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Woodland's role in natural flood management: Evidence from catchment studies in Britain and Ireland

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ABSTRACT

Despite the attention currently given to the potential environmental benefits of large-scale forest planting, there is a shortage of clear observational evidence regarding the effects on river flows, and what there is has often been contradictory or inconclusive. This paper presents three independently conducted paired-catchment forestry studies covering 66 station-years of flow measurements in the UK and Ireland. In each case coniferous evergreen trees were removed from one catchment with minimal soil disturbance while the adjoining control catchment was left unchanged. Trees were removed from 20% - 90% of the three experimental basins. Following woodland removal there was a large increase in dry weather baseflow at all sites. Baseflows increased by about 8% after tree removal from a quarter of the Hore basin and by 41% for the near-total cut at Howan. But the changes were more complex for peak flows. Tree harvesting increased the smallest and most frequent peak storm flows, indicating that afforestation would lead to the suppression of such events. This was however restricted to events well below the mean annual flood, indicating that the impact of forests upon the largest and most damaging floods is likely to be limited. Whilst a forest cover can be effective in mitigating small and frequent stormflows it should never be assumed to provide protection against major flood events.

KEY WORDS:

Forest Harvesting, Streamflow, Natural flood Management, Before-After-Control-Impact, Evidence-Based Forest Impact

1. INTRODUCTION

Woodlands are the world’s biggest single land cover, and change in forest extent is the greatest land use alteration by area. In many parts of the world, especially in the tropics, there is concern about the rapid loss of the forests due to population growth and economic pressures, while in most Western European countries the forest area has been increasing, largely driven by environmental concerns. The greatest *relative* increases in Europe have been in Britain and Ireland (FAO, 2010; Keenan et al., 2015) rising by over 35% and 50% respectively in the last 40 years albeit both from a very low base, and there is considerable scope for further woodland expansion.

Catchment studies worldwide have almost universally found greater *annual evaporation* (lower total runoff) from forests compared with short vegetation (Bosch and Hewlett, 1982; Zhang et al., 2001). This applies both in humid areas due to higher canopy interception losses, and also in arid areas due to trees’ greater rooting depth. Conflicting opinions remain, however, about the effect of forestry on flow *regimes*, especially extreme peak flows. Trees have often been claimed to moderate river flow extremes, reducing peak flows and releasing waters more slowly helping to sustain dry weather flows. Yet despite much research, considerable controversy remains and a recent literature review found a marked lack of consensus as to the magnitude, and even direction, of forests’ impacts on high flows (Stratford et al., 2017).

The idea of using trees as part of *Natural Flood Management* of a catchment is very attractive and is in tune with the role of trees to lock up large amounts of carbon and to aid environmental rehabilitation and biological diversity. So it is crucially important that its role in flood amelioration is properly understood.

Opinions about the impact of forests on low flows are also divided. Forests’ greater evaporation will generally reduce net recharge to soil moisture and so deplete stream baseflows (Allen and Chapman, 2001; Andréassian, 2004), yet in some cases, due to improved infiltration, afforestation may increase groundwater recharge and hence low flows (van Dijk and Keenan, 2007; Neary et al., 2009). Some scientists are sceptical of uncritical claims of forests' hydrological benefits, pointing to many interacting physical characteristics of river catchments that may influence flood generation (DeWalle, 2003). Several studies have attributed observed streamflow differences between wooded and non-wooded basins to soil and geological variations, rather than to the vegetation (Cosandey et al., 2005). Furthermore, some associated aspects of commercial forestry, including pre-planting drainage, building access roads, and use of heavy machinery during felling leading to soil compaction may result in hydrological impacts that are quite distinct from the 'natural' effects of the forest itself.

The uncertainty and folk law concerning the role of forests have meant that both the friends and enemies of forestry have "claimed more than they could prove" (Andréassian, 2004). Nevertheless there is a common perception among many natural resource managers and the public that forestry is an inherently natural land cover and so will automatically result in an environmental enhancement. Rojas et al. (2003) reported a general lack of scientific data to support many of the claims of hydrological benefits made in assessments of environmental services.

Many previous studies were either of single site and short term, or else reviewed multiple studies by different people and used different analysis techniques (Tembata et al., 2020; Page et al., 2020; Bathurst et al., 2020; Stratford et al., 2017; Soulsby et al., 2017; Fahey and Payne, 2017; Green and Alila, 2012). When assessing the hydrological impact of a forest cover, the felling techniques used in these studies were much more aggressive than those in current use and in many cases site damage during felling due to soil compaction and gullying, as well as new forestry extraction roads could have had a major role and create a false impression of the effect of the *forest itself* (Bathurst et al., 2020). We believe that this study of multiple sites using raw data analysed in a consistent manner can add real value to the debate. This study used *Before-After-Control-Impact* (BACI) method which is a rigorous approach in any comparison study of flow changes is essential to provide an objective analysis of forest impacts based on observations in catchment studies. The forest felling activities in this study followed the best management practices to minimise the soil disturbance, which allowed to assess the effect of the forest itself on the flows, rather than any changes of soil conditions.

2. MATERIALS AND METHODS

2.1 Methods

This paper uses data from three catchment forest studies in Britain and Ireland using *environmentally sensitive* harvesting techniques under modern forestry guidelines to minimise soil damage. These techniques are very different to those used in earlier felling studies, and the environmental conditions (in terms of climate, soils and tree species) were distinct from those prevailing in many earlier widely reported North American studies.

To study and interpret the impact of land cover on river flows researchers often use comparatively small basins where catchment characteristics are known and vegetation can be manipulated and then directly related to streamflow behaviour. The simplest approach is a direct comparison of outflows from a forested and a non-forested catchment, similar in all the characteristics believed to affect runoff, but differing in their vegetative cover. It can be difficult to find adjacent reference basins that do not also differ in some of their other physical characteristics. A more rigorous strategy that overcomes many of these problems requires two similar catchments (both forested) to be monitored in a pre-felling ‘calibration’ period to establish a relationship between their flows. Then the trees on one basin are felled and the subsequent flows of the two basins are compared and any differences from the previously established relationship are indicative of the forest impact. This paired catchment, *Before-After-Control-Impact* (BACI) experimental approach separates climatic variability effects from streamflow changes due to forest cover. This is now a well-established research tool in assessment studies that reduces the confounding influences of weather and catchment characteristics, and enables a more rigorous analysis to distinguish catchment changes from climatic variability and which with care can then be used to provide information on any changes in flood risk (Alila et al., 2009).

The site damage and downstream impacts on stream ecology and hydrology led to tighter regulation on how such work should be carried out. These concerns became addressed in a series of environmentally sensitive *Forest Guidelines* in both the UK and in Ireland for good forest management, including tree harvesting (Forestry Commission, 2003; Forestry Commission, 2011; Forest Service, 2000). The use of specialised forest machinery such as harvesters and forwarders enables timber to be extracted and lifted entirely clear of the ground with minimal soil disturbance. Brash ‘mats’ composed of branches and the tops of trees support the felling machinery and protect the underlying soil from rutting, compaction and erosion to minimise soil structural damage. In addition on some of the steeper slopes a cable crane may be used. Providing the work is carried out responsibly, and avoids periods when there is heavy rainfall, forest harvesting impacts on watercourses can be largely ameliorated by proper management (Nisbet et al., 2002).

This provides the opportunity to 'repurpose' the existing results of some recent forest felling studies which had been originally established to determine the impacts of forest harvesting under modern guidelines, particularly on stream water quality. A key point of these guidelines is to minimise soil damage, and so any observed changes in hydrology will be primarily due to the presence or absence of the trees, rather than by any changes to soil conditions.

2.2 Study sites

A review of the literature identified a small number of paired catchment studies where modern techniques to reduce soil damage had been used in felling woodland and the impacts on flow regimes had not been published. Three independent studies were selected in this paper; they were located several hundred kilometres apart, but each has a humid maritime climate which is typical of the majority of forests in their respective countries. The study sites (see Figure 1 and Table 1) are situated within:

a) Hore study site is located in *Hafren Forest*, a large forest block in mid-Wales on the eastern side of the Plynlimon mountain (Foster et al., 2001). Two small catchments established by the Institute of Hydrology (now part of UK Centre for Ecology and Hydrology) were used for this study comprising the 390 ha grassland Gwy, used for sheep grazing, and the 310 ha Hore, predominantly under coniferous forest. About 25% of the Hore was felled in July 1985 to June 1987 as part of a water balance study (Roberts and Crane, 1997).

b) Howan study site is in located in *Kielder Forest* on the Scotland / England border, N. Europe's largest man-made forest (Robinson, 1998). Two catchments in Coalburn Catchment, each with mature closed canopy forest were instrumented comprising a

150 ha control basin and the adjacent 20 ha Howan Burn catchment that was felled in 2008, and the results have not previously been published.

c) Burrishoole site is located in *Nephin Forest* in western Ireland in Co Mayo on the *Nephin Beg* mountain range, one of the largest contiguous forest blocks in Ireland. Small research catchments in Burrishoole were established by the National University of Ireland Galway (NUIG), as part of a larger study into ecosystem response to environmental change. They comprise an 8 ha control basin and a 12ha experimental basin felled as part of a water quality study (Rodgers et al., 2011; Rodgers et al., 2010; Rodgers, 2008).

The study areas have similar physical characteristics. The sites share many common features representative of large forests in their respective countries in terms of generally peaty soils and underlying low permeability geology. Comparative hydrological data had been collected at each pair of catchments before the removal of the woodland on one. All sites had streamflow measurement structures and their catchment areas are sufficiently small that the nature, timing and extent of the forest felling is known accurately. In common with about 75% of the UK and Ireland's *existing* forests, as well as half of the *current planting* the sites had fast-growing commercial conifers that are tolerant of acidic, waterlogged and often peaty soils. The tree felling operations were all in line with the current guidelines ensuring that the results of these studies reflect the impact of the *tree removal* rather than the *soil damage* by heavy machinery that may have unintentionally distorted the results of many early felling studies.

There are three drainages in the Nephin sites which were ditched before the initial planting. The ground topographies are the same for the study sites before and after felling. Post-felling cultivation at the Kielder site (Table 1) involved mounding scooping out a small depression to provide material for a raised, drier, mound for each tree, which is designed to avoid creating an artificial drainage system, and its resulting problems – flooding, siltation downstream. It is nothing to do with topography, and the remnant old drainage system is not deliberately destroyed.

All the sites were equipped with flumes, where water levels were recorded every 15 minutes in Hore and Howan, and 5 minutes in Burrishoole. Instantaneous flow data were used for peak flow analysis in this study. The precipitation characteristics were similar during the before and after felling periods in Hore and Howan sites, while the weather was drier in the summer before felling than after felling in the Burrishoole sites (Rodgers, 2008).

3. RESULTS

The experimental design for the three studies comprised contiguous paired ‘control’ and ‘experimental’ catchments with continuous flow measurements before and after felling. In total the measurements cover 66-station years of hydrological observations and 610 storm pairs. The impacts of felling are described below for low flows and for peak flows.

3.1 Low flows

In this study, low flows were analysed by comparing the paired basin flows during a series of dry weather periods. There are many different ways to characterise low flows, including frequency, duration or severity, and conclusions about flow changes may be dependent on the metric chosen (Robinson and Dupeyrat, 2005). Rather than using a particular single index value we took periods when the control catchment flows were exceeded for more than 80% of the time, and after excluding any periods with recorded precipitation all the remaining flows were accumulated chronologically (Figure 2).

All of our experimental sites show a clear and consistent increase in baseflows after felling relative to the control catchments. Baseflows increased by about 8% after tree removal from a quarter of the Hore basin (Figure 2a) and by 41% for the near-total cut at Howan (Figure 2c). At Burrishoole the results needed closer examination as ongoing field observations revealed that blockage of a drain during harvesting led to unmeasured seepage from an adjacent 4 ha area into the downstream harvested study catchment enhancing its measured dry weather flows. Accordingly, the flows were adjusted proportionately to account for this additional area, and although subject to greater uncertainty than the other sites the results are broadly in line with them (Figure 2b).

The changes found at all the sites of forests reducing streamflow in dry weather periods is consistent with our understanding of the hydrological functioning of basins. Forests almost always lead to a reduction in the lowest flows, and in this study their removal resulted in an increase in baseflows. This finding is consistent with a review by Smakhtin (2001) of the published international literature on low flows which concluded that forestry *generally* reduces dry weather baseflows. Similarly, (Iroumé et al., 2005) found that decreasing the vegetation cover could increase baseflow. By adopting a traditional parried catchment approach, (Fahey and Payne, 2017) found that compared with tussock grass, following forest canopy closure the afforestation reduced the low flow (Q95) by 26%, with an average reduction of 78% for small events. These findings are consistent with our study.

3.2 High flows

At each of the study sites a large number of rainstorm events were identified and the maximum Instantaneous flows from the catchment pairs were plotted before and after the felling (Figure 3). A least squares regression was fitted to the flow peak pairs in each period. A high correlation coefficient with limited scatter before the felling provides a measure of the consistency in response of the control and experimental catchments and a measure of the confidence that any differences following harvesting can be attributed to the vegetation change. The slope coefficients are broadly scaling factors reflecting the relative sizes of the control and experimental catchments in each pair. None had an intercept coefficient statistically significantly different from zero. Where the period of record of the control catchment was sufficiently long, the mean annual observed flood peak was estimated. The period of streamflow measurements at Burrishoole was too short to estimate this with certainty, but records from the control catchment and the fact that the Burrishoole gauge was overtopped several times – which is not included in the analysis of this study – during this study period indicate that the measured peaks were well below the mean annual flood.

In all three studies the post-felling peaks lie slightly above the pre-felling relationship, but the overall increase was small and was not statistically significant. None had an intercept coefficient statistically significantly different from zero.

These results provide little evidence of any consistent forest impact on peak flows, for sites chosen to be broadly representative of the bulk of present-day UK and Irish forests. They also provide an indication of the likely trend for other types of forest planting, and so bring into question some of the assumptions of the potential of woodlands for natural flood management. Nonetheless, the results in Figure 3 suggest that there may have been a change at the lower magnitude end of the peak flow pairs.

Figure 4 shows evidence of an increase in the *smaller* and more frequent flow peaks for the Burrishoole and Howan basins, although not at the Hore, which had the smallest area felled and showed no evidence of any discernible change. At Howan there was a statistically significant increase in small events (slope and intercept; P> 0.001) corresponding to peaks up to about 1.3 m^3/s (occurring typically about 3 times per year at the control catchment). Burrishoole showed a statistically significant increase in the smallest peaks after felling (intercept increase p>0.001) occurring typically about 10 times per year indicating that a forest can suppress peak flows – albeit only for the smallest events predominantly in summer.

These three studies show that, contrary to much popular opinion, tree harvesting (with minimal soil disturbance) did not result in a significant detectable increase in large peak flows from any of the study sites. Any change was restricted to the minor peaks, well below the mean annual flood, and to catchments in which more than half of the area was changed. Forests have only a restricted effect on peak flow suppression. The peak flows are generated through runoff and subsurface flows in storm events. The evaporation and interception capacity of a forest canopy is limited in a storm event and so is proportionally weaker at the times of heavy rain, and hence the effect of the forest on larger floods is limited. If forest harvesting and biomass removal has little impact on high flows, the associated conclusion must be that reforestation effects on peak flows will also be minor.

This increase in magnitude of the most commonly observed (smaller) floods would help to reconcile the frequent ‘public’ perception that streamflow peaks “increase” after felling, with the ‘scientific’ evidence that forests’ role in reducing the rarer, larger (and most damaging) flood events is very limited.

4. DISCUSSION

4.1 Impact of forest on low flows and high flows

There has been much less attention in the literature regarding how forestry affects baseflows than annual yield or peaks. Variety of conclusions about the impact of forestry on low flows have been reported. Some researchers report a reduction in groundwater recharge due to afforestation some report the opposite response, and others report a mixed response that varies over time (Allen and Chapman, 2001; van Dijk and Keenan, 2007; Neary et al., 2009). In this study, the increase of low flow increase was observed after harvesting. The findings were consistent with Smakhtin (2001), Iroumé et al. (2005) and Fahey and Payne (2017).

The variety of conclusions about the impact of forestry on low flows could be due to the complexity of the mechanisms of low flows generation which are often site-specific. Low flows are fed by soil and groundwater; greater evaporation losses from the forest canopy reduces soil water contents and recharge to the water table and therefore decreases baseflow. Dry weather low flows are normally derived from groundwater discharge and so the local geology may exert a dominant effect, masking the influence of land cover and management. Studies at both the Hafren (Hudson, 1988) and Kielder (Newson, unpublished data) found lower soil moisture in dry weather periods under the closed canopy forest than under adjacent grass, indicating the potential to create a buffer in the upper soil to store up to the equivalent depth of several centimetres of storm rainfall. In this study, the three study sites all had low permeability bedrock so the effect of local geology on the results should be minimised. In addition, in this study the paired catchments have similar drainage system and little soil disturbance before and after felling, which could mitigate the potential impact of the ground condition changes on dry flow.

The three widely located independent studies presented here provide a consistent picture that forestry can reduce the magnitude of the smaller and more frequent floods, but this influence reduces for larger and more damaging floods and forests have a limited impact on the highest flows. The findings are consistent with many studies around the world. For example, Fahey and Payne (2017) assessed the impact of afforestation on stream flows using a tussock grass catchment as the control site in New Zealand, and found that the mature forest reduced average peak flows for small events by 78%, and had less impact on peak flows during high magnitude storms. Similarly, Silveira et al. (2016) investigated the effects of converting the natural grassland to forest on water resources and concluded that forest could reduce specific discharge by 17.2%. In Chile, Iroumé et al. (2005) analysed the impact of different land uses on runoff and peak flows in four experimental catchments and found that forest harvesting generated increase in summer runoff, which was due to the combined effect of the vegetal cover and topography. Bathurst et al. (2020) further studied the impact of forest on flood using catchments in the UK, New Zealand, USA and Chile and found that while forest reduced peak flows in low to moderate floods, it had less impact on large flood events, and forest activities such as road network and drainage ditches modified the impacts. Soulsby et al. (2017) used the Storm Frank on December 30, 2015 as an opportunity to study the impact of forest on flood peak during an extreme weather event. They analysed the rainfall-runoff response in Dee catchment, UK and concluded that forest had very low potential to ameliorate flooding of such magnitude.

However, some studies were reported otherwise. Green and Alila (2012) conducted a meta-analysis of four catchments and concluded that forest harvesting could increase the magnitude of peal flows over flood event size of up to 50-year return period, but this could be because the floods were caused by snowmelt rather than rainfalls. Reviewing multiple studies by different people could also draw a different conclusion. Tembata et al. (2020) analysed flood disaster dataset, climate data and satellite land cover data from China and concluded that broadleaf trees and mixed-tree forests forest could mitigate flood occurrence. Bradshaw et al. (2007) analysed data collected from 56 developing countries for the period from 1990 to 2000 used an information theory-based approach. They concluded that forests are correlated with flood risk and suggested reforestation for the mitigation of severity of flood-related catastrophes. Van Dijk et al. (2009) suggested that the forests' mitigation on floods could be due to the forest associated landscape changes and activities rather than the trees.

4.2 Impact of forest associated activities on flows

Though it appears at variance with the extensive historic literature reporting increases in peak runoff associated with clear felling (Anderson, 1976; Cheng, 1989; Thomas and Megahan, 1998), there now is a growing consensus that forests generally have little impact on large peak flows (Laurance, 2007; Calder and Aylward, 2006), and that exceptions arise from situations when soil damage caused by the forest removal itself has directly led to reduced infiltration and soil storage capacity (Bruijnzeel, 2000). The large increases in flooding and erosion reported in the scientific literature were often an artefact of the felling operations rather than a true representation of the role of the forest itself (Van Dijk et al., 2009; van Dijk and Keenan, 2007). If not conducted carefully forest harvesting can reduce soil infiltration and porosity leading to less soil water storage capacity and encouraging surface runoff, which is then facilitated by harvesting roads, ditches and skidding trails connecting runoff generation areas directly to the main stream network. Furthermore, it is also increasingly recognised that many early famous catchment studies (including *Hubbard Brook*, *Coweeta* and *HJ Andrews*) only examined small events, and were not concerned with assessing the impacts of infrequent, severe, flood events (DeWalle, 2003). It was not perhaps to the foresters' disadvantage that tree removal appeared to increase the frequency and severity of flood risk. Bathurst et al. (2018) even found that due to forest ditching, comparing with grassland, the forest catchment had larger flood peaks.

The more sympathetic felling techniques currently in use are very different to those used in earlier published studies. Several reviews (Beschta et al., 2000; Robinson and Dupeyrat, 2005; DeWalle, 2003) noted that felling studies where significantly increased peak flows had been reported were often subject to severe soil disturbance by the logging or associated road construction. A forest cover can provide protection against soil erosion and associated increased flood risk downstream. Cosandey et al. (2005) found woodland greatly suppressed floods in an area on steep slopes with severely eroded soils, but had little impact in areas of well-vegetated permeable soils where a dense grass cover provided as good a protection against floods as woodland.

The present study shows the crucial role of careful forest management to protect the soil in minimising the potential adverse effects of felling on flood risk. Harvesting trees with *minimal* soil disturbance does not lead to increases in annual peak flows. The concomitant conclusion must logically be that planting trees will have a much lesser impact on flood reduction than would be hoped.

4.3 Natural flood management and forest

Dadson et al. (2017) reviewed the published literature (observations and modelling) on the potential role of *Natural Flood Management* in the UK, including the impact of forest cover. They concluded that the broad impact on peak flows is greater for small floods, and lessens for larger floods due to the relatively limited amount of canopy storage and generally drier soils beneath forest stands compared with grassland. Under sustained winter rainfall, soil saturation will occur and little mitigation of high flood flows would be expected.

This raises the key question, not addressed, at what flood return interval do flow peaks converge, with/without trees? Figure 4 shows that this is restricted to peaks well below the mean annual flood in the three catchments studied. Is the convergence likely to occur at larger or smaller flood frequencies in other basins, and what factors may be at work?

The observed benefit found in the three study catchments shown here was limited to peaks well below the mean annual flood, but the return interval may be dependent upon soil conditions and there could be situations, such as areas of steep slopes and soils prone to erosion, where greater benefits can be achieved. In the erodible basins observed by Cosandey et al. (2005) the ability of forests to suppress flood peaks extended to larger magnitude (less frequent) events than the British and Irish studies reported here. A similar result has been found in modelling studies. Birkinshaw et al. (2011) used a model simulation approach to provide insights into the impact of forest cover on peak flows of differing magnitudes. Their results suggested that peak flow suppression might occur up to the 10-year return interval flood. A similar indicative flood magnitude of 10 years was reached in a modelling study of small steeply sloping basins in the Cascade Mountains of USA (La Marche and Lettenmaier, 2001).

Combining the observational evidence with the model scenarios provides a consistent picture that tree removal would increase smaller peak flows the most, with a reducing impact at higher flows. The flood magnitude at which the peak flows converge was much smaller (and more frequent) in the flatter and well vegetated British and Irish catchments than in steeply sloping mountains, where the greater potential for soil loss after felling extended the flood magnitude up to which peak flows were suppressed by the presence of forests.

The small catchment results reported here are not necessarily directly transposable to very large catchments, due to the small percentage of a larger basin affected and as variations are smoothed by the pooling of sub-catchment outflows. Over 25% of the basin area had to be affected before any impact could be detected on peak flows. Some long-term catchment studies have linked an observed reduction of river low flows to forest felling (Muma et al., 2011) but others report an increase (Pike and Scherer, 2003). Often a critical question is not addressed – namely what is forestry compared against? Changes in the forest area must necessarily result in a corresponding loss or gain of the alternative land use, which itself may alter streamflow behaviour. Non-forest land such as intensive farming and pastureland overgrazing may lead to soil structural damage and increase storm runoff (Marshall et al., 2014), where afforestation activities such as building roads and digging drainage systems can change the hydrological characteristics of the forest sites. In this study, sites with and without tree cover were compared, where the land use and soil conditions were not affected. Many previous studies such as Fahey and Payne (2017) compared the forest sites with grasslands and had similar findings as this study. However, Bathurst et al. (2018) compared the forest site – one of the control sites used in this study - with grassland and found that the forest catchment had larger flood peaks, due to forest ditching, indicating that the effect of afforestation activities on flow is more significant than the tree cover effects.

The timing and extent of land use changes is often a matter of conjecture in large-scale historical studies. Consequently, claims that historic flow records of large complex river basins demonstrate the impact of changes in forestry cover (overwhelming all other factors) must be treated with great caution and investigated carefully. Hence the continuing need for closely monitored small basin studies.

5. Conclusions

By analysing data collected from three independently conducted paired-catchment forestry studies covering 66 station-years of flow measurements, this study concluded that while forest can reduce baseflows, its impact on reducing flood peak flows decreases (possibly to zero) for larger flood events and for larger basins – Large floods and large catchments are the two cases of most importance for flood damage and loss of life. There is continuing debate concerning of the impact of forestry on flood peaks, and the belief in the moderating role of a forest with regard to *large* floods is far more widespread in *public* opinion than in *scientific* circles. There is an urgent need for effective dissemination and consistent promotion of the scientific evidence so that decisions can be made on the basis of merit. It would be unwise, to use the limited evidence of flood peak suppression for example, to justify urban development on land with a history of flooding because it was situated downstream of a newly planted forest.

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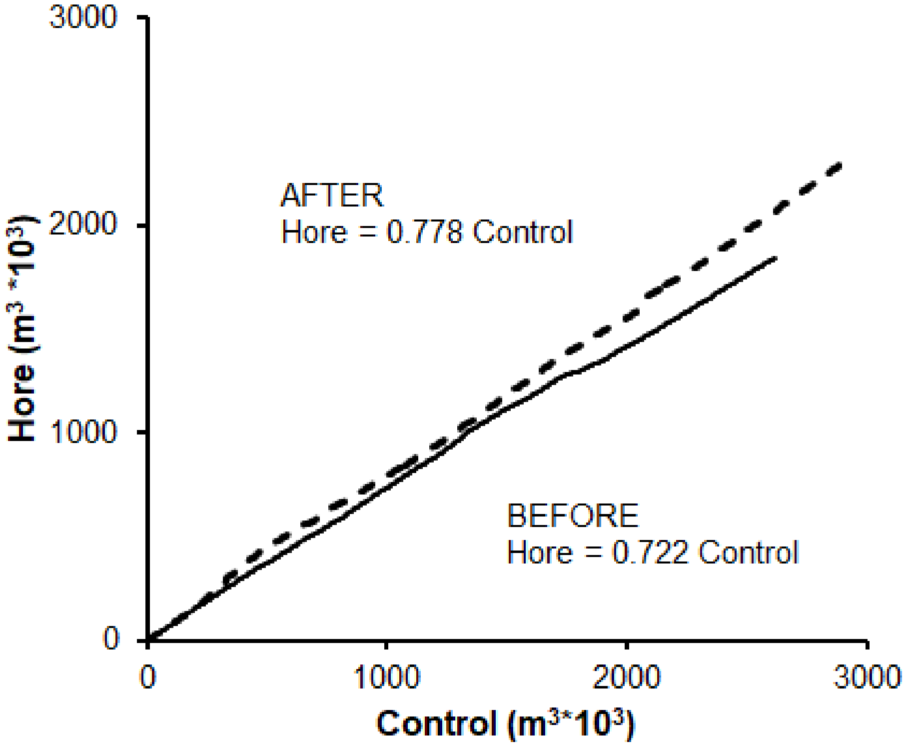
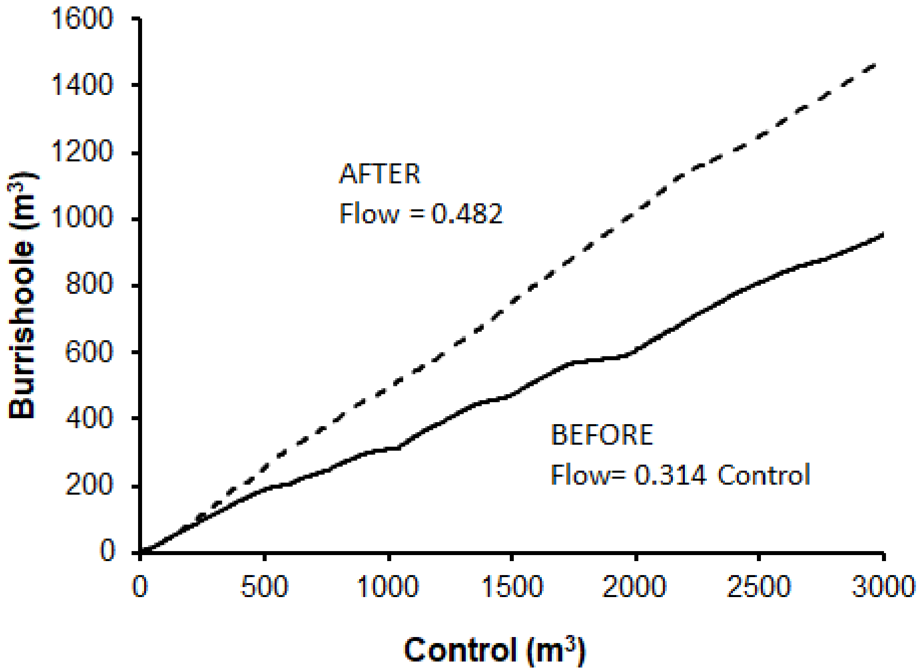
Figure 1 Cumulative low flows for dry weather periods before and after felling: a) Hore, b) Burrishoole and c) Howan

a) Hore (25% felled)



b) Burrishoole (60% felled)



c) Howan (100% felled)

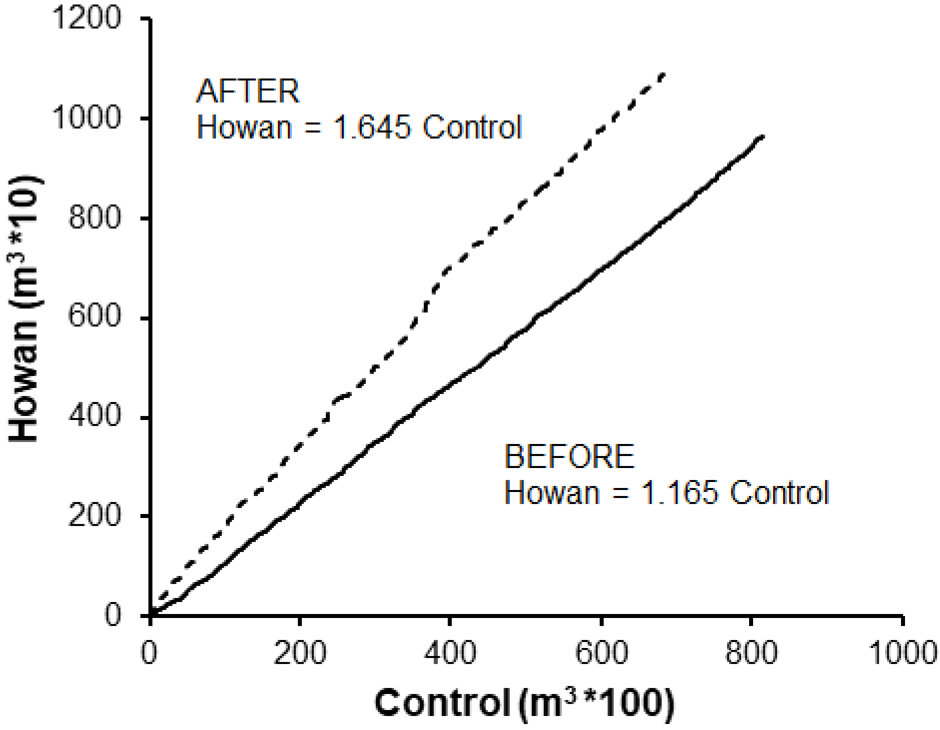
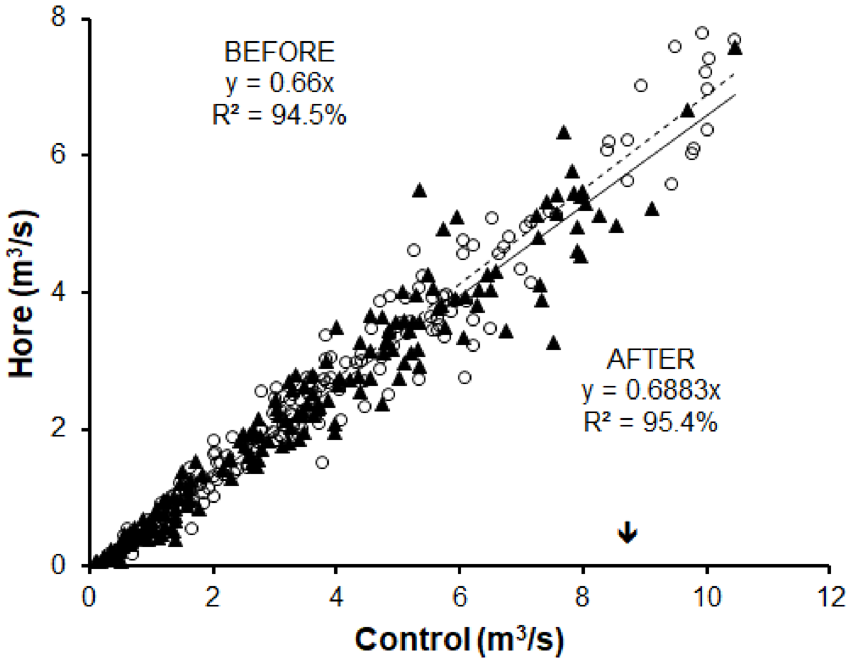
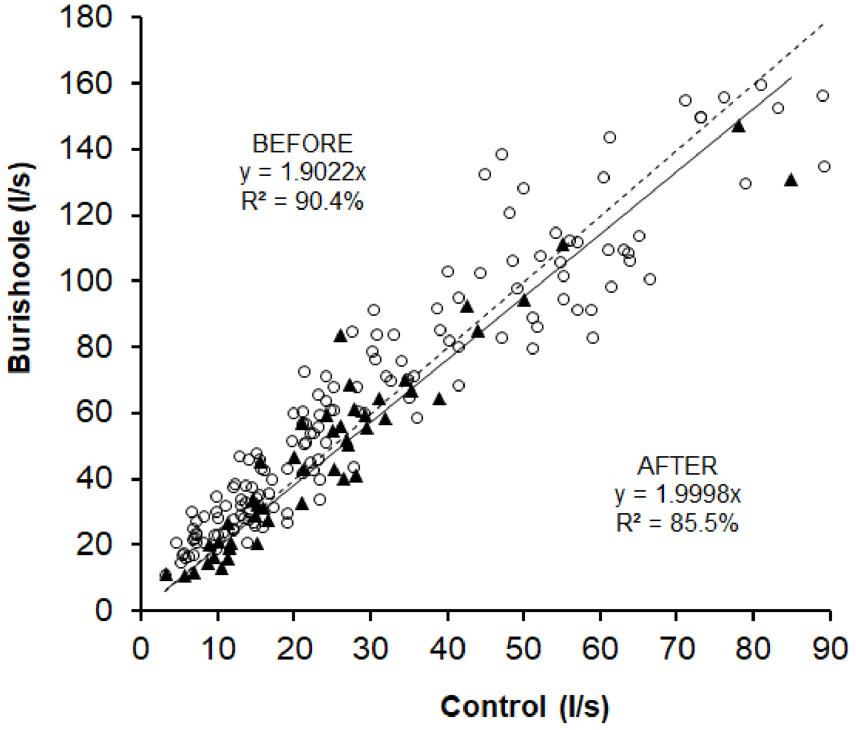


Figure 2 Scatterplot of peak flows before (▲) and after felling (○) with best fit lines (continuous and dashed respectively). The intercepts were not significantly different from zero. ↓ is the estimated mean annual flood at the control basins (Hore control: 8.8 m^3/s; Howan control: 2.3 m^3/s).

a) Hore



b) Burrishoole



c) Howan

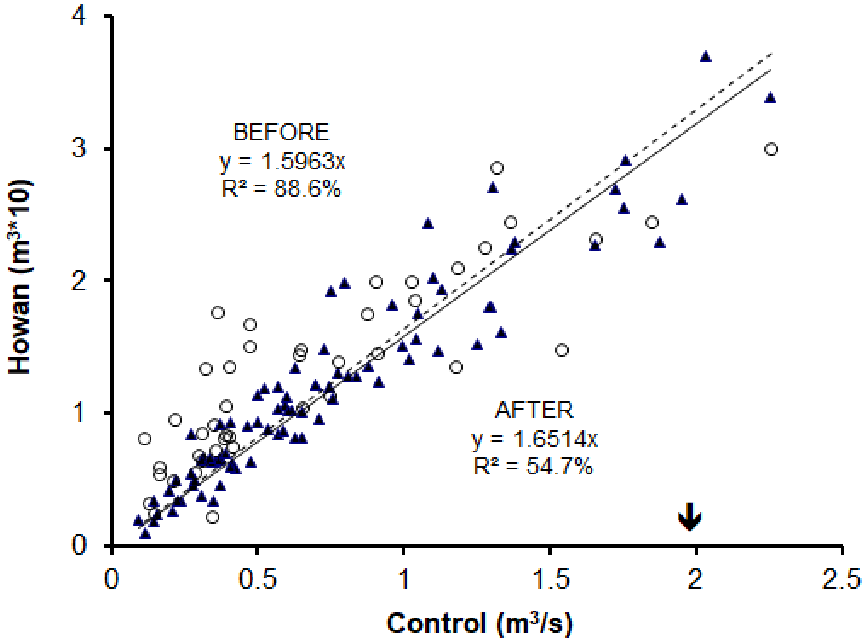
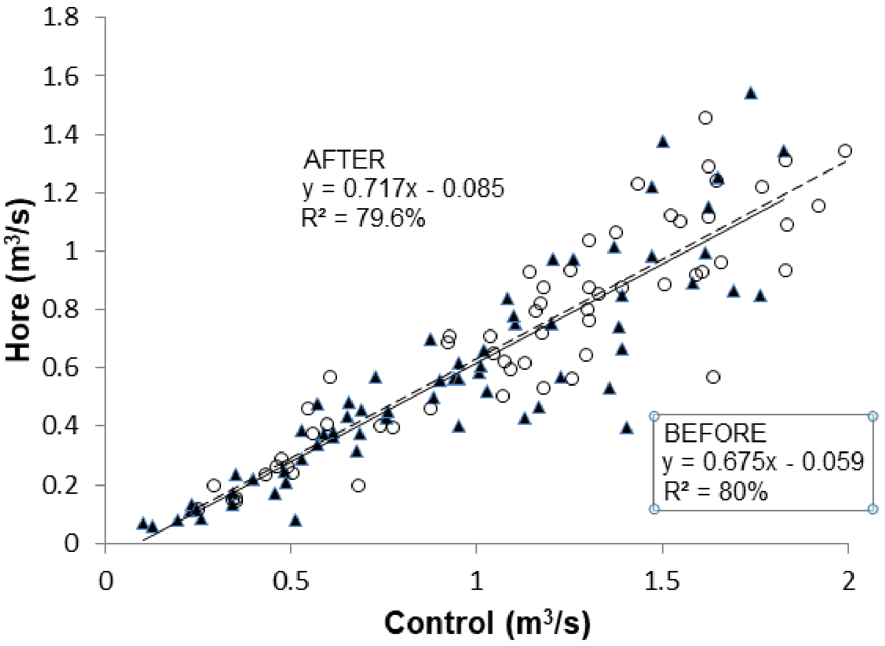
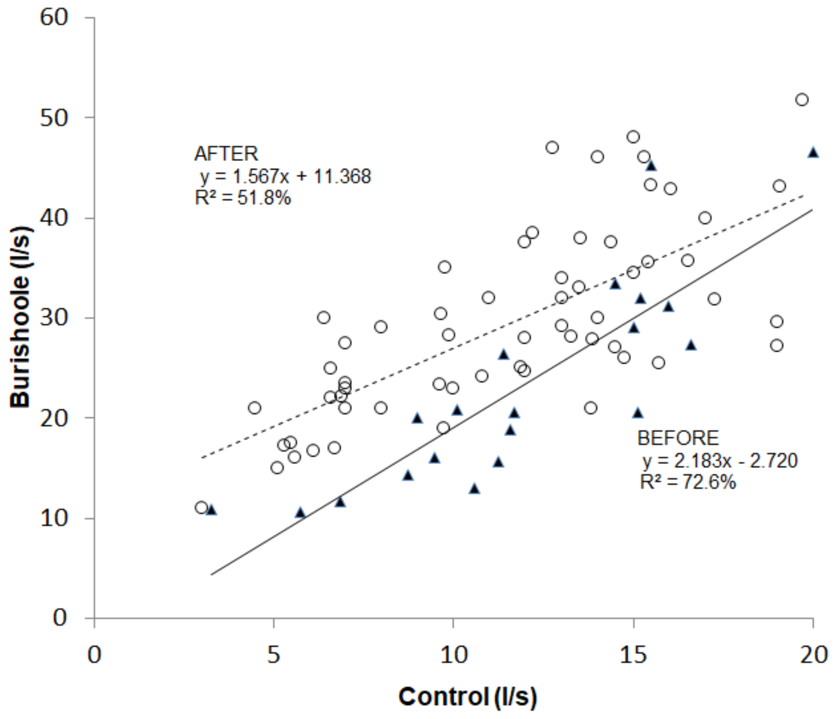

BEFORE
y = 1.5963x
R² = 88.6%
AFTER
y = 1.6514x
R² = 54.7%
Howan (m³*10)
Control (m³/s)
0
1
2
3
4
0
0.5
1
1.5
2
2.5

Figure 3 Scatterplot of minor peak flows before (▲) and after felling (○). Best fit lines include a statistically significant intercept for Burrishoole and Howan. Same symbols as Fig 2.

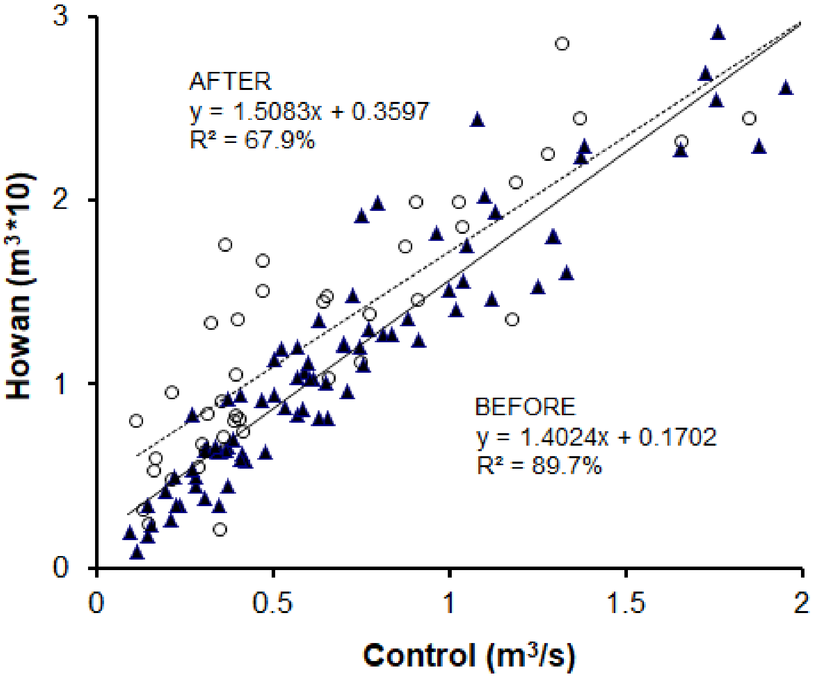
a) Hore



b) Burrishoole



c) Howan


AFTER
y = 1.5083x + 0.3597
R² = 67.9%
BEFORE
y = 1.4024x + 0.1702
R² = 89.7%
Howan (m³*10)
Control (m³/s)
0
1
2
3
0
0.5
1
1.5
2