original scientific article
received: 2016-02-15

DOI 10.19233/ASHS.2016.34

PHYSICAL AND SOCIAL ASPECTS OF LAND DEGRADATION IN MEDITERRANEAN HIGHLAND TERRACES: A GEODIVERSITY APPROACH

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ABSTRACT

The aim of the present research was to investigate the mechanisms leading to the erosion and destruction of terraces under Mediterranean climatic conditions, with special focus on the bulge of the terrace retaining wall. The main research area were abandoned terraces in the Western Galilee in Israel. Experimental plots to measure runoff and sediment yield were installed in the abandoned and cultivated terraces. Runoff coefficients for most plots were less than 1% and highest sediment yield was 8.3 g/m^2 for one plot. Runoff and sediment yield were high in the steep slopes sites and low in the low gradient terraces.

Keywords: agricultural terraces, land degradation, geodiversity, soil erosion, mediterranean- type climate

ASPETTI FISICI E SOCIALI DEL DEGRADO DEL SUOLO NELLE TERRAZZE SUGLI ALTIPIANI MEDITERRANEI: UN APPROCCIO BASATO SUL CONCETTO DI GEODIVERSITÀ

RIASSUNTO

Lo scopo della presente ricerca è stato quello di studiare i meccanismi che conducono all'erosione e alla distruzione delle terrazze a causa delle condizioni climatiche Mediterranee, con una focalizzazione particolare sulla protrusione del muro di contenimento della terrazza. L'area principale dello studio ha riguardato le terrazze abbandonate della Galilea Occidentale in Israele. Sono stati istallati lotti sperimentali per misurare il deflusso e la produzione di sedimento nelle terrazze abbandonate e coltivate. I coefficienti di deflusso per la maggior parte dei lotti sono stati inferiori all'1% e la produzione più elevata di sedimento è stata di 8,3 g/m^2 per un lotto. Il deflusso e la produzione di sedimenti sono stati elevati nei siti dei pendii ripidi e bassi nelle terrazze a scarsa pendenza.

Parole chiave: terrazze agricole, degradazione del terreno, geodiversità, erosione del suolo, clima di tipo mediterraneo

INTRODUCTION

This research addresses the problem of changing human activities in the fragile environment of the historical agricultural terraces in the Mediterranean highlands. The high degree of connectedness of this coupling is a major threat to one of the oldest achievements of Man in the development of the Earth's natural resources. Over more than a millennium soil accumulated in the man-made terraces being the economic basis for a flourishing culture and an increasing landscape geodiversity. Old developed systems of agricultural terraces are found in high relief settled areas in different parts of the world (Inbar, Llerena, 2000).

Building of terraces achieved five purposes:

1. Developing a flat area in the mountain area for cultivation.
2. Accumulation of soil in steep shallow soil slopes.
3. Increasing the soil water storage, and in irrigated areas to allow efficient use of water.
4. Reducing soil erosion (farmers probably did not mean this achievement).
5. Creating a microclimate, increasing sun radiation and decreasing frost events.

The abandonment of the terraces leads to an increased rate of soil erosion and sediment yield values. From the socioeconomic point of view, land degradation determines social changes in the rural communities and is one of the factors in the migration process of the young rural population to the overcrowded urban areas.

The abandoned terraced areas were afforested mainly by pine plantations, increasing the recurrence of forest fires. A huge forest fire burned thousands of hectares of pine trees in the Carmel mountain in 2010 and old terraces from different historical periods were discovered.

A comprehensive review on agricultural terraces in the Mediterranean region was recently published by Arnaez et al. (2015).

Biodiversity is considered by the scientific community a major goal for Man, but few projects emphasize the geodiversity problem. The abiotic world of mountains and rock is seen as stable, static and much too prolific ever to be endangered (Gray, 2004). In natural systems, Man's activities may degrade Geodiversity and their impact will depend on the stability of the geomorphic system. In Biodiversity the extinction of biological species is irreversible, but also the extinction of geomorphic landforms like glaciers or wetlands are irreversible processes. Thirty years ago there was no major interest in "biodiversity" and "sustainability" of ecosystems. There is a need to increase geoconservation principles and goals (Gordon, Leys, 2001). In recent years there is a growing concern on the issue among geomorphologists and in the last *International Association of Geomorphologists Congress* in 2013 in Paris a working group on landform assessment for Geodiversity was established (IAG Newsletter, 2016).

Agricultural mountain terraces are a positive anthropic impact on the natural landscape and the aban-

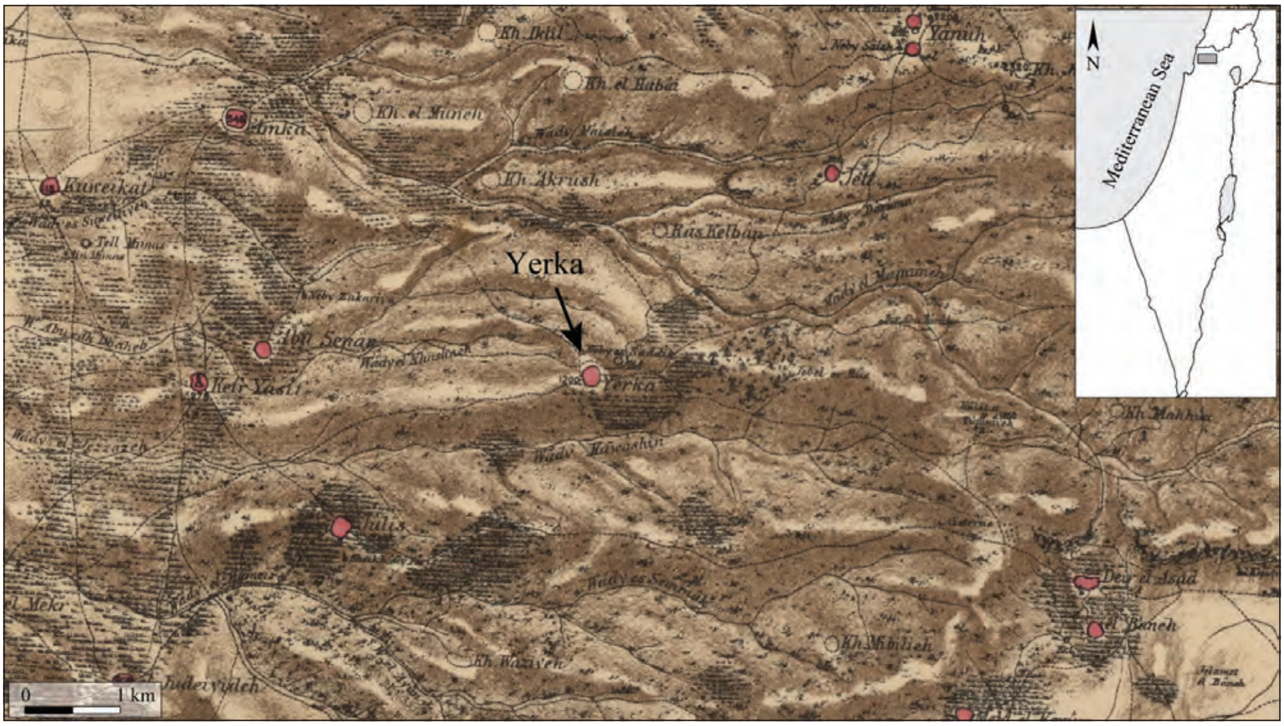

Figure 1: Location map. PEF (Palestine Exploration Fund, 1870) map shows signs of terraces near the Yirca village.

Fig. 2: View of the study site: Western Galilee.

donment process increases the environmental degradation. Man's activities changed for centuries most of the landscape, and fragile environments like the Mediterranean, are losing the agricultural terraced landscape, probably the most important land cultural heritage from early stages of human history.

Mediterranean areas are characterized by three common principles: climate, relief and human impact history. The climatic boundaries are 900 mm for the upper humid areas, 275 mm for cool coastal stations and 350 mm for warm interior stations; 65% of rainfall should be concentrated in the winter half year. The coldest month in winter has an average temperature below 15 °*C* and temperatures below 0 °*C* do not exceed 3 % of the total year hours (Inbar, 1998).

Land degradation, in its broad meaning, is "the deterioration of physical and chemical properties of the soil and inland waters that occur as a result of environmental change and which result in soil erosion, problems of sedimentation and flooding, the loss of fertility and sometimes in salinization" (Conacher, 1998). The degradation process includes visible forms, like erosion or deforestation. Other forms are less visible, such as salinization and water contamination.

Soil erosion, land degradation and desertification are processes that affect most of Mediterranean landscapes, and may be related to social and environmental degradation leading to overpopulated cities, famine, and concern about the needs for future generations.

Mediterranean landforms merit thorough enquiry. They are among the most vulnerable and fragile environments on Earth.

Considering the Mediterranean-type climate region as an unstable earth surface system, the most important implication for the human- environment relationship is that managers, planners and land users have to be aware of the inherent instability of the system. Human interference in the environment exacerbates the negative natural biophysical processes, and the results are more frequent and more severe geomorphic processes like floods, landslides, soil erosion, etc.

Mountain semiarid habitats are most common in the Mediterranean regions, and their ecosystems are characterized by intensive erosive processes. Agricultural land use is a major factor affecting erosion processes, and in mountainous areas the conservation or abandonment of terraces is a crucial factor in soil loss. For over more than two millennia soil accumulated in the human

Fig. 3: Modern terraces built by machine in the lower valley.

made terraces, which were the economic basis for flourishing cultures. In the Eastern Mediterranean countries terrace construction began at ancient periods, at least since the fifteenth century BC. In the Iberian countries early terraces are probably from the Roman period. Other researchers suggest older ages and speculate that terracing developed earlier than 5000 years B.P. (Gibson et al., 1991). Old terraces were dated to three main periods—late Bizantine, Medieval and Ottoman—by OSL methods in the Jerusalem area (Davidovich et al, 2012).

Abandonment of agricultural land is widespread in the mountainous area of the Mediterranean countries of Europe. Erosion processes increased due to the abandonment of terrace fields, as in the Western Mediterranean countries and in old land terrace systems in Israel and Jordan.

The aims of this study were to find what are the degradational processes after abandonment of terraces due to changing human activities in the fragile mountain environments of a typical Mediterranean landscape in the Lower Galilee in Northern Israel.

STUDY AREA

The study was carried out on agricultural terraces near the Yirca village in the Western Galilee, Israel (Figure 1). Average annual precipitation is 710 mm. Rainy season begins in October and ends in April, and the rainiest months are December, January and February. Mean annual temperature is 20 °*C*.

Terra rossa and rendzina are the soil types. The terra rossa falls within the range of the inorganic clays of high plasticity, whereas the rendzina falls within the range of the inorganic clays of medium plasticity, on the chart of the Unified Soil Classification System. Soils are shallow and depths vary from a few centimeters to 50-80 centimeters, and their occurrence is usually on pockets. In the terraces soil accumulation depends on the height of the retaining wall. Most of terraces are abandoned and on some of them olive trees are cultivated. In the fifties tobacco plants, cereals and legumes were cultivated on the terraces (Figure 2 and 3). In the Judean hills, forested areas by the national forestry institution—the Keren Kayemet Leisrael—were formerly terraced. After forest fires, the recommendation by forestry and soil experts is to rehabilitate the old terraces and plant on them native trees species like oaks, that are more resilient to fire than pines.

Terraces were formed and filled with local soil, and for centuries permanent maintenance provided the economic basis for flourishing cultures. Slope angles dropped from 100% to 10% or less. Manure, ash and

Fig. 4: Experimental plot #1: plastic fences are the limits of the plot.

human waste filled the terrace and contributed to its consolidation and development. Vegetation holds most of the soil and its removal by grazing is the main erosive agent.

METHODOLOGY AND RESULTS

The study program is based on field experiments:

1. Experimental plots

Five experimental plots were installed on abandoned terraces and one control plot on a cultivated terrace, in order to measure runoff and sediment yield from terraces after rainstorms

The plot area for each terrace is between 2 m^2 and 36 m^2. The plot is bordered by a plastic fence closed at a lower apex with a plastic tube delivering water and sediment through a pipe to closed containers (Figure 4). Rainfall was measured by rain gauge daily. Water and sediment are collected after each rain and the total amount or a sample is kept for sediment content and analysis at the laboratory.

The three experimental years were relatively dry and no major rainstorm was recorded. Runoff was negligible during most of rainstorms and few sediment samples were collected. The largest runoff event occurred after a 20 mm/day rainstorm. Runoff from abandoned level bench terraces with remaining retaining walls is very small (4.2 lit/m^2/year on the average). Sediment yield from such terraces is also very small (6.15 g/m^2/year on the average) (Table 1).

The large difference between the runoff values of the experimental plots may be explained by local factors, failure in collecting the runoff and infiltration processes. Sediment yield values are smaller on high runoff events, therefore the difference among parcels is less than in the runoff values.

The highest runoff coefficient for a single storm was 0.85 and sediment yield 309g for plot. Annual runoff coefficients for most plots were less than 1%.

Sediment yield values measured in the experimental plots were about 6 g/m^2/year or the equivalent to 6 ton/km^2/year which is considered a negligible rate o very low in comparison with world average rates of about 100 t/km^2/yr (Young, 1969). Only during high magni-

Table 1: Runoff and sediment yield in the experimental plots on abandoned terraces. Plot 1 is on a cultivated terrace.

Plot	Area (m2)	Average Runoff events per season	Runoff/Rainfall	Runoff (L/m2)	Sediment yield (g/m2)
1	5	2.75	0.14	1.1	16.0
2	36	3.5	0.07	0,51	0.26
3	15	4.35	0.26	2.03	3.83
4	22	8.5	0.46	2.88	8.32
5	10	4.33	2.33	18.6	7.41
6	2	3.3	0.04	0.13	1.07

tude rainstorms with very low frequency, probably with a return period of 1:50 years, large wall failures occur and erosion from the terraced slopes is considerable. On the terraced slopes there is no natural vegetation and being uncovered by vegetation high magnitude erosion processes may affect them during high magnitude catastrophic processes. In the cultivated terraces the rate of infiltration is high and there should be no erosion.

2. Rainfall simulation

A field portable rain simulator was used to measure runoff and infiltration rates on different physiographic conditions and terraces land uses. The equipment was adapted from a model used in Spain (Calvo et al., 1988) and it consists: 1) of two pressure pumps, giving a constant pressure of 1.7 Atmosphere, equivalent to a rain intensity of 40 mm/hour; 2) an aluminium structure holding the pipe to a spray nozzle jet at a height of 170 cm above ground; 3) a metallic ring 56 cm diameter fixed about five cm in the ground, limiting the draining ground area into a collecting tube and can. The simulator produces rainfall with a realistic drop size and it was applied until a constant rate of runoff was achieved, usually after one hour or if the infiltration rate was very high and no runoff occurred, the simulation was suspended after two hours. The rainfall amounts and intensities are considered to be high and of low frequency in this area. Water and sediment samples were collected every 3 to 5 minutes throughout each experiment. Samples were oven-dried (110 °C) and weighed and sediment yield was calculated.

All tests were carried out in the dry season in dry antecedent soil moisture conditions. In the cultivated and low gradient terraces infiltration was high. In high steep slopes runoff started after 15-20 minutes and rates of infiltration were 15-20 mm/hour. Runoff and sediment yield were high in the steep slope sites, and low in the cultivated and low gradient terraces.

Runoff generation on the rendzina soil is quicker than on terra rossa soil. The average time gap between the onset on rain and the beginning of runoff on dry rendzina as inferred from the results of the rain simulation experiments is 12 minutes, compared with 65 minutes for dry terra rossa. The average time gap between the onset of rain and stabilization of the infiltration rate is shorter for the rendzina soil—73 minutes—than for the terra rossa soil—155 minutes. The average final infiltration rate in rendzina is smaller than in terra rossa—2.32 cm/hour compared with 3.46 cm/hour on the average. According to the results of the rainfall simulation experiments, terra rossa soil is much more erodible than rendzina soil. The generation of saturated runoff

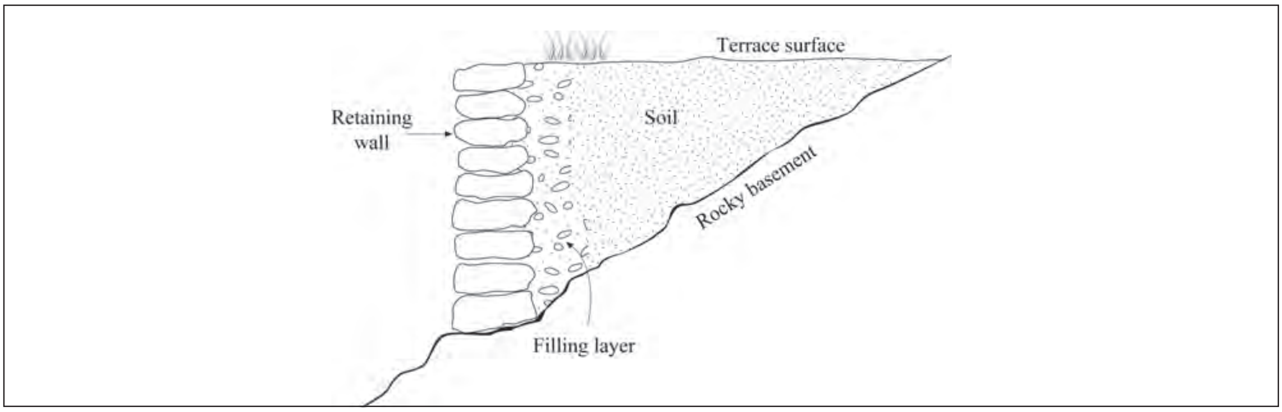

Figure 5: Terrace components.

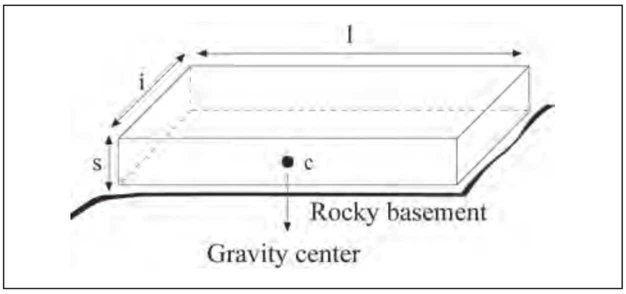

Figure 6: Retaining wall rock axis.

upon such terraces depends upon water content of the upper 30 cm soil layer at which extreme changes in water content occur during the rainfall season.

3. Terraces morphometry

A traditional agricultural terrace is made of three distinctive parts: 1) A built stone retaining wall. 2) An intermediate filling layer made of small stones. 3) A level of soil created by colluvial sedimentation behind the wall and the filter layer (Zgaier, 2009), (Figure 5). The building stones are angular and bladed, and their long axis is about 30 cm and the average weight 25 kg. Most terraces area is between 10 m^2 to 30 m^2. The average length is 10 m and width varies between 2 m and 5 m. The typical wall is one meter high and three meter long.

The height of the wall is proportional to the angle of slope, and it may vary from one meter or less for 10 % angle slopes, up to three meters or more for slopes above 45% values. No mortar was used in the wall building. The wall stones were collected from the terrace vicinity, as part of the work of cleaning stones from the slopes. There was no transport of soil from downslope valleys. The building of the wall requires knowledge and experience, and elongated and angular rocks increasing friction were preferred. Rocks axis were put perpendicular to the wall (Figure 6).

Physiographic and morphometric characteristics of the terraces were measured: length, width, area, stoniness and slope terrace; length, height, stone dimensions and curvature of terrace wall. Wall swelling and bulge development is characteristic to many retaining walls before their failure, and they develop due to the lateral soil pressure and its shearing effect. The wall collapse determines the starting of accelerated soil erosion from the terraces (Figure 7).

Figure 7: Collapsed wall.

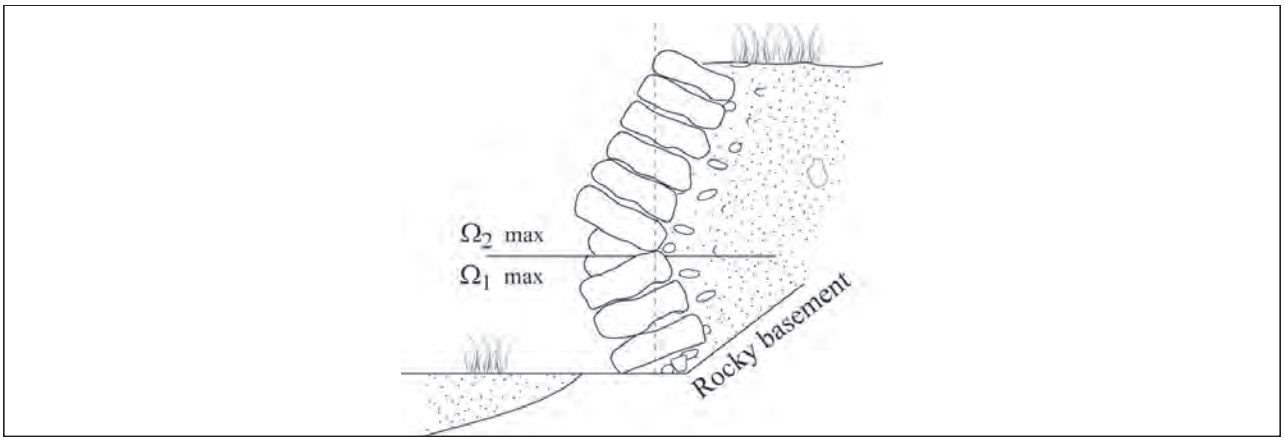

Figure 8: Wall bulge on the 1/3 lower section.

The terrace wall is the main factor determining the terrace stability or degradation. Saturated soils and its shearing effect determines pressure and swelling on the walls until failure occurs (Salas Pinto, Vasques Villanueva, 1987; Pallares Bou, 1994). The wall bulge appears at 1/3 height and divides the wall in two sections (Fig. 8). The angle Ω of a stable wall is about 85degrees. An unstable retaining wall was defined when at least one of its two segments had an actual base angle only slightly smaller than the maximum tilt angle of its base (Fig. 9). All wall failures checked in the field reached the critical value before the slide process. Figure 9 shows in a

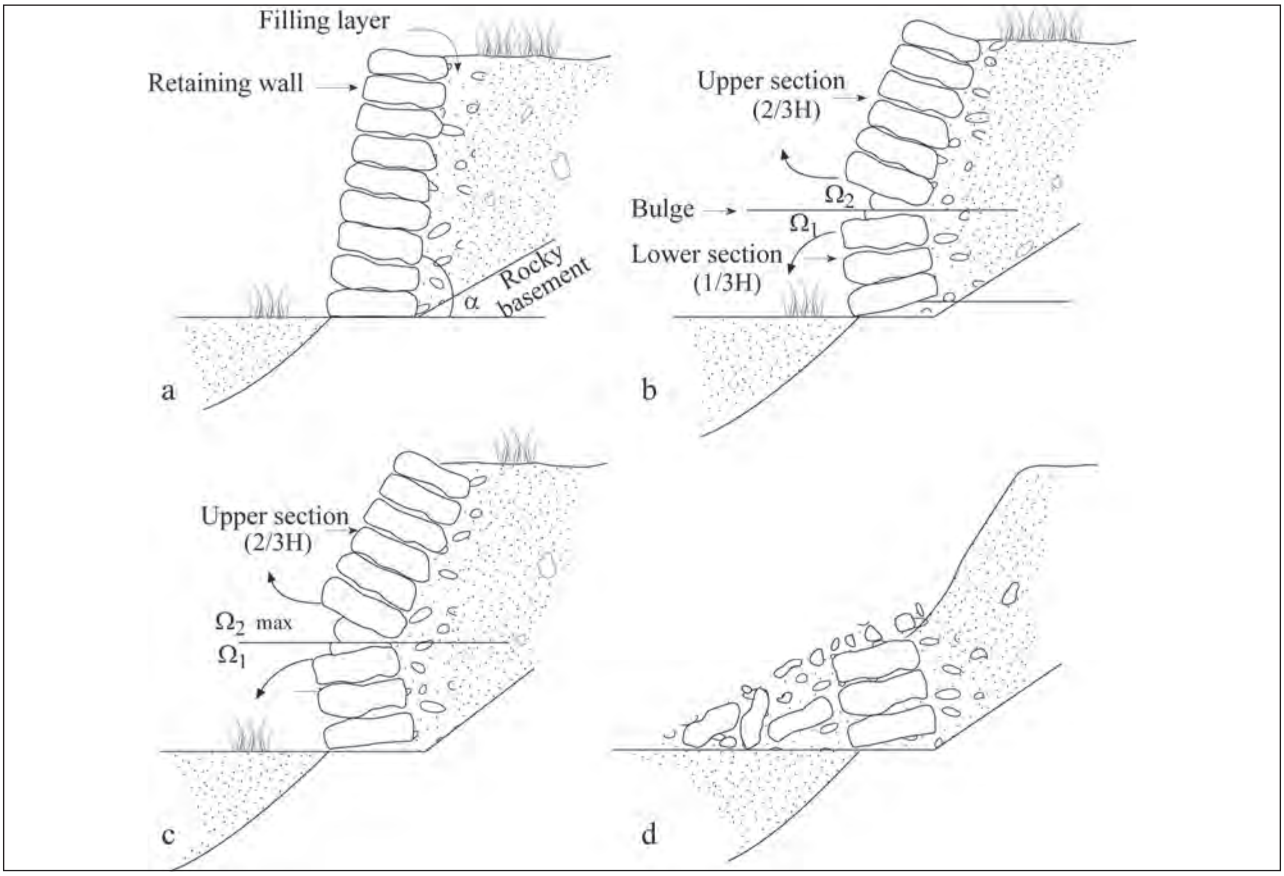

Figure 9: Stages in the process of wall collapse: a) retaining wall; b) bulge on the 1/3 lower section; c) bulge collapse; d) wall collapse.

Figure 10: A collapsed wall landslide.

schematic way the stages in the process of wall collapse. Maintenance is constant in the cultivated terraces, but manpower shortage affects the proper and constant reparation of wall stones slides. A similar process occurs in the Spanish Pyrenees, with the abandonment of cultivation in the mountain slopes even if terraced (Garcia-Ruiz, Lasanta-Martinez, 1990).

4. Shear stress field values for terraces soils

Shear stress values were found for terra rosa soils in the Yirca site in Israel under dry and wet conditions. Measurements were taken in field conditions by a specially designed equipment which proved to be effective. Soil was detached from the sides and the shear values of the soil were measured by the dynamometer.

Three main facts were evident: the cohesion of both soils was small; their angles of internal friction were large; and saturation caused a significant drop in their cohesion and only a slight decrease in their angles of internal friction. The large drop in soil cohesion after saturation is attributed to a drop in soil moisture suction.

Two kinds of failures were observed:

1. Wall collapse- without the soil behind the wall.
2. Sliding of the upper two thirds of a wall segment.

Two factors may be responsible for the small values of cohesion of both soils:

1. The abundance of stones in terra rossa.
2. The fact that both soils had never been over-consolidated in the past.

The large values of the angles of internal friction and the slight drop of these values after saturation were attributed to the high stone content of both soils (Zgaier, Inbar, 2005).

Saturation of terra rossa and rendzina, the soils of which the terraces in the study area are composed, caused a large drop in their cohesion and a slight drop in their angles of internal friction. The drop in the cohesion of terra rossa was larger than that of rendzina. The drop of cohesion due to saturation can lead to terrace landslides. The factors affecting terrace failure: soil pressure after heavy rains, cattle, animal or man destruction of the wall.

CONCLUSIONS

Erosion and sediment yield values occur during high magnitude rainstorms. Rainfall simulation tests showed that runoff and sediment yield were higher in the steep slope terraces and low in the cultivated and low gradient terraces. According to the rainfall simulation experi-

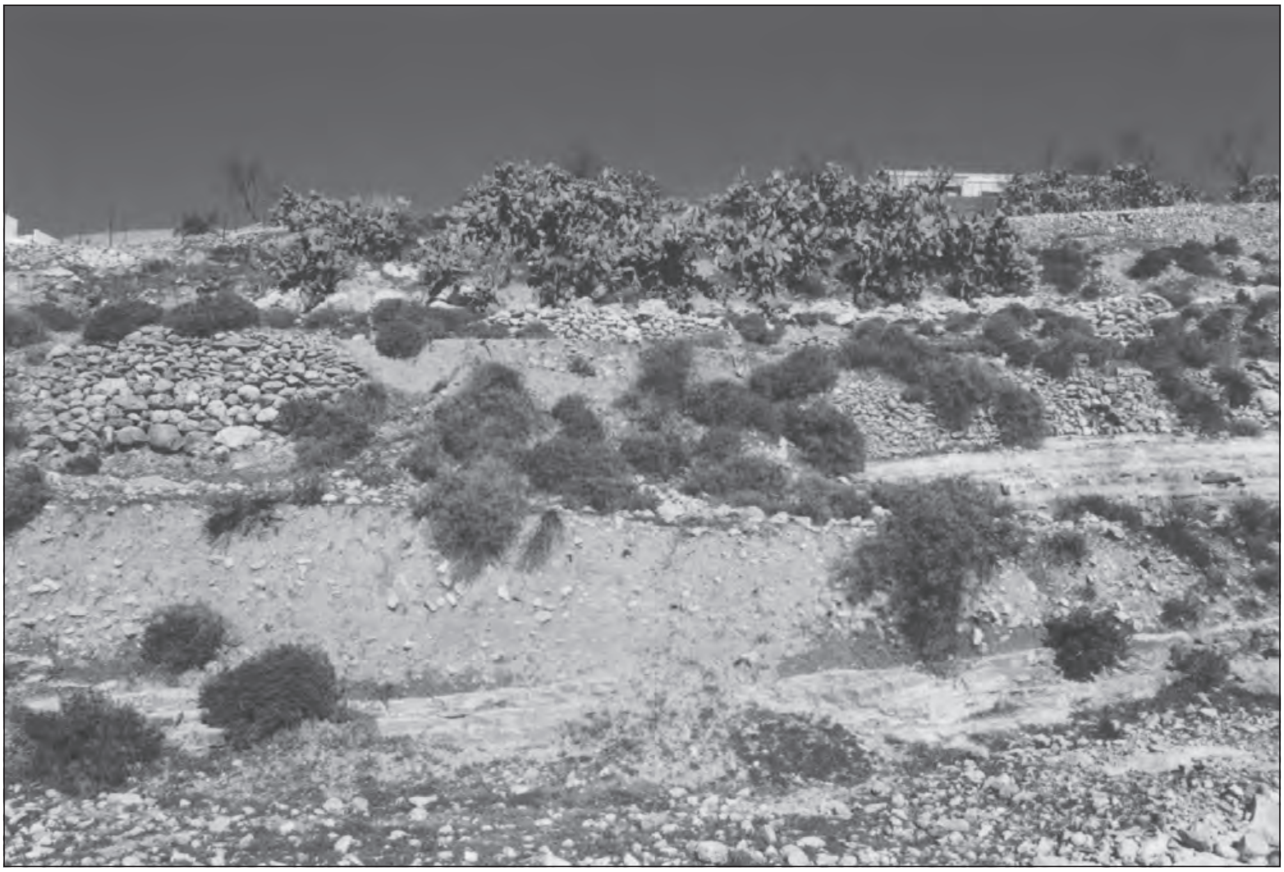

Figure 11: Landslides on collapsed terraces.

ments terra rossa soil is much more erodible than the rendzina soil.

Landsliding is one of the most important mass-wasting processes that affect agricultural hillslope terraces retained by dry built stone walls in Mediterranean regions (Figure 10). The built stone retaining wall is the critical part of the terrace, and its building requires knowledge and experience. Terrace landslides occur in winter during or immediately after heavy rains (Figure 11). Soil saturation affects the strength of the terrace soils, and the effect of the changes of soil strength on the stability of these terraces against landsliding.

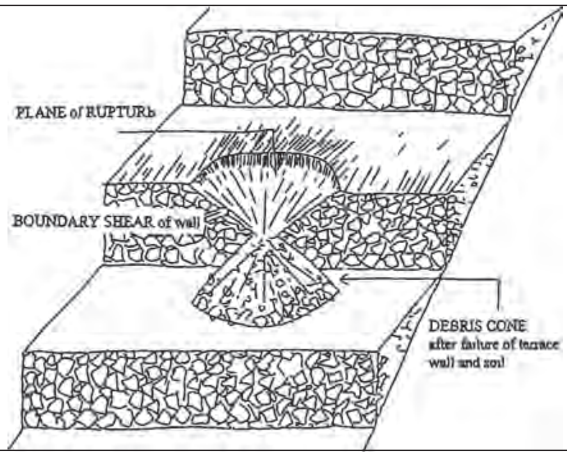

Figure 12: Schematic view of a collapsed terrace.

Figure 13: Recent debris cone formed after a heavy rainfall storm.

The total destruction of the terraces may take centuries but the process is irreversible. The wall are the crucial component of the terrace and their failure determines the destruction process (Figure 12).

In the Lower Galilee the old traditional agricultural practices were based on terraces farming. The urbanization process and low income from agricultural work brought to the abandonment of terraces and increased rates of erosion.

In the Judean hills, forested areas by the national forestry institution- the Keren Kayemet Leisrael- were formerly terraced. After forest fires, the recommendation by forestry and soil experts is to rehabilitate the old terraces and plant on them native trees species like oaks, that are more resilient to fire than pines.

Terrace degradation is a function of physical, economic and social factors, like land use and ownership, distance from the village, community strength, etc. The linkage between the biophysical land degradation has its roots in household and social behaviour. Soil erosion control by terracing is expensive because local labor shortage and was found to be the most expensive soil conservation technique under local conditions.

Socioeconomic factors in the Mediterranean hills and mountains are changing land use along with human behaviour. The self consuming traditional agriculture is changing to a market oriented economy for labor and agricultural production.

The traditional agricultural activity was formerly concentrated on terraced slopes. The difficulties associated with accessibility and use of machinery, the increase in labor costs, the high cost of maintenance and the extensive migration of people from rural to urban areas resulted in a progressive abandonment of part of the terraced land (Figure 13). Nevertheless, the actual price market of high quality wine and olive oil, together with a growing rural tourism interest have highlighted the need for restoration and conservation measures in the terraced land.

There is a gravitational process pulling down the young population of the mountain villages to more and diverse job and studies opportunities at the coastal cities. This brings to shortage of labor power for long term soil conservation practices like terrace and irrigation and ditches canal maintenance, leading to soil erosion from the abandoned traditional terraces. No soil will be transported back uphill and rural migrants will not go back to the mountain villages. Both gravitational processes- soils flowing down from the mountain slopes to the sea floor and people migration from the villages to the coastal cities are linked and irreversible.

Like the large monuments in the world—Pyramides and Temples—old agricultural terraces are a real monument in the history of Man for the desire of life, and should be preserved as a cultural human heritage.

ACKNOWLEDGEMENTS

The research was supported under grant C12-006 US-Israel Cooperation Development Research Program. We wish to thank the comments by two anonymous reviewers for the constructive suggestions for the improvement of the manuscript.

FIZIKALNI IN DRUŽBENI VIDIKI DEGRADACIJE TAL NA TERASAH SREDOZEMSKIH VIŠAVIJ: GEODIVERZITETNI PRISTOP

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POVZETEK

Kmetijske terase spadajo med najpomembnejše sledi delovanja človeka na zemeljskem površju. Izgradnja teras povsem spremeni izvorne naklone naravnih pobočij. Na antropogeno ustvarjenih terasah se že več kot dve tisočletji nabira prst, ki je bila ekonomska osnova za razcvet uspešnih kultur. V pokrajinah vzhodnega Sredozemlja sega tradicija izgradnje terasiranih pobočij že vsaj v obdobje poldrugega tisočletja pred našim štetjem. Namen raziskave je bil raziskati mehanizme, ki vodijo v erozijo in uničenje kulturnih teras na območjih s sredozemskim podnebjem, s poudarkom na deformacijah podpornih zidov teras ter določitvi stabilnosti teras z vidika njihovih dimenzij. Testne ploskve za merjenje odtoka vode in količine erodiranega sedimenta so bile vzpostavljene na opuščenih in vzdrževanih kulturnih terasah. Vrednosti odtoka vode in erozije sedimentov so bile višje na strmejših pobočjih od vrednosti izmerjenih na položnejših terasah. V Sredozemlju je med najpomembnejšimi procesi odnašanja sedimentov na pobočjih s kmetijskimi terasami izdelanimi s suhozidi, plazenje tal. Poseganje človeka v že sicer ranljivo sredozemsko okolje pospešuje naravno erozijo gradiva in lahko privede do pogostejših in intenzivnejših geomorfnih dogodkov, kot so poplave, zemeljski plazovi in erozija prsti.

Ključne besede: kmetijske terase, degradacija tal, geodiverziteta, erozija prsti, sredozemsko podnebje

SOURCES AND BIBLIOGRAPHY

Arnaez, J., Lana-Renault, N., Lasanta, T., Ruiz-Flano, P. & J. Castroviejo (2015): Effects of farming terraces on hydrological and geomorphological processes. A review. Catena, 128, 122–134.

Calvo, A., Gisbert, J. M., Palau, E. & M. Romero (1988): Un simulador de lluvia portatil de facil construccion. In: Sala, M. & F. Gallart (eds.): Metodos para la medicion en el campo de procesos geomorfologicos, Monografia 1. Barcelona, Soc. Espanola de Geomorfologia, 102.

Conacher, A. J. (1998): Problems of land degradation: Introduction. In: Conacher, A. J. & M. Sala (eds.): Land Degradation in Mediterranean Environments of the World. John Wiley and Sons, 491.

Davidovich, U., Porat, N., Gadot, Y., Avni, Y. & O. Lipschits (2012): Archaeological investigations and OSL dating of terraces at Ramat Rahel, Israel. Journal of Field Archaeology, 37, 192–208.

Garcia-Ruiz, J. M., Lasanta-Martinez, T. (1990): Land-use changes in the Spanish Pyrenees. Mountain Research and Development, 10, 3, 267–279.

Gibson, S., Ibbs, B. & A. Kloner (1991): The Sataf project of landscape archaeology in the Judean Hills: A preliminar report on four seasons of survey and excavation. Levant, XXIII, 29–34.

Gordon, J. E., Leys, K. F. (2001): Earth science and the natural heritage: developing a more holistic approach. In: Gordon, J. E. & K. F. Leys (eds.): Earth Science and the Natural Heritage: Interactions and Integrated Management. Edinburgh, The Stationery Office.

Gray, M. (2004): Geodiversity, valuing and conserving abiotic nature. John Wiley & Sons.

IAG/AIG (2016): Newsletter No. 32, 1/2016.

Inbar, M. (1998): The historical development of land degradation in the Eastern Mediterranean. In: Conacher, A. J. & M. Sala (eds.): Land Degradation in Mediterranean Environments of the World. John Wiley and Sons, 491.

Inbar, M., Llerena, C. A. (2000): Erosion Processes in High Mountain Agricultural Terraces in Peru. Mountain Research and Development, 20, 1, 72–79.

Pallares Bou, J. (1994): Procesos que conducen a la rotura de muros en terrazas de cultivo, Norte Castellon. Cuaternario y Geomorfologia, 8, 3-4, 23–26.

Salas Pinto, D. F., Vasques Villanueva, A. (1987): Andenes: Parametro, Operacion y Mantenimiento. Lima, Peru, Universidad Nacional Agraria La Molina.

Young, A. (1969): Present rate of land erosion. Nature, 224, 851–852.

Zgaier, A., Inbar, M. (2005): The influence of soil saturation on the stability of abandoned agriculture hillslope terraces under Mediterranean climatic conditions. In: Garcia, C. & R. J. Batalla (eds.): Catchment Dynamics and River Processes: Mediterranean and Other Climatic Regions. Elsevier, 69–86.

Zgaier, A. (2009): Landslides on agricultural hillslope terraces under Mediterranean climatic conditions. Isr. J. Earth Sc., 57, 249–261.