VALIDATION OF INPUT DATA TO SUT-SEBAL ALGORITHM AND SENSIVITY ANALYSIS OF THE RESULTS WITH RESPECT TO THE MODIFIED INPUT PARAMETERS

EXAMINER ET VALIDER LES DONNEES D'ENTREE DE L'ALGORITHME SUT-SEBAL ET ANALYSE DE SENSIBILITE DES RESULTATS CONCERNANT LA MODIFICATION DES PARAMETRES D'ENTREE

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ABSTRACT

SEBAL Algorithm (Surface Energy Balance Algorithm for Land) is a thermodynamics-based model, which is applied for estimating evapotranspiration (ET) in large areas faced with lack of field data, by using remote sensing data. In this study SUT-SEBAL algorithm, which has been developed by changing some of the relations defined in SEBAL algorithm at Sharif University of Technology, is used for estimating ET in Varamin plain. The input data layers of SUT-SEBAL are validated and then the sensitivity analysis of the results is done. In the SUT-SEBAL algorithm, air temperature, surface temperature and dew point temperature are important parameters which affect the results. So, the validation of the spatial distribution layer of these parameters is necessary. In this study air temperature is estimated using available field data and different methods like Kriging or Distance Weighting methods (normal and inverse). Then the regression equation is obtained and fitted to the daily air temperature data and the height of the corresponding stations. Then the equations are applied to the DEM (Digital Elevation Model) to produce the temperature layer. Validation and evaluation of the produced layer is done using cross-validation analysis which is a suitable tool for reviewing effective parameters in each study. The results show that the use of the regression equation will lead to better results. Then the distribution layer of the dew point and surface temperature, which is produced using remote sensing techniques, is validated and adjusted by using field data. Regarding the results, it can be concluded

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that the remote sensing model overestimates the surface temperature and needs to be corrected. It is also to be mentioned that the estimated dew point temperature needs to be adjusted. So, the results are adjusted using the regression equation between the model results and the field data. Finally, the sensitivity analysis of the parameters, which are used in SUT-SEBAL algorithm, shows that air temperature, dew point temperature and surface temperature are the most effective parameters and sunshine is the least effective one due to the limited variation.

Key words: *Evapotranspiration estimation, SUT-SEBAL algorithm, sensitivity analysis, energy balance.*

RESUME

L'Algorithme SEBAL (Algorithme du Bilan d'énergie de surface de la terre) est un modèle à base thermodynamique, qui est appliqué en utilisant les données de télédétection pour évaluer l'évapotranspiration (ET) des grands secteurs affrontés par le manque de données des champs. Dans cette étude, l'algorithme SUT-SEBAL est développé à l'Université Sharif de Technologie en changeant certaines relations définies dans l'algorithme SEBAL, et utilisé pour l'évaluation ET dans la plaine de Varamin. Les couches de données d'entrée de SUT-SEBAL sont validées et ensuite est faite l'analyse de la sensibilité des résultats. Dans l'algorithme SUT-SEBAL, la température de l'air, la température de la surface et la température du point de rosée sont les paramètres importants qui affectent les résultats. Ainsi, il est nécessaire de valider la couche de distribution spatiale de ces paramètres.

Dans cette étude, la température de l'air est évaluée utilisant les données disponibles des champs et les différentes méthodes telles que Kriging ou Coefficient de Distance (normal et inverse). Alors, l'équation de régression est obtenue et adaptée aux données de température de l'air quotidiennes et la hauteur des stations concernées. Les équations sont appliquées au DEM (Modèle d'Elévation Numérique) pour réaliser la couche de température. La validation et l'évaluation de la couche sont faites utilisant l'analyse qui est un outil approprié pour passer en revue les paramètres efficaces dans chaque étude. Les résultats montrent que l'utilisation de l'équation de régression mènera à de meilleurs résultats. Ensuite, la couche de distribution de la température du point de rosée et de la température de surface produite par les techniques de télédétection, est validée et ajustée en utilisant des données des champs.

Concernant les résultats, il est conclu que le modèle de télédétection évalue excessivement la température de surface qui doit être corrigée, et que la température du point de rosée doit être ajustée. Ainsi, les résultats sont ajustés utilisant l'équation de régression dans les résultats des modèles et les données des champs. Finalement, l'analyse de sensibilité des paramètres utilisée dans l'algorithme SUT-SEBAL, montre que la température de l'air, la température du point de rosée et la température de surface sont les paramètres les plus efficaces et le soleil est moins efficace en raison de la variation limitée.

Mots clés: *Evaluation d'évapotranspiration, algorithme SUT-SEBAL, analyse de sensibilité, Bilan d'énergie.*

1. INTRODUCTION

Water management experiences from the around the world has shown that in most cases plans for the development of water resources without assessing the current situation, could not be implemented or may have undesirable effects. Satellite images are appropriate tools to provide required data with the lowest cost. These images show changes in water use and land cover in different times and places.

SEBAL Algorithm (Surface Energy Balance Algorithm for Land) is one of the remote sensing techniques which is a thermodynamics-based model. It can be used for estimating evapotranspiration (ET) for large areas where all the relevant data may not be available. SEBAL Algorithm is developed by Bastiaanssen in 1995 and was applied in different studies in Spain, Italy, Turkey, Pakistan, India, Egypt, and China to estimate the rate of the ET (Bastiaanssen et al, 1998a and 1998b).

In this study SUT-SEBAL algorithm, which has been developed by changing some of the relations defined in SEBAL algorithm at Sharif University of Technology, is used for estimating ET in Varamin plain. SUT-SEBAL is applied successfully in Sistan and Gharesoo subbasin by EWRC Office (Arasteh, 2004; Emadzadeh, Maryam, 2008). In this paper, preparation and validation of information layers, which are required for the estimating ET, are examined. Finally, after processing the satellite images, sensitivity analysis of the parameters is performed.

2. STUDY AREA

The approximately 1200 km^2 Varamin plain at an average altitude of 950 m amsl is located in south- east of Tehran. This area is cold in winter and dry and hot in summer with desert climate. Varamin is one of the agricultural products suppliers not only for Tehran but also for other parts of the country from many years ago. Wheat and barley constitute half of the cultivation in Varamin and they are cultivated during the whole year. Groundwater resource of Varamin plain is available from unconfined aquifers. Jajrood and Shoor rivers constitute Surface water resources, which provide 40% of agricultural water demand in Varamin. Figure 1 shows the location of Varamin plain in Iran and Tehran (Tehran Regional Water Company, 1996).

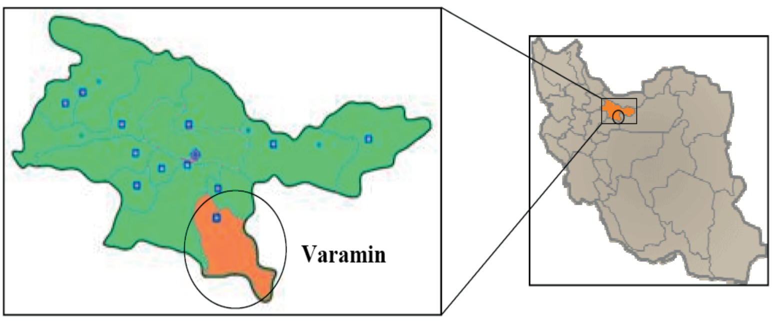

Fig. 1. Location of Varamin plain in Iran and Tehran (la localisation de plaine de Varamin en Iran et Teheran)

3. DATA AND METHODS

Net energy reaching earth's surface is used for heating the land and its surrounding air, plants' ET and evaporation from the soil surface. This physical process is the basis of the SUT-SEBAL algorithm which is shown in Figure 2. According to this process net solar radiation is the source of the energy and H, G and ET are the energy users.

$$\lambda ET = R_n - G - H \quad (1)$$

where, λET is the latent heat of ET (energy used for ET), Rn is the net radiation at the surface of the earth, G is the ground heat flow and H is the sensible heat flow.

Energy balance algorithm is an image processing model which estimates actual ET (ET_{act}) and other energy exchanges at the land surface, using digital data collected by satellite sensors. In this method ET, one of the components of the energy balance, is computed at each pixel of the satellite image. Additional information about SEBAL and SUT-SEBAL algorithm is available in other references (Arasteh, 2004; Bastiaanssen et al, 1998a and 1998b).

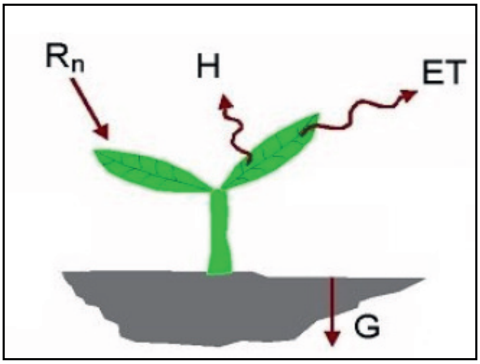

Fig. 2. Energy balance components at ground level (les composantes de la balance de l'énergie au niveau du sol)

Air temperature, dew point temperature, wind speed, and sunshine are the required information layers for SU-TSEBAL algorithm. In this paper remote sensing models are used for estimating air temperature and dew point temperature layers. Other required information layers are produced using interpolation methods and field data measurements.

Surface temperature layer is produced using split windows method, which uses the brightness temperature of 4th an 5th channels of AVHRR sensor (Prabhakara et al, 1974). Split windows method is based on the fact that the atmosphere shows different reactions at different wavelengths. General equation of this method is.

$$T_s = c_{4^\wedge 2}.BT4^2 + c_4.BT4 + c_{45}.BT5.BT5 + c_5.BT5 + c_{5^\wedge 2}.BT5^2 + offset \quad (2)$$

Where, T_s is surface temperature (°K), and BT4 and BT5 are the brightness temperature of 4th and 5th channels of the satellite images, respectively (°K).

Dew point temperature, as a measure of the surface humidity, is determined based on the empirical equation – 3, presented by Smith (1966).

$$T_{dp} = 25.4453[\ln(\lambda + 1) + \ln(U) - 0.1133] \quad (3)$$

Where, T_{dp} is dew point temperature (˚F), U is the amount of actual precipitable water in the atmospheric column, and λ is a constant, related to the latitude. Actual precipitable water, U, can be determined using equation 4:

$$U = 17.32\left(\frac{T_{B4}-T_{B5}-0.6831}{T_S-291.97}\right) + 0.5456 \quad (4)$$

Where, T_{B4} and T_{B5} are the brightness temperature of 4th and 5th channels of the satellite images respectively (˚K).

Data collected from nine synoptic stations in the study area (Mamazan, Garmsar, Firooz Kooh, Firooz Kooh Aloodegi, Abali, Mehrabad, Dooshan, Karaj and Chitgar) are used for producing temperature layer. The results of the four different interpolation methods are compared using validating parameters for selecting the best method.

In this study satellite images of Varamin plain during 2006-2007 water year with 1Km spatial resolution are derived from NOAA-AVHRR. In order to estimate ET, the cloud-free images are processed. Month-wise number of processed images is shown in Table 1.

After estimating ET, sensitivity analysis of the results with respect to the surface temperature, air temperature, and dew point temperature is done by examining the effect of the 5% decrease and increase in each of these parameters.

Table 1. The number of processed images in each month (le nombre d'images traitées en chaque mois)

Year	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2005-2006	1	1	2	1	1	1	1	1	3	2	3	2	2

4. RESULTS

1-4- Producing information layer and data validation

1-4-1- Air temperature:

In this study, air temperature is produced by means of two different approaches. In the first, air temperature is estimated using available field data and different interpolating methods like Kriging or Distance Weighting methods (NDW and IDW). In the second approach, the regression equation is fitted through the daily air temperature and the altitude of the corresponding stations. Then the equation is applied to the DEM (Digital Elevation Model) to produce the temperature layer. Validation of these methods is done by cross validating of the parameters. The results of the cross validation of the parameters are shown in Table 2 for 3 different days.

Table 2. Cross validation parameters of different methods of interpolating air temperature in 3 different days in 2006 (paramètres de validation croisée des méthodes différentes de l'interpolation de l'air température en 3 jours différents en 2006)

SE Prediction	y intercept	R^2	Regression coefficient	power	method	No. of field Data	Date
4.61	-0.06	0.25	1.07	1	IDW	10	15 Mar
4.33	2.61	0.33	0.77	2	IDW		
2.52	28.05	0.77	-2.07	1	NDW		
2.99	22.28	0.68	-1.4	2	NDW		
3.61	-0.54	0.54	0.95	-	Kriging		
2.5	2.1	0.78	0.81	_	Regression equation		
5.14	8.7	0.03	0.45	1	IDW	10	06 Apr
5.02	8.6	0.08	0.44	2	IDW		
3.31	48.91	0.60	-2.38	1	NDW		
3.81	37.65	0.47	-1.59	2	NDW		
4.23	-3.78	0.34	1.18	-	Kriging		
0.98	0.74	0.96	0.95	_	Regression equation		
4.93	-6.66	0.22	1.28	1	IDW	10	15 May
4.64	1.57	0.31	0.91	2	IDW		
2.967	71.58	0.72	-2.39	1	NDW		
3.37	54.7	0.64	-1.61	2	NDW		
1.94	1.65	0.88	0.92	_	Regression equation		

From the results, it can be concluded that the best approach for interpolating is the linear regression due to the maximum value of R^2 and the minimum RMSE. An example of the regression equation and related cross validation chart are shown in Fig. 3. Figure 4 shows the corresponding temperature layer which is produced using this method.

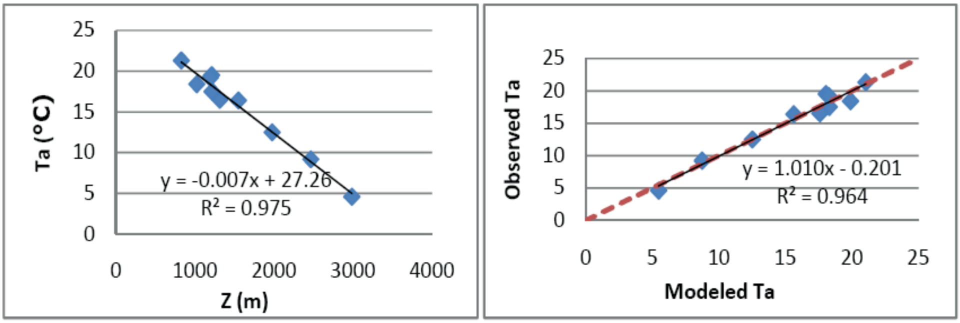

Fig. 3. Linear regression between air temperature and altitude (left) and related cross validation chart (Right) – 6th April 2006 (équation de régression linéaire entre la température de l'air et la hauteur (à droite) et le tableau de validation croisée (à gauche) - 6 Avril 2006)

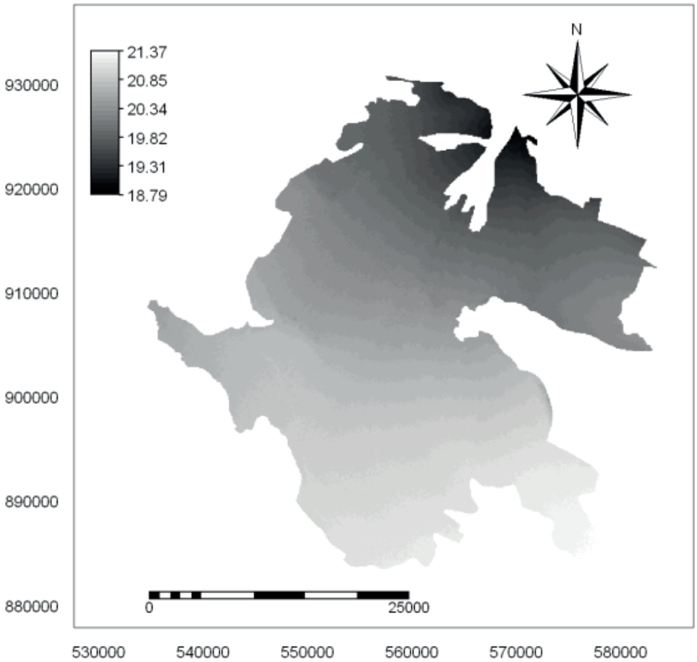

Fig. 4. Air temperature layer produced using regression equation between height and temperature - 6th April 2006 (couche de température de l'air produit par équation de régression entre la hauteur et la température - 6 Avril 2006)

2-1-4 -Surface temperature

For validating surface temperature layer, it is necessary to compare the remote sensing results and field data which is derived from the nine synoptic stations in the study area. The right side of the figure 5 shows the difference between field data, which is measured in Garmsar station, and remote sensing results. In the left side of the figure 5 regression equation fitted to the observed surface temperature in Garmsar station and related remote sensing results is shown.

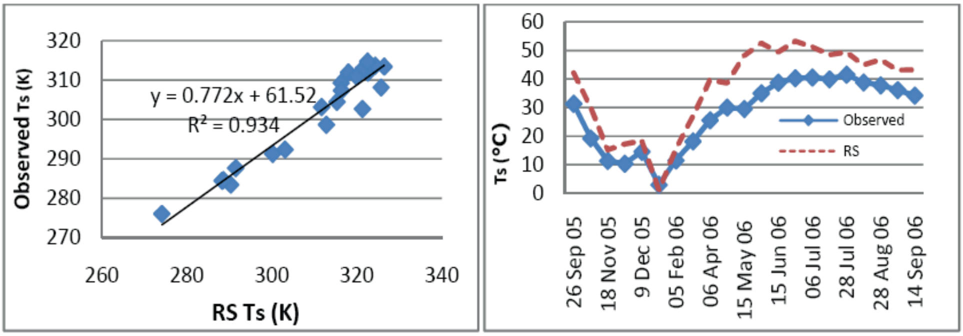

Fig. 5. Comparing observed surface temperature and remote sensing results (right) and fitted regression (left) to the observed surface temperature and remote sensing values in Garmsar station in 2006-2007 water year (comparer la température de surface observées et la résultat détecté à distance de (à droite) et l'équation de régression ajustée à la température observées de surface et les valeurs de détecté à distance de la station de Garmsar en 2005-2006 année de l'eau)

3-1-4- Dew point temperature

First, it is necessary to compare the remote sensing results and field data. Then, the remote sensing results should be corrected if needed. In this study the comparison between field data and remote sensing results in Garmsar station is done in order to find the suitable regression equation between observed data and the results of the fitted model. Then the selected equation is used to adjust the results of the model. Figure 6 shows the differences between field data and remote sensing results and the regression equation fitted to the observed surface data and the results of the model.

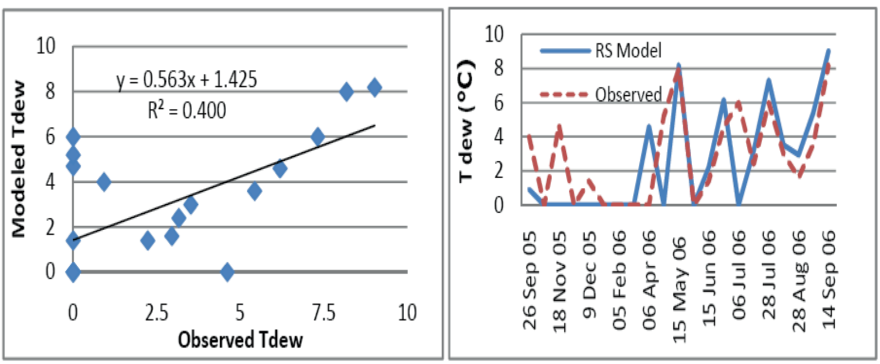

Fig. 6. Comparing observed dew point temperature and model results in Garmsar station in 2005-2006 water year (Figure 6 - comparer la temperature observée du point de rosée et les résultats du modèle en station de Garmsar en 2005-2006 année de l'eau)

2-4- Sensitivity analysis of ET with respect to the input parameters:

In order to understand the behavior of ET respect to the changes in surface temperature, air temperature, and dew point temperature, sensitivity analysis of these parameters should be done. The results of the sensitivity analysis are shown in table 3. Because changes in surface temperature will result in changes in dew point temperature and long wave radiation, it is expected to be the most effective parameter. Regarding the results, it can be concluded that the most effective parameter is surface temperature and sunshine is the least effective one.

Table 3. Results of the sensitivity analysis of ET respect to the input parameters -6th April 2006 (Résultats de l'analyse de sensibilité d'ET concernant les paramètres d'entrée d'Avril au 6 2006)

	+ 5%	- 5%
Ts	-94%	64.6%
Tdew	4.5%	-4.5%
Ta	3.9%	-3.9
sunshine	-2.4%	-7.7%

5. CONCLUSIONS

SUT-SEBAL algorithm is an image processing model in which required data is provided using field data and satellite images. In order to achieve more accurate results, it is necessary to validate input information layer. In this study, validation of air temperature, surface temperature and dew point temperature is examined and finally the sensitivity analysis of these parameters is done. The results show that the remote sensing model overestimates surface temperature and should be adjusted. Dew point temperature obtained from the model also requires to be corrected. It can be concluded that among all the tested methods, linear regression equation fitted to the air temperature and corresponded height provides better results. Sensitivity analysis of the input parameters shows that surface temperature is the most effective parameter and sunshine is the least effective one.

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