Climate Change and Water Resources: Renewal Of Crops Water Requirements In Egypt

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Abstract-Agriculture in the Egypt is responsible for the major share of the country's total water consumption (83%). It therefore plays a key role in economy (26%), labor market (33%), demography, and dominates water resources. However, maintaining enough water for agriculture with reasonable quality will be increasingly difficult due to population growth, climate change, and competition with other activities (industries, urbanization, etc.). And, because of the lack of a uniform and consistent reference to crops' water consumption; a national water requirements database was established. The process faced several difficulties including: wide agro-climatic regions, variant ETovalues,numerous crop varieties, in addition to climate change, and dynamic cropping pattern based on free marked needs.
This research aims at unifying and updating the national database on crops water consumptions (CWC) and water requirements (practical WR) through: 1) Tracing misleading and errors in water requirements predictions by statistical and causal analysis on prediction equations' parameters, 2) Renewing WR overall the climatic Agro-Ecological zones by applying modeling techniques, and 3) Predicting the most probable scenarios for water availability, cropping pattern, and crop-productivity.
The assignment combined the well-known bio-physical agricultural models, and statistical causal analysis framework to assess productivity and water requirements over the national level,regarding theclimate change vulnerability concepts.
The study anticipated climatic negative impactson the crop-productivity summarized as a decrease in productivity of: rice by about 11%, soybeans by (28%), maize by (19%), wheat by (28%), and barley by (20%).
The study also anticipated an increase in water consumption reflected as: rice by 16%, soybeans by 15%, and maize by 8%, while wheat and barley's consumptions will decrease by 1% and 2% respectively.

I INTRODUCTION

Agriculture in the Egypt isresponsible for the major share of the country's total water consumption (83%). It thereforeplays a keyrole in economy (26%), labourmarket (33%), demography, and dominates water resources. However, maintaining enough water for agriculture with reasonablequality willbeincreasinglydifficult due to population growth, climate change, and competitionwithotheractivities (industries, urbanization, etc.). And, because of the lack of a uniform and consistent reference to crops' water consomptions; a national water requirementsdatabase was established. The processfacedseveraldifficultiesincluded: wide agro-climaticregions, variant ETo values due to variant predicting techniques, numerous crop varieties, in addition to stresses due to climatic changes, and dynamiccropping pattern based on free marketneeds. This resulted in difference in the estimated"*Crop Water Consumptions*" (CWC), according to official data source and estimation techniques.

1.1 StudyProblem and Objectives

It turns out that the lack of a standardizedand unified referencecrop-water consumptions/requirementsin Egypt is a major problemfacing water management, distribution, and planning. Scientifically;a standard basisisessential forlong-term and short-termplanning of water resources in the light of availability and vulnerability.In addition itis essential for predictiveagricultural capacitystudies, andfor prediction of future requirements and agricultural expansion planning on the national level.

1.2 Variance in evapotranspiration values "ETo"

As a start,variousavailable data fromdifferent sourcesshowedsignificantdifferencesbetween the moral estimatedcrop-water consumptionvalues, whichwhen was deeplystudiedrevealedthe following:

- First, variance in referenceevapotranspiration values "ETo", within 15%.
- Difference in ETo is due to varianceof calculationmethods and estimatingmodels.
- Differencein "ETo"maybeillustratedalsoby variance in calculationperiods.
- Cleardifferencesemerged in "ETo" valuesdue toundergoneseveralAgro-climatic zones.

In thiscontext, the visionwas to unify"ETo" valuesuponagreedregions (ACZs), sothatwecanunify the foundations of estimating water consumption on the national level, what was of most importancefor the National Committeeon Water Consumptions.

1.3 Variancein Crop Coefficient "Kc"

Crop coefficient "Kc" values variedamong the relevant authoritiesup to 40%, resulted in significantdifferencesin estimated water consumption. Possible reasonswerestudied as following:

1. Although of availabilityof actualconsumption values for cropsin the most of agronomystudies and reports, therewas a lack of unified and standardizedmethod for estimatingKc and ETo; due to severalreasons:using severalmethods, and/or adoption of the averagesKcvaluesignoringthe growthstages, or consideringdifferentplanting dates.
2. The greatdiversity of cropvarieties,preventing unification of Kc values for the same single crop [due to quick maturity, and changingof climaticand environmentalconditions].
3. Diversity of the crop coefficient calculationmethods (i.e. adjusted Stage / Kc Curve).

1.4 Climatic Changes

Egyptwillbe one of the mostaffected countries according to numerousscientific reports of "International Panel on Climate Changes". This couldlead to inundationof more than one-third of the Nile Delta as a result of the sealevelrise. According to the hazardestimated; 15~20 million peoples, and 15% of the most fertile agriculturallands maybe vulnerable. In addition possible significantdeclineof water resources is expected. Particularly, agriculture as a basic Egyptianeconomicactivityand societalentitieswill be the most affected(El-Bagoury 2008), and influencemayextends to the regionalcommunitydemographic compositions.BecauseEgypt is located in the arid and fragile environmental area, and dependsmainly on the Nile river, the Egyptian agriculture is particularly sensitive to climate change, in bothwater consumption and productivity as follows:

- Climate Changeswillresult in an increase in temperature and change its pattern (Attaher, and Medany, 2008), which in turn, will affect agricultural productivity, as well as changeenvironmental and agricultural domain.
- Thermal change will affect water resources or alert water bodies threatening, as well as increasewater deficit.
- This will lead to higherevaporation and increaseof water consumption, and perhaps change the physiologicalbehaviour of the plant;
- Climate Changeshave negativeeffects on marginal agricultural areas and increasingdesertification rates (Abou-Hadid, A. F., 2009);
- It has social and economiceffects marginal and coastal areas;
- Potentialriseofsealevel and itsnegative impact on agricultural land in Delta.

II. MATERIALS AND METHODS

Updating of the crops water consumptions (CWC) was assigned to the "National Commission on Water Requirements" to update the national database. The assignment aimed at analysis of sources of the significantdifferences in (CWC), and practical water requirements (WR). Tracing of differences of the main deducing components revealedthat: 15% of differencesare due tovariance in Evapotranspiration (ETo), while 40% are due to variancein crop coefficient; (Kc) in some cases!As this research aims at unifying and updating the national database on crops (CWC) and (WR), and to predict impact of the climatic changes on both WR and productivity, activities were planned to optimize prediction techniques as well as updating agro-climatic zones and database.The study objectives could be summarized into:

- Update"Reference Evapotranspiration" (ETo) due to Climatic Changes
- Update Kc due to the introducedand dominant spices, and determine its data under the "Climatic Changes".
- UpdatingConsumptions (Cu) of AEZ
- Prediction of WB underClimatic Conditions and Development
- Affirmation of water requirements conceptions between MWRI & ARC.

Through the National Commission on Water Requirements assignments; the author, as a leader of working groupe, proceeded to:

1- Reviewed ETodatabase, available from different sources.
2- Evaluate the specific applied ETo and Consumption Prediction methods in relevant institutions.
3- Review and Evaluation of accuracy and conversion of the used Mathematical Models.
4- Recommendand approve of trusted methods for ETo, Kc, and Consumption for all "**AEZ**".

In addition; detailed approaches included explicit findings of the "Climate Change Risk Management in Egypt" mission in land classification and Agro-Ecological zones mapping. These inputs included using the geo-referencing topographic maps. Then land cover maps were produced and considered for the different classes (Alluvial, New agricultural, Natural areas, Coastal development areas, and water bodies). The second action was determination of the Agro-ecological Zones (AEZs) regarding the intersection between the numerous dominant parameters including: hydrological considerations, morphology land cover, soil categories, and evapotranspiration (ET_o) regions (fig. 1). Also Eto and Kc predictors were evaluated and detected to trace the difference source through a causal analysis procedure (fig.2). A comparison between different methodologies was carried out and evaluated through review of several outputs of relevant researches. After all, field trothing investigations, measurements, and data obtained from modelling and relevant research project "Matching between Water Demand and Availability" were used to emphasis the correct values (table 1).

Table 1. Water consomptions for main crops due to update evapotranspiration and Crop coefficient; Kc.

Governorate	**Alex.**	**Dommiat**	**KafrEl Sheik**	**Dakhlia**	**Behira**	**Gharbia**	**Ismailia**
Crops	**Seasonal Etc**	**Seasonal ETc**	**Seasonal ETc**	**Seasonal ETc**	**Seasonal ETc**	**Seasonal ETc**	**Seasonal ETc**
Wheat	472.35	464.86	446.85	505.31	525.3	517.32	629.45
Cotton	896.47	893.84	885.03	955.44	975.41	969.12	1054.96
Sugar cane	1072.48	1055.41	1063.45	1136.09	1187.37	1167.29	1357.57
Rice	807.07	777.81	774.42	829.47	844.96	839.1	926.63

The specific activities: 1) Tracing of misleading and errors' sources in the water requirements predictions (and prediction equations') by using statistical approaches and causal analysis, 2) Refining the Agro-Ecological zones, 3) Renewing WR overall the climatic Agro-Ecological zones by applying modelling techniques, and 4) Predicting the most probable scenarios for water availability, cropping pattern, and productivity.

According to the research objectives; all the available database of evapotranspiration (for the agro-ecological zones AEZs), and crop coefficients (for the dominant crops) were reviewed and assessed (F. Khalil, et. all, 2012). Some of the databases were updated than others while some were distributed in accordance to different "AEZs"! Thus; the commission had to re-predict the required parameters to assure the desired consumption values basically in regard to fundamental dominant parameters (i.e.; ETo and Kc). The given figures below reveal the variance between several databases regarding ACZs (see fig. 1), and some of the prediction methods (see fig. 2, and 3).

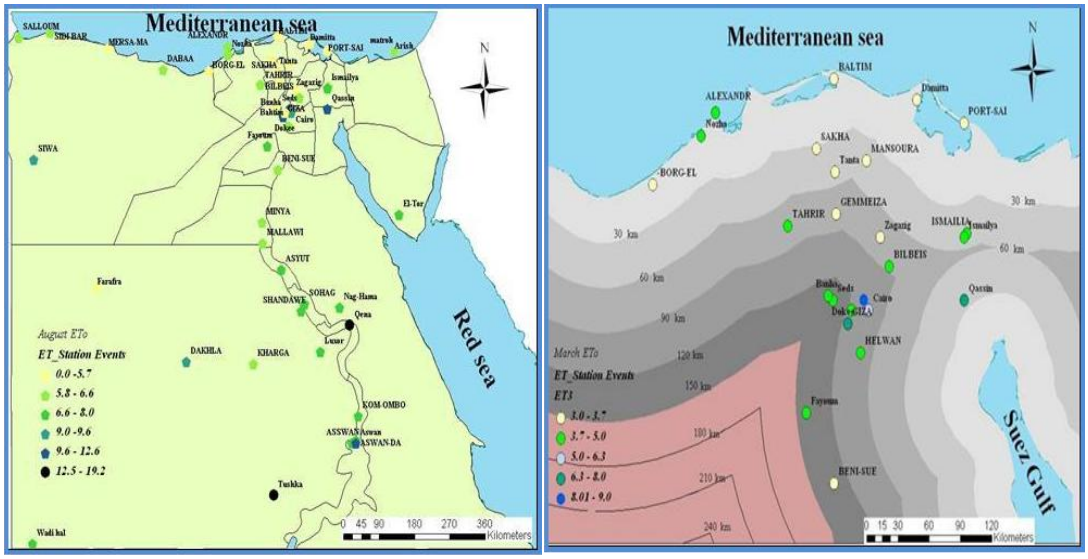


Fig. 1a, B. Agro-Climatic Zones Due To GIS And Graphicalmethods.

III. RESULTS AND DISCUSSION

In general the project specific outputs could be summarized into:

- Unify the national Agro-Climatic Zones based on reasonable criteria.
- Update of **ETo** due to Climatic Changes
- Update of**Kc** due to Climatic Changes
- Updating Consumptions (**Cu**) of **AEZ**
- Prediction of **WB** under Climatic Conditions and Development

First of all, as a basic foundation for crop-water consumption, the national Agro-Climatic Zones were unified based on hydrological and *ETo* determinates, applying GIS zoning multi criteria[1], to enable a unified and trust consumption prediction. Fig. 1, c presents the main Egyptian Agro-Climatic Zones.

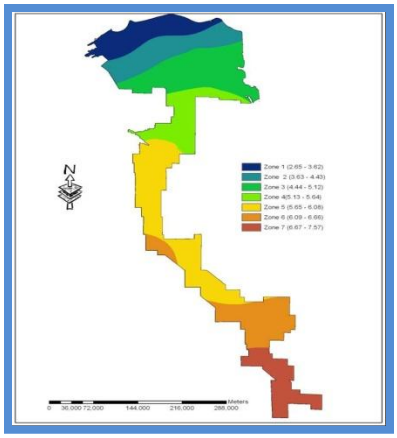
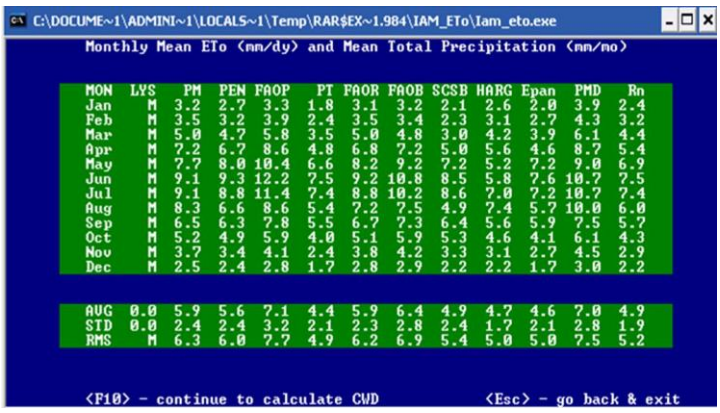


Fig. 1, C; The Main Egyptian Agro-Climatic Zones

Evapotranspiration (ETo) and crop coefficient (Kc) were updated through several stages due to the research outputs and regarding the "Climatic Changes" predicted through the mission activities. Renewal of the evapotranspiration reference coefficient had been achieved by applying the most common and confident models likewise "IAM BariETo" Model, "FAO ETo Calculator", and "ICARDA ETo Tool" (see runs' results fig. 2a, b, c).



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Monthly Mean ETo (mm/dy) and Mean Total Precipitation (mm/mo)

MON	LYS	PM	PEN	FAOP	PT	FAOR	FAOB	SCSB	HARG	Epan	PMD	Rn
Jan	M	3.2	2.7	3.3	1.8	3.1	3.2	2.1	2.6	2.0	3.9	2.4
Feb	M	3.5	3.2	3.9	2.4	3.5	3.4	2.3	3.1	2.7	4.3	3.2
Mar	M	5.0	4.7	5.8	3.5	5.0	4.8	3.0	4.2	3.9	6.1	4.4
Apr	M	7.2	6.7	8.6	4.8	6.8	7.2	5.0	5.6	4.6	8.7	5.4
May	M	7.7	8.0	10.4	6.6	8.2	9.2	7.2	5.2	7.2	9.0	6.9
Jun	M	9.1	9.3	12.2	7.5	9.2	10.8	8.5	5.8	7.6	10.7	7.5
Jul	M	9.1	8.8	11.4	7.4	8.8	10.2	8.6	7.0	7.2	10.7	7.4
Aug	M	8.3	6.6	8.6	5.4	7.2	7.5	4.9	7.4	5.7	10.0	6.0
Sep	M	6.5	6.3	7.8	5.5	6.7	7.3	6.4	5.6	5.9	7.5	5.7
Oct	M	5.2	4.9	5.9	4.0	5.1	5.9	5.3	4.6	4.1	6.1	4.3
Nov	M	3.7	3.4	4.1	2.4	3.8	4.2	3.3	3.1	2.7	4.5	2.9
Dec	M	2.5	2.4	2.8	1.7	2.8	2.9	2.2	2.2	1.7	3.0	2.2
AVG	0.0	5.9	5.6	7.1	4.4	5.9	6.4	4.9	4.7	4.6	7.0	4.9
STD	0.0	2.4	2.4	3.2	2.1	2.3	2.8	2.4	1.7	2.1	2.8	1.9
RMS	M	6.3	6.0	7.7	4.9	6.2	6.9	5.4	5.0	5.0	7.5	5.2

<F10> - continue to calculate CWD <Esc> - go back & exit

Fig. 2-A; IAM Bari Program: "***Eto***" For Middle Egypt Region.

[1] Final Report On: Description of Agro-ecological Ecosystems of Egyptian Agriculture; LOA-10 Under Project UNJP/EGY/022-LOA-10, "Climate change risk management in Egypt", May 2011

Fig. 2-B; FAO ET0 Calc. Results:ET0 Values Jan. To June "***Eto*** Middle Egypt Region".

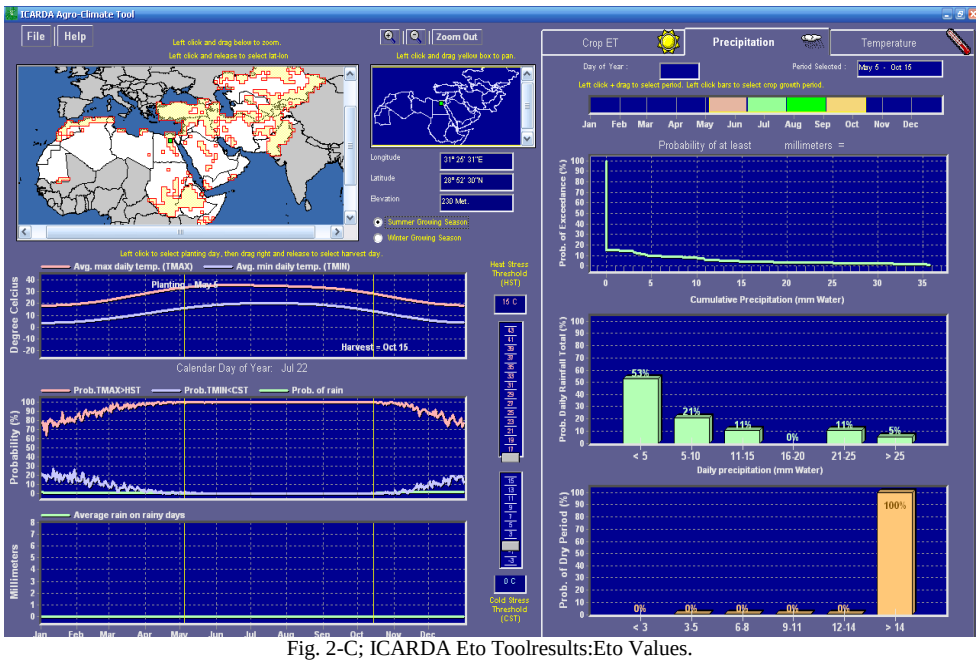

Fig. 2-C; ICARDA Eto Toolresults:Eto Values.

Both biophysical experimental researches and models were employed to predict the actual update Kc values due to current conditions and future climatic changes, regarding variance of consumptions (Cu) over the "AEZ". Crop coefficientswereupdatedusingdedicated bio-physical model (BISm UC DAVIS), and resultsof Kc updatingare presented in Table2.

Table 2; Updated Kc values for Alexandria Province; using BISm Model.

Crop	Planting date	Harvest date	Growth stages					Kc/stage				
			A	B	C	D	E	A	B	C	D	E
Wheat	15- Nov	1-May	15- Nov	18-Dec	29-Jan	21-Mar	1-May	0.37	0.37	1.1	1.1	0.55
Clover	1-Nov	10-May	1-Nov	18-Dec	4-Feb	24-Mar	10-May	0.57	0.57	1.15	1.15	0.8
Sugar beet	15-Nov	15-May	1-Sep	19-Sep	18-Oct	15-Jan	1-Mar	0.36	0.36	1.15	1.15	0.95
Cotton	15-Mar	21-Sep	15-Nov	12-Dec	4-Feb	9-Apr	15-May	0.32	0.32	0.95	0.95	0.5
Sugar cane	1-Feb	31-Jan	15-Mar	12-Apr	1-May	24-Aug	21-Sep	0.45	0.45	1.25	1.25	0.75
Rice	15-May	15-Oct	1-Feb	1-Feb	4-Apr	7-Oct	31-Jan	0.45	0.45	1.25	1.25	0.8
Corn	15-May	1-Sep	15-May	20-Jun	10-Jul	24-Sep	15-Oct	0.26	0.26	1.05	1.05	0.6

ETo sets were updated using the *Crop-MATCH* model, developed by the author. Adjustments of Kc were carried out by applying (BISM) model and verified through experimental researches findings (fig. 4). According to the obtained result, it was available to predict both of the (CWC) and water budget (WB), estimation of crop productivity under climatic changes (using further bio-physical models like CROP-SYS and SALTMED), then development of the "National crop water consumptions (CWC) and practical water requirements (WR) data base.

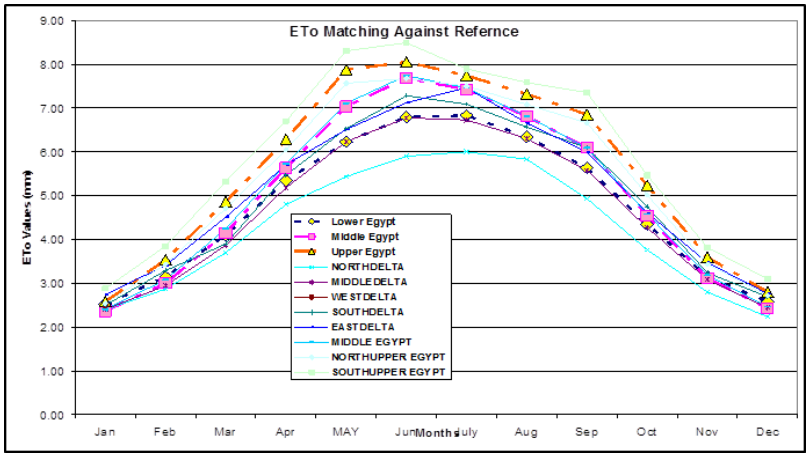

Fig. 3; Tracingetovariance Overall Egypt Aczs (NWRC).

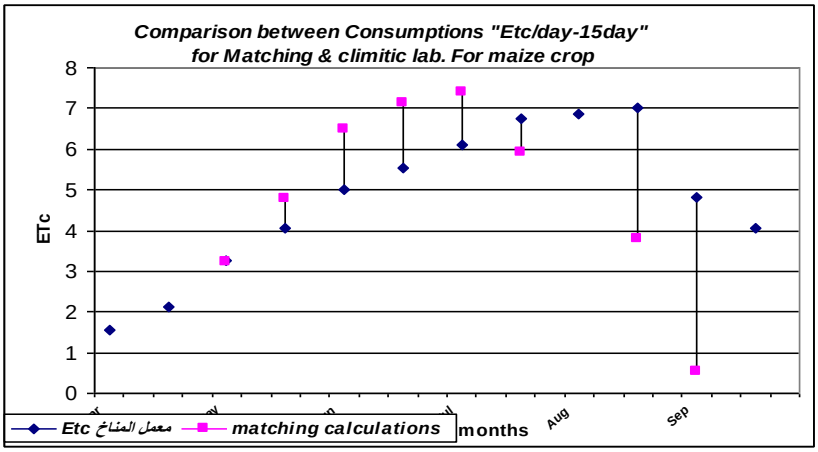

Fig.4;Comparing ***Etc***according To (ARC, & NWRC, MWRI,), For A Sample Crop (Maize).

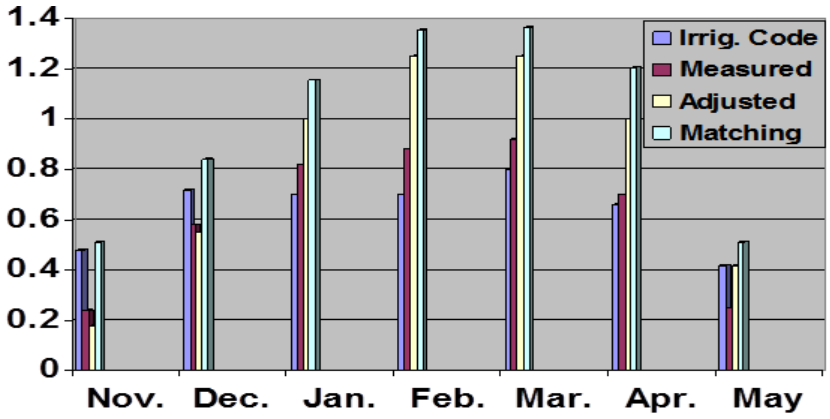

Fig. 5. Justification Of The Crop Coefficient According To Multicriteriaprocess.

IV. CONCLUSIONS

The study yielded an updated and renewed ETo values for the unified standard Egyptian ACZs, and unified updated Kc database for the dominant crops. The study anticipated a climatic impact summarized as a change of the ago-climatic zones due increase of temperature and change of its trend, in addition to increment in (CWC) and reduction in crops' productivity, decline of water resources, as well as hazard to Delta Region due to sea water rise. Predicted decrease in productivity of the major crops can be expected as: rice by about 11%, soybeans by (28%), maize by (19%), wheat by (28%), and barley by (20%). The study also anticipated an increase in water consumption reflected as: rice by 16%, soybeans by 15%, and maize by 8%, while wheat and barley's consumptions will decrease by 1% and 2% respectively. In addition, it became available an affirmed and unified "Water Requirements" conception between MWRI & ARC, with a database for the climatic changes impacts and vulnerability.

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