INTEGRATION OF A STRESS FACTOR IN SEBS FOR IMPROVING THE ESTIMATION OF EVAPOTRANSPIRATION DURING WATER STRESSED CONDITIONS

UNIVERSITY OF KWAZULU-NATAL

Centre for Water Resources Research

NRF National Research Foundation | SAEON South African Environmental Observation Network

South African NATIONAL PARKS

WATER RESEARCH COMMISSION

GCS Water & Environmental Consultants

water affairs
Department: Water Affairs
REPUBLIC OF SOUTH AFRICA

Gokool S, Riddell ES, Jarmain C and Chetty KT

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INTRODUCTION

- **Monitoring and gauging of hydro-meteorological fluxes in arid and semi-arid environments remains fairly limited.** **(Lange et al., 2005, Costa et al., 2013)**

- **Subsequently, may limit extensive hydrological research to be undertaken in these environments.** **(Lange et al., 2005)**

- **In such circumstances satellite earth observation (SEO) technologies may prove to be invaluable.**

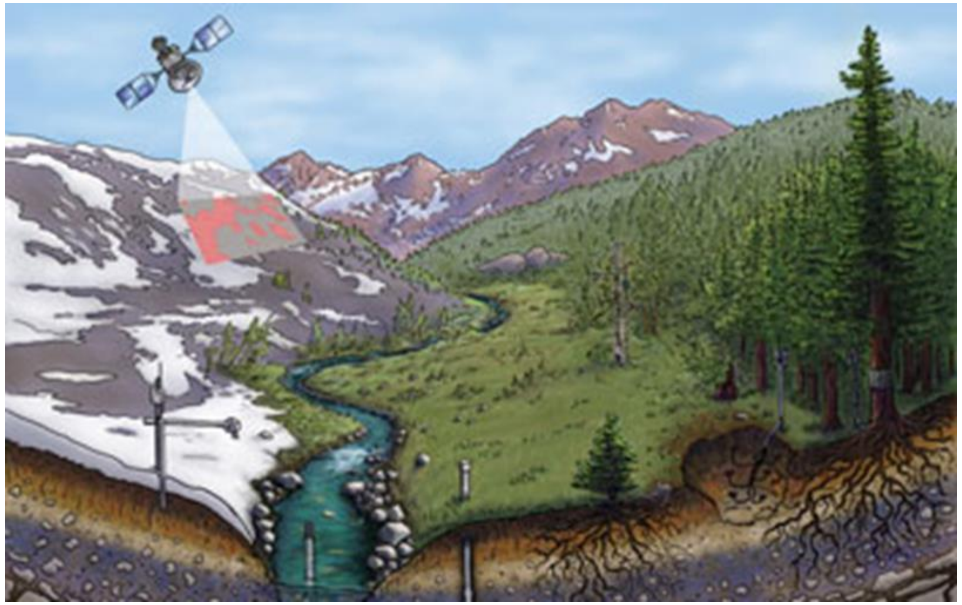
INTRODUCTION

- **In recent times satellite-based approaches are being utilized more frequently for hydro-meteorological observations.** **(Gokmen et al., 2012)**

- **Numerous satellite-based methods have been formulated for the estimation of ET.** **(Bastiaanssen., et al 1998; Senay et al., 2007; Gokmen et al., 2012)**

- **Some of the most commonly applied models include;**

1. **SEBS** **(Su, 2002)**
2. **SEBAL** **(Bastiaanssen et al., 1998)**
3. **METRIC** **(Allen et al, 2007)**



INTRODUCTION

- **Satellite-based ET estimation models makes allowance for the relatively timeous and cost effective quantification of ET.** **(van Dijk and Renzullo, 2011)**

- **Accurately representing ET dynamics under different climatic regimes may prove to be challenging.** **(Seneviratne et al., 2010)**

- **These approaches may overestimate ET in arid and semi-arid environments.**
  (Seneviratne et al., 2010)

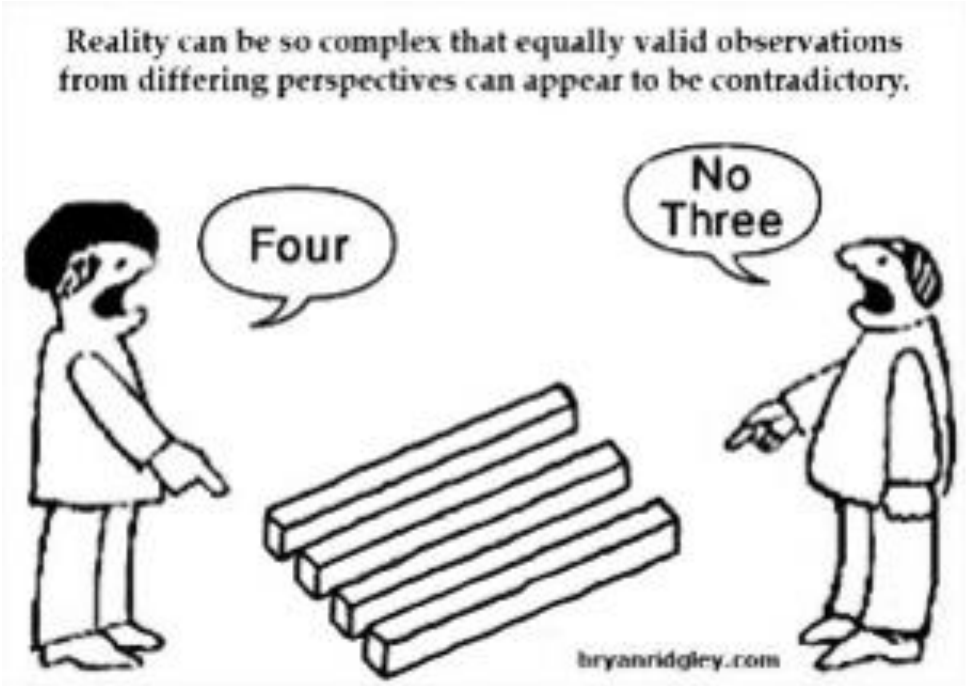
INTRODUCTION

- **Inability to adequately represent the influence of soil moisture availability and biophysical characteristics.** (Gokmen et al., 2012; Pardo et al., 2014; Wu et al., 2014; Huang et al., 2015; Li et al., 2015)

- **Influence of these parameters, implicitly encompassed in model input variables.**

- **Assumption may be valid for environments in which the available energy is the limiting factor for ET.**

- **Underestimation of sensible heat flux for water limited environments.**



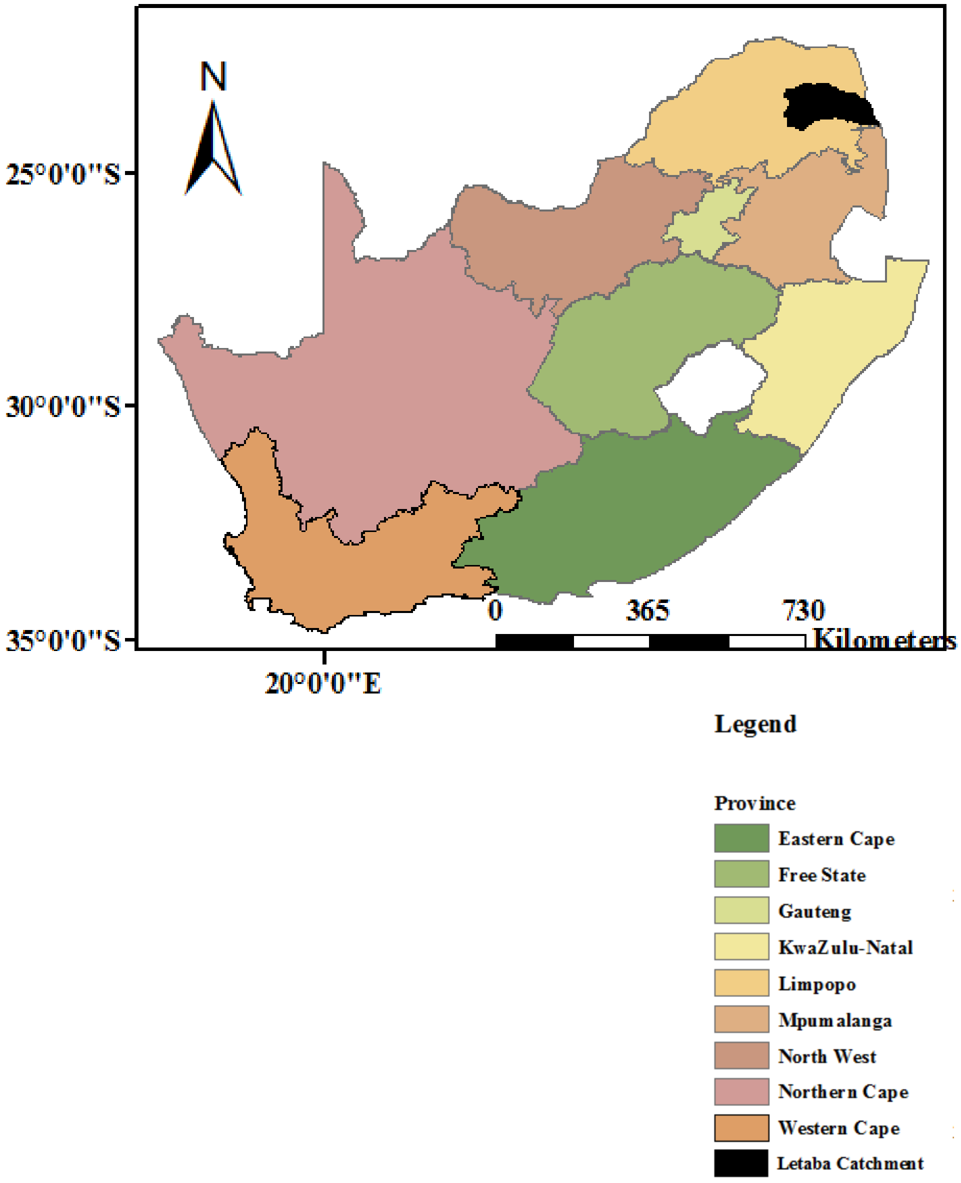
OVERVIEW AND AIM OF THE STUDY

Background

- **SEBS was applied to determine the ET within a semi-arid savanna landscape.**

Criteria for model selection:

- **Extensively applied for the estimation of regional fluxes and ET** **(Yang et al., 2010; Zhuo et al., 2014)**
- **Freely available of the ILWIS platform**
- **Relatively user-friendly**
- **Tutorial information available**



OVERVIEW AND AIM OF THE STUDY

Background

- **Previous studies have reported uncertainties in flux and ET estimates.**

- **Over-estimation of ET ranged from 0.50 to 3.00 mm d^{-1}.**

  (Timmermans and Meijerink, 1999; Lubczynski and Gurwin, 2005; van der Kwast et al., 2009)

- **General degree of overestimation was shown to be higher for regions dominated by sparse vegetation coverage and drier soils.**

  (Pardo et al., 2014)

OVERVIEW AND AIM OF THE STUDY

Background

- **Recent studies have attempted to correct this limitation through the integration of a scaling factor in SEBS.**

- ***$SEBS_{SM}$*** **(Accounts for the influence of soil moisture)** **(Gokmen et al., 2012)**
- ***$SEBS_{NDVI}$*** **(Accounts for the influence of LST and biophysical characteristics)** **(Pardo et al., 2014)**

- **These modified versions of SEBS have been shown to provide improvements in mapping of ET to better quantify regional energy and water fluxes.**

OVERVIEW AND AIM OF THE STUDY

Rationale

- **In this study we propose the use of an alternative scaling factor to better characterize ET at the field scale.**

- **The proposed scaling factor considers the influence of environmental stress on fluxes and is given as:**

$$Kc_{act} = \frac{ET_a}{ET_o}$$

Where:

***Kc**$_{act}$*, **hereafter referred to as *ESF*, is the actual crop coefficient which accounts for the influence of environmental stress (Allen et al., 2005)**

OVERVIEW AND AIM OF THE STUDY

The aim of this study was to implement the modified version of SEBS to capture the ET within a semi-arid savanna landscape.

<u>Specific objective:</u>

- **Original SEBS ($SEBS_0$) vs Modified SEBS formulation ($SEBS_{ESF}$)**

- **The modelled ET acquired for each of these approaches was validated against Eddy covariance ET measurements.**

MATERIALS AND METHODOLOGY

Study Sites

- **Site 1: Riparian zone of Groot Letaba River**

  (Riddell et al., 2017)

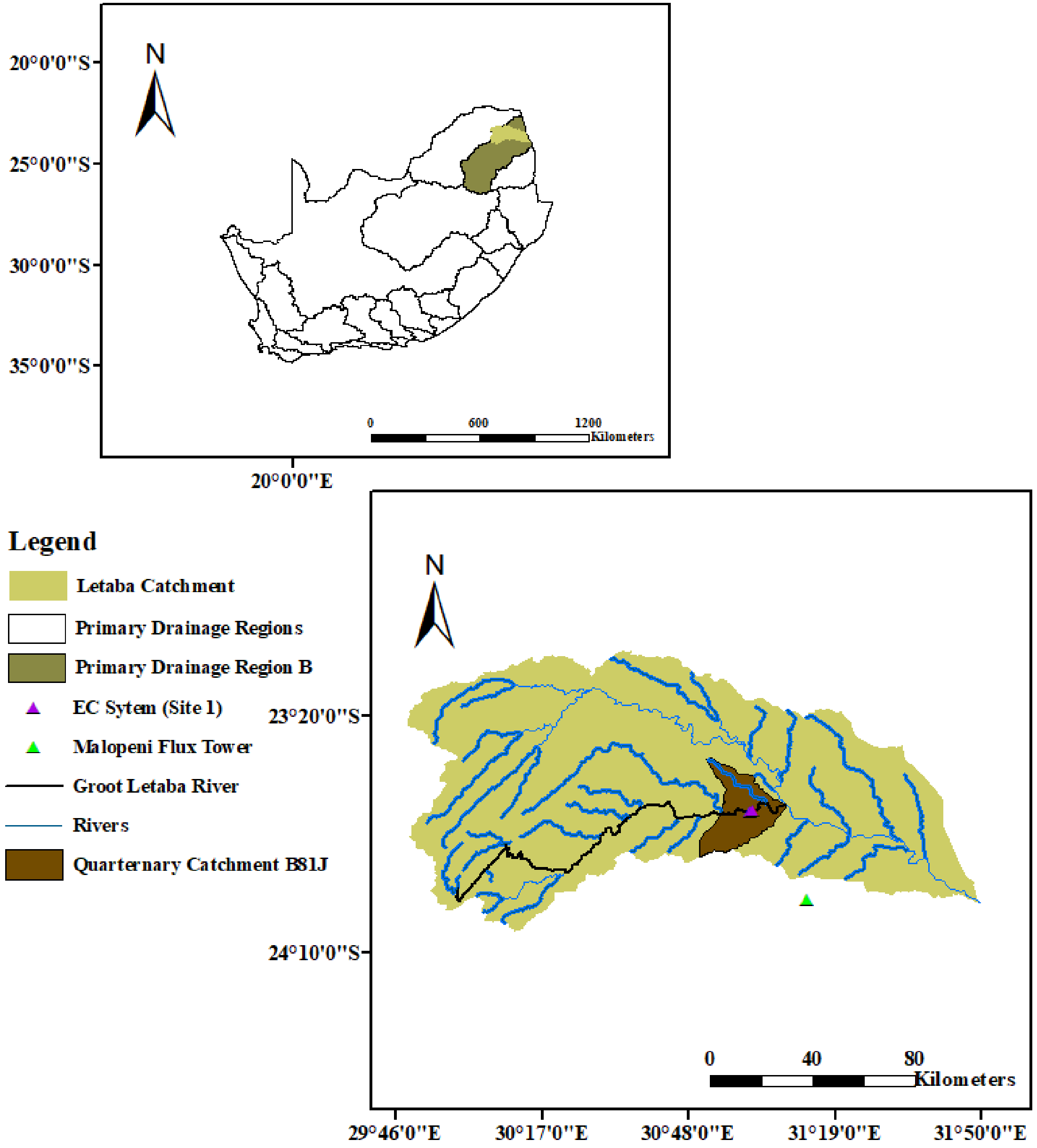
- **Site 2: Malopeni Flux Tower (CARBOAFRICA network)**

  (Ramoelo et al., 2014)

- **The measuring sites are situated in a semi-arid summer rainfall region.**

- **Warm conditions in the eastern region to cooler conditions in the mountainous regions.**

(Katambara and Ndiritu, 2010; Pollard and du Toit, 2011a)



MATERIALS AND METHODOLOGY

Study Sites

- **A vast majority of the study region is underlain by gneiss and granite.** **(Heritage et al., 2001)**
- **The study sites are dominated by pristine savanna vegetation.** **(Ramoelo et al., 2014; Riddell et al., 2017)**

Site 1

***Phragmites mauritianus* (Lowveld Reed)**

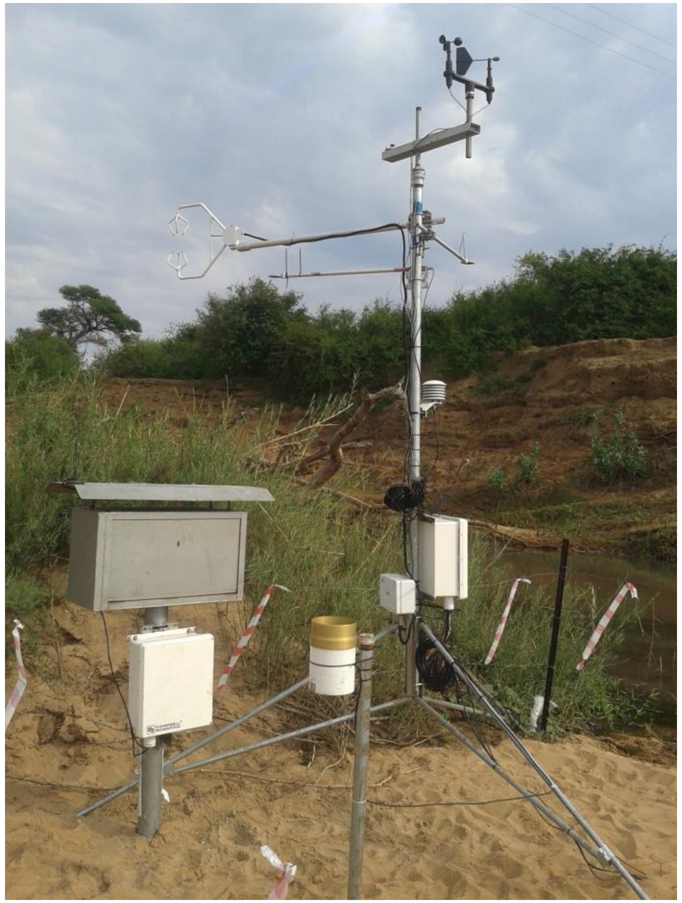
Site 2

***Colospherpemum mopane* (Balsam or Butterfly Tree)**

MATERIALS AND METHODOLOGY

Data Sets: Meteorological Data

- Energy flux and meteorological data were acquired from EC flux towers installed at Sites 1 and 2.



- Site 1 measurement period (17th June to 22nd October 2015)

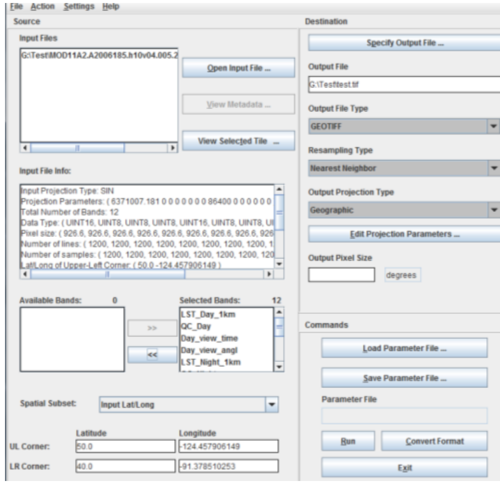
- Site 2 measurement period (18th May to 11th November 2016)

- The timing of the study coincided with a large El Nino induced drought period.

MATERIALS AND METHODOLOGY

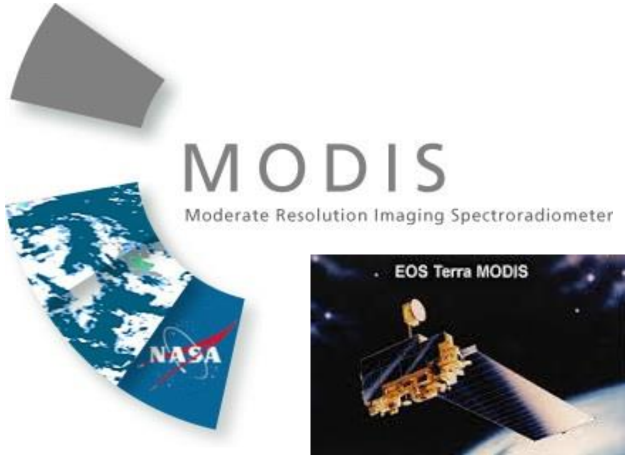
Data Sets: Satellite earth observation data

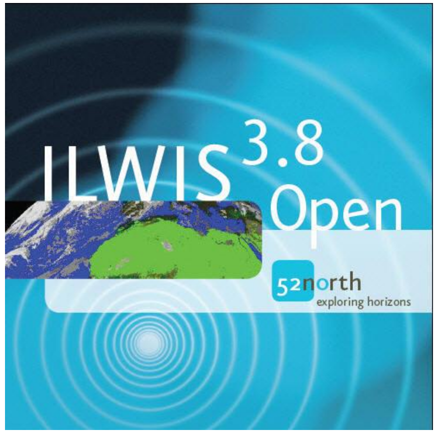
- Satellite images were acquired for the corresponding measurement periods



1. 13 (2015 and 2016) clear sky Landsat (7 and 8) Level 1 Geotiff products
2. 106 (2015) and 101 (2016) clear sky MODIS Level 1 B Terra images

- Pre-processing of images was conducted using ILWIS, the MODIS Swath Tool and HDF view (Su and Wang, 2013; Singh et al., 2014a and USGS, 2015)





MATERIALS AND METHODOLOGY

SEBS Processing and Modifications

- **The requisite land surface parameters and meteorological data were used as inputs to SEBS.**

- **The *ESF* scaling factor was then used to adjust the evaporative fraction estimated in SEBS.**

1. $$ESF = \frac{ET_a}{ET_o}$$

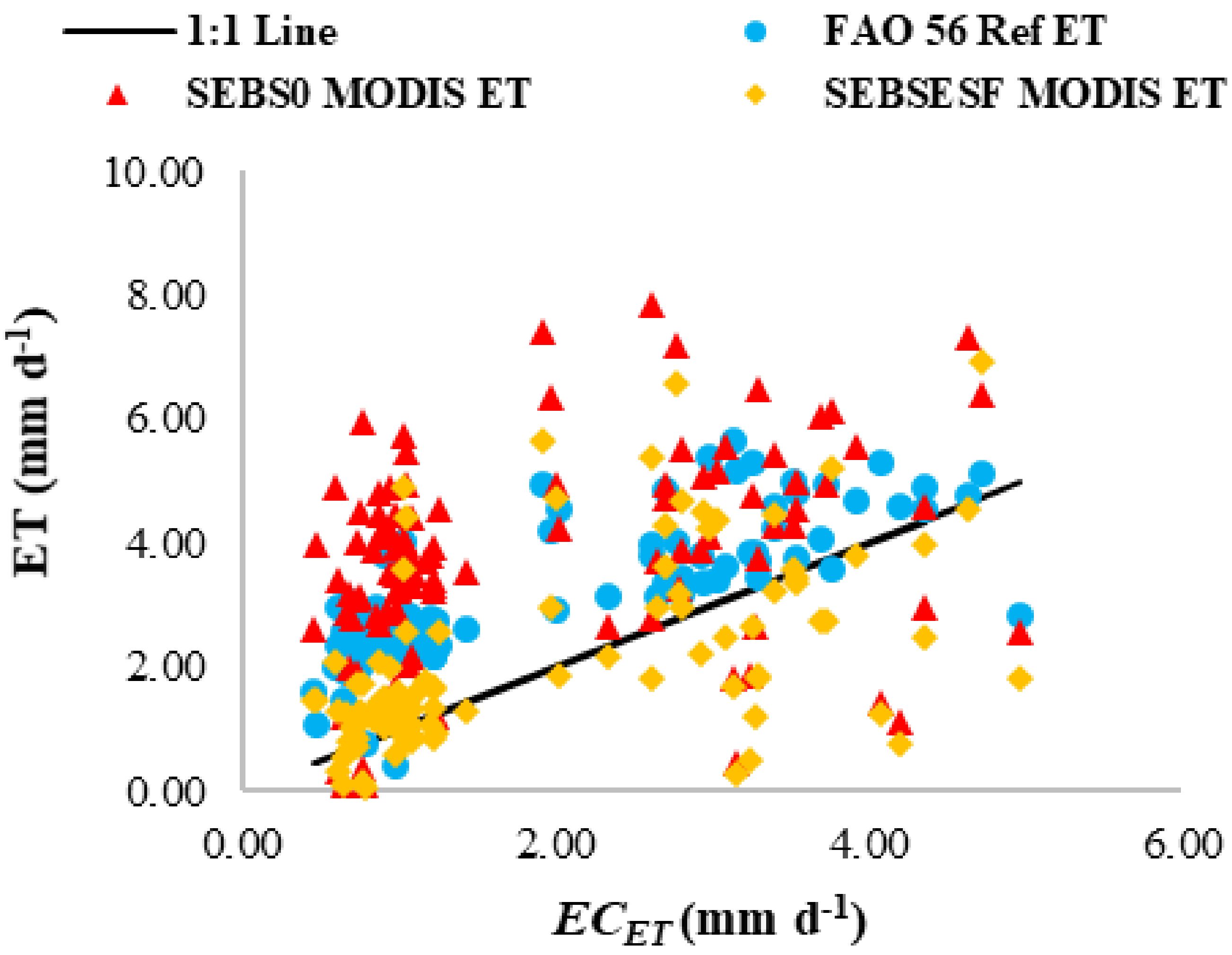
2. $$EF_{new} = EF_{old} * ESF$$ **Based on the approach adopted by Pardo et al. (2014)**

- $\boldsymbol{EF_{new}}$ **was then applied in conjunction with the R_n and G_0 previously determined in $SEBS_0$**

- **The sensible heat flux was also recalculated using EF_{new}, to ensure closure in the energy balance equation.**

RESULTS

Site 1: SEBS ET derived from MODIS Data

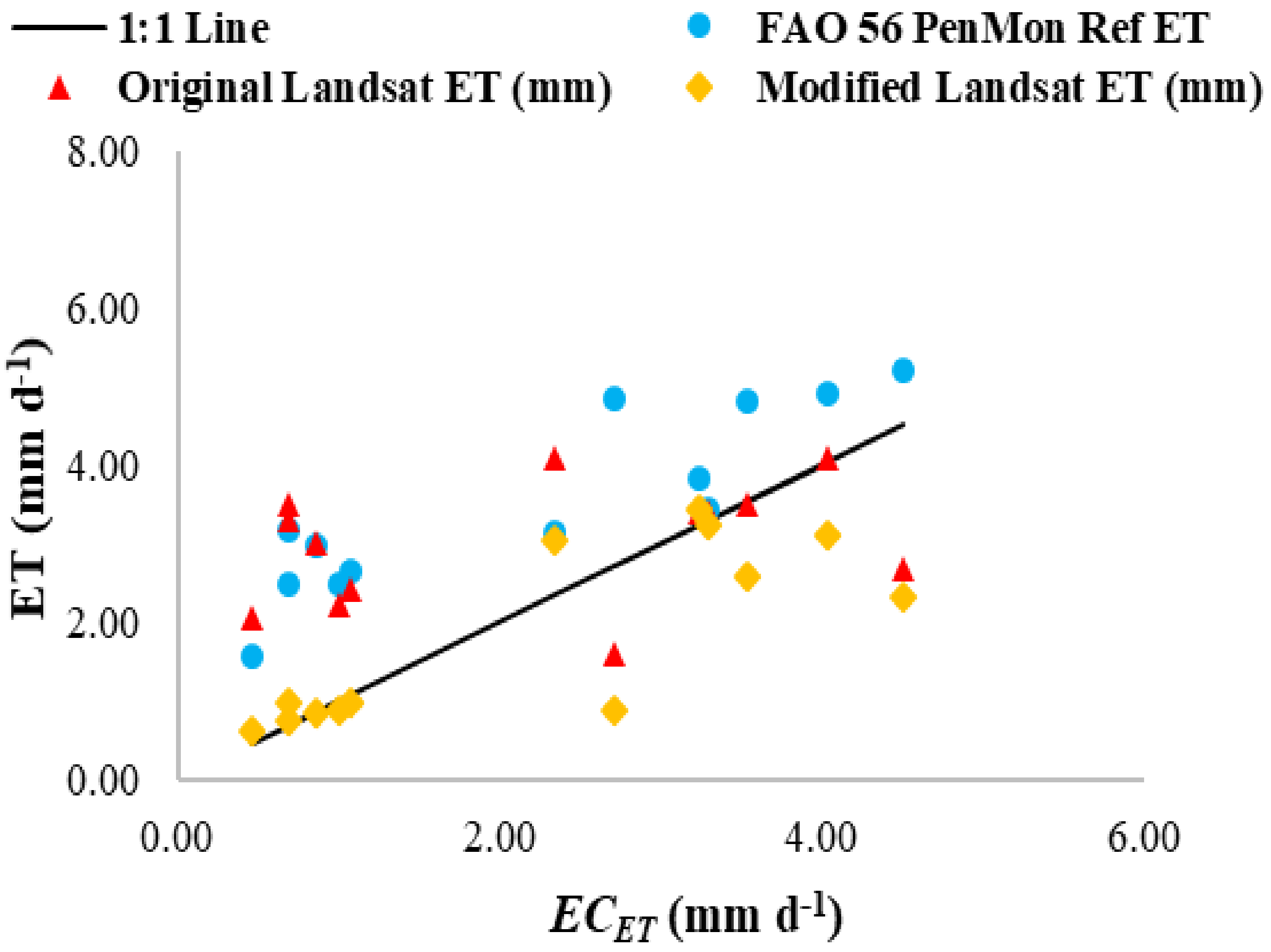


	$SEBS_0$ ET	$SEBS_{ESF}$ ET
RMSE	2.57	1.31
R^2	0.10	0.31
Nash-Sutcliffe	-3.34	0.14
AAR (± 15 %)	5 %	21 %
AAR (± 30 %)	9 %	42 %

- **Improved correlation with EC_{ET}**

RESULTS

Site 1: SEBS ET derived from Landsat Data

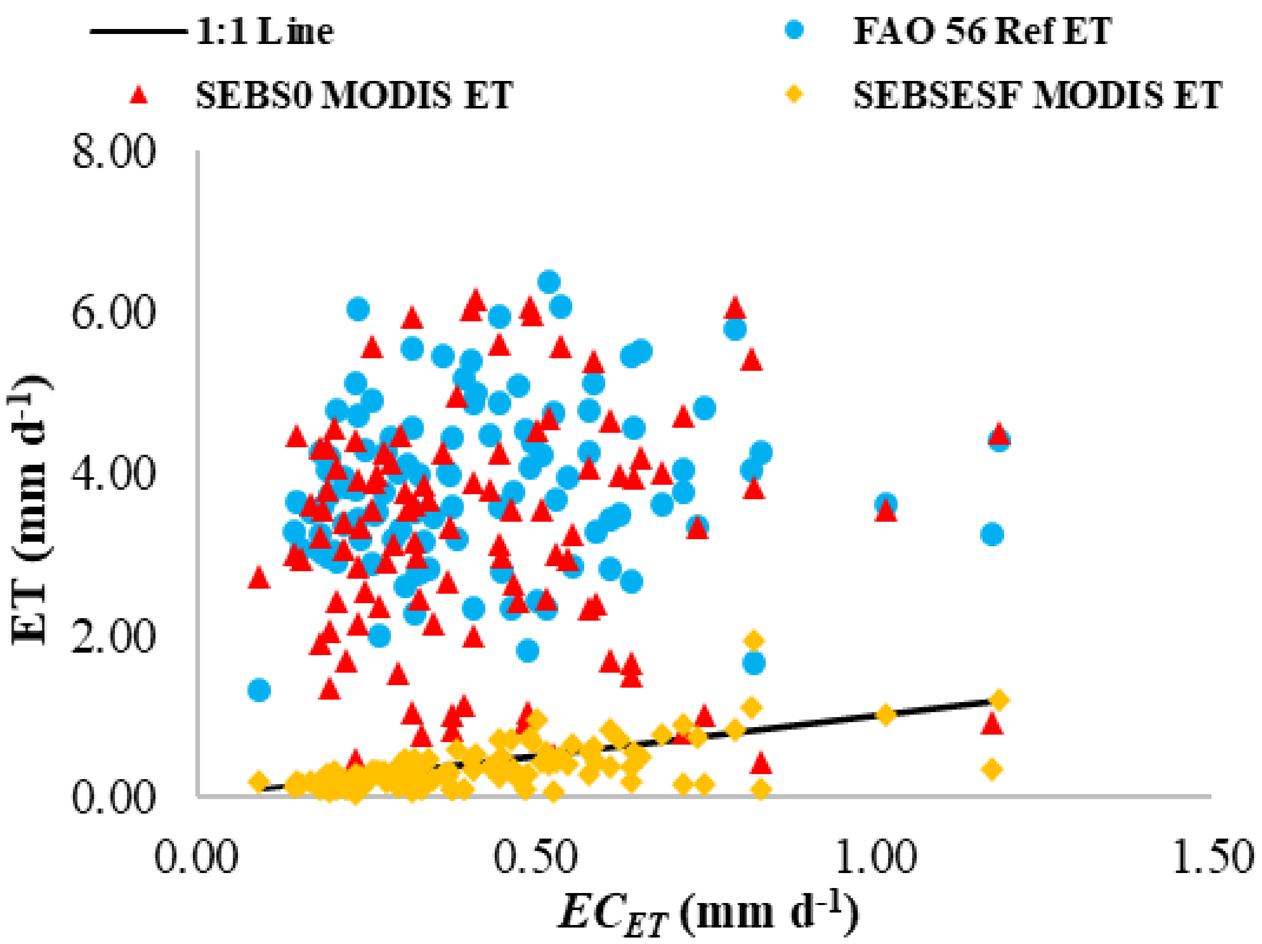


	$SEBS_0$ ET	$SEBS_{ESF}$ ET
RMSE	1.61	0.90
R^2	0.10	0.65
Nash-Sutcliffe	-0.34	0.58
AAR (± 15 %)	23 %	46 %
AAR (± 30 %)	31 %	69 %

- **Improved correlation with EC_{ET}**

RESULTS

Site 2: SEBS ET derived from MODIS Data

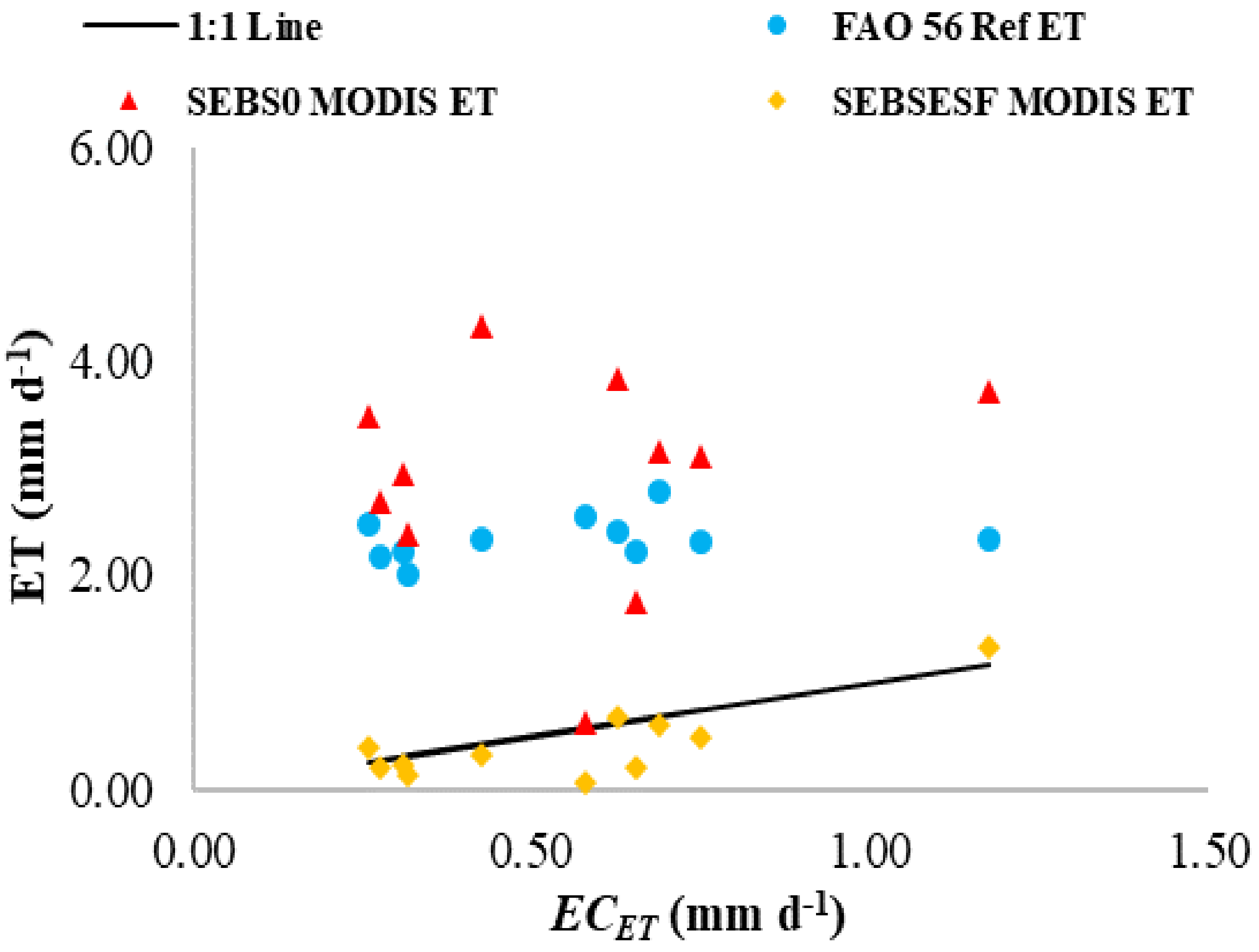


	$SEBS_0$ ET	*$SEBS_{ESF}$* ET
RMSE	2.87	0.15
R^2	0.01	0.38
Nash-Sutcliffe	-219.78	-0.17
AAR (± 15 %)	2 %	34 %
AAR (± 30 %)	3 %	53 %

- **Improved correlation with *EC_{ET}***

RESULTS

Site 2: SEBS ET derived from Landsat Data



	$SEBS_0$ ET	$SEBS_{ESF}$ ET
RMSE	2.56	0.24
R^2	0.01	0.65
Nash-Sutcliffe	-95.02	0.16
AAR (± 15 %)	10 %	27 %
AAR (± 30 %)	10 %	55 %

- **Improved correlation with EC_{ET}**

DISCUSSION AND CONCLUSIONS

Key Findings

- **Significant improvement in the correlation between measured and modelled ET.**

- **Significant decrease in the degree of over-estimation in the modelled ET estimate.**

- **Significant increase in the percentage of estimates within an acceptable accuracy range.**

DISCUSSION AND CONCLUSIONS

Key Findings

- **Improvements to MODIS derived ET estimates were lower than for Landsat derived ET estimates at both sites.**

- **This could be attributed to the spatial resolution of MODIS ET (1 km spatial resolution).**

- **MODIS ET estimates captured ET of land uses outside the footprint of the EC flux tower.**

DISCUSSION AND CONCLUSIONS

Key Findings

- **The performances of the modified version of SEBS is dependent on the adequate derivation of the *ESF.***

- **Therefore careful consideration needs to be taken when determining the potential ET for the study area.**

- **Availability of spatially representative *in-situ* measurements required to derive the ESF.**

- ***$SEBS_{ESF}$* approach is well suited for local mapping of ET, however it may be difficult to implement this approach for the regional mapping of ET.**

DISCUSSION AND CONCLUSIONS

Key Findings

- **Further testing and validation of the *SEBS*$_{ESF}$ approach is recommended in other environmental settings.**

- **Preliminary findings highlight the potential of implementing *SEBS*$_{ESF}$ for the local mapping of ET.**

ACKNOWLEDGEMENTS

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