Developing a Fire Danger Rating System for India

- Lessons from across the World

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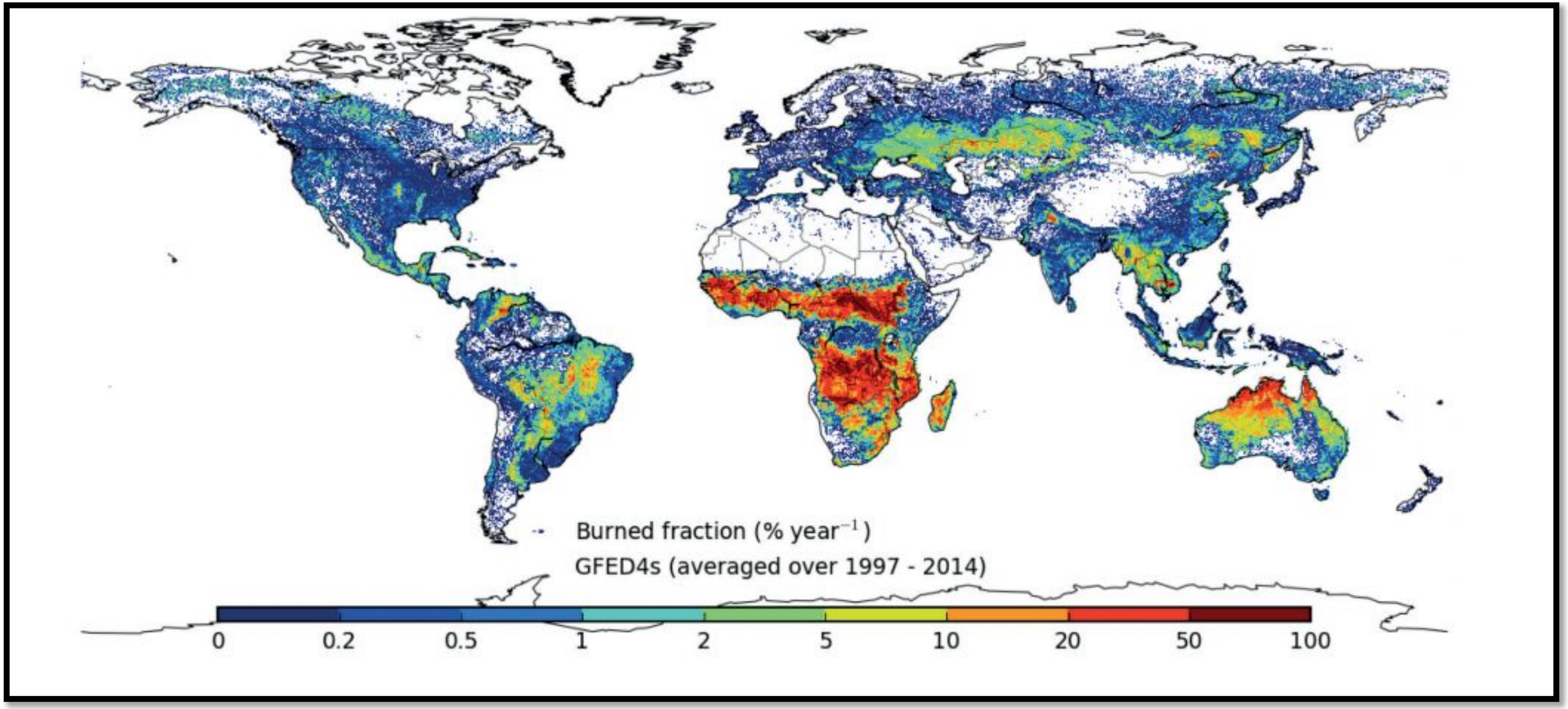
Conservator of Forests, Solan, HP

Structure of Presentation

- Large Forest Fires in India
- Fire Danger Rating
- Major FRDS across the world (Australia, Canada, USA)
- FDRS development in India
- Lessons in adoption of FDRS

Fires across the world



Global distribution of annual area burned, averaged over 1997-2014. White areas show no fire activity. Source: Global Fire Emission Database version 4, Giglio et al. 2013

Increasing frequency of extreme fire events

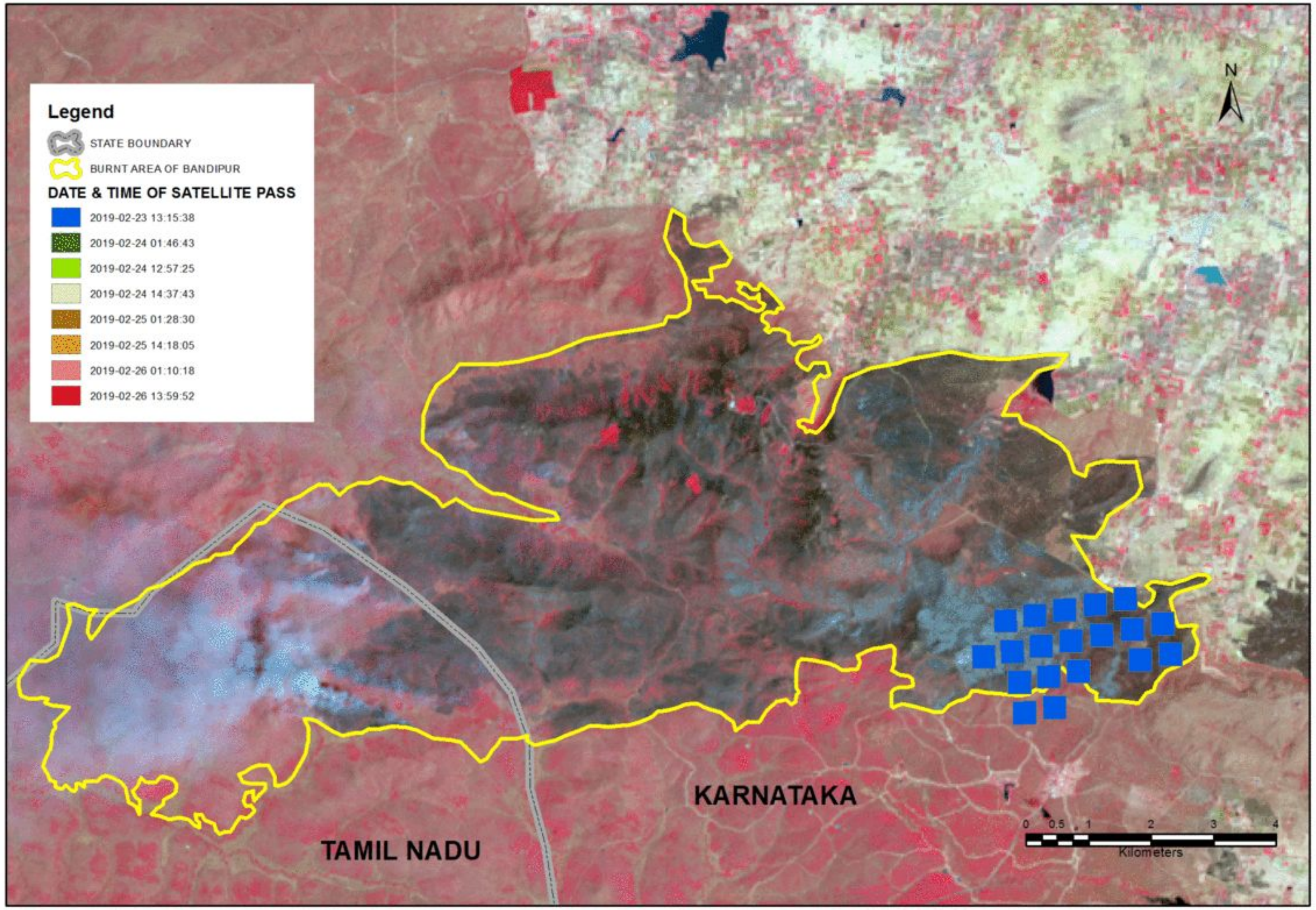
- Hundreds of people die in Europe every year due to wild fires (more than 100 in Portugal alone every year)
- 2017-2018 fires claimed more than 50 people in California
- In 2009, 173 lives were lost in the Black Saturday fires in Australia
- Kurangani Fires of Tamil Nadu, India led to loss of 23 lives
- In 2017 - 1600 homes lost in Chile, >2500 in Fort McMurray fire in Canada in 2016
- 2020 - Worst California wildfire season recorded history (1.7 mill Ha)
- Some large fires like the August complex fire 2020 cost more than a billion dollars to control

- Expanding human imprint in fire affected landscapes
- Changing Climate
- High costs of Fire Management

Gundulpet Fire- Bandipur TR & Mudumalai TR

23rd F

SNPP VIIRS Pass wise Fire Progression at Bandipur Tiger Reserve



Forest Fire Monitoring by FSI- A Timeline

Year	Milestone
2004	Dissemination of Forest fire alerts based on MODIS data started
2010	Initiation of SMS alerts on number of fires in State/District
2012	KML alerts to nodal officers through email
2012	FSI's Vulnerability of India's Forests to Fires Report published
2015	Burnt Scar assessments started (Pilot areas)
2016	Pre warning alerts piloted
2016	Automated email alerts to nodal officers using python script
2017	**FSI Forest Fire Alert System 2.0 released on 23rd January 2017. Complete automation of the entire process; VIIRS data use started**
2017	Long term Characterization study of Forest Fires in India was carried out
2018	Improved feedback system for forest fire alerts
2019	**FSI Forest Fire Alerts System version 3.0 (FAST 3.0) released on 16th January, 2019 Development of Early-Warning System for India- based on Pilot FDRS Study**

Automated monitoring of large forest fires using near-real time satellite data

Forest Fire Danger Rating System

- allows fire managers to **estimate today's or tomorrow's fire danger** for a given area.
- Fire Danger Ratings describe conditions that **reflect the potential, over a large area, for a fire to ignite, spread and require suppression action**.
- combines the **effects of existing and expected states of selected fire danger** factors into one or more qualitative or numeric indices that **reflect an area's fire protection needs.**

Key questions answered by FDRS

- **Rate of spread – Present and Future**
- Difficulty of control (Type of initial attack, equipment, manpower needs)
- Intensity of Fire (High, moderate, low)
- **Type of fire (Crown or Ground?)**
- Probability of " Blowing up" or explosion
- Spotting potential and spotting distance

Use of FDRS

- Links an organization's **readiness level** (or pre-planned fire suppression actions) to the potential fire problems.
- Knowledge of these levels can help-
  - Farmers to postpone burning agri waste, debris
  - Forest contractors working in the forest may consider extra precautions when using equipment that might produce sparks,
  - tourists make decisions about whether or not to visit a forest area,

- In some cases, the State Forest Department may even restrict certain activities based on the fire danger levels.

Objectives of FDRS

- Planning and execution of fire fighting operations
- Resource allocation and mobilisation
  - Crew allotment and despatch tool- Canada
- Risk reduction and mitigation
- Develop scientific approaches for identification of high fire prone areas

FDRS in India- Journey sofar..

Year	Milestone
2016	Early-warning alerts (piloted based on current season fire points)
2016	KBDI pilot study, KBDI calculator software
2017	Improved EWS (Grid based) using IITM weather forecast data
2018	Semi-automated EWS
2019	Basic FDRS (FWI based)

Early Warning/ Pre-warning → Basic FDRS → Comprehensive FDRS

Keetch Byram Drought Index- KBDI (1968)

- It's a continuous reference scale for estimating the dryness of the soil
- Assumes fully saturated soil with 8 inches of rainfall has KBDI =0
- Ranges from 0 to 800
- DF today equals DF Yesterday + DF Today

KBDI Equation in SI Units (Rainfall in mm and Temp in ^{0}C)

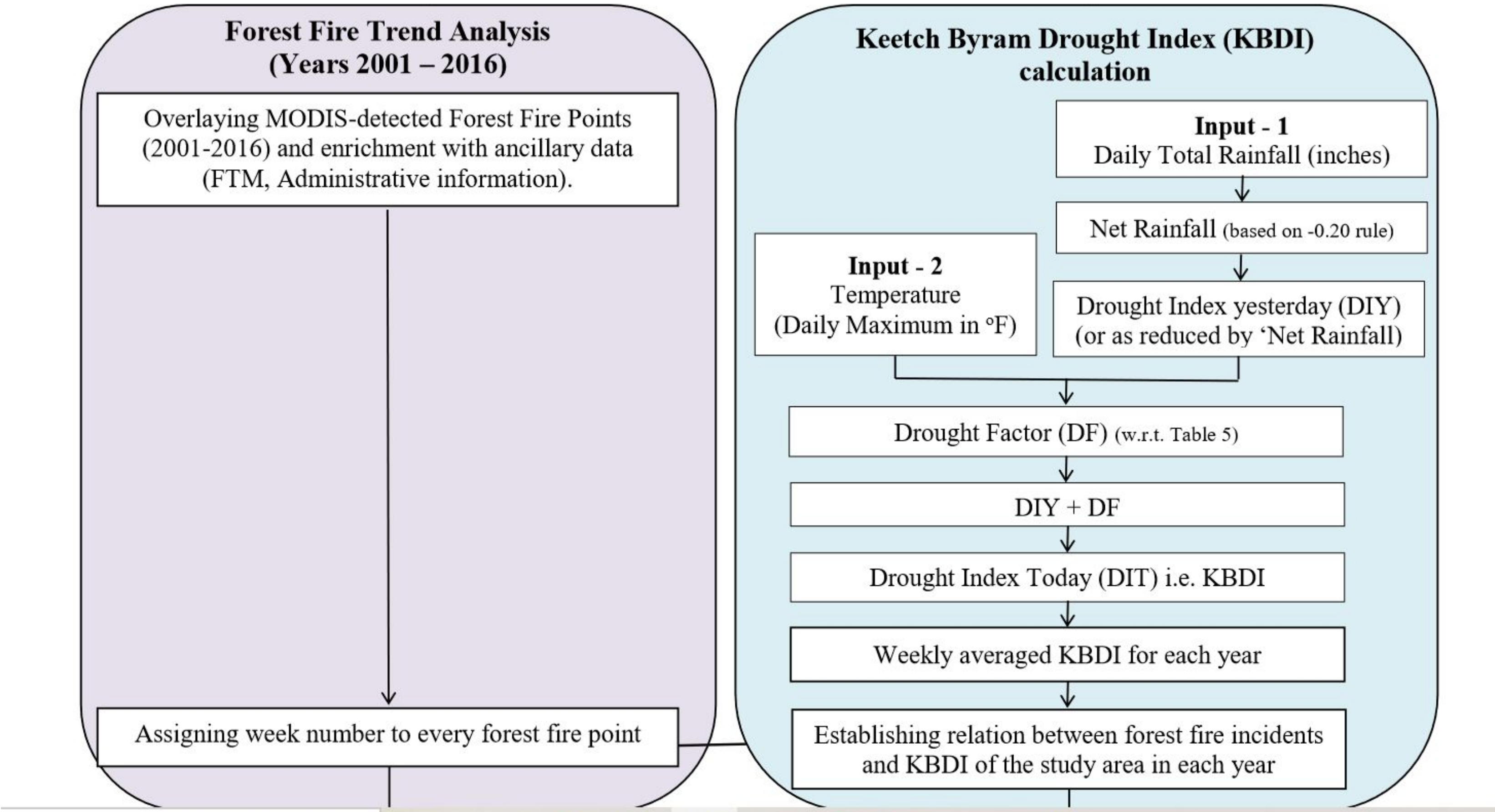
$$DF = \frac{(2000 - KBDI) \times (0.9676^{(0.0875 \times T_{\max} + 1.552)} - 8.299) \times 0.001}{1 + 10.88^{(-0.00175 \times Ann_{Rain})}}$$

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

Stages of Keetch Byram Drought Index (as per Keetch-Byram, 1968).

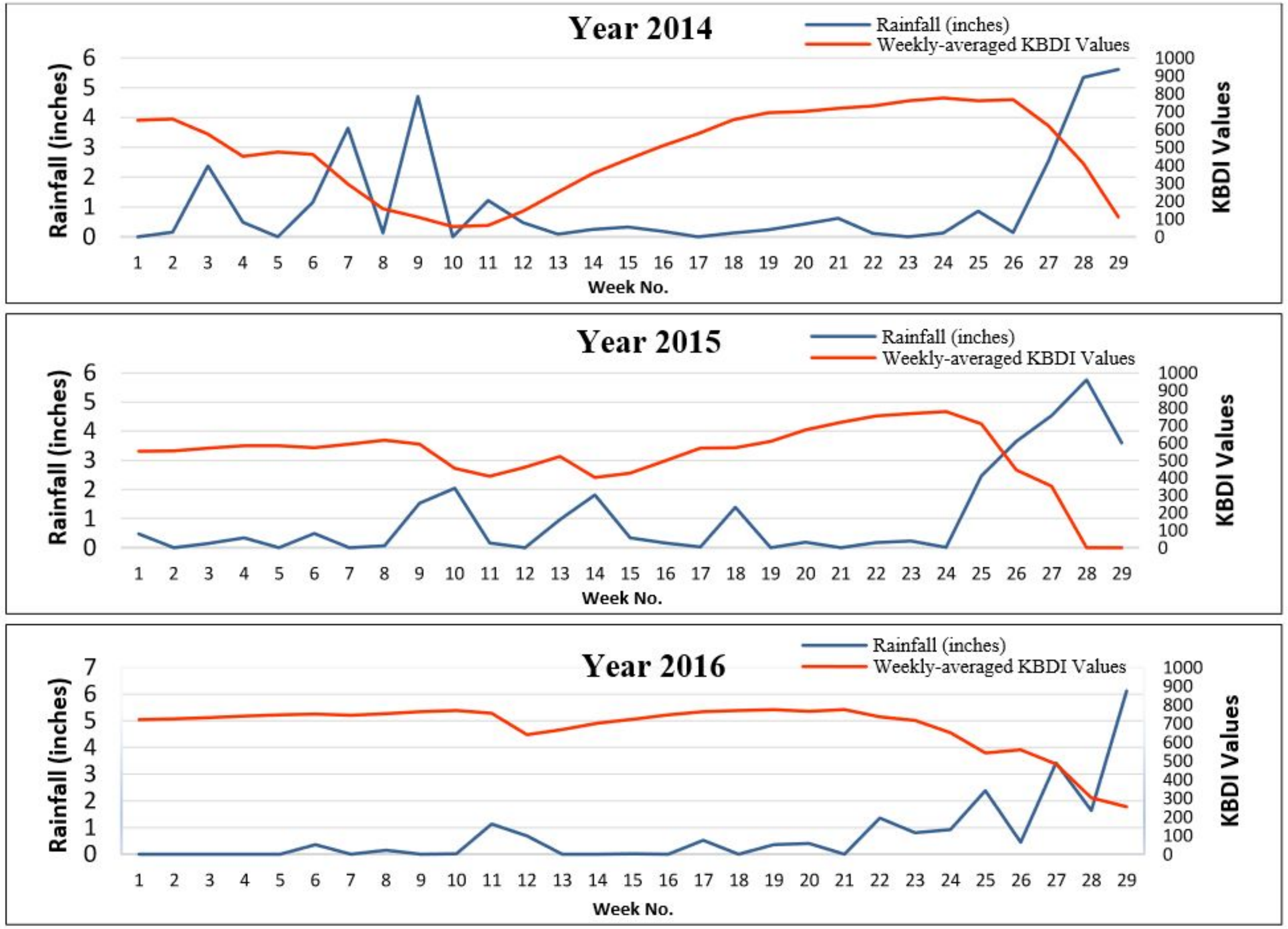
Index value	Drought stage	Index value	Drought stage
0 - 99	0	400- 499	4
100 - 199	1	500- 599	5
200- 299	2	600- 699	6
300- 399	3	700-800	7

KBDI application- Pilot Study in Shiwaliks of Uttarakhand



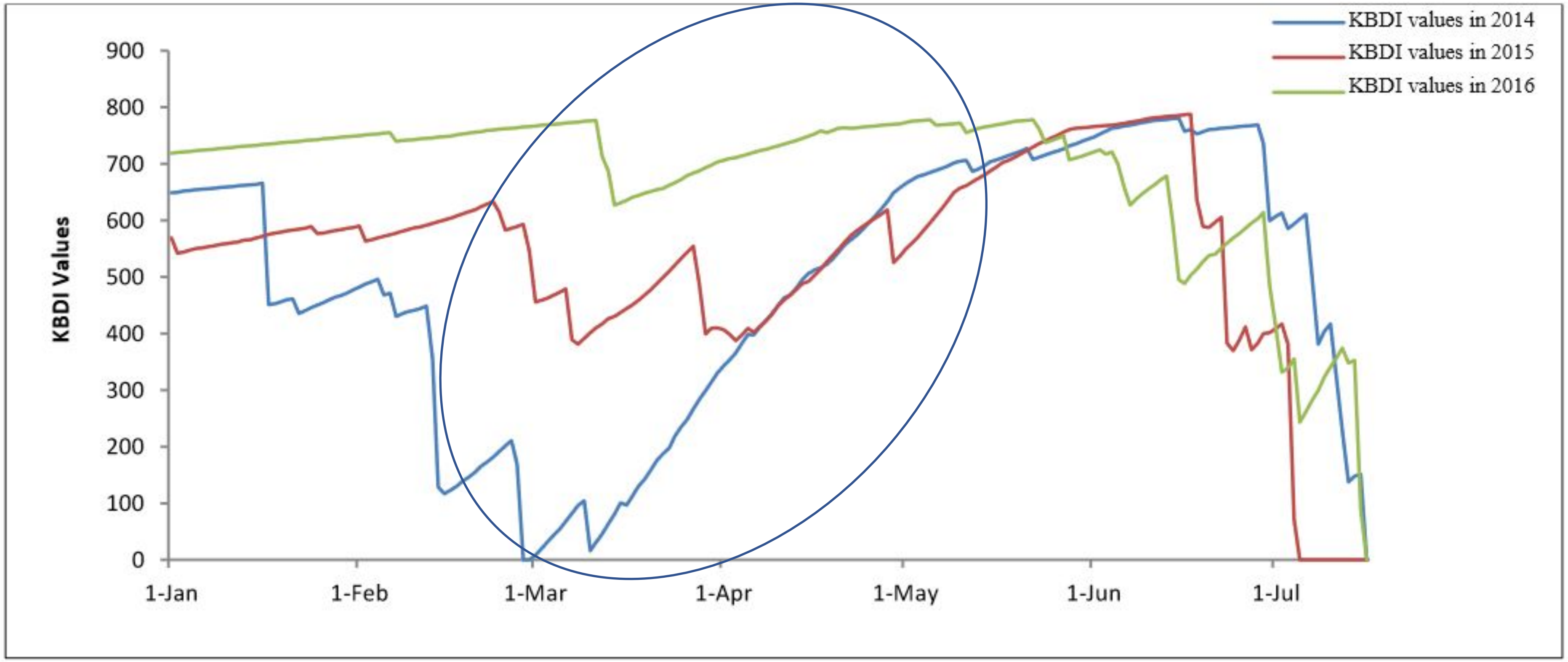
-Daily rainfall data GIOVANNI for their product TRMM_3B42_Daily_v7.
- Daily maximum temperature was acquired from MOSDAC (Meteorological and Oceanographic Satellite Data Archival Centre). (AWS) ISRO0989-15F3DD (IIRS Campus. Dehradun
For missing days, data from AWS-ISRO0987-15F3DB (Agriculture & Soils Division IIRS-1)

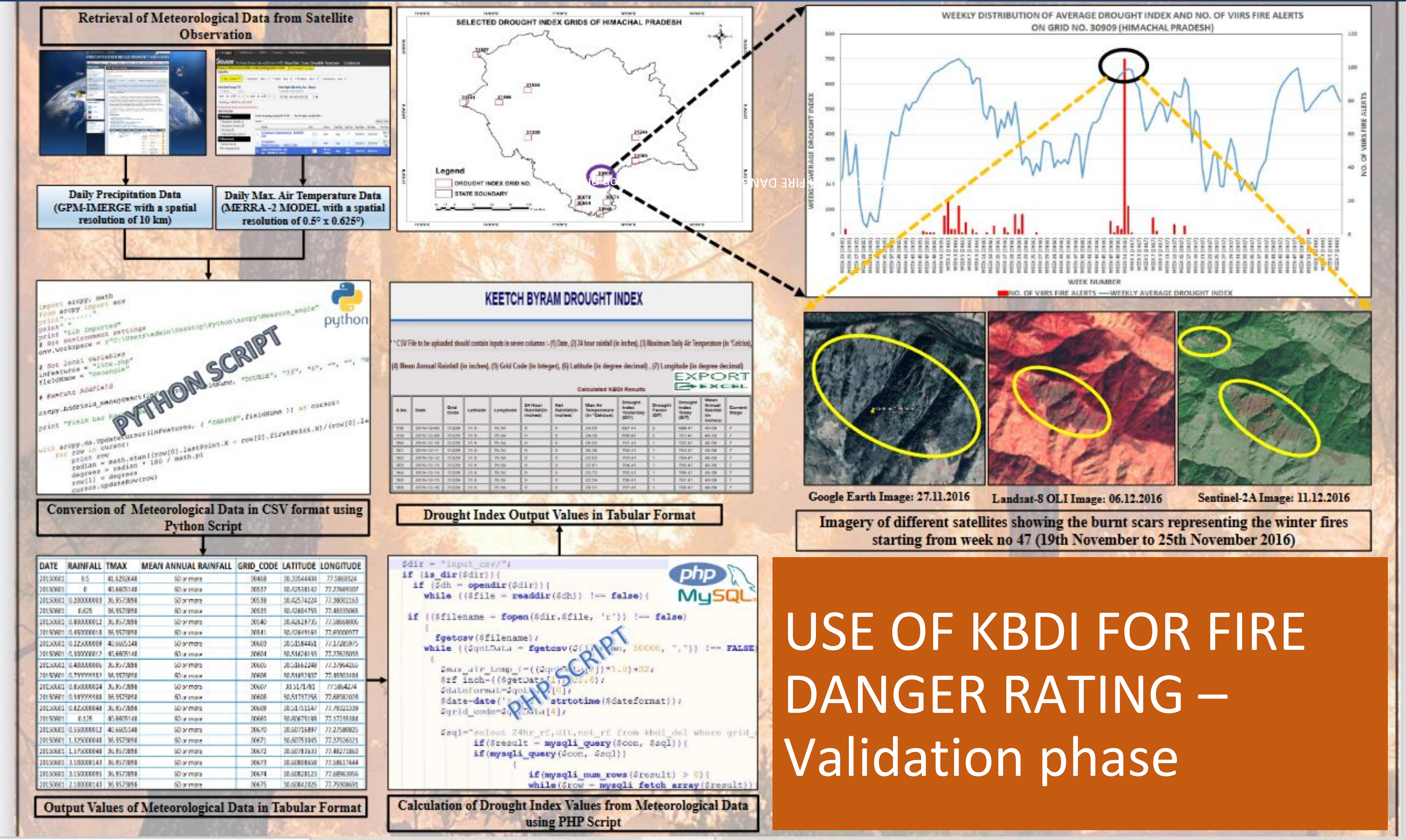
KBDI application- Pilot Study in Shiwaliks of Uttarakhand



Graphs showing relationship between weekly total rainfall (in inches) with KBDI values.

Fire Season KBDI, Uttarakhand Shiwaliks (2014 to 2016)





USE OF KBDI FOR FIRE DANGER RATING – Validation phase

Popular Fire Danger Rating Systems in the World

Canadian Forest Fire Danger Rating System (CFFDRS)

✔Fire weather Index system

- Temperature
- Relative humidity
- wind speed
- rainfall

✔Fire Behaviour Prediction system

- Fuel type
- Weather (FFMC, ISI& BUI wind speed and direction)
- Topography (Percent Slope Upslope Direction)
- Foliar moisture content

National (USA) Fire Danger Rating System (NFDRS)

✔ current weather
✔ fuel types,
✔ live & dead fuel moisture

MCArthur Forest and Grassland Fire Danger Rating System- Australia

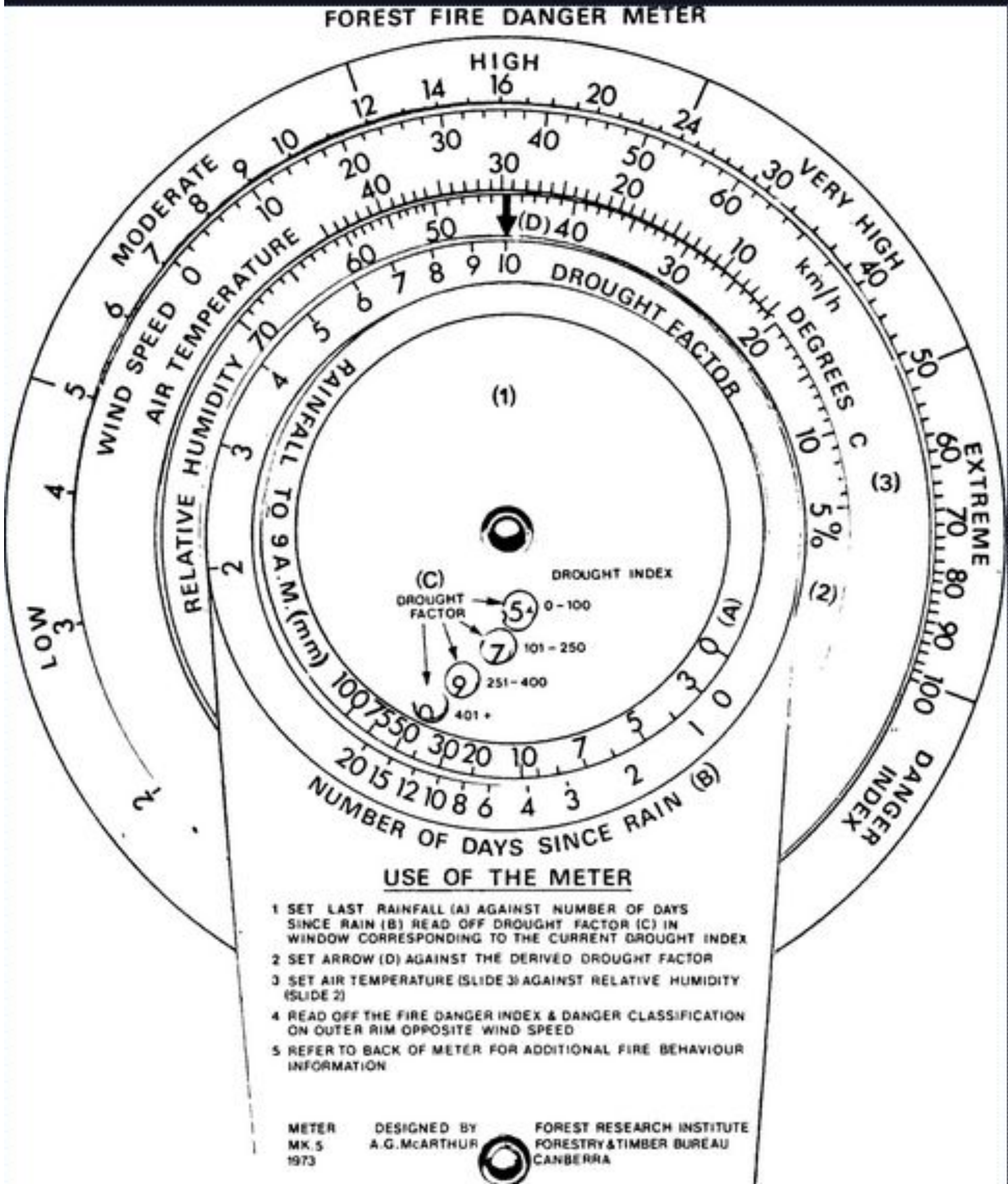
- Results of over 800 experimental fires and wildfire observations brought together into an easy-to-use system to determine the fire danger in forested areas of Australia
- McArthur Forest Fire Danger Meter (FFDM) first appeared in operational use in 1967 as the Mk 4 FFDM
- Typically based on expected fire behaviour of Eucalyptus forests with Fine Fuel Load of 12.5 tonnes / Ha over level topography
- Divided into five fire danger ratings (Low, Moderate, High, Very High, and Extreme) that represent the degree of difficulty of suppression
- Metric version in 1973; widely used in Australia till date

How to use the MK-V FFD meter?

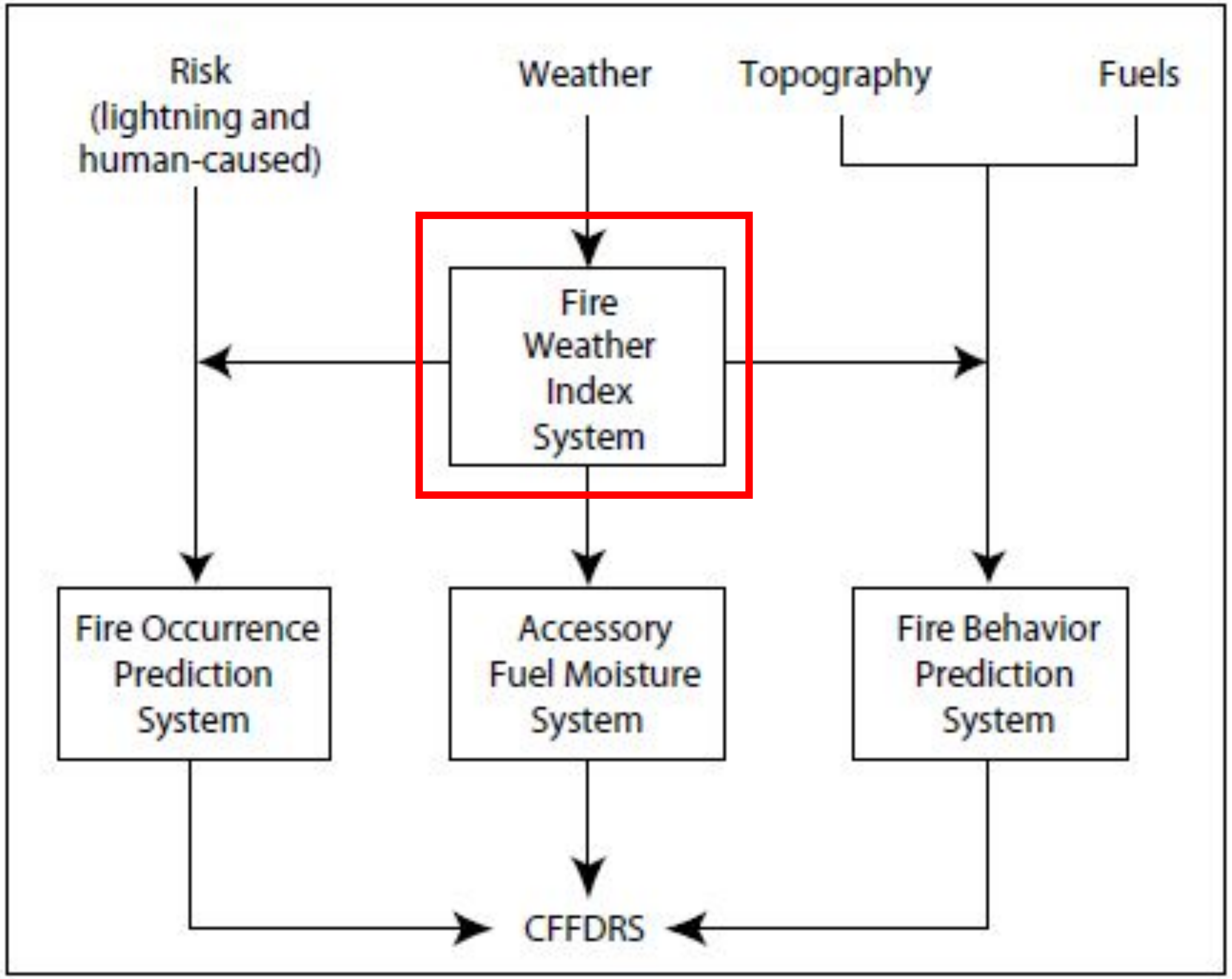
- Rotate the innermost wheel and set it to last rainfall (in mm) (A) against number of days since last rainfall (B)

- Read C (Drought factor) corresponding to current KBDI value
- Rotate the adjacent wheel and set D to arrived drought factor C

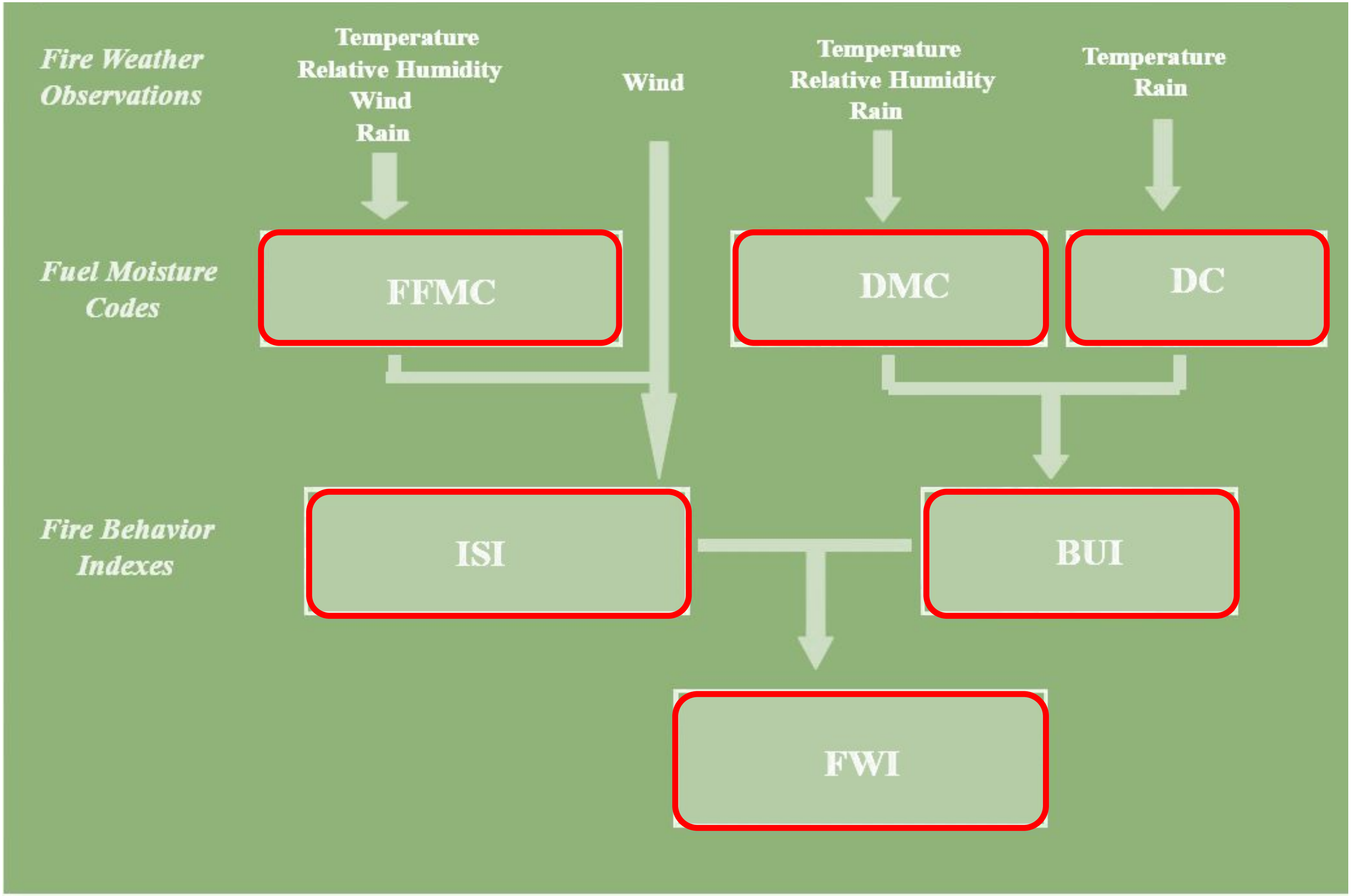
  - Rotate the next wheel to align observed/predicted Air Temp to RH
- Read the FFD value to the corresponding wind speed
- Read Ros, Flame Ht and Av Spotting Distance from back of the meter corresponding to FFD



Components of Canadian Fire Danger Rating System (CFFDRS)



Overview of Fire Weather Index



FWI calculation model : an example

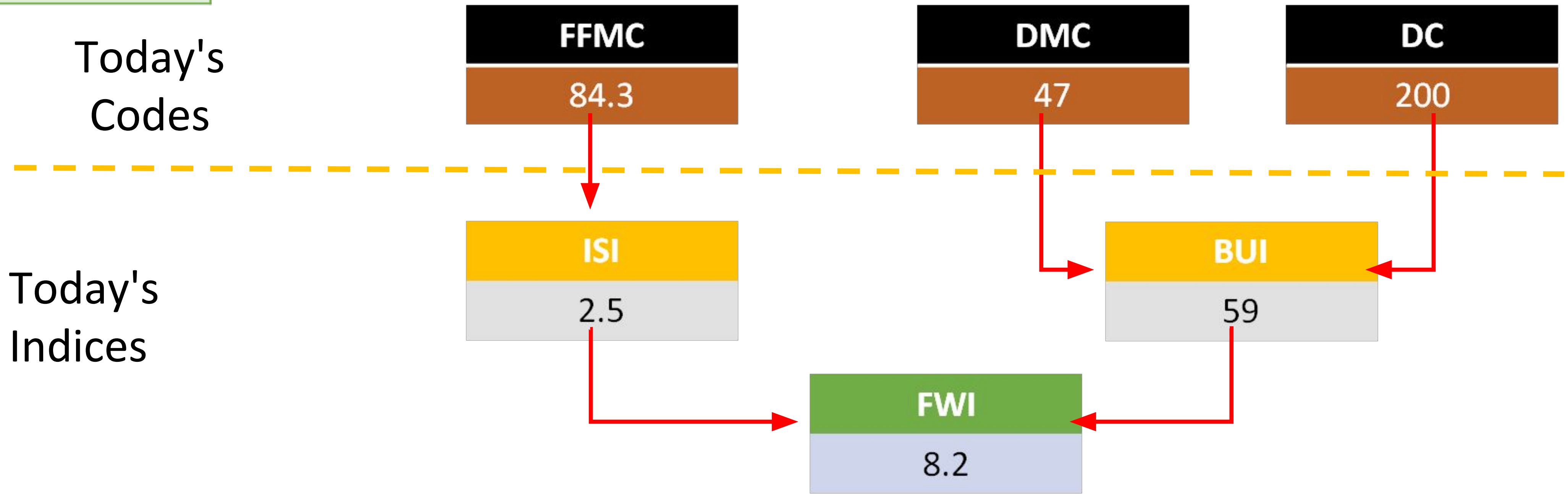
LATITUDE	23
MONTH	01

Today's 12:00 Weather

TEMP	30.0
WIND	5.0
RH	60.0
24 hr RAIN	1.0

Yesterday's Moisture Codes

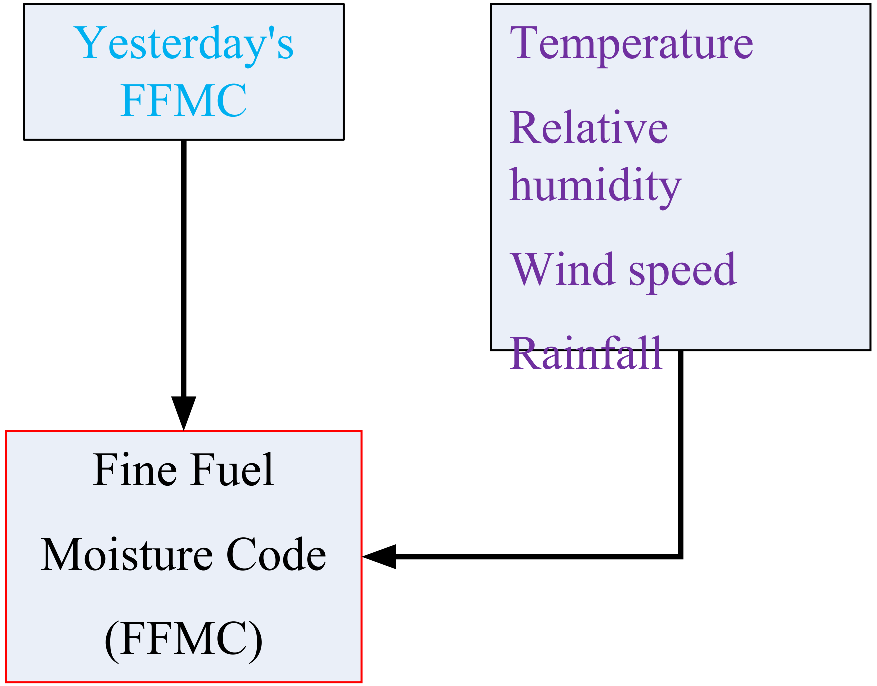
FFMC	85
DMC	45
DC	195



Fine Fuel Moisture Code (FFMC)

The FFMC is a numerical rating of the moisture content of **litter** and other **cured fine fuels** (needles, mosses, twigs less than 1 cm in diameter).

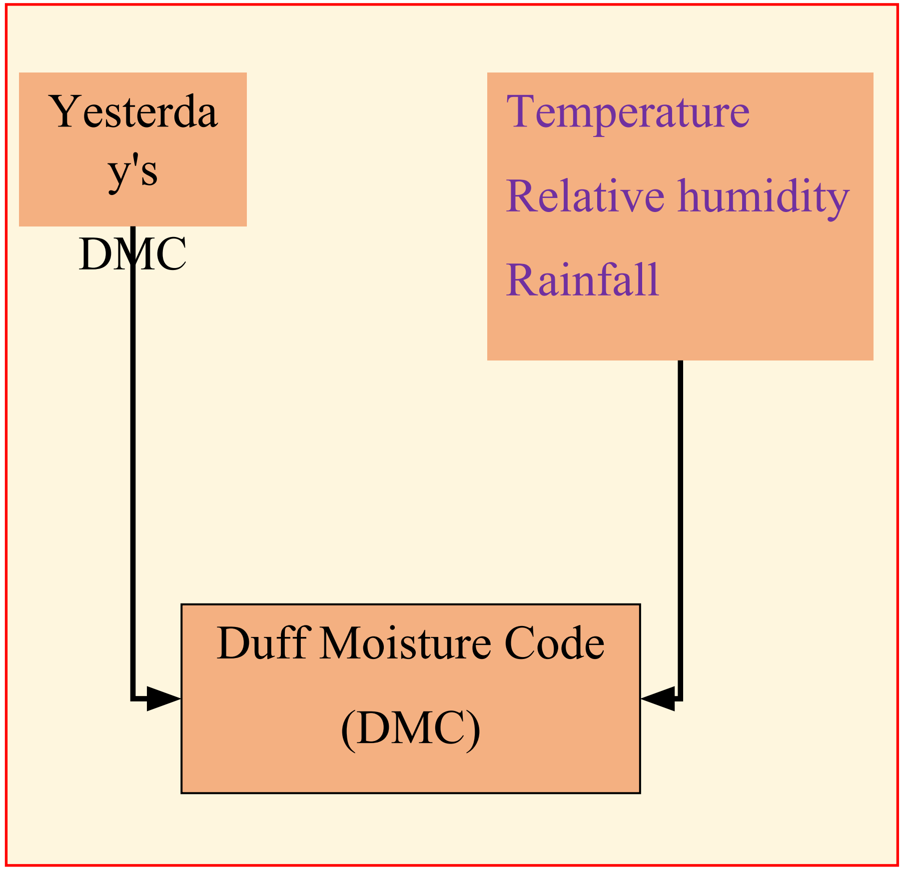
- Litter layer, and other cured fine fuels
- 0 – 1.2 cm depth in the forest floor (0.25 kg/m2)
- **Plays a significant role in ignition probability and spread**



Duff Moisture Code (DMC)

The DMC indicates the moisture content of **loosely-compacted organic layers of moderate depth**

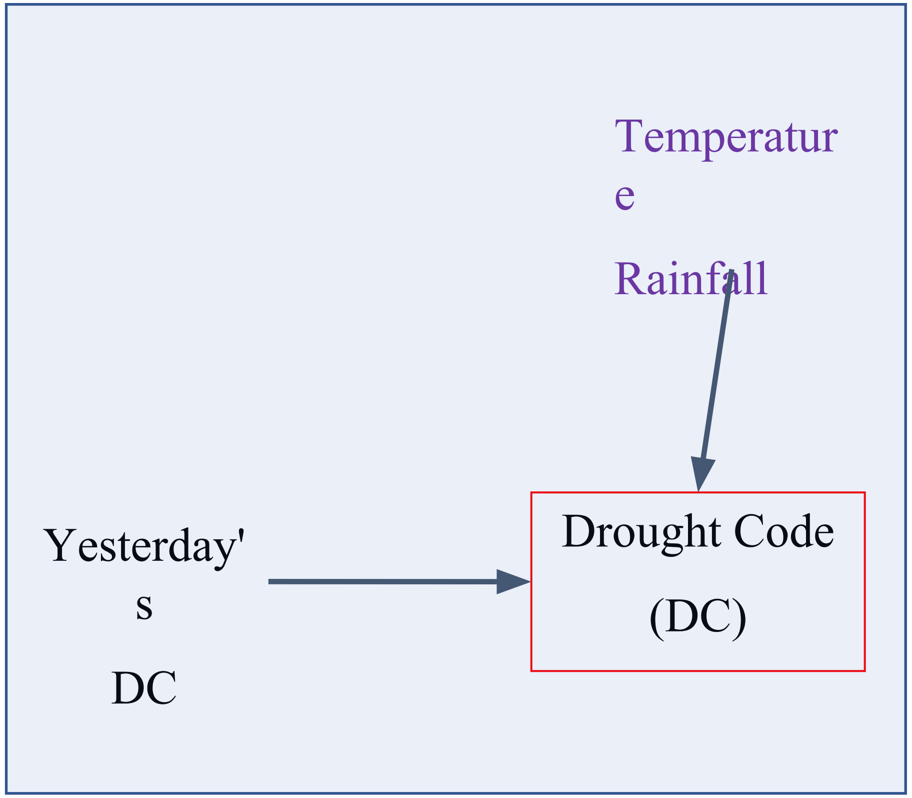
- ❖ Loosely compacted, fermenting (decomposing) organic matter
- ❖ 1.2 – 7 cm depth in the forest floor (5 kg/m2)
- ❖ Contributes to lightning receptivity and **over all fire intensity**
- ❖ Affected by rain, temperature, and relative humidity
- ❖ A 24-hour rainfall of less than 1.5 mm has no effect on the DMC because of interception of the forest canopy and the fine fuel layer



Drought Code (DC)

The third fuel moisture code is the DC, and it is an indicator of **moisture content in deep, compact organic layers**

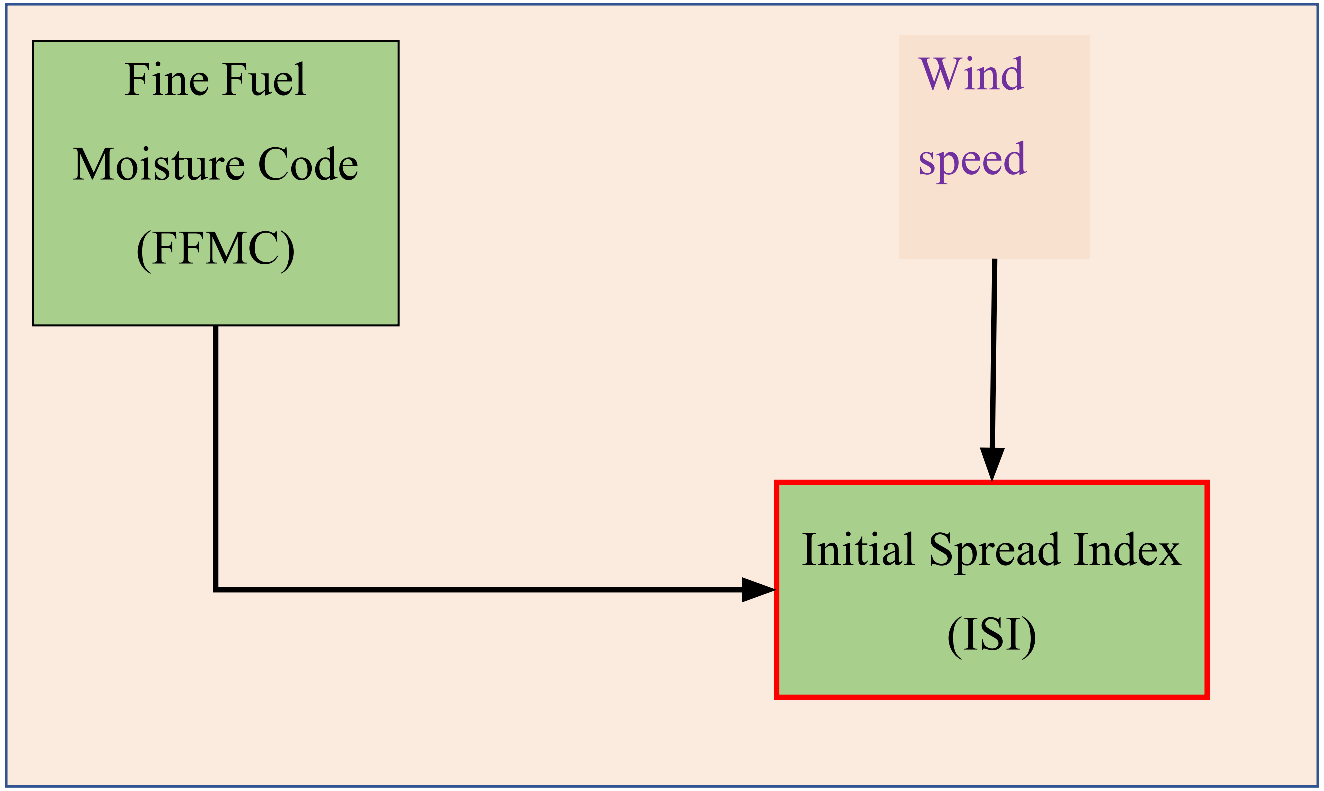
- Temperature and rain affect the DC
- wind speed and relative humidity do not affect because of the depth of this fuel layer
- A 24-hr rainfall greater than 2.8 mm is required to affect the moisture content due to interception by upper fuel layers and the forest canopy
- Deep layer of compact humus (decomposed) organic matter
- 7+ cm depth in the forest floor (25 kg/m2)
- **Contributes to depth of burn, intensity, and suppression difficulty**
- The DC fuels have a very slow drying rate, with a time lag of 52 days



Initial Spread Index (ISI)

The ISI combines the FFMC and wind speed to indicate the **expected rate of fire spread** .Generally, a 13 km/h increase in wind speed will double the ISI value.

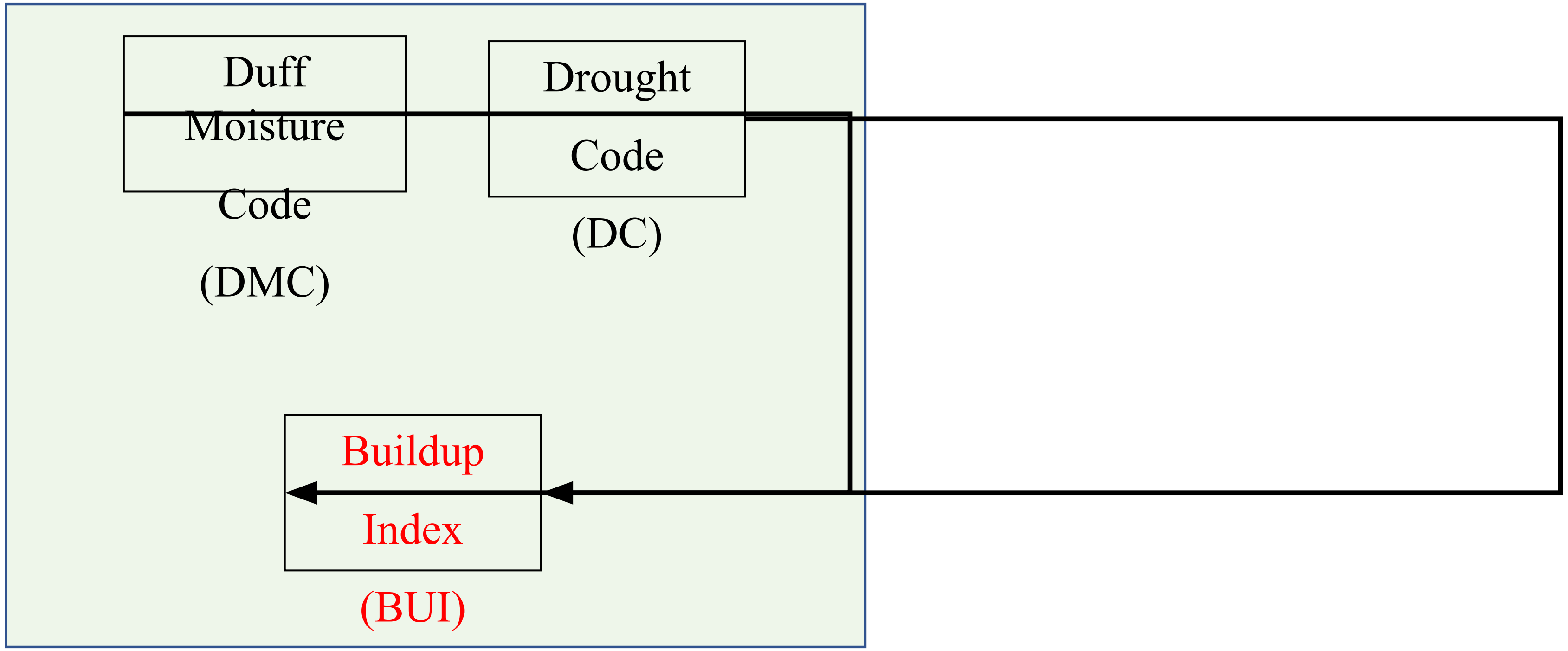
- It's accepted as a good indicator of fire spread in open light-fuel stands with wind speeds up to 40 km/h
- Varies greatly based on current wind conditions
- Represents ROS as a relative term (i.e. ISI = 17 > ISI = 10 => higher ROS)



Build-Up Index (BUI)

The BUI is a weighted combination of the DMC and DC to indicate the **total amount of fuel available for combustion by a moving flame front** (Fig. 6). The DMC has the most influence on the BUI value.

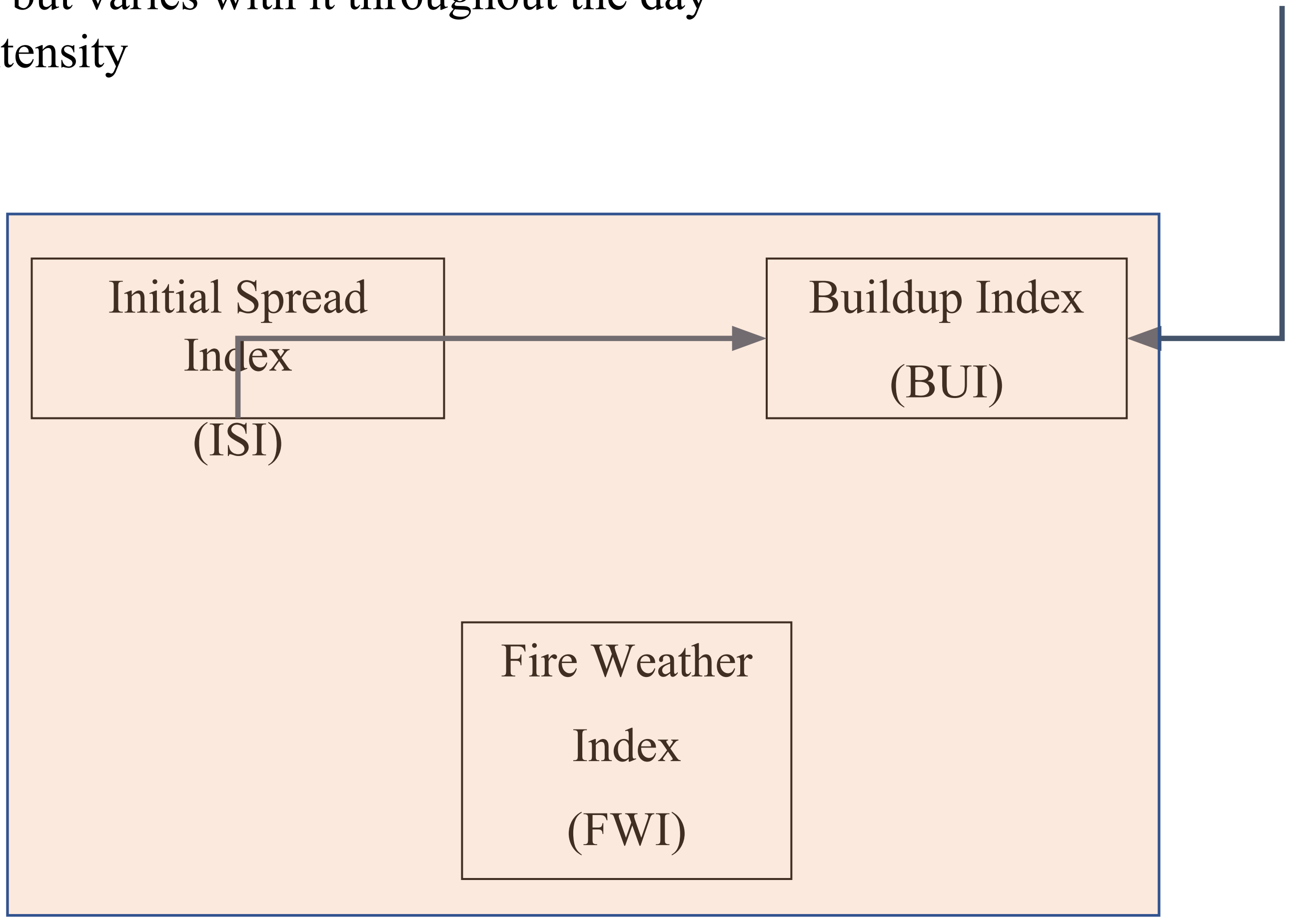
- ❖ Combines DMC and DC, with increased weight placed on the DMC
- ❖ Does not vary throughout the day
- ❖ Represents total fuel available for consumption



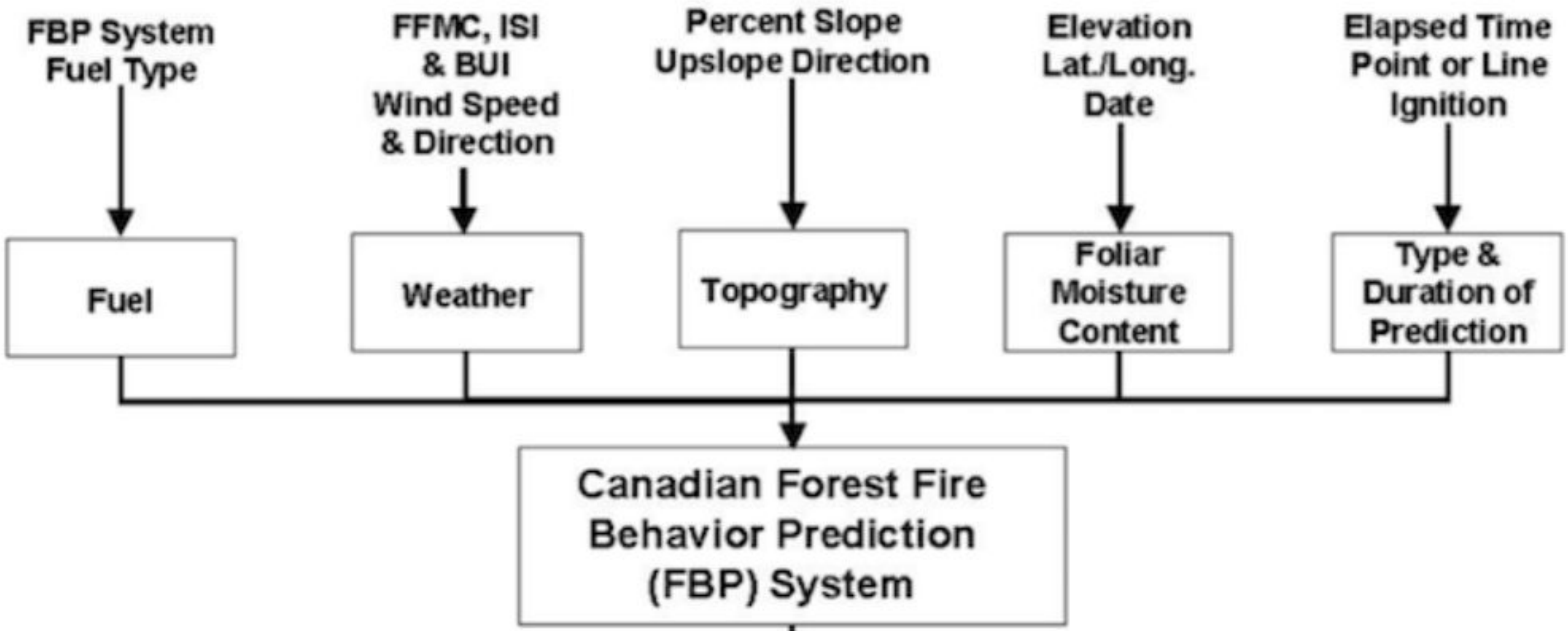
Fire Weather Index (FWI)

FWI numerical rating of the **potential frontal fire intensity**. In effect, it indicates **fire intensity by combining the rate of fire spread with the amount of fuel being consumed**.

- ❖ Combines the ISI and BUI, with increased weight on the ISI
- ❖ Is more stable than the ISI, but varies with it throughout the day
- ❖ Represents potential fire intensity



Fire Behaviour Prediction System (FBP)



Fire Behaviour Prediction System Outputs

PRIMARY OUTPUTS

- RATE OF SPREAD (ROS) (Meters per Minute)
- Fuel Consumption (Kilo watts/minute)
- Fire Description (Surface/creeping/crown)
- Fire Intensity (Flame length/class)

SECONDARY OUTPUTS

- Fire spread Distances (Head, Flank and Backfire)
- Elliptical Fire Area and perimeter
- Rate of Perimeter growth
- Length to Breadth ratio

5 MAJOR FUEL GROUPS

- Conifer
- Deciduous
- Mixedwood
- Slash
- Grass

HOW TO CALCULATE FBP?

Inputs for GENERAL FBP

- FFMC
- ISI
- BUI

(For 1400 hrs)

↓

- Identify Fuel type and modifier

↓

READ RoS

Inputs for Local/Specific FBP

- Calculate Local FFMC (adjusted)

↓

- Identify Fuel type and modifier

↓

- Calculate effective windspeed

↓

- Use local FFMC and effective windspeed for local ISI and backing ISI

↓

- BUI

↓

READ RoS Head and RoS Back

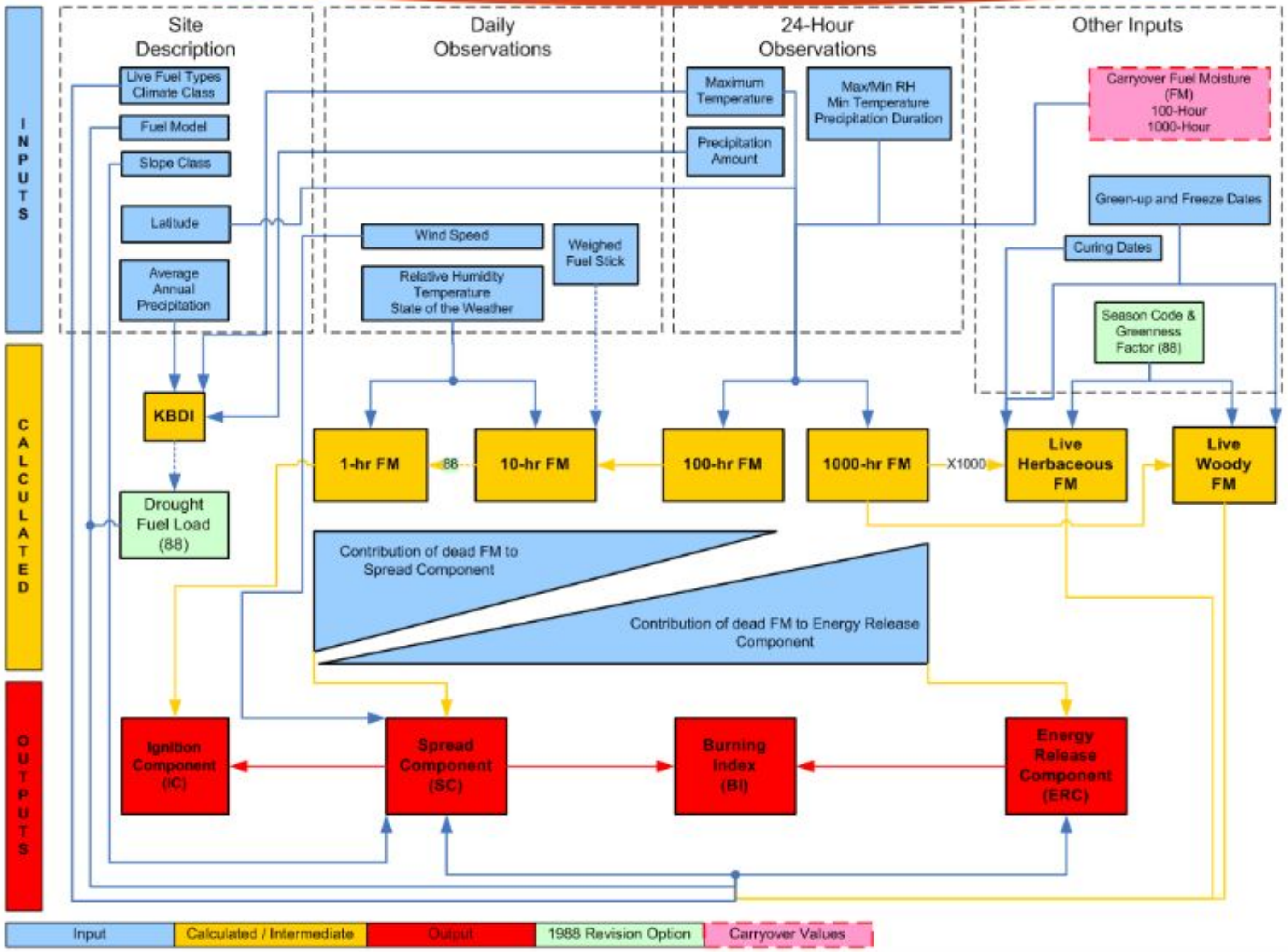
The CFFDRS is popular because it:

- Is relatively simple to use; modular approach;
- Can be adapted to a variety of environments;
- Includes many interpretation aids (such as posters, reference tables, and electronic data-processing and display systems) that support a variety of situations.

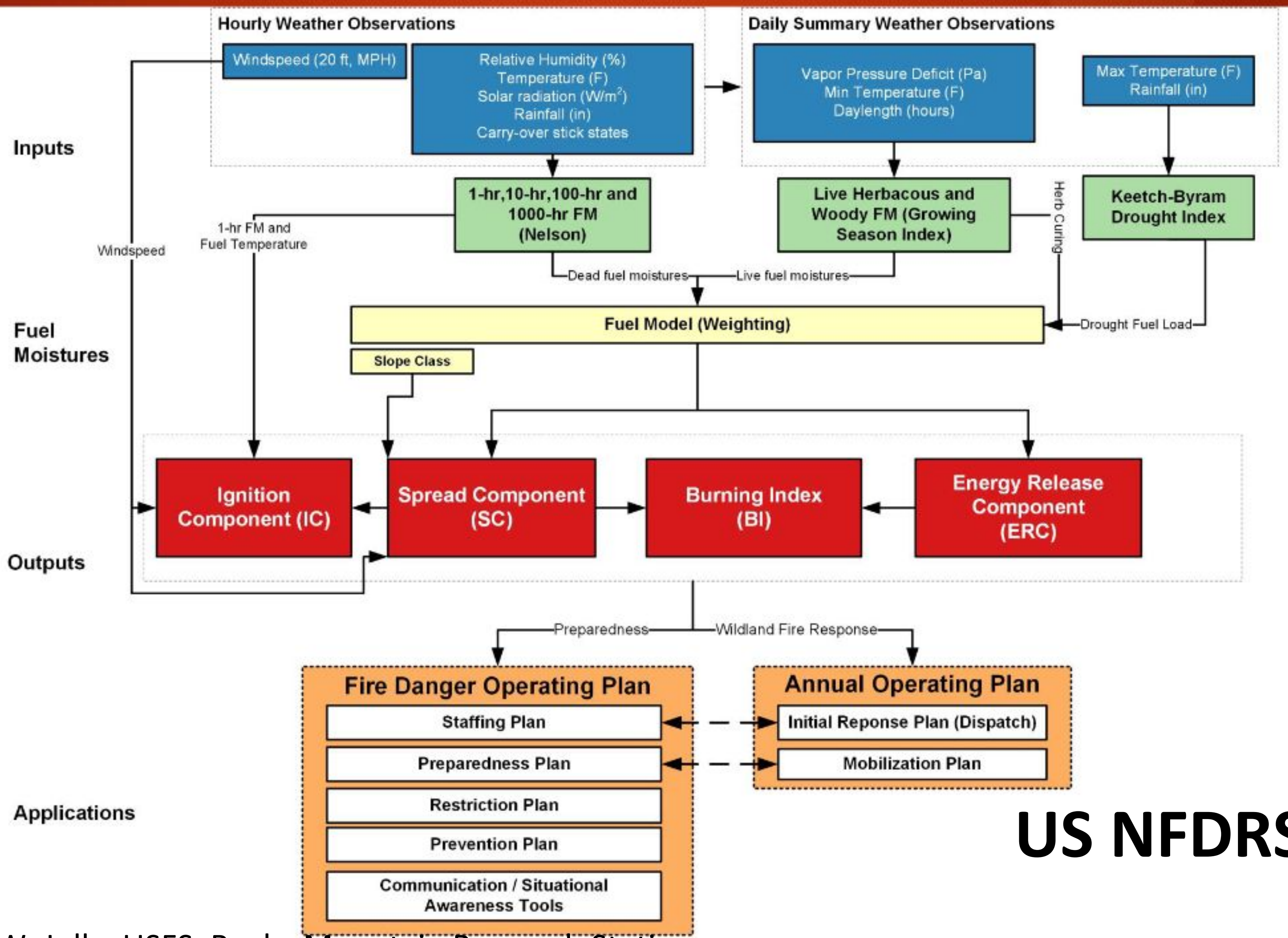
International uptake of the CFFDRS

- The CFFDRS related information products have led to Canada being recognized globally as a leader in fire science and in fire management expertise.
- This rating system has been fully implemented in Canada, New Zealand, in parts of the U.S.A.
- Components of it have been used in many countries, including Spain, Portugal, Sweden, Argentina, Mexico, Fiji, Indonesia and Malaysia etc.
- FWI itself is used as FDRS in many instances

Structure of the 1978/88 National Fire Danger Rating System



Source: Matt W. Jolly, USFS,
Rocky Mountain Research Station



US NFDRS 2016

Source: Matt W. Jolly, USFS, Rocky Mountain Research Station

Use of Fire Weather Index (FWI)
as
Basic Fire Danger Rating System (FDRS) in India

FDRS in India- Journey sofar..

Year	Milestone
2016	Early-warning alerts (piloted based on current season fire points)
2016	KBDI pilot study, KBDI calculator software
2017	Improved EWS (Grid based) using IITM weather forecast data
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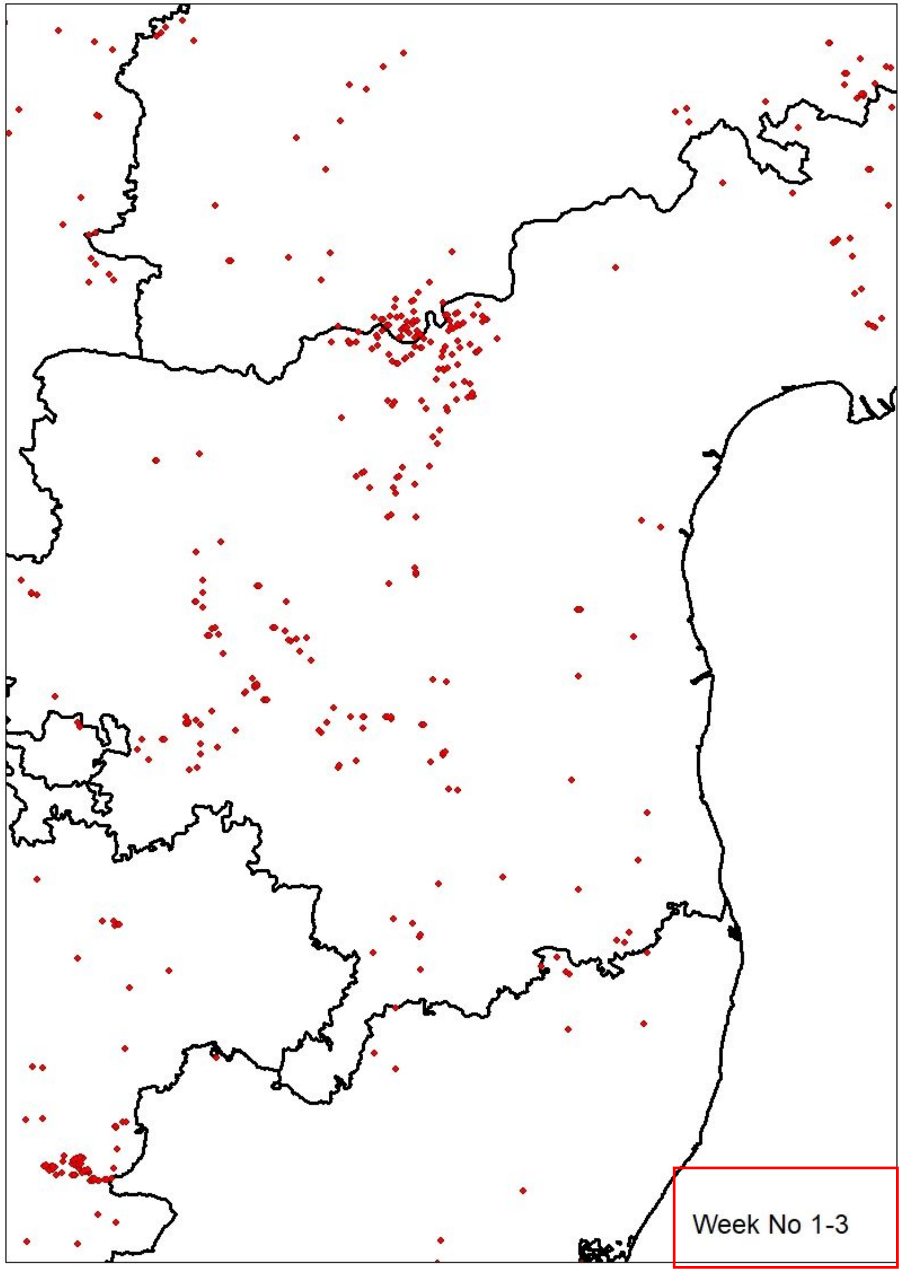
Early Warning/ Pre-warning → Basic FDRS → Comprehensive FDRS

Nagarjuna-Sagar -TR pattern of Forest Fire Points (FFP)



Parameters used in Improved Early-Warning Alert System, 2017

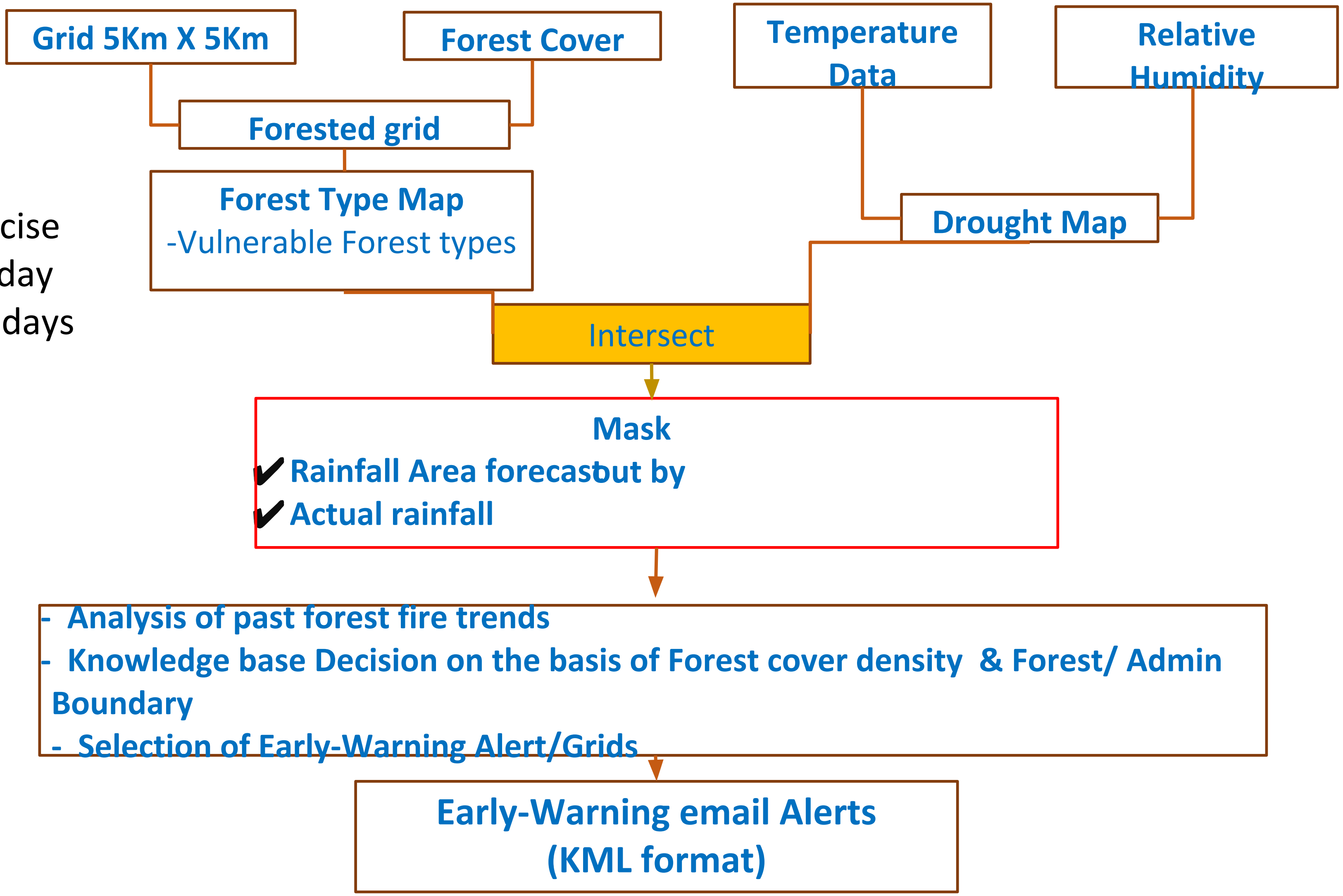
- Forest Type
- Forest Cover
- Temperature
- Relative Humidity
- Rainfall
- Analysis of past forest fire trends – Human factor!

Forest Type, Forest Cover: Proxy of Fuel type and fuel load

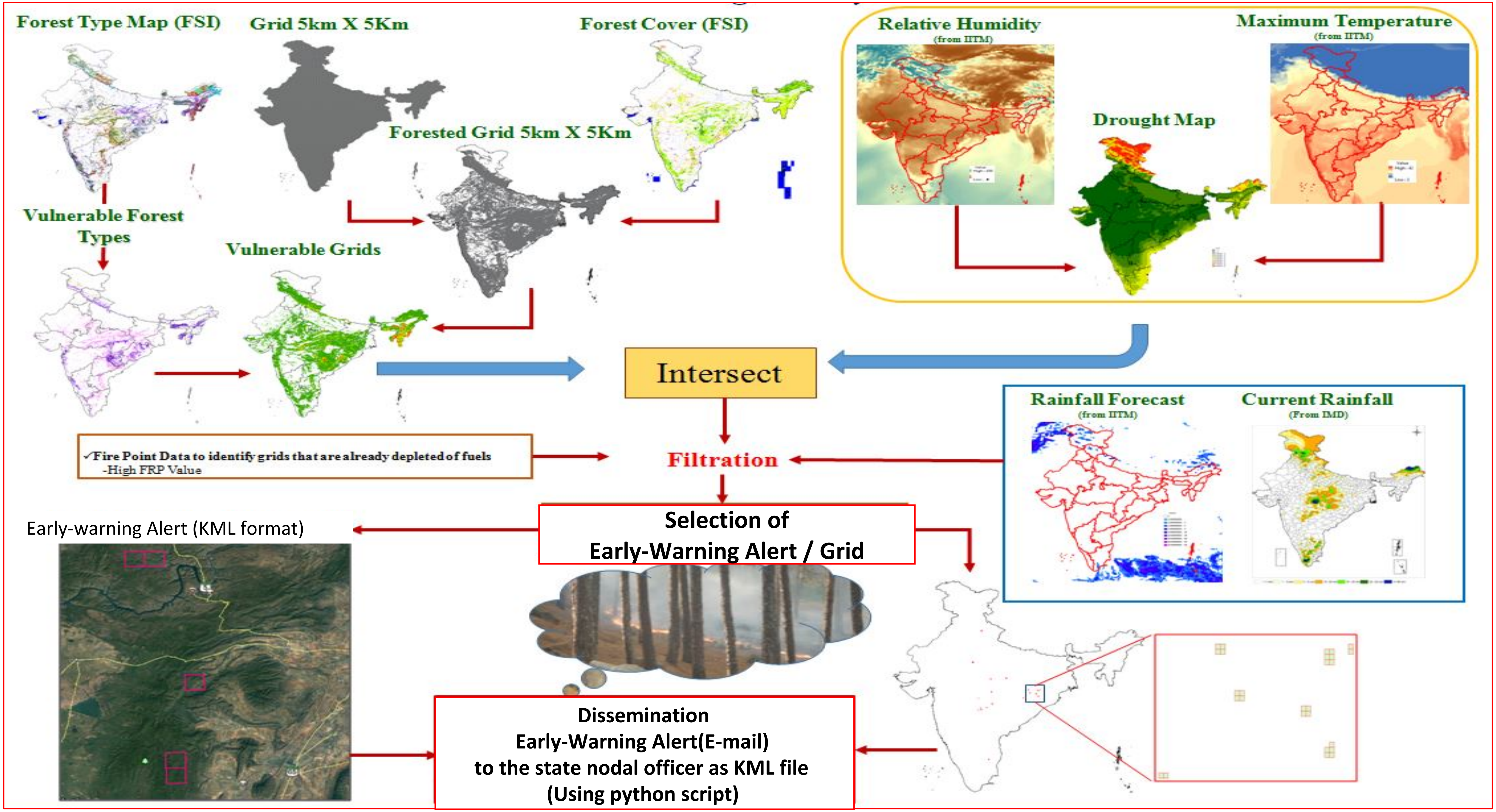
Relative Humidity, Rainfall: Drought/Weather

Grid based Improved Early-Warning Alert System (EWS), 2017

- Weekly Exercise
- Alerts on Friday
- Validity of 7 days

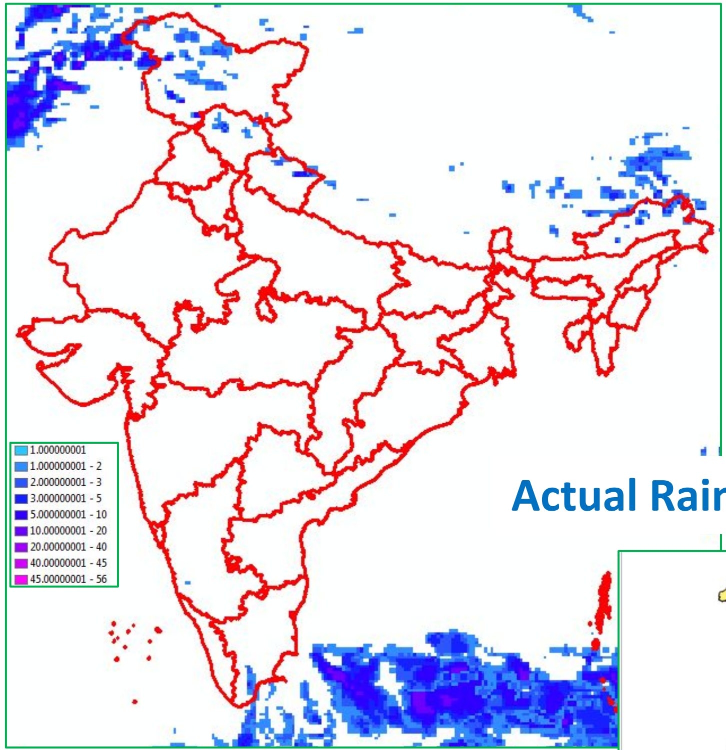


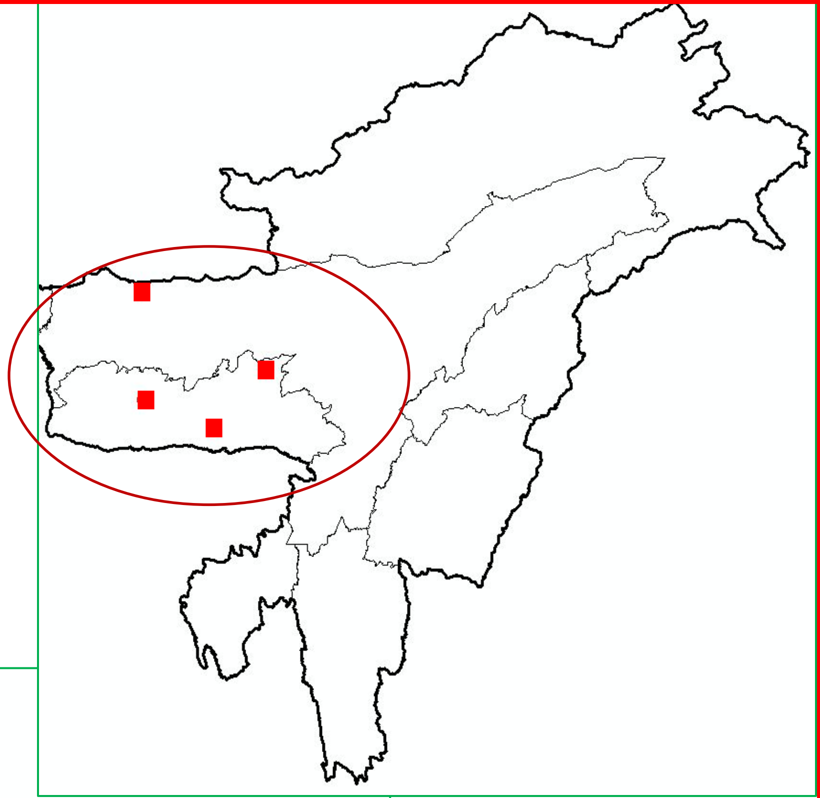
Schematic diagram of the methodology followed in Early-Warning Alert System (EWS)



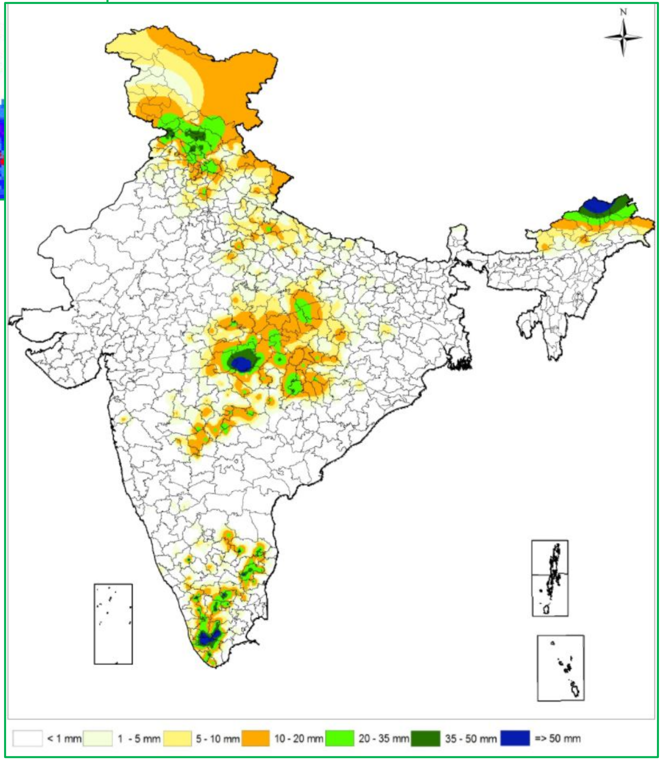
Forecast Rainfall (in cm) from IITM

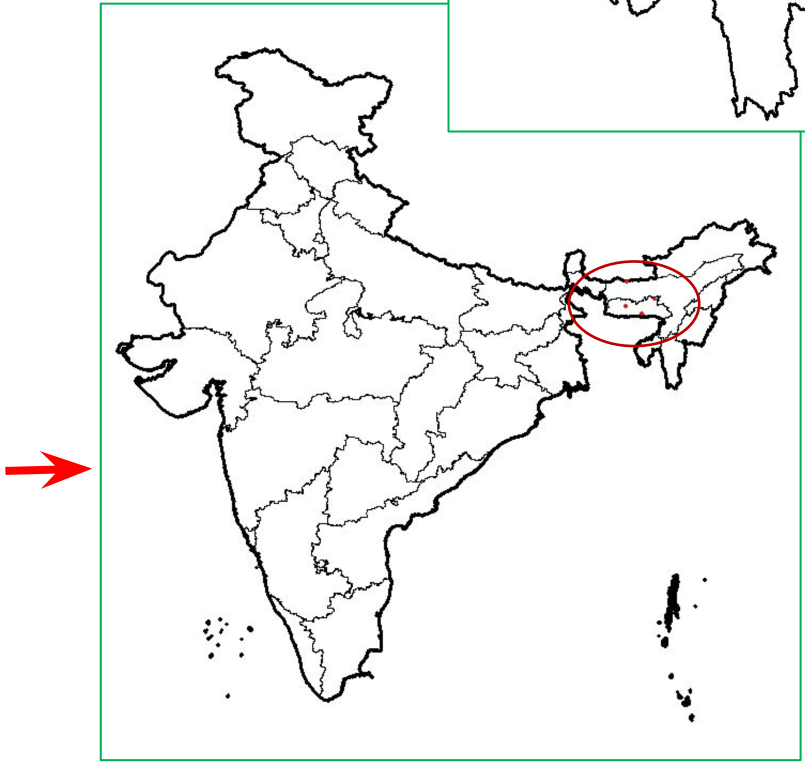
Mask-out by rainfall



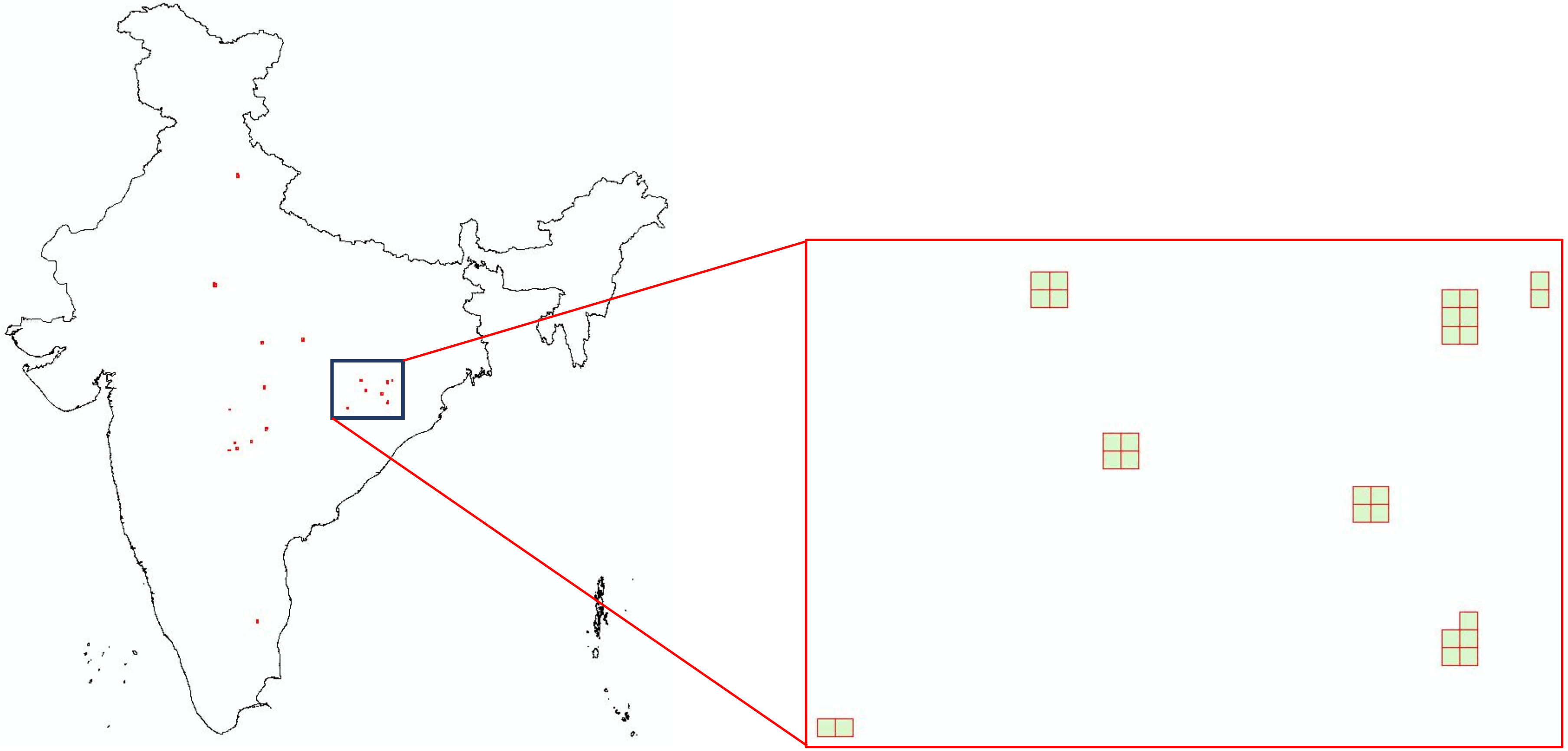


Actual Rainfall (in mm) from CRIS, IMD bulletins





Selected grids for weekly alert



Early-Warning Forest Fire Alerts of 20181109 for ASSAM

prewarningalerts@gmail.com

to cf.nodal, biswastapas007, evforester

Fri, Nov 9, 12:51 PM (3 days ago)

Sir/Madam,

Forest Survey of India also provides Early-Warning Forest Fire Alerts for forest areas based on prevalent weather, forest type and fire information.

Such areas have higher probability of having large and high intensity forest fires during the ensuing week.

In the current early-warning alert generated on 09_11_2018 (DD_MM_YYYY), certain areas in your state have also been alerted.

The early-warning areas is in the form of Google Earth compatible KMZ file which are attached with this email for your information.

This alert is valid upto 15_11_2018(DD_MM_YYYY).

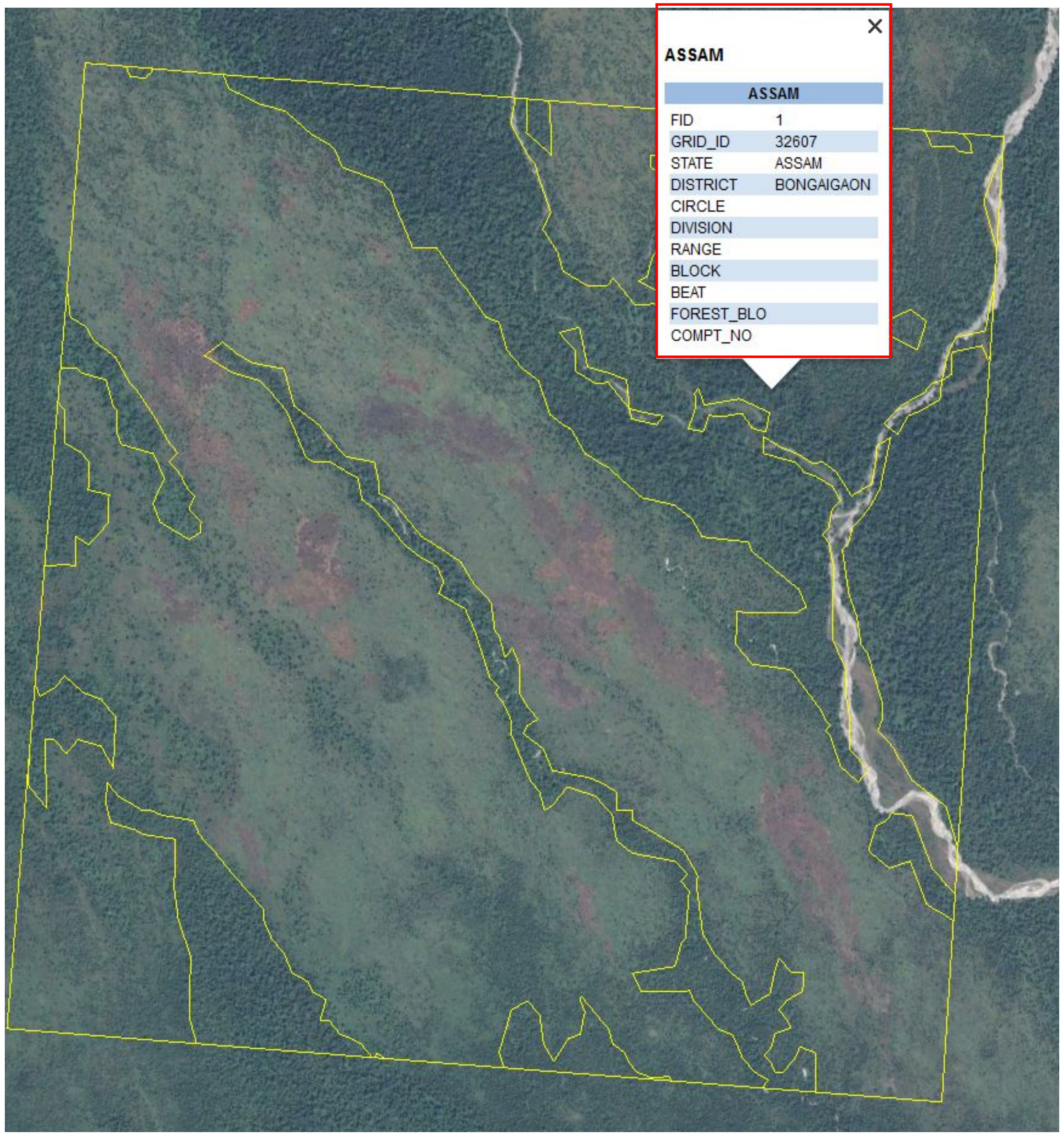
We hope the early-warning is of use to you in planning forest fire management. Kindly provide your feedback on this issue which will help us to improve further.

With Regards,
Forest Fire Monitoring Team,
Forest Survey of India,
Ministry of Environment, Forest and Climate Change,
Kaulagarh Road, Dehradun- 248195.
0135-2754191 Ex-272

Early Warning 201...

Reply | Reply all | Forward

KML disseminated to nodal officer through e-mail



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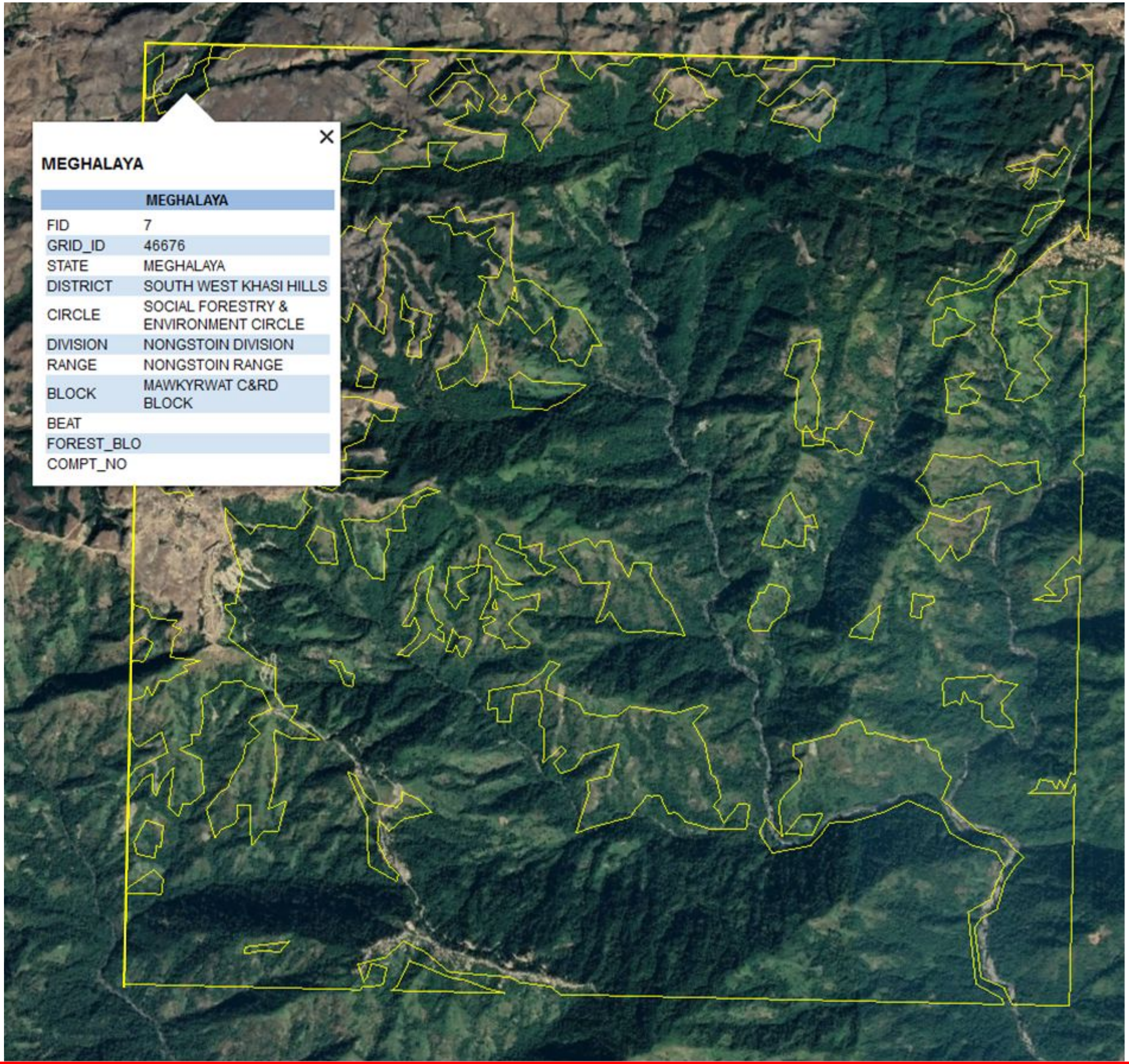


Fire Weather Index (FWI) generation using GEOS-5 daily database from NASA'S GFWED

Steps involved

1. Selection of Forested Grids
2. FWI downloaded from GFWED through FTP access
   - ✔ *GEOS-5 experimental NRT version available for two days before the present date*
   - ✔ *based on Temp, RH, wind-speed, snow depth observations*
3. Masking of FWI data within forested grids
4. Threshold generation for Physiographic zones
   - ✔ *14 physiographic zones clubbed into 8 Zones for simplicity*
   - ✔ *FWI range over peak fire season across various years used to generate threshold along with fire history*
   - ✔ *Large fire database also used for this purpose*
5. Testing using past scenarios
6. Finalise categories (4 to 6 qualitative category)
7. Dissemination of Danger Rating once in two days

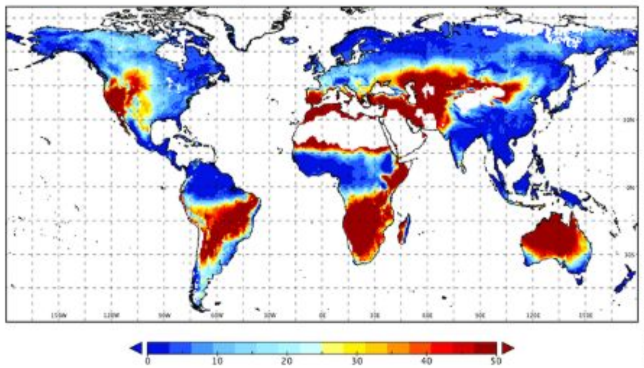
Global Fire WEather Database (GFWED)

The Global Fire WEather Database (GFWED) integrates different weather factors influencing the likelihood of a vegetation fire starting and spreading. It is based on the Fire Weather Index (FWI) System, the most widely used fire weather system in the world. The FWI System was developed in Canada, and is composed of three moisture codes and three fire behavior indices. The moisture codes capture the moisture content of three generalized fuel classes and the behavior indices reflect the spread rate, fuel consumption and intensity of a fire if it were to start. Details on the development and testing of GFWED can be found in Field et al. (2015), applications of the FWI System can be found in Taylor and Alexander (2006), and technical descriptions are provided by van Wagner (1987) and Dowdy et al. (2009).

Data Versions

FWI System calculations require measurements of 12:00 local time temperature at 2m, relative humidity at 2m, and wind speed at 10m, daily snow-depth, and precipitation totaled over the previous 24 hours.

GFWED is comprised of eight different sets of FWI calculations, all using temperature, relative humidity, wind speed and snow depth estimates from the NASA Modern Era Retrospective Analysis for Research and Applications version 2 (MERRA-2) (Rienecker et al., 2011). Each of the eight versions uses a different precipitation estimate, ranging from the MERRA-2 estimates, to rain-gauge only estimates to three different satellite-based estimates, listed in the table below.



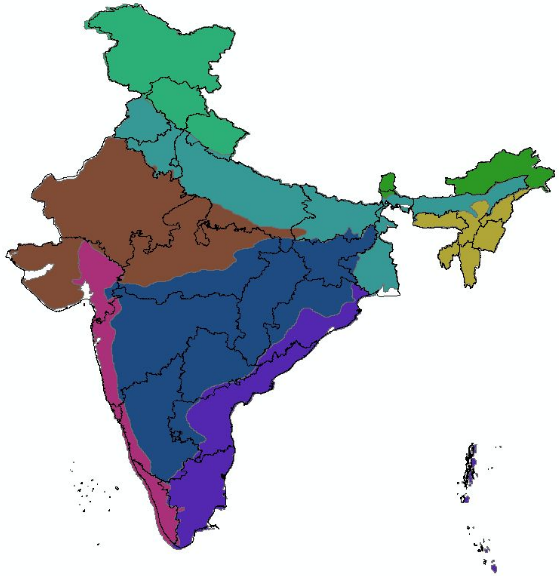
Mean July Fire Weather Index from 1980-2012, based on the Chen et al. (2008) daily precipitation estimate over land. Figure created using the Panoply desktop application.

Experimental, near-real time versions using GEOS-5 analysis fields in place of MERRA-2 are available going back to mid-2014 for some versions, including those using GPM precipitation. 8-day experimental forecasts are available going back to December 2017.

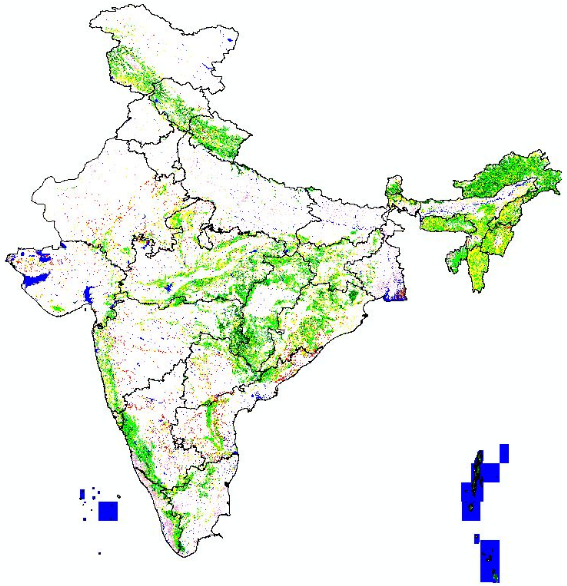
	Data source	Period	Latency	Coverage	Resolution	Description
T, RH, wind-speed, snow depth	MERRA-2	1981-Present	~2 months	Global	0.5°×2/3°	All versions of the FWI calculations use the MERRA-2 T, RH, wind speed and snow depth estimates
	GEOS-5	2014-present (analysis) December 2017-present (forecasts)	~12 hrs	Global	0.25°×0.25°	NRT 7-day forecasts, analysis versions using GEOS-5, IMERG and CPC precipitation

Steps Used

Physiographic Zones

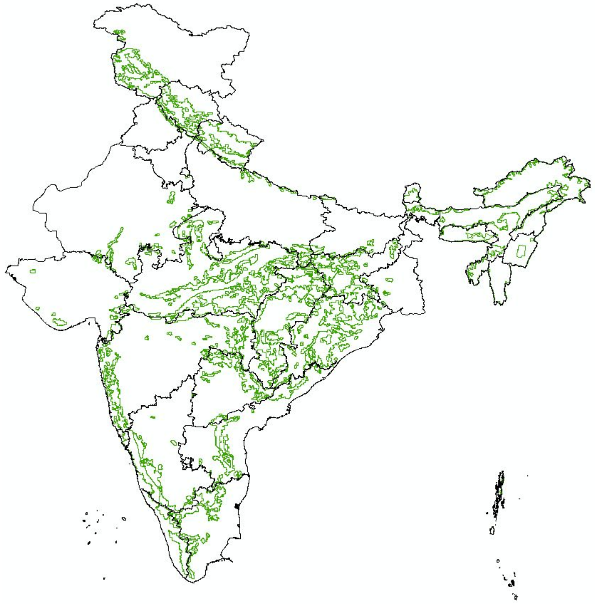


Forest cover Density map



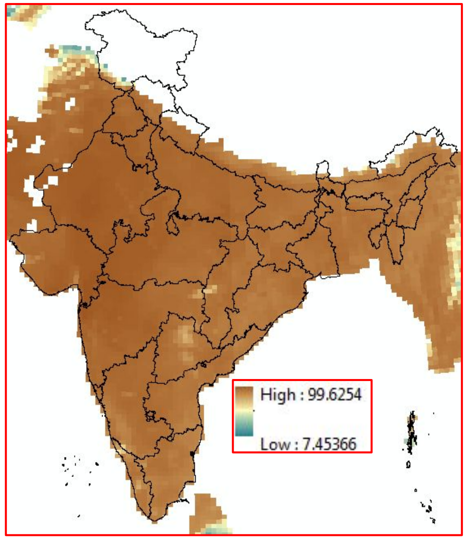
Standard Grid of FSI
(5Km x 5km)

Forest cover Area
(50% forest density and RFA)

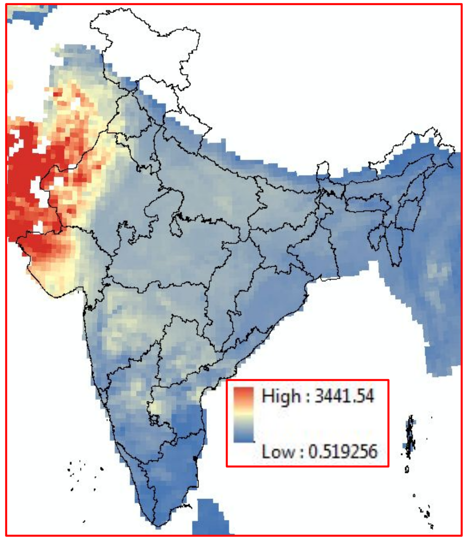


Components of Fire weather Index

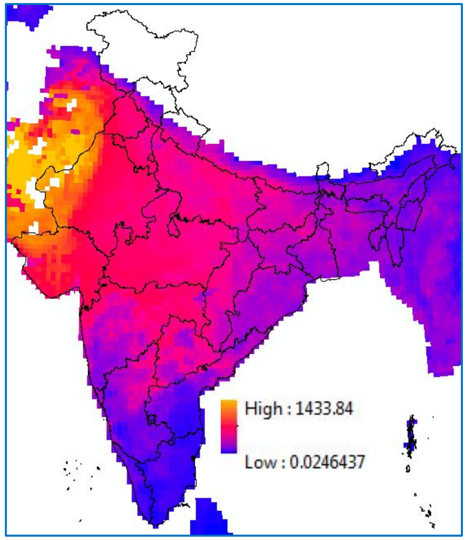
FFMC



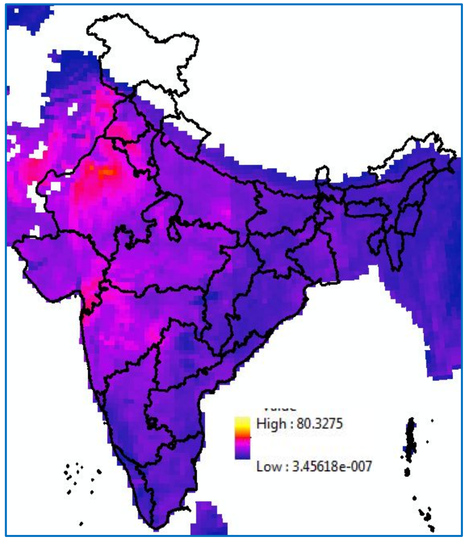
DC



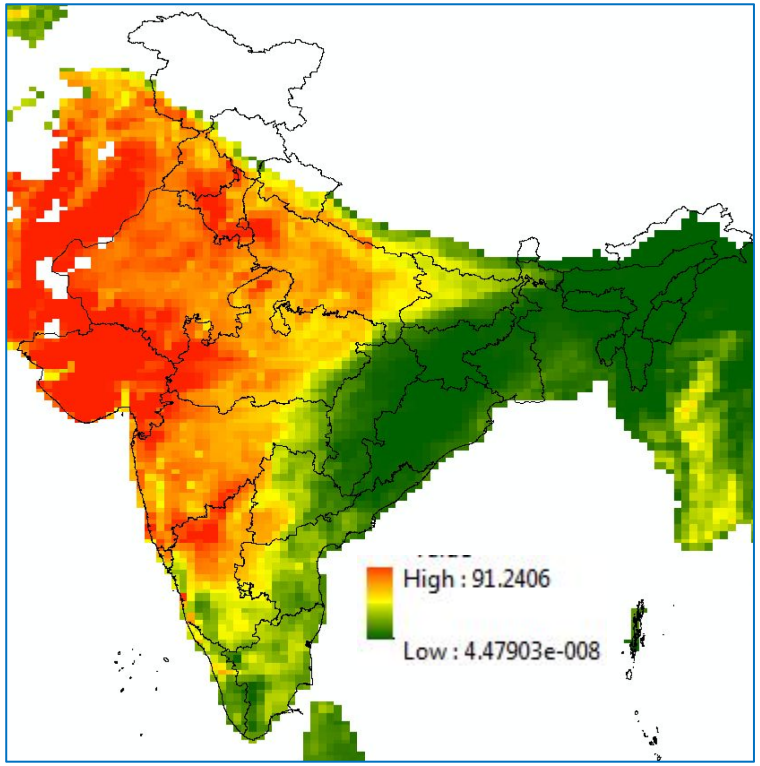
DMC



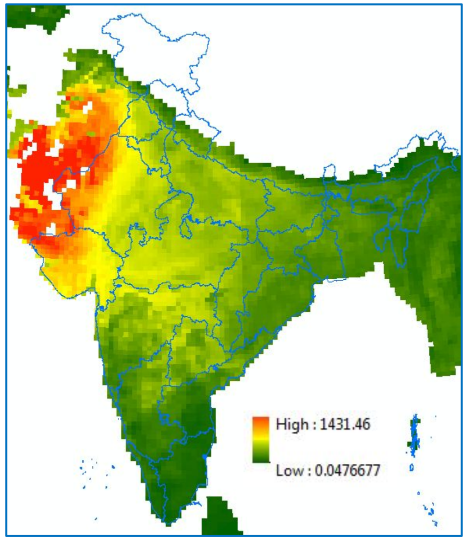
ISI



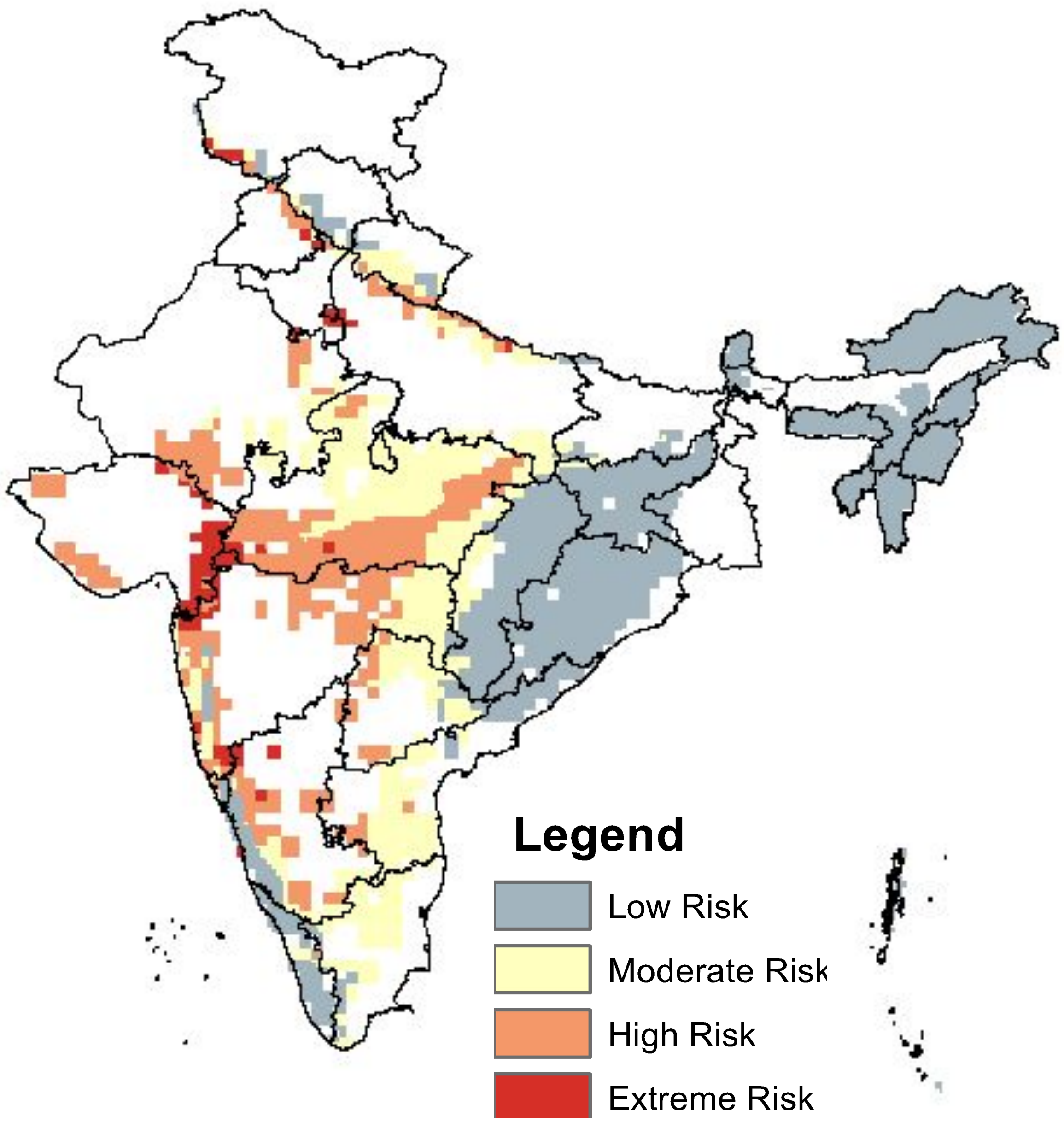
FWI



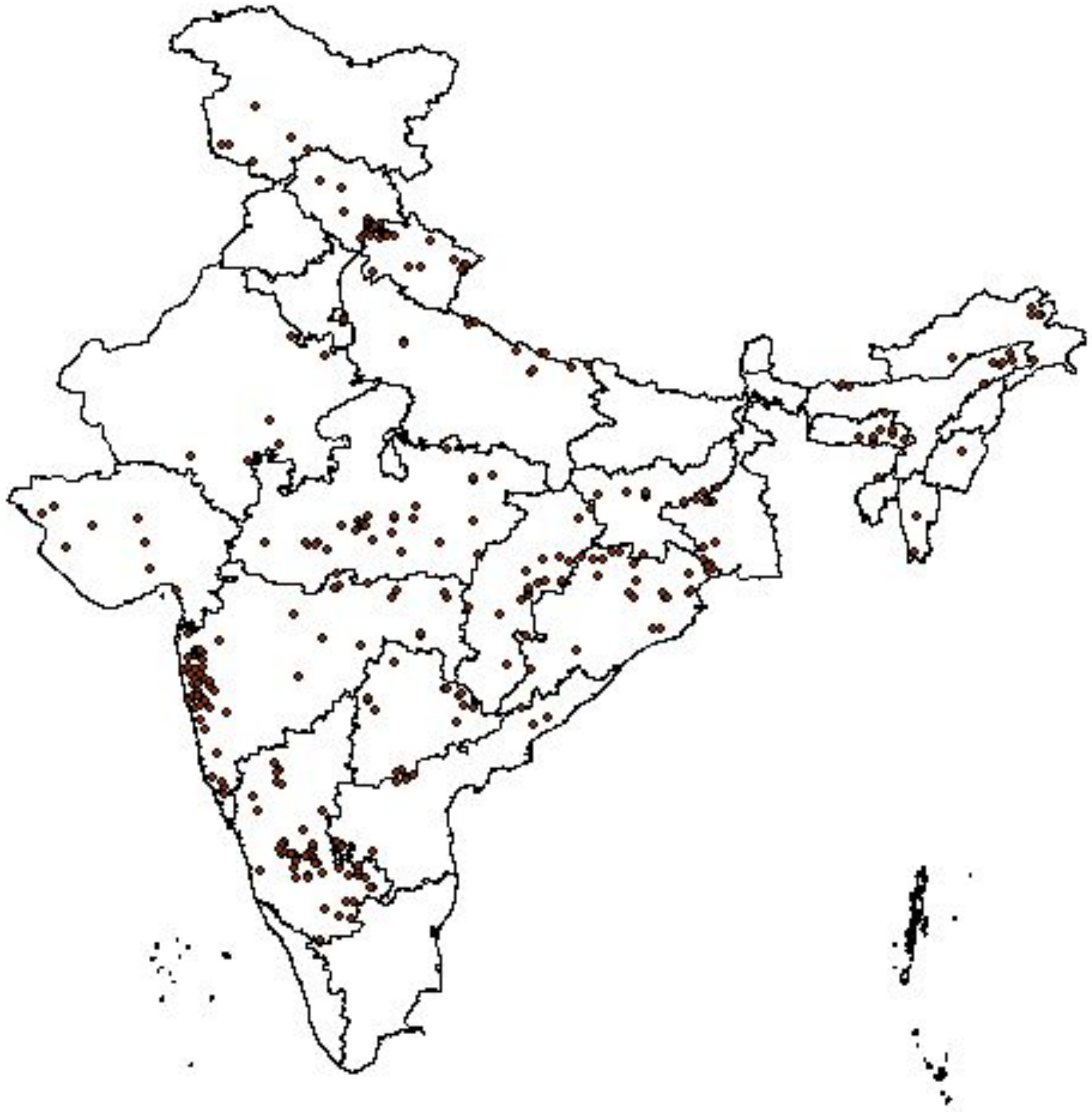
BUI

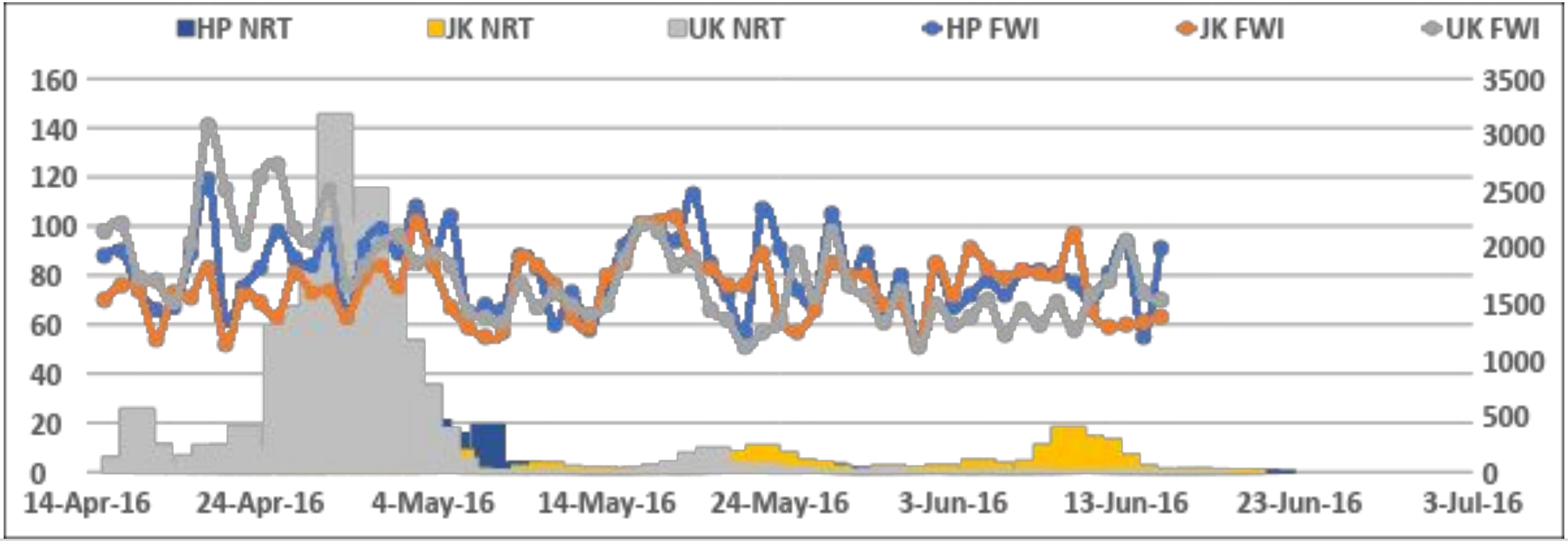


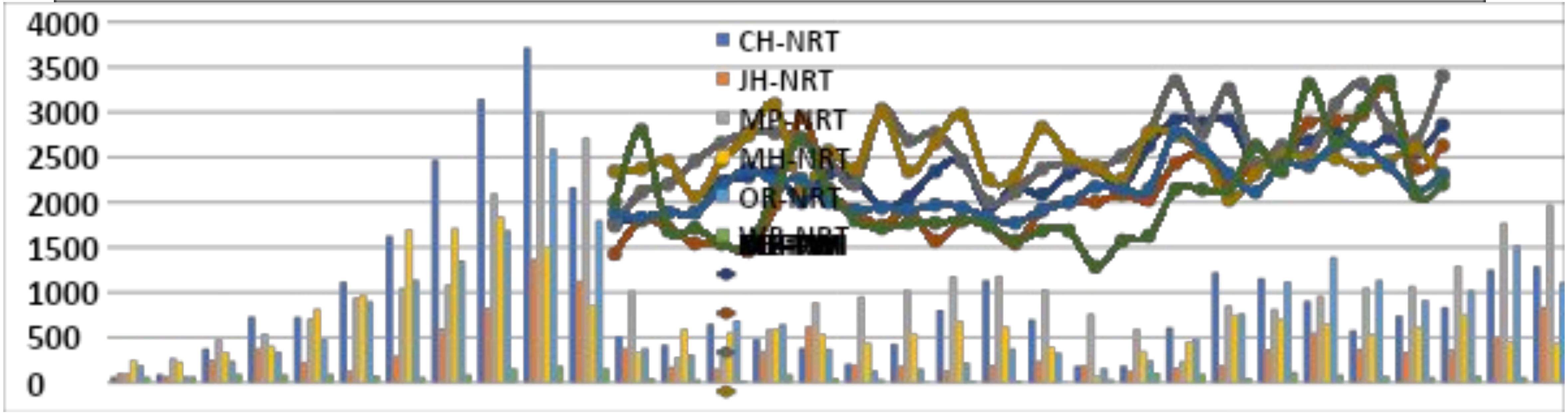
Fire Weather Index (FWI) data of 22 Dec 2018



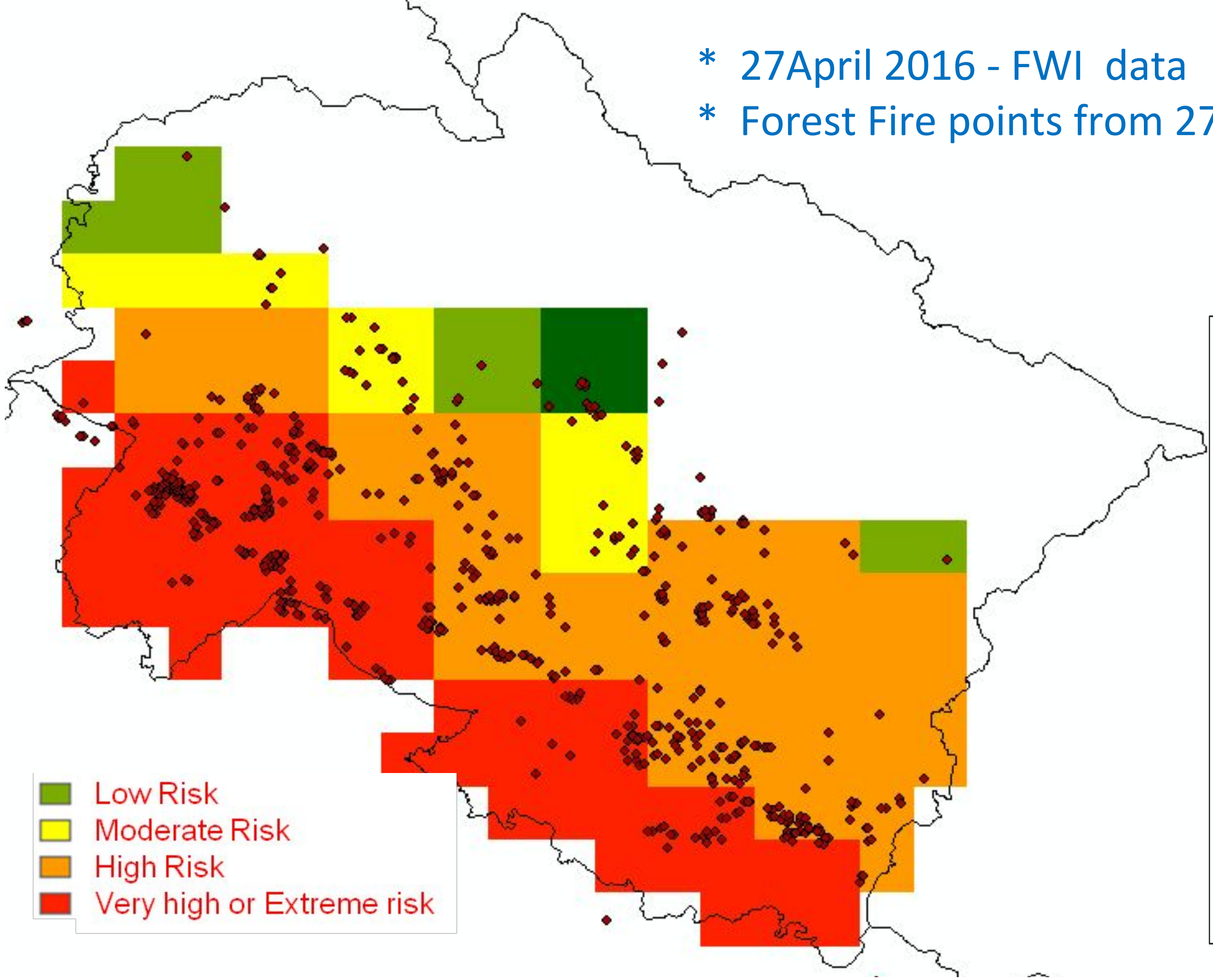
Fire points data from 22 Dec 2018 to 26 Dec 2018



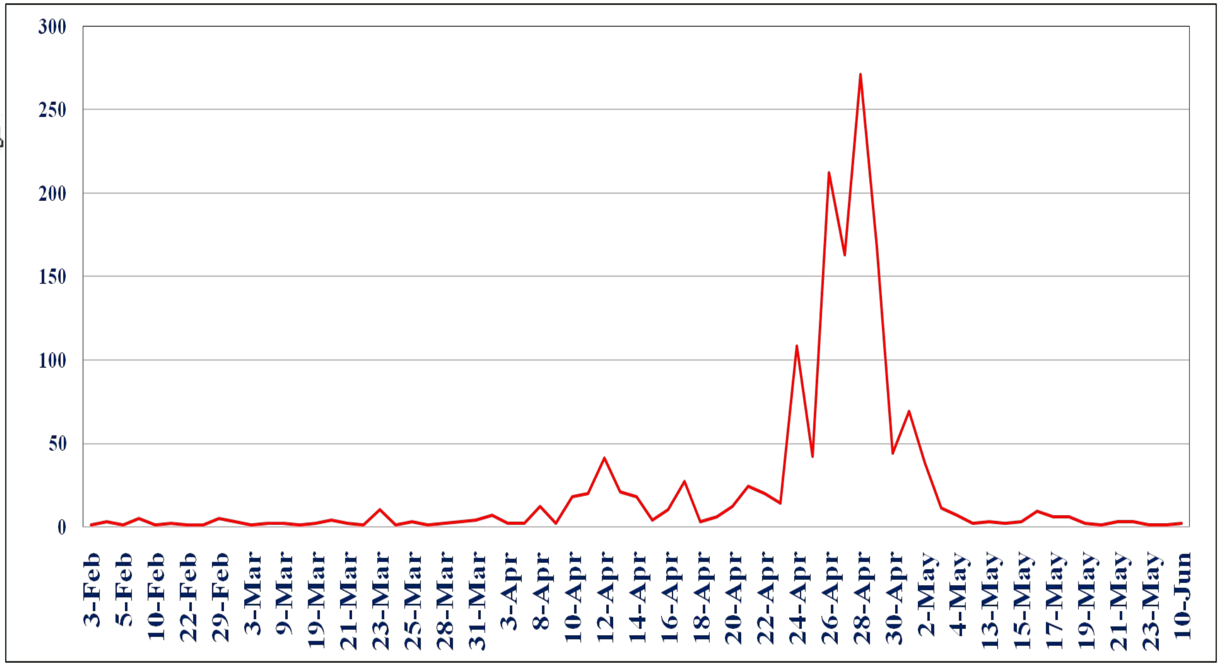

HP NRT
JK NRT
UK NRT
HP FWI
JK FWI
UK FWI
160
140
120
100
80
60
40
20
0
3500
3000
2500
2000
1500
1000
500
0
14-Apr-16
24-Apr-16
4-May-16
14-May-16
24-May-16
3-Jun-16
13-Jun-16
23-Jun-16
3-Jul-16


4000
3500
3000
2500
2000
1500
1000
500
0
CH-NRT
JH-NRT
MP-NRT
MH-NRT
OR-NRT

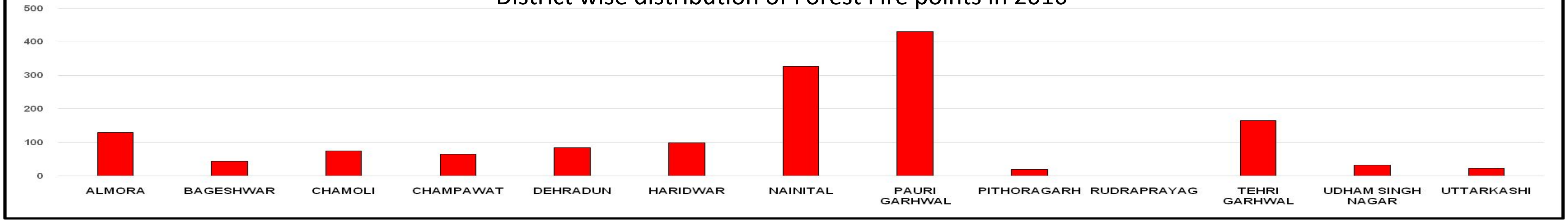
* 27April 2016 - FWI data
* Forest Fire points from 27th April to 30th April 2016



Date wise distribution of Forest Fire points in 2016

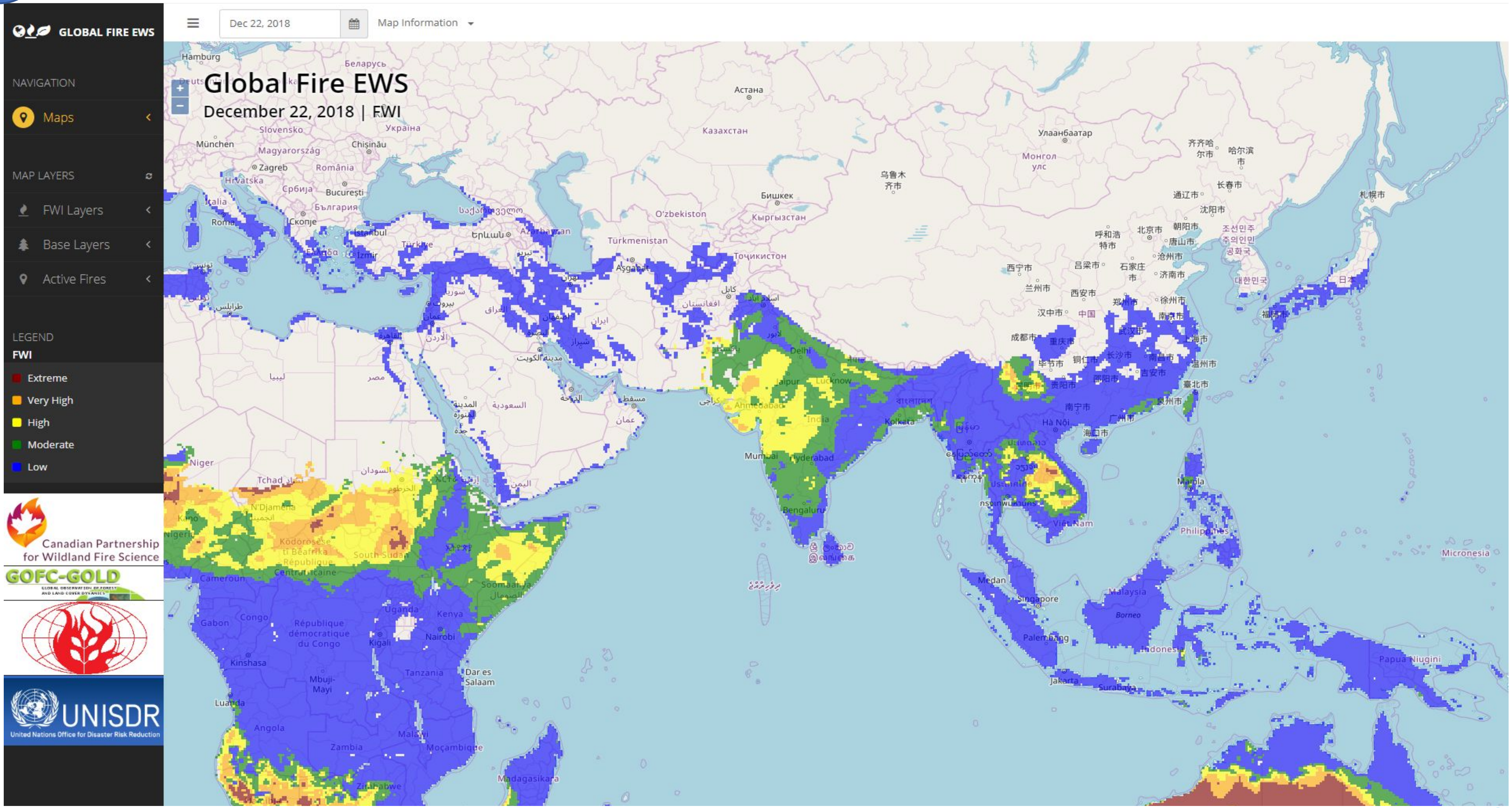


District wise distribution of Forest Fire points in 2016



Global Early Warning system for Wild-land fire mapping products
global fire EWS 10-day forecasts

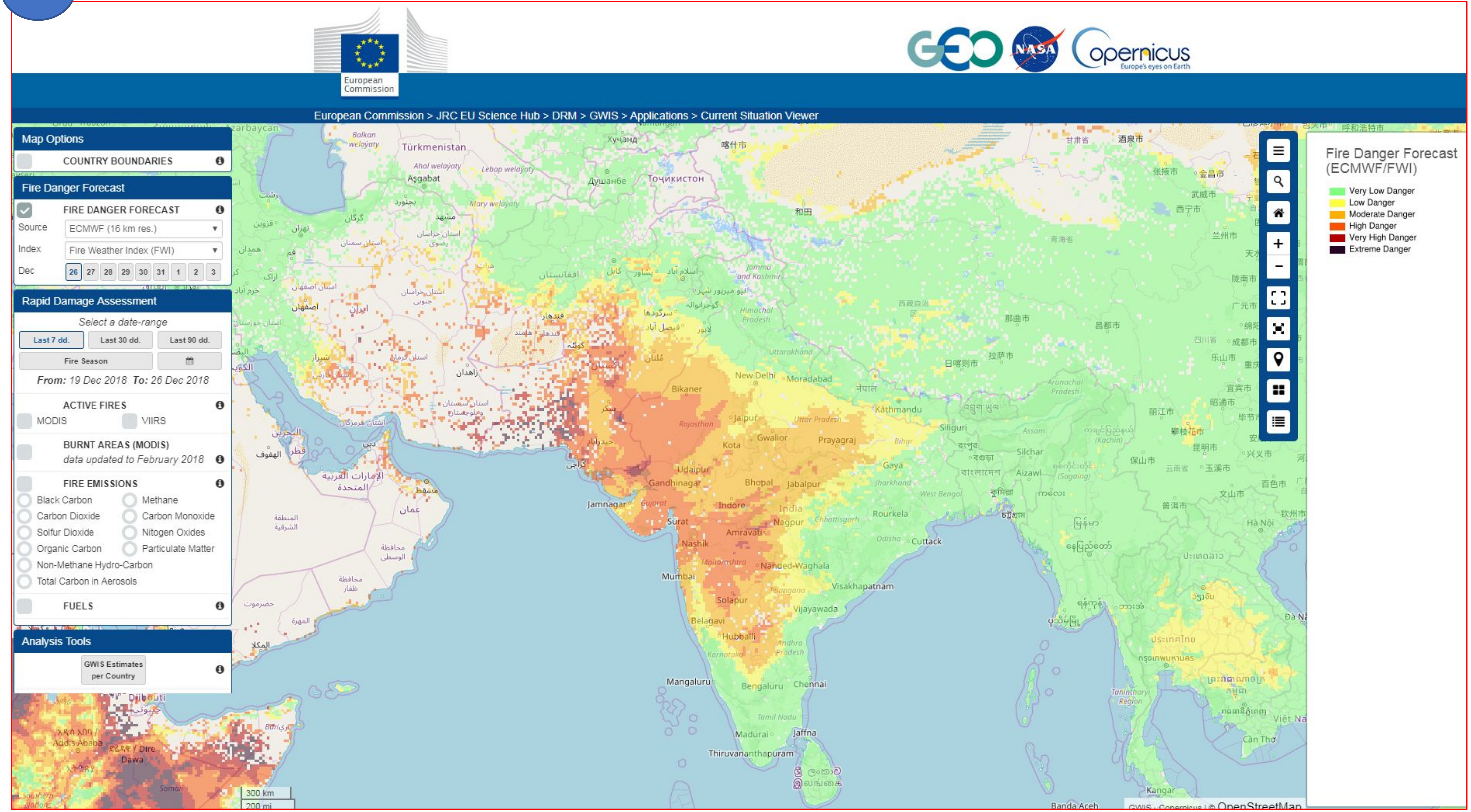
1



Data GEOS-5

2

http://gwis.jrc.ec.europa.eu/static/gwis_current_situation/public/index.html



26 Dec 2018

Source of data European Centre for Medium-Range Weather Forecasts **(ECMWF).

** 7-days forecast data

Data GEOS-5

How is this different from previous approach?

- Use of scientific, time tested indices rather knowledge based decisions that vary with significantly
- Involves assigning fire danger classes (quantitative and qualitative) rather than choosing vulnerable grids
- Possible to alert twice a week due to ready availability of data and minimal data processing compared to previous version
- **Ease of dissemination through WMS, maps etc.,**

Issues in adoption of FDRS

- There is no substitute to scientific research

  - need to develop relationships between fire weather, fuels, topography in accordance with our fire occurrences/behaviour/impacts that are unique to our States/regions.

- Develop guidelines, decision tools, training to SFDs based on local research and operational experience
- Upgrade tech infrastructure and use of appropriate technology to gather, process and disseminate fire weather data (weather stations, standards, coordination among agencies)
- Inter-agency co-ordination (Central, State, Research, NDRF, SDRF, Industry etc)
- Policy support and international cooperation

Success l Failure

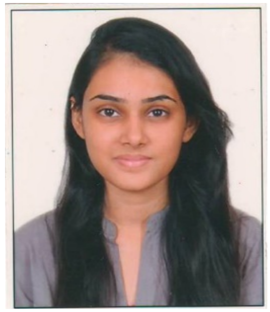
FIRE TEAM
FOREST SURVEY OF INDIA

Vikas Gusain

Tanay Das

Anupam Pal

Satyendra Kumar



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Tapas Biswas

Nirmal Singh

Sujit Kumar Jally

Abhishek Chaudhary

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Solan Forest Circle
evforeser@gmail.com