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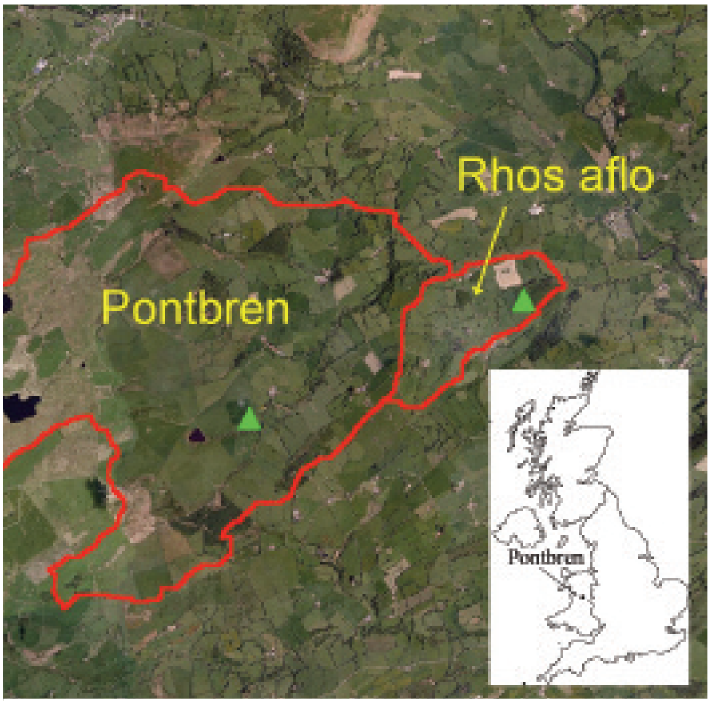
The Robinwood Friartuc report:

Effects of Tree Configuration on rainfall patterns and soil hydrology



Comisiwn Coedwigaeth Cymru
Forestry Commission Wales

PROJECT PART-FINANCED BY THE EUROPEAN UNION
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This report has been produced as a result of the Robinwood Project, a 45 month European Interreg 111c Regional Framework Operation project – a first for Wales and delivered by Forestry Commission Wales on behalf of the Welsh Assembly Government. It looked at how we should manage our trees and forests to provide solutions to hydrological issues, increase the amount of wood used in heat and energy and the key role they play in helping to regenerate rural communities across Europe.

The Italian project leaders named the project after Robin Hood – a deliberate play on the UK folk hero best known for taking from the rich and giving to the poor. Research carried out by the project now provides valuable new information on how forests can provide all kinds of opportunities for the future.

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Section 1 Introduction

Very little is known about how linear woodland features planted as shelter belts on upland hill farms effect the amounts and patterns of rainfall reaching the ground and what the consequences are for soil hydrology. The objective of this project is to provide scientific data to address this issue and to contribute to larger research projects into the effects of land use management and flood risk currently ongoing in Wales. The work will contribute to understanding a key component of the hydrological cycle in upland farm landscapes and in identifying the role trees may have in the prevention of flooding and soil erosion.

A considerable amount of research has been undertaken in the past on the effects of even-aged conifer forest canopies on rainfall interception and transpiration losses (Calder, 1990) but much less information is available for native broadleaf trees in the uplands (EA 1998) although there has been some research on lowland hedgerows (Herbst 2005). New forest management regimes are being proposed for the uplands for which there are few data on the likely effects on rainfall patterns and soil hydrology. In the context of farm woodlands, there is increasing emphasis on developing linear broadleaf woodland features to provide shelter for stock with the added benefit of improving rainfall infiltration into heavy textured soils supporting high levels of grazing (Carroll et al., 2004).

This project will contribute to ongoing research on land use and hydrology already being undertaken at Pontbren, a headwater catchment of the Upper Severn river in mid-Wales, UK. This work is funded by a major UK initiative on flood risk research known as the Flood Risk Management Research Consortium and focuses on soil hydrology and flood runoff generation. The purpose of this project is to fill an important gap in the current research programme in relation to the interception of water from linear woodlands. It will also contribute directly to the main Robinwood measure examining the role that trees may play in the prevention of flooding and soil erosion.

Section 2 Aims and objectives

The project objectives are:-

a) To understand the effects of linear woodland features planted in agricultural landscapes on the interception and distribution of rainfall reaching the soil

b) To measure the effects of rainfall interception by linear woodland features on soil moisture status beneath and adjacent to the trees.

Section 3 Methodology

3.1 Site description

The work is based within two catchments in the Upper reaches of the River Severn, Powys, mid-Wales, UK (Latitude 52.65, Longitude -3.41). The Pontbren catchment is the larger catchment, draining an area of 1800 ha, the second catchment is the adjacent and smaller ‘Rhos aflo’ catchment (400 ha). The land in this area is situated between 130 m and 425 m a.s.l. and although these are not necessarily ‘upland catchments’ in a global context, this is considered an upland region in terms of UK agriculture (Marshall et al., 2007). Site topography is undulating and the area experiences a typically maritime climate, with prevailing south westerly winds from the Atlantic Ocean. Maritime climates generally are fairly humid, accompanied by considerable amounts of precipitation, since the main moisture source is not very far away. This is characterised at Pontbren by a long-term annual average precipitation of approximately 1230 mm (Institute of Hydrology, 1999). The dominant soils at Pontbren are the Cegin association, consisting mainly of cambic stagnogleys with stagnogleyic brown earths on steeper slopes and cambic stagnohumic gleys (Wilcocks association) at higher altitudes. Both Cegin and Wilcocks series are widespread in Wales on glacial drift derived from Ordovician and Silurian sediments. The Pontbren catchment is believed to be underlain by Silurian greywackes, which may explain the noticeable sand content of some of the soils, and the frequent stones and boulders composed of coarse sandstone and grit (Bird et al., 2003).

Figure 3.1 gives an aerial photograph of the study site, showing the catchment boundaries and locations of the tree planted areas; Figure 3.2 shows the soils map of the area. Fieldwork for the main part of this study started in February 2006 and is anticipated to finish in February 2008. It focuses upon three tree planted areas. In all tree planted areas, the same measurements were taken in order to determine rainfall interception and the throughfall 'shadow' effect. Details of the individual experiments follow.

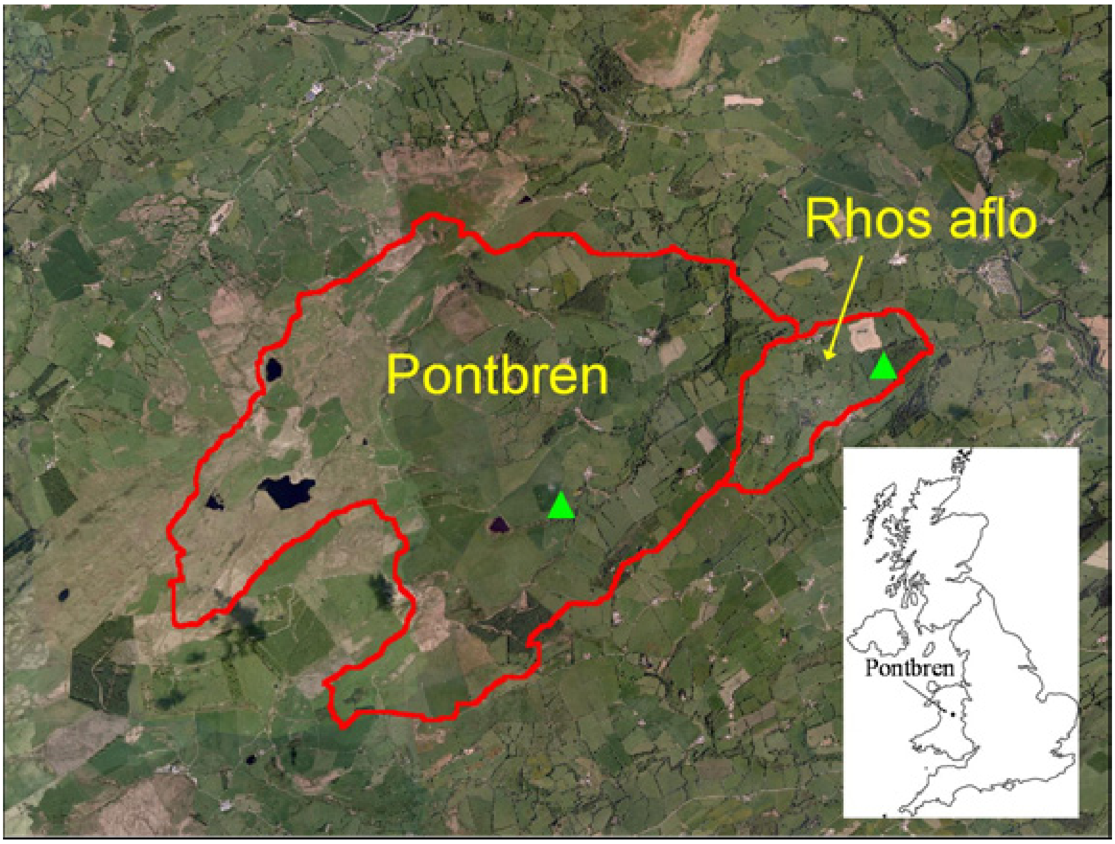

Figure 3.1. Aerial photograph of the study site and (inset) it's location within the UK. Catchment boundaries are in red. Green triangles depict the locations of the tree planted areas, being Cae Drains; Pant Powsi and Half Moon at Tyn y Bryn farm, within the larger Pontbren catchment; and Tyn y Fron trees within the smaller Rhos aflo catchment

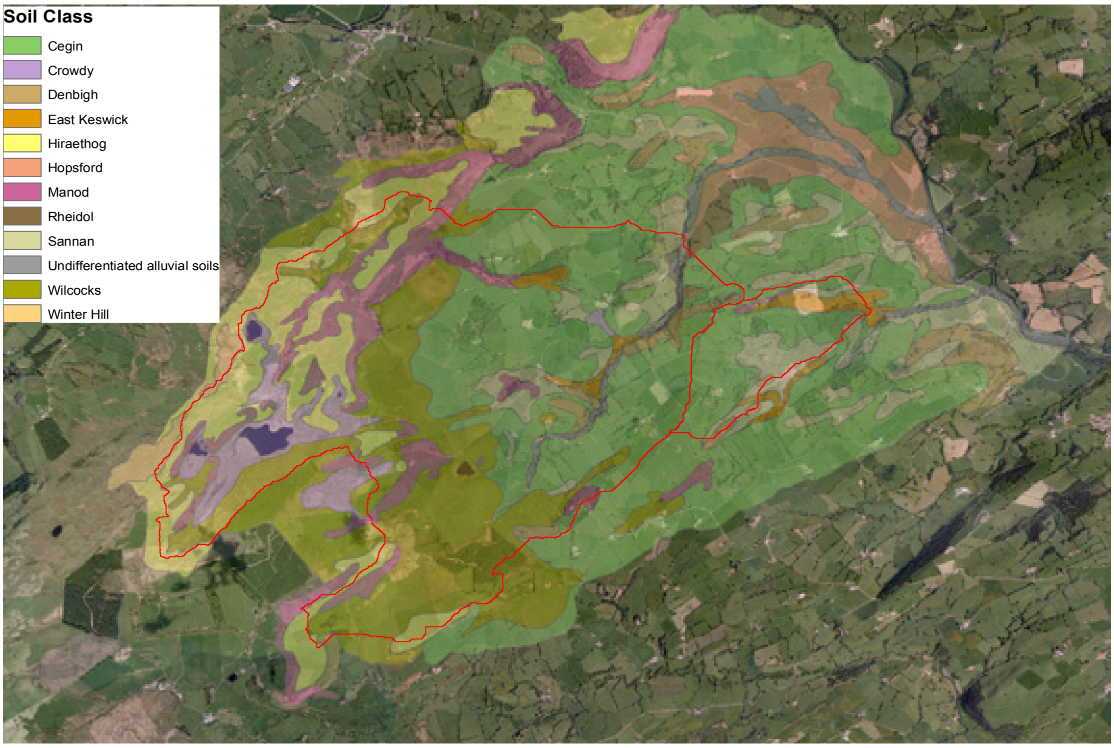

Figure 3.2. Soils map of the Pontbren and Rhos aflo catchments. Catchment boundaries in red.

3.2 Rainfall interception and the throughfall shadow effect

3.2.1 Introduction

Observed differences in soil moisture content between the tree planted areas and the pasture at Pontbren, may be attributed to either differences in soil structure (allowing more rapid infiltration and drainage) and /or differences in the amount of rainfall that is reaching the ground. If interception loss (with resulting direct evaporation from the canopy) is playing a large part in influencing the hydrology in the tree planted area, there will be marked seasonality in the difference in soil moisture content, with the former being much drier in the summer when there is maximum canopy coverage. Measurement of throughfall and stemflow will quantify the interception loss from the tree canopy whilst field measurements of soil water content (Neutron probe) and soil moisture tension will describe the soil response.

In the case of both rainfall interception and transpiration, the current thinking is that a hedgerow, or tree shelter belt (TSB), is not a unit in isolation but a wider area which takes into account the influence on the land immediately adjacent (around 3-5 unit heights) on either side (Herbst et al., 2006). In their study of interception loss by hedgerows, Herbst et al. (2006) showed that, depending on wind speed and direction, rainfall intensity and orientation of the hedgerow with respect to the prevailing wind, there can be a significant throughfall 'shadow' because of the hedgerow presence. In the case of transpiration, some of the losses from the hedgerow might be offset by reduced losses from the crops/pasture immediately adjacent.

To define soil water losses due to transpiration, a transect of soil moisture measurements from one side of the hedgerow to the other can be used (pers. comm. John Roberts, CEH Wallingford). Changes in soil moisture content can then be used to help determine the total effect of the shelterbelt i.e. trees plus grass, evaporation / transpiration on soil hydrology.

3.2.2 Experimental design

The experimental design for the throughfall and soil moisture transects had to take into consideration:

- orientation of the tree shelter belts with respect to prevailing wind
- tree height
- length of transect for soil moisture and throughfall / rainfall measurements
- the area affected by the throughfall shadow

Collectors, therefore, were placed both inside and outside of the tree shelterbelts.

Of the three main tree shelterbelts (TSB's) within this study, two are located at Tyn y Bryn farm, within the Pontbren catchment (namely Cae Drains and Pant Powsi – see Figure 3.1). These stands run in a west-east, down-slope direction, lining the two edges of a representative tree planted hillslope of approximately 300 m in length (eastern aspect; average slope of 8%) that has been instrumented to investigate the effects of soil structure, trees and under-drainage on hillslope scale flood response (Marshall et al. 2007). Figure 3.3 gives an aerial photograph of the tree planted hillslope showing the main instrumentation and location of Cae Drains and Pant Powsi. Their predominant tree species are *Betula pendula* L. (silver birch) and *Betula pubescens* L. (downy birch) with some other species planted within. At both of these sites, the 'throughfall shadow' effect is being investigated by measuring rainfall along transects of rainfall collectors. These are positioned in the adjacent pasture perpendicular to the tree planted area, on both the windward and leeward side. This will enable the horizontal extension of the zone which is being influenced by the presence of the TSB to be determined. The remaining TSB is situated within the Rhos aflo catchment, at Tyn y Fron farm (Figure 3.1) on the windward edge of a mature forest stand (although this is not technically a tree shelterbelt, for ease of reference, this forest edge will be referred to as such within this report). Here, the area of instrumentation was selected to consist mainly of birch trees, in order to be of a similar composition to Cae Drains and Pant Powsi. At this site, rainfall is measured along transects within the adjacent pasture on the main windward side. At all three sites rain throughfall is measured as well as stemflow from a number of trees within the tree planted areas.

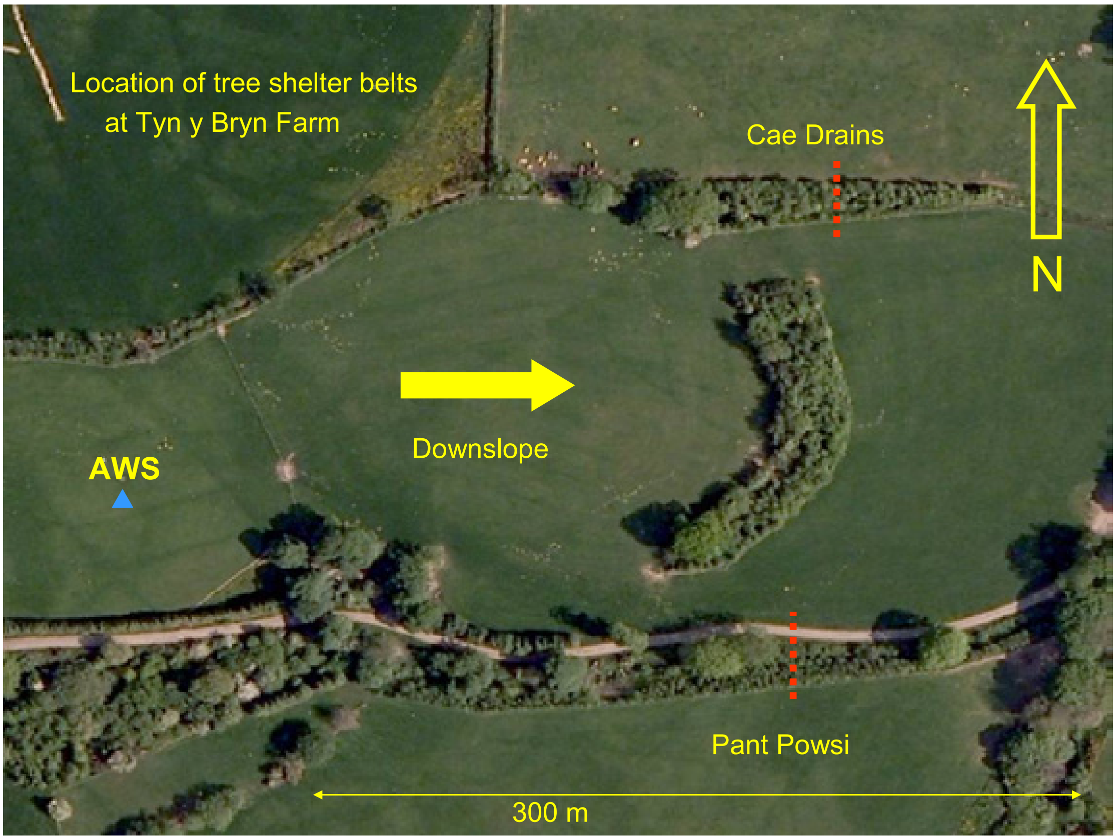

Figure 3.3. Aerial photograph of the tree planted hillslope at Tyn y Bryn farm, showing the main instrumentation for this study; AWS – automatic weather station and it's associated rain gauge (blue triangle); dotted lines show siting of instrument transects.

Transects of neutron probe access tubes allow soil moisture measurements to be taken to a depth of 120 cm (further details can be found in Section 3.2.3.4). A nest of three tensiometers installed at each site provides continuous measures of soil water potential, Ψ (cm H_2O) at 10 cm, 30 cm and 50 cm depth. Throughfall, stemflow and overland flow are also measured within the tree planted hillslope, where the tree planted shelter belt runs in a north-south direction. Table 3.1 provides details of the instrumentation of the TSB's; Figure 3.4 shows an example layout of the instrumentation.

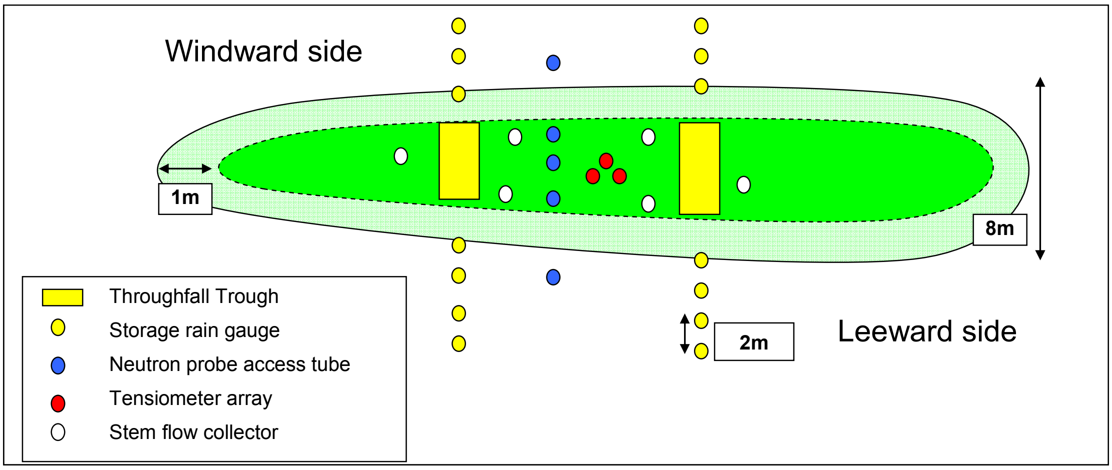

Figure 3.4. Example layout of the instrumentation in the tree shelter belts

Location	Instrumentation / experiment	No.	Purpose	Sampling time	Relative hypothesis
Tyn y Bryn Farm – Cae Drains tree planted area	Storage Rain gauge	14	Rainfall (mm)	Bi-weekly	H1
	Throughfall collector	2	Throughfall (mm)	10 minute	H1
	Stemflow collector	6	Stemflow (mm)	Bi-weekly	H1
	Tensiometer nest (10, 30, and 50 cm depth)	1	Soil pore water pressure (cm H_2O)	10 minute	H1; H2
	Neutron probe access tube (measuring depth 120 cm)	5	Soil moisture content (cm^3cm^{-3})	Bi-weekly	H1; H2
Tyn y Bryn Farm – Pant Powsi tree planted area	Storage Rain gauge	14	Rainfall (mm)	Bi-weekly	H1
	Throughfall collector	2	Throughfall (mm)	10 minute and bi-weekly	H1
	Stemflow collector	6	Stemflow (mm)	Bi-weekly	
	Tensiometer nest (10, 30, and 50 cm depth)	3	Soil pore water pressure (cm H_2O)	10 minute	H1; H2
	Neutron probe access tube (measuring depth 120 cm)	7	Soil moisture content (cm^3cm^{-3})	Bi-weekly	H1; H2
Tyn y Bryn Farm Instrumented Hillslope – Tree Planted Hillslope – Half moon	Throughfall collector	2	Throughfall (mm)	Bi-weekly	H1
	Stemflow collector	6	Stemflow (mm)	Bi-weekly	
	Neutron probe access tube (measuring depth 120 cm)	3	Soil moisture content (cm^3cm^{-3})	Bi-weekly	H1; H2
Tyn y Fron Farm – tree planted area	Storage rain gauge	9	Rainfall (mm)	Bi-weekly	H1
	Throughfall collector	2	Throughfall (mm)	10 minute	H1
	Tensiometer nest (10, 30, and 50 cm depth)	1	Soil pore water pressure (cm H_2O)	10 minute	H1; H2
	Neutron probe access tube (measuring depth 120 cm)	4	Soil moisture content (cm^3cm^{-3})	Bi-weekly	H1; H2
Tyn y Bryn Farm - Hilltop	Storage Rain gauge	1	Rainfall (mm)	Bi-weekly	H1
Rhosaflo farm – manipulation plots	Storage Rain gauge	1	Rainfall (mm)	Bi-weekly	H1
Laboratory	Tension table apparatus	4	Construction of soil moisture characteristic curves	On-going	H2
Laboratory	Pressure plate apparatus	2	Construction of soil moisture characteristic curves	On-going	H2

Table 3.1. List of instrumentation at the Pontbren site related to this study

3.2.3 Methods

3.2.3.1 Meteorological data

An automatic weather station (AWS) has been installed at Tyn y Bryn farm. This is situated approximately 200m upslope of the Cae Drains and Pant Powsi TSB's (Figure 3.3). The AWS is comprised of sensors measuring incoming solar radiation, net radiation, air and soil temperature, relative humidity, wind speed and wind direction. All data are recorded as 10 minute averages onto a solar powered CR10 data logger (Campbell Scientific Ltd, Shepshed, UK). A tipping bucket raingauge with a resolution of 0.2 mm per tip has been installed close to the AWS and data from this is recorded at 10 minute resolution onto a micro-datalogger ('Tinytag', Gemini Data Loggers Ltd, Chichester, UK).

Using gross rainfall measurements and horizontal windspeed, the rainfall inclination angle (in degrees from vertical) was calculated, for all 10 minute intervals with precipitation. This was determined using the formulae given by David et al. (2006):-

First, average raindrop diameter ϕ (mm) was calculated from rainfall intensity i (mm hr^{-1}):

$$\phi = 2.23(0.03937i)^{0.182} \qquad (1)$$

Second, the terminal fall velocity of raindrops u_r ms^{-1} was computed from the mean droplet size ϕ:

$$u_r = 3.378(\ln\phi) + 4.213 \qquad (2)$$

Finally, the rainfall inclination angle α was calculated using:

$$\tan\alpha = \frac{u_w}{u_r} \qquad (3)$$

where u_w ms^{-1} is the wind velocity.

Average inclination angle for a storm event was calculated as the weighted mean of the 10 minute values, with the ‘weights’ being the amounts of rainfall in each time step.

3.2.3.2 Net rainfall

A mixture of 14 simple storage raingauges, with a funnel diameter of 152.4 mm (6”) and two 130 mm wide plastic guttering rainfall collectors, attached to tipping bucket gauges, were used to examine the net rainfall both inside and outside each of the tree shelter belts (TSB’s). Following the method of Herbst et al. (2006), the manual gauges were arranged to cover the complete area of influence of the trees outside of the TSB’s. On the windward side of the TSB’s, two transects of three collectors; and on the leeward side, two transects of four collectors were placed in a row pointing orthogonally away from the TSB (Figure 3.4). Figure 3.5 gives a photograph of the rain gauges.

Figure 3.5 Photograph of throughfall shadow rain gauges at Pant Powsi, Tyn y Bryn farm.

Due to the presence of sheep in the adjoining pasture, the simple storage raingauges had to be modified so that they were raised to a height of about 90 cm (3’) a.g.l., in order to be above the level of any interference. All manual gauges were emptied bi-weekly, as weekly measurements were not logistically possible.

The trough style collectors were of sufficient length to span the width of the TSB when placed orthogonally within it. This should allow the measurements to encompass any spatial variability below the canopy (Herbst et al., 2006; David et al., 2006). The calibration factors of the tipping buckets ranged between 0.14 and 0.22 mm per tip and the data were recorded onto ‘Tinytag’ data loggers (Gemini Data Loggers Ltd, Chichester, UK) at 10 minute intervals.

Figure 3.6 Photograph of trough style throughfall collectors within the tree shelter belts showing tipping bucket gauge (foreground, left-hand side).

3.2.3.3 Stemflow

Outline description of the stemflow collectors

After several field trials, a modification of the stemflow collector by Reynolds and Stevens (1987) was used. Here, water trickling down the tree stem was intercepted by a spiral of flexible PVC rubber tubing sealed to the surface of the bark. Water then runs down the channel formed between the bark and the tubing until entering the bore of the tubing via a slot cut through its upper surface. Water finally flows through a simple filter device before entering a tipping-bucket gauge in order to calculate the volume of stemflow (Reynolds and Stevens, 1987).

Installation of the stemflow collectors

The collectors were installed at a height just below the lowest branch. This is lower then that suggested by Reynolds and Stevens (1987), but due to small height of the trees (due to the age) this was deemed more appropriate.

The stemflow collector consists of a length of clear plastic tubing made from silicone rubber (on the smaller trees) or PVC rubber (on the larger trees), wrapped in a single spiral around the stem of the tree, such that the entire tree circumference is encircled by the spiral (see Figure 3.7). The spiral was attached to the tree by threading a piece of fishing line through the tubing so that both top and bottom of the helix could be fastened to the tree. This method meant that the force of the line inside the tubing would hold the whole of the spiral against the tree without it slipping away from its position. However, the fishing line began to damage the bark of the smaller trees once the growing season began and the stems began to swell. Consequently, the fishing line was removed and the top and bottom of the spirals attached to the stems with Duck©Brand tape.

The junction between the tubing and the bark of the tree was sealed with exterior grade silicone sealant (Unibond UPVC & Wood Exterior Frame Sealant 473019, B&Q Stores, UK) extruded using a cartridge gun with a fine nozzle. A hole was cut through the upper wall of the tubing to allow water to trickle down the spiral and enter the bore of the tubing and then the collection vessel. A continuous wall (~20 mm high) was constructed along the upper surface of the spiral by layering successive beads of sealant on top of the tubing, so forming a channel between it and the stem, within which the water can flow. This was then sealed at the bottom against the stem of the tree, to form a watertight barrier.

Figure 3.7. Stemflow collector attached to a silver birch

Blockages have occurred due to slugs residing in the stemflow spiral channel and/or the bore of the tubing. Slug and snail barrier gel (Westland Slug Blocker, B&Q stores, UK) was applied in an unbroken ring around the stem of the trees, above and below the stemflow spirals in an attempt to repel the slugs

The collection vessels consist of 10L containers (attached to a 10L vessel overflow container) where stemflow volumes are recorded every two weeks.

Sampling strategy

Stemflow volume is often very variable both temporally and between individual trees and the exact sampling requirement will be determined by the age and heterogeneity of the woodland (Reynolds and Stevens, 1987). As yet, there is no standard guideline to the number of collectors which are required to obtain a representative sample of stemflow. However, the trees in the experimental sites are even-aged, and therefore less heterogeneous than natural woodland, so we can assume they will require fewer collectors. Accordingly, six stemflow spirals have been randomly installed around the trees to obtain an average value of stemflow.

3.2.3.4 Soil water measurements

Soil moisture content

Neutron probe measurement of soil moisture content

Transects of neutron probe access tubes across the tree planted area and in the adjacent pasture allow changes in profile soil moisture content, θ (cm3cm^{-3}), to be measured to a depth of 120 cm. Measurements are taken bi-weekly at 10 cm depth intervals. An in depth report on neutron probe practice can be found in Bell (1987). A brief description follows:

Background theory

Soil moisture content is defined on a volumetric basis as volumetric water content (θ) *i.e.*:

$$\theta = \frac{\text{Volume of water}}{\text{Volume of wet soil}}$$

The neutron probe device is commonly used during field experimentation when rapid, non-destructive measurements of volumetric water content (θ) are required. The machine operates by emitting fast neutrons from an Am/Be source lowered down a hollow sealed aluminium access tube. Fast neutrons released into the surrounding soil at the measurement depth are thermalised (i.e. slowed down) by hydrogen nuclei present within the sphere of influence of the neutron cloud (typically 15-30 cm radius). The intensity of the slow neutrons is then measured as a count rate over a standard time interval (16 or 64 seconds) by a slow neutron BF3 counter situated immediately adjacent to the original fast neutron source. The primary source of hydrogen nuclei in soils is water molecules, enabling a linear relationship to be derived between count rates and volumetric water content for a given soil texture (Bell, 1987).

Neutron probe calibration

For the duration of the fieldwork programme, the neutron probe counts, undertaken over 16 second intervals, were converted into volumetric water contents using the generic clay soil calibration proposed by Bell (1987):

$$\theta = 0.958\ R/R_w - 0.012$$

where θ is volumetric water content, R is the count rate (per second) for the soil sampled at that depth, and R_w is the corresponding count rate in water. Since the counts per second (R) are relative to 100 % soil moisture content (R_w), the neutron probe was calibrated each time it was used in the field. For this, a large aluminium dustbin was filled with de-ionised water with an aluminium access tube secured vertically in the middle. A standard multiple reading technique was employed where five readings over sixty-four seconds were averaged to form a mean value for R_w.

Neutron probe measurement technique

Aluminium access tubes have been inserted into the soil at selected locations in the experimental site.

For all measurements, an Institute of Hydrology (IH) neutron probe was used. The probe was positioned over an aluminium access tube protruding 10 cm a.g.l.. The source and detector were then lowered into the ground to a specific depth. Readings were taken over a 16 second time period at 10 cm depth intervals, to a depth of 120 cm.

Soil water potential

A nest of three tensiometers installed at each site provides continuous measures of soil water potential, Ψ (cm H_2O) at 10 cm, 30 cm and 50 cm depth.

Section 4 Results

4.1 Introduction

In this section, a selection of fieldwork results from the Pontbren experimental site, described in Section 3, are presented and discussed. Results from the throughfall shadow transects show that the extent of the shadow area is not only dependent upon the physical properties of the tree shelter belt, but that it is governed by three meteorological conditions: 1) rainfall intensity; 2) wind speed and 3) wind direction, and that the effects of these variables differ between the seasons.

4.2 Meteorological conditions during rainfall

The rainfall pattern at the research site differed between the seasons. A much wider range of rainfall intensities were observed during the summer months, but the majority of the rainfall (68%) fell at rates of 6mm hr-1 and below. Just over 8% of the rain in the summer fell at rates greater than 22 mm hr-1. Rates as high as this did occur in the winter, but this only constituted 1% of the total rainfall. In comparison to the wide range of summer rainfall intensities, 96% of winter rainfall was at intensities of 6mm hr-1 and below Figure 4.2a.

The difference in windspeed during rainfall events between the seasons was even greater. Rainfall events with low windspeeds of up to 2ms-1 accounted for half of the rainfall amount recorded in the summer, but for just 10% in winter. Typical windspeeds during rainfall events in winter ranged from 4 to 8ms-1 and almost 20% of rainfall in winter was accompanied by windspeeds exceeding 8ms-1, speeds which didn’t occur in the summer where the highest windspeed recorded was in the group 4 to 5ms-1 (Figure 4.2b). Together the seasonal differences in rainfall intensity and windspeed caused even larger differences in the rainfall inclination angle between summer and winter. Almost all of the summer rain fell at angles below 30˚ compared to almost all of the winter rain falling at angles greater than 30˚ (Figure 4.2c). This shows that wind-driven rainfall plays a much larger role in controlling the interception loss in the winter than in the summer. Most of the winter rain fell when the wind came from the west-south-west, whereas, most of the summer rain fell when the wind came from between the east and north-east sector (Figure 4.2d). Anecdotal evidence from the farmers suggests that the rainfall this summer, coming under an easterly wind, is a-typical. Figure 2 could also suggest this showing that, in summer '06, most of the rain fell when the wind came from between the west and south-west sector. More data would be required to confirm this. However, this anomaly was attributed to a shift in the jet stream, and has been given as the reason for the unprecedented rain and flooding that has been experienced this summer in the UK (http://news.bbc.co.uk/1/hi/uk/6918123.stm).

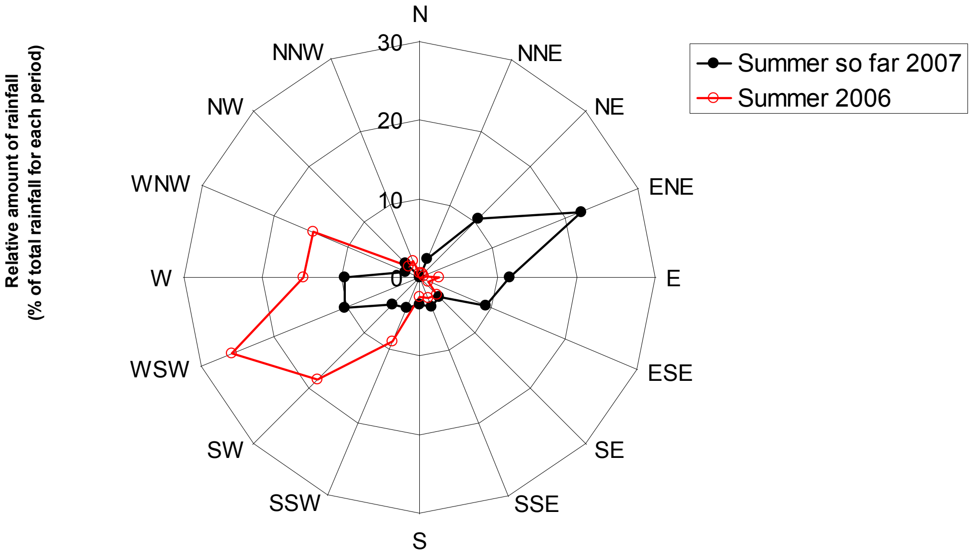

Figure 4.1 Hodograph to show wind direction during rainfall for summer 2006 and summer 2007.

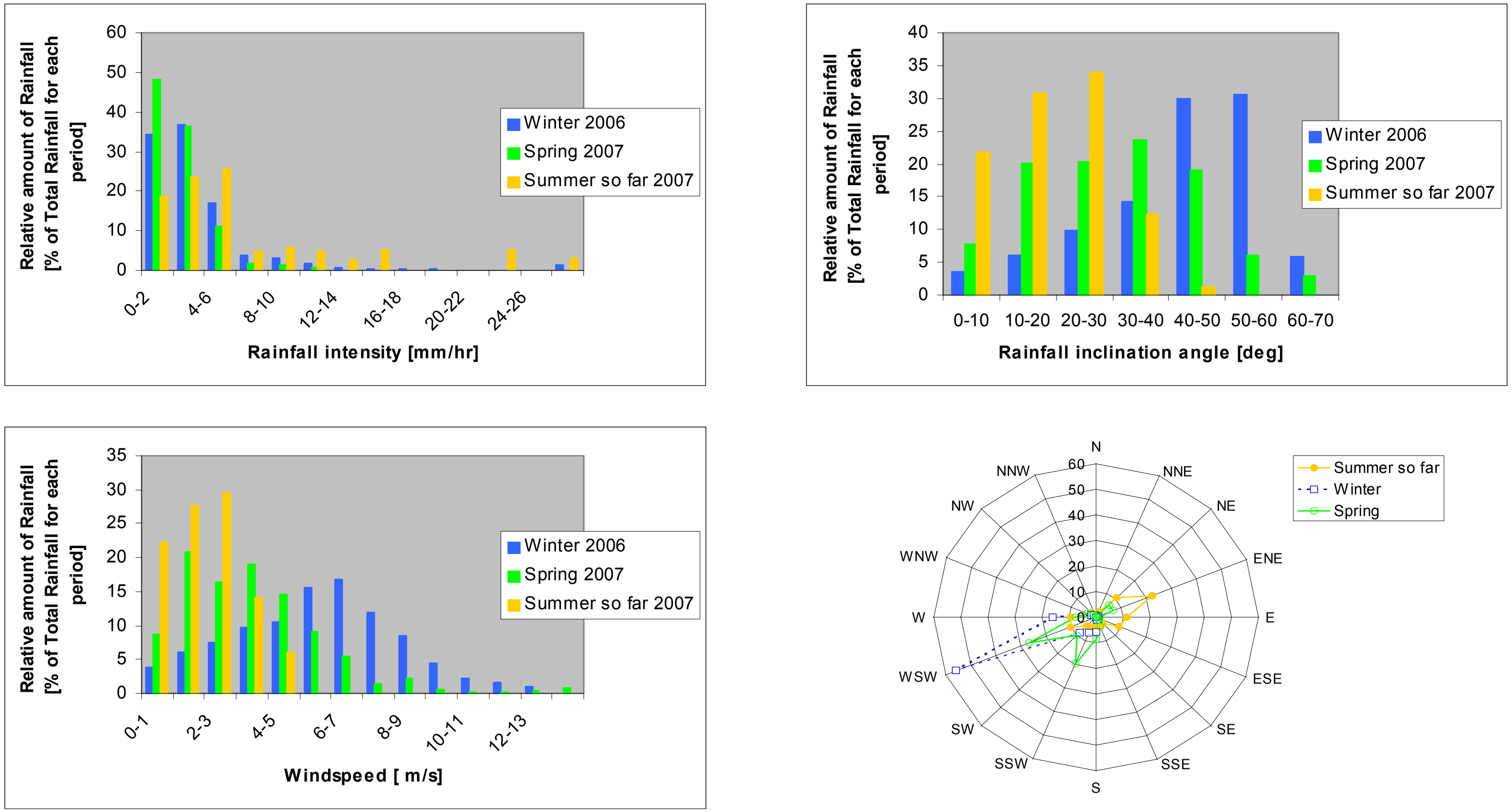

Figure 4.2 (a-d) Meteorological conditions during rainfall at the research site 2006/07. 'Winter' refers to the months December to February, 'spring' March to May and 'summer so far' June only.

4.3 Spatial variability of net rainfall outside the tree shelter belts

The collection of rainfall along transects outside the tree shelter belts revealed a high spatial variability across the ground areas covered by them in winter. Figure 3a shows that, during winter, the area where throughfall was influenced by the presence of the TSB was not restricted to the canopy surface area, but spanned over a width of at least 6m from its edge on the leeward side. However, there seems to be little or no spatial variability during the summer (Figure 4.3). This can be explained by the lower windspeeds and higher rainfall intensities, that were recorded in the summer, leading to smaller rainfall inclination angles, hence the area of rainfall depletion being greatly reduced. This idea is illustrated in Figure 4.4. It is therefore important to include the whole area that is covered by the TSB in any measurements, and models of throughfall.

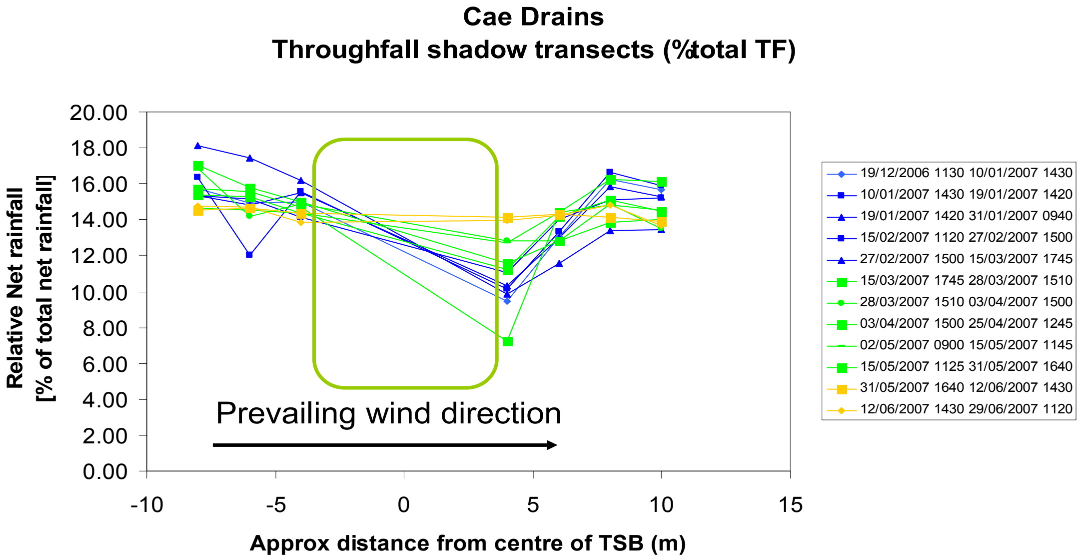

Figure 4.3 Spatial distribution of throughfall in two transects either side of the tree shelter belt. Green square indicates position of tree shelter belt. Tree height here is between 6 and 8 metres.

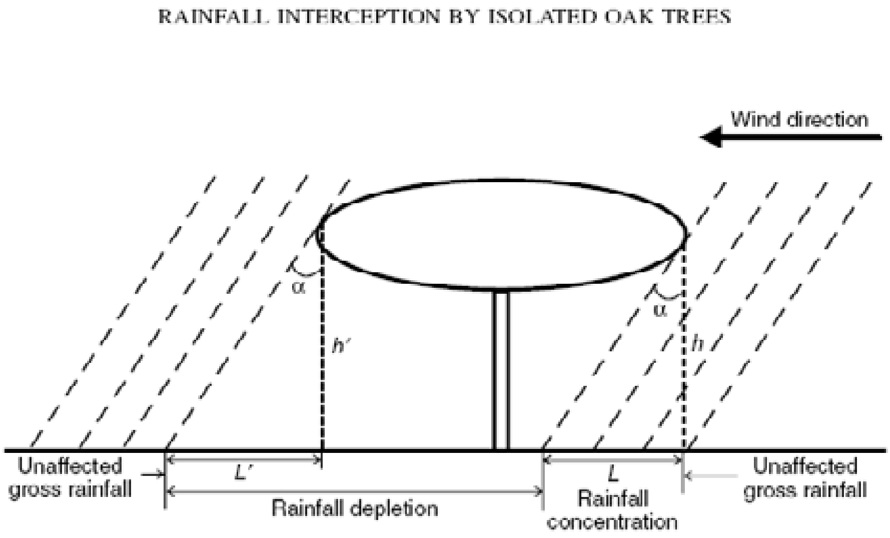

Figure 4.4 Illustration of rainfall inclination angle (α) and area of rainfall depletion. *Source* David et al., 2006. Please note that wind direction in this illustration is reversed i.e. prevailing winds at the site are from the opposite direction.

4.4 Spatial variability of soil moisture outside the tree shelter belts

As with net rainfall, the soil moisture measurements show spatial variability across the ground areas covered by the TSB's (). At depths below 30cm, the lowest moisture contents are recorded near the typical leeward side of the TSB. Soil moisture content at each depth increases with increasing distance from the fence. At depths of 30cm and above, the pattern is reversed. The former can be attributed to the spatial variability in net rainfall, the latter to the different evaporative conditions with distance from the TSB, namely differences in turbulence and incident solar radiation.

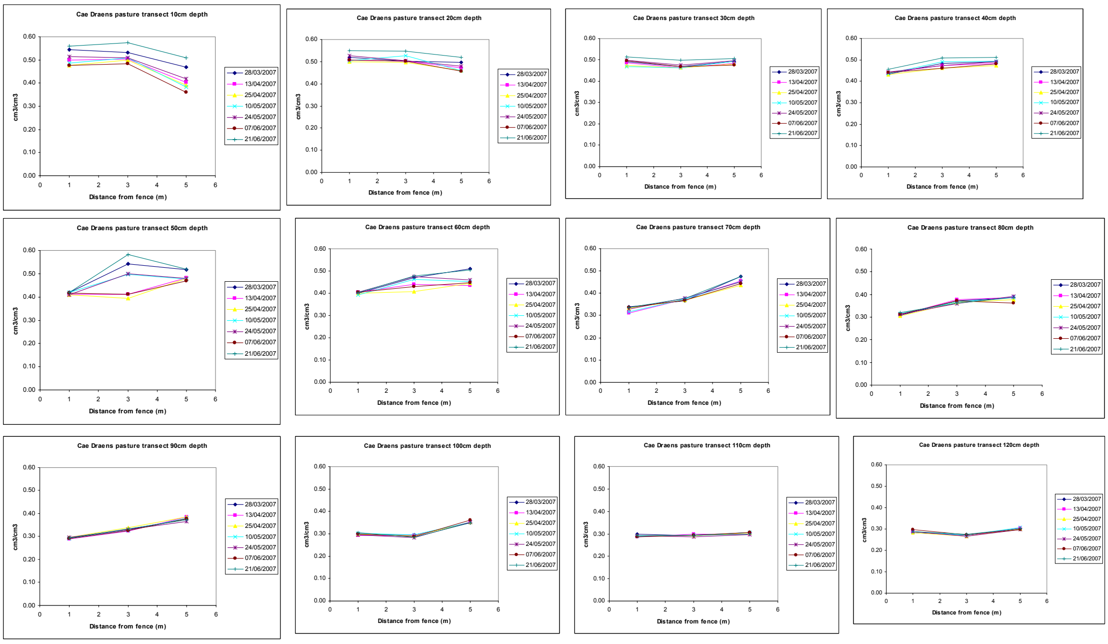

Figure 4.5 Spatial variability of soil moisture content

4.5 Throughfall within the tree shelter belts

Figure 5 shows cumulative total rainfall versus throughfall for the period of measurement for two tree planted sites. At Tyn y Fron, an established woodland edge, 56% of the total rainfall reaches the ground beneath the trees in the form of throughfall. Slightly less rain reaches the ground beneath the younger Cae Drains trees (46%).

In order to calculate the total interception loss, stemflow measurements are required.

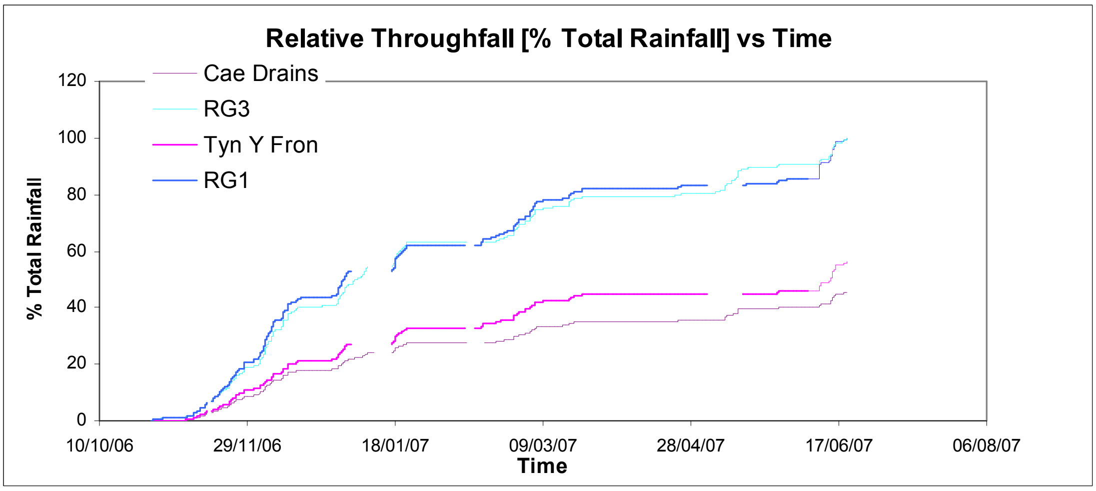

Figure 4.6 Cumulative total rainfall versus throughfall .

Section 5 Conclusions

It has been shown that linear woodland features planted as shelter belts on an upland hill farm can effect the amounts and patterns of rainfall reaching the ground both within, and on the leeward side of the tree shelter belt. Incident rainfall is decreased, with the amount of rainfall that actually reaches the ground, increasing with increasing distance from the leeward edge of the tree shelterbelt. The consequences for soil hydrology are that, in the areas that receive a decreased amount of rainfall, soil moisture content is also decreased and, within the shadow area, follows the same pattern as that of the rainfall.

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