Periodica Polytechnica
Civil Engineering

61 (4), pp. 904–910, 2017
https://doi.org/10.3311/PPci.10283

RESEARCH ARTICLE

Application of Different Evapotranspiration Models to Calculate Total Agricultural Water Demand in a Tropical Region

Thi Hong Ngoc Tran[1,2,*], Márk Honti[2]

Received 16 November 2016; Revised 30 January 2017; Accepted 27 March 2017

Abstract
Today, water in the Long Xuyen Quadrangle-An Giang (LXQAG) (Mekong River delta, Vietnam) is becoming scarce in some seasons and some districts in the region, especially when the scenarios of climate change will affect water resources in the future. Therefore, it is necessary to make decisions about water conservation and distribution to ensure compatibility with the social objectives such as economic efficiency, sustainability and fairness. The mathematical models used for water distribution and balance calculations are the prominent themes nowadays. To perform this task, it needs to calculate the water needs for all economic sectors. In this article we are particularly concerned about water demand calculation methods for crops and aquaculture. Because these are the two main commodities accounting for the highest water usage in the region. Water demand for crops is calculated through potential evaporation using the methods of Hargreaves & Samani; Priestley and Taylor and Penman-Monteith to check if the first two simpler methods with less data demand could be used to estimate evapotranspiration. The results show that the simpler methods were significantly different and therefore water demand calculations must be based on the Penman-Monteith method for the water demand of crops and the methods of Penman to calculate expansion evaporation for aquaculture.
The result shows that the total water demand in 2015 is 6,428 million m^3/year. It is estimated that in 2020, agricultural water demand will rise by 71% compared to 2015 to 22,531 million m^3/year. The main reason for this rise is that the local managers expect the catfish farming area to increase by 80%, if people apply the "VietGAP standards".

Keywords
Vietnam, An Giang Province; evapotranspiration; rice paddies; aquaculture

[1]Department of Environment and Sustainable Development, Faculty of Environmental Engineering, An Giang University, Vietnam. No 18 Ung Van Khiem Street, Dong Xuyen Ward, Long Xuyen City, An Giang, Vietnam.

[2]MTA-BME Water Research Group, Hungarian Academy of Sciences, Budapest, Műegyetem rkp. 3, 1111 Hungary.

[*] Corresponding author email: tthngocagu@gmail.com

1 Introduction

Water resources have always been closely linked with the activities of human life. Unequal distribution of water resources in both space and time has posed the greatest problems in terms of water security to various social and economic sectors. In South-East Asia the competition for water between economic sectors has become fierce due to fast population growth, industrialization, and urbanization. [15]. The Mekong River Delta is an important agricultural and economic region in South Vietnam which experiences all these problematic symptoms of social and economic expansion. The Long Xuyen Quadrangle-An Giang Provice (LXQ-AG; Fig. 1) of Vietnam is a subregion of the Mekong River Delta, where a network of canals have provided water resources for a wide variety of purposes: irrigation for agricultural crops, fresh water aquaculture, animal husbandry, poultry, supply for domestic use and industry. However, water resources in the area have been overused: water wasn't used efficiently and shows sign of degradation at many places. Surface water pollution in channels is typical. The main pollution sources are human waste, and waste from livestock and poultry, and aquaculture [2]. Further exploitation of water resources for commercial purposes and water pollution is increasing [17]. In fields deep inside the region (farther from the large rivers at the perimeter) the water quality situation is usually more serious. Pesticide pollution is not yet widespread, but in some places contamination has already affected aquatic ecosystems [34].

In areas, like the LXQ-AG, where agricultural and aquacultural activity is intensive the total regional water demand is dominated by processes strongly bound to evaporation and evapotranspiration (ET). The direct and regionally representative monitoring of evapotranspiration is difficult, so mathematical models based on meteorological data and crop quality data are typically used to estimate a potential ET (ET_0), of which a certain fraction determined by water availability will be actually evapotranspirated. Different methods exist for estimating ET_0. Energy balance techniques have been used widely and Szilágyi [27], Sellers [28], Webb [38], Rosenberg [25], and Tanner [30] have reviewed these methods in detail. Besides these physically-based relationships, several empirical formulae have been developed to relate evaporation to one or few meteorological parameters and fair agreement with evaporation pans has been obtained ([23],[31],[4],[36],). However, these require calibration to local circumstances. Evapotranspiration estimates are less frequent for tropical than for temperate regions, so water demand calculations are therefore more uncertain. In general, the daily average ET in the tropics is about 5.2–7.1 mm [14]. During the wet season, ET > 5.5 mm/day is typically observed in South Vietnam [35]. These values are expected to vary depending upon location-specific factors. For example, during drought stress, even in the wet season, ET rates from wetland rice may increase because of high advection from adjoining areas [35]. These approximate numbers project a significant agricultural water demand, which renders the region vulnerable in terms of water security.

In recent years, rice cultivation in this region faces many difficulties due to the high variability of weather conditions. It has been observed that severe droughts, which recently take place during the first growth stage in February or March, and heavy rains, which often fall in September or October, cause a lot of damage to the Winter-Autumn crop. On the other hand, the October crop normally suffers from water logging and floods at the vegetative phase, and also from the shortage of water at the late reproductive phase [32]. Climate change and the use of water resources in upstream countries have impacted severely the Mekong Delta, including LXQ-AG. Saltwater intrusion has been threatening agricultural production as well as people living in the region [9]. With the recent introduction of high-yielding, nitrogen-responsive rice varieties, the actual yield of rice cultivation now depends greatly upon the water supplied. The socio-economic development of LXQ-AG region until 2020 aims to ensure that rice production and aquaculture contribute to food security of the growing population [17]. Therefore, the water demand of agriculture is expected to increase in the future. Moreover, the impact of climate change increases the water demand for crops, because the temperature and evaporation increases [39].

This paper focuses on the estimation of agricultural water demand in the LXQ-AG in 2015 and makes projections for 2020. For the estimation of agricultural water demand we first evaluate different models of potential evapotranspiration.

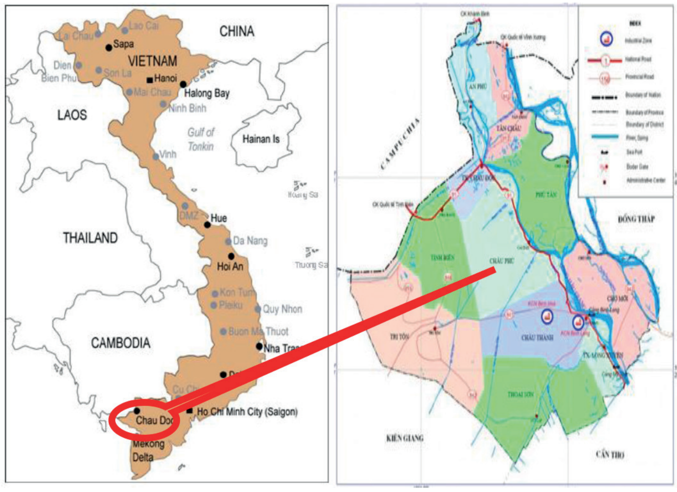

Fig. 1 Vietnam (left) and location of LXQ-AG (right)

2 Methods

The agricultural water demand of the region is calculated on summing up the water demand of aquaculture, and agriculture for both 2015 and 2020. Both of these demand constituents are complex are complex and climate-dependent, as they require reliable estimates of evapotranspiration (for crop water demand) and open water evaporation (for water demand of aquaculture). To ensure the robustness of our calculations, we compare two simpler models of potential evapotranspiration to the widely accepted Penman Monteith model and assess their performance in this tropical region.

2.1 Meteorological data

Monthly meteorological data (air temperature, relative humidity, precipitation) were available from the statistical and hydrological yearbooks of An Giang province for the last 6 years [29]. Average meteorological conditions were assumed by calculating means for all meteorological statistics.

2.2 Potential Evapotranspiration

We calculated potential evapotranspiration (ET_0) on the daily scale by the modified Hargreaves [12], [1], Priestley-Taylor [22] and FAO Penman-Monteith equations [1]. The modified Hargreaves equation [12]; The Hargreaves model is an empirical model based on extraterrestrial radiation and temperature:

$$ET_0 = a + b\ 0.0023\ (T_x - T_n)^{0.50}(T + 17.8)R_a / \lambda \qquad (1)$$

where ET_0 = reference grass evapotranspiration estimated (mm d^{-1}); Tx = maximum daily temperature (°C), T_n = daily minimum temperature (°C), T = daily mean temperature, $T = (T_x+T_n)/2$; R_a = extraterrestrial radiation (MJ m^{-2} d^{-1}), λ = latent heat of vaporization (MJ kg^{-1}). The a and b coefficients can be used to fit the equation to local conditions, their default values are a = 0 and b = 1.

The Priestley-Taylor [22] equation is a less empirical model, it is a simplification of the Penman-Monteith equation (see later) by replacing the aerodynamic term with an empirical coefficient:

$$ET_0 = \frac{1}{\lambda}\frac{\Delta(R_n - G)}{\Delta + \gamma}\alpha \qquad (2)$$

Where R_n = net radiation (MJ m^{-2} d^{-1}); G = soil heat flux density (MJ m^{-2} d^{-1}); γ = psychrometric constant (kPa ˚C^{-1}); Δ = slope of the saturation-vapour pressure relationship (kPa ˚C^{-1}). According to [27], the coefficient α (>1) is included to express the increasing effect of large-scale entrainment of drier, free-tropospheric air [3]; [8]; [6]; [16]; [13]; [26]; [27].

The physically-based FAO Penman-Monteith equation [1] is the most widely-used and least-empirical model of evapotranspiration and therefore used here as a benchmark for the two simpler, empirical models:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)} \qquad (3)$$

where T = mean daily air temperature at 2 m above ground (˚C); u_2= wind speed at 2m above ground surface (m s^{-1}); e_s= saturation vapor pressure (kPa), e_a= actual vapor pressure (kPa).

2.3 Actual crop evapotranspiration

Potential evapotranspiration for non-reference crops (ET_c) was calculated through potential evapotranspiration (ET_0) and the crop coefficient by using the formula:

$$ET_c = K_c ET_0 \qquad (4)$$

Where K_c is the crop coefficient. K_c varies between crops, the cultivation season and growth stages of plants (germination, growth, flowering, fruiting, harvesting). A locally valid seasonal relative Kc curve has been determined experimentally by Le [17].

Values for K_c were assumed based on the experimental results and studies of FAO for rice in Southeast Asia (Tab.1).

Table 1 The crop coefficient (K_c) for the different growth phases of rice in Southeast Asis according to the experimental results of FAO [10].

Growth Phase	Initial	Develop-ment	Middle	Late	Harvest
K_c	1.1–1.15	1.1–1.15	1.1–1.3	0.95–1.05	0.95–1.05

Since the objective of this study is to calculate water demands, we assumed water to be available throughout the year and did not distinguish between potential and actual evapotranspiration.

2.4 Open water evaporation

The latent heat flux (mm d^{-1}) of the small wet patch (representing ponds used for aquaculture) is defined by the Penman (1948) equation:

$$ET_P = \frac{\Delta(Ta)}{\Delta(Ta)+\gamma} R_n + \frac{\gamma}{\Delta(Ta)+\gamma} f_u (e^* - e_a) \qquad (5)$$

Where *Ta* is the air temperature over the drying land surface, ea is the actual vapor pressure (hPa), e* is the saturation vapor pressure at *Ta*, and fu is the wind function, traditionally expressed [3] as:

$$f_u = 0.26(1 + 0.54\ u_2) \qquad (6)$$

Where u_2 is the wind speed (m/s) at 2m above the ground.

2.5 Water demand of aquaculture

Water demand for aquaculture depends on season, types of fish and farming methods. The majority of people in the project area breed catfish using 2 seasons/year and each season is 5–6 months. The breeding period from beginning to end is 90 days. The depth of the pond for catfish and breeding is between 1.5–2 m. People who raise fish for export need to change the water every 10 days, each time changing 33–50% of the initial volume of water. For breeding, water should be changed weekly; and every time the 50% of the initial water volume is replaced [24].

Thus, the total water demand for aquaculture includes:

- The water needed for renovating the pond before stocking.
- The amount of water required in the pond
- The replaced water in different stages during the farming process
- Evaporation.

2.6 Other water demands

Water demands for livestock were assessed based on per capita values from National Standards of the State of Vietnam [33]. Ecological water demand wasn't assessed separately because most water bodies in the study region are artifical and heavily managed.

3 Results

3.1 Comparison of evapotanspiration models

As expected, the three different models of ET_0 resulted in different estimates for annual potential evapotranspiration. The Penman-Monteith model estimated 1,364 mm yr^{-1}, while the Hargreaves and Priestley-Taylor models suggested significantly higher values (1,761 and 1,549 mm yr^{-1}, respectively). This outcome highlights that simpler models lacked certain mechanisms that limited ET_0 in this warm and humid environment.

We analysed the day-to-day variability of ET_0 from the three models. The Priestley-Taylor and Hargreaves models had equal variability (ET_0 Hargreaves = 4.83 ± 0.46 mm/day, ET_0 Priestley-Taylor = 4.24 ± 0.46 mm/day).

However, the relative variability of Hargreaves (9.5%) is smaller than the error percentage of the Priestley-Taylor (10.9%). The variability of Penman-Monteith was 0.34 (ET_0 Penman-Monteith = 3.73 ± 0.34mm/day), which is obviously smaller than for the two simpler models, but the relative variability was close to the other models (9.11%) due to the significantly smaller mean value. This means that all models managed to capture the relative variability of ET_0.

To assess the importance of different meteorological forcings we calculated correlations between ET_0 and temperature or radiation. Results show that the evaporation value has a close correlation with temperature in Hargreaves method ($r^2 = 0.895$), which was expected as temperature being the primary forcing in this model. Meanwhile, the coefficients of determination of the Priestley-Taylor and Penman-Monteith were 0.64 and 0.72 respectively, which suggests that other mechanisms are better represented in these two models compared to the Hargreaves equation. Coefficients of determination with R_a were 0.40, 0.32, and 0.85 for the Hargreaves, Priestley-Taylor, and Penman-Monteith models, respectively. This suggests that the simpler models fail to incorporate the radiative forcing in a properly representative way. Therefore, we conclude that simpler models are not useful for calculating potential evapotranspiration in tropical regions without a site-specific recalibration and we use ET_0 from the Penman-Monteith model from this point on.

3.2 Crop water demand: number 3,594m³/ha

The results show that water demand for crops is generally high in the first month because of land preparation. During the next months, water demand greatly reduces. Water demand of the Summer-Autumn rice crop (the 2nd rice crop) is the highest (5,390 m³/ha). Next, the Winter-Spring season (the 1st rice crop) is 4,771m³/ha. Lowest water demand is the Autumn-Winter rice crop (the 3rd rice crop), only 2,748m³/ha, because this time coincides with the rainy season, so the extra water needed for rice is less than the remaining months. Particularly for the Summer-Autumn rice crop, water demand for rice is very high in March when it's hot, so the water is needed for soil preparation and sowing. Water demand for rice in the dry season is 6–8 times higher than in the rainy season, but cultivation methods are not significantly different for each season.

Results show that from November to March, water demand is higher than in the remaining months (Fig.2). Most people in the study area cultivate winter-spring rice. Therefore, the rice cultivation area for this season is higher than the two remaining crops. Moreover, this period is the dry season, so water demand for crops is relatively high. Particularly in March, water demand is much greater than in the remaining months (Fig.2), because this is the time for soil preparation and seeding of the Summer-Autumn rice crop, and water demand is relatively large for this activity (3.594 m³/ha). Moreover, this time coincides with the calendar of annual crops, so the total water demand of March is higher than in the remaining months and is up to 1,250.66 million m³/year. While April to August water demand ranges between 231.69–362.77 million m³/year. September and October are two months that have the lowest water demand, due to these months having relatively high rainfall, enough to meet water demands for crops (Fig.2).

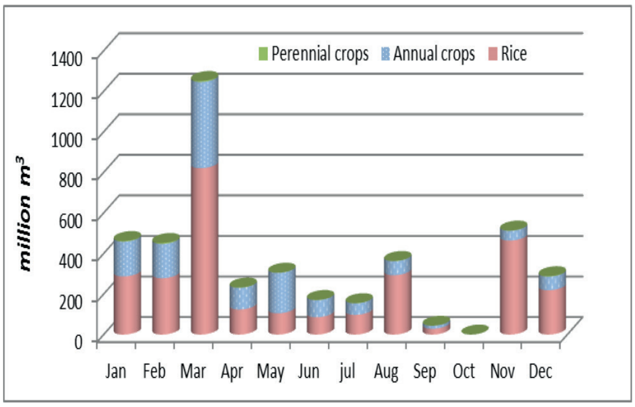

Fig. 2 Monthly water demand of crops in 2015

The calculation results show that the water demand for crop production in 2015 is 4,229 million m³, in 2020 it will be 4,394 million m³, which is an increase by 165 million m³ compared to 2015. The increase is insignificant, because the area of winter-spring crop is expected to remain stable, and the summer-autumn rice crop will decrease in the following years. The reason for this is that farmers are expected to manage losses. Therefore, some farmers will switch to vegetable crops or let their fields barren. But the area forecast of autumn-winter rice crops will rise. So, the area of annual crops will rise, but their specific water demand is small. Therefore, the expected increase of water demand of crop production is not large in the 2015–2020 period (Fig.3).

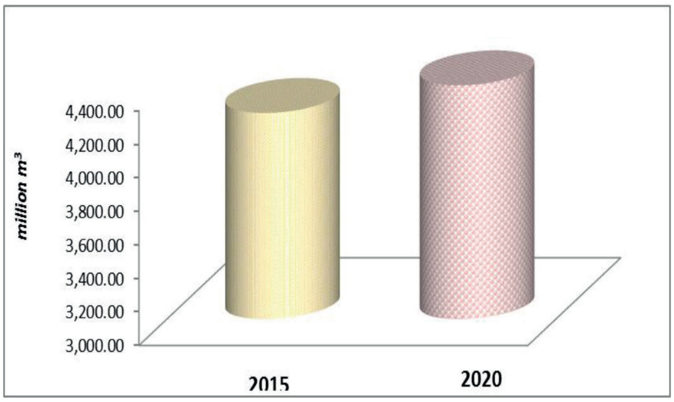

Fig. 3 Total water demand for crops in 2015 and 2020

3.3 Aquacultural water demand

The amount of annual mean open water evaporation by Penman's (1948) model is 1,697 mm yr^{-1} or equivalently 4.6 mm d^{-1}. The 2020 forecast of the average evaporation was calculated for a climate change scenario to be 5.0–6.0 mm/day, so climate change wouldn't alter the evaporated amount significantly.

The total area for aquaculture in 2015 in LXQ-AG is 2,455.8 ha. Considering pond dimensions, pond operation guidelines and the estimated evaporation, the total water demand of aquaculture in LXQ-AG is 2,188 million m³ yr^{1}. Out of this huge amount evaporation is responsible for only 2%, so pond operating guidelines are practically the sole determinants of the aquacultural water demand. Total area for aquaculture in LXQ-AG in 2020 is expected to increase to 7,540 ha 7,540 ha due to promoted development of this sector. Moreover, water demand of the expanded aquaculture sector with the new Viet-GAP operating standards [20] may exceed 18,140 million m^3 yr^1, an increase of 8.29 times compared to 2015 (Fig. 4).

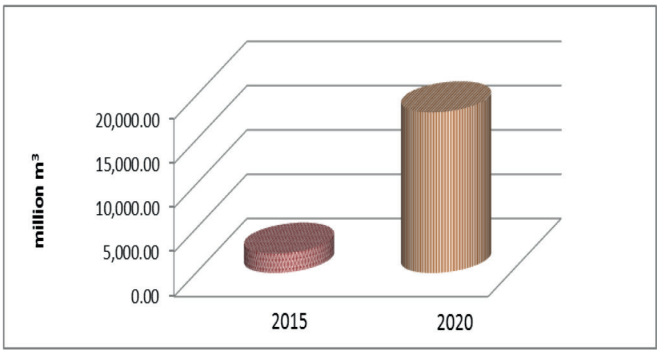

Fig. 4 Total water demand for aquaculture in 2015 and 2020

3.4 Livestock water demand

Water demands for different animal categories (buffalo, cattle, pig, poultry, goat and sheep) were assessed separately (Tab. 2) and summed up. Results show that the water demand for livestock is relatively low compared with other sectors. In 2015, water demand was around 12 million m^3 yr^1. In 2020, the projection for livestock water demand is 17 million m^3 yr^1, an increase by 41% compared to 2015 due to increasing animal numbers.

Table 2 Actual and projected numbers of animals their water demand in 2015 and 2020.

Animals	In 2015 (heads)	Water demand in 2015 (m^3/year)	In 2020 (heads)	Water demand in 2020 (m^3/year)
Buffaloes	4,224	208,138	4,895	241,201.13
Cattles	127,373	6,276,305	179,092	8,824,758.3
Pigs	84,375	923,906	253,125	2,771,718.75
Poultry	4,672,899	4,690,422	5,226,396	5,245,994.98
Goat,Sheep	5,523	50,397	8,858	80,829.25

3.5 Total agricultural water demand

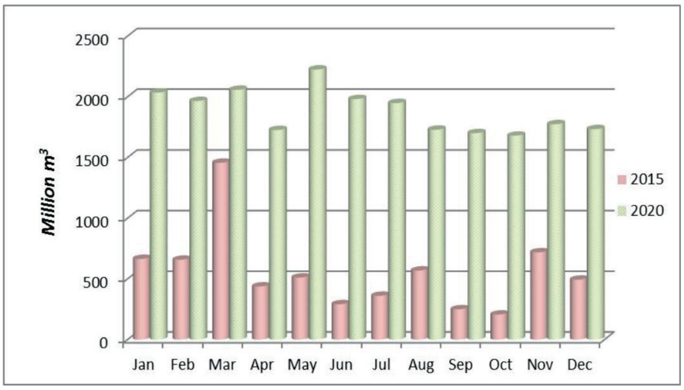

Fig. 5 Total agricultural water demand in monthly basis in 2015 and 2020.

From the above calculations we show that the water demand for agriculture (Crops: 4,229 million m^3/yr + Aquaculture: 2,187 million m^3/yr + Livestock: 12 million m^3/yr) in LXQAG in 2015 was 6,428 million m^3/yr and will be 22,531 million m^3/yr in 2020 (Crops: 4,394 million m^3/yr + Aquaculture 18,139 million m^3/yr + Livestock: 17 million m^3/yr). The demand will increase by 16,122 million m^3/yr, in which the majority is caused by the aquaculture sector. Statistical data and our calculations show that presently the water resources in LXQAG are used mostly for crops, accounting for nearly 64% of the water use, followed by the demand for aquaculture purposes accounting for 33.23%. The above results reflect the economic reality of the locality in which two key goods are rice and Pangasius spp.

Water demand for each month of the year in the research region showed that irrigation accounts for the highest proportion of water use (Fig. 5). Months with the highest water demand during the year (March) average 29 % by 2015 and 17% in May, 2020. September and October have the lowest water demand in the year, the demand for water for agriculture purposes accounted for 97% (2015); and 99% (2020). The increasing demand in 2020 compared to 2015 is the inevitable result of the economic and social development plans of local communities.

4 Discussion

Many programs have been used to calculate water demand for crops. The CROPWAT model implementing the Penman-Monteith equation (which was chosen in this study) was already used to calculate water demand for agriculture in Ninh Hoa, Vietnam [5]. The change in water demand of the crops to the scenarios of climate change on the irrigated area in Trung Ha-Suoi Hai, Vietnam has been shown [21]. To assess the ability of the water supply of the Ca river system for the economic sectors, the research applied IQQM modeling to simulate water balancing in watersheds. Hence, models can evaluate the effect of the exploitation and water use plans in the basin [19]. The experimental studies on the evapotranspiration of rice for the Spring and October crops were carried out during a five-year period in the Red River Delta of Vietnam. It was found that the evapotranspiration of rice depends highly upon the growth stages, the amount of fertilizer applied and climatological conditions. However, a linear relationship between rice evapotranspiration and each of the factors (pan evaporation, sunshine duration and atmospheric temperature) was significant only for the Spring crop [11]. Water demand was also calculated for all economic sections in the Mekong Delta including fresh water and salt-affected areas. A total of 120 sub-irrigation areas was examined for this project [34]. Irrigation demand in the Mekong Delta's provinces in 2000 was also counted by Vo [37]. Of which, the water demand for crops in LXQ-AG was 111 m^3/s and 2020 will be 141m^3/s. Our result for 2015 was 134m^3/s, in 2020 we projected 139 m^3/s. These results are consistent with Vo's results [37].

5 Conclusions

Surface water sources in LXQAG are currently being exploited, and for many different purposes, agriculture being the biggest water user.

Presently on a regional and annual scale surface water is abundant due to the vicinty of large rivers. However, water shortage already occurs in certain districts due to insufficient irrigation infrastructure capacity and relatively large agricultural usage. Projections of future water demands suggest that water supply may be increasingly pressured during climate change if that causes a reduction of available assets.

Spatially and temporally detailed water demand calculations highlight the pressure of exploitation overuse particularly in the dry season. To carry out these evapotranspiration needs to be calculated and monitored preferably on a sub-monthly scale. Based on data availability, we recommend the Penman-Monteith model to be used and suggest the collection of the necessary meteorological data in the region.

References

[1] Allen, R. G., Pereira, L. S., Raes, D., Smith, M. "Crop evapotranspiration - Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No. 56". FAO, Rome. 1998. https://appgeodb.nancy.inra.fr/biljou/pdf/Allen_FAO1998.pdf

[2] An Giang Center For Preventive Medicine. An Giang: "Most of Rivers polluted surface water resource". 2005. http://vietbao.vn/Khoa-hoc/An-Giang-Hau-het-song-rach-o-nhiem-nguon-nuoc-mat/70007322/188/

[3] Brutsaert, W. "Evaporation into the Atmosphere: Theory, History and Applications". Springer Science+Business Media B.V.1982. https://doi.org/10.1007/978-94-017-1497-6

[4] Blaney, H.F., Criddle, W. D. "Determining water requirements in irrigated areas from climatological and irrigation data". *USDA Soil Conservation Service Tech*, *Paper 96*, 48 pp. 1950.

[5] Bui, T.H. "Calculation ofwater demand in the Ninh Hoa river Basin". Hanoi National University. 2012.

[6] Culf, A. D. "Equilibrium evaporation beneath a growing convective boundary layer". *Boundary Layer Meteorology*, *70*(1), pp. 37–49. 1994. https://doi.org/10.1007/BF00712522

[7] Decision No.22/2014/TT–BNN, 2014 http://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Thong-tu-22-2014-TT-BNNPTNT-Quy-chuan-ky-thuat-quoc-gia-dieu-kien-nuoi-thuy-san-242453.aspx

[8] De Bruin, H. A. R. "A model for the Priestley-Taylor parameter a". *Journal of Climate and Applied Meteorology*, *22*, pp. 572–580. 1983. http://journals.ametsoc.org/doi/pdf/10.1175/1520-0450(1983)022%3C0572:AMFTPT%3E2.0.CO;2

[9] Doan, N. P. "20 years of agricultural and rural development in LXQAG and development orientation". Scientific Conference. "*20 years of exploitation and social and economic development of LXQ region*". p.108. 2012.

[10] FAO. Crop evapotranspiration-Guidelines for computing crop water requirements. Chapter 6-ETc- Single crop coefficient (Kc). 2001. http://www.fao.org/docrep/X0490E/x0490e0b.htm

[11] Ha, H. N., Huynh, N. P. "Evapotranspiration of Rice Fields in the Red River Delta". *Southeast Asian Studies, 20*(3), pp. 425–435. 1982. https://kyoto-seas.org/pdf/20/3/200305.pdf

[12] Hargreaves, G. H., Samani, Z. A. "Reference crop evapotranspiration from temperature". *Applied Engineering in Agriculture*, *1*(2), 96–99. 1985.

[13] van Heerwaarden, C., de Arellano, j. V-G., Moene, A. F., Holtslag. A. A. M. "Interactions between dry-air entrainment, surface evaporation and convective boundary-layer development". *Quarterly Journal of the Royal Meteorological Society*, *135*(642), pp. 1277–1291. 2009. https://doi.org/10.1002/qj.431

[14] Kung, P., Atthayodhin, C., Druthabandhu, S. "Determining water requirement of rice by field measurement in Thailand". *International Rice Commission Newsletter*, *14*(4): 5–18. 1965.

[15] Sheng, Y. K. "Urban Challenges in South-East Asia". https://doi.org/10.13140/2.1.1747.4563

[16] Lhomme, J. P. "A theoretical basis for the Priestley-Taylor coefficient". *Boundary Layer Meteorology*, *82*(2), pp. 179–191. 1997. https://doi.org/10.1023/A:1000281114105

[17] Le, M. T. "Evaluation of the exploitation and development processin LXQAG, orientation and some problems posed". Scientific Conference. "*20 years of exploitation and social and economic development of LXQ region*". page43. 2012.

[18] Le, A. T. Water demand of Crops, Chapter V. 2013.

[19] Luong et al. "Application of SWAT and IQQM model to calculate water balance Ca river Basin". *The 10th scientific conference. Institute of Hydrometeorology and Environment*. 2012.

[20] Ministry of Agriculture & Rural Development. Decision No 1503/QĐ-BNN-TCTS, 05/07/2011. 2011.

[21] Nguyen, T. A. "Some results about affection of climate change to water demand in Trung Ha - SuoiHai." 2016

[22] Priestley, C. H. B., Taylor, R. J. "On the assessment of surface heat flux and evaporation using large-scale parameters". *Monthly Weather Review*, *100*(2), pp. 81–92. 1972. https://doi.org/10.1175/1520-0493(1972)100%3C0081:OTAOSH%3E2.3.CO;2

[23] Penman, H. L. "Natural evaporation from open water, bare soil, and grass". *Proceedings of the Royal Society A: Mathematical, physical and engineering Sciences*, *193*(1032), pp. 120–145. 1948. https://doi.org/10.1098/rspa.1948.0037

[24] QCVN 02-20: 2014/BNNPTNT. 2014.

[25] Rosenberg, N. J., Hart, H. E., Brown, K.W. "Evapotranspiration. Review of research". *MP (University of Nebraska, Agricultural Experiment Station*, p. *68*. 1968.

[26] Rigby, J. R., Yin J., Albertson, J. D., Porporato, A. "Approximate analytical solution to diurnal atmospheric boundary-layer growth under well-watered conditions". *Boundary Layer Meteorology*, *156*(1), pp. 73–89. 2015. https://doi.org/10.1007/s10546-015-0018-8

[27] Szilagyi, J. "Complementary-relationship-based 30 year normals (1081-2010) of monthly latent heat fluxes across the contiguous United States". *Water Resources Research*, *51*(1), pp. 9367–9377. 2015. https://doi.org/10.1002/2015WR017693

[28] Sellers, W.D. "Physical Climatology". *University of Chicago Press*, Chicago, 271 pp. 1965.

[29] "Statistical Yearbook of An Giang, 2014". An Giang Statisticcal Office. An Giang Province, Vietnam.

[30] Tanner, C. B. "Evaporation of water from plants and soils". In: *Water Deficits and Plant Growth. 1. Development, Control, and Measurement*. (T.T. Kozlowski (Ed.)), pp. 73-106.Academic Press, New York, NY, 1968.

[31] Thornthwaite, C.W. "An approach toward a rational classification of climate". *Geographical Review*, *38*(1), pp. 55–94. 1948.

[32] "The Irrigation Departments in An Giang province". The report of flood prevention of An Giang province. 2015.

[33] The Agency of Development Research for National Water Resources Management (Vietnam), 2010. Forecasting water demand of 14 river basins, Vietnam , period 2010–2020.

[34] Vietnam-Netherlands Mekong Delta Masterplan project. Mekong Delta water resources assessment studies. 2011.

[35] Tomar.V. S., Otoole, J. C. "Water use in lowland rice cultivation in Asia: A Review of Evapotranspiration". *Agricultural Water Management*, *3*(2), pp. 83–106. 1980. https://doi.org/10.1016/0378-3774(80)90017-7

[36] Van Bavel, C. H. M. "Potential evaporation: the combination concept and its experimental verification". *Water Resources Research*, *2*(3), pp. 455–467. 1966. https://doi.org/10.1029/WR002i003p00455

[37] Vo, K.T. "Study on the Management and Operation of Large-scale Surface Irrigation Systems for sustainable Water Resources Development in the Mekong Delta, Vietnam". In: *Proceeding of the International Symposium on Sustainable Development in the Mekong River basin*. 6–7th Oct. 2005, Ho Chi Minh City, Vietnam. 2005.

[38] Webb, E. K. "Aerial microclimate". In: *Agricultural Meteorology. Meteorological Monographs*, *6*(28), (Waggoner, P. E. (Ed.)). AMS, Boston, pp. 27–58. 1965.

[39] Cline, W. R. „Global warming and agriculture" 2008. https://www.imf.org/external/pubs/ft/fandd/2008/03/pdf/cline.pdf