Some Information on the Fire-Danger Rating (FDR) System on the basis of the Keetch-Byram Dryness Index (KBDI)[1]

The Use of simple Fire Danger Rating Systems as a Tool for Early Warning in Forestry

Introduction

More and more foresters realize the importance of developing methodologies for monitoring and predicting fuel conditions in the forest to determine the fire danger in a given area. The intense forest fires raging in the province of East Kalimantan in 1997-98, as well as in Brazil drastically showed that the element fire has to be taken into account for management and conservation of forest resources in the tropics. Many of these forest fires could have been prevented if an effective fire management system had been in place at that time. One important aspect of a fire management system is the integration of early warning to ensure that the organization in charge is prepared for possible upcoming fire calamities. Several countries like Canada, Australia and U.S.A. have developed highly sophisticated Forest Fire Danger Rating Systems. In the setting of developing countries these systems are often very difficult to implement, since they are based on a lot of meteorological data and need complicated calculations. The example of East Kalimantan shows that weather stations and equipment like that which is standard in the countries mentioned above simply does not exist and for the near future will not be operationally in use. This paper intends to highlight very simple and inexpensive methods to determine fire danger and to give assistance in setting up such a system.

The Keetch Byram Drought Index

The Keetch-Byram Drought Index (KBDI) (Keetch and Byram 1968) expresses drought as an index on a scale from 0 to 2000, based on the moisture content of the soil. Zero is the point of no moisture deficiency and 2000 is the maximum drought level possible. For almost 5 years the Integrated Forest Fire Management (IFFM) Project has used the KBDI for Fire Danger Rating in East Kalimantan on an operational basis. In 1995 the index was modified and adapted to the conditions in East Kalimantan (Deeming 1995). The computation for deriving the Index is done in a simple spreadsheet by the staff of IFFM on a daily basis.
The major advantage of the KBDI is that only three variables are required to compute the Drought Index:

- Mean annual rainfall of a station,
- Today's maximum temperature, and
- Todays rainfall

The Drought Factor equation, which has been slightly modified, is now used for the calculation in East Kalimantan:

$$DF = \frac{(2000 - KBDI) \times (0.9676^{(0.0875 \times T_{\max} + 1.552)} - 8.299) \times 0.001}{1 + 10.88^{(-0.00175 \times Ann_{Rain})}}$$

where T_{max} is the daily maximum temperature and Ann_{Rain} is the mean annual rainfall for the area.

[1] This paper has been published by the GTZ Integrated Forest Fire Management Project (IFFM), Indonesia. the source is: Buchholz, G., and D. Weidemann. 2000. The Use of simple Fire Danger Rating Systems as a Tool for Early Warning in Forestry. International Forest Fire News No. 23, 32-36. The paper is available at the GFMC website under:
http://www.fire.uni-freiburg.de/iffn/country/id/id_29.htm
An annex has been added from another paper of the IFFM project.

The KBDI itself of a given day is the sum of yesterdays rating reduced by 10 times rainfall added to today's Drought Factor (DF). The Fire Danger, which is expressed through the KBDI, can range from 0 to 2000. To start calculating the KBDI for a given region, one has to go back to a period when the KBDI dropped to "0", meaning the soil was saturated by water. Keetch and Byram (1968) indicate that point as the day after a rainy period with 150 to 200 mm rainfall within one week.

The index was originally divided into three fire danger classes, for practical reasons and with the focus on the potential end user concessionaires the fire danger rating class "extreme" will be added to the classes:

Tab.1. Fire Danger Rating Classes

Numeric scale	Adjective scale
0-999	Low
1 000 - 1 499	Moderate
1 500 - 1 750	High
1 750 - 2 000	Extreme

IFFM is currently integrating this information into a GIS to evaluate the various fire danger rating conditions for parts of the province.

The Nesterov Index

Another simple Fire Danger Rating Index was developed by Nesterov (1949). This index is used with slight modifications in Russia as well as in other European countries. The Nesterov Index is based on the following parameters:

- Days without rain
- Dry bulb temperature
- Dew Point temperature (calculated from relative humidity and temperature)

$$N = \sum_{i=1}^{W} (t_1 - D_1) \times t_i$$

where

N = Nesterov Index
W = number of days since the last rainfall > 3mm
t = temperature °C
D = dew point temperature °C

The index requires daily observations of temperature, dew point temperature and precipitation. The difference between daily temperature and dew point temperature is multiplied by temperature and cumulatively added over the days since the last rainfall. Thus the index increases each day until a rainfall of more than 3 mm occurs, at which the index drops back to zero and the process begins again. The system is divided into the following fire danger levels:

Nil	0 - 300
Moderate	301 - 1 000
High	1 001 - 4 000
Extreme	4 001 +

Comparison of the two Indexes during the extreme fire season 1997

The Nesterov Index and the KBDI were tested in the 1997 fire season in East Kalimantan. This year serves as a useful example, since it was characterized by wet conditions at the beginning of the year. In February-March the drought started followed by a small amount of precipitation. Between June and October almost no rain was recorded. In this period of high fire risk most of the forest fires were recorded.

The comparison between the two indexes shows several interesting aspects of these differing fire danger ratings methods. Since the KBDI is a drought index based on the possibility of the soil to hold water, it is limited by the field capacity. The KBDI system in East Kalimantan is based on the assumption of a 200 mm field capacity. The field capacity multiplied by 10 is hence the upper limit (2 000) of the rating. The Nesterov Index does not have this limitation and so has no upper limit, this causes the extraordinary value of 18 000 by the end of September, showing extreme fire danger. Both systems follow the development in the same manner, increasing steadily with no rain, and falling down when rain occurs. The Nesterov Index, by definition, falls down to zero if rain occurs. This is a clear limitation of the Index since it assumes no fire danger on a day with more than 3 mm precipitation. For the tropics this 3 mm is much to small, since 3 mm are by far not sufficient to saturate vegetation and duff with moisture, this figure has to be increased to a higher amount. Another limitation of the Nesterov Index is the decrease of the index to zero, since this only describes the situation where rain occurs. In the tropical region there is a high variability in rainfall, the variation is that many rainstorms are very local with tracks only 5 to 10 km wide, so the assumption that fire danger drops to zero for a larger area is not appropriate for fire management purposes.

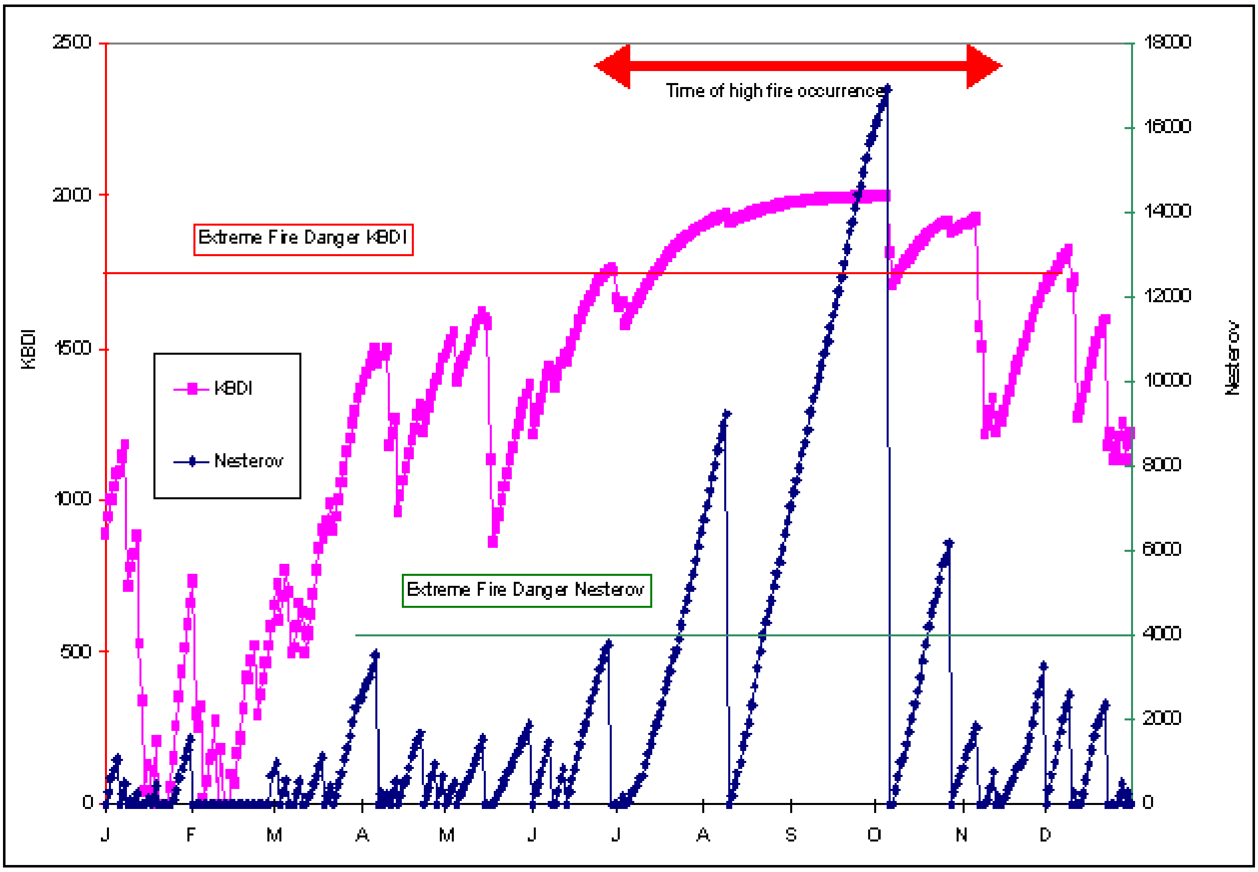

Fig.1. A comparison of the performance of the fire danger rating systems KBDI and Nesterov (note different scaling)

When comparing the number of days within each Fire Danger Rating Class, the similarities of the two systems are obvious; both systems measure approximately 50% of the days in the high fire danger rating class. The difference in the lower classes results from the sharp drop to zero of the Nesterov Index, when rain with more than 3 mm occurs, while the KBDI drops only slightly, often staying in the same class.

The comparison of the two indexes shows that they are both useful tools for early warning. The simplicity of the calculations and the few requirements to measure the input weather data makes both these formulas effective and practicable measures, especially in circumstances where the budget and trained staff is missing. These simple indexes can be calculated by the forest industry as well as the official forestry agencies, requiring only a simple weather station and a spreadsheet programme. The KBDI generally gives a more realistic overview of the fire danger situation due to the only slight decrease if rain occurs, while the Nesterov Index shows the increased fire risk in periods of extreme drought more dramatically. Since the costs for a simple weather station, which can measure relative humidity, rain and temperature in the case of the Nesterov Index, and a weather station that can measure rainfall and maximum temperature for the KBDI are rather small, this methodology is most suitable to the specific circumstances of forest protection in developing countries. An extensive network of simple weather stations that provide data for either index has to be preferred over complex high sophisticated fire danger rating systems like those that exist in western countries like America or Canada.

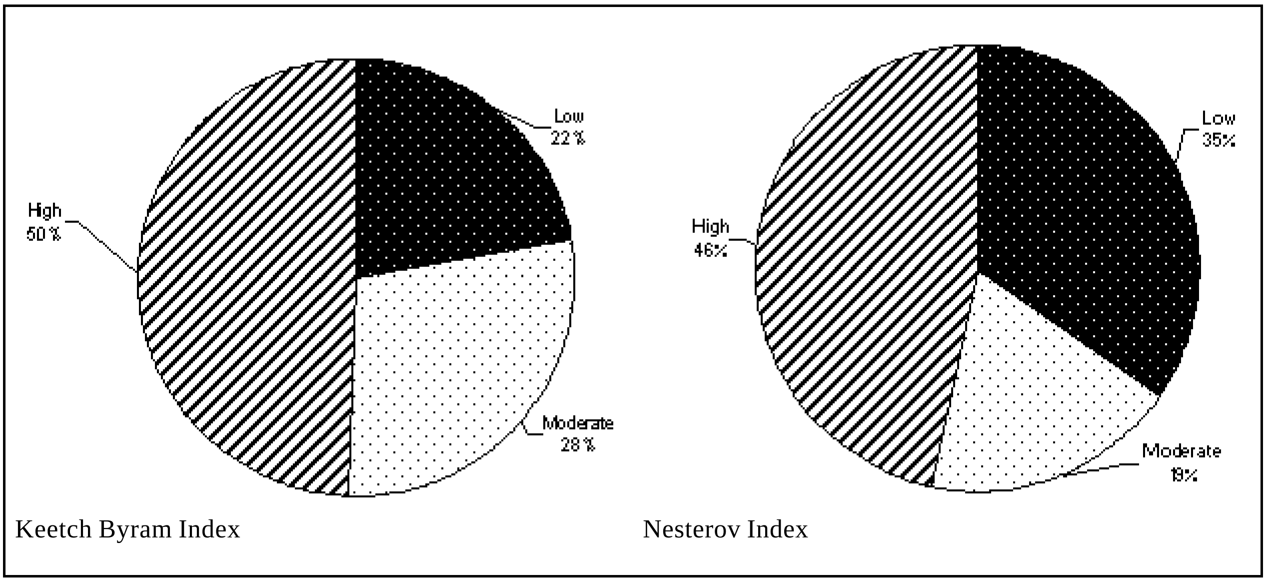

Fig. 2. Amount of days in the three Fire Danger Rating Classes according to the KBDI and the Nesterov Index in 1997

Crucial for effective fire management are the measures taken with this information, data dissemination methods and Standard Operating Systems have to be in place based on the early warning information, to ensure protection of the valuable forest resources.

The spread sheet used to calculate both the formulas and further information on Fire Danger Rating can be obtained from the Integrated Forest Fire Management Project, Samarinda, East Kalimantan, Indonesia. Contact the author at iffmfire@smd.mega.net.id.

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Appendix to IFFM Paper: Implementation of the FDRS

Implementation of a FDRS for East Kalimantan

For East Kalimantan, all that is needed are rainfall and temperature data from as many locations as is practical. It seems likely that a reliable FDRS could be established for almost the entire province, or at least for the most endangered parts of it. About 14 stations have data available for KBDI calculation. The most important requirement for an up-to-date FDRS is to have access to the latest data. In drought periods the Dryness Index has to be calculated at least twice a week to make an accurate assessment for the likelihood of fire occurrence. Due to the varying regional distribution of precipitation it seems likely that an extension of the area that is observed by KBDI calculations could become useful. Latest data should be available for almost all airport locations. If drought periods are expected, KBDI calculations can be starting. As mentioned above KBDI has not to be computed every day, but for every day.

Implementation by the Indonesian Bureau of Meteorology

The (BMG) provides the main source of climate data. IFFM and BMG therefore agreed to hand over KBDI calculation responsibility to BMG. This would ensure the sustainability of IFFM efforts to establish a FDRS based on KBDI for the entire province. It is envisaged that the BMG branch in Balikpapan take over the calculation of the KBDI. BMG runs at least nine weather stations throughout the province, but only very few data sets are complete and available. Because most of these stations are located at, or close to airports, to cooperate with BMG and thus to have easy and fast access to actual data could become important during the next drought period. If BMG, which owns stations along the coast, but only a very few in the inland, would cooperate with the Department of Public Work (PU), which mostly runs former TAD stations all over the province, an extensive network of weather-stations could be established. But as long as there is no exchange of data, the KBDI-calculations remain not actual and incomplete.

Implementation by Timber Concessions

Due to all the problems and limiting factors mentioned above, one of the most important facts for a sustainable FDRS is to motivate also timber concessions to run their own FDRS. Because timber-concessions belong to the companies most affected by the fires, it would be advisable for them to calculate the KBDI using their own weather data. This is already practiced by some companies which already had weather stations. Since only a few and easy accessible data, daily maximal temperature and rainfall, and an easy calculation program are required it is not too difficult to become independent. As long as there is not yet a working system established in East Kalimantan, which gives information and warning in advance also in a very local scale, which seems to be necessary since the rainfall distribution also differs very regional, an own fire prediction system is one way for timber concessions to realize oncoming drought periods early and to react immediately. Fire prevention, suppression and fighting activities are more efficient if they are started before or at the moment they are needed.