

Aspects and Causes of Earlier and Current Spread of *Trachycarpus fortunei* in the Forests of Southern Ticino and Northern Lago Maggiore (Switzerland, Italy)

VINCENT FEHR

Vordersteig 3

8200 Schaffhausen,

Switzerland

vincentfehr@bluewin.ch

AND

CONRADIN A. BURGA

Dept. of Geography

University of Zurich-Irchel

Winterthurerstrasse 190

8057 Zürich, Switzerland

During 2013 and 2014, we investigated the process of the spreading of evergreen broad-leaved (laurophyllous) species in the deciduous forests of southern Ticino (Switzerland) and neighboring northern Lago Maggiore (Italy). The mild climate of this region allows a diversity of exotic plants to thrive outdoors. Most noticeable is the Chinese windmill palm (*Trachycarpus fortunei*), cultivated in almost every private garden and park around the lakes of southern Switzerland. This palm species has been spreading into the nearby forests for decades. Our research deals with several aspects of the spread of *Trachycarpus fortunei* in the investigated region, such as the occurrence within the vertical layer of the forest structure since earlier surveys. The ecological conditions in which this palm species thrives best in the research area are analyzed. In addition, we discuss possible causes that may have contributed to the spread of *Trachycarpus fortunei*, such as the environmental dynamics of the past 40 years as global warming and anthropogenic impacts.

To discuss the spread of the Chinese windmill palm (*Trachycarpus fortunei*), an introduction to the actual vegetation and physical environment of the research area, is appropriate for a better understanding. The

research area is part of the Insubric region, which includes the south alpine Piedmont region of the Alps in Italy and southern Switzerland. In geobotanical terms, Insubric refers to the region between Lake Orta and

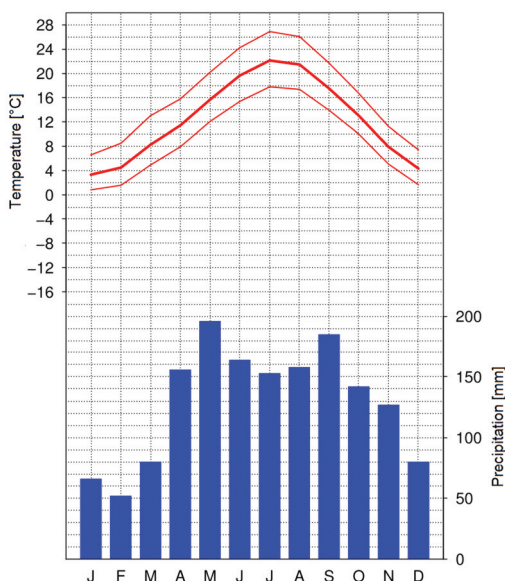
Lake Maggiore below 600 m altitude and is characterized by special climate conditions and vegetation.

Vegetation

The Insubric region can be considered as a transitional zone between the biogeographic region with temperate climate and deciduous, frost-resistant forests and the biogeographic region with warm temperate climate and evergreen broad-leaved (laurel-) forests (Klötzli 1988, Walter & Breckle 1999). The deciduous part of the Insubric forest in the research area consists of oaks (*Quercus petraea*, *Q. pubescens*), linden (*Tilia cordata*, *T. platyphyllos*), field maple (*Acer campestre*), European ash (*Fraxinus excelsior*), (sub-)Mediterranean, thermophilic species such as manna-ash (*Fraxinus ornus*), hop hornbeam (*Ostrya carpinifolia*) and sweet chestnut (*Castanea sativa*, introduced ca. 2000 BC) and alien species like the false acacia (*Robinia pseudoacacia*) (Lüdi 1944, Burga & Perret 1998, Steiger 2010). In comparison with other parts of the world with similar climatic conditions (e.g., southeastern USA, eastern China), only a few evergreen species are native in the Insubric region. These include holly (*Ilex aquifolium*), ivy (*Hedera helix*), spurge laurel (*Daphne laureola*), boxwood (*Buxus sempervirens*) and rarely European yew (*Taxus baccata*). During warm interglacial periods, many other evergreen species were common in the research area (Hantke 1978, 1980, 1983), but glaciation forced them to migrate further south. Many found it impossible to resettle in the Insubric region when the Ice Age ended ca. 10,000 years ago (Burga & Perret 1998).

Since the end of the 1980s, an increasing number of alien evergreen species have been observed spreading into the lower forests of southern Ticino and neighboring Italy (Gianoni et al. 1988, Carraro et al. 1999, Walther 2000, Schildknecht et al. 2008). The majority originate from regions with evergreen (laurel-) forests, occurring, for example, in East Asia and the Colchis (Georgia), and were introduced as ornamental plants from the 17th century onwards (Schröter 1956). This process of spread of foreign, thermophilic, evergreen, broad-leaved (laurophyllous) trees and shrubs is generally called laurophyllization (Gianoni et al. 1988).

The most conspicuous exotic species in the research area is the Chinese windmill palm (*Trachycarpus fortunei*). In 1936, self-seeding of *Trachycarpus fortunei* was noted for the first time in southern Ticino by Schröter (1936).

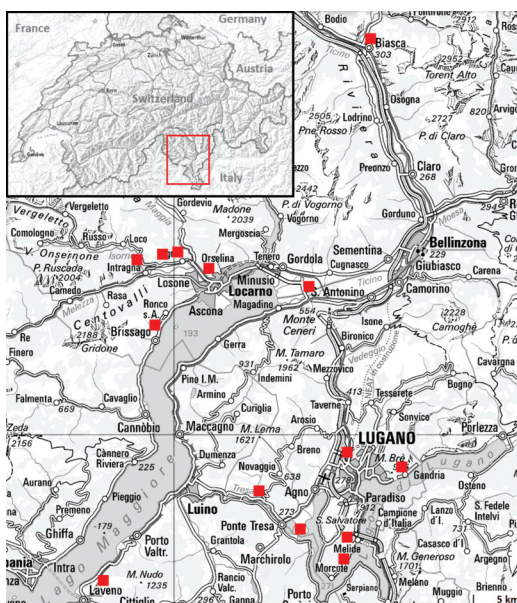


1. Climate diagram of Lugano, 1981–2010. Thick red line: average temperature [°C]; thin red lines: Average max. and min. temperatures [°C]; blue bars: total precipitation [mm]. Source: MeteoSchweiz.

Twenty years later, he reported that the Chinese windmill palm on the Brissago Islands had spread to the same extent as native species (Schröter 1956). In the 1960s and 1970s, the windmill palm established itself in the herb layer (Zuber 1979). In 1988, juvenile palms were found in the shrub layer of forest sites with favorable climatic conditions (Gianoni et al. 1988). From the 1990s, *T. fortunei* was observed advancing into the tree layer in a few areas (Walther 2000, Küttel 2001). The laurel tree (*Laurus nobilis*), the cherry laurel (*Prunus laurocerasus*) and the false camphor tree (*Cinnamomum glanduliferum*) also spread widely. For forest sites, where the laurophyllous species occur strongly, the new forest community of the Insubric laurel forest (*Laurisilva insubrica*) was defined (Carraro 2010). Since August 2014, the Swiss Federal Office for the Environment has listed *Trachycarpus fortunei* as an invasive species with high potential to spread in southern Ticino. It is considered to inhibit rejuvenation of indigenous tree species. *Trachycarpus fortunei* rarely spreads around Lake Geneva (Info Flora 2014).

Climate

The Insubric climate is characterized by mild, dry and sunny winters and high precipitation rates between April and November (Fig. 1). The summers are warm and sunny and



2. Map of the research area. Red squares: sites with vegetation records. Source: Swisstopo, modified.

thunderstorms are frequent, often accompanied by intense rainfall. The Alps shelter the Insubric region from cold surges from the north and east during winter. Additionally, the Insubric lakes have a moderating influence on the night-time temperatures during winter. An average of ca. 2000 annual hours of sunshine is recorded within the region. The average annual rainfall varies between 1500 mm and 1900 mm (Urfer et al. 1979, Aschwanden et al. 1996). An

overview of different temperature parameters at three stations in the research area and one in Zurich on the north side of the Alps is given in Table 1. Unless otherwise stated, the climate data originate from MeteoSchweiz and represent the 30 annual means from 1981–2010.

Research area and methods

In 14 sites in southern Ticino and the northern region around Lago Maggiore in Italy, 46 vegetation records were carried out between October 2013 and May 2014 (Fig. 2, Fehr 2014). The criteria for selection of a site were (1) the occurrence of laurophyllous species, (2) establishment of records along a vertical and/or horizontal transect, and (3) accessible sites. Areas away from the direct influence of the Insubric lakes were examined (Fehr 2014).

The flora of the sites was recorded using a modified Braun-Blanquet scale (Braun-Blanquet 1964). Consequently the coverage of every plant species in each canopy layer was estimated and the plant community of the record was determined. The exact number of individuals of *Trachycarpus fortunei* and laurophyllous species was recorded, and their height was estimated. The pH value of the soil was determined as well as the altitude, the slope and the distance from gardens.

Results and discussion

The Chinese windmill palm (*Trachycarpus fortunei*), the laurel tree (*Laurus nobilis*) and the

Table 1. Overview of different temperature parameters, 1981–2010 and (1961–1990), at three stations in the research area and one in Zurich on the north side of the Alps.

Southern Ticino	Location	Average annual temp. [°C]	Average temp. July [°C]	Average temp. January [°C]	Freezing days [n]	Ice days [n]
Locarno-Monti	Lake proximity	12.4 (11.5)	21.9 (20.7)	3.4 (2.7)	30.1 (35.4)	0.8 (1.5)
Lugano	Lake proximity	12.4 (11.6)	22.1 (21.1)	3.3 (2.6)	27.6 (34.8)	0.7 (0.8)
Magadino	Magadino plain, frost pocket	11.4 (10.5)	21.7 (20.6)	0.9 (0.2)	94.4 (98.7)	1.1 (2)
North side of the Alps						
Zürich/Fluntern	Station of the Swiss Plateau	9.3 (8.5)	18.6 (17.6)	0.3 (-0.5)	74.9 (88.3)	23.7 (25.9)

Source: MeteoSchweiz



3. Seedlings of *Trachycarpus fortunei* in the herb layer.

cherry laurel (*Prunus laurocerasus*) are widespread in the research area. The false camphor tree (*Cinnamomum glanduliferum*), the thorny olive (*Elaeagnus pungens*), the Japanese honeysuckle (*Lonicera japonica*) and the holm oak (*Quercus ilex*) are spreading at some sites. No new or reintroduced species were detected. The laurophyllous species are also spreading at sites away from the lakes.

Vertical distribution of *Trachycarpus fortunei* in the forest layers

To analyze the degree of naturalization of *T. fortunei*, its occurrence in different vertical forest layers on a total of 46 vegetation records

was examined. The results are represented in Table 2. In 14 records *T. fortunei* is absent. In 10 records it was detected only in the herb layer (Fig. 3), with an average coverage of 6.4%. In 10 records *T. fortunei* occurs in the shrub layer (Figs. 4 & 5) and covers about 21.2%. In 12 records the palm was encountered in the tree layer (Fig. 6) with an average coverage of 11.4%.

The spread of *T. fortunei* has advanced very quickly over the last 30 years. During the monitoring period, *Trachycarpus fortunei* has already penetrated into the tree layer, and many individuals are fertile (Fig. 7). It is

Table 2. Occurrence of *Trachycarpus fortunei* in the different vertical forest layers.

Occurrence of <i>T. fortunei</i> in the vegetation records	Number of records	Coverage [%]	Total number of palm individuals detected in 46 records
Absent	14	-	-
Herb layer (< 0.5 m)	10	6.4	> 500
Shrub layer (0.5–4 m)	10	21.2	0.5–2 m: 77; 2–4 m: 52
Tree layer (> 4m)	12	11.4	4–6 m: 17; 6–10 m: 23; >10 m: 5



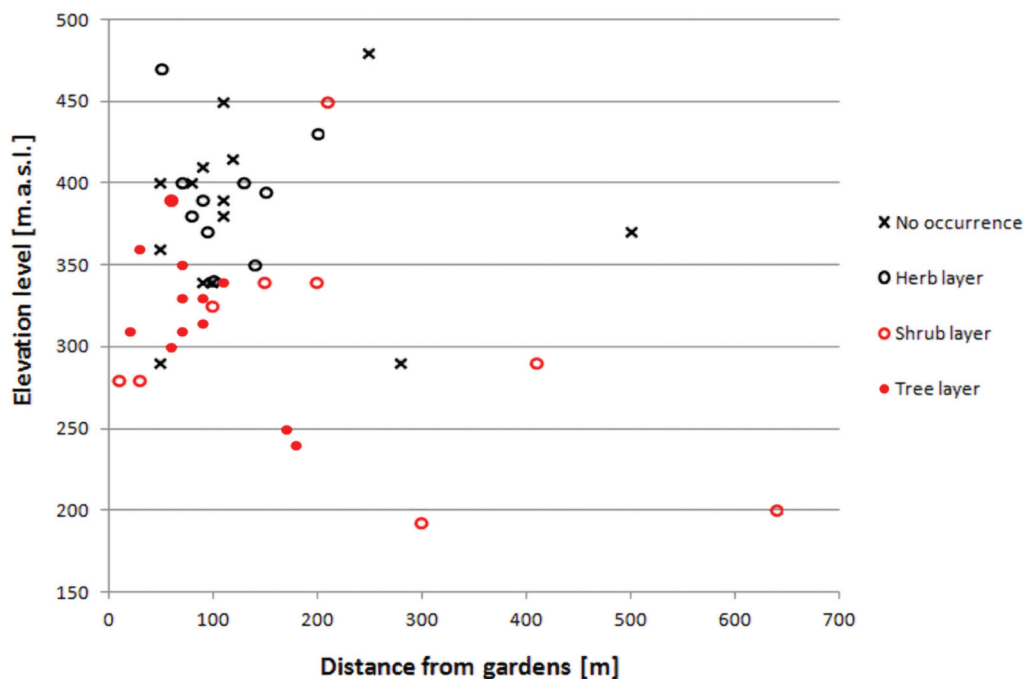
4 (top). Many individuals of *Trachycarpus fortunei* are present in the shrub layer near Manno. 5 (bottom). *Trachycarpus fortunei* dominating the shrub layer on a site on the Monte Caslano.

naturalized in the research area, as the spread no longer depends on cultivated individuals. In earlier surveys (Walther 1995, Küttel 2001),

T. fortunei was found primarily in the herb and shrub layers; only a few individuals penetrated the tree layer (Gianoni et al. 1988).



6 (top). *Trachycarpus fortunei* has penetrated into the tree layer near Melide. 7 (bottom). *Trachycarpus fortunei* fruiting near Caldè (IT).



8. Degree of naturalization of *Trachycarpus fortunei* depending on elevation level and distance from gardens.

Range shift of *Trachycarpus fortunei*

In Fig. 8, the classified vegetation records in relation to the height above sea level and the distance from gardens are represented. The highest density of *Trachycarpus fortunei* can be observed in a belt of about 150 m around settlements and within 390 m.a.s.l. Reasons for this are the favorable climatic conditions and the short distance from the seed source (large quantity of fertile, mature plants in gardens).

Altitude and distance from gardens tend to correlate negatively with each other, meaning that *T. fortunei* is found in high altitudes only near gardens but farther away from them at low altitude sites. With increasing distance and altitude, the prominence of *T. fortunei* decreases. The marginal occurrences are always small groups growing up to an altitude of 470 m.a.s.l. (and sometimes even higher) and at remote sites. The proximity to the seed source seems to have a major influence on the spread. It is assumed that the dispersal of seeds is mainly made by blackbirds (Schröter 1936).

Ecological aspects of the spread of *Trachycarpus fortunei*

Trachycarpus fortunei is usually detected in canyons and streambeds on forest sites (Fig. 9). In such areas, the soil tends to be moist most of the year and therefore germination

conditions are beneficial for the windmill palm. The palm is also able to colonize the wet alluvial forest soil of the Magadino Plain (Fig. 10). In the Centovalli between Ponte

9. *Trachycarpus fortunei* growing near a streambed near Verscio.





10. Juvenile individual of *Trachycarpus fortunei* in the Magadino Plain growing on alluvial forest soil.

Brolla and Verscio, the windmill palm is spreading in full sun on south-facing rocky slopes with shallow soils. It is likely that water lines enable them to thrive on this seemingly unfavorable site, but most of the palms show deficiency symptoms such as small crowns consisting of fewer leaves of which the oldest ones are a yellowish color. No preference for acidic or alkaline soils was observed.

Although *T. fortunei* is very tolerant to shade, such conditions leads to extremely long and thin petioles (> 2.5 m) compared with individuals growing in full sun (Fig. 11).

Deer are the likely cause of damaged leaves. A group of deer was encountered twice during fieldwork grazing exceptionally close to settlements. It is possible that during winter the evergreen leaves of the windmill palm represent an important source of nourishment for them.

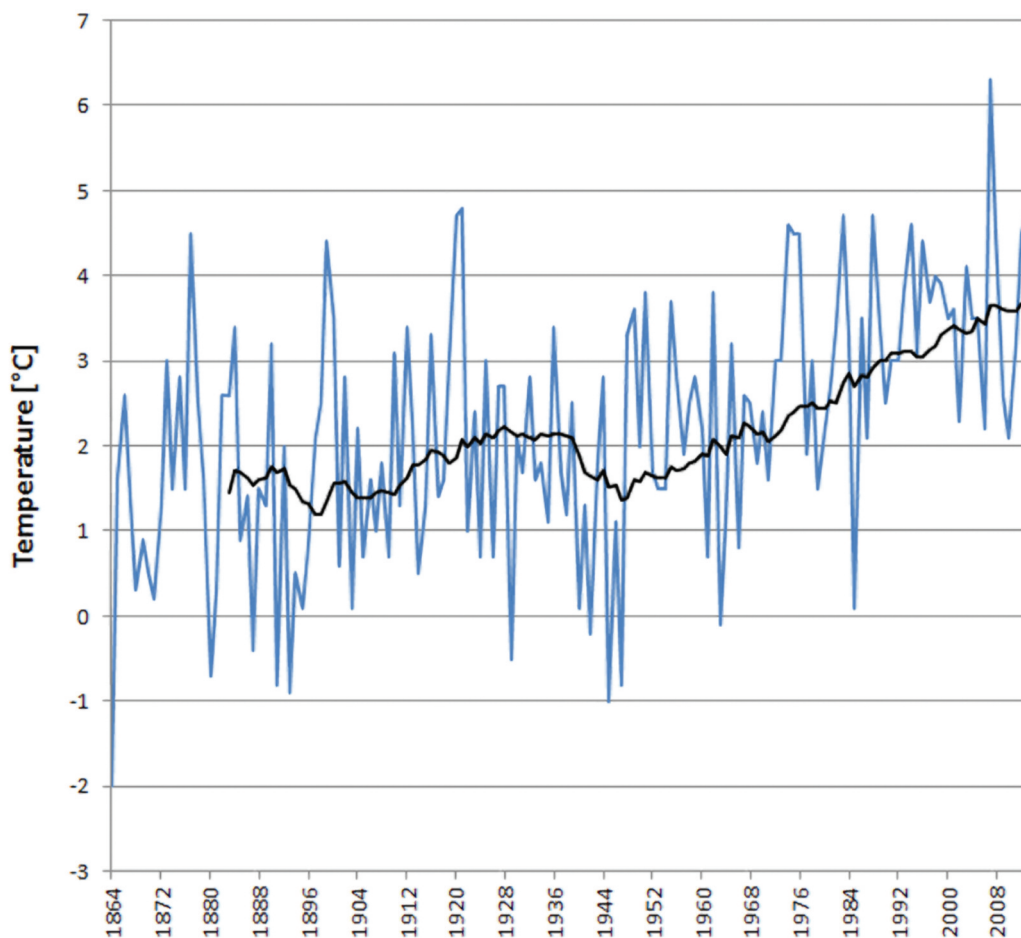
Causes of the spread

The first individuals of *Trachycarpus fortunei* were brought to the Insubric region in the 17th century by the Borromean family and were planted on the Isola Madre (Walther 2000). At the end of the 19th century the Chinese windmill palm was widely cultivated around the Insubrian lakes, but the broad spread of the palm into the forests started much later at the end of the 1980s. Global warming is

commonly considered as the main cause of the spread over the past 40 years (Carraro et al. 1999, Walther 2000). The extent to which the changing climatic conditions of the last

11. Individual of *Trachycarpus fortunei* with very long petioles growing in a shady spot.





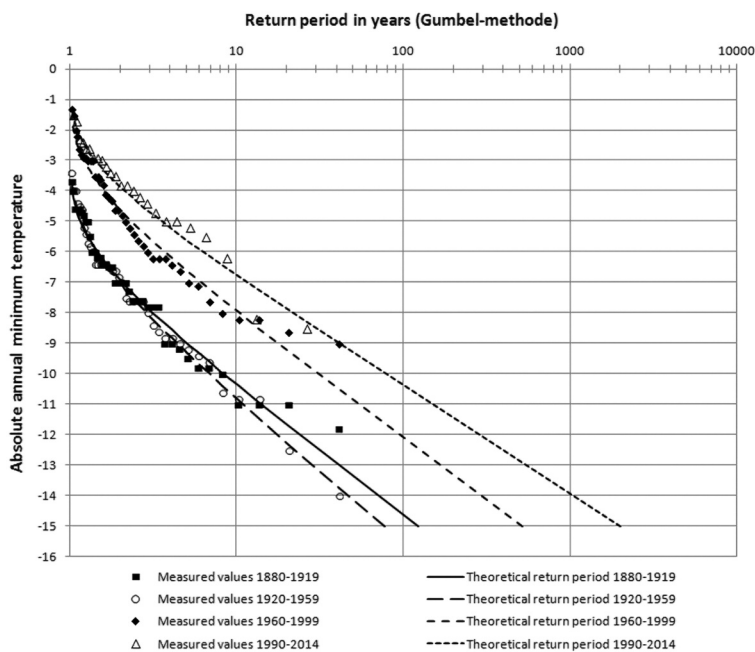
12. Average January temperature (blue line), moving 20-year average (black line), linear trend (black dashes) in Lugano.

decades have contributed to the spread and whether direct anthropogenic factors may have had an influence will be discussed in this section.

From 1864 until 1970, the average temperature of the coldest month (January) in Lugano fluctuated between 1.2°C and 2.2°C; from 1970 it increased fairly constantly to about 3.7°C today (Fig. 12). The number of frost days also decreased: in the period 1865–1960, an average of 65 frost days per year was measured; from 1980 to 2013, only 27 days were counted.

Regarding the average temperature of January, Walther et al. (2007) assumed that a minimum of 2.2°C was required for the spread of *T. fortunei*. This value is based on the climatic conditions on the northern limit of *T. fortunei* in its natural habitat (Walther et al. 2007). In Lugano, this value is reached nearly every year from 1970 onwards, correlating perfectly with the first appearance of *T. fortunei*. However, it

is questionable if the average temperature of the coldest month from the natural habitat in eastern China can be adapted to the research area, since it is not the average temperature that limits the spread of *T. fortunei*, but absolute temperature minimum values. And these minimum values cannot be derived from the average temperature in the natural habitat of the native region and transferred to the special climatic case of southern Ticino and Insubria, which has exceptionally moderate absolute temperature minimums due to the shelter of the Alps. Several juvenile windmill palms spreading in the forest of the Magadino Plain, where the average temperature in January reaches 0.9°C (1981–2010), support this argument. It is also possible that the free ecological niche, which has existed since the last Ice Age ended, allows the establishment of *T. fortunei* under worse conditions than in the natural habitat, where competition with native evergreen plants may be higher.



13. Absolute minimum temperatures of Lugano represented as a function of the theoretical return period of four different time intervals calculated with the Gumbel method.

In Fig. 13, the absolute minimum temperature of Lugano since 1880 is represented as a function of the theoretical return period of four different time intervals calculated with the Gumbel method. This method of probability theory is commonly used in predicting the chance that an extreme natural event will occur. We can see that values of about -10°C occurred every eight years between 1880 and 1959. Between 1960 and 1999, the temperature theoretically reached -10°C every 30 years, but between 1990 and 2014, only every 80 years. The theoretical return period for -15°C between 1880 and 1959 is 100 years; between 1990 and 2014, it is 2000 years. It can therefore be concluded that absolute minimum temperature values have become more moderate during the last decades but have never dropped into the lethal range for *T. fortunei* since measurements started in this area. The absolute minimum temperature measured in Lugano was -14°C in 1929, a temperature that windmill palms normally survive unscathed or with only minor damage. This is demonstrated by several juvenile windmill palms (approx. 1 m in height) growing in the forest close to the weather station of the Magadino Plain, where temperatures in winter 2012 dropped to -16°C . During the field work in summer 2013, all were found unscathed with healthy leaves.

Further evidence underlines that the climatic conditions in proximity to the Insubrian lakes

have always been sufficient for the spread of the windmill palm since records began, such as the cultivation of other plant species since the 19th century that are much more sensitive to cold than *T. fortunei*, like for example *Brahea armata* (blue hesper palm), *Cinnamomum glanduliferum* (false camphor tree), *Eucalyptus globulus* (Tasmanian blue gum), *Jubaea chilensis* (Chilean wine palm) and several *Citrus* species.

If changing climate conditions are not the crucial factor for the spread of *T. fortunei* from the 1980s onwards, what other factors could be the cause?

The spread of alien plant species depends on the propagule pressure (Williamson & Fitter 1996). Since the 1960s, settlement areas have increased continuously on the slopes around the Insubrian lakes of Ticino and Lago Maggiore area (Küttel 2001). Consequently, the number of cultivated, fertile windmill palms growing in gardens has also increased significantly. The fact that *T. fortunei* is spreading most densely near gardens strengthens the argument of increased propagation related to population and settlement growth as a major cause.

Furthermore, management of the forest could have had a major influence on the spread (Zäch 2005). After the Second World War, the reduced use of forests allowed the recovery of the herb layer, and as a result, windmill palm

seedlings were able to establish and grow up to the tree layer.

The evaluation of the direct influence of global warming on the process of laurophyllization is an approximation only, since it is an exceptionally complex issue. One problem is the handling of temperature limit values related to plants, as the cold hardness of a species is also determined by further factors such as humidity, wind and insulation. The most significant difficulty is the separation of natural signals (climatological aspects relating to plant ecology) from anthropogenic impacts.

Conclusions

Trachycarpus fortunei is widespread in the research area. The highest density of individuals was detected at an altitudinal belt 150 m around gardens below 390 m.a.s.l. At further distances from gardens and at higher altitudes, they were found in isolated, scattered groups. In many forest sites, *T. fortunei* has penetrated into the tree layer and many individuals are fertile. In previous surveys, they were mostly found in the herb and shrub layer, with further spreading depending on mature, cultivated individuals. *Trachycarpus fortunei* thrives on moist forest sides, usually along streambeds, and they are also able to colonize wet alluvial soils. They are rarely found on rocky slopes with shallow soils.

Although the spread of *T. fortunei* correlates unmistakably with the significant continuous warming over the last 40 years, these changed climatic conditions may not be considered the key factor for its spread. Absolute minimum temperatures, which are considered to be a limiting factor, were moderate enough before the time of the significant warming to enable its spread. But it is unquestionable that the warmer conditions gave laurophyllous species a competitive advantage over native plant species, allowing them to settle at higher altitudes and consequently accelerating the process of laurophyllization. It is very likely that *T. fortunei* and other evergreen species will continue to spread, and semi-evergreen forest sections will increase strongly in the research area. Very little is yet known about the impact of *T. fortunei* and laurophyllous species on the present ecosystems. Therefore, further research is needed in this field.

Acknowledgments

We thank Prof. Dr. Michael W. I. Schmidt from the Dept. of Geography of the University of Zurich for the great support of the Master

Thesis of Vincent Fehr, on which this paper is based. We would also like to thank Sunna Seithel, Jean-Luc Fehr and Claudio Geyer for their assistance in field work.

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