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Modelling ancient crop yields in a Mediterranean environment as a tool to analyze past human-environment interactions

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Throughout history, humans and the environment have had a strong interplay. For the Mediterranean region it has been hypothesized that soil erosion following the cultivation of land degraded the landscape to such an extent that it caused a crisis in ancient societies. Other studies pointed out, however, that the eroded material ended up in the wide valley bottoms, thereby creating extensive areas of fertile land that were much easier to cultivate. Thus, it is hypothesized that hillslope soil erosion actually had an important and not necessarily exclusively negative impact on ancient civilizations through accumulation of soil in the central valleys. However, to make scientific sound conclusions to what extent ancient soil erosion led to decreases in agricultural carrying capacity, there is a need for accurate quantification of these processes. This requires not only a quantitative understanding of past soil erosion, but also on soil erosion - crop productivity relations at longer timescales. Attempts to model ancient crop yield currently lack spatial and temporal detail, or do not take into account changes in soils, climate, hydrology or land management techniques that occur on these longer timescales. Here, we combine a spatially distributed soil erosion model (WATEM/SEDEM) with an agronomic model (AquaCrop) to assess the long-term evolution in crop productivity following human- and climate-induced environmental change. The AquaCrop model was adapted, i.e. made spatially explicit and taking into account changes in soil properties following erosion. Hence, for the first time a long term crop yield model was developed that allows important changes in climate, soil and land use to be included. Both models were calibrated and validated for the territory of the ancient city of Sagalassos (SW Turkey) for which a large palynological, geomorphic and archaeological dataset exists. Data on present-day crop yield were used to calibrate the AquaCrop model, whereas the sediment archive data were used to calibrate the WATEM/SEDEM model. The results show that ancient crop yield of barley varied between 0.5 and 1.5 ton/ha/year. Modeled crop yields show a strong control of precipitation, while soil thickness and to lesser extent re-infiltration of runoff also has a reasonable impact on crop yield. During drier periods, there is an increased risk to crop failures. Whilst erosion definitely has an impact on crop yield, it will not have led to a complete ruination of the land and thus crop failure. The runoff to lowland valleys changed drastically after deforestation increasing the extent of valley-bottom marshes, which could have potentially hampered agriculture in the lower lying valley areas. The crop yield model was also run under different land management scenarios. It shows the importance of irrigation in the valley areas to increase crop yield to 5-8 ton/ha/year. The effect of bare fallowing on crop yields was also quantified. Results show that it would have been technically possible for ancient farmers to greatly reduce crop failure by applying a two yearly bare fallow, and that it can strongly reduce crop yield variations in a Mediterranean environment.