UISFS 2016 · 50 SEAMEO SEARCA 1966-2016 · ISFA Indonesian SEARCA Fellow Association

ISBN : 978-602-0860-08-4

CONFERENCE PROCEEDINGS

2016

August 23-24, 2016
Bandarlampung, Lampung, Indonesia

UISFS

THE USR INTERNATIONAL SEMINAR ON FOOD SECURITY

"Improving Food Security : The Challenges for Enhancing Resilience to Climate Change"

Volume I

The University of Lampung

Indonesian SEARCA Fellow Association

Southeast Asian Regional Center for Graduate Study and Research in Agriculture

ISBN : 978-602-0860-08-4

USR INTERNATIONAL SEMINAR ON FOOD SECURITY

Improving Food Security : The Challenges for Enhancing Resilience to Climate Change

Emersia Hotel and Resort, Bandar Lampung, Lampung, Indonesia

23 – 24 August 2016
Volume 1

Organized by

Research and Community Service Institution
University of Lampung – Republic of Indonesia,
Indonesian SEARCA Fellow Association,
SEARCA

2016

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Preface
COMMITTEE CHAIR

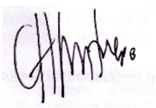
Recently, there are many discussions about food security as a complex issue of sustainable development. One of important topics is will the food needs in the future be met by the current production levels? In addition, the future production faces another sustainable development issues, one of which climate change that affects all four food security dimensions: food availability, food accessibility, food utilization and food systems stability. Improving food security, therefore whilst reconciling demands on the environment conditions which becoming the greatest challenges.

To response that challenges, The University of Lampung collaborated with ISFA (Indonesia SEARCA Fellow Association) and SEAMEO-SEARCA conduct an International Seminar on "Improving Food Security: The Challenges for Enhancing Resilience to Climate Change" in Bandar Lampung, Indonesia on August 23-24, 2016. There are 4 topics are offered as follows: (1.) Food Security and Food Production System, (2.) Food Security, Post Harvest Science and Technology, (3.) Food Security and Socio-Economic Environment Aspect and (4.) Ecological Perspectives on Food Security.

At this seminar, 111 research articles were submitted from 6 countries i.e. Indonesia, Lao, Malaysia, Myamar, Thailand, and Vietnam. The authors are researchers, practitioners included NGO, policy makers, academics as well as industrial professionals. The ultimate aim of this seminar is to deliver state-of-the-art analysis, inspiring visions and innovative methods arising from research in a wide range of disciplines. Through this activity, it is expected that research articles in all aspects related to food security can be documented, rapidly spread, communicated and discussed throughout the countries.

Thank you for your participation and looking forward to having productive discussion among participants.

Sincerely yours,



Christine Wulandari, Ph.D

Preface
The University of Lampung Rector

Many Asian countries face serious challenges on their food security due to changing consumption patterns including the demographics, declining of agriculture productivity, degradation of natural resources, rising input costs as well as cost for transportation of supply chains. All of these, need various trends anticipation of short to medium term, and this is clearly becomes efforts focused on mitigating towards the challenges. Together with SEAMEO-SEARCA and Indonesian Searca Fellows Association (ISFA), the University of Lampung (Unila) collaborated to conduct an international seminar with theme in "Improving Food Security: The Challenges for Enhancing Resilience to Climate Change" on 23-24 August 2016 in Emersia Hotel, Bandarlampung. From this international seminar, 111 research articles from six countries in Southeast Asia were compiled and expected to be used as a stepping stone for preparation of development strategies in Indonesia country or other Asian countries resolving the issues of Food Security.

This cooperation among Unila with ISFA and SEARCA in accordance with the Unila statement mission for Unila goals of 2005-2025, one of which Unila is able to build joint effort in many development aspects within various parties, including governments, publics, businesses, non-governmental organizations either national and overseas, with mutual benefit basis in sustainable frame for natural resources conservation in supporting Food Security. The other Unila goals related to the Food Security is the community welfare, in which Unila become the agent of changes and maintain the certainty and justice for the community benefits.

My very sincere appreciation to invited speakers and participants for their great contributions, to all advisory boards SEAMEO-SEARCA and Indonesian Searca Fellows Association (ISFA), reviewers, colleagues and staffs for putting remarkable efforts and their contribution to the organization of this seminar. Finally, I just hope that this seminar is able to inspire and deliver benefits to all participants, in which together we are able contribute to development of Food Security in our countries as well as to global.

We look forward to working with you and getting to know you in years ahead.

Thank You.

Your sincerely,

Prof. Dr. Hasriadi Mat Akin

Preface
SEARCA DIRECTOR

MESSAGE

The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) is pleased to support the Indonesian SEARCA Fellows Association (ISFA) in organizing this *International Seminar on Improving Food Security: The Challenges for Enhancing Resilience to Climate Change.*

SEARCA's support to this event and many similar others is a testament of our commitment to promote food and nutrition security via the route of Inclusive and Sustainable Agricultural and Rural Development (ISARD). Food and nutrition security continues to be a major problem in the region and in the rest of the world in varying degrees and complexities. This is further exacerbated by the impacts of climate change on agriculture which not only serves as the backbone of the economy but is also key to feeding a growing population that continues to struggle with poverty and hunger.

Addressing multi-faceted concerns such as food security and climate change requires collaborative efforts among various stakeholders across the region. That is why SEARCA has developed umbrella programs on food and nutrition security, and climate change adaptation and mitigation which identifies areas for cooperation in research, capacity building, and knowledge management in these two related concerns.

In all these, we are glad to have the cooperation of SEARCA's graduate alumni spread across the region. They have organized themselves into the Regional SEARCA Fellows Association, with at least 8 country chapters including ISFA. The country associations have conducted various knowledge sharing activities such as this International Seminar and plans are also underway for collaborative research projects in the regional alumni organization. By working in synergy, we have seen how the modest contributions of our graduate alumni can make a big difference to agricultural and rural development in the region – truly making them SEARCA's ambassadors in Southeast Asia and beyond.

I congratulate ISFA headed by Dr. Sugeng Prayitno Harianto for organizing this International Seminar which serves as a platform for knowledge sharing on various researches and development activities that contribute to food and nutrition security amidst the detrimental effects of climate change.

Finally, I also thank all our keynote speakers and delegates for their participation in this event and hope to see all of you again in future knowledge sharing events important to the development of the region.

Gil C. Saguiguit, Jr.
Director

KEYNOTES SPEECH

Dr. Siti Nurbaya Bakar
(Minister of Environment and Forestry, Republic Indonesia)

KEYNOTES SPEAKERS

Dr. Ageng S. Herianto, FAO Representative

Prof. Dr. Wickneswari Ratnam FASc, Universiti Kebangsaan Malaysia

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Prof. Dr. Buhri Arifin, Prince of Songkla University - Thailand

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3. Mean values of variables plant height and number of branches per Plantwith comparative parents 'Wilis', B_{3570}, and Gepak Kuning.

No. Genotype	Plant height				Number of branches per plant			
	Mean	Comparison			Mean	Comparison		
		'Wilis'	B_{3570}	GK		'Wilis'	B_{3570}	GK
142-102-4-6-4	68,61	-	-	-	9,82	-	+	-
142-163-1-1-2	67,25	-	-	-	9,06	-	-	-
142-163-1-1-10	70,79	-	-	-	10,06	-	+	-
142-163-1-16-10	61,00	-	-	-	9,94	-	+	-
142-163-1-1-14	63,99	-	-	-	9,21	-	-	-
142-159-1-16 -17	68,14	-	-	-	10,17	-	+	-
142-159-1-16 -12	58,76	-	-	-	9,87	-	+	-
142-159-1-16 -2	62,99	-	-	-	10,93	+	+	-
142-159-5-1 -6	64,89	-	-	-	10,21	-	+	-
142-159-1-14-1	69,84	-	+	-	10,38	-	+	-
142-159-1-14 -12	62,62	-	-	-	10,05	-	+	-

(+) : higherthan comparator at $\alpha = 5\%$
(-) : lower than comparator at $\alpha = 5\%$

Tabel 4. Mean values of variables number ofpithy pods, the weight of seeds per plant, and 100 seeds weightwith comparative parents 'Wilis', B_{3570}, and Gepak Kuning.

No. Genotype	Number of pods pithy				The weight of seeds per plant(g)				100 seeds weight(g)			
	Mean	Comparison			Mean	Comparison			Mean	Comparison		
		'Wilis'	B_{3570}	GK		'Wilis'	B_{3570}	GK		'Wilis'	B_{3570}	GK
142-102-4-6-4	14,74	+	+	-	65,18	+	+	+	14,13	-	-	+
142-163-1-1-2	13,59	-	-	-	56,77	-	-	-	14,38	-	-	+
142-163-1-1-10	14,65	+	+	-	61,99	+	+	-	13,58	-	-	+
142-163-1-16-10	14,56	+	+	-	64,16	+	+	+	14,57	-	-	+
142-163-1-1-14	14,92	+	+	-	62,87	+	+	-	13,54	-	-	+
142-159-1-16 -17	14,34	+	+	-	63,51	+	+	+	14,36	-	-	+
142-159-1-16 -12	13,94	-	-	-	58,33	+	-	-	14,28	-	-	+
142-159-1-16 -2	14,59	+	+	-	64,21	+	+	+	14,47	-	-	+
142-159-5-1 -6	14,77	+	+	-	65,69	+	+	+	14,59	-	-	+
142-159-1-14-1	13,98	-	-	-	64,66	+	+	+	16,23	+	+	+
142-159-1-14 -12	14,94	+	+	-	65,67	+	+	+	14,58	-	-	+

(+) : higher than comparator at $\alpha = 5\%$
(-) : lower than comparator at $\alpha = 5\%$

COMPARISON OF DIFFERENT MODELS IN ESTIMATING STANDARD EVAPOTRANSPIRATION IN LAMPUNG PROVINCE, INDONESIA

PURBA SANJAYA, TUMIAR K MANIK AND BUSTOMI ROSADI

ABSTRACT

Evapotranspiration (ET) is the loss of water to the atmosphere by the combined processes of evaporation from soil surfaces and transpiration from plants.Since various factors affect ET, including weather parameters; numerousequations have been developed to quantify standard ET. The equations vary in data requirements from very simple, empirically based or simplified equations to complex, more physically based equations. This study used six methods in estimating standard evapotranspiration using data from September 2011–Agustus 2012from Climate Station at Masgar (05°10'20" S, 105°10' 49"E, 50 m.a.s.l.) Lampung, Indonesia. The six models are: Hargreaves-Samani 1985 (H/S), FAO 24 *Radiation* (24RD), FAO 24 Blaney-Criddle (24BC), FAO 24 *Pan Evaporation* (24PAN), Linacre (Lina), andMakkink (Makk). The results were analyzed using statistics methods in error indicators, which are: *Root Mean Square Error*(RMSE), *Mean Absolute Error* (MAE), and *LogaritmicRoot Mean Square Error*(LOG RMSE), while the closeness among the models was analyzed using *Index Agreement* (I.A.). Direct measurement had also been done with measuring the water content inside lysimeters.The study concluded that Makkink model is the suitable simple model that should be chosen in Lampung lowland area to calculate $ET_o$when climate data is limited, besides the recommended FAO 56 Penman Monteith.

Keyword: Evapotranspiration, Standard Evapotranspiration, FAO 56 PM, Makkink Model

INTRODUCTION

Agriculture production in dry area is often limited by water availability. Two strategies to solvethe limited water availability areadjustingcrops planting dateto rainfall distribution and toirrigation schedule. Both strategies were based on crops water requirementestimated by evapotranspiration.

Evapotranspiration (ET) is the loss of water to the atmosphere by the combined processes of evaporation from soil and plant surfaces and transpiration from plants. Many factors affect ET, including weather parameters such as solar radiation, air temperature, humidity,and wind speed; crop factors such as crop type, variety, density, and the stage of growth; and management and environmentalconditions such as soil conditions, salinity, fertility, crop disease, and pests (Allen *et al*. 1998). Therefore, an idea of reference (standar) evapotranspiration was developed.

Estimation of the evapotranspiration has been done since Penman (1948) derived the evapotranspiration formula based on the Dalton mass transfer equation and the energy balance equation. The effort started with estimating the reference evapotranspiration (ET_0) Reference ET is defined as ‘‘the rate of evapotranspiration from an extensive area of 0.08–0.15 m high, uniform, actively growing, green grass that completely shades the soil and is provided with unlimited water and nutrients’’ (Allen,*et al*., 1994 in Bakhtiari *et al*., 2011). More recently, Allen,*et al*. (1998) elaborated on the concept of ET_0, referring to an ideal 0.12 m high crop with a fixed surface resistance of 70 s m^{-1} and an albedo of 0.23.The surface condition should be met so that reference evapotranspiration only considered weather factors that influenced evapotranspiration rate.

Numerousequations have been developed to quantify potential evapotranspiration(PET). The equations vary in data requirements from very simple,empirically based or simplified equations requiring only monthly average air temperatures e.g., Thornthwaite (1948) and Blaney and Criddle (1950)andto complex, more physically based equationsrequiring, daily data for air temperatures, solar radiation, wind speed, and relative humidity e.g., FAO56-PM (Allen *et al*.,1998), as well as characteristics of the canopy surface e.g., Penman-Monteith (Monteith, 1965).

Actual ET for a specificcrop is called crop evapotraspiration (ETc). Since water availability is essential in agriculture production especially in dry areas, accurate and consistent estimates of crop evapotranspiration(ETc) in agriculture activities are important. The most common procedure for estimating ETc is to adjustthe reference evapotranspiration (ET_0) values with the crop coefficient (Kc); which$ETc=ET_0*Kc$. The Kc represents the integrated effectof changes in leaf area, plant height, irrigation method, rateof cropdevelopment, crop planting date, leaf area, canopy resistance,albedo, soil, climateconditions, and managementpractices (Doorenbos and Pruitt, 1977 in Irmak,*et al*., 2006).

The first step to calculate crops coeficient is by estimating the reference evapotranspiration. Reference evapotranspirationcan be measured directly by lysimeters; however, establishing and maintaining lysimeters for a long time period is costly, make it physically and economically impossible to measure evapotranspiration in every area of interest. Also, for a given vegetation type, potential evapotranspiration is a climatic parameter; so it can becomputed from weather data. Therefore, potential evapotranspiration could be estimated by theoretical orempirical equations, or derived simply by multiplying standardpan evaporation data by a coefficient.Equationsthat developed by Penman Monteith is the one recommended by FAO. However, since this equation needs various climate data, it is necessary to evaluate other available equations in case that the data is not available.

Lampung Province (103° 40' – 105° 50' E; and between: 6° 45' – 3° 45' S;35.288,35 km^2) is located at Southeast tip of Sumatra. Lampung climate is characterized by monsoonal rain distribution and local characteristics. Rain season in general is from October to March with the peak on January/February and dry season is from April to September. Monthly rainfall ranges from 50 – 200 mm and annual rainfall ranges from 1200 mm(lowland area) to 2500 mm (highland area). Lampung economic is dominated by agriculture products mainly coffee, chocolate, rubber and sugarcane. Lampung is also considered as main area for cash crops such as paddy, soybean and maize. Therefore, finding good and reliable method in estimating crops water requirement is necessary for better agriculture management.

The objective of this research were to compare different methods in estimating standard evapotranspiration for calculating crops evapotranspiration in Lampung area, Indonesia.

METHODS

This study used six methods in evaluating potentialevapotranspirationusing data from September 2011 to Agustus 2012from Climate Station at Masgar (05°10'20" S, 105°10' 49"E, 50 m.a.s.l.) Lampung, Indonesia.The six models are: Hargreaves-Samani 1985 (H/S), FAO 24 *Radiation* (24RD), FAO 24 Blaney-Criddle (24BC), FAO 24 *Pan Evaporation* (24PAN), Linacre (Lina), andMakkink (Makk). The results from those models were compared to FAO Penman-Monteith (56PM) as the standard model.To evaluate the relation betweenmodels, the results were analyzed using statistics methods in error indicators, which are: *RootMean Square Error*(RMSE), *Mean Absolute Error*(MAE), and*LogaritmicRoot Mean Square Error*(LOG RMSE), while the closeness among the models was analyzed using

Index Agreement (I.A.).Potential evapotranspiration was also observed in this study; using a lysimeter (3x2x1 m),a certain grass (*Sporabulusdiander*) which is the same type as timothy grass was planted on the common lysimeter. Since the lysimeter was maintained to have adequate soil water content, the evapotranspiration was evaluated by measuring the difference of soil water content every day. The measurements were done for 30 days using sensors called Kett gypsum block.

DESCRIPTION OF MODELS

1. Hargreaves-Samani 1985 (H/S) (Hargreaves and Samani, 1985)

The equation of this model is:

$$ET_o = 0.0023(T_{mean} + 17.8)(T_{max} - T_{min})^{0.5} R_a \quad (1)$$

WithET$_o$is standard evapotranspiration (mm/day), T_{mean} is daily mean temperature (^{o}C),$T_{max}$is maximum temperature(^{o}C), $T_{min}$is minimum temperature, andR$_a$ Dailyextraterrestrial radiationof the atmosfer (MJ/m^2/day).

2. FAO 24 *Radiation* (24RD) (Doorenbos and Pruitt, 1977)

The equation of this model is:

$$ET_o = K_p \times E_{pan} \dots \dots (2)$$

$$K_p = 0.108 - 0.028u_2 + 0.0422\ln(FET) + 0.1434\ln(RH_{mean}) - 0.000631[\ln(FET)]^2 \ln(RH_{mean}) \dots\dots (3)$$

WithET$_o$isstandard evapotranspiration (mm/day), $K_p$ispan evaporation coefficient, E_{pan}isClass A pan evaporation (mm/day), $u_2$ismeanwind speed at 2m high (m/s), $RH_{mean}$is relative humidity (%), and FET is distance between pan and crops (m).

ISBN 978-602-0860-08-4

3. FAO 24 Blaney-Criddle (24BC) (Jensen, *et al*., 1990)

The equation for this model is:

$$ET_o = a + bf \; \ldots \ldots (4)$$

$$f = p(0.46T + 8.13) \ldots \ldots (5)$$

$$a = 0.004RH_{min} - \frac{n}{N} - 1.41 \ldots \ldots (6)$$

$$b = 0.908 - 0.00483RH_{min} + 0.7949\frac{n}{N} + 0.768[ln(U_d + 1]^2$$

$$-0.0038RH_{min}\frac{n}{N} - 0.000443RH_{min}U_d + 0.281\left[ln(\frac{n}{N} + 1)\right] \ldots \ldots (7)$$

$$-0.0097[ln(U_d + 1][ln(RH_{min} + 1]^2\left[ln(\frac{n}{N} + 1)\right]$$

WithET$_o$ is standard evapotranspiration (mm/day), P is percentage of day length, T is daily average temperature (˚C), RH is minimum relative humidity (%), n/N is ratio of possible actual day, and U_d is wind speed at 2 m (m/s)

4. FAO 24 *Pan Evaporation* (24PAN)(Doorenbos and Pruitt, 1977)

The equation of this model is

$$ET_o = K_p \times E_{pan} \ldots \ldots (8)$$

$$K_p = 0.108 - 0.028u_2 + 0.0422\ln(FET) + 0.1434\ln(RH_{mean}) - 0.000631[\ln(FET)]^2\ln(RH_{mean}) \ldots \ldots (9)$$

ET$_o$is standard evapotranspiration (mm/day), K_p is pan coefficient, $E_{pan}$is class A Pan evaporation (mm/day), $u_2$is average wind speedat 2m high (m/s), RH_{mean}relative humidity (%), andFET is distance between pan and green crops (m).

5. Linacre (LINA)(Linacre, 1977)

The equation of this model is:

$$ET_o = \frac{\left(\frac{500\,T_m}{100 - A}\right) + 15(T - T_d)}{(80 - T)} \ldots \ldots (10)$$

$$T_m = T + 0.006h \ldots\ldots (11)$$

ET_o is standard evapotranspiration (mm/day), T is mean temperature (°C), A is latitude of the climate station (°), T_m is elevation of climate station (m), and T_d is average dew point temperature (°C). T_d equation is:

$$T_d = \left(\frac{f}{100}\right)^{\frac{1}{8}}(112 + 0.9T) + 0.1T - 112 \ldots\ldots (12)$$

T_d is average dew point temperature (°C), T is mean temperature (°C), and f is average daily relative humidity (%).

6. Makkink (Makk) (Makkink, 1957).

The equation of this model is:

$$ET_o = 0.61 \frac{\Delta}{\Delta + \gamma} \frac{R_s}{2.45} - 0.12 \ldots\ldots (13)$$

Which R_s is solar radiation (MJ/m^2/day), Δ is vapor pressure curve (kPa/°C), and γ is psychrometricconstant (kPa/°C).

7. FAO 56 PM (56PM) (Allen, *et al.*, 1998)

The equation of this model is

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34\, U_2)} \ldots\ldots (14)$$

ET_0 is standard evapotranspiration (mm/day), R_n is net radiation on crops surface (MJ/m^2/day), G is continuous heat flux to soil depth (MJ/m^2/day), T is dailytemperature(°C), U_2 is wind speed at 2 m (m/s), e_s is vapor pressure (kPa), e_a is actual vapor pressure (kPa), Δ is vapor pressure curve (kPa/°C), and γ is psychrometric constant (kPa/°C).

In this study the ET_0 estimation fromFAO 56 Penman-Monteith model as the standard model was calculated using CROPWAT.CROPWAT isa computer program recommended by

FAObased onFAO 56 Penman-Monteithmodel (Allen,*et al*., 1998). Climate Parameters are needed by each model is presented in Table 1.

Indicators

The error indicators equation used to evaluate the model is:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(ET_{osi} - ET_{omi})^2} \dots \dots (22)$$

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|ET_{osi} - ET_{omi}| \dots \dots (23)$$

$$LOG = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\log ET_{osi} - \log ET_{omi})^2} \dots \dots (24)$$

$$I.A = 1 - \frac{\Sigma(ET_{osi} - ET_{omi})^2}{\Sigma[|ET_{osi}'| + \|ET_{omi}'\|]^2} \dots \dots (25)$$

$$ET'_{osi} = ET_{osi} - \overline{ET_{omi}} \dots \dots (26)$$

$$ET'_{omi} = ET_{omi} - \overline{ET_{omi}} \dots \dots (27)$$

With$ET_{osi}$is Penman-Monteith standard evapotranspirationas the standard model, and$ET_{omi}$is others evapotranspirationmodels.

Table1. Climate parameters needed by each estimation model

No	Model	Climate data needed by each model							
		E_{pan}	T	R_s	R_n	RH	P	U_2	R_a
1	56PM		√	√	√	√	√	√	√
2	24BC		√			√	√	√	
3	H/S		√						√

4	Makk		√	√					
5	24RD		√	√		√		√	
6	24PAN	√				√		√	

RESULTS AND DISCUSSIONS

The first error indicator (RMSE) is presented in Table2. Based on the comparison among the six models, the error indicator RMSE ranged from 0.32-1.99 which means that ET_0 difference among the models was 0.32 mm to 1.99 mm/day. This is not a small number since 1 mm/day ET in 1 ha area is equivalent with water loss of 10,000 liter/day or 3.6 million liter/year.

Tabel.2. RMSE value among the estimating models of ET_0

	RMSE						
	56PM	Makk	24BC	24PAN	24RD	H/S	LINA
56PM	0	0,34	1,30	0,75	0,69	1,35	0,88
Makk	0,34	0	1,61	0,48	0,49	1,52	1,12
24BC	1,30	1,61	0	1,99	1,92	1,12	0,79
24PAN	0,75	0,48	1,99	0	0,33	1,93	1,54
24RD	0,69	0,49	1,92	0,33	0	1,98	1,54
H/S	1,35	1,52	1,12	1,93	1,98	0	0,59
LINA	0,88	1,12	0,79	1,54	1,54	0,59	0

Using Lampung climate data, the lowest RMSE was found betweenFAO 24 *Radiation*andFAO 24 *Pan Evaporation*while the highest RMSE was found between model FAO 24 *Pan Evaporation*andFAO 24 Blaney-Criddle. For Lampung, estimation ET model with the closest estimation to FAO 56 Penman-Monteith is Makkink model with RMSE value 0.34.

The second error indicator (MAE) is presented in Table 3. Similar results with RMSE were found in error indicators bothMAE and log RMSE (Table 4). Makkinkmodel was the model which is closest to FAO 56 Penman-Monteith.

Table.3. MAEvalue among the estimating models of ET_0

MAE							
	56PM	Makk	24BC	24PAN	24RD	H/S	LINA
56PM	0	0,28	1,06	0,62	0,67	1,28	0,86
Makk	0,28	0	1,28	0,40	0,45	1,50	1,08
24BC	1,06	1,28	0	1,69	1,74	0,95	0,68
24PAN	0,62	0,40	1,69	0	0,25	1,90	1,48
24RD	0,67	0,45	1,74	0,25	0	1,95	1,53
H/S	1,28	1,50	0,95	1,90	1,95	0	0,47
LINA	0,86	1,08	0,68	1,48	1,53	0,47	0

Tabel.4.LOG RMSE among the estimating models of ET_0

LOG RMSE							
	56PM	Makk	24BC	24PAN	24RD	H/S	LINA
56PM	0	0,04	0,13	0,11	0,10	0,14	0,10
Makk	0,04	0	0,17	0,08	0,07	0,16	0,13
24BC	0,13	0,17	0	0,23	0,22	0,11	0,08
24PAN	0,11	0,08	0,23	0	0,06	0,23	0,20
24RD	0,10	0,07	0,22	0,06	0	0,23	0,19
H/S	0,14	0,16	0,11	0,23	0,23	0	0,06
LINA	0,10	0,13	0,08	0,20	0,19	0,06	0

MAE between FAO 56 Penman-Monteith and other modelsranges from 0.28 mm/day (Makkink) to 1.28 mm/day (Hargreaves-Samani 1985) and LOG RMSE ranges from 0.04 mm/day (Makkink) to 0.11mm/day (FAO 24Blanney-Criddle).

 ISBN 978-602-0860-08-4

Table 5 shows the results of Index of Agreement (I.A.). Consistently, Makkink model gave the best results with I.A. 0.77 followed by Linarch (0.42) and FAO Pan evaporation (0.42)

Tabel.5.Index of Agreement among the models

I.A							
	PM	MK	BC	Pan	24 RD	HS	Linarch
PM	1	0,78	0,09	0,42	0,55	0,26	0,42
MK	0,78	1	-0,35	0,80	0,81	0,10	0,10
BC	0,09	-0,35	1	-0,40	-0,22	0,79	0,85
Pan	0,42	0,80	-0,40	1	0,95	-0,03	-0,08
24 RD	0,55	0,81	-0,22	0,95	1	-0,03	-0,01
HS	0,26	0,10	0,79	-0,03	-0,03	1	0,93
Ln	0,42	0,10	0,85	-0,08	-0,01	0,93	1

From those results, it can be concluded that Makkink model is the suitable simple model that should be chosen in Lampung to calculate ET_o besides the recommended one FAO 56 Penman Monteith, especially when the climate data is limited.

So far the estimating model that broadly used is FAO 24 PAN which is based on observation on class A evaporation pan. This model did not give a good estimation compared to the FAO 56 PM model (RMSE 0.75; MAE 0.62; Log RMSE 0.11 and I.A. 0.42). In comparing 24 PAN model to 56PM, using 3 years data in 2 stations in Lampung, Manik*et.al.*(2012) found that the coefficient correlation between those two models are low (r=0.3 for Branti Station and 0.5 for Masgar station).

Monthly average ET_0 results from each model in 1 year is presented in Figure 1. Most of the models had the similar trends with FAO 56 PM but with different closeness. Some models underestimated FAO 56 PM (Makk, FAO 24 RD and FAO 24 PAN) while some overestimated (24 BC, H/S and Lina). Makkink(Makk) model was closely similar with FAO

56 PM in month of January-March, October -December) and a little underestimated in March – October (dry season).

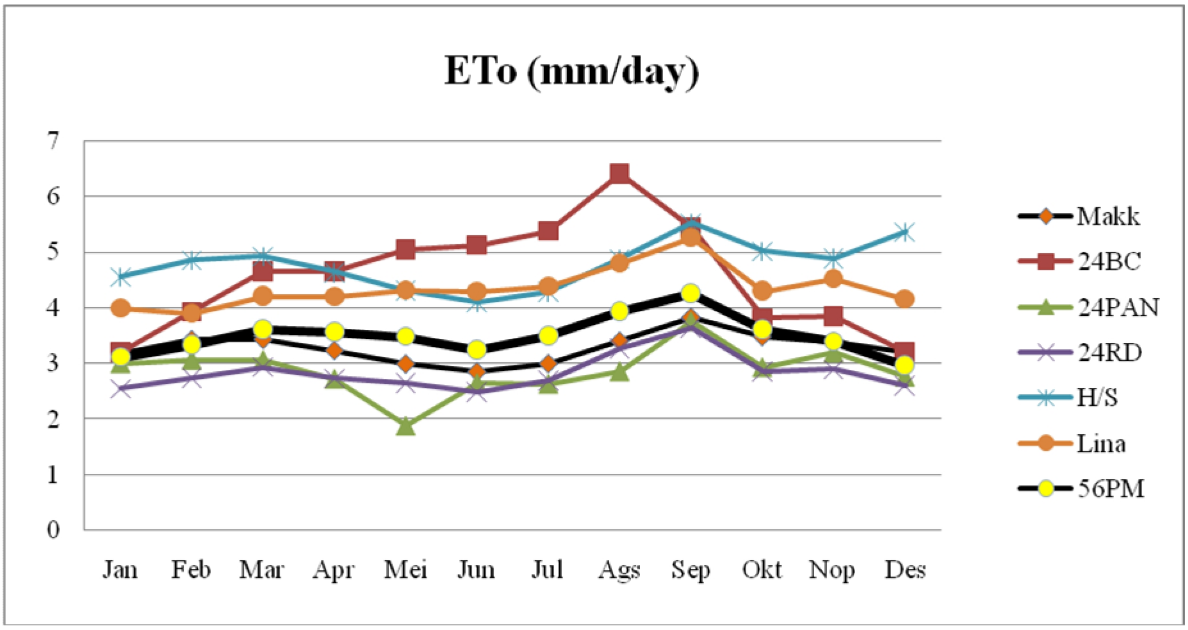

Figure 1. Monthly average of ET_o results from each model in 1 year

Research about comparing different models has been done in some countries. *Chen et al* (2005) used 7 estimating models in four provinces of Taiwan and found that Makkink and Hargreaves-Samani models were the best models in estimating ET_o when compared to FAO 56 PM. Chowhury,*et al* (2010) also found that in India, Makkinkmodel had the closest estimation to FAO 56 PM with a little underestimated result.

Makkink model (equation no. 13) is the simplest model among others in this study, the model is calculated use only two basic data, maximum and minimum temperature data. Psychrometricconstantis 66,1 kPa/°C, R_s and Δ are calculated by these equations below.

$$R_s = \sqrt{(T_{max} - T_{min})} R_a \dots\dots (28)$$

$$\Delta = \frac{4098\left[0,6108\, exp\left(\frac{17,27\, T}{T+237,3}\right)\right]}{(T+237,3)^2} \dots\dots (29)$$

Which Rs is solar radiation (MJ/m2/day), Δ is vapor pressure curve (kPa/ºC), and Ra is daily extraterrestrial radiation of the atmosfer (MJ/m2/day) from FAO Irrigation and drainage paper 56meteorological data table (Allen,*et al*., 1998).

Xu and Chen (2005) did similar study in Germany with comparing 7 models and found that Granger-Gray and Makkink models were the best models for the area. In North China Schneider,*et al*. (2007) compared 4 models with direct observation and concluded that Hargreaves-Samani and Makkink models were the best models in estimating ET_o even better than FAO 56 PM.

Jacobs,*et*al (2004) conducted research on estimating ET_0 in Florida, using remote sensing method with data from GOES. The results showed that FAO 56 PM is the best model with R^2= 0.92 however this result is not much different with estimated results from Makkink model which gave R^2= 0.90.

The results for direct measurement inside lysimeters(Table 6.) show that evapotranspiration rate predicted by models were higher than measured by gypsum block. Potential evapotranspiration calculated by models show the atmosphere power in evaporating water on soil surface; the rate should be higher since in Tropical area because the radiation is intense and air temperature generally high. Soil moisture reflects the balance of precipitation, runoff, ET and exhibited various types of pulse events (*Wang,et al*., 2012). Because of soil water movement, on soil surface water availability could be limited even when it kept being watered because the water percolates to the deeper level but it also could be moist even when no water added to it since water could be moves up to the surface . When atmosphere power to evaporate water is higher than soil moisture, it could be concluded that during the observation the soil surface was not wet enough to meet atmosphere needs.

Table 6. Actual Evapotranspiration observed by soil water content method and compared to potential evapotranspiration by FAO 56 and Makkink models

Day of Observation	Soil Tension (kΩ)	Volumetric Soil water content(%)	Δ S (%)	Cummulative Water loss (mm)	ET (mm)	ET FAO 56 (mm)	ET Makkink (mm)
1	122	43.963			0.000	2.67	3.11
2	113	45.044	2.701	2.701	0.000	4.04	3.64
3	131	42.960	-5.210	-2.509	5.210	2.52	2.85
4	143.33	41.691	-3.171	-5.680	3.171	4.34	3.63
5	146.67	41.367	-0.812	-6.492	0.812	4.94	3.54
6	157.33	40.377	-2.473	-8.965	2.473	4.4	3.44
7	160	40.140	-0.593	-9.558	0.593	2.17	3.25
8	154	40.679	1.347	-8.211	0.000	4.49	3.48
9	153.67	40.709	0.076	-8.135	0.000	2.41	2.76
10	152.67	40.801	0.230	-7.905	0.000	3.94	3.56
11	148.33	41.208	1.017	-6.889	0.000	3.78	3.26
12	169	39.368	-4.599	-11.487	4.599	4.59	3.44
13	171	39.203	-0.415	-11.902	0.415	2.98	3.02
14	168.33	39.424	0.555	-11.347	0.000	3.09	3.43
15	179	38.558	-2.166	-13.514	2.166	2.72	2.9
16	176.67	38.743	0.462	-13.052	0.000	3.73	3.19
17	188.33	37.841	-2.253	-15.305	2.253	3.18	2.58
18	203.33	36.761	-2.701	-18.006	2.701	2.93	2.97
19	236.67	34.620	-5.352	-23.358	5.352	3.19	2.87
20	280	32.249	-5.926	-29.285	5.926	3.57	3.13
21	246.67	34.036	4.468	-24.817	0.000	4.5	2.8
22	249	33.904	-0.331	-25.148	0.331	4.14	3.61
23	251.67	33.754	-0.376	-25.524	0.376	2.32	2.78
			Total ET (mm)		36.380	77.970	70.130
			Average ET (mm)		2.599	3.506	3.184

This study concluded that Makkink model is a simple model that can be chosen in Lampung as an alternative to calculate standard evapotranspiration in an area with limited climate data needed to apply FAO 56 PM. During the study, water availability on soil surface was not enough to meet atmosphere need; this condition could limit crops growth.

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