lack of staff. The Bank of England and many of the clearing banks also remained closed. A vagrant was killed by a falling wall in Lincoln Inn's Fields. In Kennington over 200 people had to be evacuated from a 18-storey block of flats after exterior walls were stripped from the 14th floor by the force of the wind. Parts of St Bartholomew's Hospital, a Grade I listed building, were damaged by falling plane trees. Several shops in Oxford Street were damaged: Selfridge's lost several plate glass windows. Windows were broken at the top of St Paul's Cathedral, causing glass to fall 85 metres to the floor beneath the dome.

A prison ship with about 50 people on board broke free from its moorings at Harwich in **Essex** and drifted helplessly for two hours, almost running aground in the Stour estuary. Troops were called in to help at a mobile home site near Clacton, where 110 caravans had been blown over. Near Chelmsford, 17000 birds were killed or injured when a poultry farm lost its roof during the storm. In **Suffolk** Lowestoft's dock had to be cleared when a vessel carrying explosives began to sink, while Felixstowe was closed for some time after a barge sank at the mouth of the River Orwell, blocking the main shipping channel into the port. All 360 schools in the county were closed; 30 were damaged by falling trees. A man died on the A10 near King's Lynn in **Norfolk** after crashing into an articulated lorry while swerving to avoid a fallen tree. Perhaps the luckiest escape of all occurred in the southern North Sea, some 65 km off the Norfolk coast. A major alert was triggered in the area after the *Smit Lloyd One,* a semi-submersible diving vessel, lost all power and steering and began to endanger oil and gas rigs in the area. The 79 crew and six divers, four undergoing decompression, remained on board as rescue vessels braved mountainous seas to keep the vessel from two rigs: forty crewmen had to be evacuated by helicopter from one. Norfolk coastguards said that "A most terrible accident could have resulted". Finally, on the other side of the country, a motorcyclist was killed when a gust swept him into the central reservation on the M62 at Prescot in **Merseyside.**

And on the Continent . . .

Four people were killed, and at least 15 injured, in France. At Caen, the bell tower of the famous Abbaye des Hommes (built in 1066) was blown down, crushing four cars below. Fire services were called out to attend 5300 emergencies in 18 hours in three areas on the Channel coast. Severe damage was caused to buildings in several parts of Brittany, and a number of sailing boats broke their moorings. A number of ships were reported in trouble but none was lost.

DAMAGE TO TREES AND WOODLANDS IN THE STORM OF 15–16 OCTOBER 1987

By C. P. QUINE

Forestry Commission, Northern Research Station, Roslin

THE storm of 15–16 October 1987 caused widespread damage to woodland and non-woodland trees in the south-east corner of England. Trees of great scientific and aesthetic value were blown over or broken as strong winds crossed an area rich in botanic gardens, stately homes and scientific collections. Damage to trees in collections such as Kew, Wakehurst, Ventnor and Bedgebury was severe. Orchards, particularly in Kent and Essex, were also devastated. Public appeals have been launched by, for example, Kew and the National Trust to assist in repairing the damage, and the Government has introduced special replanting grants for fruit growers.

Large areas of productive woodlands, valued for their timber production and contribution to the landscape, were also seriously affected. Preliminary figures produced by the Forestry Commission and the specially convened Forest Windblow Action Committee, indicate the scale of the destruction as outlined in Table 1. These windblown trees represent a significant proportion of the growing stock in the affected counties (Table 2) and the volume of timber is considerable even in national terms. Approximately 15 million trees are believed to have been blown over during the storm. The volume of coniferous wood involved is equivalent to around 5 months total UK production, while the broadleaved timber represents approximately 2 years UK production.

TABLE 1 Approximate volumes of windthrown timber (in thousands m^3)

	Suffolk	Essex	Kent	East Sussex	West Sussex	Surrey	Hampshire	Other	Total
Woodland conifers	510	10	230	380	350	110	90	230	1910
Woodland broadleaves	200	90	310	360	450	160	110	150	1830
Non-woodland (conifers and broadleaves)	30	10	20	10	30	20	10	40	170
Total	740	110	560	750	830	290	210	420	
Grand total									3910

TABLE 2 Approximate percentage of original standing volume blown down

	Suffolk	Essex	Kent	E. Sussex	W.Sussex	Surrey	Hampshire
Woodland	13	4	18	24	19	6	2
Non-woodland	3	2	4	6	5	3	2

Destruction of woodlands on a lesser though equally dramatic scale has occurred in Britain on three other occasions since 1945. Foresters term these as 'catastrophic' events – a definition dependent upon the coincidence of strong winds and heavily forested areas rather than related to a particular windspeed. Table 3 lists their salient features and Fig. 1 shows their location and representative wind records.

TABLE 3 Summary of catastrophic wind damage to British forests since 1945

Date	Region	Volume (in millions m^3)		
		Conifers	Broadleaves	Total
31 January 1953	North-east Scotland	1.53	0.27	1.80
15 January 1968	Central Scotland	1.53	0.11	1.64
2/3 January 1976	Mid-Wales, Midlands and East Anglia	0.93	0.03	0.96
15/16 October 1987	South-east England	1.93	1.98	3.91

On each occasion the widespread damage was associated with winds gusting in excess of 80 knots, but undoubtedly the duration of the event and frequency of the high gusts had an important role.

The volume of timber thrown in the last storm is considerably greater than that of previous events, and the proportion of broadleaved timber is dramatically different. Although it is tempting to ascribe the latter in particular to the fact that many broadleaved trees were still in leaf, it is important to be aware of the differences in woodland character between the affected regions. The comparison is most readily made between the 1953 and 1987 storms using data from Forestry Commission censuses of woodlands in 1947–49 and 1979–82 (Forestry Commission 1952; Locke 1987). Effects of woodland age distribution are masked by the differences in species composition and by the format of available data. The data on woodland composition in Table 4 has been derived in each case from the four counties most seriously affected – in 1953 these were Aberdeen, Banff, Kincardine and Moray, and in 1987 these were West Sussex, East Sussex, Kent and Suffolk.

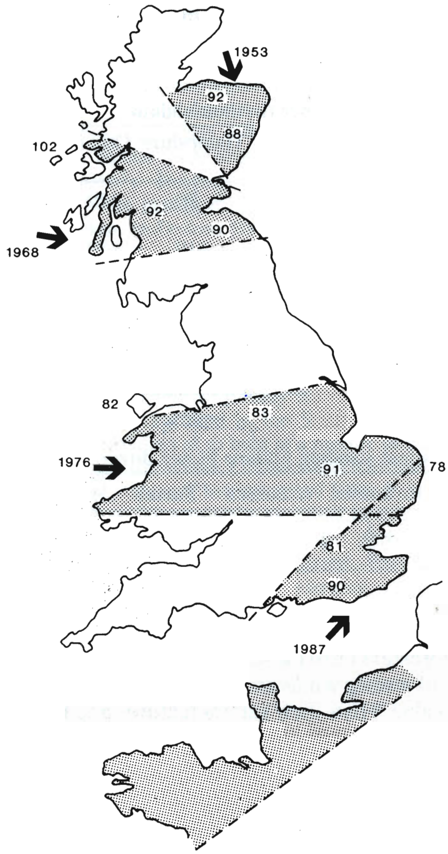

Fig. 1 (left) Regions affected by catastrophic damage to forests since 1945. Representative highest gusts in knots are also shown

Fig. 2 (below) Comparison of conifer: broadleaf proportions in regions affected by 1953 and 1987 storms

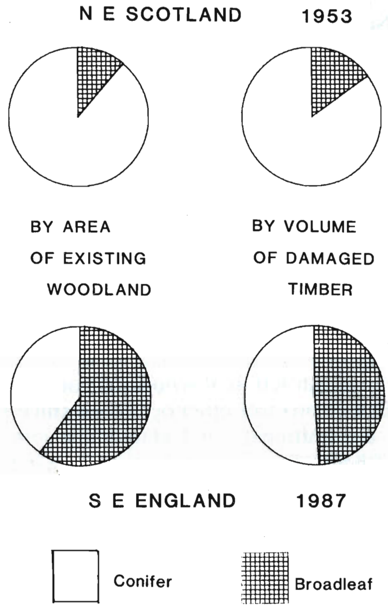

TABLE 4 Comparison of woodlands in regions affected by 1953 and 1987 major storm events (high forest refers to stocked woodlands, but not coppice, scrub or cleared woodland)

		Per cent land area covered by high forest	Per cent area high forest coniferous	Per cent area high forest broadleaved
31 January 1953	North-east Scotland	6.0 (range 4.0–12.2)	89	11
15–16 October 1987	South-east England	8.2 (range 5.5–13.5)	40	60

The proportions of conifers and broadleaves in the unaffected woodland and in the damage estimates is illustrated in Figure 2. It is important to note that the woodland figures are on an area basis, while the damage estimates are on a volume basis. Data for north-east Scotland in 1949 is only available on an area basis. Volume estimates for the four most seriously affected counties in south-east England for 1979–82 give 37 per cent conifers, 63 per cent broadleaved timber, i.e. very similar to the estimate derived by area.

The proportions of damaged timber mirror the differences in composition of the woodland in the two regions. There is no tendency to increased damage to broadleaved trees that appears attributable to their being in leaf.

Woodlands and forests on the Channel and Atlantic coasts of north-west France were also seriously damaged by the October storm. Preliminary estimates (Reure 1987) suggest a volume of 7–8 million m^3 broken or uprooted, but no division is yet available for broadleaved and coniferous timber. The area most seriously affected was a 50 km wide coastal band running from Morbihan to Seine-Maritime (see Fig. 1). Approximately 20 per cent of the whole forest area of Brittany is reported to have been destroyed.

The forests of continental Europe, like Britain, have suffered several catastrophic windthrows since 1945. Notable recent examples include a storm on 6 and 7 November 1982 in the Massif Central region of France which resulted in 12 million m^3 of windthrown trees (Champs *et al.* 1983); and a storm on 24 and 25 November 1981 in Denmark which caused windthrow estimated at 3 million m^3, equivalent to 2–3 years production for the country (Lohmander and Helles 1987). On 17 October 1967, Denmark suffered major forest damage which included a substantial proportion of broadleaved timber (988 000 m^3 conifers, 1 352 000 m^3 broadleaves). This was attributed to serious waterlogging and the trees being in leaf (Jakobsen 1986) although the area affected was rich in broadleaved woodlands.

Considerable research effort was put into seeking relationships between degree of damage and site and crop factors for both the 1953 and 1968 British gales (Lines 1953; Steven 1953; Holtam 1971). Whilst there was a correlation in many instances between damage and tree height (and therefore age) this was never conclusive and relationships with other characteristics such as soil type and topography proved difficult to unravel. After conducting an aerial survey of the 1968 gale area one researcher commented (Neustein 1971) "Most of the damage could be attributed variously to topographic and to assumed soil factors but it would be untrue to say that the logic of the damage pattern was wholly clear from a bird's eye view. It was often impossible to determine why crops in apparently equally susceptible sites had escaped damage other than by attributing this to the vagaries of the wind".

It is too early to draw conclusions on the characteristics of damage to trees and woodlands in the most recent storm but preliminary observations indicate similar difficulties in attempting to rationalise the degree of damage solely on the basis of site and stand factors. Initial damage surveys indicate that conifers are more vulnerable to windthrow than broadleaves, that woodland trees are more vulnerable than isolated trees, and that individual urban trees are more vulnerable than rural trees. The susceptibility of urban trees, which no doubt contributed to the public's impression of the catastrophe, has been attributed to root damage, to funnelling of the wind between buildings, and to their previous lack of wind exposure relative to rural trees. It has also been noted in urban areas how rarely trees fell in the direction of, or struck, the nearest buildings; this may reflect the channelling of the wind around these large structures.

Despite the dramatic impact of these 'catastrophic' events, foresters particularly in upland Britain have regarded 'endemic' wind damage as more important and more costly. Endemic windthrow within forests occurs as a result of the more modest gales that affect upland areas in most winters. Forest research has for many years concentrated upon predicting its occurrence and upon the possibilities of limiting such windblow. A risk assessment guide for managers has been produced, known as the Windthrow Hazard Classification (Booth 1977; Miller 1985), that is based on scorings for soil type, elevation, topographic shelter and regional windiness. In the absence of comprehensive wind data for upland areas the latter was defined using results from a network of tatter flags and by reference to published windspeed maps (Miller *et al.* 1987). Windthrow risk within a calculated hazard class is indicated by the height of trees at which windblow is expected on average to commence. By testing the economic implications of different rates of progression of the damage, managers can then decide at which stage to fell the affected stand.

At present applied research work carried out by the Forestry Commission is attempting to improve estimates of average rates of progression of endemic windthrow for different stand types and is also assessing the stability implications of different ground preparation techniques. More fundamental research work, carried out in conjunction with the Institute of Terrestrial Ecology and the University of Oxford, is studying the detailed aerodynamic interactions between airflow and tree movement. In response to the storm of 15–16 October 1987 specific investigations have been mounted by the Forestry Commission to study factors influencing the stability of roadside, parkland and urban trees and the role of disease and decay in contributing to the damage. The results of these investigations will be published in due course. In addition growers have been given guidance on harvesting and marketing the fallen trees as these aspects can present special problems to the inexperienced owner.

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SOME WIND SPEED AND TEMPERATURE OBSERVATIONS DURING THE STORM OF 15–16 OCTOBER 1987

By R. F. TEMPLEMAN, H. R. OLIVER, M. R. STROUD, M. E. WALKER, T. ALTAY and S. L. PIKE

Institute of Hydrology, Wallingford

THE NERC Institute of Hydrology processes data recorded by a network of *Didcot Instruments* Automatic Weather Stations (Strangeways 1972; Strangeways and Smith 1985). Some of the stations are operated by the Institute in support of its commercial and research activities, others are operated by independent organisations or are loans from the NERC equipment pool and use the Institute's data translation service to obtain data listings. The stations, which are battery powered, log solar radiation, net