Chapter 7
Agriculture: Cultivation on Slopes

Péter Csorba

Abstract Among all anthropogenic geomorphological features, agricultural terraces on slopes have the largest relief-modifying impact, equally affecting soil, climatic, hydrologic and biogeographic conditions. Terraces are the predominant elements of landscapes in many parts of the world. The techniques of terrace construction and maintenance show regional characteristics, adjusted to the local natural resources, economic demands or crop requirements. The size of terraces primarily depends on slope inclination, their material on the availability of stones and their degradation on climate. Staircase terraces are an obstacle to air movements and, therefore, have a significant microclimatic impact. While in Hungary terraces are applied almost exclusively in vine plantations, in the Mediterranean, in addition to vineyards, terraced olive, citrus and chestnut plantations are almost equally common. The maintenance and reconstruction of agricultural terraces is an important task in landscape conservation, particularly at World Heritage sites.

Keywords Slopes · Cultivation · Erosion · Terraces · Vineyards

Among land-use types, agriculture demands the largest area. Humans have always intended to use lands of moderate slope gradient for arable land and plantations. Steep slopes susceptible for landslides, rock-falls and collapse were only brought into long-term use when there was no other suitable land or a valuable product that was worth the high risk and surplus investment with significant costs could not be produced. Too high a relief is a major obstacle to cultivation all over the world – although in various degrees on the different continents.

According to the data in Table 7.1, Europe is, with the exception of nutrient deficiency, in a far more advantageous position for all indicators.

There is an urgent need for the utilization of steep hillsides in major population concentrations, i.e. in Southeastern Asia from Pakistan to Japan. A similar

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Table 7.1 Percentages of limiting soil properties for plant growth by continent (after Rid 1984)

	Relief	Nutrient deficiency	Aridity	Extreme wetness	Permafrost	No significant limitation
Europe	12	33	8	8	3	36
North and Central Asia	38	9	17	13	13	10
South Asia	43	5	23	11	–	18
Africa	13	18	44	9	–	16
North America	10	22	20	10	16	22
Central and South America	14	31	25	10	–	20
Australia	8	6	55	16	–	15
World	22	23	28	10	6	11

demographical pressure is apparent in Central America, whereas, as shown by the table, agriculture in North America, Africa and Australia is less restricted by such topographic disadvantages.

Topographic change associated with agriculture is less significant in the case of *grazing*. Where on 25–30% slopes, large-scale landscaping (the establishment of terraces) is required for crop cultivation and plantation purposes, there are no notable topographic obstacles to grazing. As large animals are able to graze when standing in slope direction, erosion by animal treading along contour lines will create terracettes, regular 'visible contour lines' ('cow isohypse'; Plate 7.1).

To control erosion during the *afforestation* of steep slopes, smaller scarps are made to dissect the slope. Such features are gradually washed away within 10–20 years. For forest management and transport, roads are cut into slopes of a gradient exceeding 25–30% and mass movements often result. Deforestation in the Mediterranean is accompanied by interventions with severe geomorphologic consequences. Since the 1970s many forests have been destroyed in summer fire events. It is understandable, therefore, that forests burned down in the surroundings of famous holiday resorts had to be restored most urgently – even for landscape aesthetic reasons (Plate 7.2). As a solution providing both profit and green landscape, the plantation of eucalyptus trees is preferred in countries like Portugal, where this species already composes 30–35% of the forest stands (Horváth et al. 2003). Most of the eucalyptus plantations for industrial purposes are placed on terraced slopes, creating a rather regulated, uniform and artificial landscape.

From the point of view of geomorphology, the impact of land-use types mentioned above is negligible compared to *large-scale terracing*. Among the anthropogenic geomorphologic consequences of agriculture and forest management, only the construction of artificial terraces on slopes has a relief-modifying impact that *affects all landscape factors* in an area, including soil, climatic and hydrologic as well as biogeographic conditions. Terraces become the predominant element of landscape functioning and scenery and can even be regarded as a new landscape type (Csorba and Zsadányi 2003).

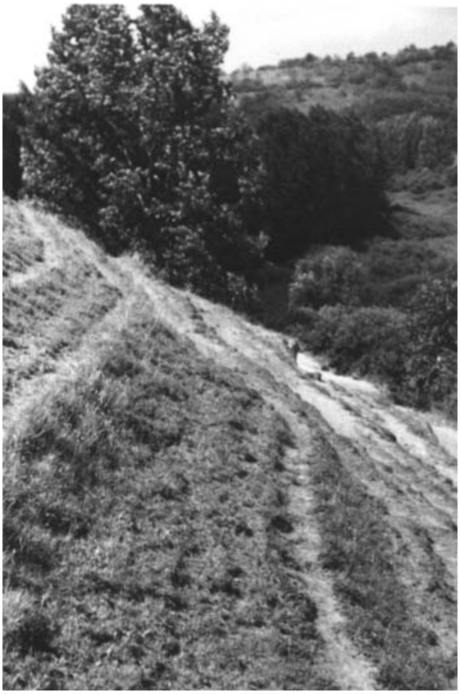

Plate 7.1 'Visible contour-lines' trod by grazing animals near Eger-Síkfőkút (Csorba 1974)

Plate 7.2 Afforestation following a forest fire in South Portugal (Csorba 2005)

Terraces are constructed in Hungary almost exclusively for vine plantations (Csorba and Novák 2003; Lóczy and Nyizsalovszki 2005). In the past decades, arable terraces have been abandoned almost everywhere in the country. In the Mediterranean, in addition to vineyards, terraced olive, citrus and chestnut plantations are almost equally significant. It is more characteristic, though, that rice being a staple in tropical and subtropical regions is grown on extensive terrace systems. It is also usual that coffee, cocoa, pepper and tea plantations occupy terraced slopes in tropical landscapes. Strip cultivation of steep slopes in Southeastern Asia goes back to thousands of years. Moreover, in this region, strip cultivation agriculture also has to overcome violent tropical rainfalls and earthquakes.

The *establishment of terraces* starts with landscaping. Taking advantage of the natural unevenness of slopes, terraces of various heights, widths and materials are constructed. This agrotechnical solution was applied usually for slopes steeper than 12–17%. Strip cultivation is rather expensive with a significant (10–20%) net area loss occupied by terrace risers. Terracing obviously obliterates former flora and fauna entirely, topsoiling is usually necessary and water regime is also considerably transformed – particularly in the case of irrigated strip cultivation, which inevitably involves the drainage of terrace surfaces.

The technique of terrace construction and maintenance shows regional characteristics, although these are adjusted to the local natural resources, economic demands or crop requirements, for instance, whether there are suitable stones available nearby to build supporting walls, what should be the capacity of transportation roads between terraces, how large should be the spaces and distances between stocks and rows. The first authentic documents on the construction of rock terrace supports around Tokaj originate from the 1620s. Thus, at some locations, the terraces and stone walls visible today were constructed 250–300 years ago (Boros 1996; Plate 7.3).

Plate 7.3 Old stone walls near Mád (Tokaj-Hegyalja Region) (Csorba 2006)

Where stones appear on the surface, they are frequently collected and piled up along plot boundaries. The coarse debris will, in the course of time, make up a dike along the slope with a length of 50–100 m, being a characteristic anthropogenic topographic element, e.g. of vineyards in the vicinity of Tokaj. These downslope stone stripes with vegetation cover only along their rims are locally called ‘obala(s)’. They have a typical microclimate and, remaining relatively undisturbed, they provide valuable ecological shelters for biota.

The size of terraces primarily depends on slope inclination. The steeper the original slope is, the narrower the terraces can be constructed with higher risers. Exact size data show a high deviation, as there are staircase terraces with a width of 2–3 m as well as extensive terrace surfaces of 40–60 m width, which also allow mechanical cultivation.

The next basic difference is whether the *terrace tread* is:

– *horizontal*,
– *sloping at 4–8%* or
– *of reverse gradient*, i.e. sloping inward by 3–5%.

The slope of terrace treads is usually 4–8%. On terrace surfaces of lesser gradient, debris accumulation is common and produces various anthropogenic geomorphologic landforms (Plate 7.4).

Plate 7.4 Loess mud accumulated after a violent summer shower on a vineyard terrace near the village of Tarcal (Tokaj-Hegyalja Region) (Csorba 1996)

Terrace risers can be

– *slopes of earth*, mostly grassed, or
– *supporting walls*, extremely steep or subvertical walls of stone or concrete.

The solution to be applied is usually selected by the potential erosion hazard (depending on the erosivity of precipitation and the erodibility of the terrace surface). Terracing undoubtedly improves moisture storage capacity, effectively hinders erosion, impedes the removal of fertile soil or (chemical) fertilizers, facilitates irrigation and mechanized cultivation. On loess, however, a horizontal or inward terrace tread may result in disastrous consequences (as for the ‘Rákóczy-szőlő’, a Tokaj vineyard terraced in 1960–1961). Due to the high vertical permeability of loess, water remaining on the surface or assembled in the inward inclined section of the slope led to extensive dissolution, piping, within a few years (Fig. 7.1). It is inevitably triggered by the ponding of rainwater in a terrace corner, dissolving calcium and concentrating chloride. This chemical process is then followed by the development of increasingly widening drainage routes, inducing mechanical loess degradation. Stucking a pole and concrete pillars into the terrace surface, the loess structure was destructed and piping intensified (Plate 7.5). Within a few years, as slumps of 2–3 m both in diameter and depth developed on the terrace surface, viniculture had to be abolished. In order to prevent damage, prolonged waterlogging has to be precluded and terrace surface slope has to have a 1–2% slope. It is a further advantage when vine poles and pillars are placed on a low ridge making water unable to dissolve passages along them.

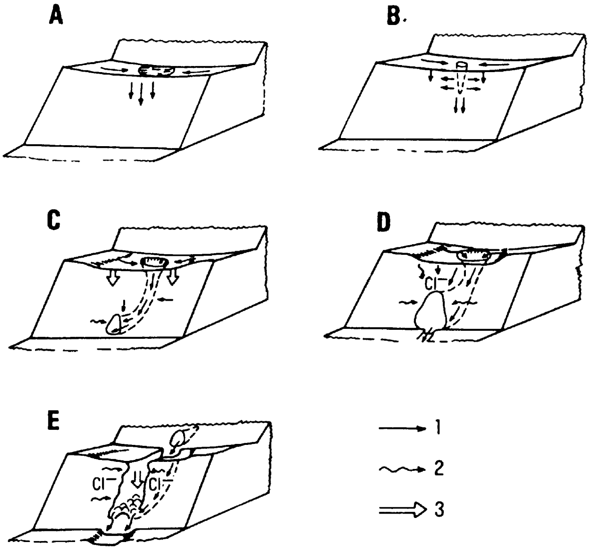

Fig. 7.1 Loess degradation through piping (Kerényi and Kocsis-Hodosi 1990)

Certain techniques have always been available to *drain rainwater*. Among them, the most simple was when settling pits (so-called lector pits or lectors) were constructed along the margins of all terraces, and runoff from the plots and the terrace surfaces were collected in them. This way, the ponding of surplus rainwater, representing an erosion hazard increasing towards the footslope, was counteracted.

Plate 7.5 Loess degradation through piping. Underground passages formed by impounded water around a vine pole on a terrace surface (top left) in the course of time, conduct water to the lower terrace (centre), Nagy Kopasz Hill, Tokaj (Csorba 1988)

The digging of lector pits was already ordered by a regulation on vine cultivation of Tokaj from 1641.

Today, concrete trench drains are constructed adjacent to major terrace systems, which surround the entire terraced slope and effectively drain the water received from nearby areas. Similarly to other European vine-growing regions, V-shaped concrete paved transport roads also function as drainage ditches (Plate 7.6).

Plate 7.6 A concrete road also functioning as a drainage ditch between terraced irrigated vineyard plots, in the vicinity of Tarcal (Tokaj-Hegyalja Region) (Csorba 1985)

In order to mitigate erosion damage from surface runoff, the *protection of slopes* cannot be neglected. Where terrace walls, 3–8 m high and inclining at 70–90%, are composed of the local material, they are usually densely grassed. In Hungary, the plantation of Robinia trees is a common means to stabilize slopes (in the case of the high bank along the northeastern shore of Lake Balaton or around the village of Pere in the valley of the River Hernád, Northeastern Hungary). At other locations, strawberry plantations and fruit trees were also planted (or preserved) on terrace risers. The grass cover involves an ecological hazard: it may shelter pests and, therefore, a thorough chemical weed control may be necessary. Covering slopes with plastic foils is meant to tackle the problems caused by both erosion and weeding. Foil cover, indeed, also reduces the loss of humidity by evaporation and, thus, promotes savings on irrigation. This technique is not yet widely used as foils are easily damaged, decomposed by sunshine in 2–3 years; the types resistant to weather and mechanical damage are rather expensive. (The terrace slope seen left on Plate 7.6 is covered by an experimental foil strip.)

Among the disadvantageous features of terraces, primarily the *adverse changes in the microclimate* are usually emphasized (Csorba 2006; Nyizsalovszki and Lóczy 2008). Staircase terraces are an obstacle to air movements. As a consequence, cold air reaching the terrace will not be able to move further towards the slope, forms a permanent air pond and susceptibility for frost in summer and autumn significantly increases (Justyák and Pinczés 1976). As proved by a *frost* damage mapping project carried out at Tokaj (Pinczés and Marton-Erdős 1983), strip cultivation resulted in severe damage in vineyards where previously such natural disasters occurred only rarely. The zone susceptible to frost stretches to an elevation 10–20 m lower, and this threat has become more common at the midslope, with rather favourable ecological conditions in other respects. Frost damage mapping also proved that the degree of frost damage decreased towards the outer margins of terraces (Fig. 7.2). The most intensive frost damage could be located to the inward base of terraces exceeding 10 m in width, horizontal or with reverse gradient (Pinczés and Marton-Erdős 1983). At the foot of strip-cultivated slopes, public roads or railway lines are often found, the embankments of which frequently impound cold air flow and result in frost damage on lower terraces.

The impoundment of air flow by strip cultivation does not only increases frost hazard, but also increases the temperature of *pockets of hot air* during the summer. This increases evaporation demand and cultivated crops use more water. In the wine-producing regions of Germany, Austria and France under a more humid climate, the tendency to mist and, consequently, the hazard of fungoid diseases is higher in the valleys between terraced slopes. The modified microclimate of terraces will influence soil temperature, humidity balance, indirectly influencing the intensity of chemical processes and microbial activities in soils. It is detected that humidity conditions decrease the value of irradiation, which influences the quality of yield of crops with higher demand of sunlight.

For downslope-cordoned vine plantations on terraces, variations in irradiation between the outward and inward sides are less developed and the hazard of fungoid

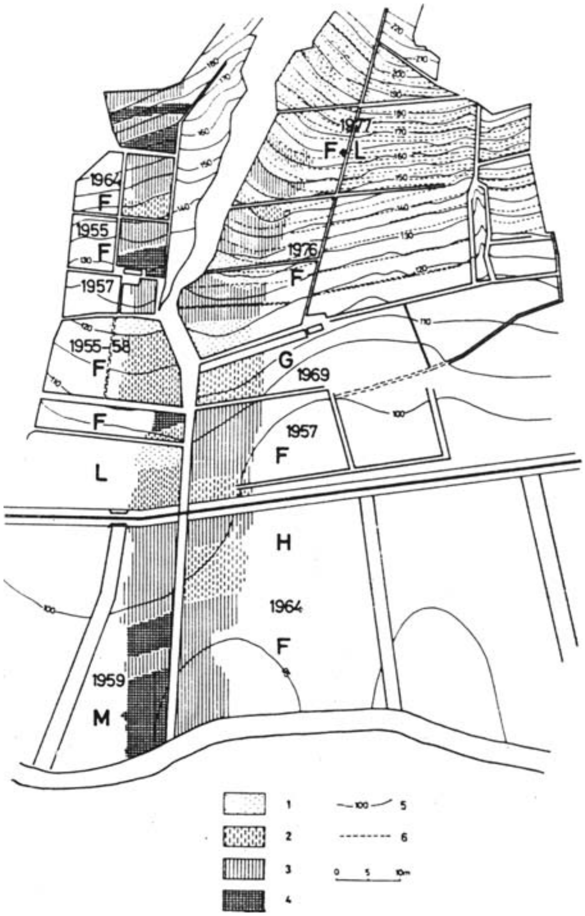

Fig. 7.2 Frost damage map for the vineyard terraces of the Szarvas Farm Road at Tarcal. 1: slight; 2: moderate; 3: severe; 4: extremely severe frost damage, 5: contour-line; 6: terrace margin. Years indicate the time of vine plantation. (Pinczés and Marton-Erdős 1983)

disease is higher in the inward, shaded, side, cooler and more humid, where the sugar contents of berries will also be lower.

Terraces, especially systems supported by stone walls – as indicated by one of the examples above – are rather *permanent features* in the landscape. Despite occupying only a fraction of the area, they have a central role in the protection of some landscapes. Landscape units renowned for strip cultivation are often emblematic regions of countries, like Tokaj or Badacsony (on the northern shore of Lake Balaton) in Hungary. In addition, strip cultivation takes place on foothills; terraces are visible from long distances. It is probably not a coincidence that a number of cultural *World Heritage* landscapes present strip cultivation (see http://whc.unesco.org/en/list World Heritages Sites). The most spectacular among them are the rice terraces in the Philippines and in Java, but the vineyards along the River Duoro in Portugal, Cinque Terre in Italy (Plate 7.7) or the agricultural

Plate 7.7 Vineyard terraces on steep slopes facing the Ligurian Sea (Cinque Terre, Italy) (Csorba 2001)

landscape of the Wachau Gorge in the Austrian section of the River Danube are also unique landscapes.

There are probably inordinately 'over-regulated', almost entirely *reconstructed landscapes*, as e.g. Kaiserstuhl in the Rhine Valley (Plate 7.8), or the wine region facing Lake Biel in Switzerland and the Mosel Valley in Germany. On the other hand, *abandoned* and declining *terrace systems* are not visually attractive.

Plate 7.8 800 km of vineyard terraces were reconstructed in the Rhine Valley, on the Kaiserstuhl Hill (Germany) between 1969 and 1972 (Csorba 2000)

Uncultivated terraces retain their intense landscape-forming impact for decades; secondary vegetation on abandoned terraces will not mask the physical, ecological and visual impacts of the former cultural landscape, as at several locations in the Rhine Valley. The question arises: what to be done with crumbling stone walls? Their restoration or reconstruction is rather expensive. Strip cultivation has a strong and long-term impact on the present and future land-use potential of slopes. When terraces are built, land use becomes fixed and more flexible land-use practices are excluded.

The construction of terrace systems is cost-intensive and demands massive efforts from the community. Their *maintenance* also requires permanent labour investment. Therefore, a worldwide decline in rural population, especially in its active groups capable of work, means that less and less people are left to maintain the terrace and irrigation systems. It is evident that the shortage of labour in the countryside will soon be reflected in the conditions of these remarkable structures. For some time, the abandonment of terraces in peripheral location would not prohibit the functioning of the system; however, when the maintenance of crucial points of the system is neglected, landscape functioning will be severely inhibited.

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