GEOÖKODYNAMIK

BAND 10, HEFT 2/3, 1989

INHALT: S.



**HERAUSGEBER:** Prof. Dr. Otmar Seuffert
Geographisches Institut der TH Darmstadt
in Verbindung mit dem
"Verein für Erdkunde zu Darmstadt e.V."
Schnittspahnstraße 9 - D-6100 Darmstadt
Tel. 06151/162719 oder 165318

**SCHRIFTLEITERIN:** Bianca Ott

**ERSCHEINUNGSWEISE UND BEZUGSBEDINGUNGEN:**

"GEOÖKODYNAMIK" erscheint in unregelmäßigen Abständen, in einem Gesamtumfang von ca. 200 - 400 Seiten (2-4 Hefte) jährlich. Sie kann über den Buchhandel oder unmittelbar vom Verlag bezogen werden. Persönliche Subskription ist nur beim Verlag möglich.



# GEOECOLOGICAL AND MORPHOLOGICAL PROCESSES ON ABANDONED VINE-TERRACES IN THE CINQUE TERRE (LIGURIA)

THOMAS CARL & MICHAEL RICHTER, ERLANGEN

## SUMMARY

In the European part of the Mediterranean region about 10.000 km of vineyards and olive-tree cultivations, which are located on terraced slopes and the maintenance of which requires intensive manual care, have been abandoned since the turn of the century. This process must be seen as the result of various periods of emigration, seasonal 1migration, commuting, and spreading tourism; the population decrease in the Cinque Terre is shown in Fig. 3. After the abandonment of cultivation a fast and favorable development in plant succession has taken place on the specially prepared and improved terrace soils (Fig. 8). It starts with a 3-4 year initial phase which brings forth geophytic and annual weeds and leads over to an open herbaceous grass (Chenopodietea -> Thero-Brachypodietea, Fig. 7). During the phase of cultivation and the first fallow years micro-climatic conditions and rainfall input reach their extremes. In this period breaches in the supporting walls, breaches which in the Cinque Terre are aided by a strong sidewardly directed percolation along a compaction horizon at a depth of approximately 40 cm (Fig. 13) and by sludging of fine-grained material within the joints of the wall occur with increased frequency. At the beginning of the second fallow decade interception losses increase as a result of an emerging shrub succession with homogeneous blackberry-polycorms. The frequency of wall-breaks lessens with decreasing interflow, intensified water requirements of the plants, concentration of hydrophile litter, and lower effective precipitation (Tab. 2). This is especially true of the phases of initiation of a wood succession with high maquis and pine formations as well as of the terminal phase with holm oak forests (Rhamno-Prunetea -> Cisto-Lavanduletea -> Quercetea ilicis) which is reached about sixty years after abandonment. During the final phase surface run-off rarely occurs (Fig. 11); the processes of wall-break are now confined to the mechanical force of root pressure alone. Considered ecologically the fallow development happens rapidly and without problems provided man does not interfere; but the richness in species decreases with the assimilation of sites (Fig. 9).

Therefore it is advisable to continue cultivation on the remaining vine terraces. The importance of the terrace landscape for tourism means that economical and ecological arguments in favour of its maintenance do not come into conflict.

**ZUSAMMENFASSUNG**

Im europäischen Teil des Mittelmeergebietes sind in Hanglagen, die bei der Landnutzung einer intensiven manuellen Pflege bedürfen, seit der Jahrhundertwende etwa 10.000 km Rebland und Ölbaumkulturen aufgegeben worden. Dieser Prozeß ist als Folge mehrerer Auswanderungsperioden, der saisonalen Abwanderung, des Pendlerwesens und des aufkommenden Tourismus zu sehen; für die Cinque Terre wird der Bevölkerungsrückgang in Abb. 3 aufgezeigt. Hier findet auf den anthropogen stark aufgebesserten Terrassenböden nach Bewirtschaftungsaufgabe eine rasche und günstig verlaufende Pflanzensukzession statt (Abb. 8). Sie beginnt mit einem 3-4 Jahre bestehenden Initialstadium mit geophytischen und einjährigen Wildkräutern, das zu einem offenen Staudenrasen überleitet (Chenopodietea -> Thero-Brachypodietea, Abb. 7). Während der Bewirtschaftung und der ersten Brachejahre herrschen die extremsten mikroklimatischen Verhältnisse und der höchste Niederschlags-Input. Mauerbrüche, die in den Cinque Terre durch eine starke seitwärtige Perkolation in einem Verdichtungshorizont in etwa 40 cm Tiefe (Abb. 13) und durch Feinmaterial-Verschlämmung in den offenen Mauerfugen begünstigt werden, treten verstärkt in diesem Zeitraum auf. Mit Beginn des zweiten Brachejahrzehnts erfolgt bei aufkommender Verbuschung durch homogene Brombeer-Polykormone eine Erhöhung der Interzeptionsverluste. Die Mauerbruch-Ereignisse nehmen mit Verminderung des Interflows bei erhöhtem Wasserbedarf der Pflanzen, Anreicherung hydrophiler Laubstreu und geringeren Bestandsniederschlägen ab (Tab. 2). Dies betrifft insbesondere die Stadien einer beginnenden Verwaldung mit Hochmacchien und Pinienbeständen sowie das Terminalstadium mit Steineichenwäldern (Rhamno-Prunetea -> Cisto-Lavanduletea -> Quercetea ilicis), das etwa 60 Jahre nach Bewirtschaftungsaufgabe erreicht ist. In der Schlußphase kommt es nur noch selten zu Sickerwasser-Überschüssen (Abb. 11); Mauerbruch-Prozesse beschränken sich nun allein auf mechanischen Wurzeldruck. - Nach ökologischen Gesichtspunkten erfolgt die Brachlandentwicklung in den Cinque Terre ohne Einwirkung des Menschen problemlos und rasch; die Artenvielfalt läßt allerdings mit der Standortangleichung nach (Abb. 9), so daß eine Fortführung der Bewirtschaftung auf den verbliebenen Rebterrassen empfehlenswert ist. Da die Terrassenlandschaft der Cinque Terre von touristischem Belang ist, bilden ökonomische und ökologische Argumente für deren Erhaltung keinen Interessenskonflikt.

## 1. SUBJECT-MATTER AND METHODICAL PROCEDURE

As a contribution to a practice oriented landscape ecology G. HARD (1973: 93) proposed an "ecology of utilization and change in utilization, of cultivation and abandonment, of usefulness, load, load carrying, and regeneration capability of areas of a landscape". The terms "abandonment" and "regeneration capability" express the essence of natural fallow development which has been a subject of growing interest in physio-geographical and botanical studies for about 15 years. In the light of the EC policy concerning discontinuation of use of land areas in response to agricultural overproduction in the EC the subject of natural fallow development has caught the attention even of politicians.



In the existing literature, however, there are almost no references to progressive lines of development on Mediterranean fallow-land, although precisely here, in the European states which lie along the Mediterranean, there is evidence of a drastic decrease in agriculture: Viniculture and olive-tree cultivations in Italy, Greece, Yugoslavia, and Southern France are particularly affected. Moreover for about three decades changes have been taking place in the fertile alluvial plains where the two traditionally cultivated crops have been superseded by citrus- and peach groves, as well as by specialised crops in foil-greenhouses (vegetables and flowers) and field vegetables.

Vineyards and olive-tree groves on slopes which require an intensive manual care are most affected by abandonment. In the Mediterranean region parcels of land which do not allow the use of modern technical implements, had, here and there, already ceased to be cultivated at the turn of the century. Such regions were favored for a reforestation policy which must be judged negatively in the light of current scientific thought.

The paper in hand intends to contribute to the consideration of the following questions: whether a fast plant succession is ensured on uncultivated vineyards in a Mediterranean climate; what changes take place in micro-climate and soil-water regime; and how abandonment affects soil erosion.

The phyto-sociologically based vegetation survey and the studies referring to micro-climate and soil were conducted by the co-author during a stay in the Cinque Terre from September 1980 until October 1981. The principal author carried out his geomorphological field studies from May to September 1985[1].

The surveys of vegetation development are based upon a statistical analysis of 80 phyto-sociological listings in cultivated and abandoned vineyards and olive-tree groves. The time for which the land had lain fallow was inquired from the owners and subsequently the areas where chosen after the "location-for-time-substitution" principle (A.D.M. PAINE, 1985).

On the Cinque Terre slopes plant succession is superposed by an obvious climatic vertical gradient. To find out its degree of influence meso-climatic data were permanently registered at six weather stations. Micro-climatic surveys were carried out through a series of short-interval measurements taking the form of parallel studies in various plant formations on a daily and weekly basis. Moreover the recording of the stratification of temperature and humidity level near ground as well as recording of evaporation and interception permitted calculations of water-regime-balances in various fallow stands.

However, particularly with terraced regions aesthetic considerations must be set against positive ecological fallow development. In an "artificial landscape", like the Cinque Terre, grown over centuries consideration must be given to the attractiveness of the unique terraced slopes to tourists. Consequently it must be asked to what extent does the abandonment of cultivation lead to a gradual destruction of the terrace landscape.
The processes of change in the anthropomorphous soils were established by means of soil -

[1] *We would like to thank DFG and DAAD for financing our work.*

physical and soil chemical methods. The results about particle-size displacement, pore volume and infiltration variation provided a basis for judgement, not only concerning the pedogenesis but also those processes causing the wall-breaks during the terrace dilapidation. Mappings and statistical analysis of the extent and distribution of wall-breaks show how fallow vegetation, petrographic conditions and relief modify the process of decay.

A concluding judgment on the ecological fallow development in vineyards can be made with regard to Central European conditions. The Cinque Terre paper is just one part of a detailed study about the subject in question which was conducted throughout the entire Mediterranean region. More detailed analysis of further supra-, meso- and thermo-mediterranean regions will follow in a more comprehensive paper (M. RICHTER, going to press).

## 2. THE RESEARCH AREA

### 2.1 Position and physio-geographical survey

The Cinque Terre covers an area of 33.8 km in the province of La Spezia in south-east Liguria. It is divided into three communities with five isolated villages located on the coast. South of the biggest settlement, Monterosso, are located the two remote villages of Vernazza and Corniglia to which the slope localities of San Bernardino, Fornacchi and Pianca belong. Further south a road leads from La Spezia to the villages of Manarola and Riomaggiore and the locality of Volastra which belongs to them. Before the Cinque Terre were connected to the railroad network in 1879 it was a remote region which was, with the exception of Monterosso, difficult to reach even by sea. The area's border runs along the crest line of a coastal range which culminates in Monte Malpertuso with 812 m above sea level. Thus the Cinque Terre are limited to a coastal declivity of the foothills of the Ligurian Apennines.

According to E. ABBATE (1969) three geological units which are the basis of an intensive land use with terraces can be distinguished between Monterosso and Riomaggiore (Fig. 1):

1. Fine-grained sandstone complex from the Upper Oligocene (Macigno = Tuscan Sequence II)
2. Eocene shale zone with lime-sandstones and siltit intercalations (Lime-Clay Series = Ligurian Sequence I)
3. Island like deposits of foliated calcareous marl and fine-grained limestone (Groppo del Vescovo-Limestone = Ligurian Sequence I).

As major components of the bed-rock these three units strike from NNW to SSE and form layers of an almost vertical dip. However, at many points the tectonic structure of the Cinque Terre also shows a chaotic arrangement which obviously evidences an intensive deformation of the Macigno (a layer of the Tuscan Nappe) and the other allochthonous units. This is particularly true of the Ligurian Sequence deposits which were interbeded as olistostromes into the upper part of the Macigno-sandstone (K.-J. REUTTER, 1968: 188). - Two other geological formations play no role in agriculture in the Cinque Terre:

4. Barren gabbro and serpentinite complex west of Monterosso (Ligurian Sequence III)
5. Small Quarternary terrains of debris which consist of sandstone and shales as well as boulder beaches



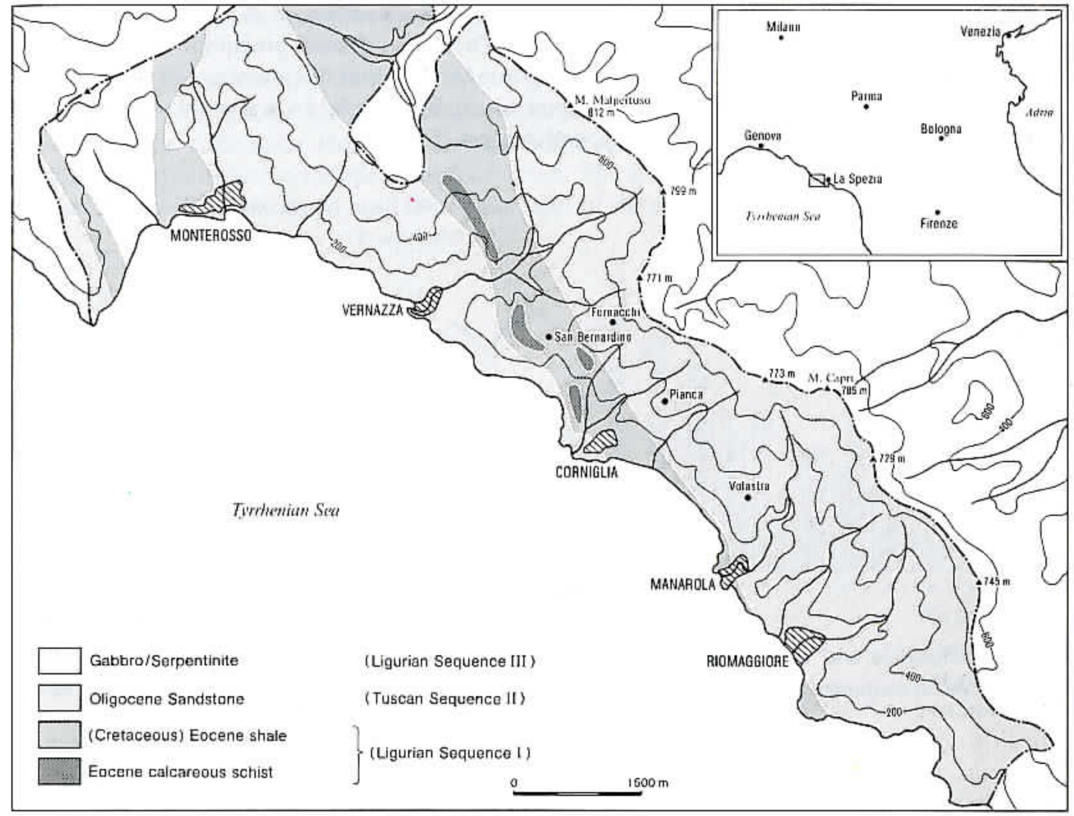



*Fig. 1: Position, borders, and geological survey of the Cinque Terre.*

The Cinque Terre coast ranges are morphologically characterized by steep slopes which over wide areas have a gradient of more than 30°. With regard to the terraces this has the effect that in places the height of the supporting walls surpasses the width of the terrace level at the back of it. In petrographic-tectonically unstable places the extreme steepness which is ultimately caused by the surf results in mass-shiftings (R. TERRANOVA, 1984). In particular the Ligurian Lime-Clay Series which submerges into the sea between Corniglia and Riomaggiore is characterized, above the beaches of Corniglia, by landslides. The exceptional frequency of wall-breaks in this area results in Corniglia being the most affected part of the Cinque Terre with regard to abandonment.

Level areas, existing as relics of marine abrasion platforms occur at only a few altitudes like 110 m, 300 m, and 450 m. The slope localities of the coastal village centres are bound to these areas where, in an otherwise predominantly steep relief, the conditions are most favorable. The positions of the principal settlements concentrate around the mouths of perennial brooks. V-shaped valleys cut deeply into the slopes above Vernazza, Manarola, and Riomaggiore whereas Monterosso is located in an extended depression on a bay. Corniglia is the only settlement located on a spur, at nearly 100 m above sea level.

Particularly in the cold season when the influence of the west winds is intensified the SW-aspect of the declivity results in a clear luff effect. The mean annual precipitation amounts to ca. 1000 mm (Levanto, 2 m above sea level: 952 mm/a; Montale di Levanto, 149 m above sea level: 1112 mm/a). Potential evaporation comes to ca. 500 mm/a. In a normal year a rainfall deficit prevails in the months of June, July, and August (Fig. 2).

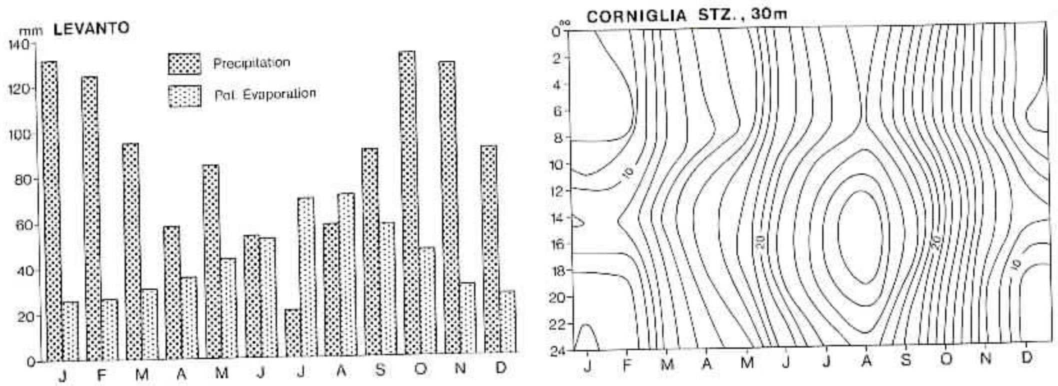



*Fig. 2: Precipitation and evaporation of Levanto, a village north of the Cinque Terre (Mean of 1951-72; Pot. evaporation computed after PAPADAKIS) and thermo-isopleths diagramm of Corniglia-Stazione (1981-82).*

The Cinque Terre can be divided into three thermal levels. Up to 100 m above sea level the sea breeze causes an obvious reduction of temperature peaks during the day so that here the diurnal range is below 5 K. A warm slope climate follows, up to nearly 400 m above sea level which is the favored region for intensive land use through vineyards and olive-tree groves. Nearing the crest of the foothills a zone with smaller diurnal variatons follows. Here, especially in the colder half of the year condensation clouds cause a shade effect. The mean of the vertical temperature gradient is remarkably high: 0,8 K/100 m.

This fact, together with an increase in precipitation with gaining altitude, leads to a distinct vertical vegetation gradation. In the region close to the sea thermo-mediterranean floristic elements can also be found owing to the effect of intensified salt-ventilation. The tree spurge is the dominant representative. However the meso-mediterranean species predominate, particularly in the warm slope region. On this level holm oak forests can be regarded as the climax population (B. NOVAK, 1987). Above 400 m supra-mediterranean floristic elements already predominate. Here, the prevailing species is the pine (Pinus pinaster) which has proved itself reproductive at this level despite frequent forest fires. This applies too to extended stands of bracken which are common in the crest region.

The following results relate mainly to the area of most intensive utilisation on the level between 100 and 400 m above sea level which certainly belongs to the meso-mediterranean zone.



## 2.2 Socio-economic aspects as reasons for abandonment

Because of the steep slopes in the Cinque Terre an intensive agricultural utilisation could be realised only through the terrace system. In the late Middle Ages high yields from viniculture and olive-tree cultivation led, in the course of free trade with the Republic of Genoa, to growing prosperity in the independent federation. The population increase, as an expression of economic stability, continued until the second half of the 19th century (Fig.3).

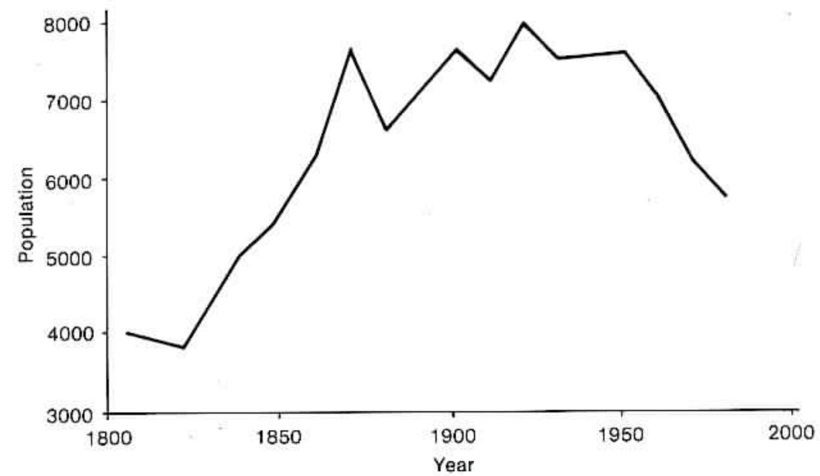



*Fig.3: Population development in the Cinque Terre.*

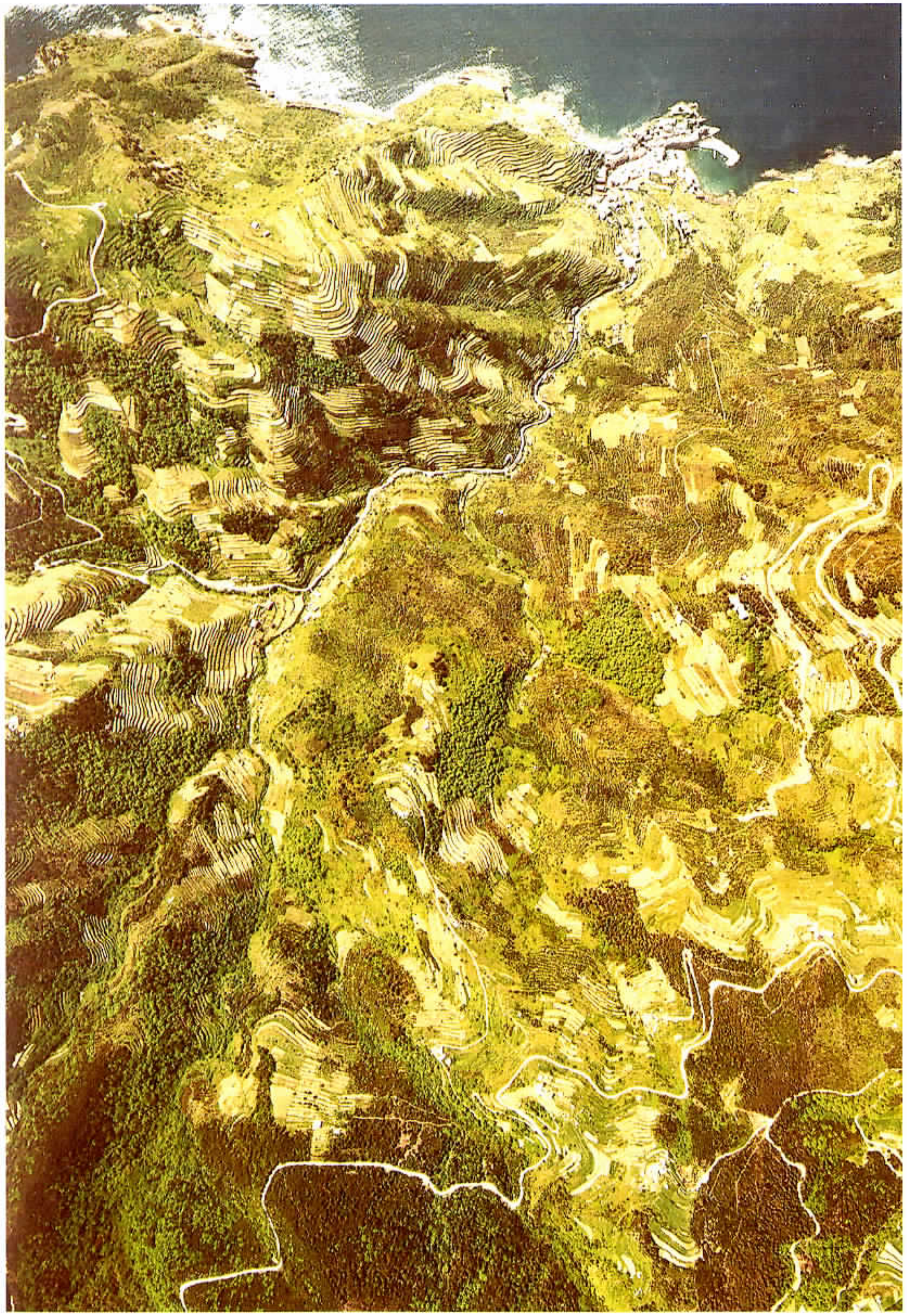
At that time of a beginning overpopulation, however, the prospect of better production conditions and vast land reserves caused the first wave of emigration to the Americas (especially to Argentina and Chile). At the same time, between 1870 and 1880, when the rail-road from Rome to Genoa was constructed, the vine-dresser's field of activity began to change. After the villages had been connected to the network of traffic new opportunities existed for easier internal migration to La Spezia and Genoa. In the nineteen-twenties disastrous crop failures as a result of a phylloxera infestation led to a second wave of emigration. However, the decisive reason for the population decrease and the change in the social structure was the enormous economic development during the decades after World War II. The growing differentiation within the economic structure intensified agriculture's degree of dependence on natural production conditions, technical possibilities, tenure and the market conditions.

Today, both the pull-factor of the north Italian centres of industry and trade and the unfavourable relief conditions must be considered the main reasons for abandonment in the Cinque Terre. The steep and narrow-terraced terrain and the low-built trained arbours make it impossible to use machines. The enormous fragmentation and narrow footpaths make it difficult to reach the parcels of land. In addition to the high costs of production remarkable labor and financial expenditures for the repair of damaged supporting walls also exist. Therefore a breach in a wall often causes the abandonment of a terrace. After all marketing of the wine produced seldom extends beyond the regional borders since only a third of the wine producers fulfill the requirements of quality necessary for the description "DOC". Nowadays the wine-grower often sells the wine directly to tourists or, to a great extent, uses it for his own consumption.

*Photo 1: (left page) Color areal photograph of Vernazza (June 1973). The dark green forest stands in lower altitudes are mostly olive-tree groves. The light green vineyards contrast with the sharp terrace contours; at greater distances from the sea and higher altitudes bracken and pine formations are predominant (licensed by Istituto Geografico Militare, Firenze, No. 2598/3151, 02/14/1979).*

*Photo 2: (right page) Vineyard terracing above Manarola (March 1984).*





When a living could no longer be made out of viniculture the effects of permanent emigration were aggravated by the development of commuting, with the result that terraces came to be cultivated only part-time. As a result of emigration a relative over-ageing of the inhabitants can be observed which leads to a labor shortage and consequently to the abandonment of farms. The most recent stabilization in the variation of population has been caused by increasing tourism and recent subventions from the provincial government for measures to preserve the landscape.

## 3. BASIC ASPECTS OF TERRACING AND LAND USE

It may be presumed that in the 11. century farmers coming from the adjacent Val di Vara began the construction of the terraces (C. VERBAS, 1978: 19). The labor was heavy and lasted many generations. Most of the slope region between 100 and 400 m above sea level was covered with terraces which were supported by rough dry stone walls (Photo 1 and 2). In this way cultivation of the extremely steep slopes was made possible. In addition the terracing lessened the erosive removal of the soil and influenced the drainage of the slope by reducing surface run-off and improving the water storage capacity of the soil.

In order to construct the terraces the dense forest and maquis stands first had to be removed. The building of the dry stone walls was done from the lower slopes upwards (Fig. 4). In the

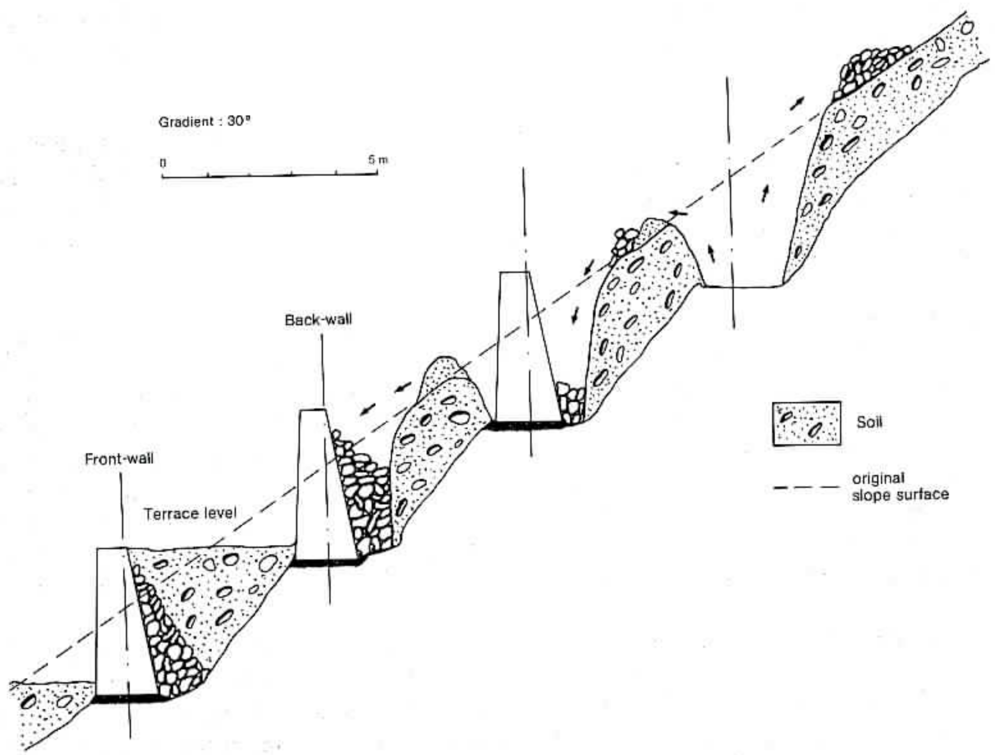



*Fig.4: Diagramm showing progressive steps in terrace construction (cross-section)*



first phase trenches were dug running parallel to the slope. The bottom of the trenches was given a foundation of pebbles. Sandstone, which was supplied from the neighboring quarries, was the main building material for supporting walls. In the shale and limestone terrains this bedrock was also taken for construction. On the hill-side of the wall coarse rocks were packed to ameliorate the drainage flow and to reinforce the wall. Finally the bench of the terrace was levelled.

The average width of a terrace is between three and four metres. However it varies depending on the gradient from one and a half to twelve metres. The gradient together with the terrace width determines the height of the wall. On extremely steep slopes it reaches four metres to ensure an economically viable floor space. The average height is around two metres. The footpaths, as the only possible means of reaching the land parcels, run along double-strength walls. The several terrace levels are connected by stairs, made of stone, which are imbeded in the walls.

A cross-section (Fig.13) shows that the structure of a terrace displays little uniformity in respect of material and its arrangement. The wedge-shaped drainage unit made of rough boulders is placed behind the wall. The soil depth reaches up to three metres depending on the wall height and decreases to a depth of 40 cm in the direction of the terrace immediately above. The terrace bench is given a general grade of 1-3 % according to what is necessary for satisfactory drainage and is densely covered with debris. Furrows, made by turning over the soil, run towards the front-wall but are often filled up with alluvial material during heavy rain. Sometimes, by way of small gullies behind the terrace crown, the surface run-off follows the lateral gradient down to the next point of confluence.

The wall is trapezoid in section so that the front is slightly inclined backwards. The foundation reaches only several centimetres below the lower terrace level. The supporting walls are built of flat coarse stones which are placed on their best bearing surface without any binder. Compactness and stability are achieved mainly by carefully filling the spaces with smaller stones. The terrace crown consists of a layer of flat stone slabs.

Apart from the eventuality of an extended landslip the terrace landscape is threatened only by wall-breaks. These lead, through a series of phases of dilapidation, to a complete destruction of the terrace system by allowing the reactivation of the gravitational forces of the slope at scattered but crucial points (Fig.5 and 6). The farmer understandably is interested in maintaining only terraces under cultivation. On a farm with the average dimensions of one and a half hectares (=cultivated land; ISTAT, 1981) two to five wall-breaks per year have to be repaired. In the case of a single breach two to ten cubic metres of stones have to be replaced (P. ELIA/A. ROSSI, 1984: 78). When the wall is damaged cultivation is limited to a period of about two years following the damage since a wall-break initiates the destruction of the terrace.

On the arable land of the Cinque Terre it is viniculture which prevails. The production areas are mainly bound to the poor, loose sandy soil of the Macigno. Olive-trees on the other hand grow on the calcareous shale soil. Here, vines are cultivated only on favorably exposed positions (Fig. 5). Because of the practice of inheritance by equal division, property is scattered in small parcels all over the slopes. In Fig. 5 the particular distribution of the fallow phases shows the enormous fragmentation.

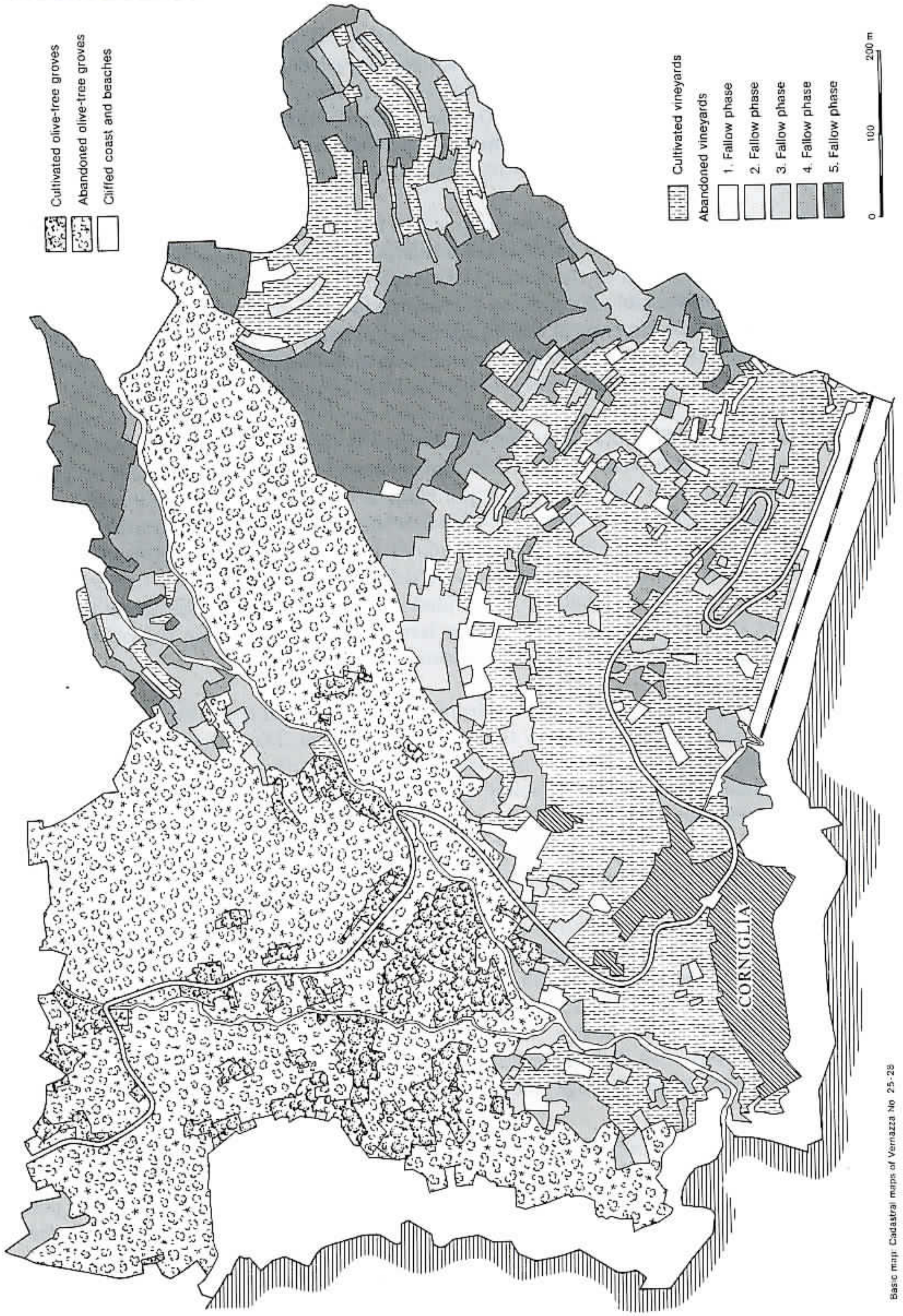



*Fig.5: Map showing distribution of land use and fallow phases in Corniglia in summer 1985.*



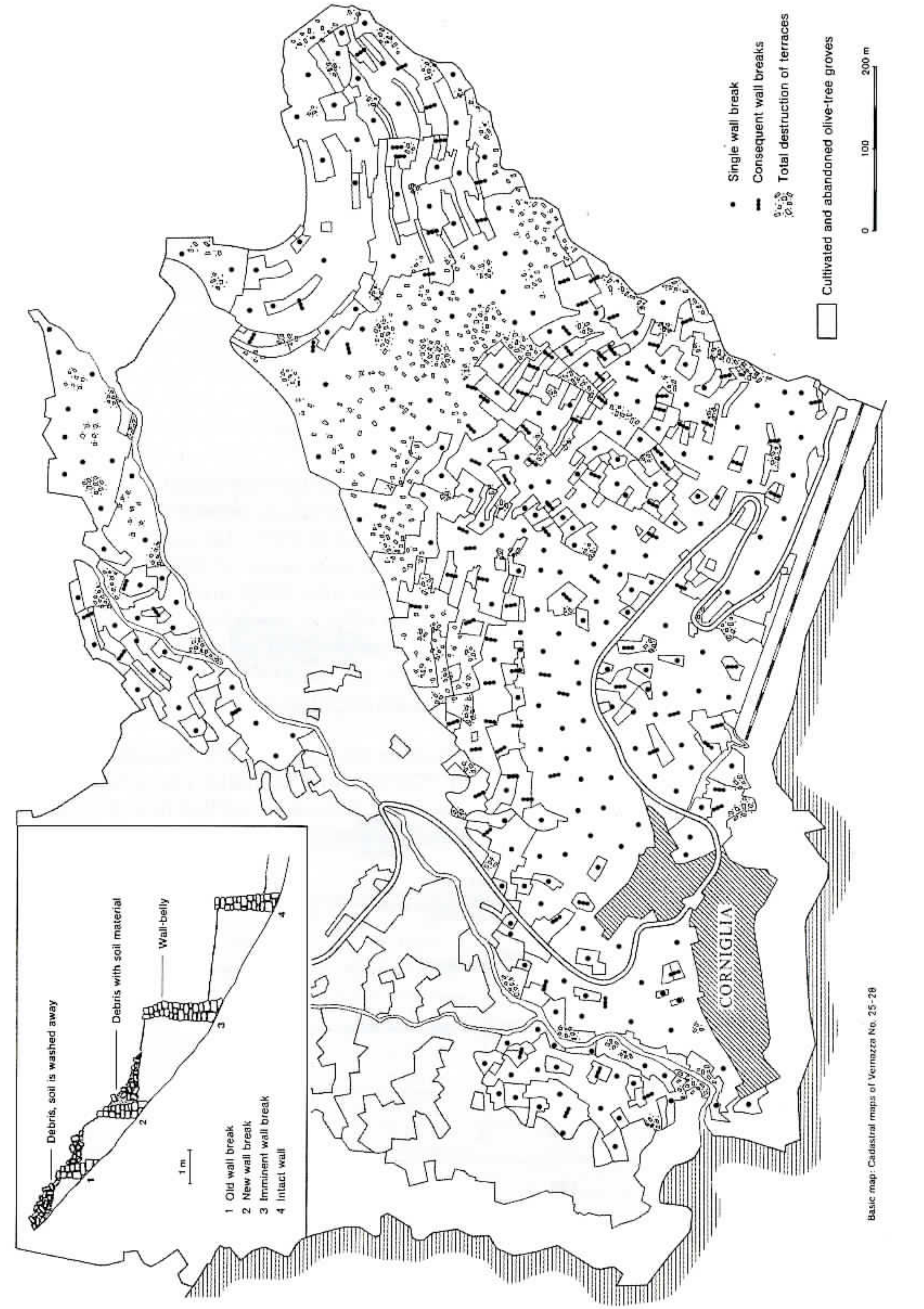



*Fig. 6: Map showing the distribution of wall-breaks and terrace dilapidation in Corniglia in summer 1985. Above, left: diagramm showing phases of terrace destruction in profile.*

The vines are trained, without exception, by using the pergola system. They are planted in line with a spacing of one to two metres. The young shoots are tied to a network of wire which is spread at about one metre above the terrace ground. The low training system guarantees a high productivity by using the heat radiation of the ground and the back-wall. Moreover it provides shelter from the sea breeze. However, the diminished circulation near the ground stimulates the occurence of fungal diseases and vermin.

Once or twice a year the vine-dressers break up the ground to a depth of approx. 20 cm. For natural fertilization the ground is trenched at intervals of several years to a depth of 40 cm. The trenches are filled with foliage, draff, organic house waste, lupin seeds, etc. The vine absorbs the organic ingredients and these give rise to the typical, slightly bitter taste.

## 4. ECOLOGICAL SITE CHANGE

### 4.1 Vegetation development on abandoned vineyards

As regards the natural potential vegetation of the Cinque Terre one may expect Quercion ilicis in the meso-mediterranean level and Quercion pubescenti-petreae in the supra-mediterranean zone above 400 metres. In addition to these as a result of the fundamental reorganization caused by cultivation and terracing current vegetation includes associations of root crop and weeds from the Fumario-Euphorbion. The rock-sites close to the coast which are very much characterized by thermo-mediterranean species, and the plant cover of which was degraded by deforestation, must also be treated as anthropogenic maquis. They show parallels to Oleo-Ceratonion. Smaller natural communities in special locations are descibed by B. NOWAK (1987); although not widespread they form an important species potential in the fallow succession.

This potential is quite substantial as can be seen from an analysis of a floral list made up by G. ARIELLO (1957) in which 850 species appear. Not counting cultivated plants 188 species were registered in an individual phyto-sociological listing. They are classified in a spectrum of area-types in the following table:

| Floristic element | Number of species | Share of species in % | Share of covering in % |
|---|---|---|---|
| Thermo-mediterranean | 12 | 6.3 | 5.1 |
| Meso-mediterranean | 98 | 52.0 | 62.9 |
| Supra-mediterranean | 44 | 23.4 | 19.6 |
| Eura-suboceanic | 15 | 8.3 | 4.2 |
| Others | 19 | 10.0 | 8.2 |
| | 188 | 100 | 100 |



The presentation is based on the listings made for the preparation of table 1 in which the various fallow phases are first classified in qualitatively rated age groups. Species with less than seven appearances are not represented in the list. - After the first analysis of the species spectrum an assignment is made on the basis of class-level taking into account the average degrees of covering (Fig. 7). Parallel to this the surveys allow an interpretation of the variation in life-form distribution on the bases of species and formation (Fig. 8).

From Fig. 7 it can be seen that in the course of the sociological progression of the Cinque Terre there is a changing succession in the class-membership. At the beginning of the fallow development, however, it takes several years until the Chenopodietea species of the cultivation phase is superseded. In this connection the neophyte Oxalis pes-caprae deriving from South-Africa, the vegetative spread of which is stimulated by hoe cultivation by means of bulb sprouts and split storage-rhizophores is of particular interest. Oxalis, together with Arisarum vulgare, causes a geophyte boom which lasts several years (Fig. 8, below) and which differs from the scheme of an initial therophyte peak. The latter is more common in Central European and supra-mediterranean vine-fallow developments.

It is only in the second fallow phase that a xerotherme herbaceous grass with dominating hemicryptophytes comes to the fore (Fig. 8). At this point the typical plant is Dittrichia (syn.

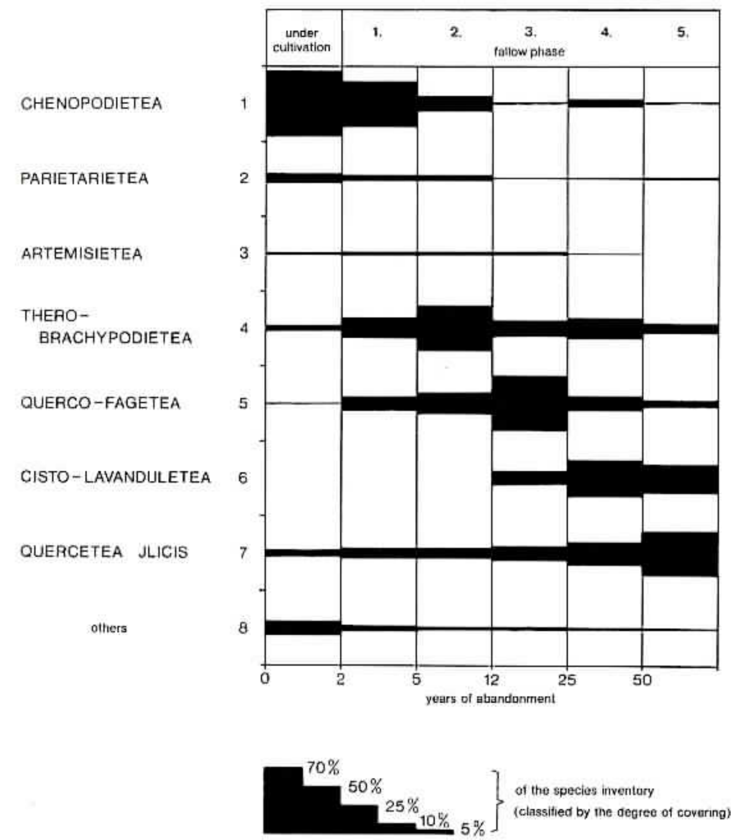



*Fig. 7: Percentage of phyto-sociological membership of all listed species of the Cinque Terre on class-level in consideration of the various fallow phases.*

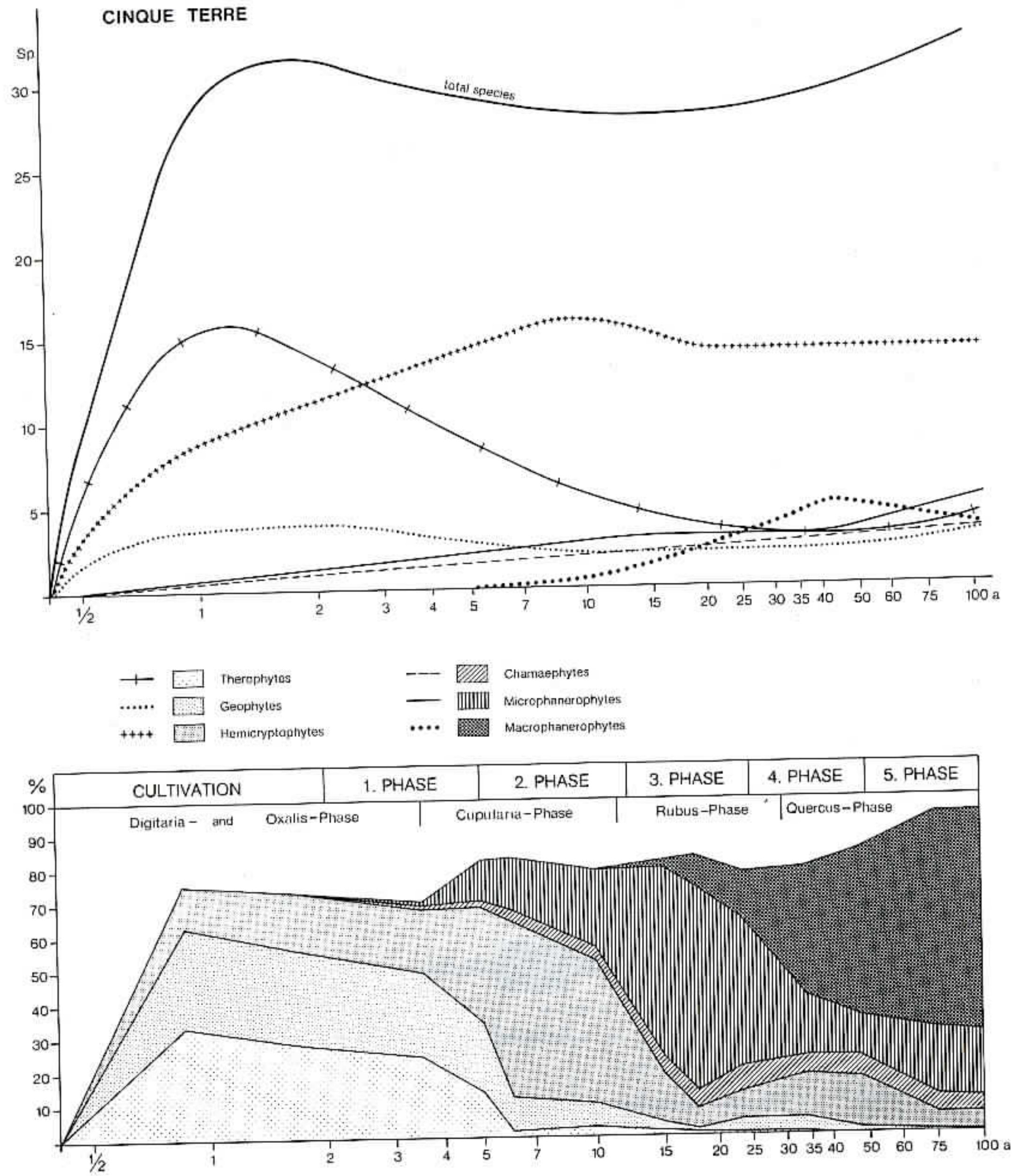



*Fig. 8: Life-form change in the vine-fallow succession. Variation of species share (above) and cover share (below).*



Cupularia) viscosa which in the Mediterranean region occurs in large quantities in ruderal locations and on fallow-land. Dittrichia indicates perennial nitrogen herbaceous fields. Brachypodium rupestre forms temporary stands of grass so that as opposed to fallow successions in other regions the false brome does not cause a long-termed ground sealing. Thus, in the Cinque Terre the vine-fallow is characterized by a hemicryptophyte phase which lasts only 10 years. The phyto-sociological classification of the herbaceous grass phase under Thero-Brachypodietea is done on the basis of species which occur less massively, but Dittrichia viscosa must also be included in this class.

During the third fallow phase Rubus ulmifolius becomes an indicative form which spreads very intensively by means of off-shoots. These polycorms form an impenetrable thicket, which particularly in the abandoned olive-tree groves, reaches up to four metres in height. For this reason the blackberries must be classed with the phanerophytes in the analysis of Fig. 8. With a degree of covering of 44 % they reach a mean value which is singularly high during the whole fallow succession (Tab. 1). They are the leading species for Pruno-Rubion ulmifolii which are interpreted as an alliance of Pruno-Rhamnetea; the allocation to the Querco-Fagetea which is usual in Central Europe is questionable since blackberry-polycorms can form stands even in the thermo-mediterranean climate. Liana like Rubia peregrina and Asparagus acutifolius also appear in this first shrubbery phase but, unlike the blackberries, they survive until the final phase.

It appears from table 1 that in the fourth fallow phase the Rubus-polycorms fall apart within a short time. Their soft humous litter initiates a favorable soil formation which is a positive precondition for the wood-growth of Erica arborea and Pinus pinaster. Firstly both form maquis which belong to the Cisto-Lavanduletea. This population is poor in species since ericoid litter as well as pine-needles produce a badly decomposing raw humus layer with a toxic effect. In addition a supersession of heliophile species, which already shows itself as a result of the dense foliage during the blackberry phase, must be taken into account.

The negative effect of the raw humus layer on the undergrowth is not, however, certain. The humous litter has a more positive effect on the growth of holm oaks since it guarantees a better water supply during the dry spell. In the Cinque Terre the rise of the sprouts is also fostered by the sub-humid climate as well as by dense Quercus ilex stands which are located directly above the vineyards on rocky sites. The covering of the ground certainly increases in the holm oak forests (Fig. 8 below) but the litter decomposes more easily than in the preceding phase.

A judgement on the composition of species in the climax communities of the Cinque Terre is not possible at the moment since the oldest phase of abandonment runs only to approx. 80 years. During the first section of the fifth fallow phase beginning at 50 years Erica and Pinus remain amply present. Only with the steady rise of the holm oaks the two representatives of the preceding phase are superseded. The slight augmentation in species in the holm oak forests must not be overvalued since counter to this an exceptional poverty of individuals in the undergrowth must be taken into account.

For the final denomination of the consecutive plant communities the method of K. KOPECKY and S. HEJNY (1978) is applied . Under this system the naming orientates itself by the higher

*Tab. 1: Phyto-sociological table showing 57 listings in vineyards and vine fallow formations of the Cinque Terre. From the total amount of 188 species only 71 are registered in the table due to their appearence in more than six areas of analysis.*
*LF = Life-form (T = Therophyte, G = Geophyte, H = Hemicryptophyte, C = Chameophyte, L = Liana, Pi = Micro-, Pe = Meso-, Pa = Macro-Phanerophyte); AZ = Number of species.*
*The classes of continuity from I-V correspond to the presence of cases in % of the particular phases (intervals of 20 %); K = Cultivated land, B1-B5 = 1.-5. fallow phase. Mean degree of covering in %.*

| LF | | AZ | CONTINUITY | | | | | | MEAN DEGREE OF COVERING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K | B1 | B2 | B3 | B4 | B5 | K | B1 | B2 | B3 | B4 | B5 |
| T | Mercurialis annua | 8 | II | I | . | I | • | I | + | + | • | + | • | + |
| T | Heliotropium europaeum | 7 | III | I | • | • | • | • | + | + | • | • | • | • |
| T | Euphorbia peplus | 9 | III | I | • | • | • | • | + | + | • | • | • | • |
| T | Vicia sativa | 8 | III | I | I | • | • | • | + | + | + | • | • | • |
| H | Symphytum tuberosum | 9 | III | I | I | I | • | • | 3 | + | + | + | • | • |
| T | Raphanus raphanistrum | 10 | III | I | I | • | • | • | + | + | + | • | • | • |
| T | Calendula arvensis | 11 | IV | I | • | • | • | • | 3 | + | • | • | • | • |
| T | Misopates orontium | 13 | V | I | • | • | • | • | 3 | • | • | • | • | • |
| H | Convolvulus arvensis | 14 | V | I | I | I | • | • | 3 | + | + | + | • | • |
| T | Poa annua | 13 | IV | I | • | • | • | I | 3 | + | • | • | • | + |
| T | Digitaria sanguinalis | 14 | V | I | I | • | • | • | 7 | 3 | + | • | • | • |
| T | Bromus sterilis | 9 | II | I | I | I | • | I | 2 | + | + | + | • | + |
| G | Arum italicum | 9 | II | II | • | I | • | I | + | + | • | + | • | + |
| H | Oxalis corniculata | 9 | III | III | • | • | • | • | 3 | 3 | • | • | • | • |
| T | Solanum nigrum | 16 | III | III | II | II | • | I | + | + | + | + | • | + |
| G | Muscari neglectum | 14 | III | III | II | • | • | • | + | + | + | • | • | • |
| T | Sonchus oleraceus | 23 | V | IV | II | II | I | • | + | + | + | + | + | • |
| H | Reichardia picroides | 13 | III | II | III | I | • | • | + | + | + | + | • | • |
| T | Euphorbia segetalis | 19 | IV | V | I | I | • | I | + | + | + | + | • | + |
| H | Hyoseris radiata | 21 | III | IV | III | I | I | I | + | + | + | + | + | + |
| T | Veronica cymbalaria | 21 | IV | III | III | II | I | I | + | + | + | + | + | + |
| T | Stellaria pallida | 23 | V | IV | II | I | • | II | 5 | 4 | + | + | • | + |
| T | Fumaria capreolata | 24 | V | IV | III | I | • | I | 6 | + | + | + | • | + |
| H | Parietaria diffusa | 25 | IV | V | III | I | • | I | 2 | + | + | + | • | + |
| H | Daucus carota | 38 | V | V | V | IV | II | I | + | + | + | + | + | + |
| H | Picris hieracioides | 26 | III | IV | III | IV | II | • | + | + | + | + | + | • |
| T | Conyza bonariensis | 22 | II | IV | II | III | I | II | + | 2 | + | + | + | + |
| G | Arisarum vulgare | 33 | V | IV | IV | IV | II | I | 4 | 4 | + | + | + | + |
| G | Oxalis pes-caprae | 32 | IV | IV | IV | IV | II | III | 20 | 17 | 7 | + | 3 | + |
| T | Foeniculum vulgare | 18 | III | II | III | I | III | • | + | + | + | + | + | • |
| H | Viola hirta | 9 | I | II | I | II | • | • | + | + | + | + | • | • |
| G | Allium triquetrum | 10 | II | III | I | • | I | • | 1 | + | + | + | • | + |
| T | Linaria vulgaris | 10 | I | III | I | II | • | • | + | + | + | + | • | • |
| T | Avena sterilis | 13 | I | IV | I | II | • | • | + | + | + | + | • | • |
| H | Calystegia sepium | 12 | I | II | I | III | • | • | + | + | + | + | • | • |
| H | Carex divulsa | 10 | I | II | I | I | I | • | + | + | + | + | + | • |
| H | Sanguisorba minor | 7 | I | • | III | I | • | • | + | • | + | + | • | • |
| H | Oryzopsis miliacea | 13 | • | II | III | I | I | I | • | + | 1 | + | + | + |
| T | Briza maxima | 20 | I | II | III | III | II | III | + | 2 | + | + | + | + |
| H | Dactylis hispanica | 43 | III | V | V | IV | V | V | + | 1 | 7 | 1 | + | + |
| H | Dittrichia viscosa | 46 | III | V | V | V | V | IV | + | 5 | 20 | 3 | 1 | + |
| H | Galium lucidum | 21 | II | II | III | II | IV | I | + | + | + | + | + | + |
| L | Clematis vitalba | 13 | I | III | II | II | I | • | + | + | + | 5 | + | • |
| L | Hedera helix | 17 | I | II | II | III | III | I | + | + | + | 2 | + | + |
| T | Cynosurus echinatus | 7 | • | I | • | I | I | I | • | + | • | + | + | + |
| H | Trifolium arvense | 7 | • | I | I | I | I | I | • | + | + | + | + | + |
| Pe | Spartium junceum | 7 | • | • | I | I | II | I | • | • | + | + | + | + |
| H | Euphorbia characias | 7 | • | • | • | I | III | I | • | • | • | + | + | + |
| H | Aster sedifolius | 10 | • | • | II | I | II | II | • | • | + | + | + | + |
| L | Rubia peregrina | 45 | II | IV | IV | V | V | V | + | + | 4 | 5 | 4 | 1 |
| Pi | Rubus ulmifolius | 43 | II | III | IV | V | V | V | + | 5 | 17 | 44 | 9 | 1 |
| H | Psoralea bituminosa | 36 | II | IV | III | IV | IV | V | 2 | 6 | 2 | 1 | 1 | + |
| H | Carlina corymbosa | 31 | • | III | IV | IV | IV | V | • | + | + | 1 | + | + |
| L | Smilax aspera | 31 | I | III | II | IV | IV | V | + | + | + | 3 | 3 | 5 |
| L | Asparagus acutifolius | 31 | II | II | III | III | IV | IV | + | + | + | + | 2 | 2 |
| H | Dianthus ferrugineus | 24 | I | I | III | III | IV | IV | + | + | + | + | + | + |
| C | Helichrysum italicum | 28 | • | I | III | IV | V | IV | • | + | + | + | 1 | + |
| H | Brachypodium rupestre | 28 | • | I | III | IV | V | V | • | + | 7 | 1 | 7 | 3 |
| T | Odontites lutea | 19 | • | • | III | II | IV | III | • | • | + | + | + | + |
| H | Centranthus ruber | 29 | II | II | II | III | IV | V | + | + | + | + | + | 1 |
| H | Lathyrus latifolius | 24 | • | II | II | III | IV | V | • | + | 2 | 1 | + | + |
| C | Sedum sediforme | 25 | I | I | II | III | IV | IV | + | + | 2 | + | + | + |
| Pe | Erica arborea | 21 | • | I | I | IV | III | V | • | + | + | 7 | 22 | 22 |
| Pa | Pinus pinaster | 19 | • | I | I | IV | IV | III | • | + | + | + | 10 | 9 |
| G | Polypodium vulgare | 21 | • | • | II | II | IV | V | • | • | + | + | + | + |
| Pe | Rhamnus alaternus | 16 | • | I | I | I | IV | III | • | + | + | + | 3 | 2 |
| G | Asplenium onopteris | 16 | • | • | • | II | IV | IV | • | • | • | + | + | + |
| Pe | Pistacia terebinthus | 16 | • | • | • | I | IV | IV | • | • | • | + | 1 | 2 |
| Pa | Quercus ilex | 16 | • | • | • | + | III | V | • | • | • | + | 1 | 14 |
| Pi | Euphorbia dendroides | 9 | • | • | I | I | II | III | • | • | + | + | 6 | 2 |
| Pi | Calicotome spinosa | 9 | • | • | + | + | + | III | • | • | + | + | 2 | 7 |

units of vegetation of the BRAUN-BLANQUET school (here: the degree of alliance) which are placed behind the most frequent separation species of the several phases. This procedure is chosen since it is a question of derived communities with a flow of combinations of newly occuring and vanishing companions which show a broad ecological amplitude or have an accidental character. In such cases this principle of classification prevents a boundless extension of new association terms of the kind which was criticized by S. PIGNATTI (1968) as an "inflationary development" in the denomination of plant- sociological unities. - In addition to the denomination of the associations, the renewed analysis of the species distribution in the fallow phases makes a more accurate time definition of the phases possible. On this occasion the flowing variation of species is checked with regard to continuity and the mean covering values. The following phases can be chronologically and nominally stipulated:

K <1½ yrs=Oxalis pes-caprae -(Fumarion-Euphorbion Görs 66)
Var. of Misopates orontium, Convolvulus arvensis

B I 1½-4 yrs=Oxalis pes-caprae -(Fumarion-Euphorbion Görs 66)
Var. of Conyza bonariensis, Psoralea bituminosa

B II 4-12 yrs=Dittrichia viscosa-(Thero-Brachypodion Br.-Bl. 36)

B III 12-25 yrs=Rubia peregrina -(Pruno-Rubion ulmifolii Bol. 54)

B IV 25-60 yrs=Pinus pinaster -(Cisto-Ericion H-tiç 57)

B V > 60 yrs=(Quercion ilicis Br.-Bl. 31)

(K=Cultivation phase; BI-BV=1.-5. fallow phase).

In the Cinque Terre the usual invasion of species during the first fallow years is soon slowed down by an over-abundant development of the Rubus-polycorms. A comparison of the species inventories for the different areas surveyed indicates a considerable lack of uniformity in the course of the first two fallow phases (Fig. 9). Only the domination of the blackberries causes a floristic approximation in the different assemblages. The floristic index of similarity IS (calculated after T. SOERENSEN, 1948) increases in the course of the wood-growth up to the final community.

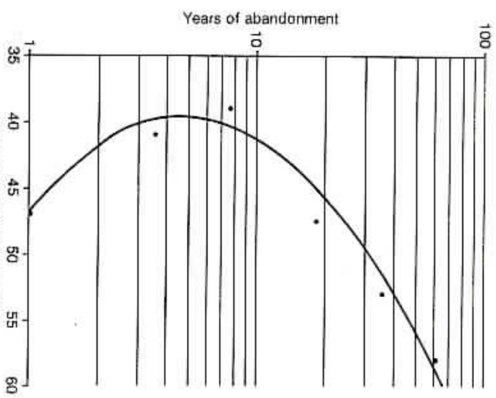



*Fig. 9: Floristic similarity (IS=similarity index after SOERENSEN) of the plant listings in the various fallow phases.*



This phemonenon indicates a gradual consolidation of the species cover. The development in the fallow succession of the Cinque Terre from differing initial conditions to assimilated final communities can be understood by considering the gradual advance of the natural forests above the vineyards. Whereas during the first fallow decade the combination of plants is controlled by effects arising from the immediate vicinity which result from the manifold and close-meshed mosaic of different development phases and cultivated vineyards (Fig. 5).

### 4.2 Micro-climate and soil-water regime in the fallow succession

Compared to the Central European vine-fallow succession in the Cinque Terre a faster regeneration of the forest stands can be observed since the early rise of shrubs which spread vegetatively prevents the establishment of "pseudo-stable" grass populations (G. HARD, 1975). This situation causes an early change from a differentiated micro-climatic pattern on a very small scale during the initial shrub-grass formations to a homogeneous climate of uniform shrub and forest stands which also contributes to floristic evenness.

Thus the ecophysiological stress caused by the micro-climatic factors, cold, heat and water-vapor saturation deficit of the air, is tempered with the increasing thickness of the stand. The wood formation not only causes the equalization of the temperature and humidity amplitude but also a decrease in evaporation losses near the ground. This advantage still does not contribute to a melioration of the climatic water-regime balance since at the same time rainfall input is diminished by increasing interception losses (Fig. 10).

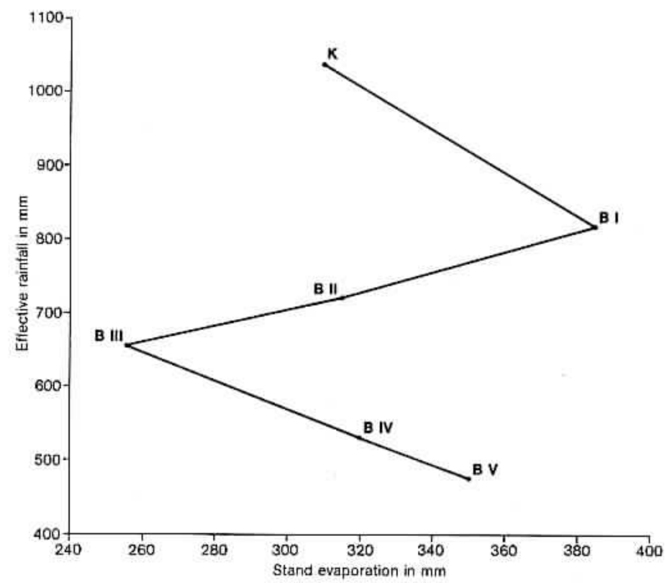



*Fig. 10: Diagramm showing the variation of the precipitation/pot. evaporation ratio in consideration of the formation change in the vine-fallow successions. Evaporation: computed values of open field evaporation in Levanto (after PAPADAKIS), reduced by means of Piche-measurements. Effective precipitation: open field rainfalls of Levanto, renduced by means of interception measurements.*

The slightly lower evaporation losses have to be set against the higher transpiration consumption as a result of the intensified water requirement of the plants with the growing of the phyto-mass in the course of the fallow succession. Consequently a decrease in the mean soil moisture can be observed. As evidence for this, values of the soil moisture tension from a year long series of measurements carried out in various fallow formations of Corniglia's skeletal shale-rigosols may be presented (analysis of tensiometer measurements):

| Depth | Vineyard | | | Herbaceous grass | | | Maquis | | |
|---|---|---|---|---|---|---|---|---|---|
| | a | b | c | a | b | c | a | b | c |
| 15 cm | 156 | 119 | 90 | 144 | 117 | 104 | 99 | 126 | 140 |
| 30 cm | 181 | 91 | 93 | 188 | 88 | 89 | 101 | 119 | 145 |

a=Number of days with soil moisture tension below available field capacity (pF <1.8)
b=Number of days with readily available soil water (pF 1.8-2.9)
c=Number of days with more difficult water supply (pF >2.9)

The rule of a mean decrease of soil moisture in the course of the vine-fallow succession must be augmented by a differentiated view of the moisture conditions within the humous top-soil and the sub-soil. In the open plant formations of the initial phase the evaporation losses surpass the transpiration consumption within the former rigole-horizon, in the course of which the first permanent wilting point is reached for most of the therophytes. The horizon of lowest moisture and the main rhizosphere move deeper as overshadowing and humus concentration increase (cf. A. SHACHORI et al., 1967).

The greater water consumption can be proved by calculating ecological water-regime balances in which soil class and phyto-mass are included along with climatological parameters. The calculation is done by application of the formula provided by R. PFAU (1966) and by including the tabular data of the root zone capacity (=field capacity minus permanent wilting point) prepared by W. SCHMIEDECKEN (1978: 148). In the given examples of a water-regime balance for weed formations during the phase of cultivation and for a holm oak forest in the final phase a sandy loam with a main supply zone of one meter is assumed. In consideration of the shifting permanent wilting point specific to ephemeral herbaceous plants and sclerophyllous woodland towards higher tension values, root zone capacities between 200 mm/m in the first and 350 mm/m in the second case are assumed.

Moreover, the monthly values of the potential evaporation (calculated after J. PAPADAKIS, 1965) are included in the formula (reference station: Levanto). Unlike the effective precipitation which is also considered these remain constant in the succession of the fallow formations. This procedure is based on the deliberation that the decrease in temperature near the ground which is caused by overshadowing is almost equalized by an established heat accumulation above the stand surface. Thus, one need assume only small differences in the mean potential evaporation of the specific air body in various ecotopes.



Fig. 11 shows that the rigosols of the vineyards are water saturated for almost nine months a year. In a holm oak stand on the other hand the evapotranspiration losses are so high that the

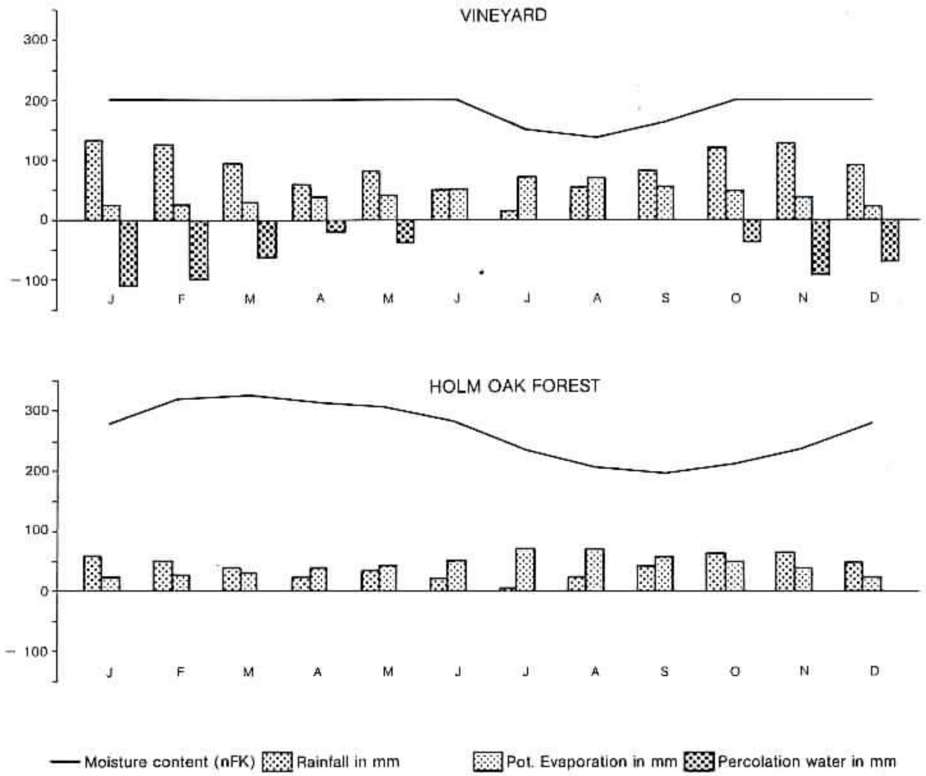



*Fig. 11: Water-regime balance for a cultivated vineyard and a vine-fallow of the final phase with holm oak forest.*

effective rainfall only episodically, after heavy rains in spring, causes a short-termed fill of the medium pores . Here the mean of many years shows a more or less distinct deficit in the available field capacity throughout the whole year.

Taking account of many calculations of the water-regime statements can be made about the variation of mean year deficits, maximum deficits during the most arid month and the number of months with field capacity deficit in the course of the entire vine-fallow succession. It can be deduced from these quantities (Fig.12) that in the Cinque Terre a distinct decrease in the available soil moisture sets in only with the decline of the blackberry-polycorms; that is approx. 20 years after the abandonment and with the rise of the woodland.

The growing desiccation of the soil during the late fallow phases causes a decrease in interflow in the direction of parcels located below fallow-land. For the vegetation of such a location the dearth in the input of water from a neighboring wooded site must be considered a negative effect. A positive effect on the other hand is the smoothing of extreme run-off peaks in the brook-beds owing to a diminished drainage water and percolation water input. Moreover the minimized water surplus, a result of denser plant assemblages, causes a reduction in the risk of erosion (cf. H. DIECKMANN et al., 1985) and of terrace decay.

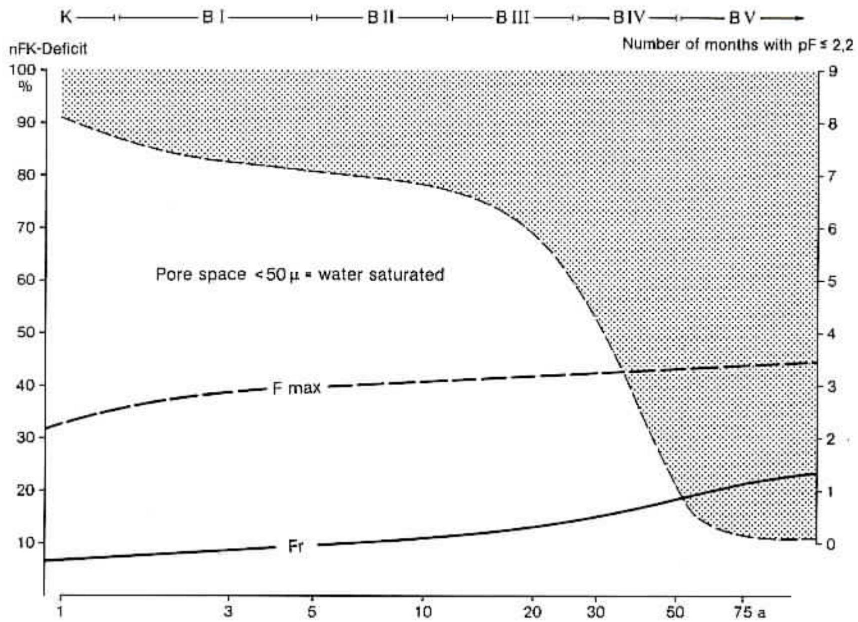



*Fig. 12: Variation of the soil moisture deficit in the course of the vine-fallow succession. $F_{max}$ = maximum deficit of the driest month; $F_r$ = relative deficit, referring to the whole year; nFk = available field capacity with minimum soil moisture tension pF = 2.2; K = Cultivation; BI-BV = 1.-5. fallow phase. Station of reference: Levanto.*

## 5. THE TERRACE DILAPIDATION

### 5.1 Symptoms and process

The process of terrace dilapidation starts with the initial wall-break. The breach is indicated well in advance by a convex bulge in the wall ("wall-belly": Fig. 6 left, above). This weak point is always found in the upper third of the dry stone wall. In the event of a collapse at this point the stones slide down to the lower terrace and form a scree cone there (Photo 3). The semi-circular breach recess has a steep, slightly concavely vaulted slip face. In the morphological sense there is a small soil slip which is caused by the reduction of the wall stability.

The immediate cause of a wall-break is the water movement in the terrace soil and in the supporting wall. The water input of a bench terrace is composed of the effective rainfall and run-off water from higher parts of the slope (=drainage water; see Fig.13). A close look at



*Photo 3: Recent wall-break in Corniglia (June 1985).*

profiles of broken walls during heavy rainfall show that small channels build up within the deformable joint material in which the water percolates through the wall. One can speak of a very small form of erosion. Because of the relative levelness of the terrace ground and the high permeability of the soil (high skeletal content and low bulk density as a result of tillage) surface run-off of considerable amounts occurs only during extreme rainfalls. Then a breach recess serves as a run-off channel to the next lower row of terraces so that the damaged passage is a point of attack for regressive erosion. Intact walls hardly ever are damaged by surface run-off.

Studies of the particle-size and pore-size distribution in various depths indicate, in the case of a sandstone substratum a compaction horizon in the zone behind the wall at a depth of approx. 40 cm (Fig. 13 and 16). On cultivated terraces the soil is regularly loosened manually down to that depth. The small air capacity in this zone causes a reduction in hydraulic conductivity so that water accumulates above the compaction horizon. Within the hydraulic potential field of the wall percolation water changes direction towards the wall since the flow resistance within the joints is less than that within soil. The closer this process happens to the wall the more intense is the evasive flow. Thus, in the contact zone between wall and compaction horizon it may come to an increased sludging of fine material into the joints.

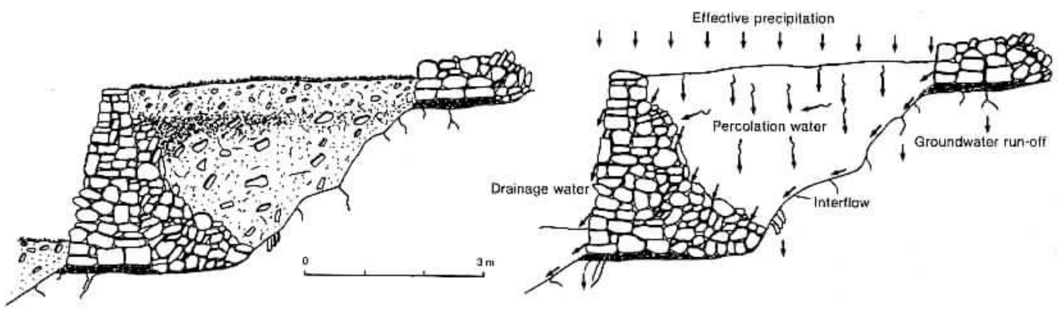



*Fig. 13: Cross-section of a terrace with compaction horizon (left) and water movement within the terrace soil and the supporting wall (right; after own studies and H. KUTSCH, 1982).*

Since they have to resist the maximum earth pressure likely to occur the dry stone walls are built extra large; and yet variations of span conditions do take place which might cause a breach. These structural changes in the wall come to pass step by step and start long before the first indications of a breach can be perceived. The water movement within the ground and the wall results in processes of displacement in the course of which fine soil material is sludged into the joints at some points and joint material is washed out at other points. Thus the bearing points of the stones and consequently the span distribution within the supporting complex are permanently disarranged. Where span conditions are least favorable the stability is not great enough to support the earth masses in the event of intensive seepage. The water saturated joint material then serves as a sliding surface on which the mobility of the weak wall segment is further increased. Firstly during the slow process a wall-belly is formed which results in a further deterioration of the span conditions. The weight of the dry stones above the weak segment can no longer be transmitted vertically onto the foundation but is turned outwards where the wall displays the convex bulge. On the underside of the vault fine joint material and pebbles are pushed out of the wall compound. The weakening process can last for several years until the pressure of the earth and the weight of the stones exceed the counteracting force of the wall: Then the wall breaks.

The further decay of the terrace landscape is caused by erosive and gravitational forces. In the breach recess the damage is extended by regressive erosion which cuts back into the terrace ground. The destabilisation is transmitted to the foundation of the backwall by the ensueing



relief from pressure. Moreover the additional burden of the slide masses on the lower terrace also contributes towards a breach in that level. The consequent wall- breaks are mostly observed in the first two fallow phases (compare Fig. 5 with Fig. 6). When this phase of dilapidation is reached the damaged supporting walls, particularly at the rim of the breaches, no longer offer protection against the natural displacement processes of the slope. During rainfalls the non-compact rubble masses slide down and cause a downhill extension of the terrace destruction. In the final phase neither wall ruins nor terrace levels can be recognized. Since slope areas with the latter characteristic are predominantly covered with forests it must be assumed that the speed of the dilapidation processes increases with progessive destruction. Assuming an average fallow age of 60 years for the holm oak- and pine-stands a temporary system stabilization can be observed only a few decades after an initial wall-break and a phase of intense mass transportation processes.

## 5.2 The dependence of the dilapidation process upon the site factors

In the phase of the initial breach the dynamic force of soil water is the causal factor in the process. The studies show a functional relationship between this factor and the site parameters of soil, vegetation cover, and relief. The occurence of wall-breaks is bound to intensive and long-lasting precipitation and consequently runs parallel to the annual distribution of rain. Breaches occur most frequently when the soil is saturated at the end of the rainy season in March and April (Fig. 2). Thus, frequency and duration must be considered important. The intensity of rainfall is important in so far as higher rates provide a larger transportation potential for the shift of material within the soil. In addition to that the probability of surface run-off increases with the intensity of rainfall. Thus regressive erosion is furthered in the breach recesses (see Fig. 14 for return interval of heavy rainfalls).

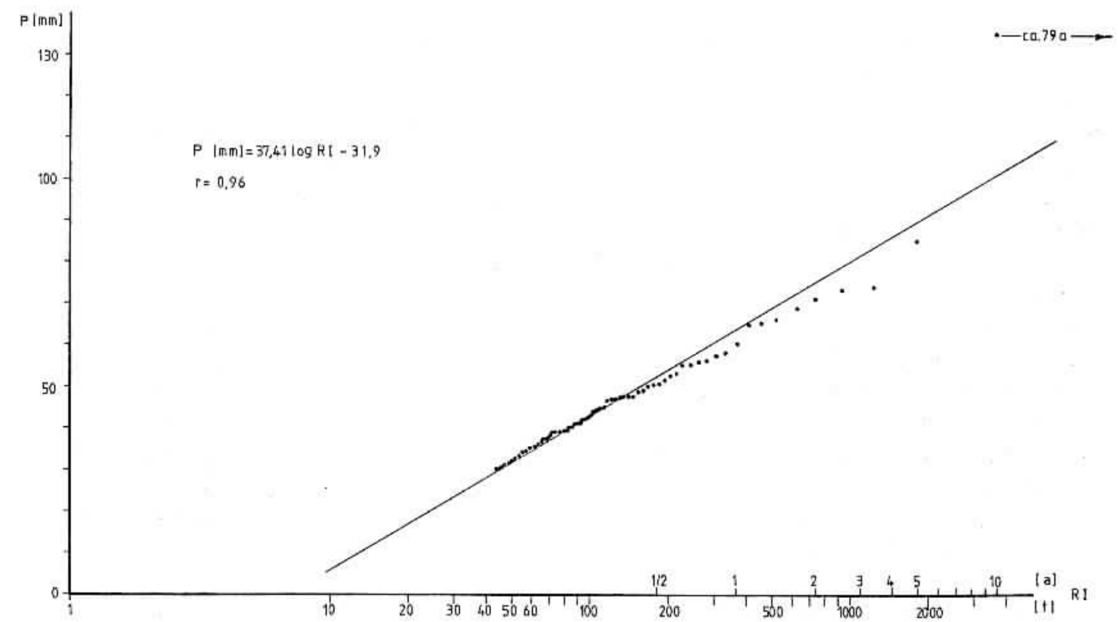



*Fig. 14: Return interval (RI) of heavy rainfall events (in the sense of G. RICHTER, 1965: 116) in years (a) and days (t) for Levanto. (Analysis of autographic rain gauge papers from 1967-76; method after F. AHNERT, 1987).*

Frequent and continuous precipitation, as essential condition for shift processes within the supporting walls occurs in winter. Certainly there are heavy falls of rain in autumn also but autumn is primarily a recuperation period during which the pores are filled after the dry summer season. In spring when the soil is water saturated the span distribution within the soil-wall-system is at its most unfavorable so that slight rainfalls suffice to cause a breach. With the drought of summer time the interaction of forces stabilizes so that hardly any wall-breaks occur then.

The solidity of the dry stones has a considerable influence on the stability of the supporting wall. Diurnal and annual ranges as well as spatial variations of temperature within the wall substance cause a thermo-weathering of the stones. The exposed rock surfaces are particularly affected in summer, during intensive insolation. The tensions which occur cause fissures and flaking. Every alteration within the dry stone arrangement either by fissures which cause a shift of the bearing forces or by flaking which causes a change of the stone contours brings about a span variation.

Deposited salt crystals also share considerably in the weathering of the wall stones. A visual estimation in the field suffices to show a dependence of the degree of weathering on the distance from the sea and the exposition. Proof of this relationship is gathered through measurement of salt concentration on the exposed side of the stones.

The compaction horizon at a depth of approx. 40 cm proves to be breach stimulating in the vineyard soils of the Cinque Terre. The degree of effect of this damming zone is determined by the soil class. From consideration of two model areas (Fig.15), selected from numerous studies, it becomes obvious that the formation of the accumulation horizon has a different intensity depending on the bedrock. An evident increase in the solidity at the depth of 40 cm especially in the clay and silt fragments can be observed in the soil above the Macigno-sandstone (Fig. 16 above). In this model area the mean breach frequency is 4.8/100 m wall length. For the soil above calcareous shale substratum (Fig. 16 below) hardly any compaction horizon can be found. Here the breach frequency is only 2.55/100 m wall length. Hence for the formation of a compaction zone the soil must display a particle-size distribution which contains enough coarse pores to reach a high infiltration capacity and which provides enough silt and clay particles to guarantee a high compaction potential.

For the vegetation's influence on the wall-break process a correlation coefficient of $r=-0.93$ with a significance level of $\alpha=0.001$ was computed. Hence the breach stimulating processes are decisively modified by the vegetation cover. The relationship is inversely proportional since breach frequency decreases with growing fallow age (Tab. 2). The evidence for this is provided by two mappings carried out in 1981 and 1985 in which the wall-break frequency in the different fallow formations during a defined time interval was ascertained (Fig. 15 left). The reason for this functional relationship is the influence of the vegetation on the hydro-dynamic processes within the soil. The decisive variables are the growing degree of covering which leads to higher interception losses and the accumulation of litter which causes a decrease in the infiltration rate. Particle-size analysis for soils of all fallow phases show that the transport of fine material within the soil and the supporting walls lessens distinctly since no differences in depth and intensity of the compaction horizon can be observed between early and more



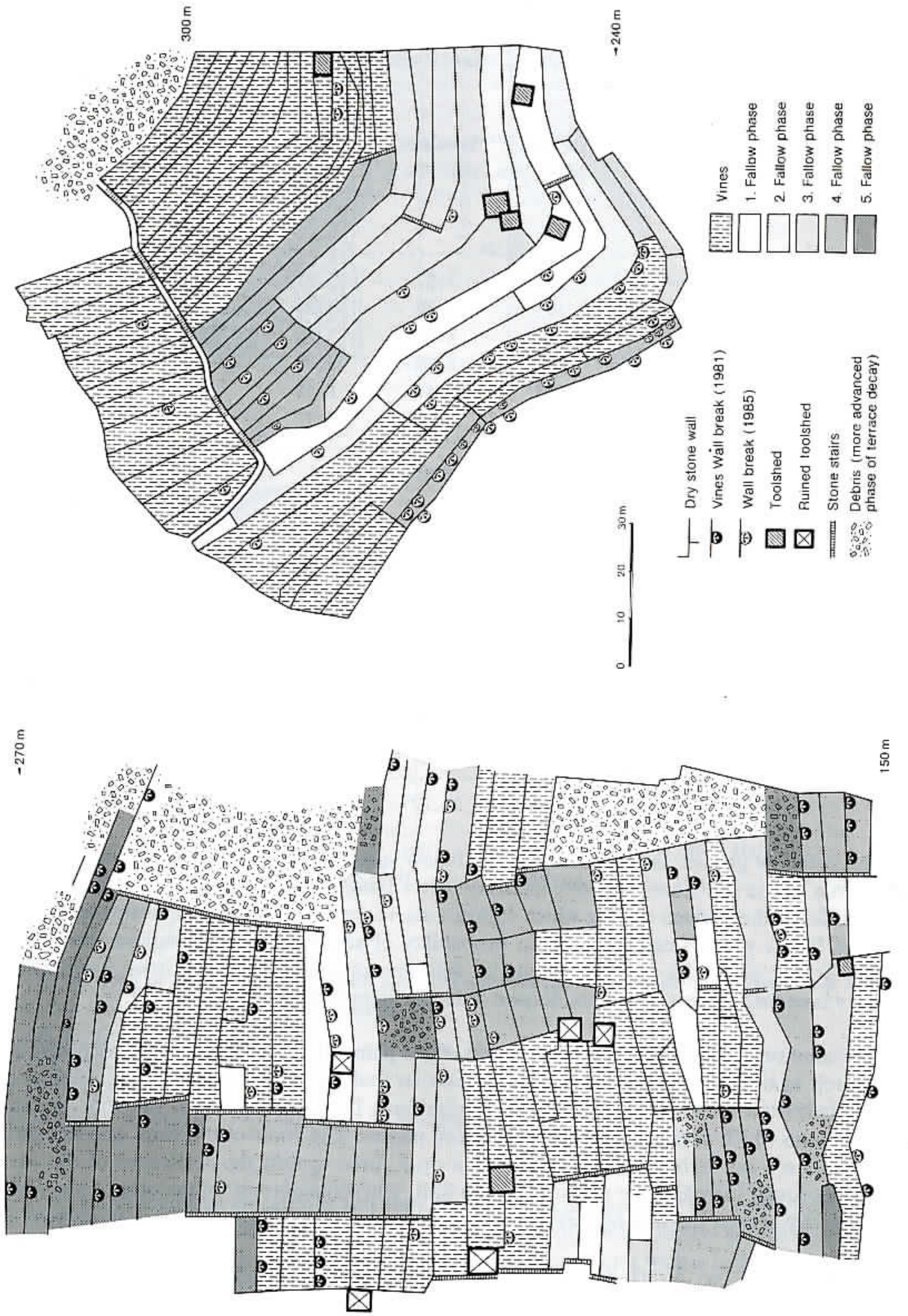



*Fig. 15: Maps showing occurence of wall-breaks in two field areas, one above Macigno-sandstone (left: Rodalabia) and one above calcareous shale (right: Guvano) in respect of the fallow phases.*

Frequent and continuous precipitation, as essential condition for shift processes within the supporting walls occurs in winter. Certainly there are heavy falls of rain in autumn also but autumn is primarily a recuperation period during which the pores are filled after the dry summer season. In spring when the soil is water saturated the span distribution within the soil-wall-system is at its most unfavorable so that slight rainfalls suffice to cause a breach. With the drought of summer time the interaction of forces stabilizes so that hardly any wall-breaks occur then.

The solidity of the dry stones has a considerable influence on the stability of the supporting wall. Diurnal and annual ranges as well as spatial variations of temperature within the wall substance cause a thermo-weathering of the stones. The exposed rock surfaces are particularly affected in summer, during intensive insolation. The tensions which occur cause fissures and flaking. Every alteration within the dry stone arrangement either by fissures which cause a shift of the bearing forces or by flaking which causes a change of the stone contours brings about a span variation.

Deposited salt crystals also share considerably in the weathering of the wall stones. A visual estimation in the field suffices to show a dependence of the degree of weathering on the distance from the sea and the exposition. Proof of this relationship is gathered through measurement of salt concentration on the exposed side of the stones.

The compaction horizon at a depth of approx. 40 cm proves to be breach stimulating in the vineyard soils of the Cinque Terre. The degree of effect of this damming zone is determined by the soil class. From consideration of two model areas (Fig.15), selected from numerous studies, it becomes obvious that the formation of the accumulation horizon has a different intensity depending on the bedrock. An evident increase in the solidity at the depth of 40 cm especially in the clay and silt fragments can be observed in the soil above the Macigno-sandstone (Fig. 16 above). In this model area the mean breach frequency is 4.8/100 m wall length. For the soil above calcareous shale substratum (Fig. 16 below) hardly any compaction horizon can be found. Here the breach frequency is only 2.55/100 m wall length. Hence for the formation of a compaction zone the soil must display a particle-size distribution which contains enough coarse pores to reach a high infiltration capacity and which provides enough silt and clay particles to guarantee a high compaction potential.

For the vegetation's influence on the wall-break process a correlation coefficient of $r=-0.93$ with a significance level of $\alpha=0.001$ was computed. Hence the breach stimulating processes are decisively modified by the vegetation cover. The relationship is inversely proportional since breach frequency decreases with growing fallow age (Tab. 2). The evidence for this is provided by two mappings carried out in 1981 and 1985 in which the wall-break frequency in the different fallow formations during a defined time interval was ascertained (Fig. 15 left). The reason for this functional relationship is the influence of the vegetation on the hydro-dynamic processes within the soil. The decisive variables are the growing degree of covering which leads to higher interception losses and the accumulation of litter which causes a decrease in the infiltration rate. Particle-size analysis for soils of all fallow phases show that the transport of fine material within the soil and the supporting walls lessens distinctly since no differences in depth and intensity of the compaction horizon can be observed between early and more



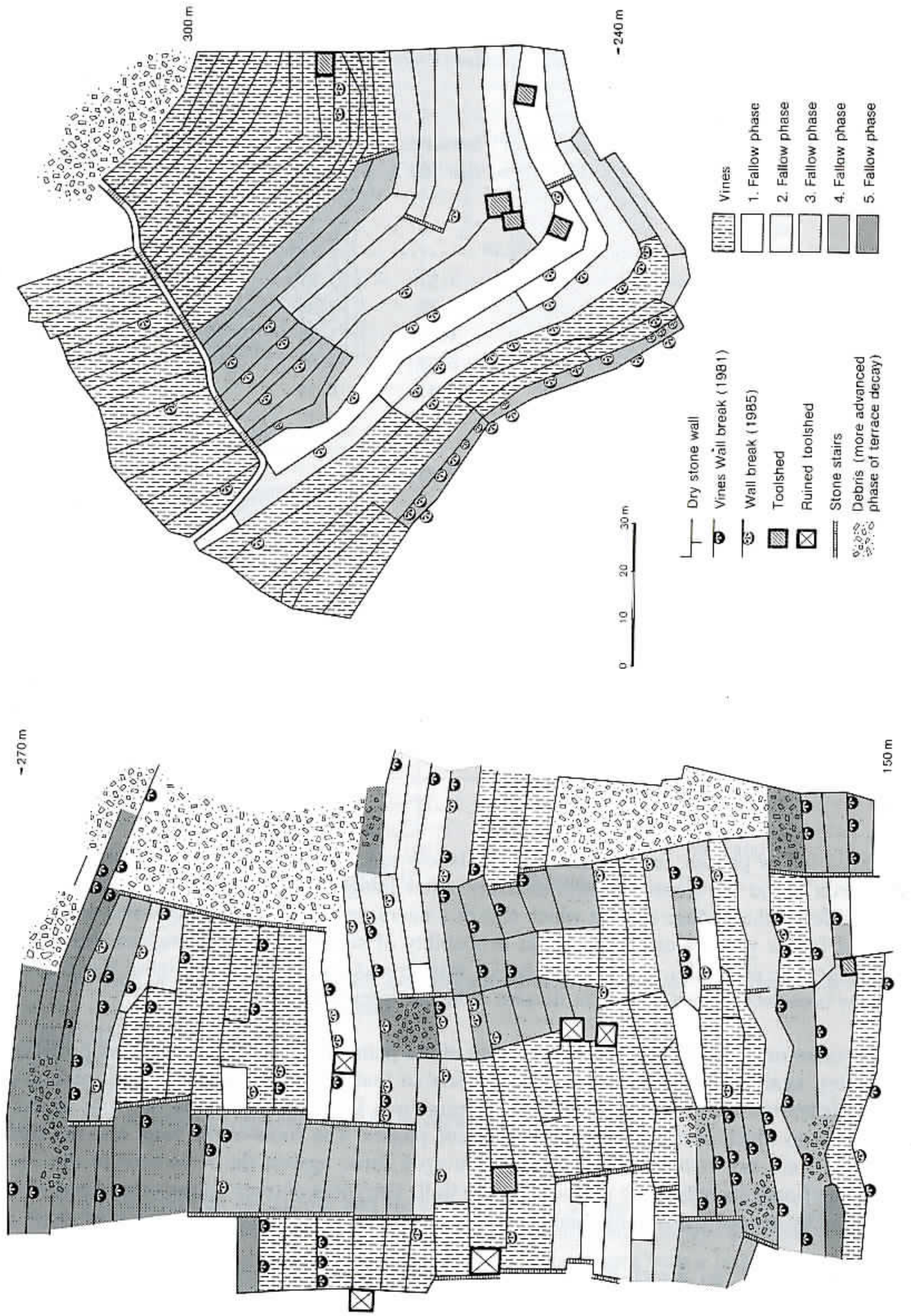



*Fig. 15: Maps showing occurence of wall-breaks in two field areas, one above Macigno-sandstone (left: Rodalabia) and one above calcareous shale (right: Guvano) in respect of the fallow phases.*

*Tab. 2: Distribution of wall-breaks and frequency increase in dependent relationship to cultivated vineyards and the different fallow phases I-V (and respectively the vegetation cover).*

| | Breaches | Length of wall in m | Breaches per 100 m | Absolute increase | Relative increase in % |
|---|---|---|---|---|---|
| Macigno-sandstone | | | | | |
| Cultivation | 18 | 958 | 1.87 | 1.87 | 30.0 |
| Phase I | 6 | 159 | 3.70 | 1.83 | 29.4 |
| Phase II | 16 | 324 | 4.90 | 1.20 | 19.3 |
| Phase III | 21 | 351 | 5.98 | 1.08 | 17.3 |
| Phase IV | 31 | 505 | 6.13 | 0.15 | 2.4 |
| Phase V | 24 | 385 | 6.23 | 0.1 | 1.6 |
| Total: | 116 | 2682 | 28.81 | - | 100 |
| Calcareous shale | | | | | |
| Cultivation | 13 | 1400 | 0.92 | 0.92 | 25.9 |
| Phase I | 3 | 133 | 2.25 | 1.33 | 37.3 |
| Phase II | 9 | 317 | 2.83 | 0.58 | 16.3 |
| Phase III | 11 | 342 | 3.21 | 0.38 | 10.7 |
| Phase VI | 15 | 421 | 3.56 | 0.35 | 9.8 |
| Phase V | - | - | - | - | - |
| Total: | 51 | 2613 | 12.77 | - | 100 |

advanced fallow phases. In the course of the fallow succession the operations which diminish the inertia of the dry stone wall lose intensity. After tillage is abandoned splash-effects due to rainfalls favor the surface sealing which causes a decrease in the percolation water capacity in the first fallow years. Consequently the probability of surface run-off is highest during that phase. At this point the risk of consequent wall-breaks caused by the erosive extension of primary breaches is most imminent despite of higher interception losses (Tab. 2).

At the same time the high degree of covering of the plants in the final fallow phase provides a protection against insolation and salt deposition so that the stone weathering is minimized. The stabilization effect of the vegetation succession is interrupted only by the root pressure phenomenon which occurs in the more advanced phases. The roots of the vines and the shrub formations are not strong enough to summon up a force against the resistance of the earth which vigorously increases the pressure on the wall. The roots of trees on the other hand either push directly against the wall by axial advance or increase the earth pressure by radial growth.

The gradient has no direct influence on the initial wall-break. A relationship exists only between the gradient and the height of the supporting walls. In respect to this relationship it



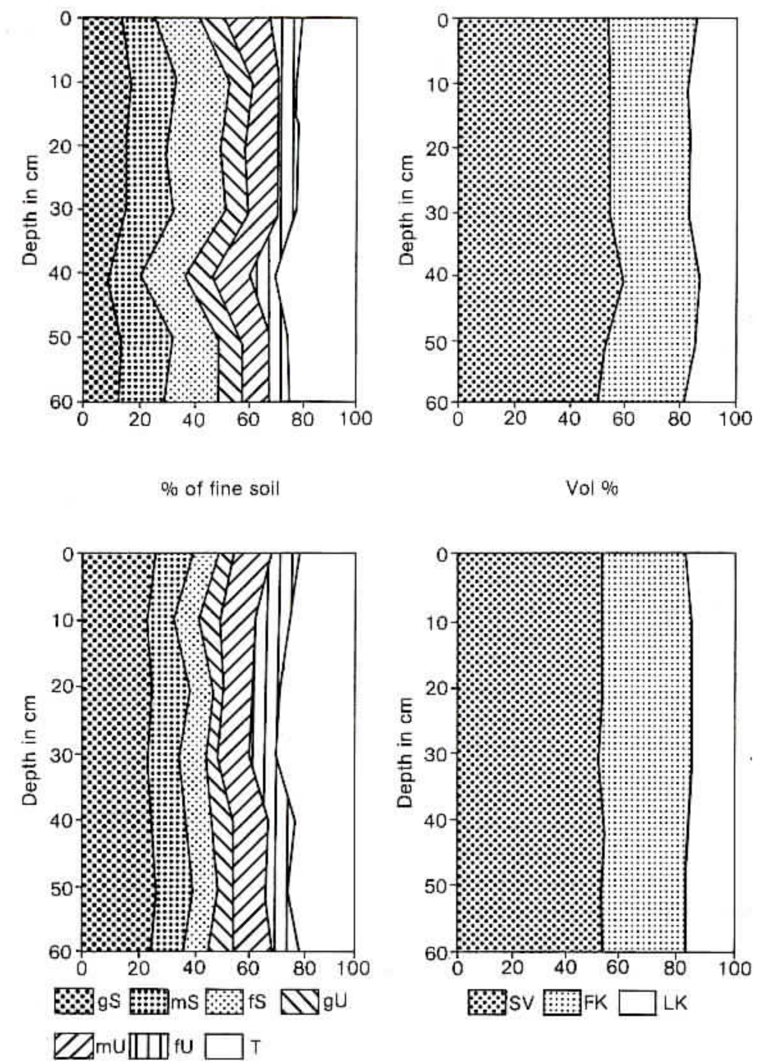



*Fig. 16: Variation of particle-size distribution and pore-size distribution along the soil depth above Macigno-sandstone (above) and calcareous shale (below).*
*gS, mS, fS = Coarse-, medium-, fine sand;*
*gU, mU, fU = Coarse-, medium-, fine silt;*
*gT, mT, fT = Coarse-, medium-, fine clay;*
*SV = Substance volume; FK = Field capacity; LK = Air capacity.*

must be mentioned that calcareous and slaty material which is used for wall construction in the regions with calcareous shale substratum (Fig. 15) has insufficient solidity- and slide-resistance coefficients after a certain wall height is reached. On steep slopes with a large vertical terrace interval, walls consisting of this stone material are more susceptible to breaching as a result of their low stability, than those made of sandstone. A clear relationship does however exist between gradient and the erosive and gravitational processes in the more advanced phases of decay. Regions with total terrace destruction are largely limited to slopes steeper than 40 %. The degree of destruction is therefore a function of the gradient. - A further dependence can be observed between the degree of destruction and the lateral curvature of the slope. As a result of the converging interflow and surface run-off consequent wall-breaks and small slips occur particularly in the sections of slope with concave lateral curvature.

## 6. ECOLOGICAL VALUATION OF THE FALLOW-LAND SUCCESSION

A secondary sucession is a question of transition from an artificial to a nature-like system. When cultivation is given up operations cease and regulators which bore the prevailing ecosystem go to ruin. In the case of viniculture these are factors of human interference like terracing and repairs of dry stone walls, tillage, fertilization or cultivation of the vines. This kind of integrated agriculture ensures a stable substitute system. The stable state is interrupted when human influence ceases and several stages of growing self-regulation follow. In successions the gradual formation of a new steady state goes along with the weakening of rhythmically occuring interference factors; that is with a decrease in micro-climatic, soil hydrological, and trophic variations during the changing course of days and seasons. With the formation of resistances like the growing density of vegetation cover or the humus accumulation an increase in "stability in the sense of constancy of form in the course of time" (H. HAEUPLER, 1982: 232) takes place.

This rule can be impressively demonstrated for the vine-fallow development of the Cinque Terre. With abandonment the anthropogenic control system is interrupted for the time being since the growth of dense plant stands is supplied mainly by mineral reserves but hardly by a autochtonous leaves production. However, after a few decades the swift wood formation causes a relative stabilization of the nutrient circulation. - At the beginning of the fallow succession micro-climatic and hydrological variations are also particularly high. Wall-breaks and the consequent dilapidation of the terraces occur during the phases of the sparsest vegetation covering, too; that is in winter, when the vines are not in leaf, and during the first fallow years.

The fact that succession phases which are aimed at the formation of a dynamic balance in a nature-like ecosystem extend with the approach towards the terminal stage remains to be considered. Very rarely such intervals can be accelerated artificially and particularly in the Cinque Terre where the vine-fallow development is characterized in any case by fast reactions. As ever there is also the question of whether forest regeneration is always desirable. For such a stabilization of regulation cycles can not be put on a level with an ecosystem's increase in endurance against irregular interference factors. As the system components most susceptible to trouble, biocenoses which are poor in species are scarcely able to build any regulators as buffers against damage which results from extreme dry spells, disastrous fires or sudden attacks by parasites. A correspondingly low resistance to destruction is observed in the Cinque Terre, particularly on cultivated vineyards and in the homogenous heath-pine stands. Grass stands which build off shoots and shrubbery-polycorms of passing fallow phases on the other hand display a better regeneration capacity.



As regards the ecological estimation of successions there are currently two lobbies holding opposite positions. In one case an uninfluenced natural development with acceptance of a probable reduction of species is preferred. The other side argues for the greatest possible richness in species with occasional human interference. Both opinions are defensible and are compatible: In the Mediterranean region there are 10.000 km of abandoned hoe cultivations with a fast succession similar to that of the Cinque Terre. Given agricultural overproduction one must assume a future increase of fallow land in order to do justice to both pressure groups.

For the Cinque Terre questions about the required steps can be answered automatically. From an ecological point of view nothing argues against an uninfluenced fallow development in abandoned vineyards and olive-tree groves. On the other hand the economic considerations may favor the supporters of the greatest possible richness in species theory: Meanwhile the terrace landscape is the region's most precious capital because it exerts a strong attraction on a "soft" hiking-tourism. For a decade now the corresponding sources of income have been made allowance for through the subsidizing of viniculture in this peripheral region in Italy. This affects the preservation of vineyards in the broadest sense: Repairs of supporting walls which occur particularly on cultivated terraces are now financed by the provincial government to the tune of 90 %.

## LITERATURE


ABBATE, E. (1969): Geologia delle Cinque Terre e dell'Entroterra di Levanto (Liguria orientale). Mem. Soc Geol. It., 8: pp. 923-1014; Roma.

AHNERT, F. (1987): An approach to the identification of morphoclimates. In: Proc. I. Internat. Conf. Geomorpholoy, (Ed.: V. GARDINER): pp. 58-188; Chichester.

ARIELLO, G. (1957): Flora delle "Cinque Terre". Ann. Museo Civ. Stor. Nat. Genova, LXIX: pp. 101-192; Genova.

CARL, Th. (1987): Merkmale, Ursachen und Prozesse des Terrassenverfalls in Corniglia (Cinque Terre/Ligurien). MA-thesis written at the Geogr. Inst. of the RWTH Aachen (unpublished).

DIECKMANN, H./HARRES, H.-P./MOTZEK, H./SEUFFERT, O. (1985): Die Vegetation als Steuerfaktor der Erosion. Geoökodynamik, 6: pp. 121-148; Darmstadt.

ELIA, P./ROSSI, A. (1984): Meccanizzazione dei vigneti delle Cinque Terre in provincia di La Spezia. Possibilitá di interventi. In: L'Informatore Agrario, XL (42): pp. 69-79; Verona.

HAEUPLER, H. (1982): Evenness als Ausdruck der Vielfalt in der Vegetation. Dissertationes Botanicae, 65; Vaduz, 268 pp.

HARD, G. (1975): Vegetationsdynamik und Verwaldungsprozesse auf den Brachflächen Mitteleuropas. Die Erde, 106: pp. 243-276; Berlin.

ISTAT (Istituto Centrale di Statistica): 3. Censimento Generale dell'Agricoltura, 1981; Roma.

KOPECKY, K./HEJNY, D. (1978): Die Anwendung einer deduktiven Methode syntaxonomischer Klassifikation bei der Bearbeitung der straßenbegleitenden Pflanzengesellschaften Nordostböhmens. Vegetatio, 16 (1): pp. 43-51; Den Haag.

KUTSCH, H. (1982): Principal features of a form of water-concentrating culture on small-holdings with special reference to the Anti-Atlas. Trierer Geogr. Studien, Vol. 5; Trier, 100 pp.
NOWACK, B. (1987): Untersuchungen zur Vegetation Ostliguriens (Italien). Dissertationes Botanicae, Vol. 111; Berlin/ Stuttgart, 259 pp.
PAINE, A.D.M. (1985): "Ergodic" reasoning in geomorphology: time for a review of the term? Progress in Physical Geography, 9 (1): pp. 1-15; London.
PAPADAKIS, J. (1965): Potential evapotranspiration. Buenos Aires, 54 pp.
PIGNATTI, S. (1968): Die Inflation der höheren pflanzensoziologischen Einheiten. In: Pflanzensoziologische Systematik (Ed.: R. TÜXEN). Ber. Internat. Symp. Internat. Ver. Vegetationskunde:pp. 85-97; Den Haag.
PFAU, R. (1966): Ein Beitrag zur Frage des Wassergehalts und der Beregnungsbedürftigkeit landwirtschaftlich genutzter Böden im Raume der EWG. Meteor. Rdsch., 19: pp. 33-46; Berlin/Stuttgart.
REUTTER, K.-J. (1968): Die tektonischen Einheiten des Nordapennins. Eclogae Geol. Helv.. 61 (1): pp. 183-224; Basel.
RICHTER, G. (1965): Bodenerosion. Schäden und gefährdete Gebiete in der Bundesrepublik Deutschland. Forschungen z. dt. Landeskunde 152; Bad Godesberg.
RICHTER, M. (going to press): Untersuchungen zur Vegetationsentwicklung und zum Standortwandel auf mediterranen Rebbrachen. Braun-Blanquetia, Vol. 3; Camerino/Baillieu.
SCHMIEDECKEN, W. (1978): Die Bestimmung der Humidität und ihrer Abstufungen mit Hilfe von Wasserhaushaltsberechnungen. Colloquium Geographicum, 13: pp. 135-159; Bonn.
SHACHORI, A./ROSENZWEIG, D./POLJAKOFF-MAYBER, A. (1967): Effects of Mediterranean vegetation on the moisture-regime. In: Forest-Hydrology (Ed.: W.E. SOPPER/H.W. LULL): pp. 291-311; Oxford.
SOERENSEN, T. (1948): A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. Det Kong. Danske Vidensk. Selsk., Biol. Skr. 5: pp. 1-34; Copenhagen.
TERRANOVA, R. (1984): Aspetti geomorfologici e geologico-ambientali delle Cinque Terre: rapporti con le opere umane. Studi e ricer. Geogr., VII (1): pp. 39-89; Genova.
VERBAS, C. (1978): Le Cinque Terre. Studi e Ricer. Geogr., I: pp. 17-144; Genova.

Adress of the authors:

Thomas Carl M.A., Großenbucherstr. 9, D-8524 Neunkirchen
Prof. Dr. Michael Richter, Geographisches Institut der FAU Erlangen, Kochstr. 4; D-8520 Erlangen

**VEREIN FÜR ERDKUNDE ZU DARMSTADT E. V.**
**D-6100 DARMSTADT; SCHNITTSPAHNSTRASSE 9**
**TEL. 06151/162719 oder 165318**



MITGLIEDSBEITRÄGE 1989:
(incl. Bd. 10, H. 1 von Geoökodynamik)

| | | |
|---|---|---|
| ordentliche Mitglieder | DM | 40,- |
| außerordentliche Mitglieder (Studenten, Schüler, Azubis) | DM | 25,- |
| Fördernde Mitglieder | DM | 200,- |
| Familienmitglieder (ohne Zeitschrift) | DM | 15,- |

**HINWEISE FÜR AUTOREN:**

Manuskripte für "GEOÖKODYNAMIK" werden mit vollständigen Unterlagen entweder als maschinengeschriebenes Manuskript (einseitig beschrieben in Schreibmaschinenschrift) oder (besser!) als Manuskript auf Diskette (5,25 oder 3,5 Zoll, verfaßt in einem verbreiteten Textverarbeitungssystem - MS Word, Wordperfekt, Wordstar) an den Herausgeber oder unmittelbar an den Verlag erbeten. Eingesandte Manuskripte gelten erst dann als zur Veröffentlichung angenommen, wenn dies vom Herausgeber ausdrücklich schriftlich bestätigt ist. Für unverlangt eingesandte Manuskripte kann keinerlei Haftung übernommen werden.
"GEOÖKODYNAMIK" legt besonderen Wert auf ausführliche Illustrationen der Beiträge durch Tabellen, Figuren, Fotos etc.. Alle Figuren (Strichzeichnungen) müssen als reproduktionsfähige Aufsichts- oder Durchsichtsvorlagen eingereicht werden. Das Maximalformat der Originale (auch Tabellen) sollte 30x20 cm nicht übersteigen. Bei der Beschriftung ist zu berücksichtigen, daß zum Druck eine Verkleinerung von 20% bis 50% erfolgt. Deshalb keine Buchstaben unter 2 mm verwenden. Gute (kontrastreiche, scharfe und aussagefähige) Bilder sind besonders erwünscht. Sie sollten im Original (Farb-, Schwarzweiß-Dia oder -negativ, diese Vorlagen geht nach Drucklegung zurück!) vorliegen. Sie werden in der Regel in Schwarzweiß, in Ausnahmefällen nach Entscheidung durch Herausgeber und Verlag auch als Farbaufnahmen gedruckt. Der Textumfang sollte 12.000 bis 15.000 Wörter nicht übersteigen. Für den Inhalt der Beiträge sind die Autoren selbst verantwortlich.
Korrekturen sind auf Druckfehler zu beschränken, es sei denn, der Autor trägt die Kosten. Jeder Autor erhält 50 Sonderdrucke seines Beitrages kostenlos (Autorenkollektive erhalten insgesamt 100 Sonderdrucke). Weitere können bei Anforderung spätestens mit Rücksendung der Korrekturfahnen gegen Kostenerstattung geliefert werden.
Es ist Aufgabe der Autoren, eine schriftliche Genehmigung beizubringen, falls Materialien reproduziert werden sollen, die bereits in anderen Publikationen erschienen sind. Keine Rücksendung von Manuskripten oder Figuren.