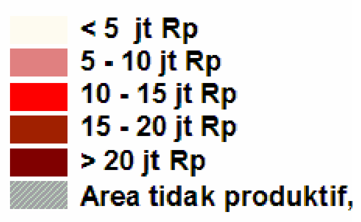

Potential fire behaviour of fuels




Accessibility for fire crews (approx. travel time)




Values at Risk: Conservation assets



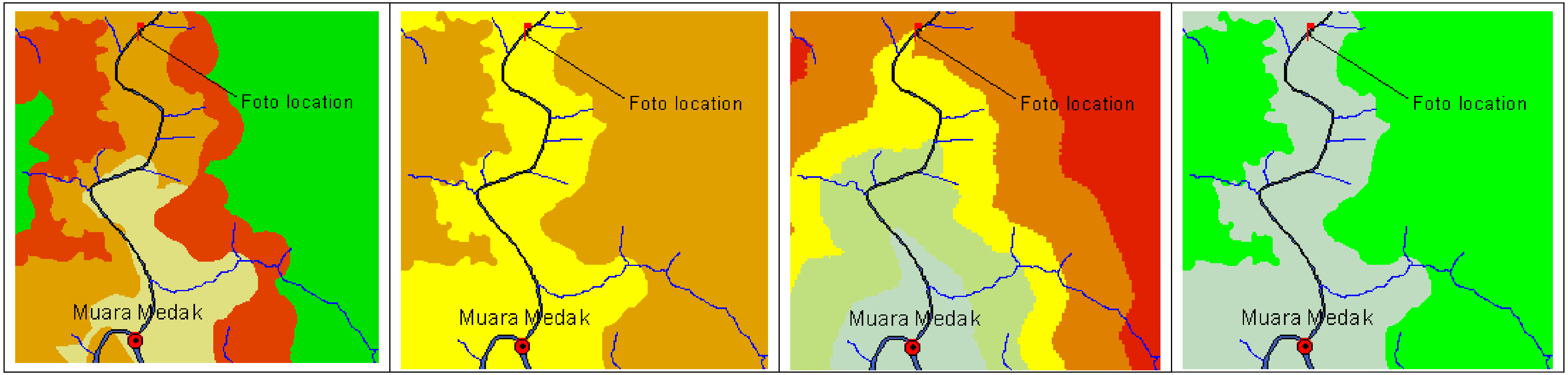

Values at Risk: Economic assets

**Alang Alang grassland near Muara Medak**

### Figure 7: Alang Alang Grassland near Muara Medak

Hotspots are observed in this fire prone grassland area almost every year. Officially, it is forest land, but the forest has disappeared apart from some remaining dead tree trunks, and the land is considered no man's land. Fire related activities are conducted on the land or nearby: Gelam collection, fishing in the Lebak Lebung system. Settlers move in and try to establish smallholder agriculture. Risk of Ignition is high because of these various fire related activities carried out in the area. Fire hazard is also high because of fast spread through Alang Alang grassland and brushes. Suppression Capacity is low due to remoteness of the area. Values at risk: in the foreground of figure 7, degraded grasslands of low economic value can be seen, in the background there is production forest: valuable as an economic asset; high conservation value and important carbon storage. It is endangered by encroachment and fires spreading from fire prone grasslands. Unfortunately, in the input land cover data from BPKH used for FTA, this area is mapped as mixed agriculture. This results in lower than actual values for risk of ignition, potential fire behaviour, and higher than actual ranking in conservation and economic assets map.

### Figure 8: Example maps from FTA for the area



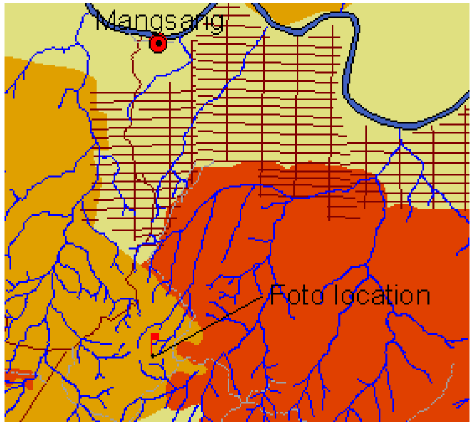
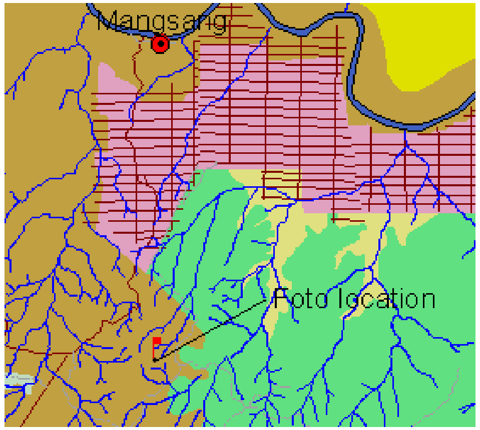
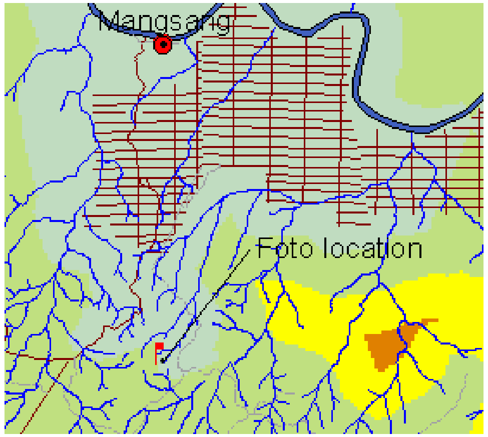
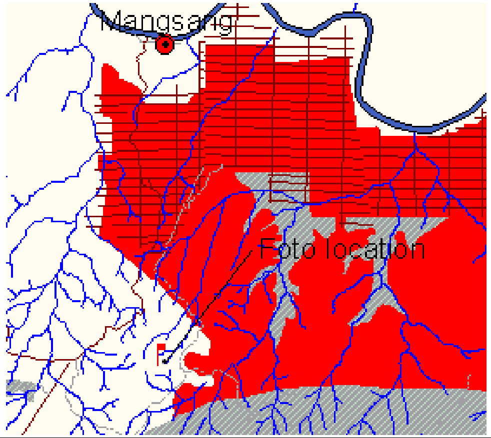
| | | | |
|---|---|---|---|
| Risk of Ignition for a normally dry year: medium to high | Potential fire behaviour for a normally dry year: medium to dangerous (in peat areas). | Suppression capacities: intermediate to slow access: good access along the river, but difficult if fire is located further off the river | Conservation values: medium value to high conservation value in nearby forest area. |

**Illegal logging near Mangsang**

**Figure 9: Illegal logging and degraded forest areas near Mangsang**

Illegal logging is an important source of fire in this heavily degraded forest area. Carelessness in logging camps and during logging activities provides for numerous ignition sources, the high amount of slash and underbrush results in a high fire hazard. If the nearby oil palm plantation company could be involved in suppression efforts, suppression capacity could be higher. Values that are at considerable risk in this area are the close oil palm plantation and what is left of the forest (some patches are still in condition for regeneration), which is on its way of rapidly being converted to unproductive grassland. Again, the area is misclassified in the land cover map as “Mixed Agriculture”, leading to errors in some of the FTA maps

**Figure 10: Location in the Risk of Ignition and fuels map**

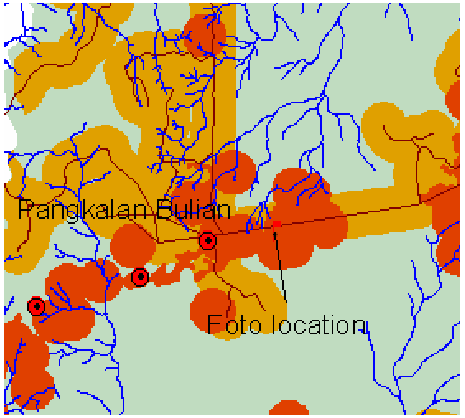
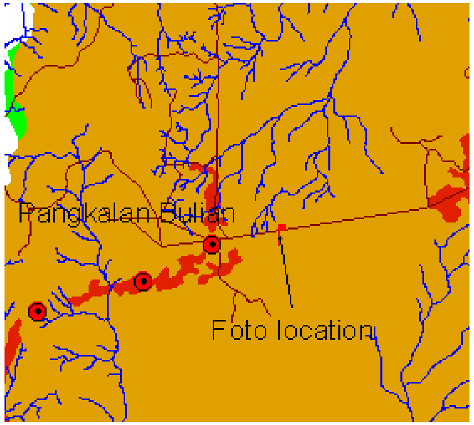
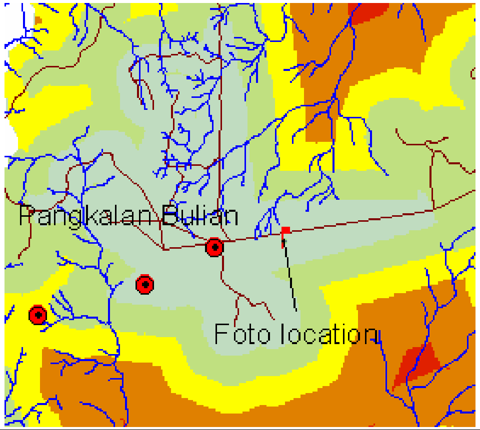
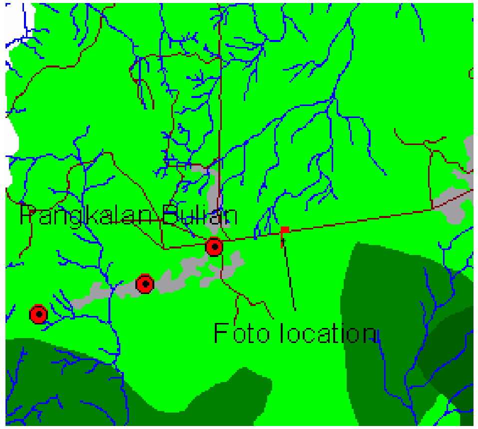
|  |  |  |  |
|---|---|---|---|
| Risk of Ignition: in reality is higher than in map due to data errors | Fuels map: misclassified due to error in land cover map ("Mixed Agriculture") | Good access for village fire crews from Mangsang (road network) | High economic values: nearby oil palm plantation and (secondary) forest area |

**Encroachment in failed HTI and degraded secondary forest along a new road, MUBA**

**Figure 11: Recently cleared field in an area of degraded secondary forest and abandoned forest plantation (PT Inhutani)**

Encroachment in areas of degraded forest or failed forest plantations and clearing for smallholder agriculture are associated with multiple fires, causing a high fire risk. In the photograph below we can see a new clearing by a spontaneous settler close to a recently constructed maintenance road along a gas pipeline. Due to the build-up of slash in the newly cleared are and the high fuel load in underbrushes in the adjacent degraded secondary forests or failed plantations, the fire hazard is also very high, especially if the land is considered "no man's land" and little interest exists in controlling fires. The area is part of one of the larger patches of remaining forest land in the district that is rapidly degraded.

**Figure 12: Location in the risk of ignition and fuels map**

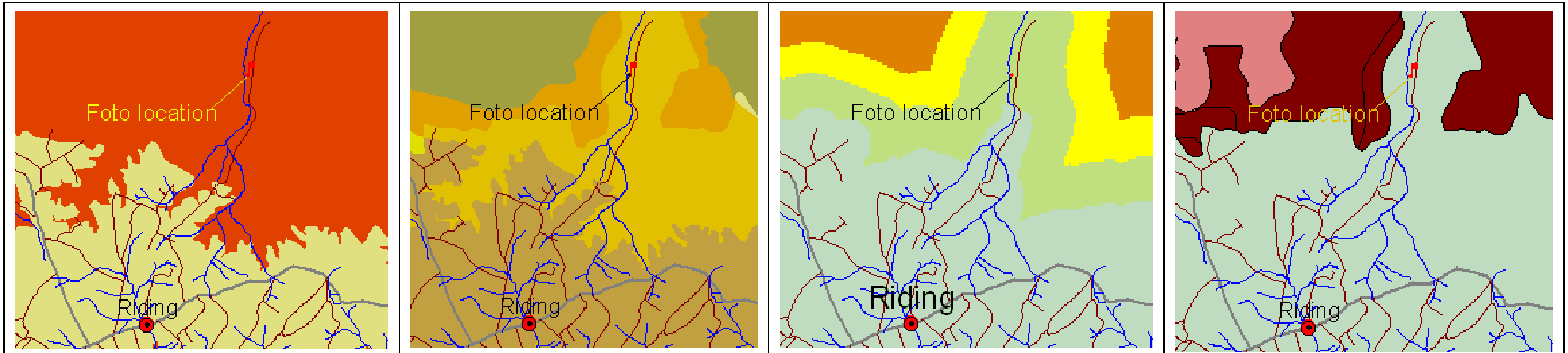
| | | | |
|---|---|---|---|
|  |  |  |  |
| Risk of Ignition: extreme along areas that surround previous fires and roads due to encroachment in forest. | Potential fire behaviour: dangerous due to high fuel loads in secondary forest. | Access by village crew: good due to road and closeness to village crew at Pangkalan Bulian. | High conservation value of forest area and very high value in nearby game reserve. |

**Area of *Sonor* cultivation in degraded peat swamps, OKI**


**Figure 13: Sonor rice field, OKI**

Sonor rice cultivation is an activity undertaken in degraded peat land areas during prolonged dry seasons. This activity is especially widespread in OKI district, where large degraded peat lands exist. In this form of rice cultivation, when the water table is low, fire is set to prepare the soil and then rice seeding is done. The farmer working the field in the photograph testifies that he does not take any effort to control the fire since this is considered “no mans land” - in fact it is part of a game reserve (HSA). The area has a very high fire hazard due to the difficulty to extinguish peat fires in the dry season. Value at risk is the total destruction of the already degraded game reserve and the heavy environmental pollution through smoke from peat fires.

**Figure 14: Location in the risk of ignition and fuels map**




| | | | |
|---|---|---|---|
| Risk of Ignition: high in prolonged dry years due to sonor activity | Fuels map: dominating fuels are swamp and peat swamp. | Access to area in peat swamp is good for village crews due to a new road from Riding | Close to the site is deep peat, an important carbon storage, which is an asset to protect |

# 3 Results from Fire Threat Analysis in the three priority districts

The following section is taken from the report of the 2005 consultancy. It should be updated by the implementing agency (Dians Kehutanan) for the Indonesian version once FTA for 2006 is done and results are made official.

## 3.1 Risk of Ignition analysis

The areas in the different risk classes are presented for the three priority districts in table 4. As described previously, the risk of ignition estimation is based on scenarios according to the overall fire situation (moderate, high and extreme) in accordance with the characteristic fire weather situation of a fire season. In the scenario corresponding to a high (*Tinggi*) overall risk depicted in table 4, over 40 % of the territory of the three priority districts are in high or extreme risk areas. The district with the highest risk is OKI due to the large area proportion of degraded peat swamp areas that are used for *sonor* cultivation and other fire-related activities in prolonged dry seasons.

**Table 5: Area of Risk of Ignition classes for 2005 in the scenario "High/Tinggi" in the three priority districts of South Sumatra**

| District | MUBA | | Banyuasin | | OKI | | All | |
|---|---|---|---|---|---|---|---|---|
| RoI Class | km² | % | km² | % | km² | % | km² | % |
| Low | 2.774 | 19% | 3.312 | 29% | 1.866 | 11% | 7.952 | 19% |
| Medium | 6.997 | 49% | 3.542 | 31% | 5.899 | 35% | 16.438 | 38% |
| High | 3.740 | 26% | 4.386 | 38% | 8.946 | 53% | 17.072 | 40% |
| Extreme | 910 | 6% | 162 | 1% | 270 | 2% | 1.342 | 3% |
| Total | 14.421 | 100% | 11.402 | 100% | 16.981 | 100% | 42.804 | 100% |

## 3.2 Fuels in South Sumatra province

Table 6 shows the spatial distribution of different fuel types. Most prominent fuel types are agriculture with 33 % and shrub land with 25 %. "Agriculture" in fact is an unspecified group of fuels which includes (mainly smallholder) plantations as well as shifting cultivation, fallow land and recent small clearings. MUBA has the highest share in this category. OKI has the highest share of shrub land on peat soil, which is a very hazardous fuel due to rapid propagation and difficulty to extinguish. 20 % of the district's area is occupied by this fuel type.

MUBA, on the other hand, has the highest share of (disturbed) forested land, partly on peat (1,066 km²), partly on mineral soil (2,257 km²). Many of these areas are also hazardous due to the heavy degree of disturbance through illegal logging, previous fires and over-exploitation.

Fuel management should therefore be an important priority in land management because in many areas of South Sumatra, hazardous fuels are widespread. This result from GIS data analysis based on land cover and soil maps is corroborated through experiences on the ground (see examples in previous chapter).

**Table 6: Spatial distribution of fuel types in the three priority districts**

| Fuel Type | MUBA | | Banyuasin | | OKI | | All | |
|---|---|---|---|---|---|---|---|---|
| | Km² | % | Km² | % | Km² | % | Km² | % |
| Forest Plantation on peat | 316 | 2% | 100 | 1% | 284 | 2% | 700 | 2 |
| Forest Plantation on mineral | 610 | 4% | 399 | 3% | 512 | 3% | 1,521 | 4% |
| Estate crop on peat | 57 | 0% | 0 | 0% | 202 | 1% | 259 | 1% |
| Estate crop on mineral | 1,131 | 8% | 379 | 3% | 1,073 | 6% | 2,583 | 6% |
| Disturbed forest on peat | 1,066 | 7% | 77 | 1% | 0 | 0% | 1,143 | 3% |
| Disturbed forest on mineral | 2,257 | 16% | 547 | 5% | 3 | 0% | 2,807 | 7% |
| Mangrove | 33 | 0% | 1,580 | 14% | 221 | 1% | 1,835 | 4% |
| Agriculture on peat | 359 | 2% | 684 | 6% | 213 | 1% | 1,255 | 3% |
| Agriculture on mineral | 6,183 | 43% | 3,191 | 28% | 3,271 | 19% | 12,646 | 30% |
| Shrub on peat | 598 | 4% | 605 | 5% | 3,376 | 20% | 4,579 | 11% |
| Shrub on mineral | 777 | 5% | 1,803 | 16% | 3,627 | 21% | 6,206 | 15% |
| Slash on peat | 96 | 1% | 359 | 3% | 1,458 | 9% | 1,913 | 4% |
| Slash on mineral | 563 | 4% | 1,129 | 10% | 2,400 | 14% | 4,092 | 10% |
| Non fuel or structures (Settlements, water) | 347 | 2% | 547 | 5% | 255 | 2% | 1,149 | 3% |
| | 14,393 | 100% | 11,400 | 100% | 16,895 | 100% | 42,690 | 100% |

# 4 Socialisation of results from Fire Threat Analysis

Results of an evaluation carried out after training and distribution of the then available FTA maps in 2005 (Kollar, 2006) revealed that the intended users were still unfamiliar with the underlying concepts of FTA and had difficulties in interpreting the maps. We therefore decided to revise the dissemination concept of FTA. One of the main points to be regarded for future dissemination is the development of use cases to demonstrate to stakeholders practical applications of FTA that have an immediate benefit for their work.

A first use case that was developed as a demonstrator was the integration of FTA in the fire alert system. At the workshop, strategies for managing fires in different locations with different threat properties were discussed in the framework of a simulation exercise. Workgroup received maps of a sample area with hotspots und the following scenario: it is the height of the fire season - what shall be done about hotspots?

Results of the workshop showed that participants were able to develop a basic fire management strategy based on the information provided by the threat maps. Further simulation exercises could greatly help to socialize FTA concepts and evaluate the information potential of the maps and thus further develop Fire Threat Analysis to improve fire management in South Sumatra. An outline of proposed actions for socialising FTA is given in the recommendations section.

**Figure 15: Simulation exercise at Fire Threat Analysis workshop**

| | |
|---|---|
| Participants working with a set of fire threat analysis maps to develop a strategy for management of a number of hypothetical fires | Assessment matrix and strategy developed by one of the work groups. The matrix uses the input from FTA maps to analyse the fires and assign each fire a priority rating and develop a strategy based on institutional responsibilities. |

# 5 Summary of main achievements during the 2006 consultancy

## 5.1 Achievements

1. Results of the evaluation phase were incorporated to improve the model for the Risk of Ignition component and develop it for the whole of South Sumatra. To do so, a new hotspot analysis was conducted for the years 2002 – 2005, differentiating between severe and less severe drought conditions. From this hotspot analysis, probabilities for two scenarios (normal and extreme dry season) were derived to feed the model for the risk of ignition component. Actual hotspot distribution was compared to the model result and it was found that the model performed quite well. The risk class breaks were newly defined, and the final risk map was produced with five risk classes.

A ground check was conducted to continue verification of the main model assumptions for FTA. The ground check was conducted in cooperation with LAPAN (Indonesian Space Agency). Thus, synergy effects for developing complementary parts of the fire information system could be achieved (e.g., burned area mapping, Fire Danger Rating)

2. New maps on Values at Risk and Fire Fighting Capacities component were produced and implemented into the FTA/SAAK software.

The Values at Risk component comprises three maps:

- Economic assets (forest assets, forest plantations, oil palm and rubber estates, smallholder agriculture, etc.). Economic values can be assigned according to annual per hectare revenues that can be lost through fire. A land suitability modifier was included to account for the lower productivity of peat soils.
- Conservation assets: Conservation assets were ranked according to legal status and assumed biodiversity in the following order:
  - Legal high-level conservation areas (National Parks, Game Reserves)
  - Legal production forest
  - Other forest area
  - Smallholder agricultural area
  - Other areas (plantations, unproductive land).
- Carbon storage: carbon storage for peatlands was calculated based on peat depth and area and an assumed bulk density and carbon content.

Access was identified as the main factor limiting fire fighting capacities in South Sumatra. The design of the capacities map therefore concentrated on accessibility. The Fire Fighting Capacities component comprises two maps:

- Accessibility map: A map showing the ease of access for different land cover types (e.g. easy access on roads and in settlements vs. difficult access in shrub swamp and secondary forest areas)
- Time to access: based on the locations of fire crews (village crews, POSKOS, Manggala Agni) time to access was simulated using cost-distance mapping algorithms. Thus areas that lie within the range were a rapid initial attack is feasible could be identified. The map, however, can not take into account organizational constraints such as the reluctance of village crews to cross the village border to operate outside their area or coordination constraints. Research on fire fighting capacities of the estate crop plantations and forest plantations was initiated, GIS ready data were however only available for a small number of plantation fire crews. On a visit to MHP forest plantation, information on fire fighting capacities was gathered and a data exchange agreed upon.

3. A workshop was held to introduce the new FTA products to stakeholders. At the workshop, a simulation exercise was held. During the exercise, participants had to work with FTA maps to develop a strategy for responding to three simultaneous fire events in a training area. Thus, participants could be trained in FTA use and, at the same time, relevance of FTA products could be assessed. The overall conclusion is that stakeholders managed quite well to develop a strategy for response based on map information, and that the maps are a benefit for decision makers in reaching management decisions in a factual, information-based manner. However, it is certainly not enough to conclusively assess FTA benefits and to introduce this method to stakeholders, and more workshops are needed to develop application cases also for other uses, e.g. in fire management capacity planning and fire-sensitive land use planning.

Introduction of the FTA application to counterparts has already been started in last year's mission. This year, amendments to the software were demonstrated to counterparts. Further trainings will be held by the GIS/RS expert of SSFFMP.

4. The step-by step manual of the FTA application has been updated with the new components.

5. The mission report gives a comprehensive introduction to FTA that can be used along with the software manual for training purposes.

## 5.2 Deliverables

8. This report.
9. FTA software: source code and extension.

10. Step-by-Step manual for production of FTA (Appendix 1 of this report).
11. Administrator's manual of FTA
12. Training material for FTA workshop (Power point presentation and sample maps on FTA components).

# 6 Conclusions and recommendations

After completion of the mission on developing Fire Threat Analysis, a number of recommendations for further action can be given. These regard aspects of further development of FTA as well as activities related to capacity building in the production and use of FTA products.

## 6.1 Further development of FTA

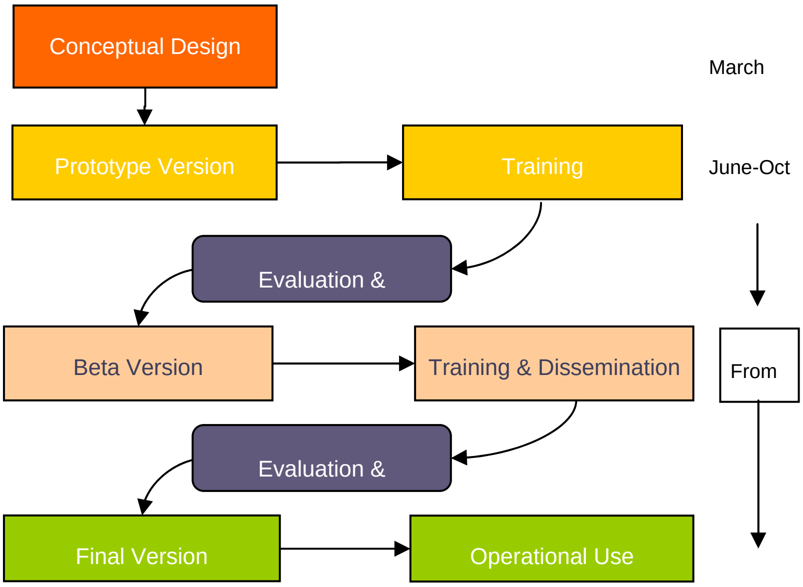
The Fire Threat Application and its outputs are now available for all four components of fire threat, namely Risk of Ignition, Potential Fire Behaviour, Suppression Capacities and Values at Risk. Both software and products need to be further socialized and tested by the involved agencies. Only sustained input from users can ensure the validity and usability of FTA maps. It is therefore recommended to systematically train users and gather experience during an evaluation, dissemination and training phase as outlined in the FTA design documents and proposal.

During the first round of evaluation that was supported by a master's thesis work it was shown that the approach of stepwise development allows for continuous improvement of both the FTA methods and the dissemination of FTA results. Many of the issues found in this first evaluation phase were addressed during the 2006 mission, while at the same time new modules were developed. It is therefore recommended to allow for a second round of evaluation accompanying the next steps in institutional implementation of FTA to further improve the software and methods. A final development step should then conclude FTA development. This step could then be accompanied by socialization at national level.

A number of issues for further development can still be treated in 2006 as they involve parameterization of the Values at Risk maps:

- Per hectare/year revenues for the different economic assets still need to be correctly assigned based on available information sources (literature, market prices, and personal enquiries). These can then be updated in FTA's initialization files.
- BPKH has offered assistance in assigning conservation values. If needed, conservation values can also be revised.
- An upcoming STE mission aims at concluding the peat survey. Together with the STE expert, ways of integrating the results of the peat survey in FTA shall be discussed. In this regard, it is important to a consistent province-wide dataset.

**Figure 16: Stepwise implementation of FTA (from FTA conceptual design, 2005)**




Further functionality that would greatly improve the benefit from FTA and could be developed during a concluding mission on FTA includes:

- During the simulation exercise (see chapter 4) it became evident that a reporting module would greatly improve the usability of FTA. Such a module would for instance provide rapid area statistics – e.g. in the form of a decision matrix – on the different components of FTA and thus provide a quick overview to decision makers.

- Improve the potential fire behaviour component with climate/weather and vegetation status information. The ongoing cooperation with LAPAN offers a great potential to routinely integrate fire weather and vegetation status (NDVI) data. This would give a much improved overview of actual potential fire behaviour than using only a fuel type map.

- Improve the risk of ignition component using burned area maps instead of hotspot data. These data are currently used to forest and other areas that are potentially suffering from encroachment. However, it has been shown that many fires are missed by hotspots. Furthermore we can not determine actual damage from hotspot data, and spatial resolution is too low. Sustainable ways of producing annual burn scar maps have been evaluated by the project, and a pilot study on burned area mapping using MODIS satellite data has been carried out in conjunction with LAPAN. Results, however, were found to be still far from satisfactory during field assessments, and it is recommended to further support the refinement of the methods for burn scar analysis by LAPAN, so a good quality product could become available that allows for operational monitoring of burned areas at medium resolution scales.

This would improve not only the Risk of Ignition component, but also help other tasks such as basic burned area accounting.

- The carbon storage map currently only contains information on below ground biomass. Simple models for above ground biomass content could be developed from literature that could be rapidly derived from land cover data. This could be a first step towards creating awareness of the different carbon stocks that could in the future be integrated in a variety of CDM mechanisms.

## 6.2 Capacity building

Fire Threat Analysis will not become functional if it is not accompanied by adequate measures of capacity building. During the 2006 mission, various potential activities geared at enhancing the institutional capacities for FTA have been discussed. Three fields of activity were identified, were FTA could create an immediate benefit to stakeholders:

1. Integration in alert system.
2. Integration in fire management planning.
3. Plan prevention activities according to threat analysis
4. Integration in land use planning process.

1. The integration into the alert system would involve several tasks:

- SSFFMP should create a demonstrator system that integrates FTA with hotspot alerts. The system would be handled by an operator who has the following tasks:
  - Check hotspot location in relation to fuels, values, suppression capacities and provide a report in the form of a decision matrix.
  - Alert the corresponding POSKO/Manggala Agni and pass the information.
- Train operators at fire management section at Dinas Kehutanan to handle the above tasks.
- Train POSKOS and Manggala Agni in interpretation and application of FTA results. Training should take place within the institutional context of the tasks of the trained entities (Who should be alerted? Who does what?), and with regard of any Standard Operating Procedures available or under development. This activity could be carried out in cooperation with a model POSKO and Manggala Agni and should be coordinated with the SSFFMP fire management expert to avoid overlapping activities.

2. This task could involve the assessment of areas with high fire threat and

deficient suppression capacities to support planning for establishment of new fire centres. In 2005, planning for establishment of new POSKOS and training of village crews was already aided by FTA maps. This process could be continued and stakeholders be aided to carry on. The methods for this task could be develped in cooperation with SSFFMP fire management expert.

3. Plan prevention activities according to threat analysis. Extension officers for fire prevention could be training with the use of FTA. This activity could be aided by the SSFFMP training expert.

4. To support fire sensitive land use planning, training modules could be developed in cooperation with SSFFMP land use planning specialist. FTA can be used for planning at Kecamatan, Kabupaten or Province level. It can help to assess suitability of areas for development according to fire threat and thus promote fire-sensitive land use planning.

All of these activities require allocation of sufficient resources in terms of SSFFMP TA hours. To take into account the limited time until the end of SSFFMP, it appears to be reasonable to concentrate on activity 1 (alert system).

Data quality continues to be one of the main obstacles to successful fire threat analysis, as well as for all other activities related to spatial analysis and planning. The field assessments during 2005 and 2006 missions revealed that input data on land cover, roads, and forest status suffers from various deficiencies. Especially land cover is very problematic due to intrinsic error sources:

- Rapid change of land cover in the most fire prone areas,
- Unclear definition of some land cover classes,
- Interpreter errors in assigning land cover classes during visual interpretation of satellite images.

Special care should therefore be taken by the project through the GIS/RS expert to support agencies in issues related to data production and quality.

## 6.3 Institutional development

To ensure sustainable availability and use of FTA, FTA production and distribution should be integrated within the institutional context that is to be further analyzed by an upcoming STE mission. Institutional setup for the sustainable implementation of FTA is currently undergoing clarification. The lead agency for producing FTA maps shall be Dinas Kehutanan/INTAG. However, a number of institutional integration issues still remain to be solved. Tackling these issues could be supported by the upcoming STE mission. In order to produce a consistent and sustainable production of FTA a number of obstacles still need to be overcome:

- Data exchange mechanisms between

agencies have to be established and institutionalized in order to make sure that the best quality data are available for FTA.

- Dinas Kehutanan as the proposed lead agency for FTA will need special support in quality assurance, training and distribution of FTA information products.
- If FTA is to be performed independently by other agencies (such as Manggala Agni) or other stakeholders, inconsistent and contradictory results from FTA may result. It is therefore important to adequately socialize the concepts of FTA and support implementing users in achieving high quality output.
- Distribution pathways and intended users of the data need to be better defined in a participatory process. The product then needs to be promoted to the intended user groups, and its use integrated into Fire Management Plans (FMP) and standard operating procedures (SOP).

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Unna Chokkalingam, Suyanto, R. P. Permana, I. Kurniawan, J. Mannes, A. Darmawan, N. Khususyiah and R. H. Susanto, 2005, Community fire use, resource change and livelihood impacts: The downward spiral in the wetlands of southern Sumatra, Mitigation and Adaption Strategies for Global Change, *in Press*

# Appendix 1

# User's Manual for the SAAK extension in ArcView GIS 3.x

# 8 Introduction to the SAAK Extension

The SAAK extension is a computer program for ArcView GIS that automatically performs the fire threat analysis as described in the main report. It can flexibly use input data that are to be provided by different agencies and for various analysis extents. In the current prototype version, the SAAK extension has only been developed for the three priority districts of SSFFMP, namely Musi Banyuasin, Banyuasin and Okan Komering Ilir. It can be applied to other districts, but has not been tested with fire data from these districts. Since the priority districts are flat and basically at sea level, terrain information is not included in the analysis. Once Fire Threat Analysis is performed for other districts, effects of terrain should be included.

The SAAK extension needs the following input data:

- Land cover
- Roads
- Fire locations from previous fire season(s)
- Land/forest status
- Soils (with peat depth information)

Additionally, for the suppression capacity component, locations of fire crews are needed. The user can input location data for village fire crews, POSKOS, HTI or Perkebunan fire crews and Manggala Agni separately so that map information can be calculated for each crew type separately or jointly.

Some of these data, namely land cover, land status and soils, are reclassified by the SAAK extension to correspond to classifications used internally by the extension. This reclassification process is interactively during the analysis operations.

To use the SAAK extension, your system has to meet the following requirements:

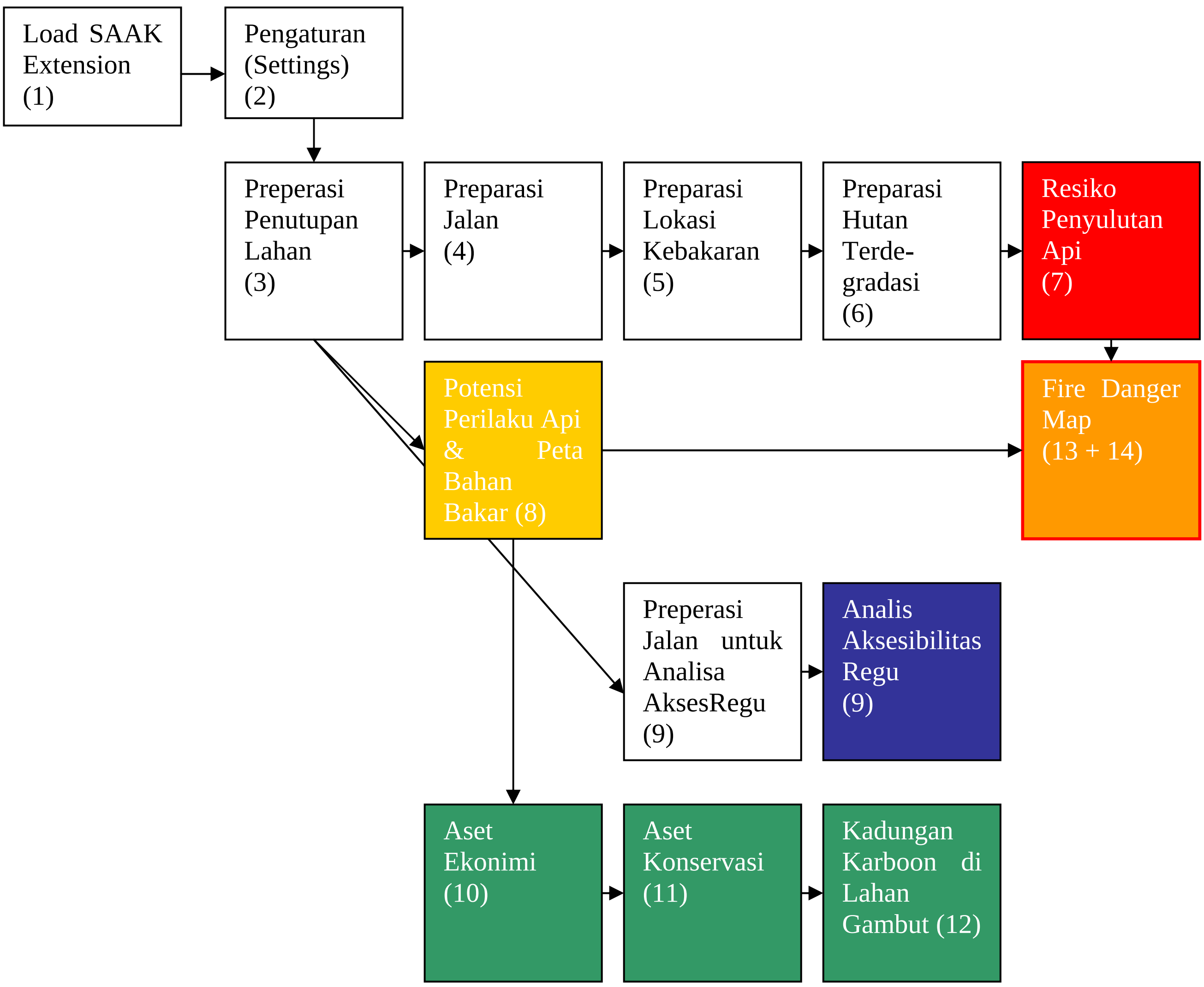
1. ArcView GIS 3.x
2. Spatial Analyst for ArcView GIS 2.x
3. Minimum processor capacity as specified for these programs. Recommended is a CPU Speed of above 1 GHz, 500 MB RAM and 500 MB free disk space for storing output data.

In the following pages, a step-by step description on the processing of SAAK maps is given. The steps needed are:

1. Loading the SAAK Extension
2. Setting file locations and the Analysis Extent

3. Preparing land cover data
4. Preparing road and accessibility data
5. Preparing previous fire locations
6. Preparing the degraded forest map
7. Running Risk of Ignition Analysis
8. Running Fuel Map Analysis.
9. Running accessibility analysis
10. Calculate economic assets map
11. Calculate conservation assets map
12. Calculate peat carbon storage
13. Convert output data to standardized grids
14. Calculate fire danger map

These steps are presented schematically in figure 1 and described in detail in the following sections.



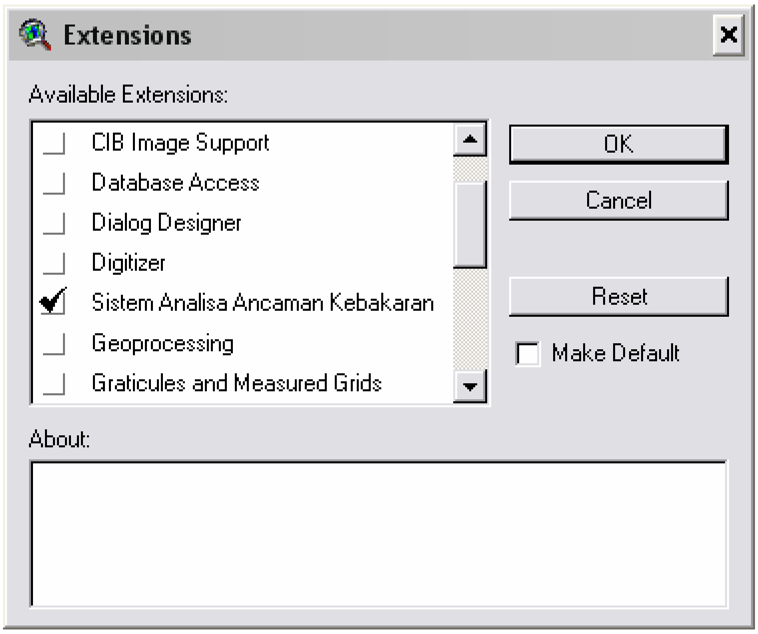
# 9 Steps for Fire Threat Analysis

### 1. Loading the SAAK extension

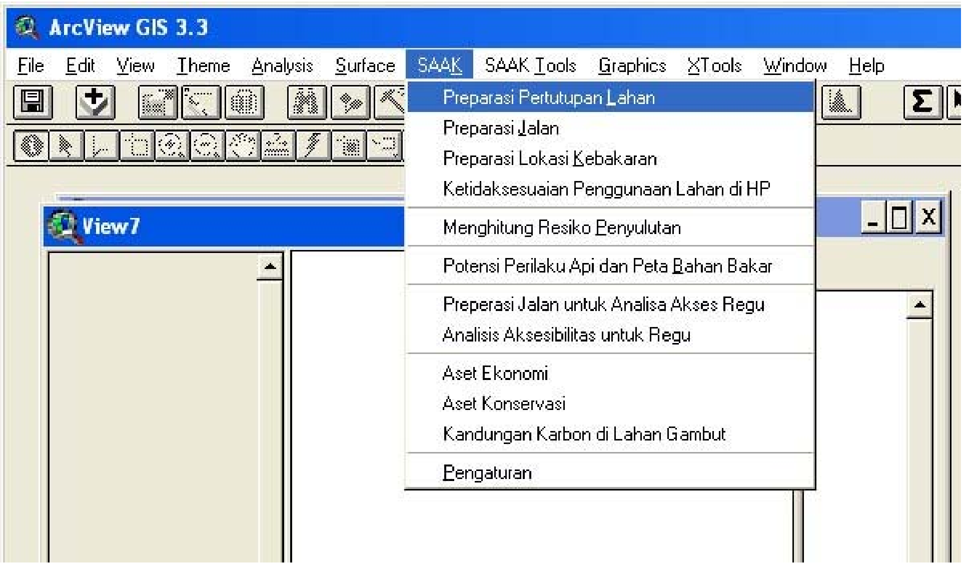
**Start ArcView** with a new View. There is no need to add data to the view.

To start the SAAK program, you must first load the SAAK extension:

1. Choose "Extensions" from the File menu
2. Click in the check box labeled Sistem Analisa Ancaman Kebakaran, then press the OK button on the Extensions dialog to load the extension.



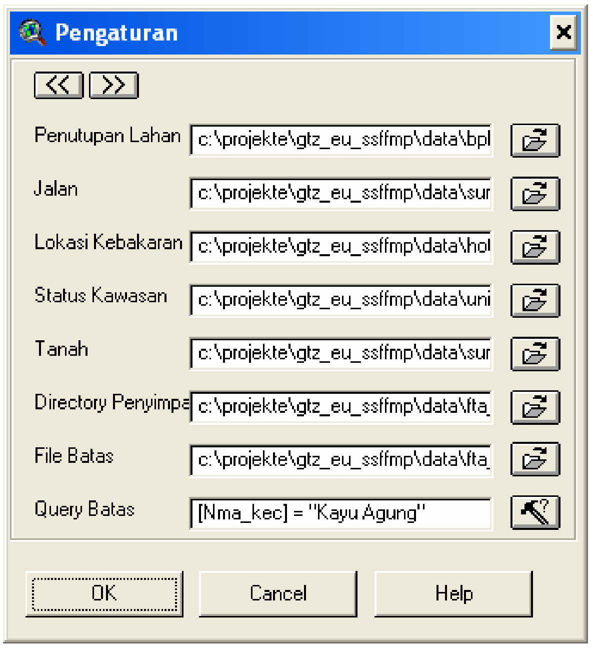

Two new menus named "SAAK" and "SAAK Tools" will appear in the View user interface.

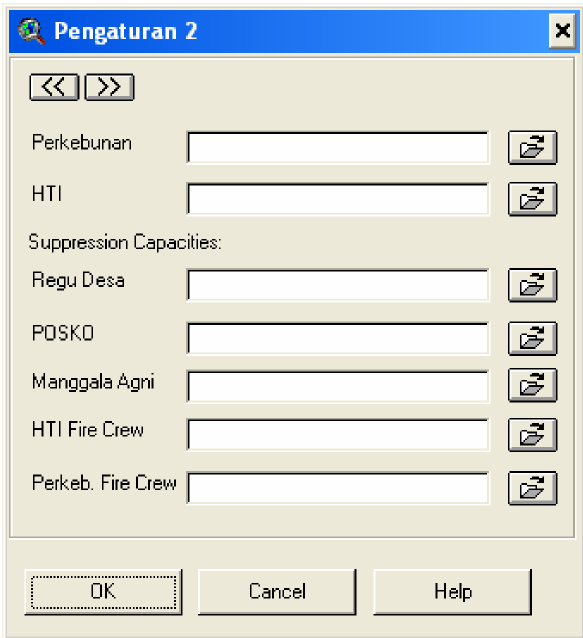

ArcView GIS 3.3
File
Edit
View
Theme
Analysis
Surface
SAAK
SAAK Tools
Graphics
XTools
Window
Help
View7
Preparasi Pertutupan Lahan
Preparasi Jalan
Preparasi Lokasi Kebakaran
Ketidaksesuaian Penggunaan Lahan di HP
Menghitung Resiko Penyulutan
Potensi Perilaku Api dan Peta Bahan Bakar
Preperasi Jalan untuk Analisa Akses Regu
Analisis Aksesibilitas untuk Regu
Aset Ekonomi
Aset Konservasi
Kandungan Karbon di Lahan Gambut
Pengaturan

## 2. Setting file locations and the analysis boundary

From the new SAAK menu choose **Pengaturan** (Settings) to set the paths to the data layers needed for the analysis.

In the window appearing you can now choose the right file for the different data layers by clicking on the file source button  for each layer.




Navigate to the corresponding directory for each data layer. Double click on the file you want to use as input data. After selecting all windows you can choose at the bottom if you want to make a Query to restrict the boundaries of the analysis set with the boundary layer “Batas”, for instance you can choose one or more districts. In this example we use the district of Musi Banyuasin.

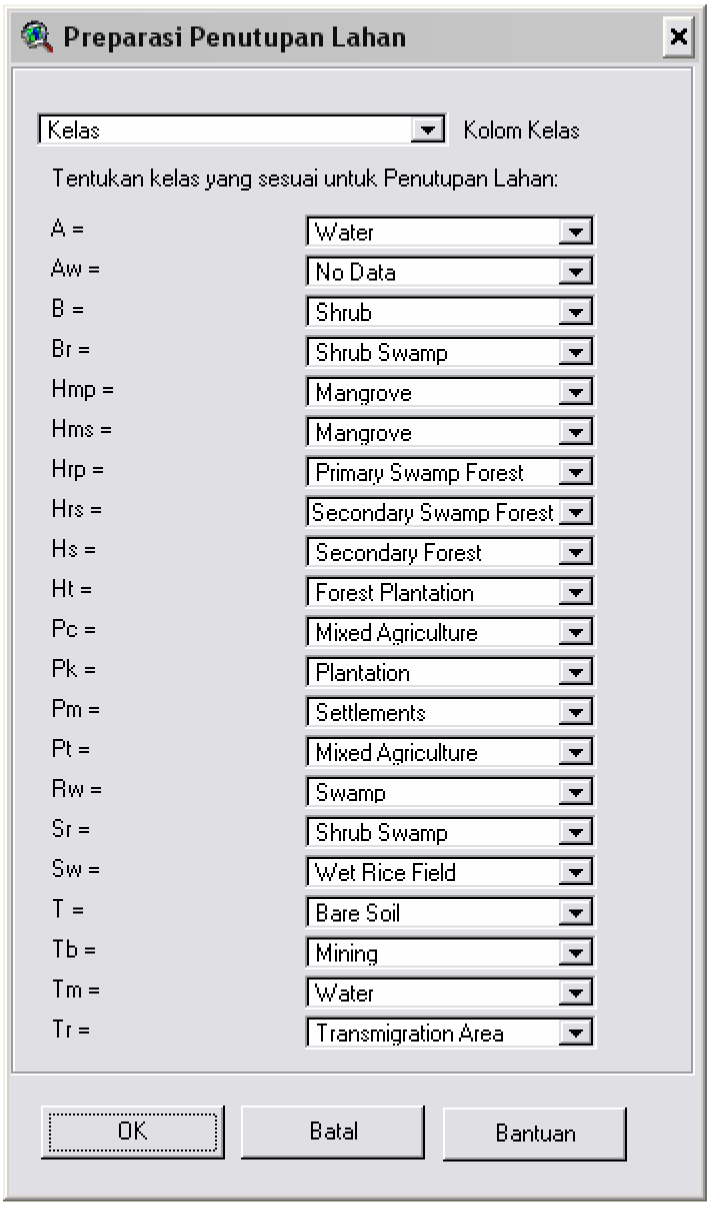
For the suppression capacity component, you have to switch to the “Pengaturan 2” dialog. You can switch between “Pengaturan” and “Pengaturan 2” dialog using the two arrow buttons on the top left side of the dialog.

When you have finished, click OK.

You can now start the analysis by working down through the items in the SAAK menu.

From that menu choose first **Preparasi Pertutupan Lahan** to load and analyse the land cover.

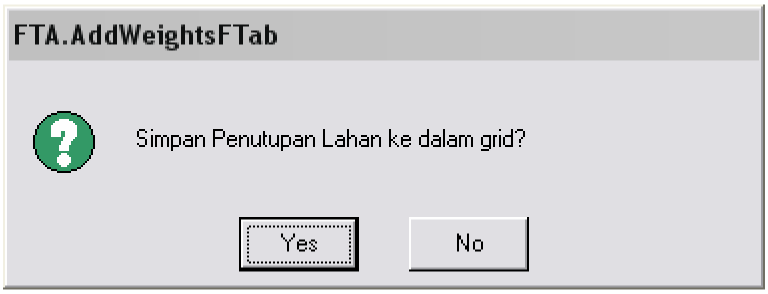
### 3. Preparing the Land Cover Data




In this window, first select the field that holds the land cover class information. Then assign the correct classification to the land cover codes in the selected class field in your input file. In this way you can use different input data for analysis and just have to map the land cover classifications of your input data to the corresponding classes that can be understood by SAAK. The program will remember your selections, so it is only necessary to repeat them once you want to change your input data, or the class assignments.

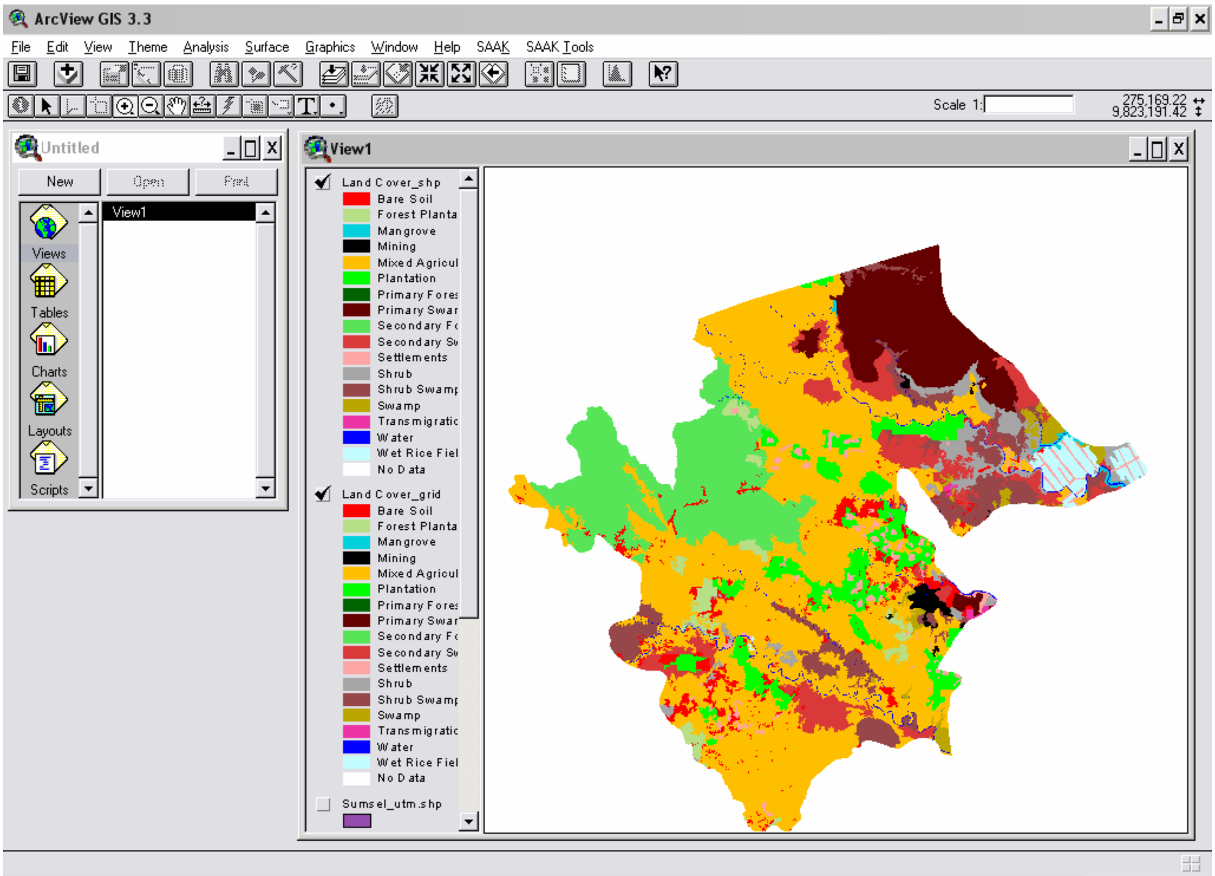
When you have finished, click OK to apply.

You will be asked to save the new land cover classifications as a grid:




You should choose "Yes" when you are sure about your settings. If you chose "No", no grid file will be built and you can continue changing the associations between land cover classes/codes in your input file and the SAAK codes. The shapefile with your land cover classes will be loaded in the full extent (not restricted by the "batas" file).

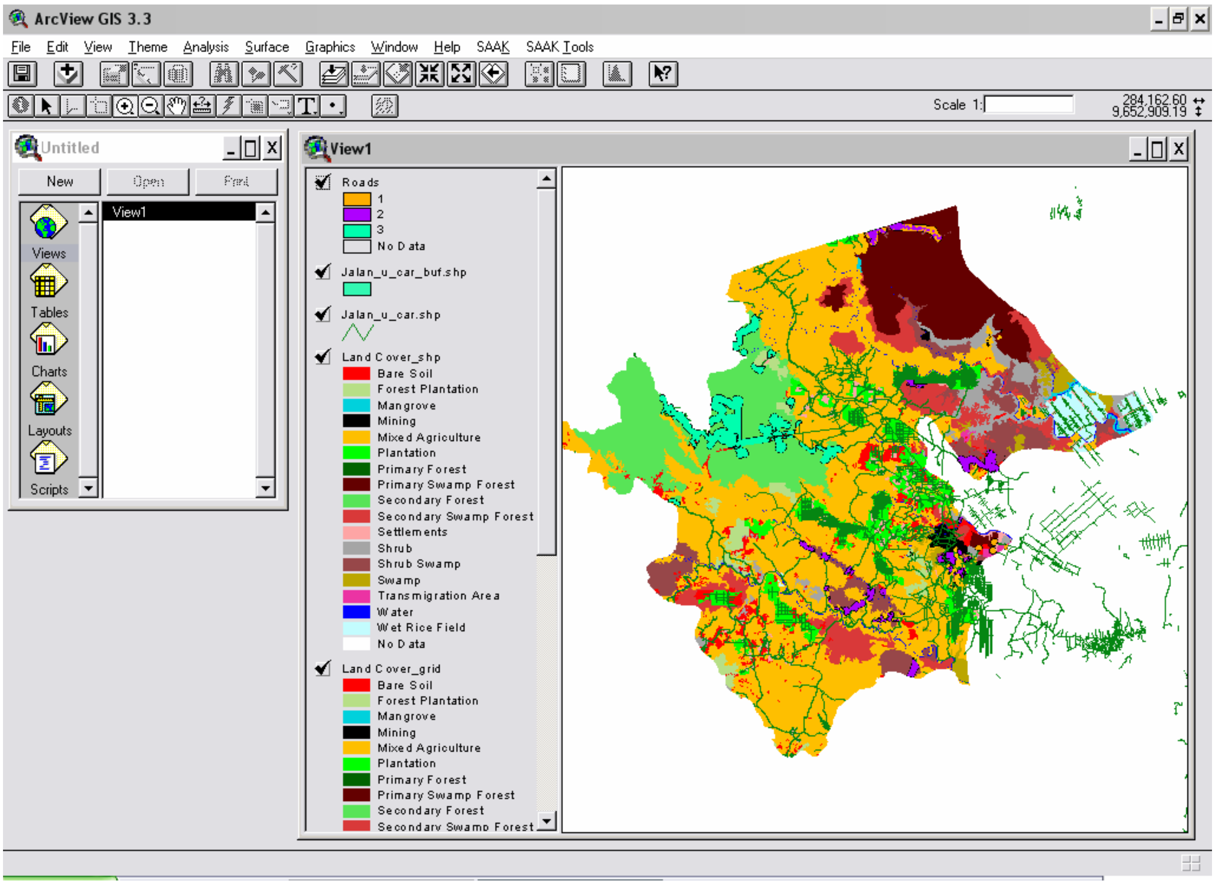
If you clicked yes, the SAAK program processes the data (may take some time) and then shows the land cover classes in a shape and a grid theme restricted to the boundaries you set in the "Pengaturan" window. To draw the themes click on the check boxes in the legend.




If the legend is not fully displayed you can enlarge the legend width by clicking and dragging the mouse on the right side of the legend.

## 4. Preparing Road and accessibility data

In the next step you can prepare the roads and do the roads analysis by choosing **Preparasi Jalan** in the SAAK menu.

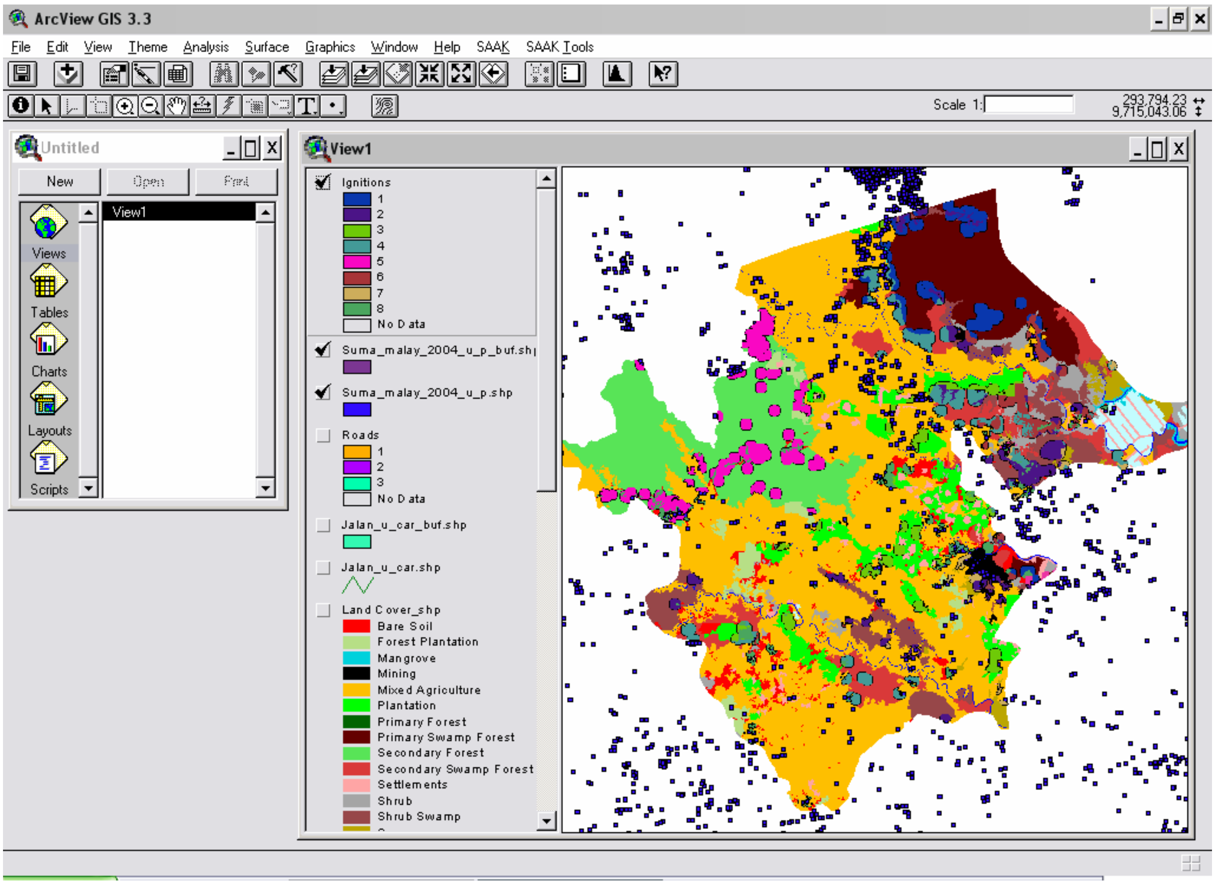



The roads analysis draws buffers of 1 km width around roads which go through areas that are endangered by various types of encroachment. These land cover types are primary and secondary forests and swamp forests as well as shrub swamps. Hot spot analysis showed that fires are especially frequent in these areas close to roads, since the access for people moving in to start land clearing and conversion activities or illegal logging is facilitated.

### 5. Prepare data on previous fire locations

The next step is to prepare the previous fire locations. Currently we use fires detected on satellite images (so-called Hotspots) in the area by choosing the **Preparasi Lokasi Kebakaran** in the SAAK menu.

In certain land cover types, fires are more likely to occur close to areas where a fire already burned in the previous year or earlier in the same year. These areas are to be found in forests or degraded land where land cover conversion or other fire related activities are going on.




The program will therefore check on which land cover a fire occurred. Hot spot analysis has shown that fires are more likely to occur in these land covers, if a fire occurred nearby before:

- Bare Soil
- Secondary Forest
- Swamp Forest
- Plantation
- Shrub and Shrub Swamp

- Swamp

The program buffers the hotspots that fall in these land cover classes and generates two new themes:

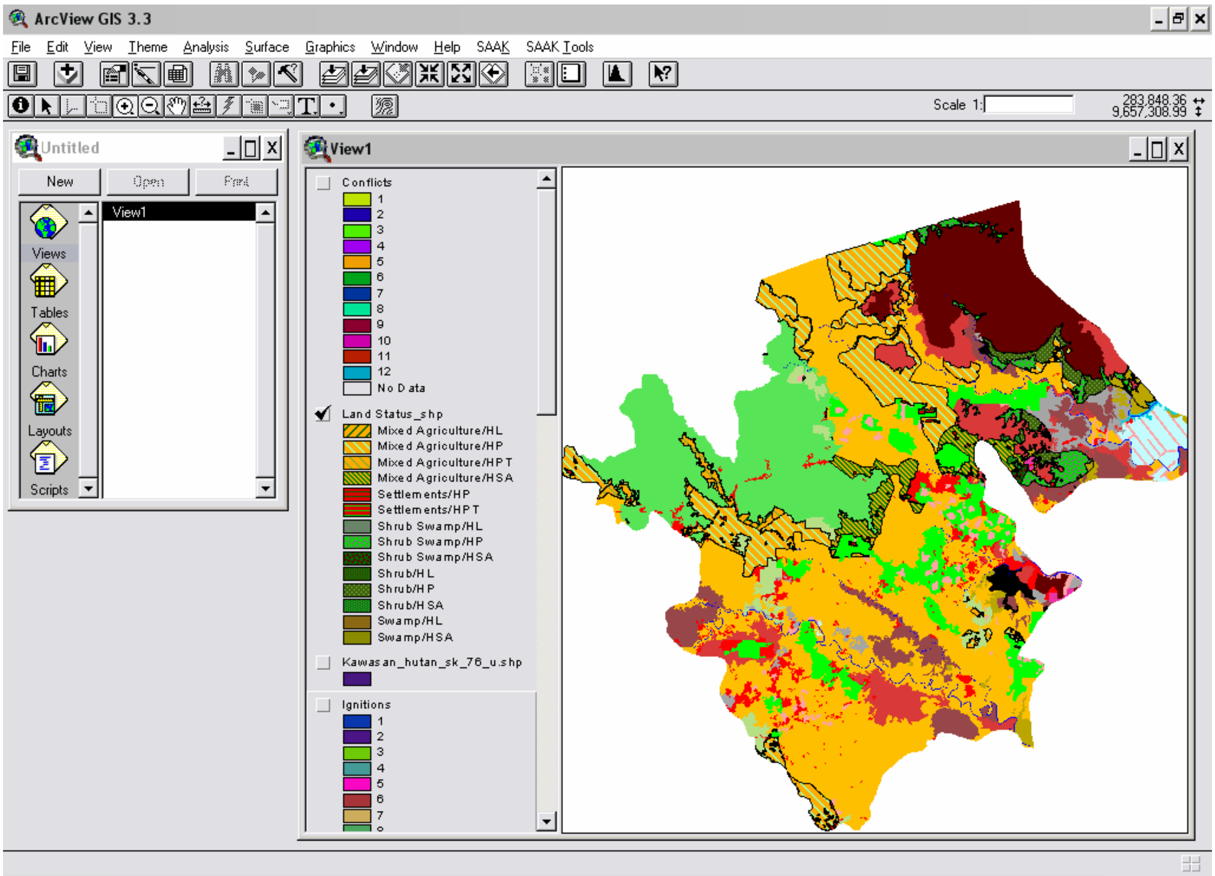
- one showing all hotspots detected in the chosen year
- one showing the 1-km buffer around hotspots in the high risk land cover classes as a shape file.

## 6. Intersecting land status and land cover

The last step in preparing for further analysis is to intersect the land/forest status map with the land cover map. In this way, we can identify areas that are officially forest land, but are actually non-forest areas (e.g. slash and burn agriculture, degraded shrub land or bare soil, plantation etc.) Often this marks an area of increased fire activity due to people encroaching in these areas, converting forest and shrub land for other uses, or starting fires due to land use conflicts.

To prepare the data, choose **Preparasi Kawasan Hutan Terdegradasi** from the SAAK menu.

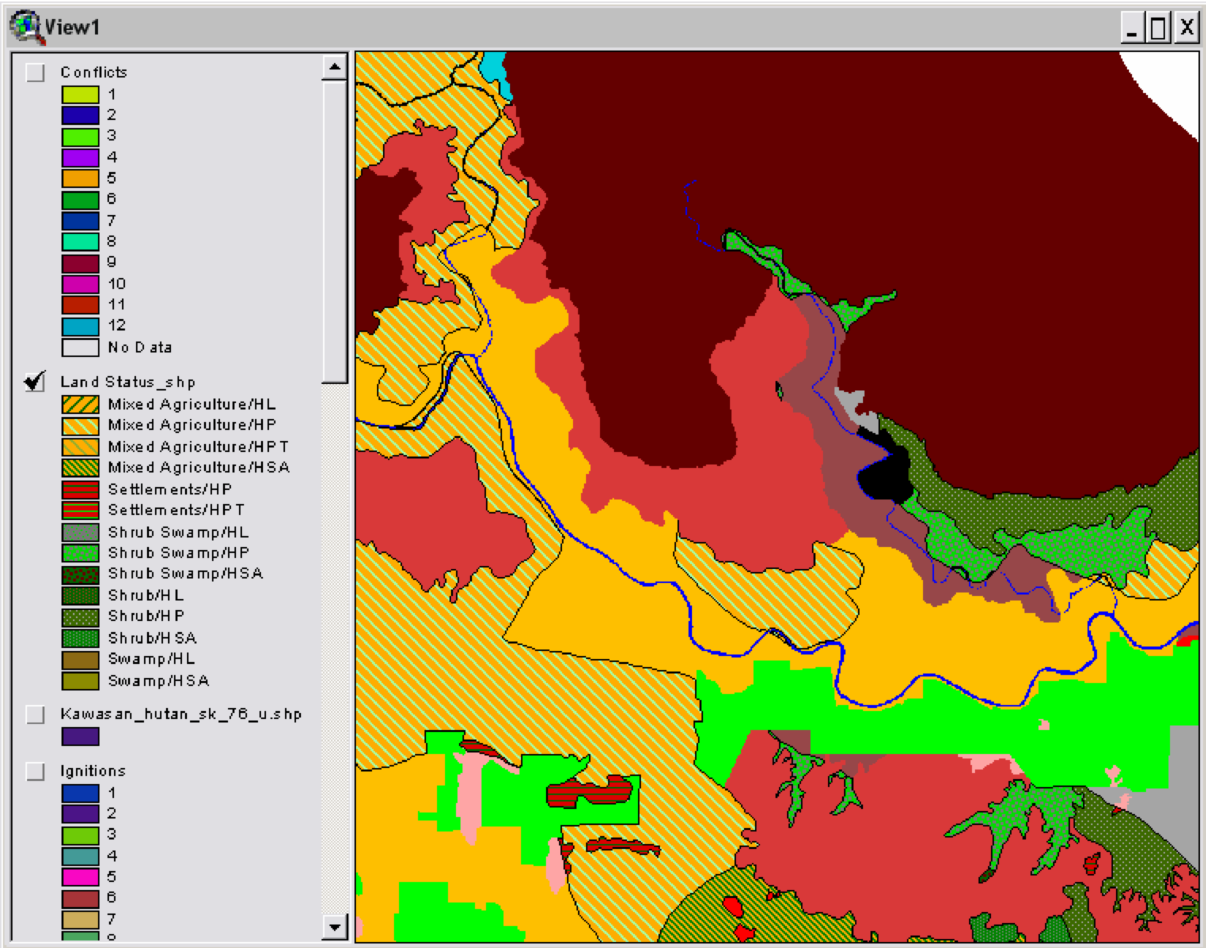
In the appearing dialog you have to match forest status codes in the data with the forest status codes used by the SAAK application (analogous to what you did when preparing the land cover data); then click OK.



The program will now intersect the land cover shape file and the land status shape file and produce a theme that highlights areas where the land status does not correspond to the official land use. The theme legend shows the forest status and the actual land cover.

The shapefile with this information is converted to grid and the grid is also loaded into the view.

In the example below we can see where the forest status differs from the real land cover:

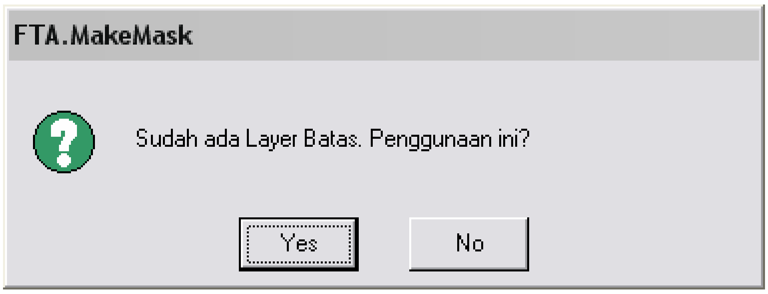



Now, after preparing all necessary input data features, we can start to analyse the fuel cover or the risk of ignition, which can be developed to output maps.

## 7. Preparing the risk of ignition map

To apply the risk of ignition analysis, choose **Menghitung Resiko Penyulutan** in the SAAK menu.

If you already have created a boundary layer in a previous analysis, this question will appear:



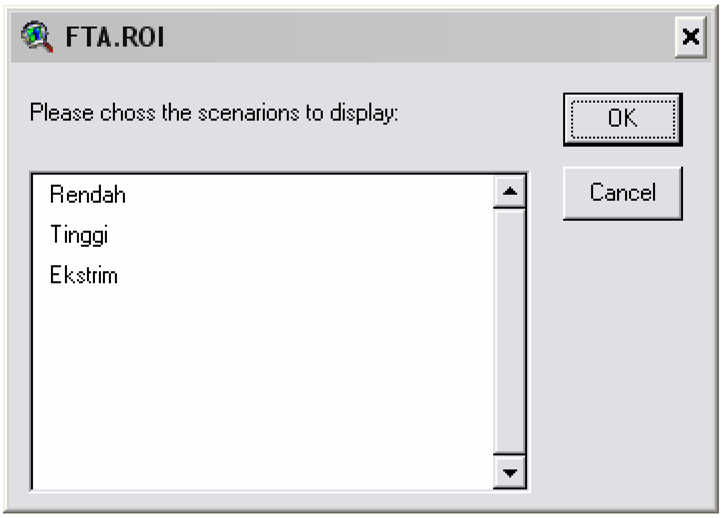

Click Yes for using the existing *batas* (borders) layer or no if you want to create a new layer; for instance if your analysis boundaries have changed.

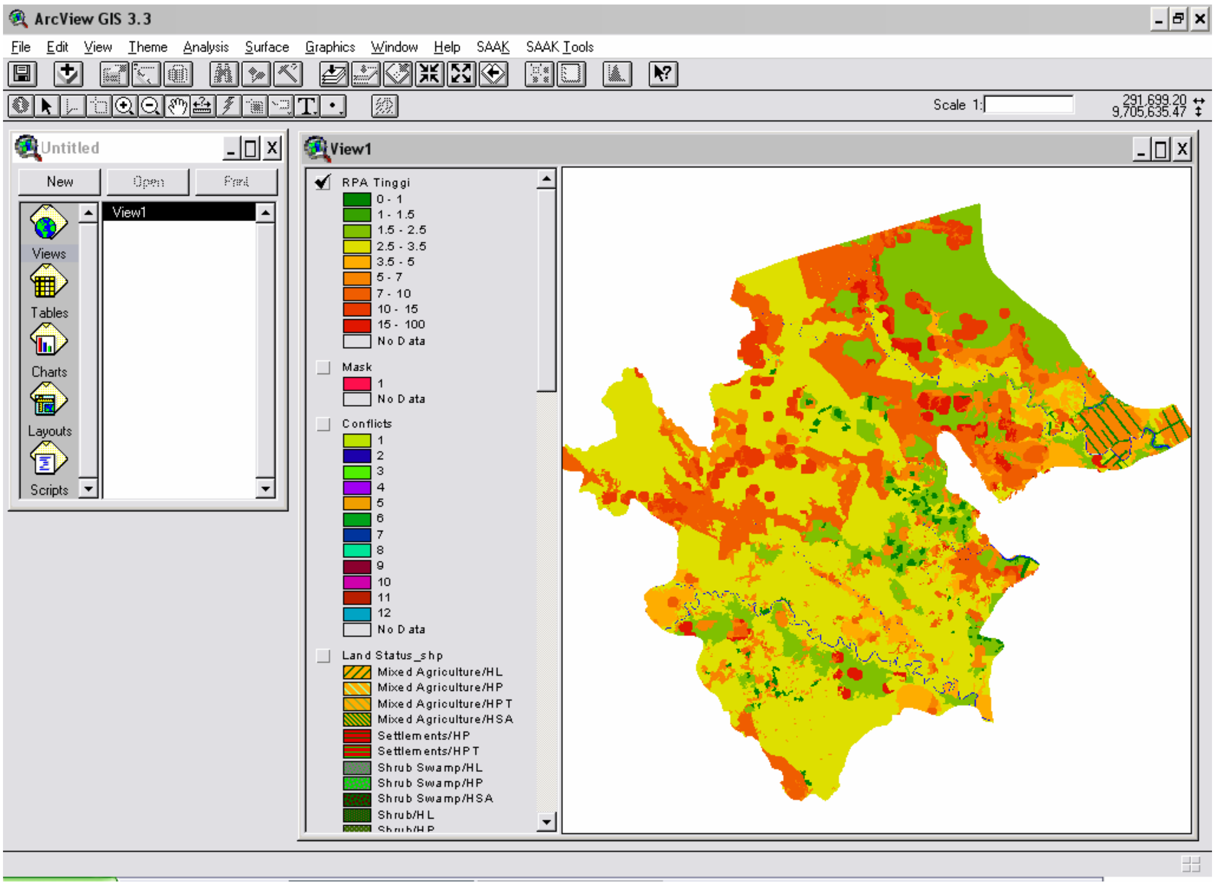
After some processing time you can choose the scenario for the output. These scenarios correspond to the expected severity of the fire situation, which is expressed through the fire danger rating system.

- *Rendah*: this relates to low to medium Fire Danger Rating,
- *Tinggi*: this corresponds to high Fire Danger Rating
- *Ekstrim*: this corresponds to extreme Fire Danger Rating.

Choose one or more of them of them and click OK. In this example we choose the scenario *tinggi*.

The selected scenario shall correspond to the severity of the expected or current fire season. The valid scenario can also change within one fire season. As fire weather gets more extreme, the risk of ignition for different areas changes.



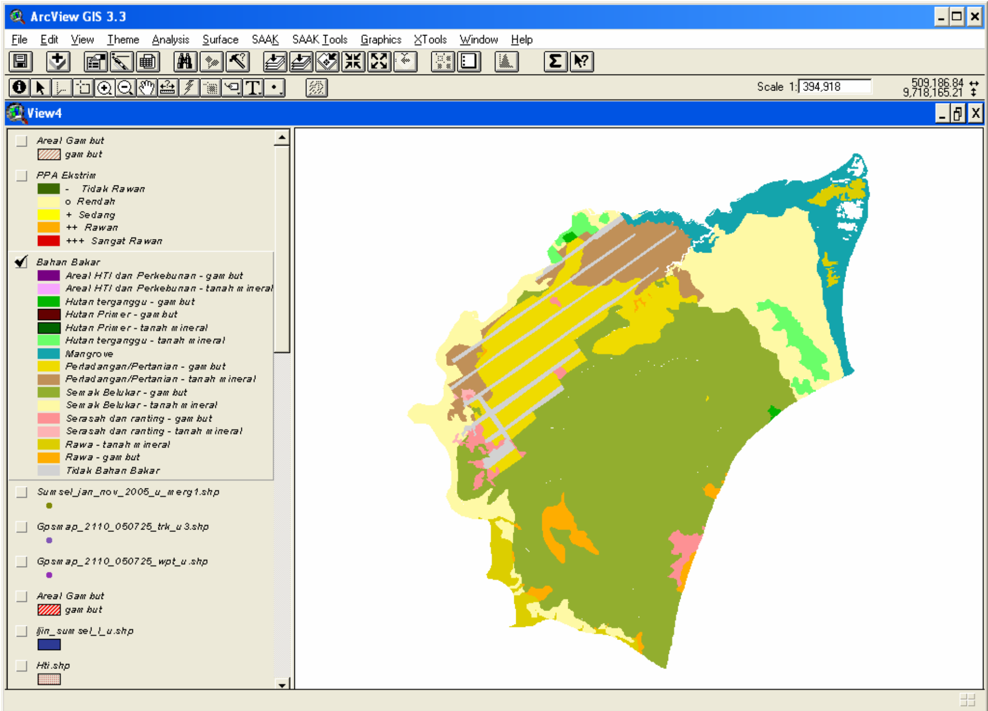



The green areas mark low or no risk of a fire to ignite; the yellow areas show medium risk and the orange and red areas implicate high risk of ignition in a dry year.

## 8. Preparing the fuel map

For preparing the fuel map choose **Preparasi Peta Bahan Bakar** in the SAAK menu.

In the appearing window you first select which field contains the soil type or group. Then select for each group if the underlying soil is mineral (*tanah mineral*) or peat (*gambut*). When you have finished, click OK and the program calculates the fuels map – as shown below for one sub-district.




## 9. Running accessibility analysis for suppression capacities

For preparing the accessibility maps, first road data need to be processed. Roads are buffered to indicate the (max.) 500 m strip that is conveniently accessible from the road. Then, impedance values are assigned to the different land cover classes, expressing the relative difficulty to move through different land covers; i.e. from very easy on roads to very difficult through shrub and secondary forest. After this calculation the user is prompted to select the crew type for which to analyse accessibility. You can select one or mor options depending on what information you are interested in. If all data are available, these options exist:

- Village crews
- POSKOS
- Mangalla Agni
- HTI or Perkebunanan crews.

The path pointing to the corresponding data, which must be point shapefiles showing the crew location, must be set in the **Pengaturan 2** panel first

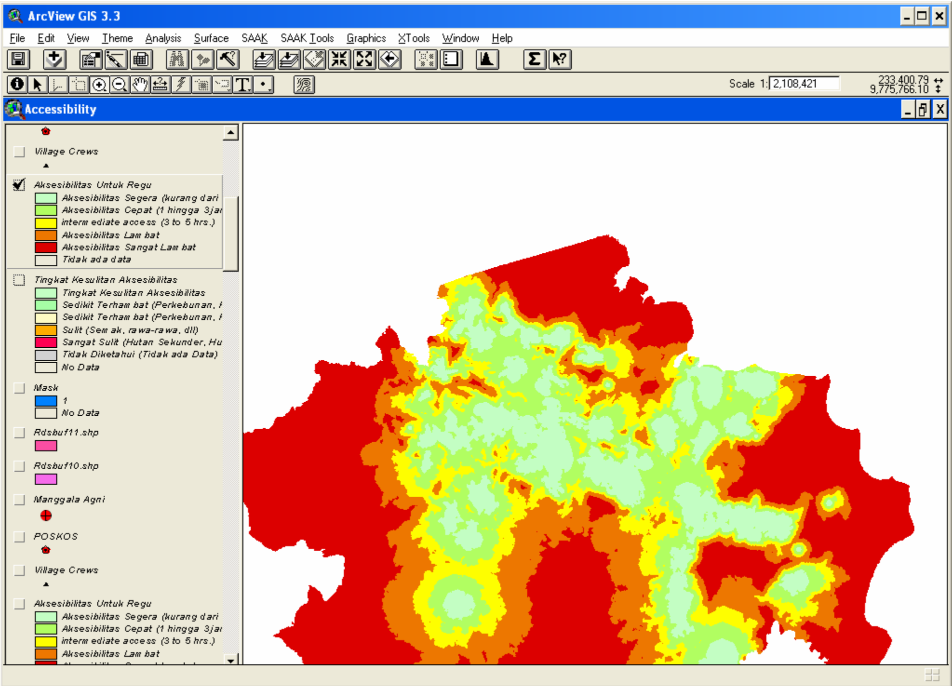
If more then one option is chosen, the program merges all location points into one. It then calculates for all locations the so-called cost distance, which is a distance map that expresses not only the linear (or beeline) distance but also takes ito account the difficulties to travel in different terrain. The output maps are therefore:

- a map showing the relative difficulty in access in different land cover types
- a map showing how fast any one of crews

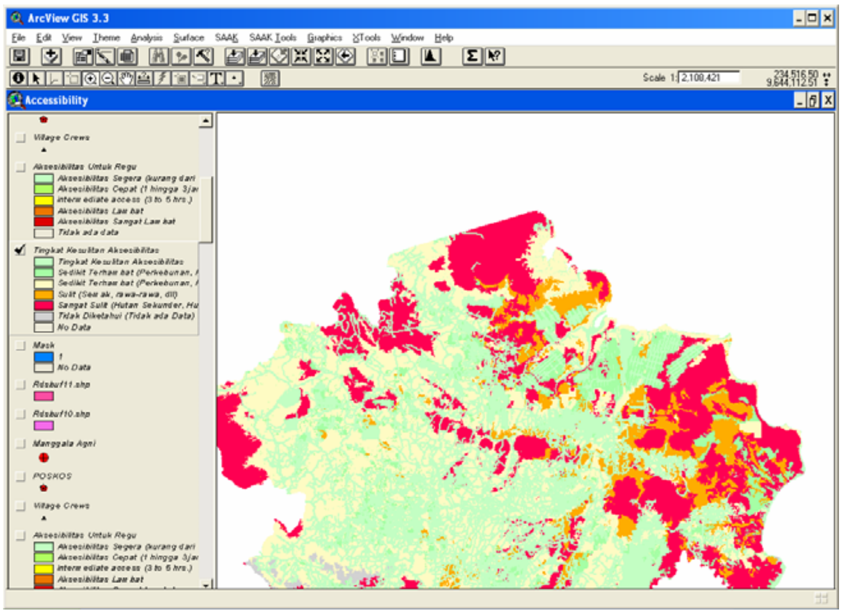
from the input data can reach any spot within the analysis area. It is thus easy to identify areas that are difficult to reach by fire crews.

On top of the maps the locations for the different crew types are displayed, so the user knows which crew types are stations at which location.

The map below shows the accessibility (estimated time to reach a fire location from the closest crew location) for village and POSKO fire crews for SumSel province. The accessibility is shaded from light green (immediate access) to dark brown (long and difficult access).




The map below shows a classification of the land covers classified according to the difficulty to travel for the fire crews from green (easy travel) very difficult travel through inaccessible land cover such as shrub, secondary forest.

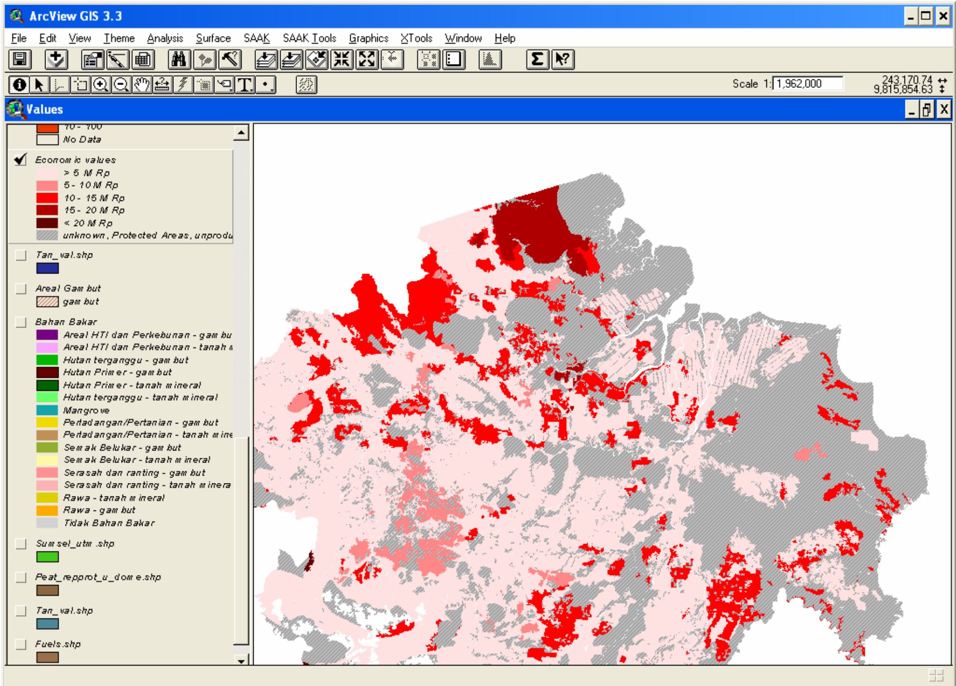



**10. Calculate economic assets map**

For preparing the economic assets map, choose **Preparasi Aset Ekonomi** in the SAAK menu.

An economic assets map will then be calculated and displayed in the view. This map comprises information from land status, soils and land cover maps – so it is important that you process these maps first, otherwise analysis of economic assets can not be performed. This means you must have run at least steps 1-3, 6 and 8 before you can run produce this map.

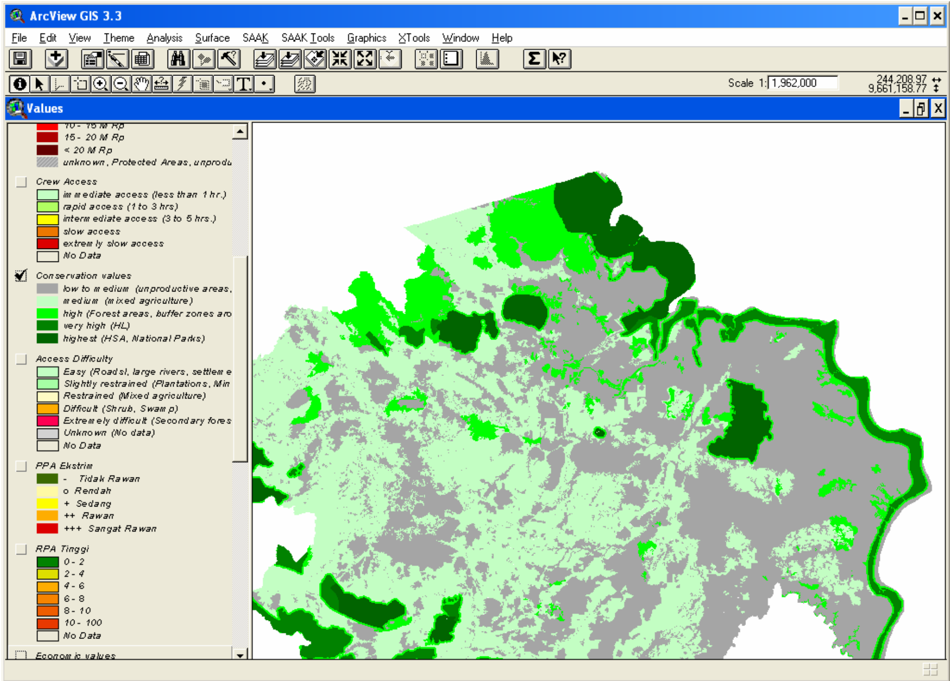
The figure below shows the economic assets colour-shaded after the estimated value of standing stock per hectare in million Rupiah.




### 11.Calculate conservation assets map

For preparing the conservation assets map, choose **Preparasi Aset Konservasi** in the SAAK menu. The conservation assets map will be calculated and displayed in the view. This map comprises information from land cover and land status maps. It also calculates a buffer around conservation areas to highlight the importance of buffer zones around these areas to prevent fires spreading into conservation areas and encroachment-related fires. To calculate this map, at least the land cover data and the land status data need to be processed first.

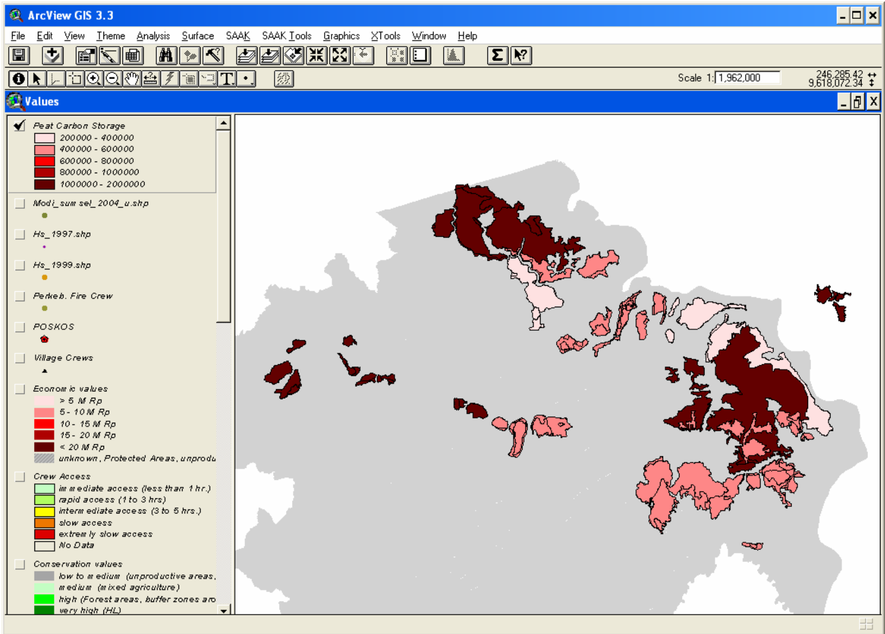
The map below shows the conservation assets map for South Sumatra in a colour ramp from light green (medium value) to highest conservation value (National Park, game reserve). Grey colours indicate low or unknown conservation value.




## 12. Calculate peat carbon storage

For preparing the peat carbon storage map, choose **Kadungan Karbon di Lahan Gambut** in the SAAK menu. The carbon storage map will be calculated and displayed in the view. The map indicates total carbon storage in peat lands derived from peat volume (peat land area * mean peat thickness) and a mean bulk density and carbon content of peat. To calculate this map, at least the soil map needs to be processed first; i.e. step 8 (fuel map) needs to be completed befor peat carbon storage can be estimated. Before the calculation, the user is prompted to point to the field in the shapefile that holds the peat depth. Peat depth needs to express the mean peat depth in the area and needs to be stored in centimetres.

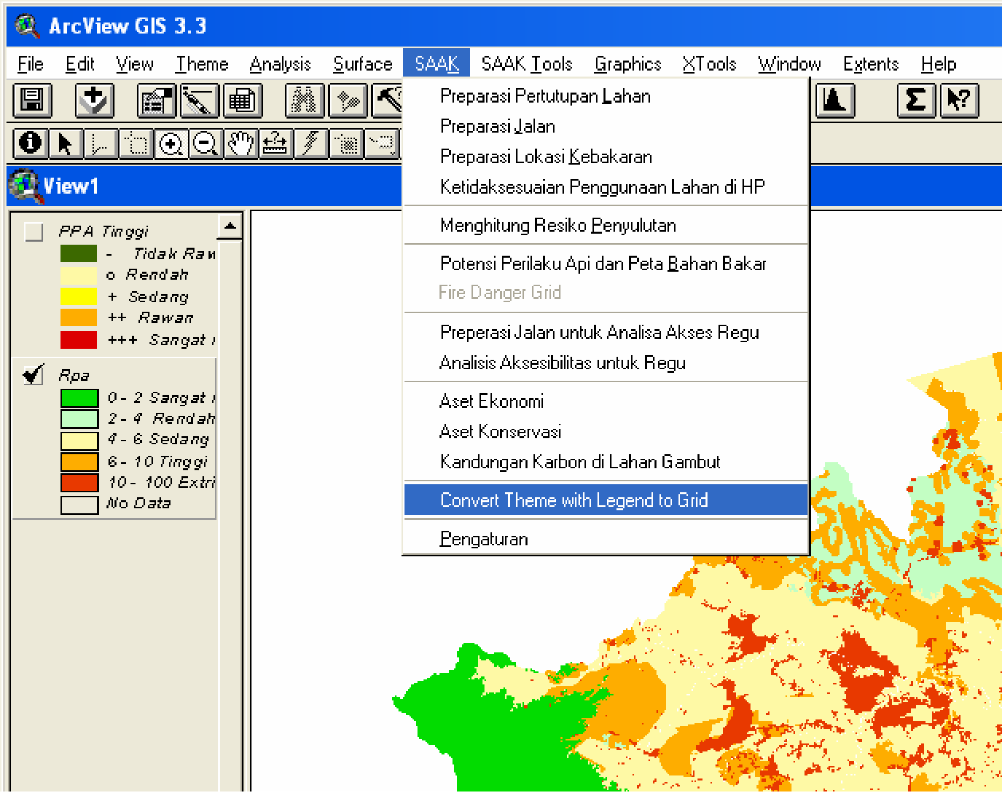
The map below shows the main peat areas with their estimated peat carbon storage in kg/ha. Grey areas are the background of SumSel province.



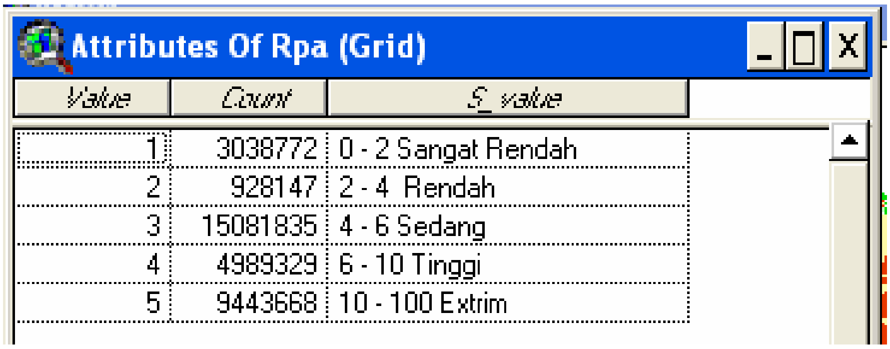

## 13. Convert any output shapefile to grid

For some purposes it is necessary to convert an FTA output shapefile or grid to a simplified grid (raster) format. To do so there is a special utility in the SAAK menu: “Convert Theme with Legend to Grid”. The input theme can be a shapefile or grid. The application takes the legend of the theme and creates a grid with the same legend and the attribute description as shown in the legend. Thus, the data of the output grid hold the same classification as the legend in the view. This is useful to convert complex output shapefiles such as the Potential Fire Behaviour map to a simpler grid, or to reclassify the (numeric) output of the Risk of Ignition grid to a classified grid output. The attribute values are stored in a field named “S_Value” in the grid output.

The figure below shows the Risk of Ignition theme and the menu item for the conversion.




The attribute table then holds the legend label as attributes as shown in the figure below.




| Value | Count | S_value |
|---|---|---|
| 1 | 3038772 | 0 - 2 Sangat Rendah |
| 2 | 928147 | 2 - 4 Rendah |
| 3 | 15081835 | 4 - 6 Sedang |
| 4 | 4989329 | 6 - 10 Tinggi |
| 5 | 9443668 | 10 - 100 Extrim |

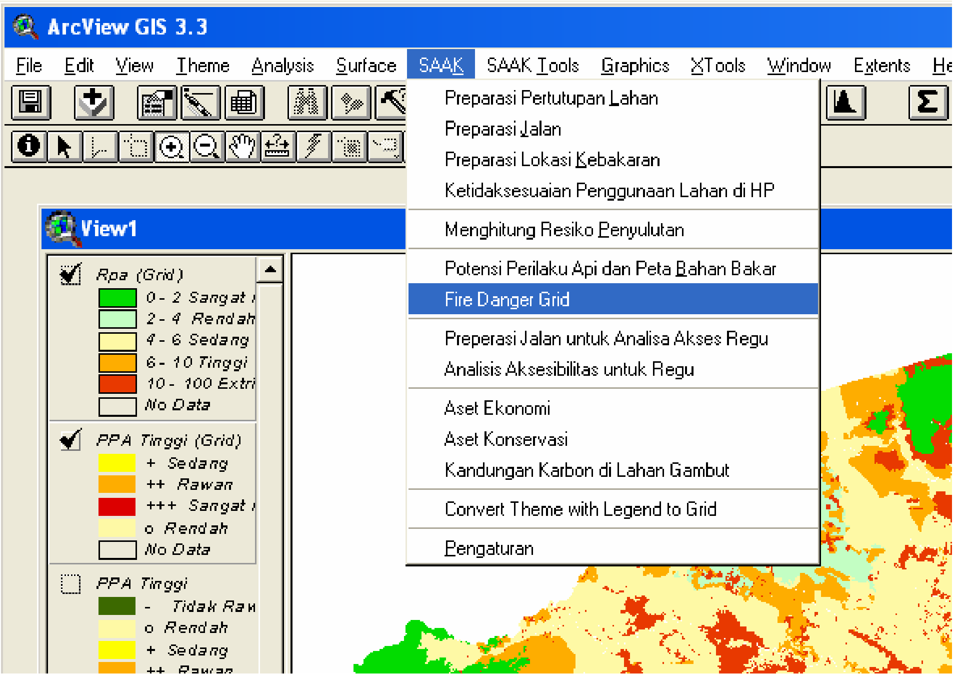
## 14. Calculate Fire Danger Map

The “Fire Danger Map” is an overlay of the Risk of Ignition and the Potential Fire Behaviour component. It thus shows a combination of where fires are probable and where their impacts will most likely be severe. Please not that due to the limitations of the Potential Fire Behaviour map this is still an experimental product.

To calculate the Fire Danger map, first the two input components have to be saved as grids as described in step 13 above.

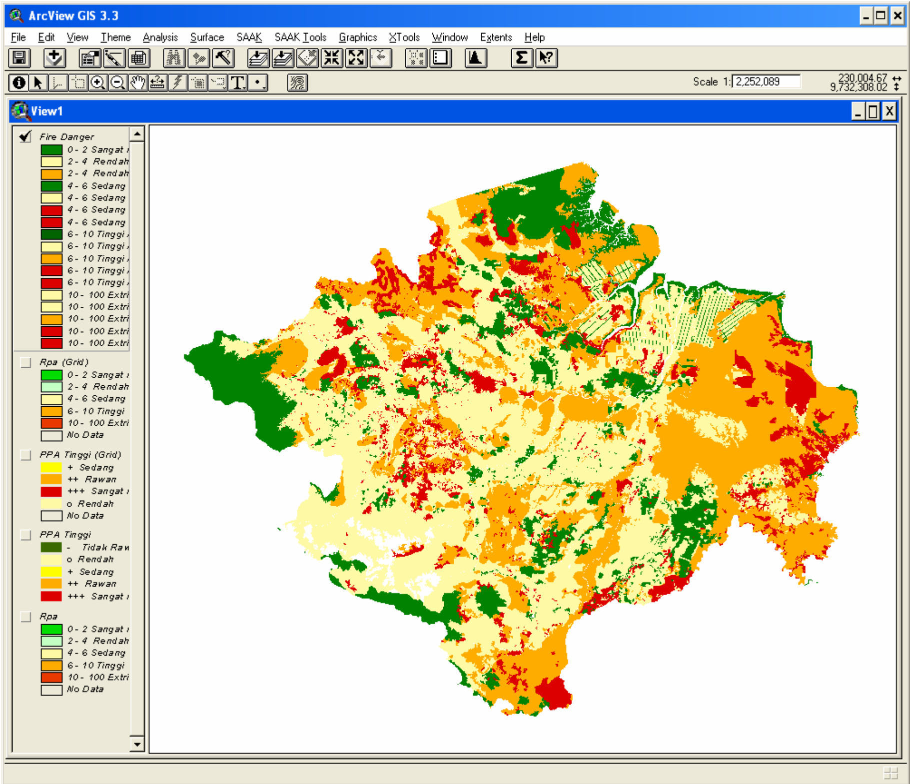
Then, both grids have to be made active (appear elevated in the table of contents, as in the figure below). After selection of the choice for the Fire

Danger Map the map is calculated by combining the two input datasets.




When the calculation is finished, the Fire Danger map is displayed (Image of next page). The legend of the Fire Danger map corresponds to the risk assessment matrix as presented in the main report.

| | **Potential Fire Behaviour** | | | | |
|---|---|---|---|---|---|
| **RoI** | - | o | + | ++ | +++ |
| **E** | **M** | **M** | **H** | **E** | **E** |
| **T** | **M** | **M** | **H** | **E** | **E** |
| **S** | **L** | **M** | **M** | **H** | **E** |
| **R** | **L** | **M** | **M** | **H** | **H** |
| **SR** | **L** | **L** | **M** | **H** | **H** |


ArcView GIS 3.3
File Edit View Theme Analysis Surface SAAK SAAK Tools Graphics XTools Window Extents Help
Scale 1: 2,252,089
230,004.67
9,732,308.02
View1
Fire Danger
0 - 2 Sangat
2 - 4 Rendah
2 - 4 Rendah
4 - 6 Sedang
4 - 6 Sedang
4 - 6 Sedang
4 - 6 Sedang
6 - 10 Tinggi
6 - 10 Tinggi
6 - 10 Tinggi
6 - 10 Tinggi
6 - 10 Tinggi
10 - 100 Extri
10 - 100 Extri
10 - 100 Extri
10 - 100 Extri
10 - 100 Extri
Rpa (Grid)
0 - 2 Sangat
2 - 4 Rendah
4 - 6 Sedang
6 - 10 Tinggi
10 - 100 Extri
No Data
PPA Tinggi (Grid)
+ Sedang
++ Rawan
+++ Sangat
o Rendah
No Data
PPA Tinggi
- Tidak Raw
o Rendah
+ Sedang
++ Rawan
+++ Sangat
Rpa
0 - 2 Sangat
2 - 4 Rendah
4 - 6 Sedang
6 - 10 Tinggi
10 - 100 Extri
No Data

# Appendix 2

# Administrator's Manual for FTA

## 1. Installing FTA and FTA directory structure

FTA can be installed from the fta.zip file by just extracting the files to their designated directories.

FTA uses the ESRI ArcView GIS program directories to store program information. These directories are usually found under C:\ESRI\AV_GIS30\ARCVIEW on your hard disk.

This directory has a number of subdirectories. FTA uses two of these subdirectories:

- ARCVIEW\Ext32, and
- ARCVIEW\etc.

The ARCVIEW\EXT32 directory is the directory that holds all extensions to ArcView GIS, such as the Spatial Analyst or the SAAK extension for FTA. The file fta.avx must be copied into this directory for the FTA extension to work.

The ArcView\etc directory is used by FTA to store additional information the program needs to function. FTA needs its own directory:

- ARCVIEW\etc\fta.

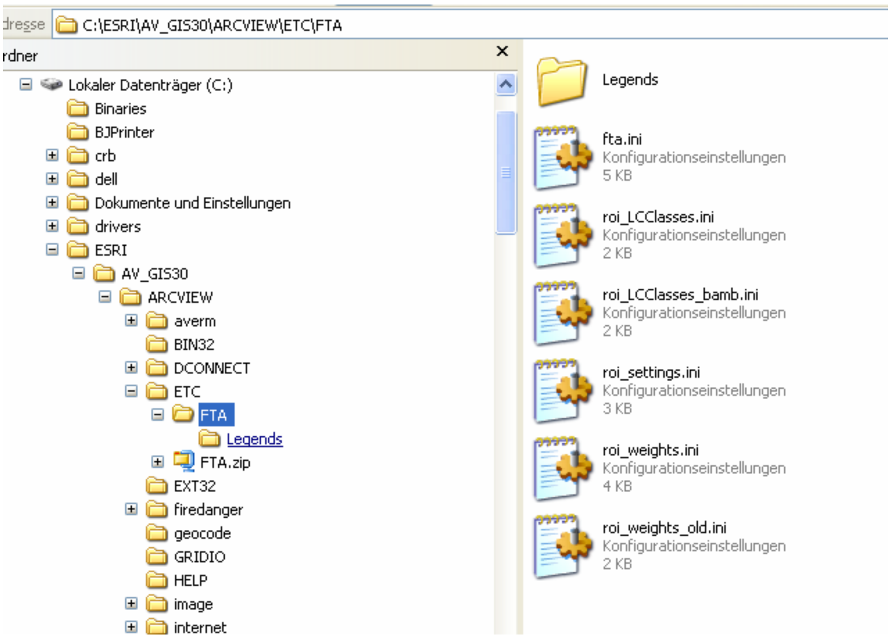
All files in the zip file that have the extension ".ini" have to be copied to this directory.

This directory, in turn has one subdirectory

- ARCVIEW\etc\fta\legends.

All files in the zip file that have the extension ".avx" need to be copied to this directory.

Once all of these files are in place FTA should work as described in the user's manual.




**Configuring FTA ini-files**

The FTA "ini" files are simple text files that can be edited with any text editor. They hold configuration information for FTA. Please take care when modifying these files; FTA may not work correctly after changes are made. So always be sure that you have a copy of the original ini files.

There are four ini files:

Fta.ini: This file holds translations of the main program messages and dialog labels.

Roi_LCClasses.ini: This file holds key-value associations between attributes in the input data and attributes used internally by FTA. This file is maintained by the program, there is no need to edit it.

roi_settings.ini: This file holds settings for FTA, mainly file names for input and output data. It is maintained by the program, and there is no need to edit it

roi_weights.ini: This file contains weights or class-value associations for the various components of FTA. It should be edited with great caution.

All ini files are structured in the same way:

Information in the ini files is stored in blocks that are marked with the #-symbol and contain a beginning and an end marker, e.g.:

```
#LandCoverWeights Begin
….
#LandCoverWeights End
```

Between the beginning and end marker, the information is stored as an association between keys and values, e.g.

```
Bare Soil $ 0.4, 0.9
```

The key (`Bare soil`) is separated from the value (`0.4, 0.9`) with a $-symbol.

In this case, the value itself in fact is a list of values: 0.4, 0.9. If the program expects a list of values, those are separated by "," as in the example.

All information in the ini-files is stored in this way. It is therefore important never to remove any block markers, because if the program can't find these markers it will not work correctly!

The following section will describe how the ini-files can be edited.

**Configuring Messages**

The message fill "fta.ini" holds the program messages. The left hand (the key) of the information stores the English version of the program message. Never change this part. The right hand side stores the Indonesian part. You are free to change this part:

```
#FileSettings Begin
Land Cover $ Penutupan Lahan
Roads $ Jalan
Previous Ignitions $ Lokasi Kebakaran
Land Status $ Status Kawasan
Soils $ Tanah
Output Directory $ Directory Penyimpanan
Mask File $ File Batas
Mask Query $ Query Batas
Title $ Pengaturan
#FileSettings End
```

The example above shows the settings for the labels in the "Settings"/"Pengaturan" Dialog.

**Configuring Weights**

The weights configuration has several sections for each of the FTA components.

The Risk of Ignition component uses the Blocks LandcoverWeights, Roadweights and IgnitionWeights. Each class in these Blocks is associated with two weights for the risk of Ignition probability (this represents the contents of table 3 in the main report), so after the $-sign there are two numbers, one for the medium and one for the high risk scenario. If these numbers are changed it should be done with caution and after new research on fire statistics in the respective land use areas are available as the numbers are based on a statistical evaluation of fire incidents over the past years derived from hotspot data (see main report).

The block for land cover weights looks like this:

```
#LandCoverWeights Begin
Bare Soil $ 0.4, 0.9
Forest Plantation $ 0.2, 0.1
Mangrove $ -2.8, -2.5
Mining $ 1.1, 1.1
Mixed Agriculture $ 0.2, -0.5
Plantation $ -0.3, -0.5
Primary Forest $ -1.6, -2.7
Primary Swamp Forest $ -0.9, -1.3
Shrub Swamp $ -0.5, 0.5
Secondary Forest $ -0.1, -0.7
Secondary Swamp Forest $ -0.1, 0.5
Settlements $ -0.3, -0.5
Shrub $ 0.1, 0
Swamp $ 0.3, 1.2
Transmigration Area $ -0.7, -1.1
Wet Rice Field $ -0.3, -0.4
Water $ -99, -99
No Data $ -99, -99
#LandCoverWeights End
```

The special value of "-99" stands for "no data" or "not applicable".

The Block "LandStatusClassMap" is used internally by the program to retrieve a list of possible land status values. The values to the keys are meaningless. If other legal land status types shall be evaluated in Risk of Ignition analysis, these have to be entered here.

"Conflictweights" refers to the analysis of land cover vs. land use (see table 3 of the main report). The weights are for weighting in the risk of ignition analysis.

SoilsClassMap is used to look up the Indonesian word for peat and mineral soil internally by the program. There should be no need to change these settings[2].

The next block is called "PFBClasses" and refers to the classes for Potential fire Behaviour. Currently, this is an association between fuel types and symbols for fire behaviour in two scenarios as described in table 4 of the main report:

```
#PFBClasses Begin
Areal HTI dan Perkebunan - gambut $ -,+++,+++
Areal HTI dan Perkebunan - tanah mineral $ -,o,++
```

[2] The right side of the $-sign may be modified (e.g. to replace "gambut" with another word). In this case the following block, the "PFBClasses" need also to be adapted.

```
Hutan terganggu - gambut $ -,++,+++
Hutan terganggu - tanah mineral $ +,++,+++
Hutan Primer - gambut $ -,-,+
Hutan Primer - tanah mineral $ -,-,+
Mangrove $ -,-,o
Perladangan/Pertanian - gambut $ o,+,+++
Perladangan/Pertanian - tanah mineral $ o,+,++
Semak Belukar - gambut $ -,+,+++
Semak Belukar - tanah mineral $ -,+,+++
Serasah dan ranting - gambut $ -,+,+++
Serasah dan ranting - tanah mineral $ +,+++,+++
rawa - tanah mineral $ -,+,+++
rawa - gambut $ -,+,+++
Tidak Bahan Bakar $ o,o,o
#PFBClasses End
```

The three different scenarios are separated by comas. If the weighting is to be changed, the symbols can be changed here.

The next block is called “ImpedanceWeights”. It is used to calculate the accessibility layer. The values indicate the relative difficulty to travel through different land covers – e.g. 1 as the lowest difficulty is assigned to roads. The last value in the list: Road Buffer Width $ 500 designates the width of the buffer that is used to buffer roads. It is set to 500 m to indicate the area that is immediately accessible from roads.

The block “TangibleValues” assignes a value in Rupiah to different land cover classes. The values (right side of the $-sign) can be changed as necessary.

The block conservation values assigns conservation values to the classes on the left side. +++ is the highest. The values (right side of the $-sign) can be changed as necessary.

**Configuring Legends**

All legends are stored in the legends subdirectory of the “FTA” directory. All legends can be changed as desired for the FTA output themes. If a changed legend is to be saved for default use by the program it has to be saved back under the theme name in the legends directory. Also, if a legend is to be restored for a theme (e.g. if a theme is not newly calculated by FTA but loaded into the view from disk), the legend can also be retrieved from this directory.

# Appendix 3

# A short Summary of the Weights of Evidence Method

**A short Summary of the Weights of Evidence Method**

In order to derive the prototype model to estimate ignition probability for the districts of South Sumatra, we decided to work only with data that are available for all districts. Using these data an empirical algorithm was established based on fire occurrence in past fire events as recorded by MODIS hotspots processed using the NASA algorithm. Where hotspots formed clusters that were obviously corresponding to a single fire event these clusters were counted as a single ignition to avoid double counting of the same fire.

The algorithm to estimate ignition probability is based on the so called Weights of Evidence model (Bonham-Carter 1994), which is a so-called Bayesian model. Bayesian approaches are based on the concept of conditional probabilities:

The probability of a phenomenon (called the response variable) to occur is determined by certain factors. If the instances of the response variable were randomly distributed in respect to a factor over a study area, the conditional probability would equal the so-called prior probability. The prior probability can be expressed as a simple area proportion: if fires occur on 50 % of a study area, and are randomly distributed, you will just have a fifty percent chance to find a fire at any point in the study area. If the presence or absence of some factor (e.g. proximity to roads or a certain land use) exerts some influence on the distribution of fire occurrence, the probability of finding a fire close to a road will be different from this prior probability – from experience we expect that it will be higher. This is called the posterior or conditional probability, because it is based on the condition of proximity to a road. To measure this influence, weights are calculated based on the relative frequency of fires in relation to the area occupied by the factor value compared to the whole study area:

$$W^{+} = \ln \frac{N(B \bigcap D) / N(D)}{[N(B) - N(B \bigcap D)] / [N(T) - N(D)]} \qquad \text{(eq. 1)}$$

Since we are looking at grids, we divide our study area in a rectangular grid of cells of a defined size, e.g. 100 x 100 m. Thus, in eq. 1, N(T) is the number of unit cells in the entire study area, N(B) the number of cells where the input factor occurs (e.g. the number of cells closer than 1.000 m to a road), and N(D) the total number of cells where fires have been registered. Thus each input factor can be assigned a weight based on its importance for the occurrence of the response variable, in our case fires. In general, weights between 0.5 and 1 are moderately predictive; values between 1 and 2 are strongly predictive; weights greater than 2 are highly predictive for the presence of the response variable (Kemp et al.. 1999). In a multi-factor analysis all input factors are overlaid, and for each raster cell the posterior probability of fire occurrence is calculated from the weights of each input factor (Bonham-Carter 1995).

**Reference:**

Bonham-Carter, G.F. (1994), Geographic Information Systems for Geoscientists: Modelling with GIS. Oxford: Pergamon, 398 pp.