AMESD SADC-THEMA

Fire Service Validation Report

	Name	Responsibility
Authors	Amon Murwira Mhosisi Masocha Isaiah Gwitira Munyaradzi D. Shekede	UZ UZ UZ UZ
Contributions from	Molline Ndongwe Taona Museva K.S. Murwira	UZ UZ SIRDC
Reviewed by		
Approved by		

TERMS OF REFERENCE

Topic

Validation of Fire service products in Zimbabwe

Period

January 2013 - 30 April 2013

Location

The validation exercise was carried out in Zimbabwe.

Contracting Authority
Botswana Department of Meteorological Services (BDMS), AMESD SADC THEMATIC ACTION.

LIST OF ACRONYMS

ACP	African Caribbean Pacific
AMESD	African Monitoring of the Environment for Sustainable Development
BDMS	Botswana Department of Meteorological Services
CAFWI	Canadian Fire Danger Index
CFFDRS	Canadian Forest Fire Danger Rating System
CEMAC	Communaute Economique et Monetaire d'Afrique Centrale
DMP	Dry Matter Productivity
ECOWAS	Economic Community of West African States
EUR	EURO
GPS	Global Positioning System
GTS	Global Telecommunication System
IGAD	Inter-Government Authority on Development
IOC	Indian Ocean Commission
JRC	European Joint Research Centre
NDVI	Normalised Difference Vegetation Index
NPP	Net Primary Productivity
SADC	Southern African Development Community
SADC	THEMA SADC Thematic Action
VCI	Vegetation Condition Index
UZ	University of Zimbabwe
WMO	World Meteorological Organization

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1.0 INTRODUCTION

Fire is a common phenomenon in most parts of the world particularly in Africa (Bird *et al.*, 1998). Studies have shown that south of the equator, approximately 168 million hectares burn annually and this accounts for 37% of the dry matter burned globally (Goldammer and de Ronde, 2004). The occurrence of fire is a key ecological process defining the structure and composition of nearly all biomes worldwide e.g., boreal forests, temperate forests, tropical forests, tropical and subtropical savannas, woodlands and open forests (Bergeron *et al.*, 2004; Bond *et al.*, 2003). Fire also plays a pivotal role in landscape management, disease control and vegetation succession (Galanter *et al.*, 2000). Although fires are responsible for shaping most of the ecosystems, they can be destructive to vegetation, property and human life (Nyatondo 2010). Thus, the early prediction of possible fire occurrence is critical for characterizing fire risk areas and informing fire management strategies in fire prone areas. However, for fire prediction models to be useful to decision makers and stakeholders there is need for assessing the accuracy assessment of the fire products.

Validation is the process of assessing by independent means the accuracy (uncertainty) of satellite data products (Justice *et al.*, 2000; Privette *et al.*, 2000). It is generally done through i) direct validation (in this case comparing satellite products to ground measurements or ii) indirect validation (using higher resolution data instead of actual ground measurements) (Boschetti *et al.*, 2010; Weiss *et al.*, 2007). Validation of satellite fire products is necessary to provide accurate information on the quality of the product. (Roy *et al.*, 2002), to identify needed product improvements (Morisette *et al.*, 2002; Strahler *et al.*, 2006) as well as instilling confidence in the use of a product. Thus, this report details the results of the validation exercise including the methods used in coming up with the results.

1.1 BACKGROUND

The African Monitoring of the Environment for Sustainable Development (**AMESD**) initiative makes use of Earth observation technologies and data to set-up operational environmental and climate monitoring applications. Launched in 2007, AMESD is scheduled to run until December

2013 and receives funding from the European Commission through the European Development Fund. The programme is managed by the African Union Commission in Addis Ababa, Ethiopia. A steering committee, composed by the main AMESD stakeholders: five Regional Economic Communities (ECOWAS, SADC, CEMAC, IGAD, IOC) and the ACP secretariat, is providing guidance to the programme. The main objective of AMESD is to provide all African nations with the resources they need to manage their environment more effectively and ensure long-term sustainable development in the region. AMESD aims to provide decision-makers in the Regional Economic Communities, the Commission of the African Union and at national level with full access to the environmental data and products they need to improve national and regional policy and decision-making processes. AMESD is establishing operational regional information services to support and improve the decision-making process in the field of environmental management, focusing on specific themes in each region. In the region of the Southern African Development Community (SADC), the theme is “Agricultural and Environmental Resource Management”.

1.2 OVERVIEW OF AMESD SADC THEMA SERVICES

Result area two (2) for the AMESD SADC THEMA aims to develop, implement and make operational three (3) core services: Agriculture, Drought and Fire in the ministries of Agriculture and Ministries of Environment of the participating SADC member states. The Agricultural Service will monitor the state of the crops and rangeland. The Drought Service will monitor drought during the whole year and deliver a decadal “Drought map” and a “Drought Outlook” in support of both agriculture and environmental issues. The Fire Service will provide a daily fire risk indication (before the fire), continuous active fire maps (in real time during the fire season, refreshed every 15 minutes) and monthly burnt area assessments (after the fire). A common “Long Range forecast” service will complement the three (3) core services and provide them a seasonal forecast outlook.

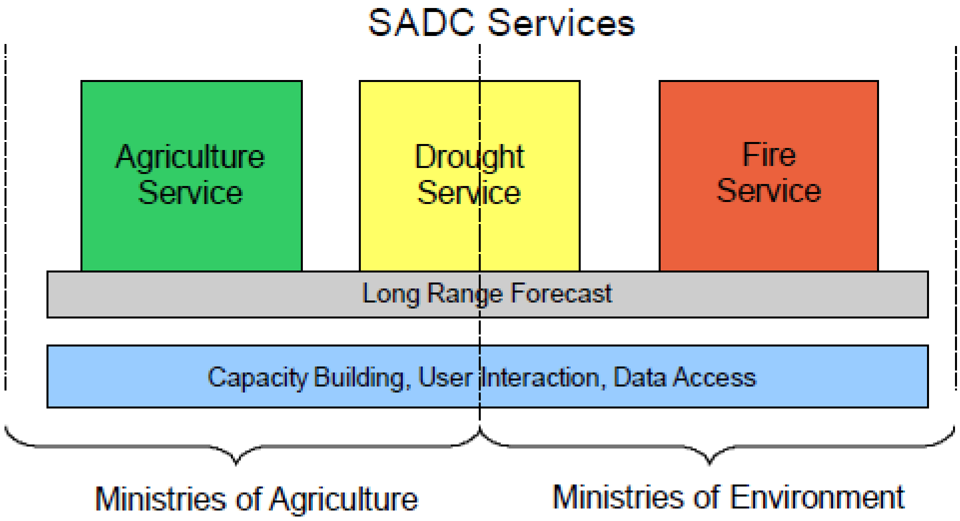

Figure 1: Schematic overview of the SADC Thematic Action services

As part of a process to make operational the AMESD SADC THEMA **products and services a validation exercise** was undertaken with the view that users and stakeholder may develop a certain level of confidence in using the products, and services and information derived therein. The SADC THEMA budgeted of 90,000.00EUR for the validation activities of the different services and products in SADC member countries. Each service will get a total of 30,000.00EUR for the validation exercise. The validation exercise initially focussed on 6 countries, and each country therefore received 5,000.00 EUR per service.

1.2 OBJECTIVES

The main objective of the validation exercise is to assess the performance of selected fire service products in Zimbabwe through a comparison of the products with field measurements

1.3.1 JUSTIFICATION OF THE VALIDATION EXERCISE

BDMS and its partners are obliged to make sure that information generated from the services is accurate, reliable and reflect the situation on the ground. The results that will come from the validation are very important for the improvement of the products.

1.4 VALIDATION GUIDELINES FOR FIRE SERVICE PRODUCTS

The AMESD fire service consists of three main parts looking at:

- Prediction of fires (Before a fire),
- Detection/Monitoring of fires (During a fire)
- Assessment of fire damage (After a fire)

This fire service relies on the AMESD Fire station which is based on the Advanced Fire Information System (AFIS) developed by South African National Space Agency. AFIS is an operation alert and mapping system providing near real-time information related to the detection, monitoring and assessment of fires in Southern Africa based on satellite data derived from the Terra and Aqua MODIS and Meteosat Second Generation (MSG) satellites. The table below provides the full list of AMESD SADC Thema fire products. The fire product which was highlighted is highlighted in Table 1

Table 1: AMESD SADC Fire service products

Fire service	
1	FP01: MODIS Active Fire product
2	FP02: Definition of MSG Active Fire (FIR) product
3	FP03: Burned Area products
4	FP04: Canadian Fire Weather Index
5	FP05: Lowveld Forest Fire danger index
6	FP06: Modis Daily true colour composite

1.5 DESCRIPTION OF FIRE PRODUCTS VALIDATED

Although there are currently 6 products generated and disseminated for the fire service, validation was only done for 1 product which is the Canadian Fire Danger Index. The other products are not selected for validation due to budget constraints and practical problems in collecting independent reference data especially for the active fire products. The validation of the MODIS burned-area product will be considered during the follow up project, MESA.

1.5.1 The Canadian Forest Fire Danger Index (CAFWI)

The Canadian Forest Fire Danger Rating System (CFFDRS) was developed by the federal forestry service in Canada. The AMESD SADC CAFWI provides for the assessment of relative fire potential based solely on weather observations. These are daily measurements of: dry-bulb temperature, relative humidity, a 10-metre open wind speed and 24-hour and accumulated precipitation, recorded at noon local standard time. The AMESD SADC CAFWI provides a three day forecast for fire danger and is updated daily. The Index comprises two major subsystems, namely the Fire Weather Index (FWI) System and the Fire Behaviour Prediction (FBP) System (Figure 2).

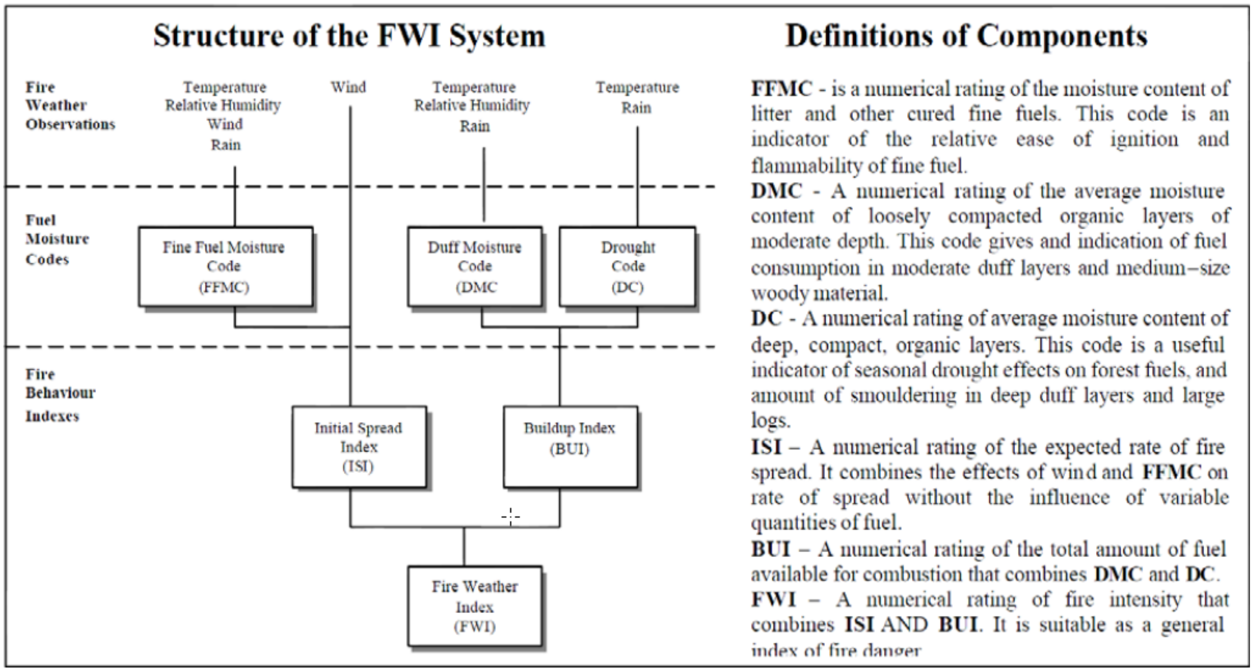

Figure 2: Structure of the Canadian Forest Fire Weather Index System and component definitions

The FWI System's six components individually and collectively account for the effects of fuel moisture and wind on ignition potential and probable fire behaviour in the form of relative numerical ratings. Three fuel moisture codes reflect the fuel moisture content of fine surface litter (Fine Fuel Moisture Code — FFMC); loosely compacted duff of moderate depth (Duff Moisture Code — DMC); and deep compact organic matter (Drought Code — DC), respectively. The codes are in fact dynamic bookkeeping systems that account for each day's precipitation and drying.

The fuel moisture codes plus wind are linked in pairs to form two intermediate and one final index of fire behaviour. The Initial Spread Index (ISI) combines the effects of wind and fine fuel moisture content (FFMC). It represents a numerical rating of fire spread rate, without the influence of variable fuel quantity. The Build up Index (BUI — based on the DMC and DC) represents a measure of the total fuel available for combustion. The Fire Weather Index (FWI) component itself combines the ISI and BUI to indicate the potential intensity of a fire.

3.0 MATERIALS AND METHODS

3.1 STUDY AREA

The validation exercise was carried out in Zimbabwe. Zimbabwe is located in Southern Africa and it covers an area of 390.580km^2. It is a land locked country bordered Zambia to the NW, Mozambique to the NE; Botswana lies to the SW and South Africa to the south (Figure 6). The latitude and longitude for the country are 18.8640 ^{0}S, 30.3339^{0}E. Zimbabwe has a tropical climate with rain season from November to March.

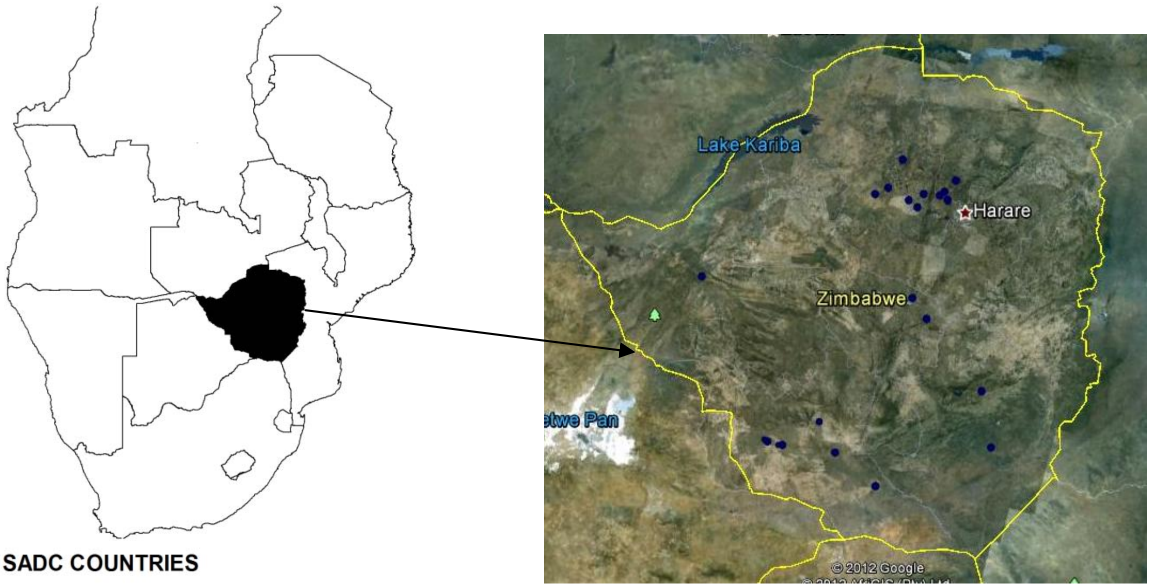

Figure 3: The location of Zimbabwe in Southern Africa. (The blue points represent the random points (*Source: Google earth 2012*)

3.2. METEOROLOGICAL/WEATHER DATA

Weather data was downloaded from the World Meteorological Organisation website via GTS stations. The weather data was input into the fire weather index. A point map was created and cross functions were executed in ILWIS to compare fire danger indices which were calculated using reference data and CAFWI values. A regression analysis was perfomed in SPSS in order to correlate the reference FWI values and CAFWI values. Further, a scatter plot of the reference FWI and the CAFWI was generated to establish the correlation between the two variables.. The relationship was further confirmed using a correlation coefficient and the slope of the regression (for the correlation between the reference FWI and the CAFWI) for the 1st, 3rd and 5th of month of October 2012.

Figure 4 shows the spatial distribution of the meteorological stations from which weather data were collected and later used in the calculation of reference fire weather indices. It can be observed that the metrological stations are not evenly distributed across the country with a higher concentration of these stations in the southern parts of the country.

Figure 4: National Meteorological Weather Stations whose data were used in the validation exercise.

The field work involved the collection of information related to vegetation status which is an input in the FWI calculator. Data on vegetation condition and fire occurrence was collected from the same sampling points as those used for drought and agriculture service products to minimise costs. This was done to collect ancillary data that would enable the interpretation and cross validation of the fire products. The AMESD SADC CAFWI provides for the assessment of relative fire potential based solely on weather observations. The weather data include daily measurements of temperature, rainfall, precipitation and wind speed.

The AMESD SADC CAFWI provides a three day forecast for fire danger and is updated daily. The independent validation datasets for the CAFWI are based on the meteorological data available from National Meteorological Service Departments. The validation sites for the CAFWI are basically the national meteorological weather stations. The weather data was obtained from all the national automatic weather stations that send their data to WMO via GTS stations. The sampling of weather stations covered a diverse range of vegetation and climatic conditions in the country.

RESULTS

Figure 5 shows the relationship between combined CAFWI and Reference Fire Weather Index (RFWI) data from the 1st to the 5th of October across Zimbabwe. Results show that there is a strong positive and significant relationship between CAFWI and RFWI (r=0.591, P=0.000, N=79). However the CAFWI is relatively higher (mean 44.89) than the RFWI (14.97). This shows the tendency of CAFWI to over predict the likelihood of fire occurrence.

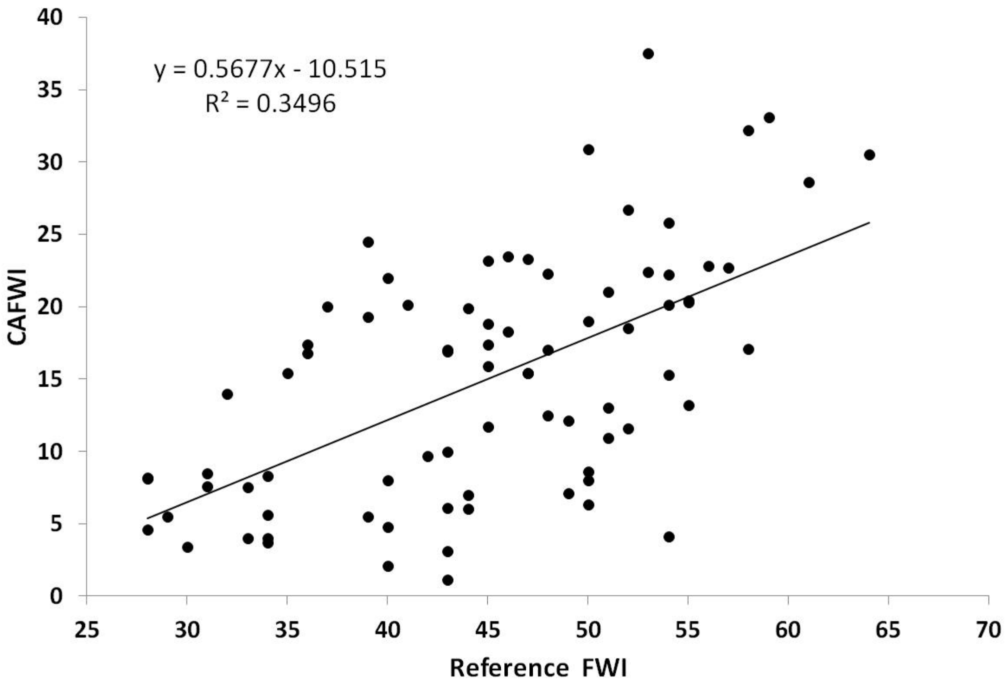

Figure 5: Relationship between CAFWI AND REFERENCE FWI

When relationships of the individual dates are considered, it is observed that the satellite derived CAFWI tend to differentially correlate with the Reference FWI. For instance while the data from the 1st (Figure 6) and the 3rd (Figure 7) of October 2012 show positive but non-significant relationship (r=0.178, P=0.454, N20, r=0.400,P=0.080,N20 respectively), results from correlation analysis of data from the 5th of October show a stronger positive and significant relationship (r=0.606, 0.006, N=19) (Figure 8).

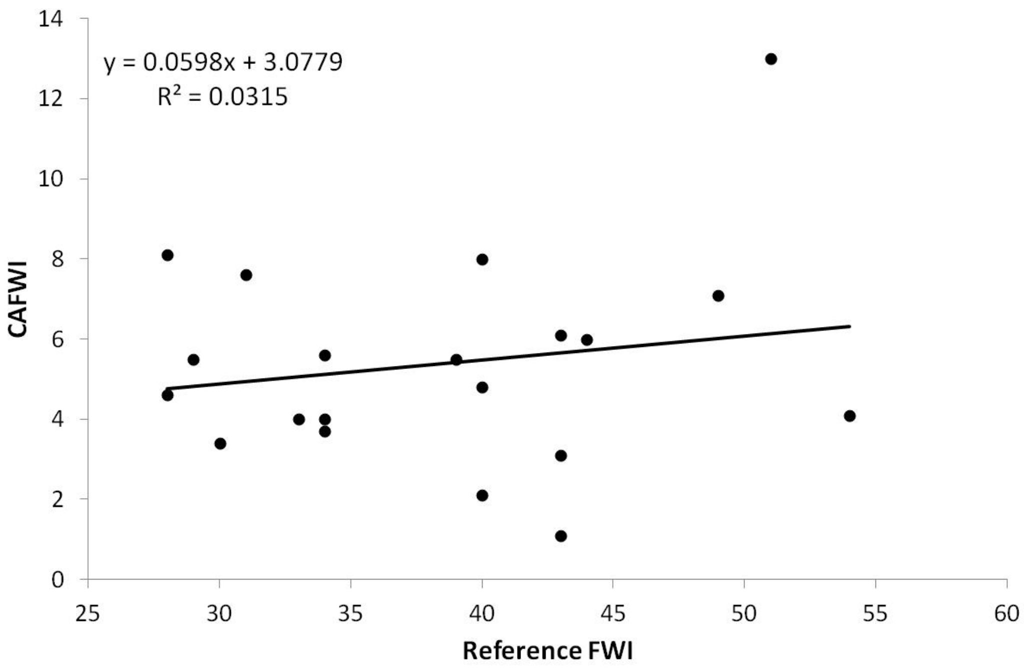

Figure 6: Relationship between CAFWI AND REFERENCE FWI (10/01/12)

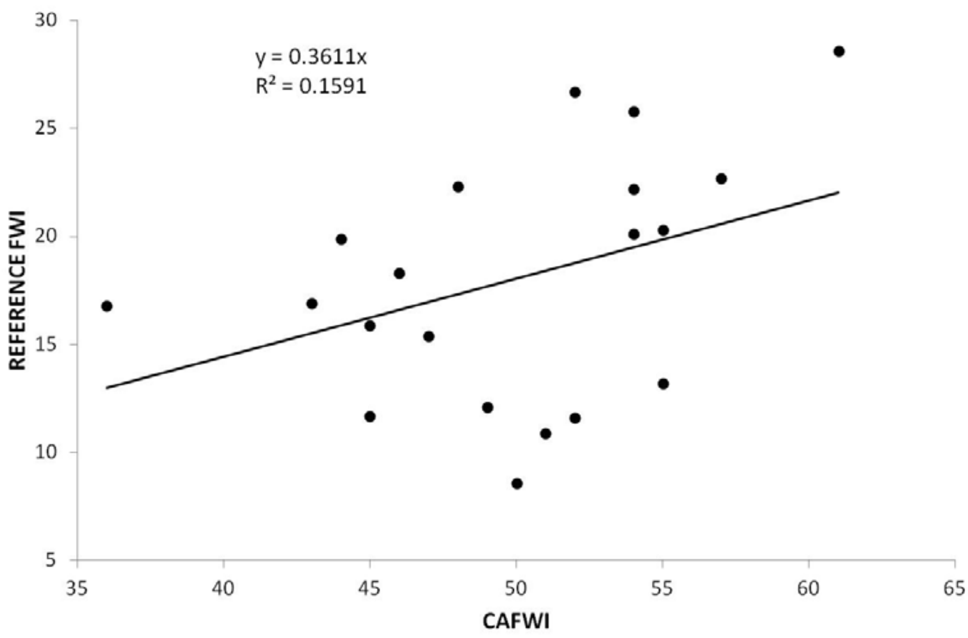

Figure 7: Relationship between CAFWI AND REFERENCE FWI (10/03/12)

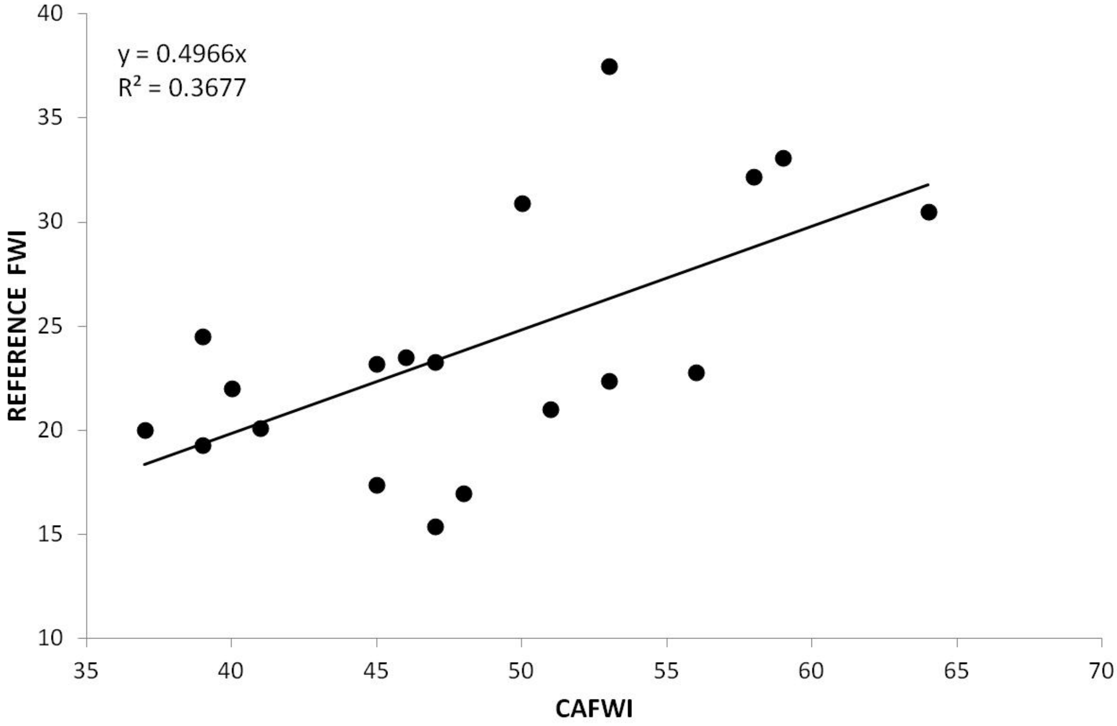

Figure 8: Relationship between CAFWI AND REFERENCE FWI (05/10/12)

DISCUSSION

The results of the correlation analysis of the Canadian Fire Danger Index (CAFWI) and the Reference Fire Weather Index calculated from ground data show that the model closely approximates observations from the ground notwithstanding differential performance of the model at different times. The lack of significant relationship of CAFWI and REFERENCE FWI for some periods could be attributed to the fact that CAFWI are calculated using satellite based weather approximates, thus may not necessarily correlate with the weather observed as point estimates on the ground. Daily operational fire plans are prepared by the overhead team using forecasted weather elements. Since weather elements change quickly over short time periods and in space, the reliability of CAFWI are dependent on how well the weather component reliably predict weather patterns across the regions of interest. Thus, an error in weather prediction has direct bearing on the performance of the Canadian Fire Danger Index. Thus, there is need for use of satellite weather systems that provide accurate predictions of the weather patterns to ensure reliability of the Fire Index used in the AMESD Project.

CONCLUSION

The aim of this study was to determine the validity of the Canadian Fire Danger Index (CAFWI through comparing its results with Reference Fire Weather Index data. We conclude that overall, there is a significant positive relationship between the Canadian Fire Danger Index (CAFWI) Fire weather indices and the fire indices calculated from ground data although this relationship does not always hold all the time. In fact there are times, when there is no significant relationship between the two products. It is however important to note that the predictions for the CAFWI are as good as the weather predictions and thus to improve fire prediction there is need to adopt reliable weather prediction models.

REFERENCES

Bergeron, Y., Gauthier, S., Flannigan, M., & Kafka, V. (2004) Fire regimes at the transition between mixed wood and coniferous boreal veld in Northwestern Quebec. *Ecology*, **85**, 1916-1932.

Bird, M.I. & Cali, J.A. (1998) A million-year record of fire in sub-Saharan Africa. *Nature*, **394**, 767- 769.

Bond, W.J., Midgley, G.F., & Woodward, F.I. (2003) What controls South African vegetation-climate or fire? *S. Afr. J. Botany*, **69**, 1-13.

Boschetti, L., Roy, D.P., Justice, C.O., & Giglio, L. (2010) Global assessment of the temporal reporting accuracy and precision of the MODIS burned area product. *INTERNATIONAL JOURNAL OF WILDLAND FIRE*, **19**, 705-709.

Boschetti, M., Stroppiana, D., Confalonieri, R., Brivio, P.A., Crema, A., & Bocchi, S. (2011) Estimation of rice production at regional scale with a Light Use efficiency model and MODIS time series. *Italian Journal of Remote Sensing*, **43**, 63 - 81.

Funk, C. & Verdine, J. (2003) Comparing Satellite Rainfall Estimates and Reanalysis Precipitation Fields with Station Data for Western Kenya. In JRC-FAO International Workshop on Crop Monitoring for Food Security in Africa. JRC, Nairobi.

Galanter, M., Levy, H., & Carmichael, G.R. (2000) Impacts of biomass burning on tropospheric CO,NO2, and O3. *J. Geophys. Res.-Atmos*, 6633-6653.

Justice, C., Belward, A., Morisette, J., Lewis, P., Privette, J., & Baret, F. (2000) Developments in the 'validation' of satellite sensor products for the study of the land surface. *International Journal of Remote Sensing*, **21**, 3383-3390.

Mermoz, M., Kitzberger, T., & Veblen, T.T. (2005) Landscape influences on occurrence and spread of wildfires in Patagonian velds and shrublands. *Ecology*, **86**, 2705-2715.

Morisette, J.T., Privette, J.L., & Justice, C.O. (2002) A framework for the validation of MODIS Land products. *Remote Sensing of the Environment*, **1**, 77- 96.

Privette, J., Thompson, A., Prince, S., & Scholes, B. (2000). Southern Africa Validation of EOS (SAVE), Washington.

Roy, D.P., Borak, J., Devadiga, S., Wolfe, R., Zheng, M., & Descloitres, J. (2002) The MODIS land product quality assessment approach. *Remote Sensing of the Environment*, **83**, 62-76.

Strahler, A., Boschetti, L., Foody, G., Friedl, M., Hansen, M., Harold, M., Mayaux, P., Morisette, J., Stehman, S., & Wodcock, C. (2006) *Global land cover validation:*

Recommendations for evaluation and accuracy assessment of global land cover maps Office Official Publ. Eur. Commun, Luxembourg.

Weiss, M., Baret, F., Garrgues, S., & Lacaze, R. (2007) LAI and fAPAR CYCLOPES global products derived from VEGETATION. Part 2: validation and comparison with MODIS collection 4 products. *Remote Sensing of Environment*, **110**, 317 - 331.