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WOODLAND RECOLONIZATION OF ABANDONED FARMLAND IN THE JULIAN PRE-ALPS (FRIULI, ITALY)

RIMBOSCHIMENTO SPONTANEO DI TERRENI AGRICOLI ABBANDONATI NELLE PREALPI GIULIE (FRIULI, ITALIA)

Abstract - Tree vegetation and soils have been analysed in five sites of the Julian Pre-Alps, on agricultural land on terraces, left fallow some decades ago. Dominant species are *Fraxinus excelsior* and *Acer pseudoplatanus*. Even if some trees established before abandonment density is still scarce and establishment is still taking place. Species composition is rather uniform but the pattern of colonisations are quite different in the five sites.

Key words: Secondary succession, Trees colonisation, Ash-maple stands, Terraces, Pre-Alps.

Riassunto breve - Sono state analizzate le caratteristiche della vegetazione arborea e del suolo in cinque località delle Prealpi Giulie in coltivi su terrazze abbandonati da alcuni decenni. Le specie dominanti sono *Fraxinus excelsior* e *Acer pseudoplatanus*. Anche se alcuni alberi si sono insediati prima della cessazione delle colture la densità è scarsa e la rinnovazione è ancora in atto. La composizione specifica è abbastanza uniforme ma la struttura orizzontale varia nelle diverse stazioni.

Parole chiave: Successioni secondarie, Rimboschimento spontaneo, Terrazze, Prealpi.

Introduction

The wide range of studies on the topic of abandoned farmland underlines the many different fields of research covered by this subject as well as its considerable geographical distribution. Publications from all over Europe cover the secondary succession of abandoned farmland as far as flora, fauna and soil development are concerned, and also consider aspects of landscape planning (DEBUSSCHE & LEPART, 1992; HANDKE & SCHREIBER, 1985; PUERTO & RICO, 1994; SCHWAAR, 1990; SURBER et al., 1974). These studies have also demonstrated that research on abandoned farmland is closely related to succession research.

In the Alps, the abandonment of agricultural land has become so widespread that in many areas fields and meadows are recolonised by woodland and the landscape has radically changed. For the Italian Alps, LOZITO et al. (1975) already pointed out the spontaneous

recolonization of large areas by woodland during the 1970s. In the Friuli Venezia Giulia Region, all of the Prealps, that is the Carnian and Julian Pre-Alps, are affected (GUIDI et al., 1994). The problem was first reported by COLAONE & PIUSSI (1975). SALBITANO (1987) and GUIDI (1990) described the species composition and stand structure of the newly formed woodlands in two communities of the Julian and of the Carnian Pre-Alps. At the same time, SALBITANO (1987) reported the remarkable speed of the recolonization process and considered the stands to be valuable both from an economic and from an ecological point of view.

SALBITANO (1987) and GUIDI (1990) already elaborated ways of determining the dynamics of the recolonization process in time and space. LOGLI (1994) continued this work by carrying out a detailed analysis of the horizontal structure of the woody vegetation coupled with dendrochronological analyses in order to determine the age structure of the trees.

This study continues the analysis of this process in small sample plots. More work has been carried out on the spatial structure and on the age structure of stands in order to verify the results obtained so far by previous studies. Natural regeneration was studied in particular as it provides important information on the woodland development process. As up to our research the soil conditions of the various sites had not been analyzed, the most important pedological parameters were determined by this study. Past agricultural practices, as well as the construction of terraces on slopes, are considered, as these considerably affect the secondary succession. Very little written information was available on these two points, which necessitated interviews of local people.

Research area

Location

The research area is located in North East Italy, 25 km north of Udine, close to the Slovenian border (fig. 1). It belongs to the municipality of Lusevera and forms part of the Comunità Montana delle Valli del Torre (Mountain Community of the Torre Valleys) - an administrative organization consisting of eight mountain municipalities which co-operate on management tasks.

Geology

The principal geological substrates are calcareous formations from the Jurassic and Cretaceous periods, as well as Paleocene and Eocene flysch. These are closely interlocked as numerous Dinaric folds cross this zone (FERUGLIO, 1954; VENTURINI & TUNIS, 1988). At Monte Musi and Gran Monte, calcareous and dolomitic rock types of the Upper Trias prevail. In the south, in the area of Lusevera and Taipana, Flysch from calcareous sands (predominant) and

marly sands of the younger Eocene occur. The area from the Torre-Valley in the West, via Monte Bernadia, to the Cornappo-Valley in the East, is covered by Cretaceous limestone (RUSSO, 1992; VENTURINI & TUNIS, 1988).

Soils

Calcareous brown earths, acid brown earths and, depending on the slope angle, transitions from brown earth to rendzina are the naturally occurring soil types (WOLF, 1972). According to MAINARDIS & SIMONETTI (1990), acid or slightly acid brown earths of half a metre or more thickness occur on Flysch, whereas on calcareous formations calcareous brown earths of low acidity are found. On steep slopes, shallow and stony rendzinas have developed which are, however, fertile. At the upper timberline and on alpine pastures, high precipitation rates have leached out the calcium carbonate, thereby acidifying the soil.

Vegetation

The predominant form of natural vegetation in the Julian Pre-Alps is woodland. Different woodland types are found there, depending on aspect, altitude and geological substrate. In the subalpine zone, European beech (*Fagus sylvatica* L.) and, to a certain extent, Austrian pine (*Pinus nigra* J. F. Arnold) forests occur on dry calcareous soils (SALBITANO, 1988). Thermophilic beech forests are found on south-facing slopes between 850 m and 1000 m altitude (SALBITANO, 1987). In the vicinity of abandoned houses, woods dominated by common ash (*Fraxinus excelsior* L.) with hazel (*Corylus avellana* L.) and wild cherry (*Prunus avium* L.) are common. On stony, calcareous soils, hazel, mountain ash



Fig. 1 - Location of the study area.
- Ubicazione del territorio studiato.

(*Sorbus aucuparia* L.) and willow (*Salix* spp.) form the shrub layer. The mountain tops are usually covered by meadows which can possibly be classified as *Bupleuro-Brometum condensati* Poldini et Feoli Chiapella, 1993 (FEOLI CHIAPELLA & POLDINI, 1993). On south-facing slopes, due to past grazing activities, this association is represented until 800 m of elevation (SALBITANO, 1987).

In the submontane region, which in the Julian Pre-Alps extends from 400 m to 700 m of elevation, though sometimes also from 300 m to 900 m, site characteristics on Flysch vary considerably from those on limestone. Sites on limestone which face south mainly support xerophilous formations such as manna-ash and hop hornbeam woods, with manna ash (*Fraxinus ornus* L.), hop hornbeam (*Ostrya carpinifolia* Scop.), field maple (*Acer campestre* L.) and hazel. Mesophilous formations composed of common ash, sycamore (*Acer pseudoplatanus* L.), small-leaved lime (*Tilia cordata* Mill.), wild cherry and hazel are widespread (POLDINI & VIDALI, 1999).

Plant names follow Flora Europaea (TUTIN et al., 1964-1980).

Climate

The climate of the Julian Pre-Alps is predominantly oceanic. The dominant South-East "scirocco" wind carries humid air from the Adriatic Sea towards the Alps. The EW oriented mountain ranges of Gran Monte (1600 m altitude), Monte Musi (1870 m) and Cuel di Lanis (1630 m) serve as barriers and often provoke orographic rainfall. The average annual precipitation in the Pre-Alps is between 2000 mm and 3000 mm, reaching 3300 mm at Musi (GENTILLI, 1964). The closest meteorological station is Vedronza at 320 m altitude. It is also the only one of seven stations of the Comunità Montana delle Valli del Torre where, apart from precipitation, temperature is also recorded. It is, however, located in the valley, just like the other six stations. For this reason, any information on the weather conditions in the mountains must be extrapolated, a process which is extremely unreliable due to the complex orography (MAINARDIS & SIMONETTI, 1990).

The average monthly precipitation rates reach their maximum in November, again peak between April and June, and are at a minimum in February. The warmest average monthly temperature is 18.2°C (in July), the coldest is -0.6°C (in January). On average, at the same altitude, the temperature on South-facing slopes is 4°C warmer than that on North-facing slopes (MAINARDIS & SIMONETTI, 1990; SALBITANO, 1987).

Demographic and economic development and landscape changes

During the last decades, emigration has increased rapidly. Thus, the population of the community of Taipana, which in 1911 consisted of 3.700 people, decreased from year to year, with emigration reaching its highest point after the earthquake in 1976; by 1988, Taipana only

had 860 inhabitants (RUSSO, 1992). The people who emigrated were predominantly young so that, as population numbers dwindled, the average age of the population increased, and the birth rate decreased. The occupation of the people also changed: while at the beginning of the century 90% of all workers were engaged in the agricultural sector, this proportion decreased to 50% in 1960, and to a mere 9% by 1986 (SALBITANO, 1987).

The demographic development described above was accompanied by a large-scale abandonment of agricultural land which was, and still is, rapidly recolonized by woody plants. Thus, the socio-economic change caused a complete alteration of the landscape. From the 1930s to the 1980s, the proportion of woodland in the land area of the community of Taipana, increased from 27% to 78% (SALBITANO, 1987).

Materials and methods

Choice of sample plots

Five representative sample plots were chosen within the environmental and climatic range of the ash-maple woodland type that occupies the largest part of the study area (SALBITANO, 1987). The size of each sample plot was chosen to match the dimensions of an individual former terraced field in the area, so that each plot had a homogeneous history of land-use. All field data were collected in 1994. Detailed information about the sample plots is reported in table I.

Sample plot	Altitude (m)	Aspect	Dimensions (width x length)	Geological substrate	Land-use history	Surroundings
Vigant	625	NE	12 x 7	limestone	hay-meadow up to 1980	all around similar terraces
Zaiama Bosco	640	N	15 x 19 / 15 x 12*	transition from limestone to Flysch	arable field up to about 1965; land-use since then unknown	N: spruce plantation; in all other directions sycamore-ash woods
Zaiama Campo	650	NW	12 x 12	transition from limestone to Flysch	Hay-meadow up to about 1982/1984	E: sycamore-ash woods; all other sides: terraces in similar conditions
Chialminis	690	N	16 x 22	Flysch	arable field up to about 1950; after that hay-meadow up to about 1980	S: sycamore-ash wood; all other sides: terraces in similar conditions
Bernadia	680	N	11 x 21	Flysch	abandoned about 1964/1969	W: spruce plantation; all other sides: terraces in similar conditions

Tabl. I - Characteristics of the sample plots (* asimmetrico).

- Caratteristiche delle aree di studio (* asymmetrical).

Soil analysis and terracing

From each sample plot, a representative soil profile was dug after explorative soil coring of the plot with an auger. Subsurface soil samples were collected from the profile, while surface soil samples were collected from other parts of each plot. Subsurface soil samples were collected from 10 cm thick sections of the profile. It was not considered useful to take a sample from pedogenetically defined soil horizons as all of the soil had been mixed and taken to the terraces by man and, therefore, could not be assigned to any naturally formed soil type. Furthermore, surface samples were taken from each area at up to 5 cm depth.

Table II gives an overview of the analyses carried out and the methods used. The classification of the pedochemical data followed the "Bodenkundliche Kartieranleitung" by the AG BODENKUNDE (1982). Prior to analysis, the samples were air-dried, passed through a sieve of 2 mm grain size and homogenised. The soil colour was determined in the laboratory by comparing it with the Japanese "Revised Standard Soil Colour Charts", using standard conditions of light and humidity.

Furthermore, a representative profile of one field terrace (Vigant) was dug starting from the wall at the valley side, in order to verify information about the construction of the terrace as obtained from interviews with the local population.

Vegetation

In order to determine the horizontal and vertical stand structure, as well as the species composition, the following particulars were recorded for all woody plants above 1.3 m height:

- position of the individual tree (coordinates within the sample plot);
- species;
- height;
- diameter at breast height.

Woody plants of up to and including 1.3 m height were classified as regeneration on the basis of previous studies (GUIDI, 1990; GUIDI et al., 1994) and divided into seedlings (<0.25 cm height) and saplings (0.25 cm - 1.3 m height).

Two to four parallel transects were set up at regular distances running between the downslope and upslope wall, to sample seedlings and saplings. The number and spacing of the transects was chosen so that 5% (for seedlings) and 10% (for saplings) of the total area was sampled. Within the transects the following particulars were recorded:

- position of the individual tree;
- species;
- height;
- age by counting annual shoots where these were clearly identifiable (see below).

Analysis	Method / Instrument used	Samples
pH value	Measurement using a glass electrode (manufactured by Schott): - in distilled water - in 0,01 M CaCl ₂ solution in proportion of 1:2,5 (PAGE et al., 1982; SCHLICHTING & BLUME, 1966; HOFFMAN, 1991)	Subsurface and surface samples
Total carbon and nitrogen content	Elemental analyzer (manufactured by Carlo Erba, NA 1500)	Subsurface and surface samples
Phosphate and potassium content available to plants	Extraction in Calcium lactate (SCHÜLLER, 1969), Measurements: - phosphate with the spectrophotometer (manufactured by Perkin Elmer 550SE) - potassium with the flame photometer (manufactured by Jenway PFP 7)	Surface samples
Cation exchange capacity	Exchange with ammonium chloride, (TRÜBY & ALDINGER, 1989), Measurements: - Calcium and magnesium with the atomic absorption spectrometer (manufactured by Perkin Elmer 1100) - Potassium and sodium with the flame photometer (manufactured by Jenway PFP 7) - Acidic cations with autotitrator (manufactured by Metrohm 678 EP/KF Processor)	Surface samples
Soil texture	combined pipette and sieve method after the humus has been destroyed (KRETZSCHMAR, 1989; PAGE et al., 1982)	in each case the lowest sampling horizon from each soil profile

Tabl. II - Overview of the methods used and the choice of samples analysed in the laboratory.

- *Metodi di analisi e criteri di campionamento.*

The numerous, vegetative bramble (*Rubus fruticosus* agg.) and field rose (*Rosa arvensis*) shoots could not all be recorded individually; instead, the extension of the polycorms was measured.

Three methods for determining the age of the woody plants were used: counting the annual shoots, counting the annual growth rings on stump cross-sections, and counting the annual growth rings on stem-cores.

By counting the annual shoots, the age of seedlings and saplings was determined for 98% of all individuals. In the case of *Fraxinus* spp. and *Acer* spp., this method was used up to a height of about 6 m which was equivalent to 15-20 years of age. For large trees and other species, however, it was necessary to use stem-cores or stump cross-sections. As this method is more time-consuming, it was carried out for a sub-sample of trees, stratified by species.

Since the oldest growth rings are not sampled with stem-cores taken at the usual core-height of 1.3 m, the age of the cored trees was determined by adding the average number of years a tree requires to grow up to 1.3 m height to the number of rings in the core, using the species specific values reported by LOGLI (1994).

Interviews with the inhabitants

The inhabitants were interviewed in order to obtain further information regarding the sample areas and past land-use. The questions asked were not standardized and covered the subjects of traditional agricultural techniques (crops grown, crop rotation, fallow period), fertilization, transitional use of land prior to its final abandonment, and utilisation and incidental plantation of woody species as well as the techniques used in the construction of terraces.

Results

Terrace construction

The terraces were constructed in order to obtain a flat surface for agricultural use. Stones were used to build a platform on the slope. This was covered with a 20 to 40 cm thick layer of earth previously taken from the site and its surroundings. During cultivation, the soil was regularly dug over with a spade to the full depth of the soil layer, thereby ensuring the mixing of the soil.

Soil analyses

The soil class of the terraces is a Rigosol with A_h - R - C_j -profile. This belongs to the Anthrosols soil unit according to the FAO soil classification system (SCHEFFER & SCHACHTSCHABEL, 1989). The $A(h)$ -horizon had a thickness of up to 10 cm, an average of 4 cm, and was locally missing. There was mull-humus on top of this, with a weak 2 cm thick O_f -horizon.

In the top soil, the pH varied from strongly acid to acid. The lowest values of the soil profile were commonly found in the upper 10 cm of the soil. Lower down, all profiles showed a continuous increase towards neutral pH values (fig. 2).

Even if the geological substrate was composed mainly of limestone and calcareous Flysch, no carbonate was detected in any of the soil samples. It can, therefore, be assumed that the carbon reserves are present in organic form. At up to 10 cm depth, the subsurface samples had a weak to medium humus content.

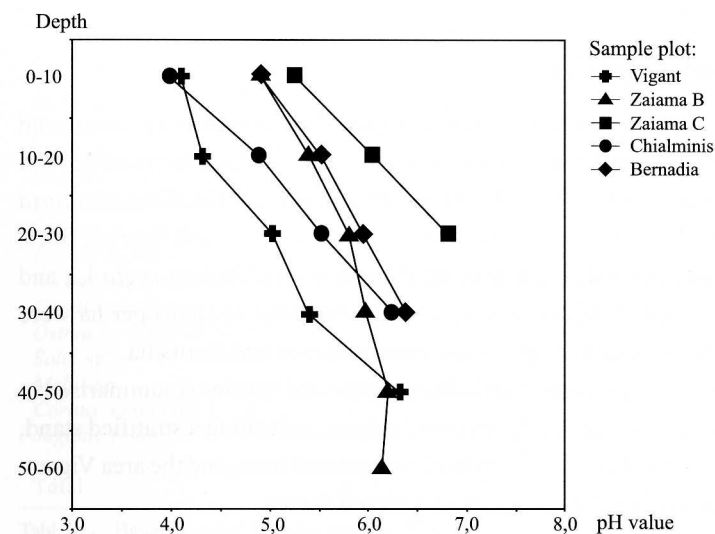


Fig. 2 - pH values within the soil profile for the five sample plots.
- Valori di pH entro il profilo nelle cinque aree di studio.

The humus content in the upper part of the top soil (to 5 cm) ranged from 4.6% to 7.6%, considered "very high".

Although the organic matter content decreased with increasing depth, its amount is still always between 1 and 3% even at 20 cm - 40 cm depth.

Analogous to the carbon content, the nitrogen content decreased with the depth of the soil profile and ranged from 0.41% to 0.26% in the top soil (0-5 cm). All sample plots were characterized by a very narrow C / N-relationship between 9.1 and 11.2.

The phosphate and potassium values were very low: the concentration of phosphate ranged from 1.5 mg to 2.7 mg P_2O_5 / 100 g mineral soil, and that of potassium from 2.5 mg to 6.2 mg K_2O per 100 g mineral soil.

The low cation exchange capacity (CEC) found (3.1 - 9.1 $cmol_c$ / kg mineral soil) is typical when base saturation attains a very high level of more than 80%. Calcium reached the highest saturation (average 62.3%), that for magnesium was 28.6%, with the lowest values for potassium (3.6%) and sodium (1%).

The analysis of the soil particle size determined the following soil textural classes:

- Sample area Vigant - medium sandy loam;
- Sample area Zaiama Bosco - medium clay loam;
- Sample area Zaiama Campo - silty clay sand;
- Sample area Chialminis - very loamy sand;
- Sample area Bernadia - sand with low clay content.

The silt component was usually high and was mainly determined by coarse silt fraction (fig. 3). The largest fraction of sand was fine sand.

Vegetation

Tree species distribution and composition

The woody vegetation of the study sites was dominated by *Fraxinus excelsior* and *Acer pseudoplatanus*, which on average represented about 65% of the basal area and 68% of the number of stems (tables III and IV). Locally abundant species included *Alnus glutinosa* (L.) Gaertn., *Tilia cordata*, *Corylus avellana* and *Sambucus nigra* L.. Fruit bearing trees, possibly a legacy of past land use, were also present: *Prunus avium*, *Juglans regia* L., and *Malus* sp. The basal areas were still relatively low, while the number of stems per ha were relatively high in the two most wooded sample areas, Zaiama Bosco and Bernadia.

Height class distribution of trees taller than 1.30 m by area and species is summarised in figures 4 and 5. The distributions are generally reverse-J shaped, indicating a stratified stand, with the exceptions of area Zaiama Campo, which has few scattered trees, and the area Vigant, which begins to show the bell-shaped distribution of a closed forest.

Natural regeneration

Natural regeneration was dominated by *Fraxinus excelsior* (89% of all seedlings and 66% of all saplings) and *Acer pseudoplatanus* (9% of all seedlings and 30% of all saplings). *Tilia cordata*, *Ostrya carpinifolia*, *Corylus avellana* and *Cornus sanguinea* were also present, but in much lower proportions (fig. 6). Most of the variability in the abundance of *Fraxinus excelsior* and *Acer pseudoplatanus* seedlings (61%) and saplings (98%) is explained by a

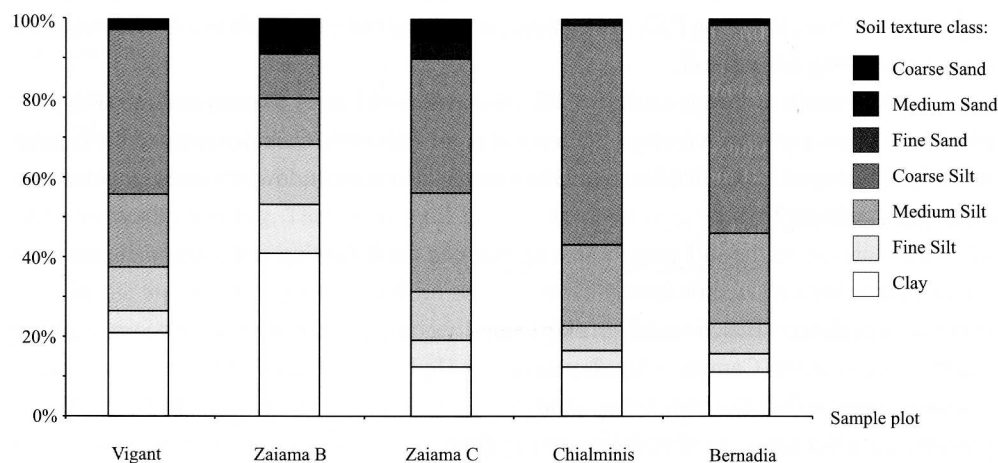


Fig. 3 - Soil particle size distributions for the five sample plots.
- Tessitura del suolo nelle cinque aree di studio.

Species	Overall Average	Vigant	By Area			
			Zaiama B.	Zaiama C.	Chialminis	Bernadia
<i>Fraxinus excelsior</i> L.	2.81	8.35	3.01	0.24	0.41	2.07
<i>Acer pseudoplatanus</i> L.	0.94	1.57	2.80	0.02	0.06	0.25
<i>Alnus glutinosa</i> (L.) Gaertn.	0.63	-	-	-	0.66	2.48
<i>Fraxinus ornus</i> L.	0.63	-	-	2.84	0.07	0.22
<i>Tilia cordata</i> Mill.	0.30	-	1.47	-	0.03	-
<i>Sambucus nigra</i> L.	0.27	1.36	-	-	-	-
<i>Prunus avium</i> L.	0.11	-	0.43	-	0.10	-
<i>Sorbus aucuparia</i> L.	0.04	-	-	-	-	0.22
<i>Corylus avellana</i> L.	0.04	-	0.11	0.01	0.04	0.02
<i>Ostrya carpinifolia</i> Scop.	0.01	-	0.04	-	-	0.03
<i>Salix</i> sp.	> 0.01	-	-	-	-	0.01
<i>Malus</i> sp.	> 0.01	-	0.001	-	0.004	-
<i>Cornus sanguinea</i> L.	> 0.01	-	-	-	0.0002	-
<i>Juglans regia</i> L.	> 0.01	-	-	-	0.0002	-
Total	5.78	11.28	7.86	3.11	1.38	5.30

Tabl. III - Basal area ($m^2 ha^{-1}$) by species. The overall average is given as a reference, and is not calculated weighing the different sizes of the areas. Species are ranked by overall average basal area.
- Area basimetrica ($m^2 ha^{-1}$) per le diverse specie. La media generale è espressa come riferimento per ordinare le varie specie e non è stata calcolata ponderando le superfici delle diverse aree.

Species	Overall Average	Vigant	By Area			
			Zaiama B.	Zaiama C.	Chialminis	Bernadia
<i>Fraxinus excelsior</i> L.	1777	3690	1620	347	199	3030
<i>Acer pseudoplatanus</i> L.	1053	357	4120	69	284	433
<i>Corylus avellana</i> L.	359	119	1092	139	142	303
<i>Tilia cordata</i> Mill.	289	0	1092	0	313	43
<i>Alnus glutinosa</i> (L.) Gaertn.	257	0	0	0	28	1255
<i>Fraxinus ornus</i> L.	132	0	0	417	114	130
<i>Sambucus nigra</i> L.	78	0	0	0	0	390
<i>Prunus avium</i> L.	48	238	0	0	0	0
<i>Juglans regia</i> L.	13	0	35	0	28	0
<i>Cornus sanguinea</i> L.	9	0	0	0	0	43
<i>Ostrya carpinifolia</i> Scop.	6	0	0	0	28	0
<i>Malus</i> sp.	6	0	0	0	28	0
<i>Salix</i> sp.	88	0	352	0	0	87
<i>Sorbus aucuparia</i> L.	25	0	70	0	57	0
Total	4139	4405	8380	972	1222	5714

Tabl. IV - Number of stems per ha by species. The overall average is given as a reference, and is not calculated weighing the different sizes of the areas. Species are ranked by overall average abundance.
- Numero dei fusti per ettaro. La media generale è espressa come riferimento per ordinare le varie specie e non è stata calcolata ponderando le superfici delle diverse aree.

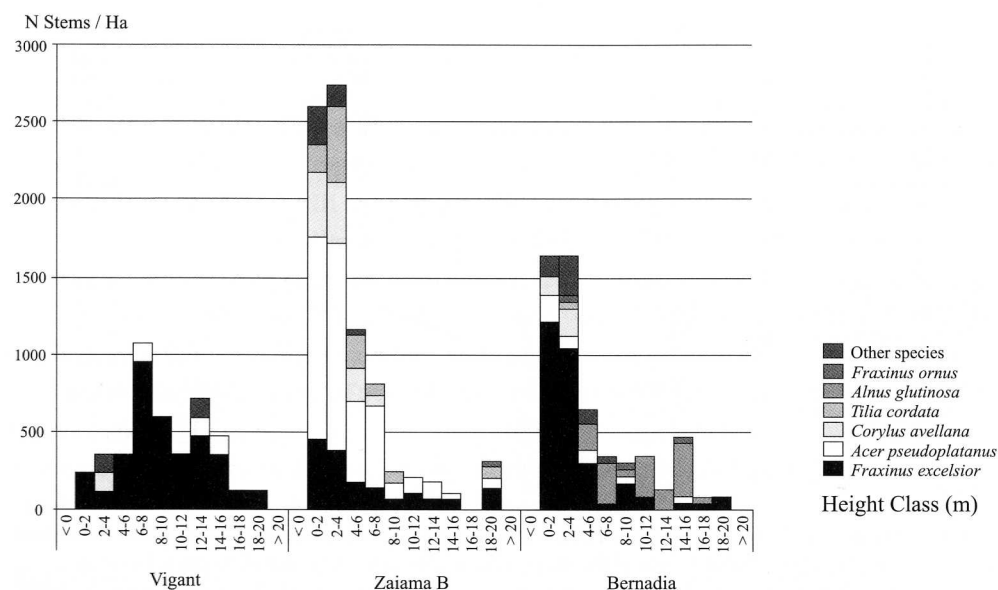


Fig. 4 - Height class distribution by species: areas Vigant, Zaiama Bosco and Bernadia.
- Distribuzione in classi di altezza per le diverse specie: aree Vigant, Zaiama Bosco e Bernadia.

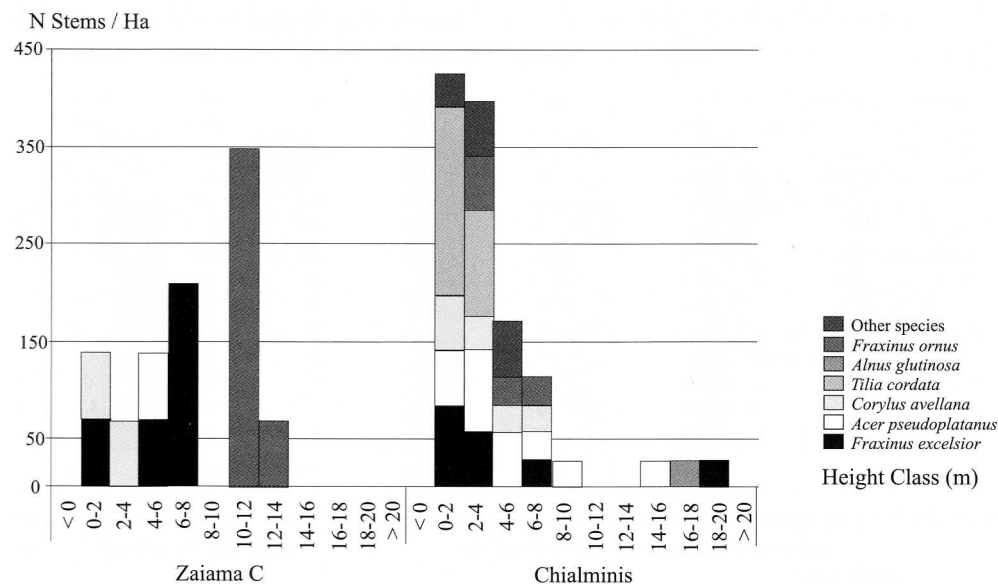


Fig. 5 - Height class distribution by species: areas Zaiama Campo and Chialminis.
- Distribuzione in classi di altezza per le diverse specie: aree Zaiama Campo e Chialminis.

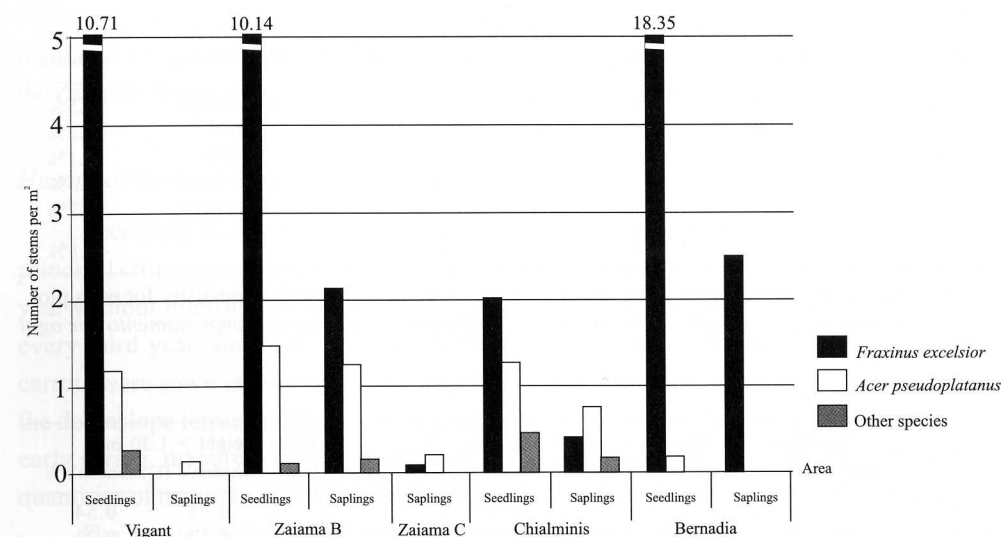


Fig. 6 - Abundance of seedlings (height < 25 cm) and saplings (height > 25 and < 130 cm) in each study area expressed as number of stems per m².
- Densità di semenzali (altezza < 25 cm) e di piantine affermate (altezza compresa tra 25 cm e 130 cm) nelle diverse aree di studio espressa come numero di fusti per m².

quadratic function of the cumulative basal areas of these two species (fig. 7). The height class distribution of seedlings and saplings is reverse-J shaped, or linear in a logarithmic scale (fig. 8) when averaged over the five areas. Individual areas generally follow the same distribution with the exception of Zaiama Campo.

Age and spatial structure

The age distribution for seedlings and saplings is reported in figure 9. The data for Zaiama campo is reported for completeness, but the number of individuals in this plot was extremely low (fig. 6). The range of age/class distribution of seedlings and saplings was much narrower in Vigant area than in the other three plots with abundant seedlings and saplings, as seedlings contributed to this data much more than saplings did (fig. 6). The range of ages was particularly high in Zaiama Bosco and Bernadia plots, where the upper quartiles spanned ages well over 10 years, meaning that vertical growth rates had fallen below 10 cm per year for some individuals.

Data on the age/class distribution of trees are reported in table V. These data cannot be consolidated with the data for seedlings and saplings, because the sampling of trees was irregular and likely biased against the oldest trees. Despite these limitations, it is interesting to notice how sometimes (Chialminis, Zaiama Bosco) the oldest sampled individuals

Area	Not available	N. of individuals per year of establishment				Year of abandonment	Sampling intensity
		1994-85	1984-75	1974-65	1964-55		
Bernadia	60	42	29	1	-	1964/1969	54.5%
Chialminis	30	8	5	-	-	1980	30.2%
Vigant	34	3	-	-	-	1980	18.1%
Zaiama Bosco	123	7	97	10	1	post 1965	48.3%
Zaiama Campo	9	5	-	-	-	1982/1984	35.7%
Total	256	65	131	11	1		44.8%

Tab. V - Age class ditribution of trees (number of individuals) and sampling intensity for each plot.
- *Struttura per età degli alberi (numero di individui) e frequenza di campionamento per ogni area.*

Area	Seedlings and Saplings (height < 1.30 m)				Trees (height > 1.30 m)		
	Age†	Num. of Spec.	Shannon's H	Shannon's E	Num. of Spec.	Shannon's H	Shannon's E
Vigant	5	2	0.03	0.05	4	0.75	0.54
Zaiama C	8	3	0.66	0.60	4	0.32	0.23
Chialminis	14	4	0.77	0.56	10	1.40	0.61
Bernadia	20	2	0.59	0.85	9	1.19	0.54
Zaiama B	23	6	1.11	0.62	7	1.29	0.67

Tab. VI - Species diversity for tree seedlings and saplings, and for trees taller than 1.30 m. The sample areas are ranked by the age class of the third oldest tree aged on the plot, as proxy of time since stand establishment († age of the third oldest tree on the plot).

- *Diversità di specie per semenzali, piantine affermate e alberi di altezza superiore a 1.30 m. Le aree campione sono ordinate in relazione alla classe di età del terzo albero più vecchio individuato nell'area, come dato sostitutivo del momento in cui si è verificato l'abbandono († età del terzo albero più vecchio individuato nell'area).*

established before the abandonment of the field, and many individuals established almost immediately after abandonment.

The spatial structure of the four plots with a higher number of individuals is reported in fig. 10. Larger trees frequently concentrate at the edge of the plots, while seedlings and saplings either follow the same pattern (Bernadia, Chialminis), or otherwise settled near the centre of the plot where fewer trees were present (Zaiama Bosco).

Tree species diversity

The diversity of tree species for both seedling and saplings was analysed using Shannon's Diversity (H) and Equitability (E) indexes (MAGURRAN, 1988). The abundance term used in the calculation of the indexes was the sum of the height of the individuals for the seedlings and saplings, and the basal area for the trees, both being proxies for cumulative biomass. The diversity of tree species generally increases with the age of the stand, although

within each area the tree layer has a consistently higher species richness and almost consistently higher diversity (Shannon's H) than the seedling and sapling layer, the only exception being the Zaiama Campo area.

History of the land use and management of terraces

According to the interviewed population, sweet corn, beans, and potatoes were the principal crops grown on the field terraces. On each terrace, the same crop was grown every year without interruption; only when productivity decreased sharply land was left fallow every third year, and then re-planted with a different crop. Often the crops were mixed: carrots were sown in-between rows of sweet corn, or pumpkins were grown hanging from the downslope terrace walls, whereas potatoes were planted on the terrace. In late winter or early spring, manure was spread on the fields and mixed up with the soil. As only limited quantities of manure were available, meadows were not fertilized.

The reason for the abandonment of agricultural land was usually the emigration of its owners. Often relatives took the field over, and land-use became extensive: fields became meadows before they were abandoned for good.

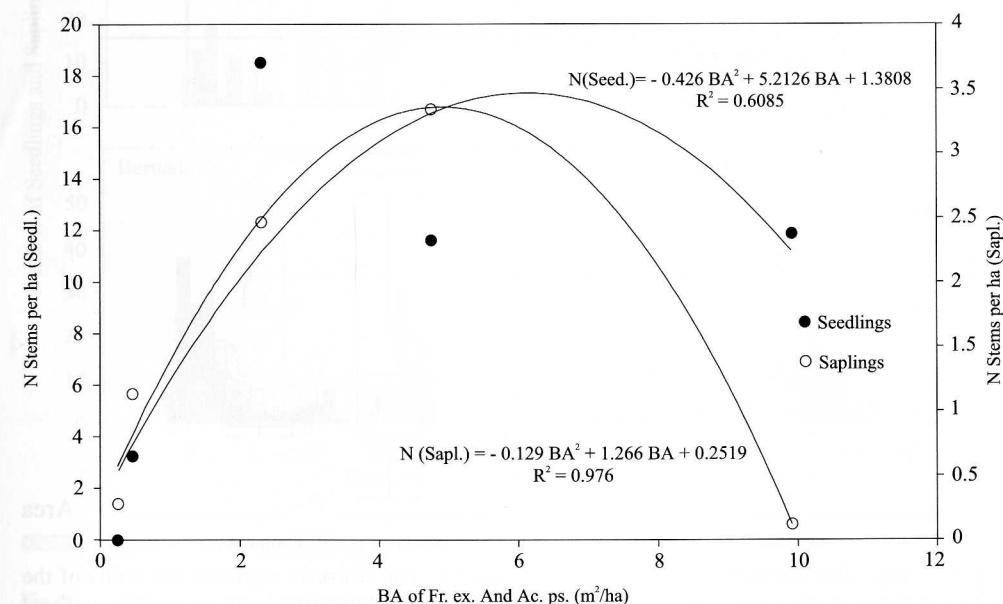


Fig. 7 - Relationship between the number of stems per m² of seedlings and saplings and the basal area of trees (*Fraxinus excelsior* and *Acer pseudoplatanus* only).
- *Rapporto tra la densità dei semenzali e piantine affermate per m² e l'area basimetrica ad ha degli alberi (solo Fraxinus excelsior e Acer pseudoplatanus).*

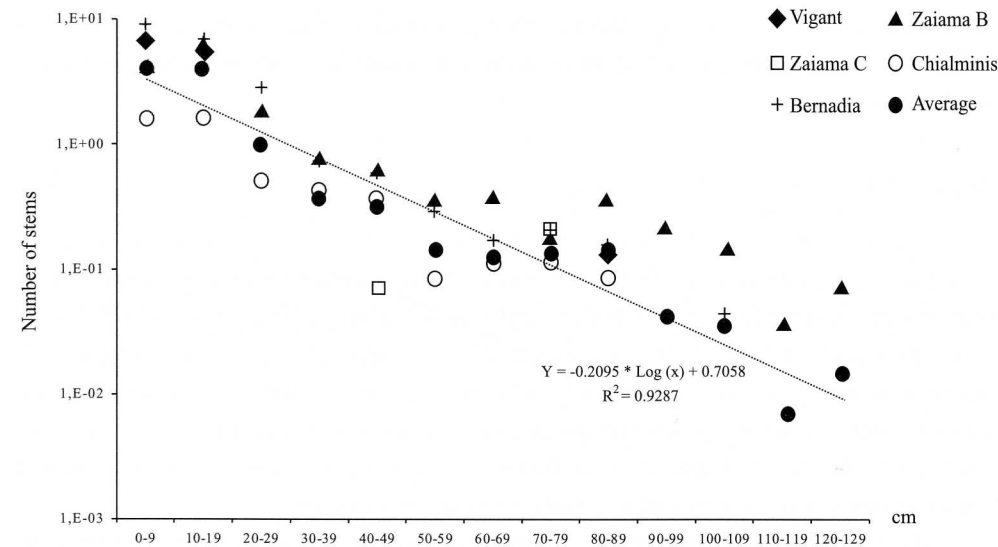


Fig. 8 - Frequency distribution of seedlings and saplings (all species) by 10 cm height class intervals. Distributions are plotted on a logarithmic scale.

- Distribuzione delle frequenze di semenzali e piantine affermate di tutte le specie in classi d'altezza di 10 cm. Le distribuzioni sono espresse in scala logaritmica.

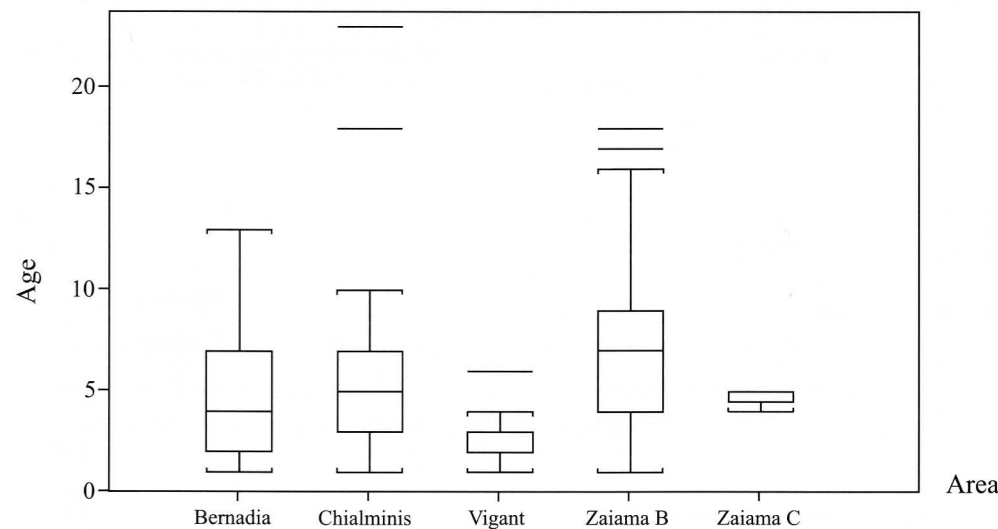


Fig. 9 - Age class distribution of seedlings and saplings. The whiskers represent the limits of the heighest and lowest, the boxes the limits of two central quartiles, split by median. Isolated lines represent outliers.

- Struttura per età di semenzali e piantine affermate. I tratti che delimitano l'asse verticale indicano i limiti dei quartili estremi, i rettangoli definiscono i due quartili centrali separati dalla mediana ed i tratti isolati indicano valori isolati.

Trees were always eradicated from the edges of fields because their roots and water requirement presented too much competition for the cultivated plants. There were, however, trees alongside pastures and meadows which provided fuelwood, fodder (foliage of ash, lime, maple, and sometimes hazel, collected at the end of September), nuts, fruit and timber. Walnut, pear, plum and apple trees were planted; common ash, lime and maple on the edges of pastures and meadows were tolerated if they grew there spontaneously.

Common alder is a special case. It was planted already in the XIX century (and perhaps even before) in the meadows in order to improve the soil fertility and increase hay production, although the alder's ability to grow in symbiotic association with nitrogen-fixing bacteria was ignored by local farmers (PIUSSI, 1998). Its foliage was considered an important fertilizer, and it was also sometimes used as fodder and litter.

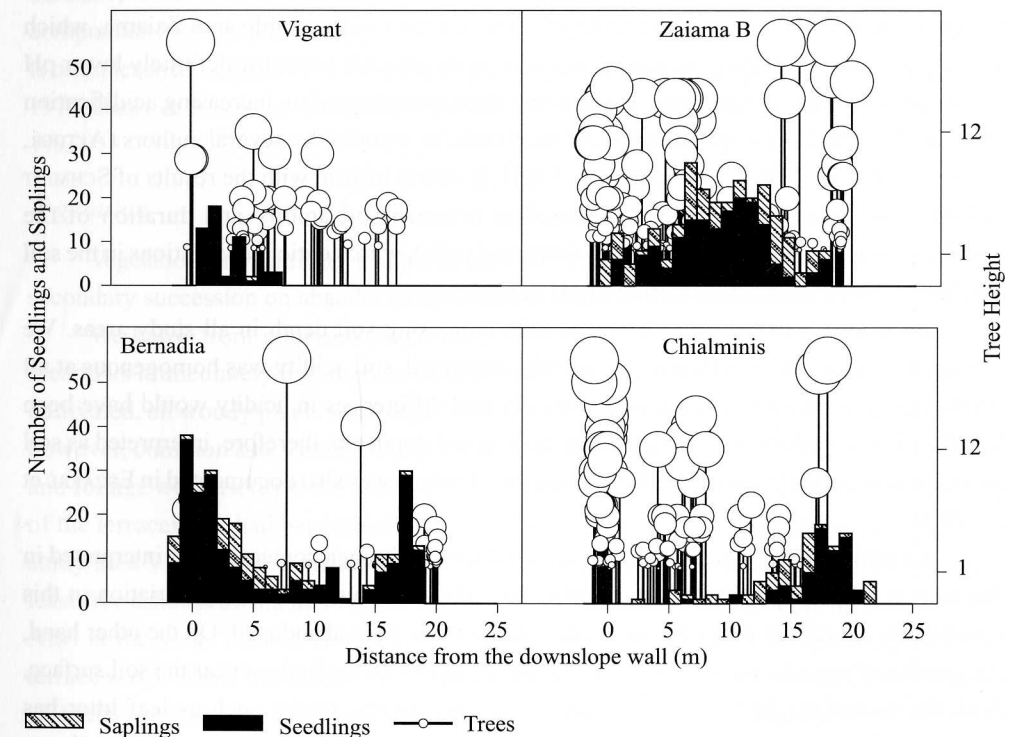


Fig.10 - The frequency distribution of seedlings and saplings as a function of the distance from the down-slope wall of the terrace is compared with a plot of tree heights.

- La distribuzione delle frequenze di semenzali e piantine affermate in funzione della distanza dal muro di sostegno a valle della terrazza viene posta a confronto con la collocazione degli alberi.

Discussion

Soils

First of all, it is surprising that the soil does not contain calcium carbonate although the geological substrate is mainly composed of calcareous material. This can, however, be explained by the high precipitation rates which dissolve CaCO_3 and leach it into the water (DUCHAUFOR, 1977). The permeable nature of the foundation of the field terraces favours the rapid infiltration of the water. Several CaCO_3 tests outside the sample plots have shown that there is no chalk anywhere in the soils of the whole sample area. It is not known if the calcium carbonate had already leached out before anthropogenic influence started or if human influence accelerated this process. As a result of the missing carbonate buffer, the pH of the soils was moderately to strongly acid.

Moreover, in a comparison of the three study areas, no relationship was found between the duration of the abandonment and levels of soil acidity. The sample area Zaiama, which was abandoned earlier than the others, about 30 years ago, did not show definitely lower pH values than the other areas. This contrasts with the expectation of an increasing acidification of the soil of abandoned agricultural land with time, as reported by several authors (ALTHER, 1981; VON BORSTEL, 1974; GISI & OERTLI, 1981). It agrees instead with the results of SCHMIDT (1993), who found no significant connection between soil acidity and duration of the abandonment, and those of SCHREIBER & SCHEFFER (1985), who mentioned variations in the soil pH, but excluded a definite lowering of pH values.

Soil acidity was shown to decrease with increasing soil depth in all study areas. We assume that, when the field terraces were still cultivated, soil acidity was homogenous at all depths because the soil was dug over annually and differences in acidity would have been levelled. The variations in soil pH with increasing soil depth are, therefore, interpreted as soil surface acidification since the field was abandoned, which was also documented in ESCARRÉ et al. (1983).

The analyses of organic substances and of the total nitrogen content can be interpreted in the same way: the top soil of all study plots had a high humus content; any variation in this content was not related to the length of time the field has been abandoned. On the other hand, the amount of organic matter and the total nitrogen content were highest near the soil surface. With the increasing duration of field abandonment, organic matter such as leaf litter has accumulated on the soil surface. The enrichment of humus in the upper part of the soil was documented or assumed also by ALTHER (1991), ESCARRÉ et al. (1983), GISI & OERTLI (1981), PUERTO & RICO (1994), SCHMIDT (1983, 1993), STAHR (1992) and STÖCKLIN & GISI (1985).

The C/N-relationship, calculated as being 10 and 11, can be considered optimal for the decomposition of organic matter even on the wooded sample plots (AG BODENKUNDE, 1982;

SCHEFFER & SCHACHTSCHABEL, 1989; SCHROEDER, 1983). Indeed, observations in the field confirmed that in wooded stands with a closed canopy the leaf litter decomposed within a year, and did not form a thick layer on top. This could be due to the composition of the leaf litter, which considerably determines the rate of decomposition (STÖCKLIN & GISI, 1985). Ash and alder, as well as lime leaves, which have a C/N-value of 20-30 and 40-60, respectively (SCHEFFER & SCHACHTSCHABEL, 1989), are easily decomposed.

The actual cation exchange capacity of the composite area samples had particularly low values of between 3 and 9 cmol/kg of soil. The soils can, therefore, store and exchange nutrients, or make them available to the plants, only to a limited extent. The amounts of phosphate and potassium available to the plants were equally low. An important reason for this is the migration export of nutrients in the soil: the plants take up the nutrients and fix them in their biomass (ESCARRÉ et al., 1983; BROLL & SCHREIBER, 1993; HARTMANN & OERTLI, 1984; SCHMIDT, 1983; 1993). Furthermore, in time phosphorus reacts to form sparingly-soluble compounds (SCHEFFER & SCHACHTSCHABEL, 1989; BLUME, 1990). The easily-mobile potassium is often leached, especially with the high rates of precipitation in the study area (VON BORSTEL, 1974; BROLL & SCHREIBER, 1993; GISI & OERTLI, 1981; HARTMANN & OERTLI, 1984; SCHMIDT, 1983; 1993).

Vegetation

Vegetation data confirm the importance of the kind of the last agricultural use in influencing secondary succession on abandoned agricultural fields (HARD, 1975; 1976).

We know from interviews with the population that many arable fields were used as meadows immediately before they were definitively abandoned. As long as the fields were cultivated, all woody plants were removed from the fields and their edges. On hay meadows, however, common ash, sycamore and small-leaved lime were tolerated because their wood and foliage were useful to the farmers. This explains why we found single trees at the edges of the terraces that had become established there before the plot's abandonment, e.g. in the study area Vigant where meadows were mown up to about 1980. In that plot there were at least five ashes growing on the downslope terrace wall which were established before 1980. Also in the areas Zaiama Bosco and Chialminis the largest trees were growing along the terrace walls. These trees likely developed unhindered after the abandonment of the terraces, as their extensive root systems have a definite competitive advantage over the more intensive roots of grasses and herbaceous plants (HARD, 1975; SALBITANO, 1987; 1988), and were able to produce large amounts of seed, possibly representing initial centres of woodland recolonization, as described by SALBITANO (1987, 1998) and GUIDI & PIUSSI (1993a; 1993b) for similar areas. The man-made terraces represented a network of nuclei from which a widespread recolonization of the area by woodland can take place (SALBITANO, 1987; 1988), because

the distance between the individual terrace walls along which the seed trees grew was usually much shorter than the distances of up to 100 m that wind-dispersed seed can successfully travel from the seed tree (SCHREIBER, 1995). As that, the wind-dispersed seed could reach virtually every point in the study area.

In addition to acting as a seed source, trees established on the walls can exclude grasses and herbaceous plants by the shadow cast by their canopy as well as by root competition. In this phase large sized trees favour the establishment of other trees, as theorised by CONNELL & SLATYER's (1977) facilitation model. This facilitation could explain the speed of colonisation by woody plants. While the abandonment of the fields could not be accurately dated, it is probable that the first woody plants became established in our sample plots within five years of abandonment, and that most trees were present after 10 or 15 years. This is consistent with the results of LOGLI (1994), who, in a similar area, found that most woody plants had established during the first decade after abandonment. In the case of the Chialminis and Zaiama Bosco study areas, several of these plants were recruited during the first years after the site had been abandoned, and possibly before hemicryptophytes became established.

The hypothesis about the initial role of the established trees in facilitating succession is supported by the quadratic relationship between tree basal area and seedling and sapling density shown in figure 7. The quadratic function culminates at about 5 m² ha⁻¹ of basal area, indicating that at these tree densities, recruitment is the highest. At higher densities the trees seemingly start to reduce the available light and thus the ability of new seedlings to successfully establish and grow.

This mechanisms of the recolonization by woodland is generally consistent with those described by SALBITANO (1987; 1988), with the exception of the role of hazel and other shrubs. In none of the sample areas are these shrubs present in large numbers. With the exception of field rose and bramble, no polycormic shoots were noted. Vegetative reproduction was limited to coppice shoots which indicated past practices of coppicing (LOGLI, 1994) and were present on every site. A successional phase of dense shrub growth, as mentioned by LOHMEYER & BOHN (1973) and MEISEL & VON HÜBSCHMANN (1973), did not take place.

The sycamore-ash stand is a pioneer stage of the secondary succession as described by ZOLLER et al. (1984). Presumably these stands can be regarded as belonging to the *Hacquetio epipactido-Fraxinetum* (Poldini 82 p.p.) Marinček ex Poldini et Nardini 1993 (POLDINI & NARDINI, 1993).

No future development of the vegetation toward more stable associations can be foreseen, moreover no specimens of beech, not even seedlings or saplings, which would represent the most important components of a future beech forest (GUIDI, 1990), were found in

any of the sample areas or in their immediate surroundings. GUIDI (1990) arrived at similar conclusions for the Carnian Pre-Alps.

The lack of potential beech seed trees (SALBITANO, 1987), and the predominance of common ash and sycamore whose seeds are dispersed by wind, are considered responsible for the great stability of the present sycamore-ash stands and for the lack of any tendency towards the development of a *Fagetum* (SCHMIDT, 1983).

Conclusions

While five cases are too few to draw general conclusions, we feel that data collected support the existence of multiple pathways in old field succession in Friuli.

Two main tree species, *Acer pseudoplatanus* and *Fraxinus excelsior*, were represented in all plots, consistently with analogous studies in nearby areas (SALBITANO 1987; LOGLI, 1994). These species make up one of the important forest types of Friuli, the ash-sycamore woods (DEL FAVERO et al., 1998). In all cases there was no evidence of a shrub phase. Abandonment was followed by soil development, with the formation of a mull humus, N enrichment and pH lowering at the surface, notwithstanding the carbonate-rich parent material. The variable soil acidity and content of organic matter at different soil depths could be used as indicators of the duration of field abandonment.

The relative abundance of the two main species, as well as the richness and diversity of tree species were variable between plots. Even larger were the differences in spatial distribution, height structure and age structure between the plots. These differences indicate that while the species involved in the successional processes might be the same, the patterns of colonisation are different. The speed of woodland recolonisation seems to vary extensively between sites. In some cases it occurs immediately after abandonment, while in other cases the colonisation is delayed for two or three decades.

These different patterns might be influenced by the presence of the terrace walls, that appear to act as "safe sites" sensu HARPER (1977) for the early establishment of trees. The presence of early established trees on the wall, as shown by the quadratic relationship between basal area and seedling/sapling density, seems to facilitate the further establishment of trees, probably by suppressing the competition of perennial grasses and altering the seedbed.

These provisional hypotheses could be tested through a more extensive survey of abandoned fields over a range of times since abandonment as well as terrace sizes. In the end, long-term monitoring is essential in order to obtain detailed knowledge regarding the successional development.

SUMMARY - Colonisation of abandoned farmland is a widespread process on the southern slope of the Alps. We have been studying five plots in the eastern Pre-Alps, located between 625 and 690 m a.s.l. on limestone and flysch, where traditional agricultural utilisation, developed on terraces, ceased approximately between 1965 and 1985. Woody vegetation was analysed in sample plots and soil profiles were studied in each site. Previous agricultural practices have been described by local old farmers.

Soils developed on terraces are Rigosols, with a mull humus. In the top soil, the pH varied from strongly acid to acid. Lower down, all profiles showed a continuous increase towards neutral and weakly alkaline pH values.

The woody vegetation is dominated by *Fraxinus excelsior* and *Acer pseudoplatanus* but several other hardwood species are present, including some fruit bearing trees, possibly a legacy of past land use. Average stand density is 4139 trees ha⁻¹; basal area 5.78 m² ha⁻¹, dominant height is mainly 18-20 m. Tree colonisation is usually still taking place and there is no evidence of a shrub phase. Some tree established before the abandonment and many more almost immediately after abandonment. These differences indicate that while the species involved in the successional processes might be the same, the patterns of colonisation are different. The speed of woodland recolonisation seems to vary extensively between sites. In some cases it occurs immediately after abandonment, while in other cases the colonisation is delayed for two or three decades. These different patterns might be influenced by the presence of the terrace walls, that appear to act as "safe sites" for the early establishment of trees.

RIASSUNTO - Il rimboschimento spontaneo di terre agricole abbandonate è un fenomeno ampiamente diffuso sul versante meridionale delle Alpi. Abbiamo analizzato questo processo in cinque località situate nelle Prealpi orientali, tra 625 e 690 m s.l.m., su calcari e su flysch, dove le utilizzazioni tradizionali, praticate su terrazze, erano cessate approssimativamente tra il 1965 ed il 1985. La vegetazione legnosa è stata esaminata entro aree di saggio ed in ogni località si è studiato il profilo del suolo. Le vecchie forme di uso del suolo ci sono state descritte da anziani agricoltori.

Sui terrazzi si sviluppano Rigosols, con humus di tipo mull. In superficie la reazione del suolo è acida o molto acida mentre in profondità il pH aumenta e diviene neutro o leggermente alcalino.

La vegetazione legnosa è dominata da *Fraxinus excelsior* e da *Acer pseudoplatanus*, ma sono presenti numerose altre specie arboree, inclusi alcuni alberi da frutto, probabile traccia delle vecchie coltivazioni. La densità del soprassuolo è di 4139 alberi ha⁻¹, l'area basimetrica è 5.78 m² ha⁻¹, l'altezza dominante è generalmente di 18-20 m, ma la maggior parte degli alberi è nettamente più piccola. Il processo di colonizzazione è ancora in atto e non si manifesta una fase ad arbusti. Alcuni alberi si sono insediati prima dell'abbandono definitivo, ma la maggior parte è comparsa nei primi anni seguenti l'abbandono. Da questi rilievi appare che, mentre le specie che partecipano al processo di colonizzazione sono le medesime nelle varie aree, le modalità di insediamento possono essere diverse. La rapidità della colonizzazione varia notevolmente tra i vari siti studiati: in alcuni casi gli alberi si insediano rapidamente mentre in altri il loro ingresso avviene dopo due o tre decenni. Queste diverse modalità potrebbero dipendere dalla presenza dei muri che reggono le terrazze i quali sembrano agire come "siti sicuri" nella prima fase di insediamento.

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