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Research Paper

EVALUATION OF THE EFFECTS OF CLIMATE CHANGE TO WATER DEMAND FOR AGRICULTURE IN DA LAT CITY, LAM DONG PROVINCE

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ABSTRACT

Research on changes in irrigation needs of short-term crops in Dalat city; including the main types: corn, beans, peanuts, vegetables, flowers and sugarcane. The demand for irrigation water is determined by climate data from 1984-2015 and CROPWAT 8.0 is used as the basis for the forecast until 2035 with climate change scenarios 2016, RCP 4.5 and RCP 8.5. The study results show that, the temperature will increase by 0.4-1.2 ^{o}C by 2035. As the temperature increases, the potential evapotranspiration of ET0 increases, leading to an increase in water demand of crops during the dry season. In the rainy season, by 2035, although the temperature increases, the rainfall is relatively heavy (increasing from 0.6mm to 8.9 mm). In 2035, the total demand for irrigation water of these crops will be around 1,363.3 mm/ha, an increase of about 4% compared to 2015 (1,310.9 mm/ha).

Keywords: *Crop water demand, CROPWAT, Climate change scenario.*

1. Introduction

Climate change (CC) has been one of the biggest challenges facing humanity. Climate change affects most sectors of the economy, including agriculture, forestry, and fisheries to oil and gas production, hydropower and shipping, etc. In particular, agriculture is one of the most directly and heavily affected by climate change.

Climate change has a great impact on plant growth, productivity, planting season, and increases the risk of plant pests and diseases. Climate change affects the reproduction and growth of cattle and poultry, increasing the possibility of disease and disease transmission of cattle and poultry. Climate change is likely to increase the frequency, intensity, volatility and extremity of dangerous weather phenomena such as storms, storms, cyclones, and natural disasters related to temperature and rain such as hot and dry weather, floods, inundation or drought, cold spells, saltwater intrusion, pests and diseases, reducing the productivity and productivity of crops and livestock. Climate change also lead to a decline in agricultural land.

The continuous increase in population, together with the ever-evolving needs of the

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world' s agricultural industry, has been creating new demands for water resources every day. In the context of global climate change, it is imperative to improve management and planning of water resources to ensure proper use and distribution of water among users. Accurate planning and supply of needed water over time and space can conserve water. The main goal of irrigation is to apply water to maintain crop transpiration (ETc) when rainfall is insufficient (Husam Al-Najar). Feng and Zhang (2007) and Salavanan and (2014) identified the plant's water needs as the total amount of water needed for evapotranspiration, from planting to harvesting for a given crop in a particular climate regime, when soil water is maintained by rainfall and/or irrigation to limit plant growth and crop yield. Each crop has its own water needs. CROPWAT is a support system developed by FAO for irrigation planning and management. CROPWAT is a practical tool for performing standard calculations for reference evapotranspiration, crop water requirements and crop irrigation requirements, and specifically designing and managing irrigation facilities. It allows the development of recommendations for improved irrigation measures, planning irrigation schedules under different water supply conditions, and evaluating production in rainy or under-watered conditions (FAO, 1992). Determine the amount of water used according to different climatic conditions.

Agriculture is one of the local strengths, bringing a great deal of economic value to its residents. Specific studies on calculating demand for irrigation water according to climate change trends in Da Lat are not much. The objective of this study is to identify the need for irrigation water for short-term crops in Dalat including: corn, beans, peanuts, vegetables, flowers and sugarcane; in the 2016-2035 period under the average climate change scenarios RCP4.5 and high RCP 8.5; based on evaporation parameters - ETo serves as a basis for calculating the amount of water to irrigate crops during the research period. The result will definitely contribute to the improvement of irrigation solutions for agricultural production in Dalat City.

2. Methodology and Data

2.1. Introduction to the study area

Dalat city is located in Lang Biang plateau, the North of Lam Dong province. To the North, Dalat borders Lac Duong district, to the East and Southeast borders with Don Duong district, to the West and Southwest borders with Lam Ha and Duc Trong districts. Dalat has a natural area of 392.29 km², surrounded by high peaks and successive mountain ranges and has an average altitude of 1,500 m. The highest place in the city center is the Museum House (1,532 m), the lowest place is Nguyen Tri Phuong valley (1,398.2 m).

In terms of climate, Dalat city is located in the tropical savanna climate region with two distinct seasons: the rainy season and the dry season. The rainy season starts in May and ends in October. The dry season lasts from November of previous year to the April of the next year. In the dry season, Da Lat is influenced by the air mass of the East Sea, bringing warm and sunny weather, little cloud, no rain, low temperature at night and large heat amplitude. During the rainy season, the northeast monsoon heavily affects Da Lat, replaced by the air mass from the south to the north. The average temperature between months of the year does not have a big difference here, especially among localities in this region that clearly shows the decrease in temperature when the terrain height increases.. The average temperature is from 18 to 26^{o}C, the weather is mild and cool year round. The most prominent feature of Dalat rainfall regime is topographical rain and rainfall due to storms and a place with heavy rainfall, but unevenly distributed throughout the year. Rainfall in the rainy months accounts for 85-90% of the total annual rainfall. In the dry season, there can be a period of prolonged drought, from January to March.

Dalat has more than 20 streams belonging to the systems of streams Cam Ly, Da Tam and Da Nhim river system. These are all upstream streams in the Dong Nai river basin, of which more than half are shallow streams, only flowing in the rainy season and exhausted in the dry season. Cam Ly Spring has a length of 64.1 km, originating from Lac Duong district, flows from the North to the South and flows into Xuan Huong Lake. This is the largest stream system of Da Lat, plays an important role in providing water for production activities as well as daily life in Da Lat. Besides, Da Lat is also famous for lakes and waterfalls with about 16 large and small lakes scattered widely, most of them are artificial lakes, playing a significant role in providing irrigation water for agricultural production.

2.2. Selective inheritance method

Using documents related to the study area on natural characteristics (topography, climate, temperature...), data on hydrological factors (river systems), current status of agricultural land use and documents on climate change. Therefore, it is necessary to refer to reliable, scientific documents and the main research object of the documents is the area of Da Lat City, from which to select the information to be consulted and restored for the study of this subject.

2.3. CROPWAT software

CROPWAT software was born in 1992, developed by the World Food and Agriculture Organization (FAO) to calculate crop water demand and irrigation planning based on data provided by users. The FAO method is based on ETo to calculate the water demand for different crops by multiplying ETo by a Kc crop factor for each specific crop. But in this project, software is used to calculate ETo as a basis for calculating the amount of water to irrigate crops during the calculation period.

Theoretical basis of the CROPWAT model:

To calculate the amount of water (IRR) needed for our crops, we rely on the water balance equation of the general form as follows:

$$IRR = (ET_c + LP_{rep} + P_{rep}) - P_{eff} \, (mm/day) \quad (1)$$

where IRR is the amount of water to irrigate crops during the calculation period (mm/day); ET_C is the amount of surface evaporation in the calculation period (mm); P_{eff} is the effective crop rainfall used during the calculation period (mm); P_{rep} is the amount of water absorbed in soil is stable during the calculation period (mm/day); LP_{rep} is the amount of soil water (mm);

Determination of field surface evaporation (ET_c):

The amount of field evaporation is calculated by the formula:

$$E_{tc} = K_c \times ET_0 \, (mm/day) \quad (2)$$

where K_C is the plant coefficients, depending on the cultivation area and the growth stage of the crop; ET_0 is the free water evaporation is calculated using the formula of Penman-Monteith.

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T_{mean} + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

where R_n is the solar radiation on crop surface ($MJ/m^2/day$); G is the heat flow in the soil ($MJ/m^2/day$); T is an average daily temperature (^oC); u_2 is the wind speed at a height of 2m (m/s); e_s is the saturated vapor pressure (kPa); ea is the actual steam pressure (kPa); Δ is the pressure gradient with temperature ($kPa/^oC$); γ is the moisture constant ($kPa/^oC$); Kc is the coefficient depends on the type of crop and the period of growth.

Calculate effective rain (P_{eff})

$$P_{eff} = 0,6 \times P_{rain} – 10 \text{ as } P_{rain} < 70 \text{ mm} \quad (4)$$

$$P_{eff} = 0,8 \times P_{rain} - 24 \text{ as } P_{rain} > 70 \text{ mm} \quad (5)$$

where P_{eff} is the effective rainfall during the calculation period (mm); P_{rain} is the actual rainfall in the calculation period according to the design rain model month (mm).

The amount of water absorbed is stable (P_{rep})

P_{rep}= K x t (mm) (6)

where K is Steady coefficient of soil stability (mm/day); t is the calculation time (day).

The amount of water used for soil preparation (LP_{rep})

The amount of water saturated the arable land (S): S = (1-Sm/100) x d x P/100 (mm) (7)

where d is the depth of water saturated soil layer (mm); Sm is the available depth of early calculation period (%); P is the soil porosity (% soil volume).

Amount of water that forms and maintains a layer of water on the field during tillage (LD).

LD= (L/T + S + P + E) - Peff (mm/day) (8)

where L is the total amount of water to be supplied during tillage (mm); T is the land preparation time (day); P, S are the amount of water permeability vertical and horizontal (mm/day); E is an evaporation of the field surface (mm/day); P_{eff} is the effective rainfall (mm).

3. Results and discussion

3.1. Status of crop structure

According to the Department of Agriculture and Rural Development of Lam Dong province, implementing the Project of restructuring agricultural sector in the period (2013-2018), showing the average growth rate of the industry reached 5.5%/year, the industry structure agriculture reached 46.8%, the average value of production reached VND 163 million/ha/year, an increase of 33.6% compared to 2013.

Internal structure of agriculture is cultivation 80.8%, husbandry 15.5%, service 3.7%; Crop productivity increased on average 3-5%/year, typically coffee rose 3.1%, vegetables up 4.8%, flowers up 3.7%; The area of high-tech application agriculture reached 54,477 hectares, accounting for 19.5% of the cultivated area.

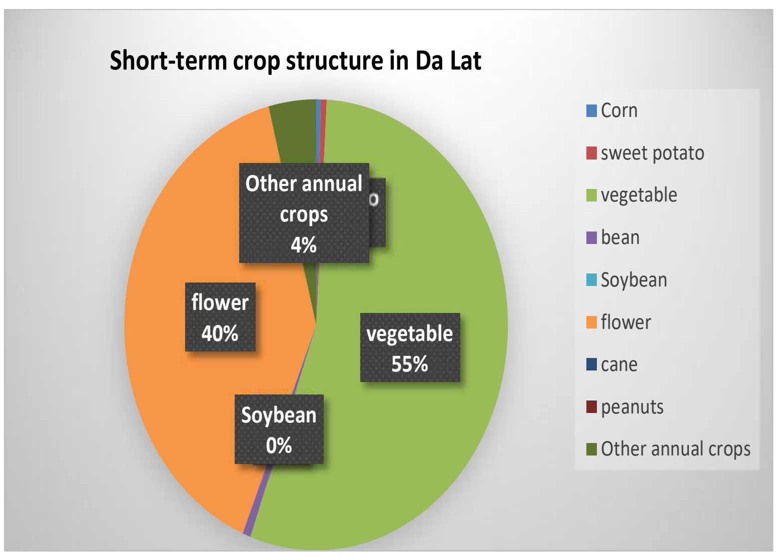

Fig. 1. Short-term crop structure in Da Lat

3.2. Irrigation needs of short-term crops in Da Lat

To calculate the water demand of crops in Dalat city, the authors used meteorological data (rain, temperature, ...) from 1984 to 2015. Meteorological data input CROPWAT software 8.0 The calculation of ETo in Dalat City in 2015 is shown in Table 1 below:

The effective rainfall calculation here is understood as the amount of rainfall after deducting losses due to runoff and infiltration. The effective rainfall calculation program in CROPWAT is used for both upland and wet rice crops.

In this topic, apply the FAO/AGLW formula. As following:

$$P_{eff} = 0.6P - 10 \text{ as } P \leq 70mm$$
$$P_{eff} = 0.8P - 24 \text{ as } P > 70mm$$

Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate...

Country: lamdong | Station: dalat

Altitude: 1475 m. | Latitude: 11.32 °N | Longitude: 107.4 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	8.4	26.4	84	192	7.8	18.6	3.47
February	9.0	27.5	81	157	8.3	20.6	3.92
March	10.0	28.4	82	150	7.9	21.3	4.16
April	12.4	28.4	87	111	6.8	20.0	3.89
May	14.5	27.6	90	127	6.2	18.8	3.64
June	15.2	26.9	92	213	5.3	17.2	3.31
July	14.8	26.3	93	256	4.8	16.5	3.11
August	15.1	26.3	94	259	4.5	16.3	3.04
September	14.7	26.3	93	152	4.3	15.8	3.05
October	12.9	25.8	92	165	4.8	15.7	2.97
November	12.1	25.7	88	289	5.8	16.0	3.12
December	9.3	25.4	87	321	6.6	16.4	3.20
Average	**12.4**	**26.8**	**89**	**199**	**6.1**	**17.8**	**3.41**

Fig. 2. Potential evapotranspiration ET0 in 2015

Table 1. Average Effective rainfall calculation results based on rainfall monitoring data of Dalat City from 1984 to 2015

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Average year
Precipitation	8.9	20.1	74.1	180.3	219.2	203.8	224.2	240.9	278.3	247.9	98.5	32.7	152.4
P_{eff}	8.8	19.5	65.3	128.3	142.3	137.3	143.8	148.0	152.8	149.6	83	31	1209.7

The result of calculating the average amount of water needed for irrigation over months by CROPWAT software is as follows:

Crop coefficient Kc is an experimental parameter, determined by the ratio of plant water demand and potential evapotranspiration in each growth stage. Crop coefficient - Kc of some plants are presented in the following table:

Table 2. Kc - coefficient of the crop

Period	*corn*	*Bean*	*Peanut*	*Sugarcane*	*Vegetable*	*Flower*
Sowing seeds	0.3	0.5	0.4	0.4	0.7	0.35
Development	1.2	1.05	1.15	1.25	1.05	1.15
Harvest	0.35	0.9	0.6	0.75	0.95	0.35

Table 3. Results of calculating the average amount of water needed for irrigation over months by CROPWAT software

Unit: mm/day

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
The amount of water needed for irrigation (mm)												
Corn	127.2	78.5	0.3	-	-	-	-	-	-	-	0	68.4
Bean	-	-	8,2	0	0	0	-	-	-	-	-	-
Peanut	71.7	108.1	61	0	-	-	-	-	-	-	-	10.7
Vegetable	84.8	97	43.4		--	-	-	-	-	-	-	27.3
Sugarcane	129	118.9	96.4	20.6	3.2	-	-	-	-	0	3.2	77.2
Flower	10.1	21.1	45.2	8.4	0	0	-	--	-	-	-	-

From the calculation results according to CROPWAT software, the total amount of water needed to irrigate short-term crops of Dalat in 2015 was 2,183,931.2 mm/day on a total of 12.173,8 ha. In which water demand is highest for sugarcane (448.5 mm/day), followed by corn (274.4 mm/day), vegetables (252.6 mm/day); peanuts (251.5 mm/day), flowers (84.8 mm/day) and other legumes are crops that use very little water (8.2 mm/day). This is due to the need of sugarcane during the sprouting, tillering and slang periods requiring sufficient water supply for plant growth. In addition, during the peak months of the dry season, evapotranspiration increases, rainwater supply is not enough for crops, so the water demand of plants such as corn, vegetables, etc. also increases. Legumes are a drought-tolerant crop, and their growing time is short, so although they are planted during the peak months of the dry season, the water requirements for their growth are small.

3.3. Assessment of the impact of climate change on irrigation demand in agriculture (until 2035)

According to the 2016 National Climate Change Scenario, RCP 4.5 and RCP 8.5, in the period 2016-2035 in Lam Dong Province, climate factors will change, namely the increase in temperature and rainfall compared to with the 2015 period as follows:

The change in temperature and rainfall in 2035 compared to 2015 under the climate change scenario in 2016 is as follows:

Table 4. Changes in temperature and precipitation according to climate change scenarios 2016

	Month	RCP 4.5 scenarios		RCP 8.5 scenarios	
		Temperature	Precipitation	Temperature	Precipitation
Dry season	5-10	0.7 (0.4 to 1.2)	3.9 (1.0 to 6.8)	0.9 (0.4 to 1.2)	4.7 (0.6 to 8.9)
Rainy season	11-4				

Assuming the humidity, number of sunny hours, wind speed in the middle of the 21st century, there is no change, only the increase in temperature, the result of calculating the standard surface evaporation of ET 0 (mm/month) according to CROPWAT software are shown in the table below.

Table 5. Calculation results of ET_0 in 2035

	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Average year
ET_o	RCP 4.5	5.53	4.02	3.84	3.92	3.71	3.38	3.18	3.10	3.11	3.02	3.18	3.26	3.60
	RCP 8.5	3.55	4.04	3.86	3.94	3.73	3.39	3.20	3.12	3.12	3.04	3.20	3.28	3.18

Climate change causes rainfall in 2035 to change. Therefore, the effective rainfall will also change accordingly as shown in the table:

RCP 4.5 Scenarios

The results of calculating the average amount of water needed for irrigation over months, forecasted to 2035, according to RCP 4.5 scenario of the 2016 climate change scenario using CROPWAT software are shown in the following table:

Calculation results from CROPWAT software under under RCP 4.5 scenario show that the total amount of water needed for irrigation has decreased slightly compared to 2015. Specifically: Sugarcane still needs water. Irrigation is highest among the remaining crops, with irrigation demand (426.9 mm/day), followed by peanuts (278 mm/day), followed by corn (269.7 mm/day), vegetables (240 mm/day), flowers (106.9 mm/day), and finally the highest drought tolerance is bean plants, with irrigation demand (13.8 mm/day). However, the irrigation demand of peanuts increased sharply from 251.5 mm/day to 278 mm/day.

Table 6. Results of calculating effective rainfall in 2035

	P_{eff} (mm)	
Month	**RCP 4.5**	**RCP 8.5**
I	12.5	13.3
II	23.1	23.8
III	68.3	68.9
IV	129.9	130.2
V	143.5	143.7
VI	138.7	138.9
VII	144.9	145.1
VIII	148.9	149.1
IX	153.2	153.3
X	150.2	150.3
XI	85.6	86.2
XII	34.5	35.2
Year	1.104,3	1237.9

Table 7. Calculation results of the average amount of water needed for irrigation over months under RCP 4.5 scenario using CROPWAT software

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	The amount of water needed for irrigation (mm)											
Corn	126.2	76.6	0	-	-	-	-	-	-	-	0	66.9
Bean	-	-	13.8	0	0	0	-	-	-	-	-	-
Peanut	111.4	106.8	31.6	0	-	-	-	-	-	-	-	26.3
Vegetable	82.8	95	35.9		--	-	-	-	-	-	-	27.3
Sugarcane	127.2	116.7	83.6	18	2.3	0	0	0	0	0	2.6	75.3
Flower	15.2	29	45.8	16.9	0	0	-	--	-	-	-	-

RCP 8.5 Scenarios

The results of calculating the average amount of water needed for irrigation over the months to 2035 under RCP 8.5 scenario using CROPWAT software are as follows:

Table 8. Forecast of average amount of water needed for irrigation by months of 2035

Unit: mm/day

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	The amount of water needed for irrigation (mm)											
Corn	126.2	76.4	0	-	-	-	-	-	-	-	0	66.8
Bean	-	-	13.9	0	0	0	-	-	-	-	-	-
Peanut	83	106.7	31.6	0	-	-	-	-	-	-	-	7.5
Vegetable	82.6	94.8	35.9		--	-	-	-	-	-	-	26.2
Sugarcane	127.2	116.6	83.8	18.3	3.7	0	0	0	0	0	2.6	75.3
Flower	15.4	27.5	45.7	17.7	0	0	-	--	-	-	-	-

4. Conclusion

It is forecast that by 2035, the temperature increase will be about 0.4-120C. As the temperature increases, the potential evaporation of ETo increases, resulting in a corresponding increase in irrigation water demand for crops; by 2035, the total demand for irrigation water for these crops will increase by about 4% compared to 2015; except for some drought tolerant plants like sugarcane. The demand increases mainly on crops that need frequent irrigation because these crops are grown in the dry season, when the temperature increases, the amount of evaporation increases; therefore the irrigation demand also increases.

The locality should have an agricultural development plan to adapt to the climate change context. Strengthening the monitoring and early warning system of drought phenomena. In the future, a monitoring system for drought and climate change must be established. Planning on small and medium-sized irrigation development, applying traditional and modern measures to use water effectively such as water-saving irrigation technology (drip irrigation, rain spray, local underground irrigation...) applied to areas where conditions for high technology application in agricultural production such as areas specializing in vegetable and flower cultivation.

Climate change can affect crop coefficients, increasing temperatures can lead to reduced plant growth time. However, the study did not mention these factors, but the results of assessing changes in irrigation demand were mainly based on changes in temperature, rainfall in the future (climate change scenarios, RCP 4.5 and RCP 8.5). Therefore, the research results of this topic only assess the impact of climate change on agriculture in a small aspect but have not yet mentioned all other impacts on crops, so it is expected that in the future there will be full of necessary data to meet the research process better.

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