Global change and massive soil erosion endangering World Heritage ancient desert agriculture sites in the Middle East

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Introduction:

Ancient agricultural fields dominate large parts of the desert landscape in the Middle East (Figs. 1 and 2) and cover vast areas in these arid regions. The ancient agricultural installations comprise stone terrace walls built within the wadis and channels for collecting the runoff from the mountain slopes and diverting flood water from the wadies (Fig. 3). In the Negev Highlands of southern Israel the total area retaining these installations comprises ca. 30,000 acres. They were built mainly during the Roman-Byzantine period (3-7th centuries) along with ancient desert towns (Figs. 4,5 and 6).

This unique and well-preserved cultural landscape was included in the UNESCO World Heritage list. However, during the last decades, a continuous process of massive soil degradation is observed in the deserts of the Middle East. In many sites the soil erosion endangers the ancient agricultural installations located within the wadies, which are subjected to powerful desert floods (Fig. 7). With the global climate change affecting the arid regions, and the magnitude and frequency of floods escalating, this process is expected to become a major threat to these important sites.



Fig. 1

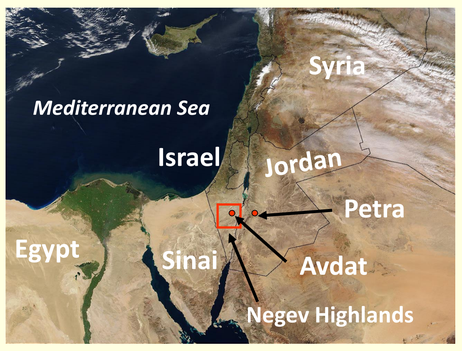








Fig. 2: The desert environment in the Middle East

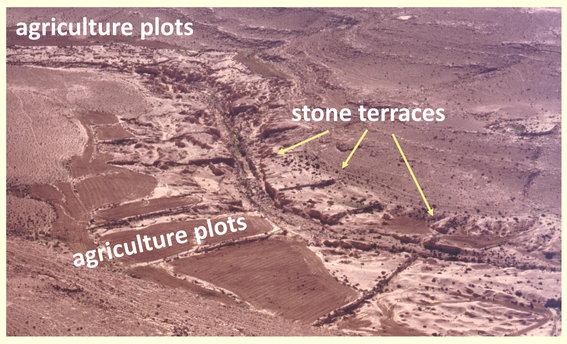


Fig. 3



Fig. 4

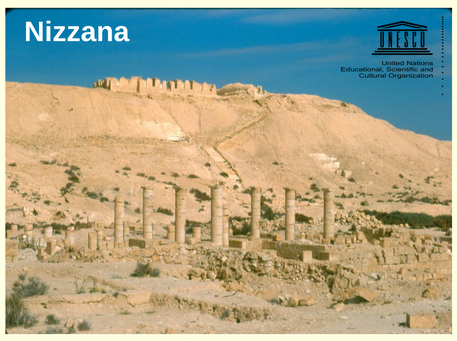
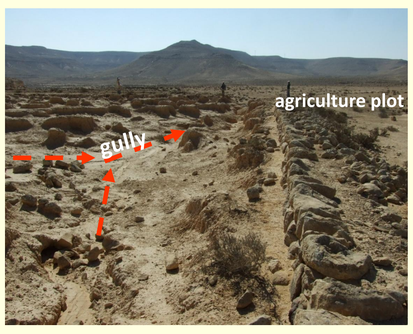


Fig. 5





Fig. 6: agriculture crops during historical times in the desert zone



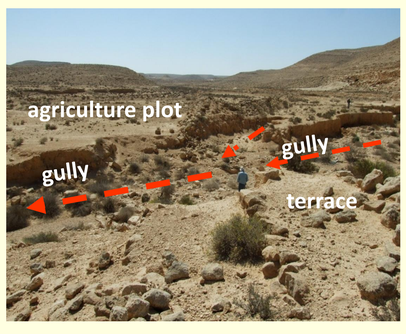


Fig. 7

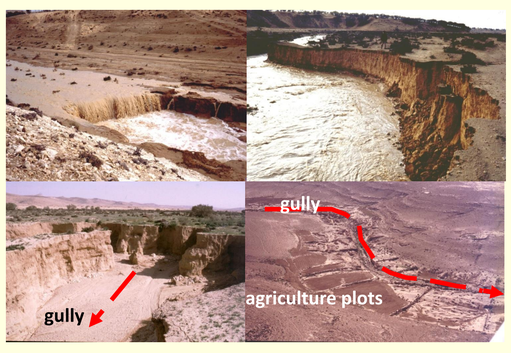


Fig. 8

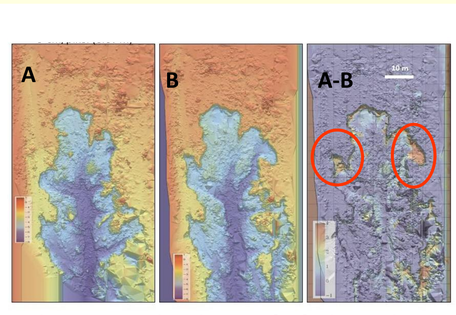


Fig. 9: Monitoring Nahal Zipporim Headcut using LiDAR 2009-2010



Fig. 10

Research aims:

1. To reconstruct the forces behind the long term process of soil erosion and desertification at geological, historical and current time scales.
2. To reconstruct the environment and climate of the region during the time the ancient agriculture was implemented.
3. To uncover the factors leading to the rise and fall of the desert agriculture in the Middle East.
4. To recommend ways for preventing further soil erosion and for long term preservation and restoration of the desert agriculture installations.

Methods:

1. Archeological survey of historical agriculture installations in the Negev Highlands.
2. Geological and geomorphological analyses of key drainage basins (Fig. 8).
3. Land degradation survey of gullies, headcuts, badland features, and biomass losses (Fig. 8).
4. Airborne Laser Scanning (LiDAR) for 3D calculation of soil losses (Fig. 9).
5. Dating key units of pre and post anthropogenic soils for long-term soil erosion using OSL (Fig. 10).

Results:

The Middle East is experiencing a long-term, non-linear process of land degradation (Figs. 11 and 12). The process of gradual soil erosion began at the termination of the glacial phase (17-14 ka) and intensified during the Holocene. The non-linear soil erosion generated a complex environmental response, leading towards increased natural desertification, long before human intervention became significant in the desert environment (Fig. 13).

The desert agriculture exploited the interaction between the characteristics of the local geological and geomorphological drainage basin, the loess soil and the desert climate. The vast construction of stone dams by the ancient farmers led to the trapping of floodwaters behind the agricultural installations and to a redeposition of fine alluvial sediments, originating mainly from the Late Pleistocene loess sections, at a rate of up to 0.8 cm/y (Fig. 12). The accumulation of the sediments contributed to soil conservation on a regional scale and counteracted the general trend of natural desertification that still continues to act in the natural arid environment (Fig. 13). However, the agricultural terraces, which were gradually raised, were at increased physical risk and became vulnerable to collapse (Fig. 12). This process became critical after the fields were gradually abandoned and a "domino effect" was generated, shifting the geomorphic process towards dramatic increase in soil erosion (Fig. 13).

Nahal Zipporim erosion site: 600 m of gully migration during the last 1000 years – mean historical retreat rate: 0.6 m/y

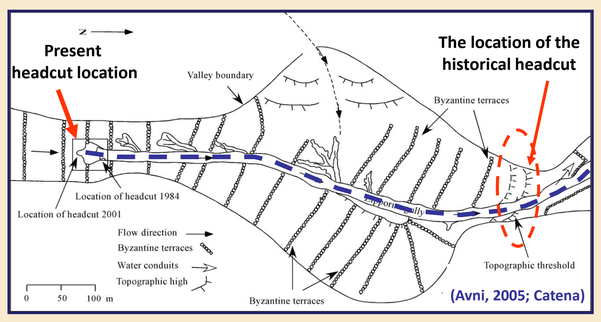


Fig. 11

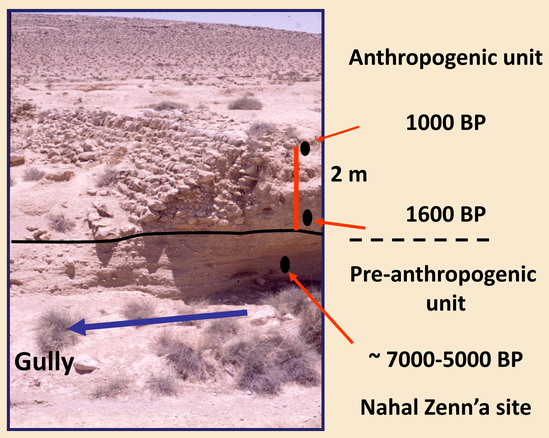


Fig. 12

Conclusions:

1. The continuing natural long-term geomorphic change from the Pleistocene-Holocene transition on is leading towards increasing soil erosion and natural desertification of the arid zone.
2. The rise and fall of the historical desert agriculture is not related to any mid-late Holocene climate or environmental change.
3. Soil conservation methods such as terrace rehabilitation and re-implementation of the desert agriculture can still be applied in the Middle East arid zones at present (Fig. 14).
4. Similar processes are operating in other arid and semi-arid regions worldwide, such as in southern Peru and northern Chile.

Simplified model:
soil, runoff and desert agriculture in the arid environments of the Middle East

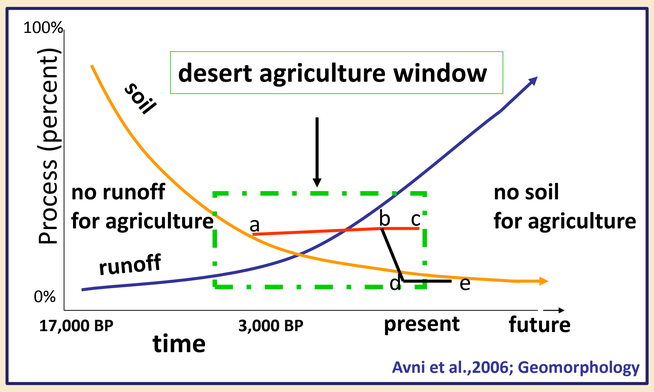


Fig. 13



Fig. 14: Negev Highlands

The implementation of desert agriculture is still possible today!

Designed by: Bat-Sheva Cohen