Climate change in the eastern Mediterranean and agriculture

Jiftah Ben-Asher[1] Fatih Evrendilek[2] Mehmet Aydin[2] Lucas Menzel[3] and Pinhas Alpert[4]
[1]*Jacob blaustein Institute for Desert Research Ben Gurion University of the Negev, Israel*
[2]*Department of Landscape Architecture, Mustafa Kemal University, 31034 Antakya-Hatay, Turkey* [3]*Center for Environmental Systems Research University of Kassel, Kurt-Wolters-Str. 3 34109 Kassel, Germany* [4]*Department of Geophysics and Planetary Sciences, Tel Aviv University, Israel*

1.Effects of CO2 Enrichment Effects on photosynthesis

Natural increase in CO_2 occurred at the end of night respiration and was interpreted as temporal enrichment of greenhouse gas. (Fig 1.)
Figure 1 shows large diurnal variations in CO2. It is a function of the crop , its age and environment. In general, at the end of the respiration period the maximum CO2 concentration was between 450 and 500 ppm and in the grapevine it was 600 ppm (not shown here). Thus it corresponds to almost doubling of CO2. This excess of CO2 was reduced to its normal level 5 hours after the start of photosynthesis. Thus, the crops served as agents for efficient carbon sequestration. The natural Mediterranean forest was kept more stable than the cultivated crops. Overall, the consequences for agriculture would probably be beneficial. There are also, important differences between the photosynthetic mechanisms of different crop plants and hence in their response to increasing CO2. Plant species such as Cotton and Soybean, with the C3 photosynthetic pathway (the first product in their biochemical sequence of reactions has three carbon atoms) use up some of the solar energy they absorb in a process known as photorespiration, in which a significant fraction of the CO2 initially fixed into carbohydrates is reoxidized back to CO2 (1). C3 species tend to respond positively to increased CO2 because it tends to suppress rates of photorespiration. This has major implications for food production in a high-CO2 world because some of the current major food staples, such as wheat, rice and soya bean, are C3 plants. In C4 plants (those in which the first product has four carbon atoms) CO2 is first trapped inside the leaf and then concentrated in the cells which perform the photosynthesis (1). Although more efficient photosynthetically under current levels of CO2, these plants are less responsive to increased CO2 levels than C3 plants. The major C4 staples are maize, sorghum, sugarcane and millet. The C4 crops are largely tropical, and most widely grown in Africa. In on our measured results we found that Dew nights affect positively the agroproductivity. We assume therefore, that CO2 enrichment will benefit humid tropical environment more than that in the semi-arid tropics environment.

2.Effects on water use by plants

There are several contradictory effects of doubling CO2 which, as we show later, happened to be Fig.1. The diurnal course of CO2 concentration in the air. Data are the moving average of four sampling channels . The C4 plant is the corn that shows the strongest gradient at 6 am and reduced to the prevailing concentration in the air at 9 am. The Mediterranean vegetation on the Taurus mountains includes Oak, Pistachio and Pine trees. In terms of diurnal CO2 variations , this is the most stable population which does not creat a strong gradient.complementary in terms of water use efficiency. On one hand, increased CO2 is triggering the closure of stomata. Small openings of the stomata through which CO2 is absorbed is associated with reduced water requirements of plants. Reducing transpiration (per unit leaf area) improves water use efficiency (the ratio of crop-biomass accumulation to the water used in evapotranspiration). A doubling of ambient CO2 concentration causes about a 40 per cent decrease in stomatal aperture in both C3 and C4 plants(2) which may reduce transpiration by 23-46 per cent.(3) This might well help plants in environments where moisture currently limits growth, such as in semi-arid regions, but there remain many uncertainties, such as how much the greater leaf area of plants due to increased CO2 will balance the reduced transpiration per unit leaf area. On the other hand The normalized results in Fig.2a display the lag time between peak photosynthesis and peak transpiration of the dew affected crops (3 crops with 3 replications n=9, 1 s.d. = 0.13). From Fig.2a, maximum photosynthetic rates were measured several hours earlier than maximum transpiration rate which occurred at about 2 pm. Fig 2b shows the actual fluxes of H_2O and CO_2 measured in the cotton field. Separated, early peaks of photosynthesis and late peaks of transpiration are contrary to the expectations described above (i.e. triggering stomata closure). Bearing in mind that the pathway for diffusion of CO_2 into leaves is similar to the pathway for diffusion of H_2O out of leaves the two processes areexpected to be in phase. That is, when water is available, plants show wide stomatal opening for CO_2 intake, but stomata are closed during drought periods, thereby slowing CO_2 intake(5). In Fig 2 however, photosynthesis in the early morning hours was weakly linked to transpiration or not linked at all. We argue here, and later demonstrate it experimentally in Table 1 , that this weak linkage is an inherent part of strategy thanks to the humid environment that is aimed at maximizing water use efficiency which is most important in habitats where water supply is limited. Today, there are increasing evidence(6,7) that in plants under humid environment (i.e. low VPD) the Abscisic Acid (ABA) signal enhance stomatal opening and CO_2 intake for carbon fixation and growth. Inversely, plants growing in arid and semiarid regions may, in response to large VPD, synthesize the hormone Abscisic Acid, which triggers closing of stomata. The presence of dew on the leaves creates temporary humid conditions in the leaf-air boundaries and increase stomata aperture. This is the biochemical basis of the measured exponential increase of stomatal conductance in response to reduction in leaf to air VPD which occurred when dew covered the leaves. The results presented in Fig.2 coincided with this theory. We displayed the normalized hydraulic conductance of the canopy(8,9) as a measure for stomatal aperture.

In summary, we can expect a doubling of atmospheric CO2 concentrations from 330 to 660 ppm under humid conditions to cause increase in growth and yield of agricultural crops. Much depends, however, on the prevailing growing conditions. Our present knowledge is based on a few experiments mainly in semi-arid Seyhan watershed (Turkey) and has not yet included extensive study of response in the field under more humid (winter) or subtropical conditions. Thus, although there are indications that, overall, the effects of increased CO2 could be distinctly beneficial and could partly compensate for some of the negative effects of CO2-induced changes of climate, we cannot at present be sure that this will be so.

3.Effects of Increased Temperatures Effects on yield

Crops in the Mediterranean basin respond to higher temperatures with an increase in yield due to increase in evapotranspiration. Because yield is linearly proportional to evapotranspiration and evaporatranspiration increases with temperature we show in Fig. 3 that yield increases with temperature. The ratio between yield increase and evapotranspiration is the long term expression of water use efficiency. A steep slope of the yield as a function of evapotranspiration indicates high efficiency but in the case of the semi arid Mediterranean the slope obtained from our model shows that wheat yield may increase by 20-25% for respective increase of 2 and 4C while the associated increase in water consumption is 18 and 40%. This increase in water demand along with exacerbated problems of water availability may force out of the cropping systems some valuable crops.

4.Effects on moisture availability

Changes of temperature would also have an effect on moisture available for crop growth, whether or not levels of rainfall remained unchanged. In general, our model show evaporation increases by about 40 mm for each deg.C of mean annual temperature. Thus if mean temperature were to 4 deg.C potential evaporation would increase by about 150 mm (assuming no change in rainfall). According to Fig. 4 the effect of this would be large in the early part of the growing season of the wheat (when water is most important) , bearable from February to March but after mid-April the soil moisture deficit would be considerably larger than at present and actual evapotranspiration would be much smaller than the potential (right side of Fig.4). For some crops, this implies substantially increased demand for irrigation in order to maintain water status that enables potential evapotranspiration. (Fig.5) . Of course, the amount of water available for plant growth is affected by a combination of climatic and non-climatic variables such as precipitation, temperature, sunshine, windspeed as well as soil porosity, slope, etc. Considerations of these variables are beyond the objectives of this paper.

5.Effects of Sea-Level Rise on Agriculture

CO_2-induced warming is expected to lead to rises in sea level. This sea level rise is as a result of thermal expansion of the oceans and partial melting of glaciers and ice caps, and this in turn is expected to affect agriculture, mainly through the inundation of low-lying farmland but also through the increased salinity of coastal groundwater. The IPCC estimate of sea-level rise above present levels under the Business-As-Usual scenario is 9 cm - 29 cm by the year 2030 with a best estimate of 18 cm, and 28 cm - 96 cm by 2090, with a best estimate of 58 cm.(4) .Preliminary surveys of salinity distribution in the Sayhan basin is shown in Fig.6.

The high salinity close to the Mediterranean probably resulted from local inundation. The most severe effects on agriculture are likely to stem directly from inundation. For example, with a 1.5 m sea-level rise, in Egypt, it is estimated that 17 per cent of national agricultural production and 20 per cent of all farmland, especially the most productive farmland, would be lost as a result of a 1.5 m sea-level rise. In addition to direct farmland loss from inundation, it is likely that agriculture would experience increased costs from saltwater intrusion into surface water and groundwater in coastal regions. Further indirect impacts would be likely as a result of the need to re-locate both farming populations and production in other regions.

6.Conclusion

Our research shows that enhanced agricultural activity may serve as an excellent agent for global carbon sequestration . Climate change could improve wheat yields, but it is not necessarily so for all crops. Similar analysis should be carried on with several other crops especially with C4 pathway. Wheat is generally rainfed on the Eastern Mediterranean coast and our scenario simulations indicated crop failure when rain was below a certain threshold unless supplemental irrigation was added. Thus, the improvement in wheat yield comes along with exacerbated problems of irrigation water due to increased consumption. Moreover, The combination of impacts of climate change on agriculture that could stem from the direct effects of increased atmospheric CO_2, in the Seyhan coastal watershed together with sea-level rise is likely to be extremely complex. In the long run it is expected that soil quality and water availability continue to deteriorate while agroproductivity may be better in the short run.

Thus production is still likely to decline with global warming. Water management could become a problem in semi-arid areas. Finally, because climate change is a long-term global environmental issue, assessing adaptation and mitigation strategies helps to encourage responsible sustainable development

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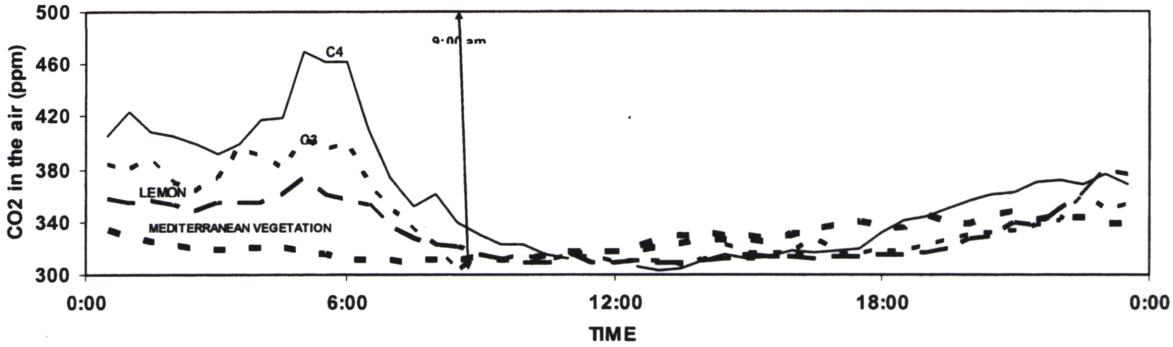


Fig.1. The diurnal course of CO2 concentration in the air. Data are the moving average of four sampling channels . The C4 plant is the corn that shows the strongest gradient at 6 am and reduced to the prevailing concentration in the air at 9 am. The Mediterranean vegetation on the Taurus mountains includes Oak, Pistachio and Pine trees. In terms of diurnal CO2 variations, this is the most stable population which does not creat a strong gradient.

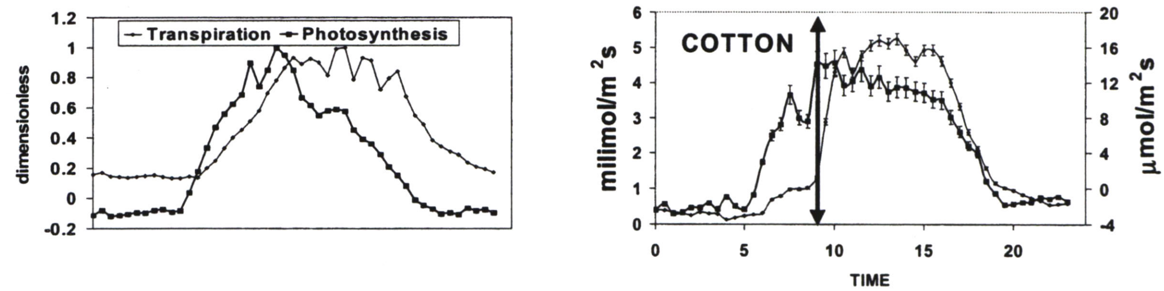


Fig.2. The effect of dew formation on the diurnal course of photosynthesis and transpiration. (a) Normalized values for the dew affected plants. (b) Example of actual data for cotton. In both displays maximum photosynthesis preceded maximum transpiration due to the combined effect of wide stomatal aperture under dew formation and high CO_2 gradient at sun rise. The double arrows line indicates 9:00 am at which the largest difference and ratio between photosynthesis and transpiration was obtained. It thus indicates the time of maximum water use efficiency.

Table 1. The effect of dew on water requirement and crops production rates under high light intensity. Data are averages of three replications in which Corn belongs to C4 group and Cotton and Soybean to C3 group. The environmental conditions were similar (PAR=1515 97 mmolm-2 s-1, CO2=325 21ppm, air temperature=31.5 2oC, and soil water content = 26.6 2 units). The only difference was the presence of dew which is characterized by small VPD

High Rh	Corn	Cotton	Soybean	Dew	Corn	Cotton	Soybean
	gr. CO_2 m^{-2} (leaf) h^{-1}				gr. H_2O m^{-2} (leaf) h^{-1}		
+	3.2	2.2	2.2	+	**116.9**	**112.3**	**103.5**
-	1.4	1.7	1.2	-	**151.2**	**291.6**	**227.5**
Photosynthetic water use efficiency					gr. dry matter per kg. water		
				+	27.5	19.9	26.6
				-	9.1	5.9	4.9
Potential CO_2 assimilation at high light intensity[17]					3-9	1.5-5	1.5-5

Fig. 3 Preliminary results from ECHAM4 climate change scenarios for the Negev region: Simulated effects for wheat production

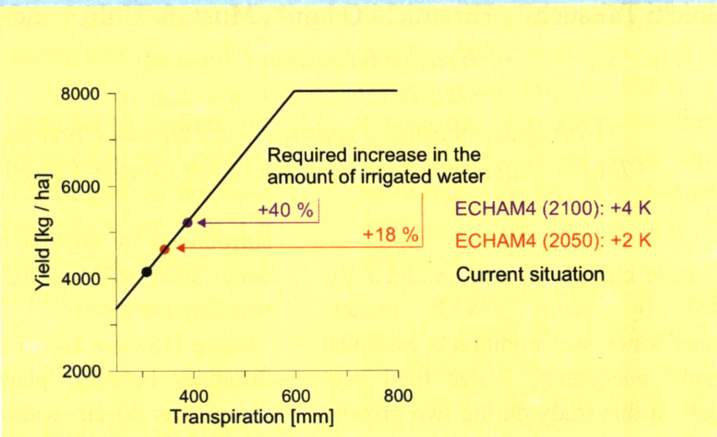


Fig 4. Application of TRAIN to simulate the water budget / productivity of wheat in Gilat: Example for year 1999 / 2000

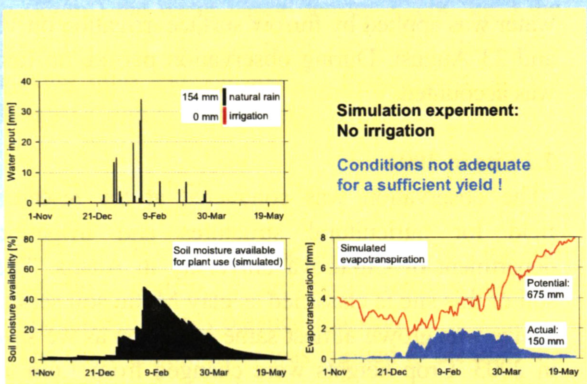
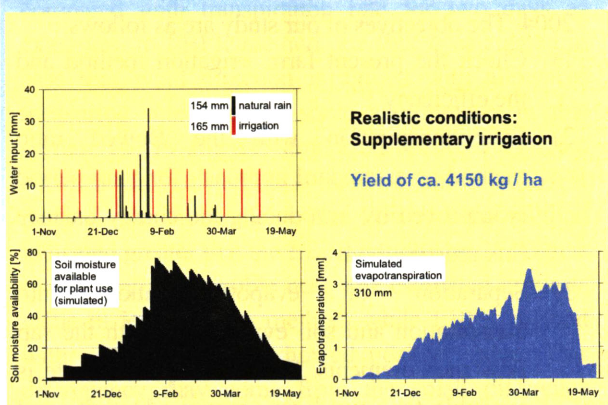


Fig. 5. Application of TRAIN to simulate the water budget / productivity of wheat in Gilat: Example for year 1999 / 2000



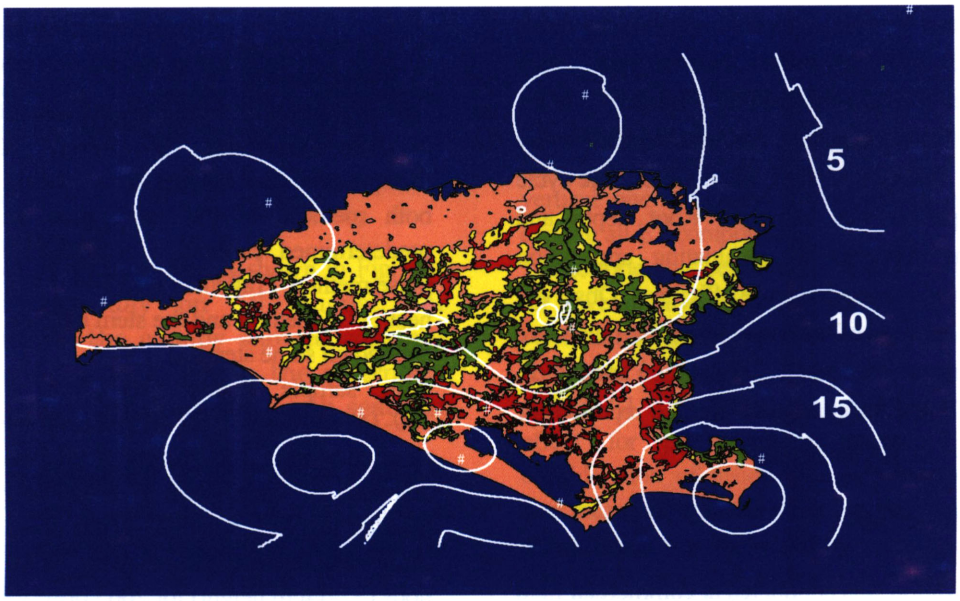


Fig. 6. Spatial distribution of EC in the Syhan basin. The numbers are the EC of the respected contour. The largest value is 25 dS/m which was determined on the Mediterranean.