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Influence of Agricultural Activity on the Surface Climate of New Delta of Egypt Using the RegCM4 †

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Abstract: Land-use changes (e.g., transition from desert to crop) can induce considerable influence on the surface climate and terrestrial water cycle (represented by potential evapotranspiration; PET). Also, regional climate models (e.g., RegCM4) can be useful tools for exploring changes regional changes associated with the land-use. In the present, the influence of a cropped area (of New Delta of Egypt) on the temperature extremes (T_{max} and T_{min}), and potential evapotranspiration (PET) was examined using a regional climate model (RegCM4). The MPI-ESM-MR was used as an atmospheric forcing to drive the RegCM4 over the Middle East and North Africa (MENA) with 50 km grid spacing and then nested over Egypt with 20 km grid spacing. To consider the effect of the cropped area, two experiments were conducted: the first one is occupied with desert (CTRL) and the other one considers the cropped area (EXP). The two experiments were integrated from 1980 to 2100 considering the moderate future scenario representative concentration pathway 4.5 (RCP45). The results showed that the cropped area induces a reduction in both T_{max} and T_{min} (by 0.5–2 °C) as well as a reduction in PET (by 5 mm month^{-1}). In summary, RegCM4 can be considered as a useful tool to examine the possible effects associated with the cropped area. Also, considering other atmospheric forcing is important to account for the uncertainty associated with the lateral boundary condition.

Keywords: Egypt; crop; future scenario; New-Delta; potential evapotranspiration

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1. Introduction

Many of global modeling studies concerning land cover changes have been conducted with results dependent on geographic location and conversion type [1–4], but there are no important studies on land use change on North Africa especially in the northeast counters despite that North Africa exposed extremely to this climate change. However, the annual temperatures increase gradually higher than the average due to the response of climate change [5], so the heat waves will be more intensive and longer. Therefore, it will be particularly affected by droughts that would be more frequent next years.

Ref. [6] reported that irrigating crop played an important physical rule in mitigating future risk associated with climate change. Various indicators were examined as a result of irrigated crop such as: surface wind speed, boundary layer height and surface albedo.

It is important to mention that New delta project in Egypt aims to increase the ag-

riculture area trying to find a smart solution for reduction of land areas suitable for agriculture (due to rising temperatures associated with climate change, also water systems and food security). However, the potential influence of the cropped area on the surface climate and PET wasn't examined over Egypt till the present day. Therefore, the present study aims to examine the regional effects associated with the cropped area of New-Delta using RegCM4 model for the following variables: maximum (T_{max}), minimum air temperature (T_{min}), relative humidity (RH) and potential evapotranspiration (PET).

2. Materials and Methods

2.1. Study Area

This study focuses on climate effect on new agriculture region called New-Delta. New-Delta lies in the north west of Egypt.

2.2. Model Description and Experiment Design

The experiment design of the control simulation (CTRL) is based on the work conducted by [7]. To examine the role of the land use (cropped area; EXPT), another simulation was done. The two simulations were integrated over the period of 1980 to 2100. The period 1980–2005 was considered as the reference period (RF), while the period 2006–2100 was considered as the future scenario. It is important to highlight that the proposed land-use change of the present study (see Figure 1) is considered as hypothetical because it was assumed that soil moisture is available during the EXPT simulation. Also, the crop land-use is represented based on some physical prosperities (such as reflectivity) and it is not based on complex physiological processes. In this work, PET was calculated using Hargreaves–Samani method following [7] to allow tracking PET changes as a result of changes in the mean air temperature.

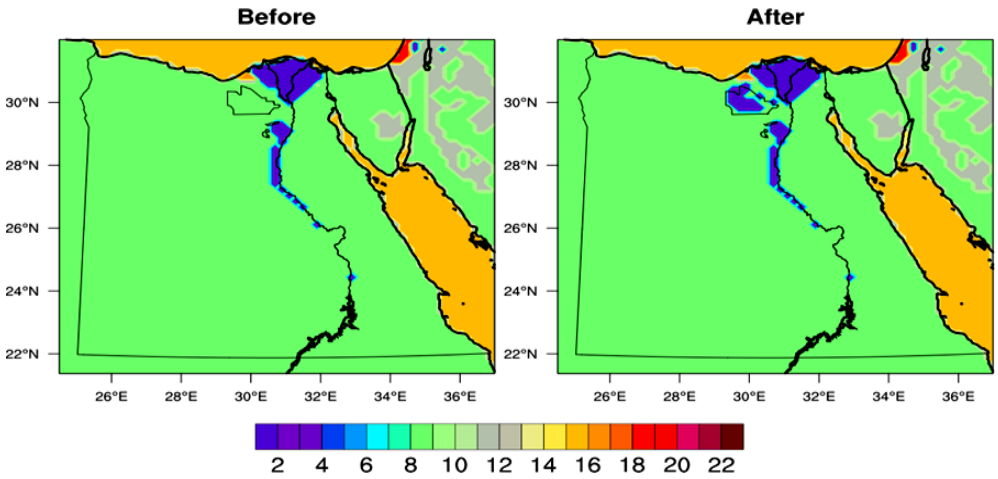

Figure 1. The figure shows the land use changes of new delta region before (**left** panel) and after cropping (**right** panel).

3. Results

For brevity in analysis, only spring season (March–April–May; MAM) to examine the potential future projected changes between the EXPT and CTRL simulations. Changes were examined for every averaged 10 years in the period of 2021–2100 as: 2021 to 2030, 2031 to 2040, 2041 to 2050, 2051 to 2060, 2061 to 2070, 2071 to 2080, 2081 to 2090 and 2091 to 2100. Rest of seasons are provided in a supplementary file. Figure 2 shows the averaged changes of T_{max} due to the cropping activity in the new-delta region. In general, it can be noted that the EXPT induces a cooling effect relative to the CTRL for all time segment. However, the degree of cooling differs with respect to the time segment being examined. For instance, from Figure 2c,g it can be noted that EXPT induces a de-

crease of T_{max} by 1.5–2 °C in the time segments 2041–2050, 2081–2090. While in Figure 2a,b,d–f,h, T_{max} decreases by 0.5–1 °C. Such cooling effect can be explained by increase of RH (see Figure 4) as a result of increasing of total evapotranspiration and decreasing of sensible heat flux.

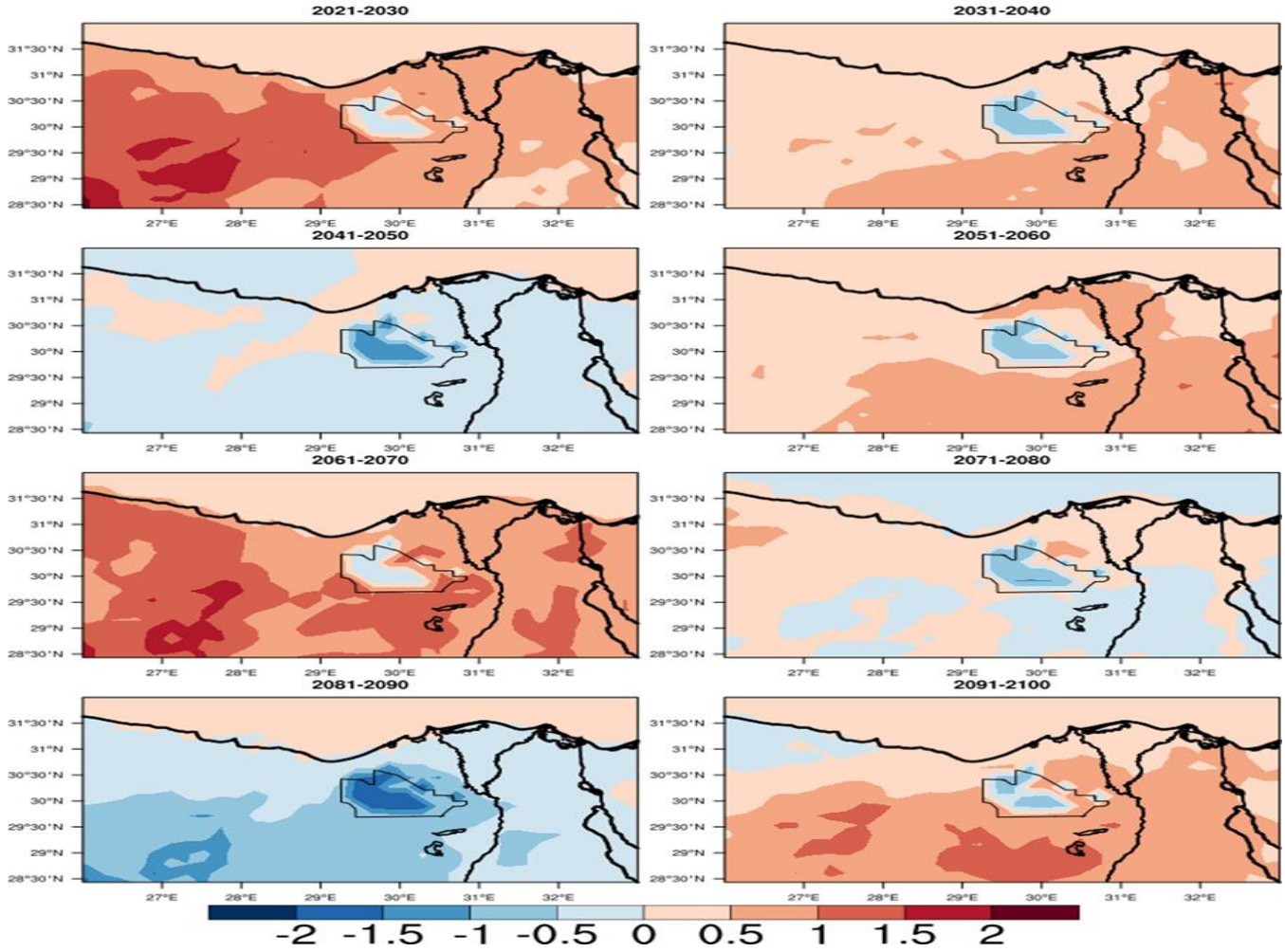

Figure 2. The figure shows the difference between RF and EXPT simulations for the maximum temperature (°C) in (MAM) season in different periods, (**a**) the period of 2021 to 2030, (**b**) the period of 2031 to 2040, (**c**) the period of 2041 to 2050, (**d**) the period of 2051 to 2060, (**e**) the period of 2061 to 2070, (**f**) the period of 2071 to 2080, (**g**) the period of 2081 to 2090 and (**h**) the period of 2091 to 2100.

In Figure 3, it can be observed that EXPT induces a considerable decrease of T_{min} relative to CTRL in all time segments particularly 2041–2050, 2071–2080 and 2091–2100 (Figure 3c,f,h). Such decrease can be attributed to the fact that the cropped area emits longwave radiation less than the desert leading to a decrease of T_{min}. In Figures 2 and 3, it can be observed that there is no remote effect associated with the cropped area. In other means, it is localized to the cropped area only. Furthermore, the regional temperature changes (T_{max}/T_{min}) outside the cropped area can be attributed to the RegCM4 physical parameterization as well as the MPI-ESM-MR as an atmopheric forcing. Concerning RH, it can be observed that EXPT is higher than CTRL by 4–8% in all time segments (see Figure 4). Such increase can be explained by: (1) decrease of both T_{max} and T_{min} and (2) increase of water vapor released to the atmosphere as a result of evapotranspiration process during day/night.

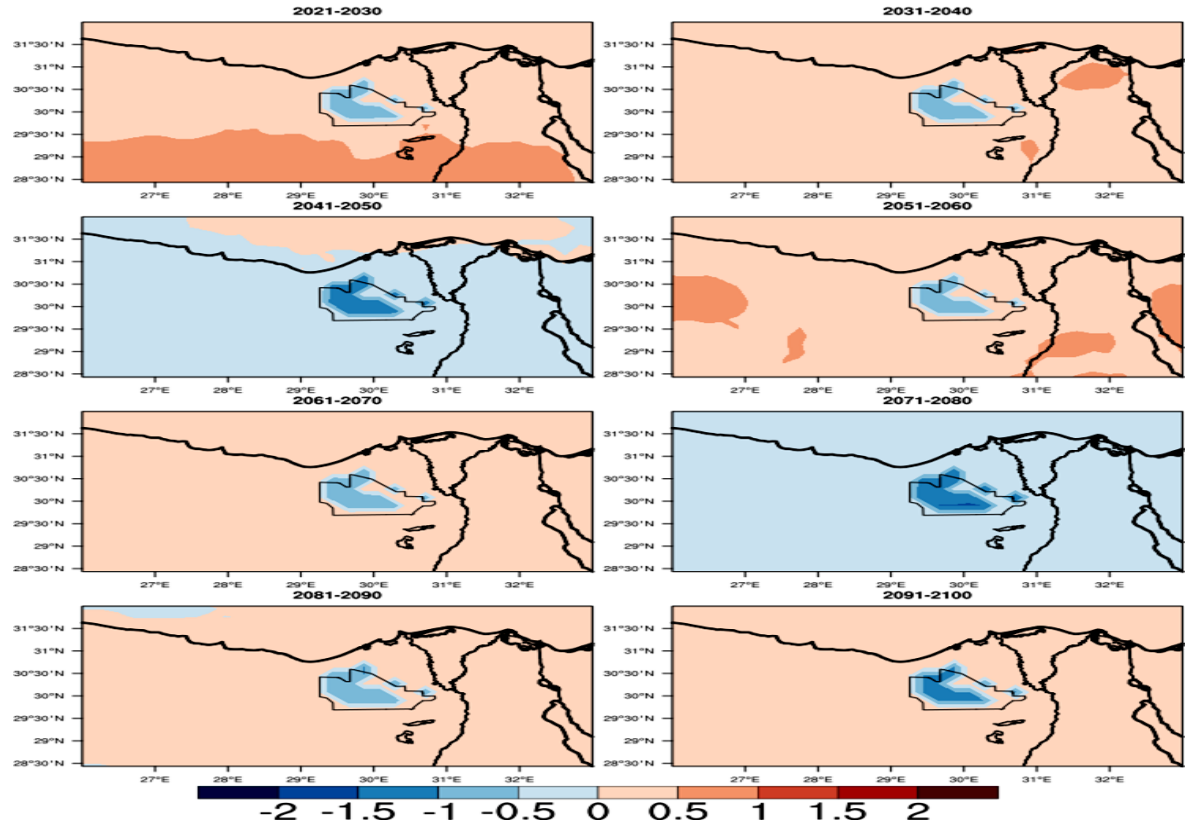

Figure 3. The figure shows the difference between RF and EXPT simulations for the minimum temperature (°C) in the MAM season for the time segments: (**a**) 2021 to 2030, (**b**) 2031 to 2040, (**c**) 2041 to 2050, (**d**) 2051 to 2060, (**e**) 2061 to 2070, (**f**) 2071 to 2080, (**g**) 2081 to 2090 and (**h**) 2091 to 2100.

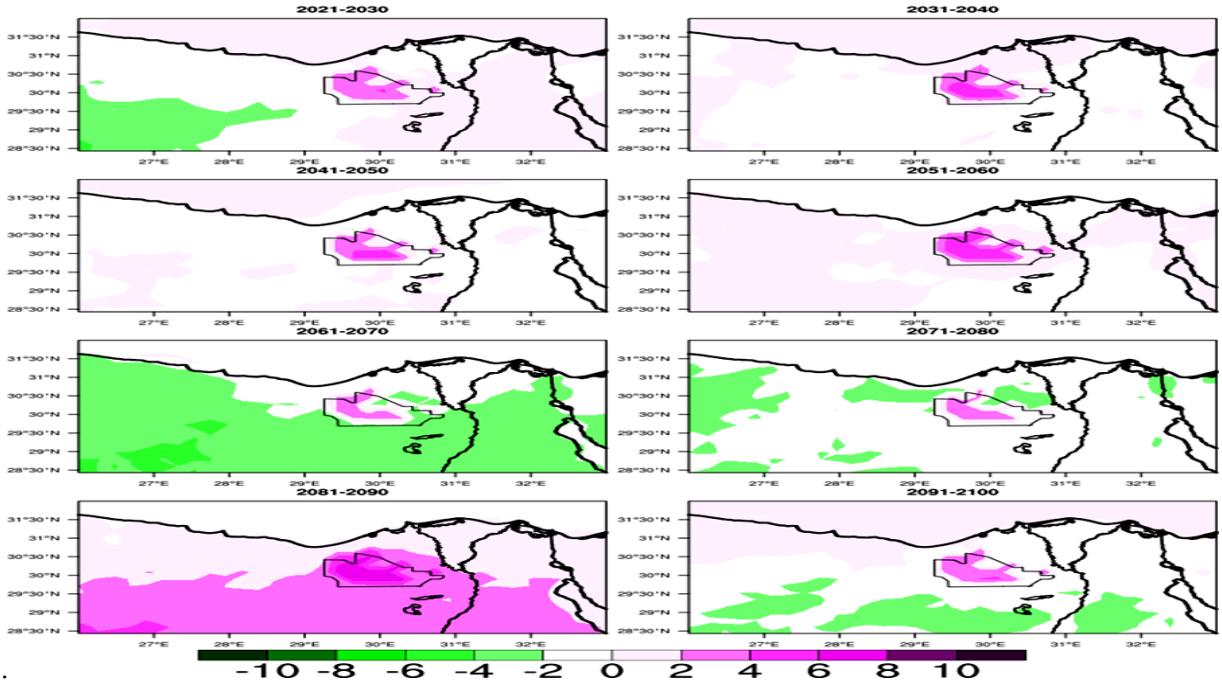

Figure 4. The figure shows the difference between RF and EXPT simulations for change in relative humidity (%) in the MAM season for the time segments: (**a**) 2021 to 2030, (**b**) 2031 to 2040, (**c**) 2041 to 2050, (**d**) 2051 to 2060, (**e**) 2061 to 2070, (**f**) 2071 to 2080, (**g**) 2081 to 2090 and (**h**) 2091 to 2100.

In Figure 5, it can be observed that EXPT induces a decrease of PET (relative to CTRL) by there is a stable decrease in PET during all period about ~5 mm month^{-1} in all time segments. Such decrease can attributed the fact that PET is a function of the mean air temperature [7]. Another reason is the decrease of the surface net radiation to drive the evapotranspiration process. It is important to highlight that there were no notable changes in the simulated total cloud cover and precipitation (not shown) suggesting that the convection process is insensitive to the land-use changes. These results are consistent with those of previous studies, which showed the direct effects of cropland are to enhance evapotranspiration and cool the surface temperature [8–12].

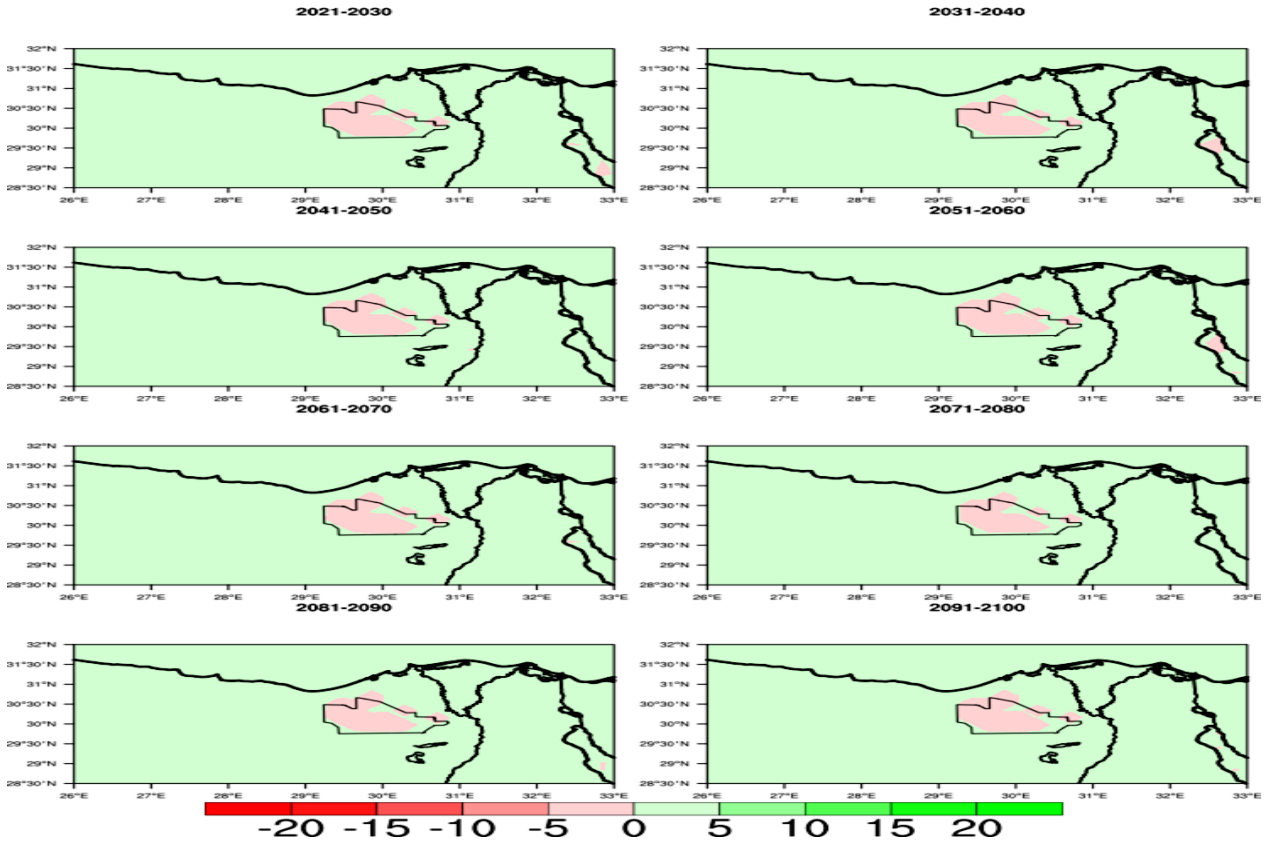

Figure 5. The figure shows the difference between RF and EXPT simulations for change in PET (mm month^{-1}) in the MAM season for the time segments: (**a**) 2021 to 2030, (**b**) 2031 to 2040, (**c**) 2041 to 2050, (**d**) 2051 to 2060, (**e**) 2061 to 2070, (**f**) 2071 to 2080, (**g**) 2081 to 2090 and (**h**) 2091 to 2100.

4. Discussion and Conclusions

Climate change has potential impacts on the agriculture activity (either positive or negative depending on the region of study). Also, crops/irrigated crops have shown considerable effects on temperature extremes with possible effects of warming reduction as a mitigation strategy [5]. However, such effects weren't examined in Egypt (particularly New-Delta region). Therefore, the regional climate model (RegCM4) was used in the present study to examine the possible effects of the cropped area (in the New-Delta region) on the maximum, minimum air temperature, relative humidity and potential evapotranspiration. The RCP45 future scenario was considered in this study.

The results showed that the cropped area induces a net cooling effect. Such cooling effect depends on the time segment of interest. As a result, a notable increase/decrease of relative humidity/potential evapotranspiration is noted. Further, there was no change in the simulated total cloud cover/total precipitation suggesting that land-use changes cannot drive the convection process. Also, land-use changes control the surface energy balance (decrease of sensible heat flux and increase of evapotranspiration) leading to

decrease of T_{max}/T_{min} and increase of RH. Further, it can be noted that land-use change only promotes localized changes with no possible remote effects.

Therefore, it can be observed that RegCM4 was a useful tool to explore possible changes associated with the cropped area on the surface climate and PET of New-Delta under the RCP4.5 future scenario. However, the irrigation effect [5] wasn't considered in the present study. Also, the present study relied on using one lateral boundary condition (LBC), one regional climate model (RCM) and one future scenario. Therefore, a future study will consider the following points: (1) inclusion of irrigation effects, (2) considering multiple LBC to account for uncertainty associated with the atmospheric forcing [7], (3) using multiple RCMs (e.g., WRF, COSMO, RCA4) to account for uncertainty of the physical parameterization and (4) considering other future scenarios (e.g., RCP8.5).

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Conflicts of Interest: The authors declare no conflict of interest.

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