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POTENTIAL OF METEOROLOGICAL RESOURCES IN THE MIDDLE EAST COUNTRIES FOR WINTER CROP PRODUCTION

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SUMMARY – The winter crop growing in the Middle East countries are more dependent on meteorological conditions than summer crops. The meteorological conditions for winter crop growing season since 1985 up to now were analyzed. The analysis was done based on the MARS-FOOD archive of meteorological data. The archive contains dekadal meteorological parameters for one degree grid points, which were derived from the global meteorological model of ECMWF (UK). The climatic water balance was used as the main integrated crop growth indicator for this study. As a result it was found that the meteorological situation improved for winter crops than 15-20 years ago within the main crop production areas. The climatic potential productivity shows positive trend, which should lead to higher yield of winter crops in many of the Middle East countries.

Key words: agro-meteorology, climatic water balance, winter crop, Middle East countries

1. INTRODUCTION

Crop production in any region of the World mainly depends on land resource potential, which is predefined primarily by soil fertility and climatic conditions. The climatic and soil limitations for crop production in many cases could be regulated throughout additional financial inputs, which practically are realized throughout adding of fertilizers or throughout constructing of irrigation systems.

The Middle East countries are characterized by semi-arid climatic conditions and low natural fertility of soils. Crop production is adapted to such conditions for maximal exploitation of land resource potential. The most important crops (wheat and barley) are cultivated here during the winter period, when the main part of precipitation takes place. This gives an opportunity to cultivate the crops primarily in rain-fed conditions. But anyway the amount of precipitation in winter is critical for crop cultivation. In these conditions changes in the amount of precipitation from year to year leads to big fluctuations in the crop yield, and affects the stability of main crops production.

Our article is dedicated to the analysis of dynamics of meteorological conditions during the winter vegetative season in the Middle East countries.

2. OBJECT AND METHODS

The potential of meteorological resources was analyzed for winter crop cultivation in the Middle Eastern countries for the area restricted by geographical coordinate 28-38^{0}N and 32-60^{0}E (fig.1).

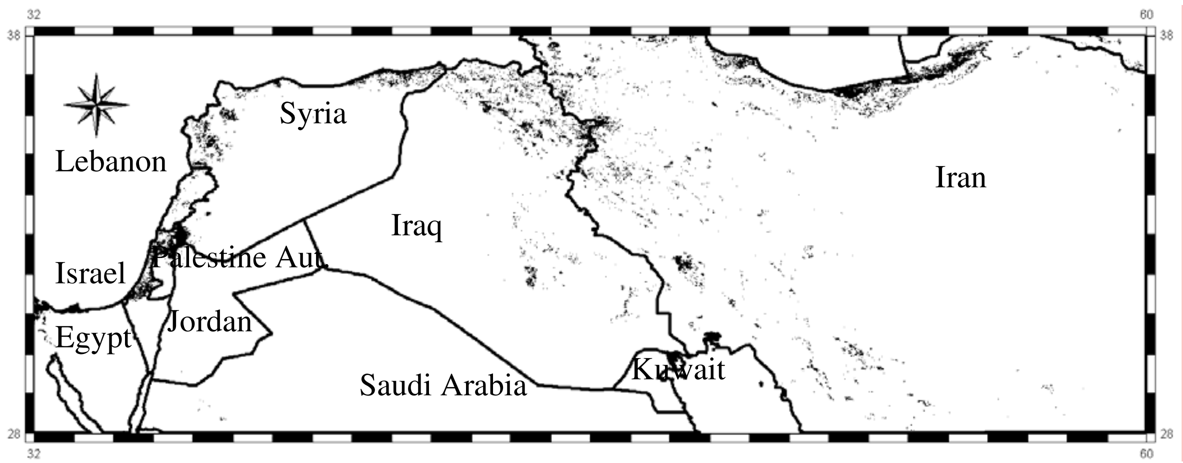

Figure 1. Area under analysis. Black pixels mask regions with winter crops

This area includes all arable lands of Jordan, Iraq, Israel, Kuwait, Lebanon, Palestine Authority, and Syria, main part of arable lands of Iran, and part of arable lands of Saudi Arabia and Egypt. The most significant crops for direct consumption of the population of the region are wheat, rice, and sugar beet (table 1). But the largest part of the last two crops is actually imported. The main forage crop is barley. Due to dry climatic conditions the main food crops (wheat and barley) are produced in these countries during winter when the maximum of precipitation takes place. The winter crop is cultivated mostly in rain-fed conditions. In Israel, Palestine Authority and Syria about 20-30% of winter cereal crops and in Iran and Iraq near half of winter crops are cultivated under irrigated conditions. Practically all winter crops are irrigated in Egypt, Kuwait and Saudi Arabia. Considering the fact that the amount of water for irrigation greatly depends on meteorological conditions it seems possible to say that meteorological conditions during the winter period must have a significant influence on the main food crops production in the countries of the region.

Table 1. Crops distribution and its significance in direct consumption of population in 2000 (FAOSTAT, 2004)

Country	Crop							
	Wheat	Barley	Maize	Millet	Soy bean	Sorghum	Rice	Sunflower	Sugar beet
Egypt	31		16		1	1	12	2	4
Iran	44				4		10	2	5
Iraq	48	3			4		16	1	2
Israel	22		1		6		2	1	11
Jordan	40		2		2		6	2	11
Kuwait	19		3		2		13		11
Lebanon	27		1		4		3	1	5
Palestine Aut.	40		2		2		6	2	11
Saudi Arabia	27		2			3	13		9
Syria	40		1		2		3	1	6

Country	Crop		
	Sugar cane	Rape seed	Potato
Egypt	5		1
Iran	4		3
Iraq	3		
Israel		1	2
Jordan			1
Kuwait			1

Lebanon	4	3
Palestine Aut.		1
Saudi Arabia		1
Syria	5	1

(grey cells – crop is cultivated; blank sells – no crop production; figures inside cells – percent of the crop in the population consumption (calculated based on data about calories per capita per day for 2000), bold figures – production is higher than import, other figures – import is higher, than domestic production, absence of figure indicates that percent is less than 0.5 or equal 0)

A Climatic Water Balance (CWB) was used as a main indicator of the potential of meteorological conditions for winter crops production. The data about CWB for the area under analysis were produced by the ECMWF (UK). The ECMWF (European Centre for Medium Range Weather Forecast) is one of the world's leading numerical modelling centres. It operates a global circulation model and runs 10 day forecasts on it each day. To evaluate the initial state of the atmosphere a data assimilation system is integrating observations from ground stations, radiosondes, satellites and many other sources. Special techniques bring these observations in balance with the meteorological equations to form a physically valid state of the atmosphere (Bouttier, F. & P. Courtier, 1998).

From the raw data meteorological indicators need to be calculated. As meteorological raw data from the assimilation analysis data set are available:

- 2m air temperature (00, 06, 12, 18 UTC),
- 2m dew point temperature (00, 06, 12, 18 UTC),
- u(east)-component of the wind vector 10 m above ground (00, 06, 12, 18 UTC),
- v(north)-component of the wind vector 10 m above ground (00, 06, 12, 18 UTC),
- total cloud cover (00, 06, 12, 18 UTC),
- snow depth (06 UTC),
- 12-hourly cumulated precipitation forecast,
- 36-hourly cumulated precipitation forecast.

From these raw data, derived indicators are being calculated: Minimum, Maximum and Mean Temperature, Precipitation, Global Radiation, Potential Evapotranspiration, and Climatic Water Balance.

Potential Evapotranspiration is calculated with the Penman formula (Penman, 1948). Input parameters are latitude, global radiation, sunshine duration derived from the effective cloud cover, temperature, dew-point temperature and wind speed. The three types of evaporation deviate are calculated by deviating the albedo and the surface roughness: for free water surface, for wet bare soil, and for closed crop canopy.

Climatic Water Balance is calculated as a difference between amount of precipitation and potential evapotranspiration for closed crop canopy.

Field data are delivered by ECMWF in FM92 GRIB code. The GRIB files are first properly stored and archived. Afterwards each GRIB field needs to be investigated by reading the GRIB header which contains information about time, parameter and geographical reference of the field stored in the GRIB body. When this information has been retrieved the values of the field can be decoded and stored in a database for further processing.

After all raw model information is pre-processed the calculation of derived daily parameters takes place. The program first reads all raw model data into the memory for fast processing. Then the derived parameters for every grid point in the requested are calculated.

The meteorological indicators are geo-referenced one degree grid points in geographical co-ordinates with the datum of Greenwich (Latitude/Longitude in degree decimal) in an ASCII text delimited file (Comma Separated Value) (MARSOP-2, 2003).

The MARS-FOOD archive of IPSC, JRC contains the derived meteorological indicators for the region under analysis for the period since 1985 up to now.

The CWB for each grid point was calculated for the “winter” vegetative season (from October to May) for the years from 1985 to 2004 based on dekadal data. Then these values were aggregated for areas with winter crops within the region under investigation. Special crop mask was created for this purposes based on the GLC2000 database (Bartholomé *et al.*, 2002), statistical data and literature search.

The long-term linear trend and common statistical parameters were determined for each grid point. The similarity of the curves of the CWB behaviour was analyzed using the hierarchical clustering approach with Euclidean distances as a main indicator of similarity.

Statistical analysis was conducted using the S-Plus software. The Arc-View GIS was used for the visualization of the results, and for spatial aggregation and interpolation of data. The latter was done based on moving average and ordinary kriging methods.

3. RESULTS

The results of hierarchical clustering analysis allow defining 4 groups of the CWB curves of each grid point. Geographically the groups are distributed as shown on the figure 2. It was found that such subdivision into groups is mainly due to the difference in absolute CWB values and its variability from year to year. The group 1 represents regions with lowest values of the CWB values and with lowest CWB variability from the year to year. The group 4 represents regions with highest CWB values and highest variability of them. Groups 2 and 3 are transitive from group 1 to group 4. Consequently in general the CWB is more favourable for winter crops in group 4, and less favourable in groups 2 and 3 and especially in group 1. But simultaneously this favourability is more unstable in group 4, where CWB values can more rapidly changed from year to year.

Figure 2 shows that regions with CWB curves belonging to the group 1 are situated in the driest zones of the countries. The regions belonging to the group 4 are situated in the Northern Iran and Northern Iraq. The winter crop belt of Syria, Lebanon and Northern Israel belongs to the group 3.

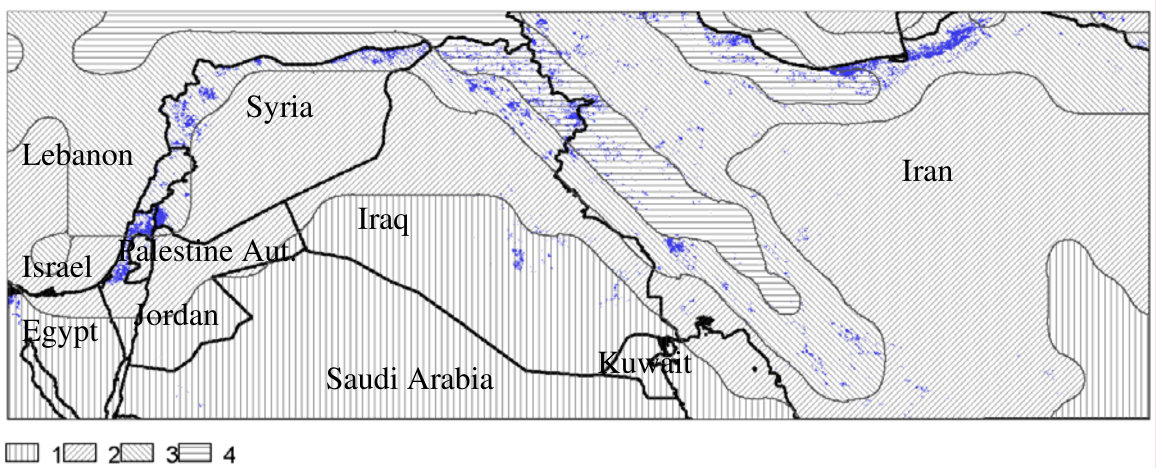

Figure 2. Regionalization of the dendrogram groups of the CWB curves. Coloured pixels mask regions with winter crops

A standard deviation was used as criteria for analysis of the CWB temporal variability during the period under analysis (fig.3). The mountainous and near mountainous regions of Iran and Iraq are characterized by the highest values of the standard deviation of CWB (200-300). The lowest values of standard deviation were observed for the desert regions of Egypt, Israel, Jordan, Iraq and Saudi Arabia.

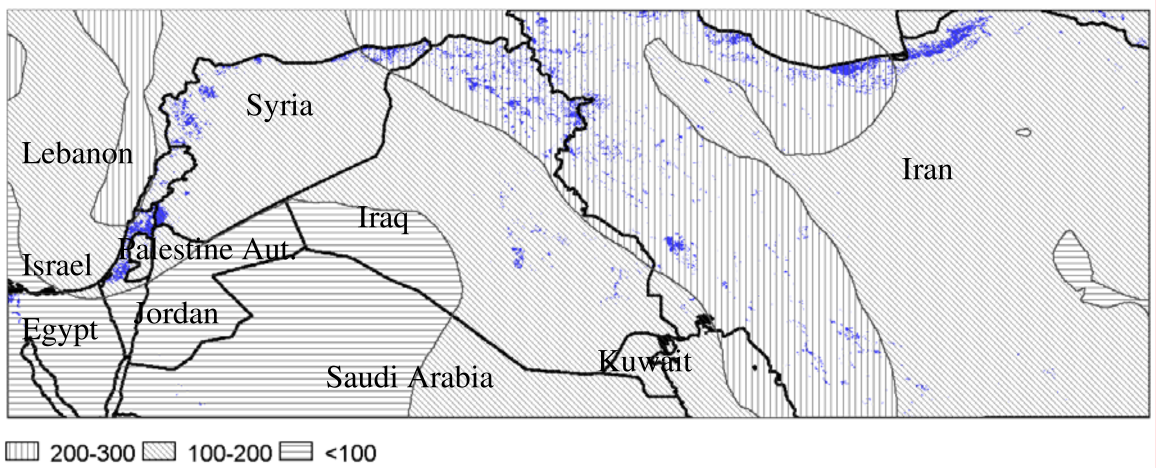

Figure 3. Standard deviation of the CWB. Coloured pixels mask regions with winter crops

The linear trend of the CWB behaviour during 1985-2004 has different slope in different regions (fig.4). Winter crop areas in Eastern Syria, Northern and Eastern Iraq, and Western Iran are characterized by a negative slope of the trend line, which indicates that in general the meteorological conditions here become worse for winter crops. The positive slope of linear trend line is observed for Northern Iran, Western Syria, Lebanon, Israel, Jordan and Palestine Authority (fig.5). Thus, it seems possible to say that for the main winter crop areas the general tendency is an improvement of CWB conditions.

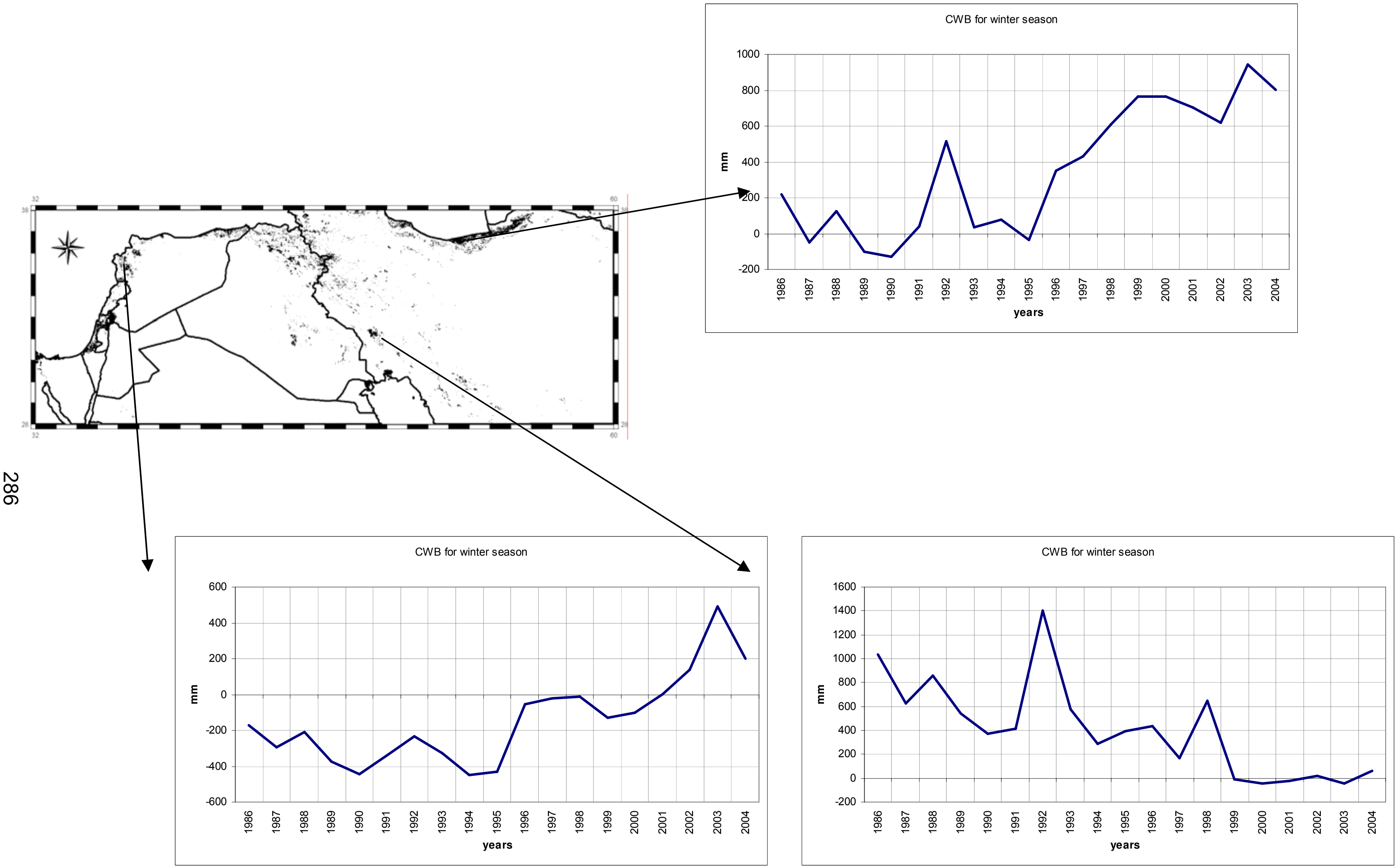

Figure 4. Examples of the CWB long-term behaviour

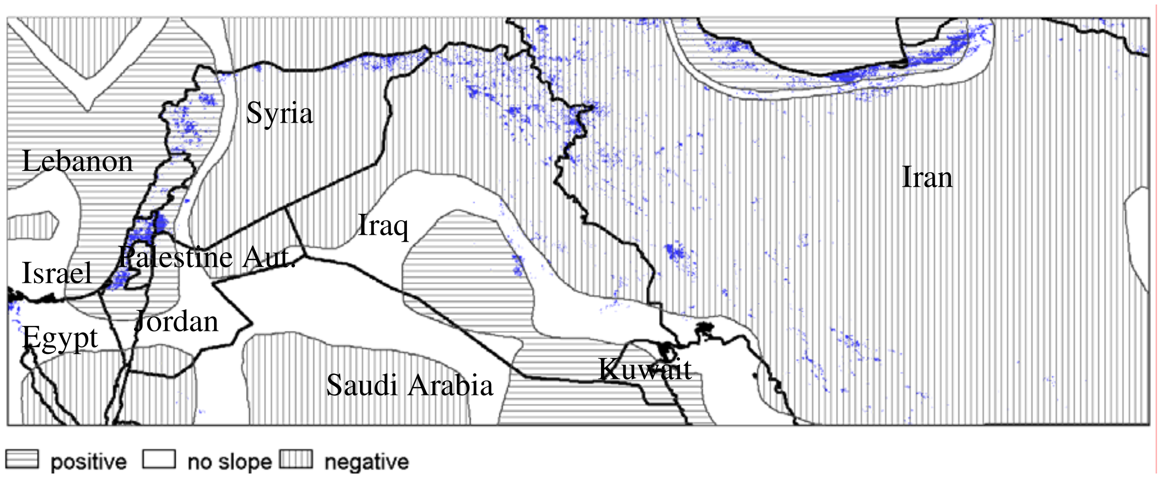

Figure 5. Slope of the linear trend of the CWB behaviour during 1985-2003. Coloured pixels mask regions with winter crops

This general tendency is complicated by year to year variability of the CBW. The aggregated for cropping areas within each country CWB values were analyzed from point of view of such kind of variability. The table 2 contains results of the analysis.

The table shows a dominance of local extremes in some years. For example, local maximums are observed in many countries of the region in 1988, 1992, 1996, 1998, and 2003 as well as local minimums are observed in 1987, 1990, 1994, 1999, and in 2001. A number of exclusions from this general regional tendency exist practically in all countries. But the period between local extremes remains everywhere near 2-4 years.

Table 2. Local minimums (-1) and maximums (1) of the CBW behaviour during 1985-2004

Country	Year																
	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
Egypt		1		-1	1		-1		1	-1	1				-1	1	-1
Palestine Aut.		1		-1		1		-1		1			-1	1	-1		1
Iran	-1	1		-1		1			-1	1	-1	1		-1			1
Iraq	-1	1	-1			1		-1	1		-1	1	-1				
Israel		1		-1		1		-1			1		-1	1	-1		1
Jordan		1		-1		1		-1		1			-1	1	-1		1
Lebanon	-1	1		-1		1		-1		1	-1	1	-1	1	-1		1
Saudi Arabia	-1		1			-1	1	-1	1	-1	1				-1	1	
Syria	-1	1		-1		1		-1		1	-1	1	-1				1

The analysis of the CWB extremes shows that the seasons 2003/2004 and 2004/2005 are likely to be characterized by local minimum in all countries of the region except Egypt, where probability of appearance of local minimum is very low. The probability of appearance of local maximum is low in all countries of the region except Egypt.

4. CONCLUSIONS

Meteorological conditions for winter crop cultivation have a tendency for improvement in the East Mediterranean countries and in near Caspian zone of Iran, which the main part of winter crop sowing area situated.

This general tendency is complicated by meteorological conditions changes from year to year. The amplitude of such changes is the highest for the regions with the most favourable conditions for winter crops and lowest in the arid regions.

More favourable meteorological conditions for winter crops are repeated through 2-4 years. Less favourable conditions are repeated within similar periods. Analysis of the local extremes of the CWB behaviour during last years shows that meteorological conditions during current and next seasons will be less favourable for winter crops than in previous two seasons in most countries of the region.

It seems necessary to stress out that meteorological condition's deviation should mostly affect the yield of winter crops in Lebanon, Syria and Iran where they are cultivated mainly in rain-fed conditions.

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