Marsh Causeway System: part of the broadscale permaculture design of Tir Penrhos Isaf

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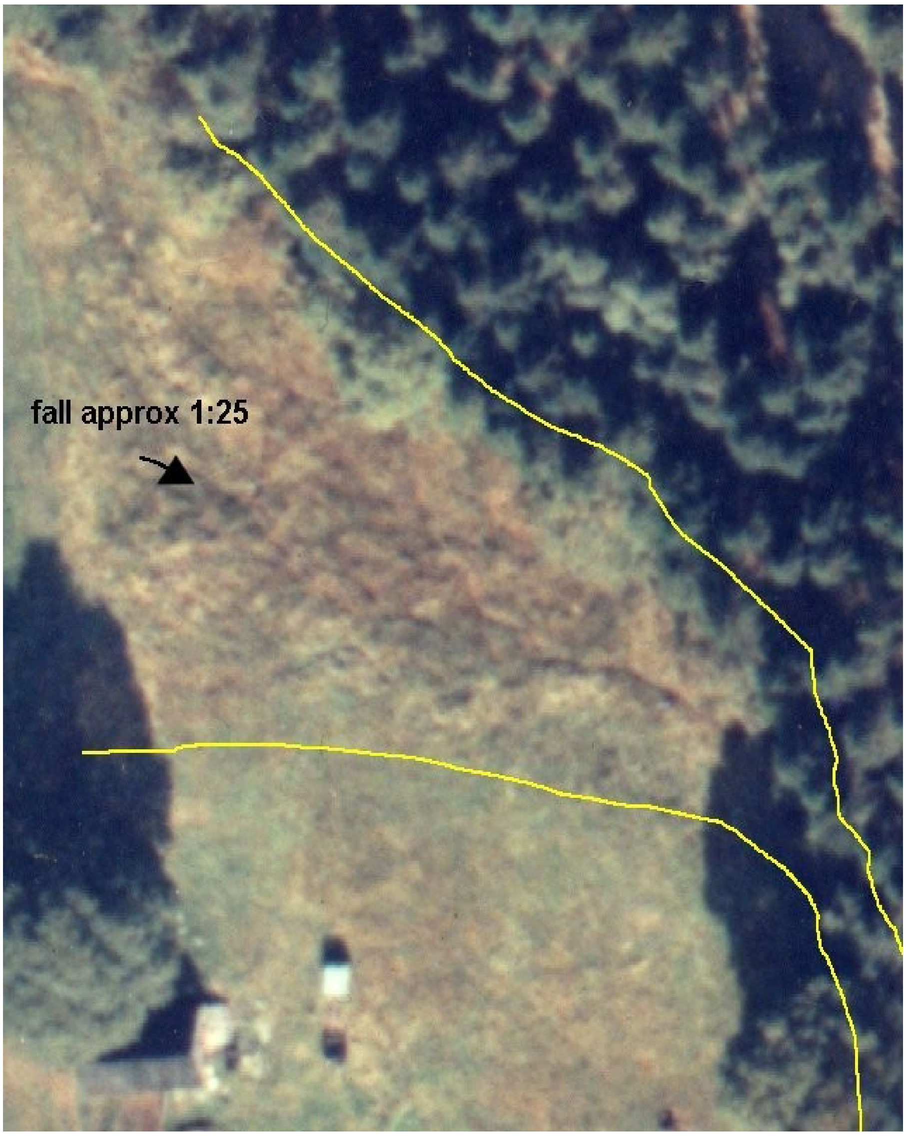
Site history and observations

In 1986 I bought a share in the land which became known as Tir Penrhos Isaf. The 7.2 acre site had been divided into 3 fields and managed as sheep pasture with some mature trees. The fields had been defined by fencing which took the most economic route (shortest straight lines) and paid no respect to changes in land forms and types.

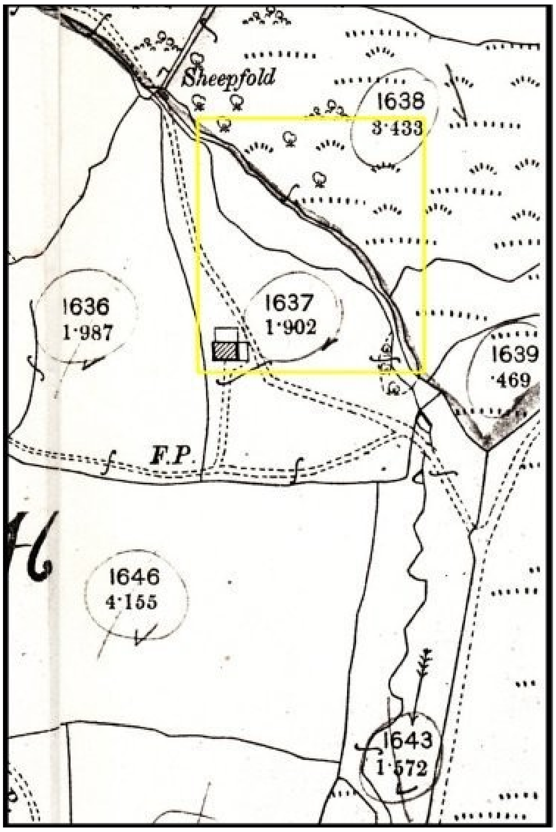
The north eastern field is marked on the 1986 aerial photograph and included steeper slopes leading into more gently sloping pasture, falling towards the east (roughly 1:25 fall). At the change in slope water seepage was visible which increased noticeably after heavy rains. Subsequent trial pits revealed an impervious clay layer lying under the gently sloping pasture at a varying depth of between 30 and 45cm. At the change in slope a seepage or spring line is produced, running roughly north-south.

To the north of this field lay a roughly triangular area which was depressed below the level of the surrounding land by roughly one metre, marked in the detail from the 1986 aerial photograph.

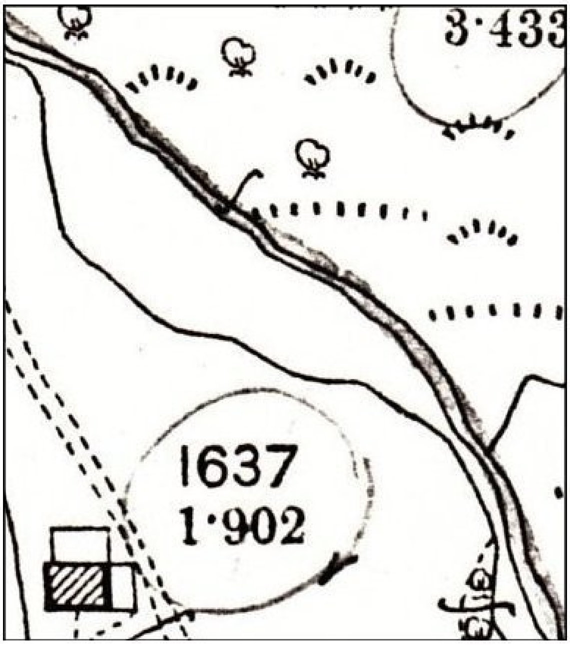


Due to the continual seepage from the spring line this area was considerably wetter than the surrounding land and attempts had been made in the past to drain it by digging a main open drain running down slope from west to east, and several additional "herring bone" ditches that ran from north west to north east to meet the main drain. These had not been especially successful and the area had remained wet and been extensively poached by livestock (sheep, cattle and horses).

Examination of old maps (1902) showed that the stream had originally run through this depressed area and at some point had been moved to run along the raised ground to the north.



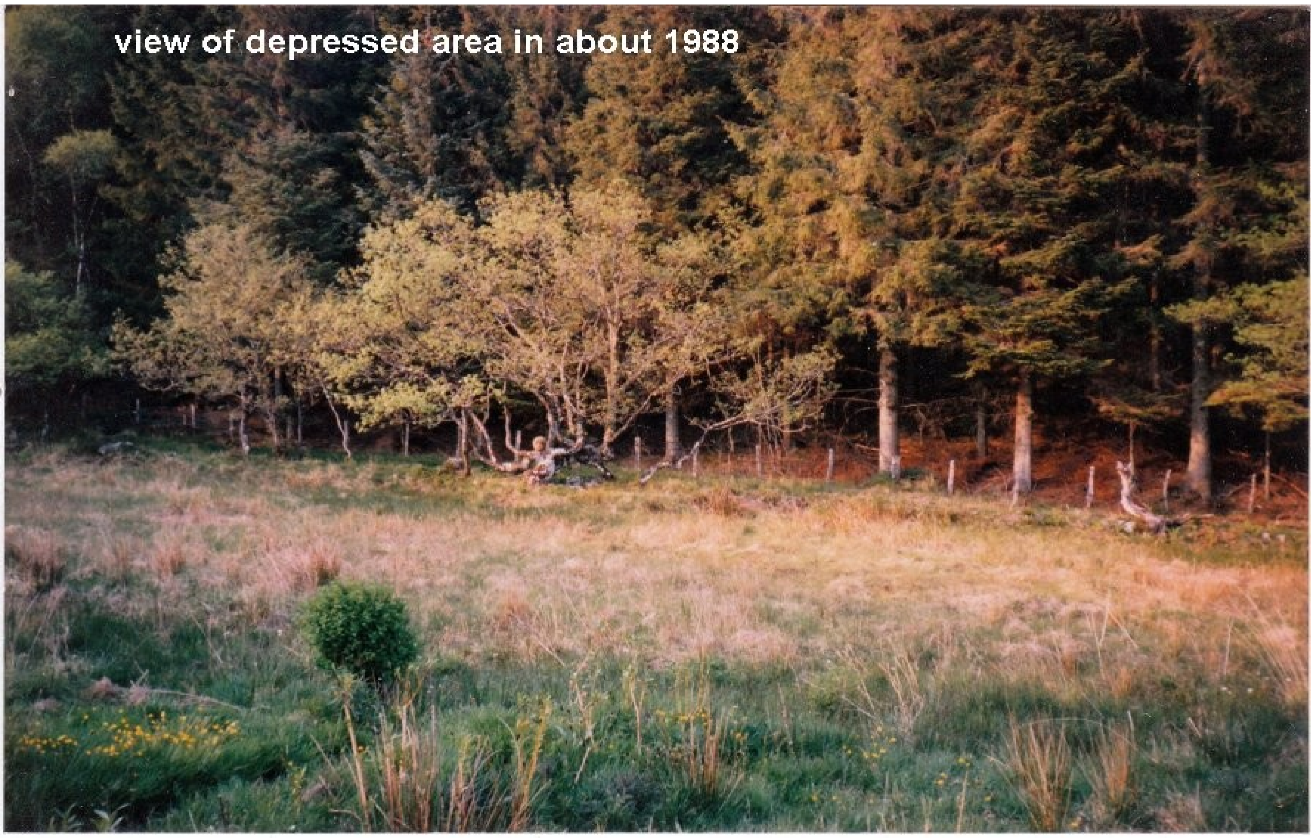
map of 1902 from Dolgellau Archives Office



enlarged detail showing
past course of the stream

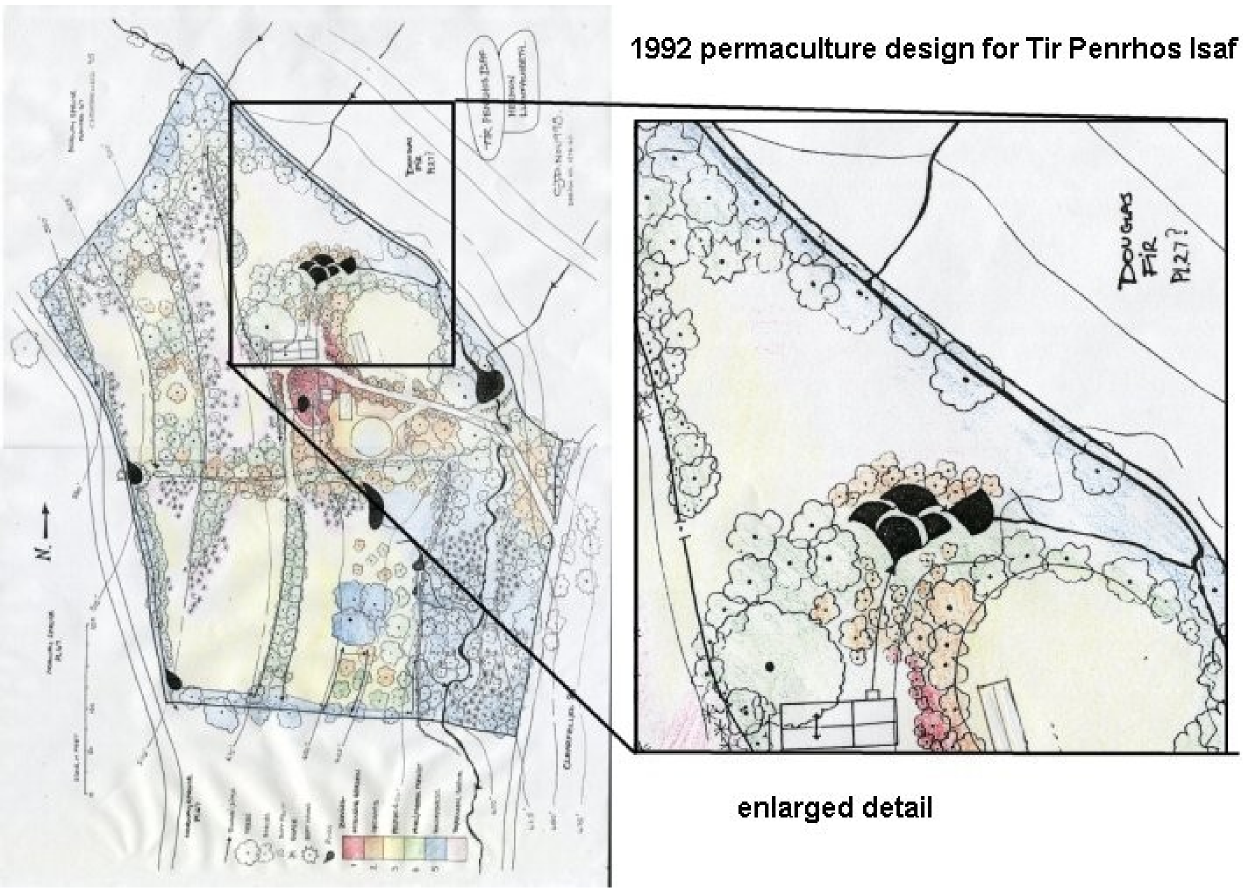
Presumably the drainage followed in an attempt to improve the pasture and stock more sheep. Interestingly, a close examination of the aerial photograph from 1986 hints at the original stream course while the drainage ditches are invisible, increasing the suggestion that they had little or no effect. Subsequent conversations with foresters suggest that drainage ditches are only really effective up to a distance of about 50cm on either side...

I have speculated on why this area is depressed in relation to the surrounding land. One possibility is that when the stream still ran thought it the area was subject to flooding and erosion. However, given the considerable use of peat as a fuel by locals over the last several centuries it is also possible that this was a small peat bog at one time and has been dug up for fuel.



Predominant species initially were sedges and some sphagnum moss.

The 1991 design included a series of rather elaborate ponds in this area, as part of a grey water treatment system and initially the area was simply removed from the grazing regime and became zone 5 wilderness.



1992 permaculture design for Tir Penrhos Isaf

enlarged detail

Eight years later (1995) the elaborate ponds had still not been implemented and the area had become largely dominated by melinea grass. The ditches had reduced in width and depth but still concentrated an often considerable discharge of water from the area, particularly after heavy rain.

Having been Informed for some years now by the concept of working with nature rather than against it, I knew that the conventional water management strategy of getting rid of water as quickly as possible was inappropriate for current and future water security and so decided to make an intervention. My primary aim was to increase the water storage capacity of the land in the soil, rather than creating dams and ponds. I chose to start small and then monitor the effects of my interaction.

First intervention

My first tentative intervention came in 1995, coincident with re-fencing a nearby paddock which resulted in the need to deal with a quantity of half rotten softwood stakes. I laid some of these lengthways in one of the drainage ditches until they were level with the surface then added more on either side to create a simple causeway.

I chose to start roughly at the centre of the depression, my reasoning being as follows; if I started at the "top" any effect "upslope" of the causeway would be difficult to detect and besides, this was drier land and quite good grazing anyway. If I had started at the "bottom" I was concerned that too much water may build up and possibly break through the causeway with consequent erosion. As rivers appear to start in the middle and grow both up and downstream simultaneously, I thought this might be appropriate here.

The first rotten stake causeway extended for about four metres. Spaces between the stakes were filled with soil from minor excavations elsewhere on the site and weedings, prunings and the like. I then watched what happened. The water backed up in the ditch to the level of the causeway but remained as open water for less than a season as various plants took advantage of the new niche and filled it. It looked a bit like a dam at first but unlike a dam it had no outlet channel and was full of leaks or rather, seeps. In "normal" conditions water seeped evenly throughout the whole length of the causeway and in heavy rainfall, as the causeway is more or less level, it flowed evenly over the whole length without building up any great speed or forming a channel. The escaping water tended to wander through the plants below the causeway rather than just all flowing back into the drainage ditch.

Interestingly, the causeway seemed to slow down the flow of water on both the upslope and downslope sides, rather like a shelter belt slowing air movement and creating shelter on both sides. This was noticeable by the fact that a build up of silt occurred not just on the upslope side, as one would expect, but also on the downslope side. Rather than water flowing through the original drainage channel, the flow was now spread out along the whole length of the causeway. This new flow formed many small puddles and hanging pools below the causeway that appeared to be suspended, hanging over and around the original ditch, giving a stepped appearance.

Observation and feedback

I kept an eye on the trial causeway over the next five years, taking special care to check it out in extreme conditions. It appeared to be stable and showed no signs of collapsing or being swept away in catastrophic flooding. I had planted some flag iris on the upslope side together with bog bean and spearwort. All these had done very well and together with native volunteers like meadow sweet and water mint had created a mass of luxuriant vegetation. The occasional addition of ducks to the system meant that small areas of water remained open for most of the year. Various dragonfly species and damsel flies also took advantage of the site and could be seen regularly patrolling the area.

I also asked for feedback from various experts including ecologists and botanist (I am particularly grateful to Annie Seddon and Dr. Martin Garnett for their positive support). Encouraged by the feeling that nothing too drastic or unwanted had happened, I entered a second stage of more extensive intervention.

Second and subsequent interventions

Over a period of several years I added three more causeways, two above the first one and one below. During the autumn and winter of 2005-06 I completed the full run of each causeway so that they crossed the depression completely from one side to the other and connected them together at the far side so as to create routes through the system.

I coppiced the willow on the site and used the larger diameters for firewood. The smaller pieces, the brash, I cut into lengths that were the same width as the causeway and laid them down either loose or tied in bundles as fascines. Again, I consolidated the causeways by tipping barrow loads of weeds onto the surface and treading them in. This operation was pretty much completed by the spring of 2006.

Once again I could observe the water above the causeways being pushed out along their lengths and seeping slowly through, depositing material on both sides.

Consequences

There are a number of important and useful consequences to this technique that I have outlined below. As with any multi-function system, it is important to maintain in mind the primary yield, as this will decide management.

- Water storage
- Access
- Productive plants
- Water filtration
- Terraces
- Carbon sequestration
- Methane
- Legal
- Ecology
- Management
- Dissemination

Water storage

This was the initial reason for the trial. The bulk of the water storage is in the soil rather than on the surface as in a pond, although mini-ponds are present as well. The surface of the first trial causeway is now approximately 1.3 metres above the water level in the original ditch. This represents a considerable increase in water storage.

As I have in effect raised the water table, this altered the through-flow of water surrounding the site. The grazing above it has become damper and on one side it is noticeably wetter. Water has also begun to emerge in new places further down the slope, including in the roots of a large Monterey pine I grew from seed which now threatens to fall over... Also, seepage from the spring line that had previously appeared towards the bottom of the main track now appeared higher up in the system. This sort of effect needs to be considered carefully before implementing the technique.

2006 saw the worst drought conditions on the site in the last twenty years although everything has still remained green. Surface water in the causeway system disappeared for the first time about a week before the drought ended. However, any surface water is very shallow and the mud that was revealed remained wet. As this is essentially a technique to increase water storage in soils, the disappearance of surface water does not represent a great reduction in its value.

During the locally catastrophic flash flood of 2001 (3.5inches in 3 hours) all the causeways overflowed to a depth of between one quarter to one half an inch, discharging into vegetation with no appreciable increase in speed. The outflow at the lower end of the system remained clear in stark contrast to the Afon Mawddach to the west which ran dark brown with earth and peat and the Afon Wen to the east which, living up to its name, turned milk white with eroded clays.

Access

Wetlands and bogs are often difficult to get into (or out of). The causeways provide a relatively easy means of access. After browsing through old copies of Current Archaeology I found reports of several Neolithic causeways or tracks through wetlands that resembled what I was doing. This was most satisfying. Subsequent research reveals that our ancestors were in fact nicking large amounts of the wood for their causeways from beaver dams and often incorporating the dams into their own access routes...

2nd from the top causeway looking south

linking causeway looking east

Productive plants

The access means it is possible to begin gardening on either side of the causeway; the causeways provide a wetter edge and a (slightly) drier edge offering a variety of microclimates to plant species. The preponderance of water means that, unlike most fields, the soil never has a moisture deficit and plants are able to sustain maximum growth throughout the growing period. The presence of slowly moving water means that the temperature does not fall as far or as rapidly as on the surrounding land. Cattle farmers have long known that marshes provide an early spring bite for stock as the slightly raised temperatures means plant growth starts earlier.

I included soft fruit cuttings in some of the fascines and many of these rooted. This means that parts of the causeways are edged with black and red currant, Worcester berry, gooseberry and black berry. These do well, usually flowering and fruiting earlier than similar plants in drier conditions and suffering less predation from birds.

Much of the material for the causeways was willow and in spring 2006 a lot of this rooted. As the causeway is walked fairly regularly it sprouted predominantly from the edges, creating in places almost two green walls to guide the way. This can be harvested regularly for fascines and added to the surface so the causeway grows the materials required for its own maintenance or to make more causeways. This has great significance for implementing the design in upland areas where materials may initially be very limited.

My use of weeds in the construction process meant that a lot of stuff inadvertently got planted, most of which does very well. These have included comfrey, cabbage, kale, strawberries, apple mint and others. Obviously much more work could be done here.

The habitat itself favoured certain native species, in particular water mint and meadowsweet, which have obvious uses.

Water filtration (grey water cleaning)

The system functions as a filter. Any flow of water is now spread slowly through the whole area, rather than channelled rapidly through a narrow ditch. The whole area is a dense mass of foliage. Water leaving the site, below the bottom causeway, always runs clear. I have not done any detailed chemical analysis but it would seem obvious that there is great potential here for cleaning water. Grey water from the dwelling areas (sinks, basins, shower) are all fed into the top of the system and I've noticed algae blooms here at some times of the year. I have recently added in bull rushes and fragmites to establish a reedy area to increase the filtration.

Terraces

During the summer, vegetation is so lush, even in drought conditions, that the actual topography of the site is concealed but in the winter when things die back, a bit, it becomes easier to see what is happening. From the lowest causeway looking upslope the area is taking on the appearance of terracing with each causeway marking the step up of the next terrace. It looks really interesting as the luxuriant vegetation gives it a wild, natural feel while the level causeways introduce a subtle sense of a more human, actively gardened order.

Carbon sequestration

The causeway is basically biomass, largely woody material and the waterlogged conditions effectively slow decay to a standstill. This has obvious wider implications for both carbon sequestration and water management if we imagine large scale causeways constructed in suitable upland locations.

Methane

While being active carbon sinks, bogs and wetlands can also be net contributors to methane emissions, depending upon the climatic zone in which they occur. As far as I can discover, current research seems to suggest that in temperate climates (such as the UK, currently) they vary from beneficial (carbon sequestration outweighs methane emissions) to around zero in terms of overall emissions (ie. carbon sequestration balances methane emissions). However, as the temperature heats up, these same systems may become net emitters.

Useful research has been carried out by scientists at Bangor University (among others) into methods of reducing methane emissions from wetlands. Temporary drainage of bogs significantly and rapidly reduces methane emissions and the reduction continues for some time after the bog is allowed to refill (1). New bog/wetland systems could easily incorporate methods for temporary drainage.

Also and significantly, systems with open surface water appear to result in greater methane emissions than those with vegetative cover. As indicated above, there is very little open water in this system. Some research also suggests that the addition of sulphates can reduce the methane emissions (2).

Legal

There may be legal implications in using this technique, depending on where it is carried out, which should be born in mind. You are legally obliged to inform the Environment Agency of any actions involving waterways including ditches.

Ecology

To my mind and that of ecologist, botanist and biologist friends (experts in their fields) the site represents a huge increase in diversity and habitat from the muddy sheep grazed lawn it once was. However, as with making any intervention in landscapes, anyone considering trying the technique should think first very carefully about the original habitat and the consequences of raising the water table on existing species. Advice from experts should be sought first where necessary.

Management

Growth is vigorous. The causeways require clearing of excess vegetation two or three times a year. This varies from hack and slash, leaving the debris on the surface, to more careful pruning of soft fruits or weaving of bramble runners and harvesting of edible species such as the mints. Any willow requires regular coppicing or pollarding otherwise it starts to shade out vegetation which then dies back to leave areas of open but shaded water. In a grey water system, these will then start to smell... I sort the willow harvest into firewood, useful poles and brash for fascines. The latter will often go through an animal field first where leaves, shoots and bark are readily consumed; willow contains the precursor to asparin and is anti-inflammatory in effect.

Dissemination

I posted previous versions of the design on my web site which receives around 200,000 hits per year. I emailed links to all the major environmental agencies including The Environment Agency and the Countryside Council for Wales. It has also appeared as an article in The Permaculture Edge. It is one of the main features in guided tours of Tir Penrhos Isaf and regularly draws favourable comment.

Subsequently I have seen reports (on the web and in print) of fascines and the like being used in bog restoration. However, in one instance the fascines were being laid all the way along the drainage ditches in an attempt to fill them in completely. This required the use of a mini digger. I have not found this necessary; the slowing of the water by the causeway allows the ditches to fill up with debris and grow over quite naturally. The above method does not increase water storage, merely restore it to its former level.

I have also seen the use of board dams to restrict the outflow from drained bogs. These did not seem to work very well. The use of dams means an outlet is required and hence the water is diverted back into its existing ditch, rather than being spread over a larger surface. Similarly, water flows towards and around the ends of the dams. The wooden dams may be holding a considerable weight of water and at some point, as they decay, wil collapse.

Wider applications

It would be useful if others could try this technique in small scale trials in order to increase our understanding of possible consequences. It seems to me safest to initially consider employing it in non-sensitive sites, ie. not in existing wetland, marsh or bogs but rather where the landform is conducive to creating new wetland systems. I would imagine that natural depressions, dried up stream sites or areas that experience surface water run off would be appropriate to begin with.

I can imagine much larger implementations, particularly in the uplands, in combination with swales and the like that would form part of a broadscale, integrated strategy for water management and carbon sequestration. There are many questions in my mind that would need to be answered on the way. For example, if the water level of an existing sphagnum bog is increased, will the sphagnum grow to fill the space all will other species take over? It is important to remember that if we raise the water table in one area, that water flow through the soils in unexpected ways and appear in areas where we might not really want it.

There are tremendous possibilities here and much to be done.

Evaluation

Design methods

The design methods used here are along the lines of design by expanding on direct observation of a site and design by adopting lessons learnt from nature (3). I have regularly observed local streams blocking with debris after stroms, such as the flash flood, and subsequently trapping materials and raising the water level.

Needless to say, these natural damns are tidied up by the valiant forestry commission workforce, thus allowing the streams to continue the annual movement of thousands of tons of rubble and silt downstream, ultimately to Barmouth, where it is mechanically (and expensively) dredged out. I had also observed in the forest how a fallen branch running across the slope will interupt the flow of material downslope.

The laying out of the causeways proceeded easily by observation, rather than the use of an A frame. The water tells us where the low points are and more fascines or soil can be added to achieve the desired level finish.

Surveying

The initial surveying, while adequate to achieve the task, could have been done more systematically, using a water level to establish relative heights through the system. It would also have been beneficial, form the point of view of subsequent measurements, to have chosen some location on the raised surrounding line to establish a spot height. Height measurements of the increase in water levels could then have been taken using this as a reference.

I did at first drive in battens marked at various heights from which I could take measurements using spirit level and tape measure and this worked well while the battens lasted but after 1o years they rotted and disappeared. A longer lasting material would be appropriate.

The relative heights of water levels immediately above and below each causeway are useful but underestimate the overall rise in the water level. This means that estimates of the increased volume of water stored on the site will be less accurate than they could. I have still not attempted such an estimate.

A detailed species survey was undertaken by a botanist friend but she has been unable to find the data as yet, though I am assured it does still exist. Nor has a detailed survey been made today. These would both be useful and interesting.

Trial pits to the clay layer in the early stages, both in the area and the surrounding land, may have given some clues as to where the raised water table would flow, as well as providing visual clues as to water depth in the soil profile.

Next steps

There are obvious opportunities to steer such a system towards aquaculture with the inclusion of more edible plant species and possibly crustaceans or fish.

The marsh causeway system has become a regular feature of the guided tours I offer, with very good feedback from visitors. However, parts of the system are at times difficult to get to due to waterlogging or excess vegetation. In particular the linking causeways would benfit from another layer of fascines.

The system requires regular management which in turn is harvesting. Any managment activities offer the possiblily of further development. It is inevitable that over time, with continued observation, further opportunities to increase the productivity of the system will appear.

Notes

1. Contrasted effects of simulated drought on the production and oxidation of methane in a mid-Wales wetland.

Soil Biology & Biochemistry 34 (2002) 61-67. C. Freeman, G.B. Nevision, H. Kang, S. Hughes, B. Reynolds, J.A. Hudson from abstract:

"our data confirm that under drought conditions, CH4 production is lower (-73%, $P<0.05$) largely because it is confined to the deeper, more anaerobic, depths. Lower production rates were found to persist at least 1 month beyond the end of the drought. (-89%, $P<0.01$)...These findings suggest that under drought conditions, the regulation of wetland methane flux occurs primarily through changes in methan e production, with methane oxidation playing only a secondary role."

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2. A possible role of sulphate in the suppression of wetland methane fluxes following drought.

Soil, Biol. Biochemistry. Vol. 26, No. 10, pp. 1439-1442, 1994. C. Freeman, J. Hudson, M.A. Lock, B. Reynolds and C. Swanson

"Our own findings suggest an apparent link between [water table height in regulating wetland CH4 emissions and inhibitory effects of sulphate on methanogenesis] whereby lower water table levels may promote higher SO2/4 concentrations (through sulphide re-oxidation) which in turn may be capable of suppressing CH4 emissions- even after a period of drought has ended." Also notes how current trends to reduce atmospheric S "may have the unexpected side effect of reducing the effects of a potentially valuable climate-change control mechanism.".

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3.Permaculture: A Designers' Manual. Bill Mollison. Tagari 1988

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