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# Crop Index anticipation using rainfall analysis over Matruh location

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**SUMMARY –** The prediction of Crop Index (CI) is very important because it leads to knowing whatever the crop production is good or not before starting the date of sowing. It is assumed that Matruh location is characterized by a growing season for some crops shorter than 150 days and generally sowing takes place when 20 mm of rain has fallen during a single decade. This paper discuses the CI for a sorghum crop and its sowing under rainy condition. The Index begins at 100 and is reduced in 2 ways. First, if there is a surplus (S) of greater than 60 mm (field capacity) then the Index is reduced by 3 units. Second, if there is a deficit (D), the Index is reduced by the percentage of this deficit in relation to the total WR for the season. Daily rainfall, mean air temperature, mean relative humidity and mean wind speed data of Matruh location are used during the period from 1973 to 1995. Using INSTAT6 Software, (Reading University, UK), rainfall analysis is performed to determine in which decade through rainy season the sowing can be started, and also to estimate potential evaporation ($P_E$) for each decade during rainy season. CI was calculated using amount of rainfall, $k_c$ and $P_E$ for each decade. Relations between sea surface temperatures and crop-monitoring index were performed. A group of CI prediction models were obtained.

**Key words:** Crop index, soil moisture, sowing, sorghum, sea surface temperature, forecast.

***RESUME –*** *"L'anticipation des récoltes à l'aide d'un indice utilisant l'analyse des précipitations dans la zone de Matrouh". La mise au point d'un indice pour la prévision des récoltes est très importante, car ceci nous permet de savoir si la production des récoltes sera bonne, avant de commencer à semer la terre. Il est bien connu que Matrouh est caractérisé par une saison inférieure à 150 jours, pour certaines récoltes, et généralement les semailles ont lieu lorsque la pluie a atteint 20 mm sur 10 jours. Nous prenons en considération l'indice du sorgho et son semée en conditions pluvieuses. L'indice commence à 100 et décroît de 2 façons : premièrement, en cas d'un excédent supérieur à 60 mm (capacité du champ), l'indice sera réduit de 3 points. Deuxièmement, s'il y a un déficit, l'indice est réduit du pourcentage de ce déficit par rapport au besoin total en eau pour la saison. Les informations concernant les précipitations journalières, la température moyenne, l'humidité relative moyenne et la vitesse du vent, obtenues à partir de la station météorologique mondiale pour la période de 1973 jusqu'en 1995 sont utilisées. En utilisant le programme INSTAT6 (Université de Reading) nous présentons les analyses des précipitations pour déterminer à quel moment de la saison des pluies nous pouvons commencer les semailles, ou encore pour estimer l'évapotranspiration potentielle pour chaque période de dix jours durant la saison des pluies. L'indice de prévision des récoltes est calculé en connaissant la quantité de pluie, de récoltes et l'évapotranspiration potentielle pour chaque tranche de dix jours. Les relations entre les températures de la surface de la mer et la surveillance de la croissance des récoltes cultivées sur une période de 90 jours, sont présentées. On a obtenu les modèles de prévision d'un groupe de récoltes en utilisant la régression multiple comprenant stepwise et la validation sur la base du programme SYSTAT.*

***Mots-clés :*** *Indice des récoltes, humidité du sol, semée, sorgho, température de la surface de la mer, prédiction.*

## Introduction

The long-range forecast of CI (Crop Index) is a very important subject nowadays. So it may be appropriate to conclude an early warning system for CI. The CI based on a water balance is calculated using actual precipitation and estimated $P_E$ using Penman's method formula. The index is used for a early warning system in a number of countries. The CI is calculated from the difference between the actual precipitation and the crop water requirement (WR). The latter are calculated using crop water coefficient ($K_c$) and potential evaporation ($P_E$). Since the beginning of the last century, scientists have been engaged in studies related to the influence of sea surface temperature (SST) on global climate variability.

Much of the research has centered on the tropical Pacific, where discoveries on the patterns of both SST and pressure have led to the El Niño-Southern Oscillation (ENSO) phenomenon. While the impacts associated with ENSO events are believed to girdle the globe in the tropics, some schools of thought also believe that local oceanic characteristics have more influence over the climate of some regions than ENSO. It is in line with this opinion that the relationships between Equatorial Atlantic Temperature (EAT) and seasonal rainfall amount on one hand and with expected CI, on the other hand are being examined in the Guinea Coast region bounded by latitude 10º N southward to the coast and longitude 7.5º W to 7.5º E. The relationship of this region to EAT has been demonstrated in Ward *et al.* (1990), Janicot (1992) and Rowell *et al.* (1995).

These studies provide SST-atmosphere diagnostic results and modeling results that give confidence in the existence of a real physical relationship between EAT and the mean of July, August and September (JAS) rainfall in the region. This underpins and justifies the more detailed statistical examination undertaken here for smaller space scales, month-by-month resolution of the relationships and ultimately, to the output from a crop model, which will incorporate indications of whether the likelihood of dry spells (that damage crops) may also be predictable.

## Data and methods

### Rainfall data

Daily rainfall data for Matruh location during the period 1973-1995, normal of maximum, minimum temperature, maximum, minimum relative humidity and sunshine duration (daily, ten days or monthly mean) were used in this study.

Sea surface temperature data are especified in Table 1.

Table 1. Type, domain, source, period and format of SSTs

| Type | Domain | Source† | Period | Format |
|---|---|---|---|---|
| Indian Ocean | -15ºS - 20ºN ; 40ºE - 60ºE | UKMO | 1925-1995 | Seasonal |
| Mediterranean Sea | 30N - 40N ; 5ºE - 35ºE | UKMO | 1925-1995 | Seasonal |
| Red Sea | 15ºN - 30ºN ; 30ºE - 45ºE | UKMO | 1925-1995 | Seasonal |
| Equatorial Atlantic | 0ºS - 10ºS ; 20ºW -10ºE | UKMO | 1925-1995 | Seasonal |
| El Niño3 | 10ºS - 10ºN ; 150ºW - 90ºW | UKMO | 1925-1995 | Monthly |

† UKMO = United Kingdom Meteorological Office.

## Methods

Considering that, a sorghum crop has a 90-day season period and $K_C$ was 0.3, 0.4, 0.5, 0.7, 0.9, 1.0, 0.9, 0.6, 0.5 for the different decades of sorghum growth (Stern *et al.,* 1996). Considering also the actual start of the rainy season and the sowing of the sorghum crop, according to the following conditions:

(i) The first occasion is with more than 20 mm in 1 or 2 days after first September.

(ii) The first occasion after first September, sum of 10 days total rainfall exceeds half the evaporation.

(iii) The first occasion that the 7 day totals exceeds 25 mm and includes at least 4 rainy days.

Then, the steps of the analysis leading to the CI were as follows:

(i) The sowing date follows the definition "the beginning of the first decade after the first of September, with precipitation greater than or equal to 20 mm".

(ii) The total WR in each decade is given by multiplying the $P_E$ by $K_C$.

(iii) The difference between the actual rainfall and WR is calculated and added to the existing reserves in the soil. These reserves cannot go above the maximum water holding capacity, nor can they become negative.

(iv) Multiple regressions were performed between obtained crop monitoring index and seasonally SST.

## Results and discussion

Using INSTAT6 software and available daily rainfall data for Matruh location we obtain, the amount of rainfall (mm) per decade for all studying years as follows in Table 2.

Table 2. Selected periods of total rainfall for every decade from rainy season

| Decade | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 0 | 0 | 0 | 4.4 | 0.1 | 1.1 | 0.8 | 0 | 0 | 0 | 15.9 | 7.2 |
| 7 | 23.3 | 0 | 0 | 0 | 8.1 | 7.8 | 5 | 0 | 0.4 | 1.8 | 0.1 | 14.6 |
| 8 | 26.6 | 2 | 0.5 | 0 | 0.2 | 0.6 | 2.1 | 0 | 17.2 | 0 | 15.7 | 0 |
| 9 | 9.6 | 5.5 | 4.1 | 5.1 | 0 | 30.5 | 20.5 | 0 | 0.8 | 6.1 | 0.3 | 6.9 |
| 10 | 0 | 37.8 | 11 | 0 | 26.4 | 5.9 | 15.7 | 5.6 | 0 | 8.1 | 0 | 27.1 |
| 11 | 6.1 | 3.7 | 0.3 | 0.1 | 76.8 | 0.1 | 27.7 | 23.9 | 0 | 8.9 | 1.1 | 12 |
| 12 | 0.2 | 1.3 | 15.3 | 0.5 | 18.6 | 1.5 | 10 | 2.2 | 0 | 5.7 | 14.5 | 0 |

Generally, the first decade is the first ten days from the month of September, so the decade 6 shown in Table 2 is the last decade for the month of October. The decades 7, 8 and 9 are for the month of November and so on (the analysis of rainfall performed for all decades though all studies years).

Applying the steps which leading to CI, the CI for all years of the study are shown in Table 3.

Table 3. CI during the period of study

| Years | CI | Years | CI | Years | CI | Years | CI |
|---|---|---|---|---|---|---|---|
| 1973 | 60 | 1974 | 100 | 1975 | 52 | 1976 | 26 |
| 1977 | 70 | 1978 | 68 | 1979 | 56 | 1980 | 59 |
| 1981 | 44 | 1982 | 67 | 1983 | 85 | 1984 | 36 |
| 1985 | 61 | 1986 | 64 | 1987 | 66 | 1988 | 75 |
| 1989 | 77 | 1990 | 87 | 1991 | 91 | 1992 | 100 |
| 1993 | 81 | 1994 | 96 | 1995 | 26 | | |

The results of multiple regressions between CI of sorghum crop for each year during the period of study (predictors) and seasonally SST (predictors, for the seasons MAM, AMJ, MJJ, JJA, JAS, ASO and SON) are shown in Table 4. Multiple regressions (Mult. R), coefficient of determination ($R^2$), probability of t (Prb.T) and skills of concluded models are shown in Table 5.

## Discussion

Data analysis shows that, the CI was correlated with Indian Ocean (INDA), Mediterranean Sea (MEDS) and NIN3. These correlations are positive and oscillating from 0.3 to 0.4 for seasons MAM, AMJ, MJJ. But for the seasons JJA, JAS, ASO and SON, CI was correlated with INDA and MEDS with positive correlation ranged from 0.3 to 0.6. Model (1) from Tables 4 and 5 can be used to predict CI after completing the month of September. The results of these computations of correlation coefficient between forecasted and actual CI is 67%. Also, we can use Model (2) to predict CI after completing the month of October, and the correlation coefficient between forecast and actual CI is 74%. From the mentioned tables, the Model (3) could be used to predict CI after completing the month of November where the correlation coefficient between forecast and actual CI is 70%. The Model (4) is used to predict CI after completing the month of June where the correlation coefficient between forecast and actual CI is 62%. Eventually, Model (5) is used to predict CI after completing the month of June where the correlation coefficient between forecasted and actual CI is 53%. The results of computation show that, the skills of the five predicted models are 39, 54, 27, 42 and 34 respectively, shown in Table 5.

Table 4. Models for different season, probability of coincidence (POC), probability of detection (POD), hit score and false alarm rate (FAR)

| Model | POC | POD Poor | POD Good | Hit Score | FAR Poor | FAR Good |
|---|---|---|---|---|---|---|
| (1) CI = 58+35.3INDA+29.1MEDS+25.7REDS-1NIN3 (JAS) | 50 | 57 | 43 | 25% | 20% | 14% |
| (2) CI = 68.8+27.7INDA+28MEDS-1.6EQA-0.95NIN3 (ASO | 40 | 43 | 29 | 10% | 40% | 17% |
| (3) CI = 71.2+43.5INDA+34.3MEDS-2.2EQA-1.2NIN3 (SON) | 40 | 29 | 43 | 10% | 25% | 29% |
| (4) CI = 69.05 + 21.6*MEDSMAM + 1.39*NIN3MAM | 50 | 57 | 29 | 25% | 00% | 25% |
| (5) CI = 51.92 + 17.2*MEDSAMJ + 13.3*4NIN3AMJ | 50 | 43 | 57 | 25% | 25% | 13% |

Table 5. Evaluation of models for different seasons after cross validation

| Model | Mult. R | $R^2$ | Prb.T | Skill |
|---|---|---|---|---|
| (1) CI = Constant+INDA+MEDS+REDS+1NIN3(JAS) | 0.67 | 0.45 | 0.05 | 39% |
| (2) CI = Constant+INDA+MEDS+EQA+NIN3(ASO) | 0,74 | 0.55 | 0.01 | 54% |
| (3) CI = Constant+INDA+MEDS+EQA+NIN3(SON) | 0.70 | 0.49 | 0.03 | 27% |
| (4) CI = Constant+MEDSMAM+NIN3MAM | 0.62 | 0.39 | 0.02 | 42% |
| (5) CI = Constant+MEDSAMJ+4NIN3AMJ | 0.53 | 0.28 | 0.06 | 34% |

## Conclusion

The possibility of using SST to forecast CI in Egypt has been explored. We find that there is a mixture of the predictor's effect on the CI in Egypt. There is a good relationship between CI and Indian Ocean, Mediterranean Sea , Niño3 and Equatorial Atlantic for seasons June, July and August (JAS), August, September and October (ASO). Also, a relationship between CI and MEDS and Niño3 SST could be observed.

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